s. 22(1)(a)(ii)

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Subject: ABARES Brief on GWP* [SEC=OFFICIAL]
Attachments: ABARES GWP Brief - Sep2020.docx

Hi s. 22(1)(a)(ii) and s. 22(1)(a)(ii), it was great to chat yesterday. Please find attached the brief we wrote last year on the GWP* GHG accounting method, and potential implications for climate change mitigation and Australia's livestock industries.

Happy to answer any questions you may have.
All the best,
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GWP* – policy implications for an alternative measurement of livestock greenhouse gas emissions

Key Points

- The Paris Agreement to reduce GHG emissions uses the GWP_{100} greenhouse gas accounting system. The GW_{100} has been criticised for not taking into account the differences between long-lived gases (e.g. CO2) and short-lived gases (such as biogenic methane that breaks down relatively quickly, of which livestock is a major source).
- GWP* is an alternative accounting methodology that takes into account how long a gas resides in the atmosphere and reduces the warming impact associated with short-lived gases. it reduces the burden on livestock owners to reduce emissions and provides an argument for biogenic methane emissions to be allowed to stabilise (rather than fall) at a constant level equal to its rate of decay.

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Summary

- Under the Paris Agreement, climate change impacts of all greenhouse gases are aggregated using a metric called GWP_{100}. Under this, all GHG emissions must be reduced to net zero to stabilise temperatures, using the GWP_{100} multipliers (e.g. 1t biogenic CH_4 = 28t CO_2 IPCC AR5).
- GWP* is an alternative metric which identifies different impacts of short- and long-lived gases. Under GWP*, short-lived GHG emissions can remain constant without contributing to rising temperatures; while long-lived GHG emissions must still be reduced to net zero.
- CO_2 is a long-lived gas, lasting for over 1000 years in the atmosphere. Methane is a short-lived gas, lasting only 12 years on average before decaying into CO_2. *Biogenic* methane is produced from organic matter, which has sequestered CO_2 during its growth.
- Livestock is a major source of biogenic methane emissions, and some industry groups propose the adoption of GWP* in GHG abatement targets. For example, New Zealand has proposed a separate biogenic methane budget (and reduction target) in its Climate Change Response Act.
- However, there are some important implications of using GWP*:

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- GWP* does not mean that biogenic methane emissions have no impact on warming. While matching methane emissions to decay rates will result in neutral warming impacts, each emission of methane also prevents the atmospheric methane concentration from declining: the marginal warming impact of each methane emission remains positive.
- The high, short-term warming impact of methane can be stored in the ocean; hence the warming effect can persist beyond the atmospheric lifetime of the gas.

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- The Paris Agreement provides indirect incentives for emission abatement in agriculture, without imposing immediate cost burdens. This is evident in Australia, with some red meat producers acquiring carbon neutral certification, and MLA setting a target for carbon neutrality by 2030, and pursuing an R&D program to bring technologies to market to achieve this.

Warming impacts of short- and long-lived greenhouse gases

The main anthropogenic greenhouse gases (GHGs) in the atmosphere are carbon dioxie (CO_2), methane (CH_4), nitrous oxide (N_2O) and synthetic gases (Table 1). These gases prevent the sun's heat from escaping the atmosphere, hence causing the climate to warm. Each GHG has a different source, warming potential and residence time in the atmosphere.

Carbon dioxide is known as a long-lived climate pollutant (LLCP) as it remains in the atmosphere for hundreds to thousands of years (Table 1) – although CO_2 can also be removed from the atmosphere, such as through sequestration by plants and soils.

In contrast, methane is known as a short-lived climate pollutant (SLCP) as it only persists in the atmosphere for an average of 12 years, before breaking down into CO_2 and water; some atmospheric methane is also removed through uptake in soil (Jackson et al. 2020; McSweeney 2020). The CO_2 produced from decayed methane will then itself contribute to global temperature and become a LLCP.

Table 1 Estimated lifetime of major greenhouse gases and warming potential under GWP_{100}

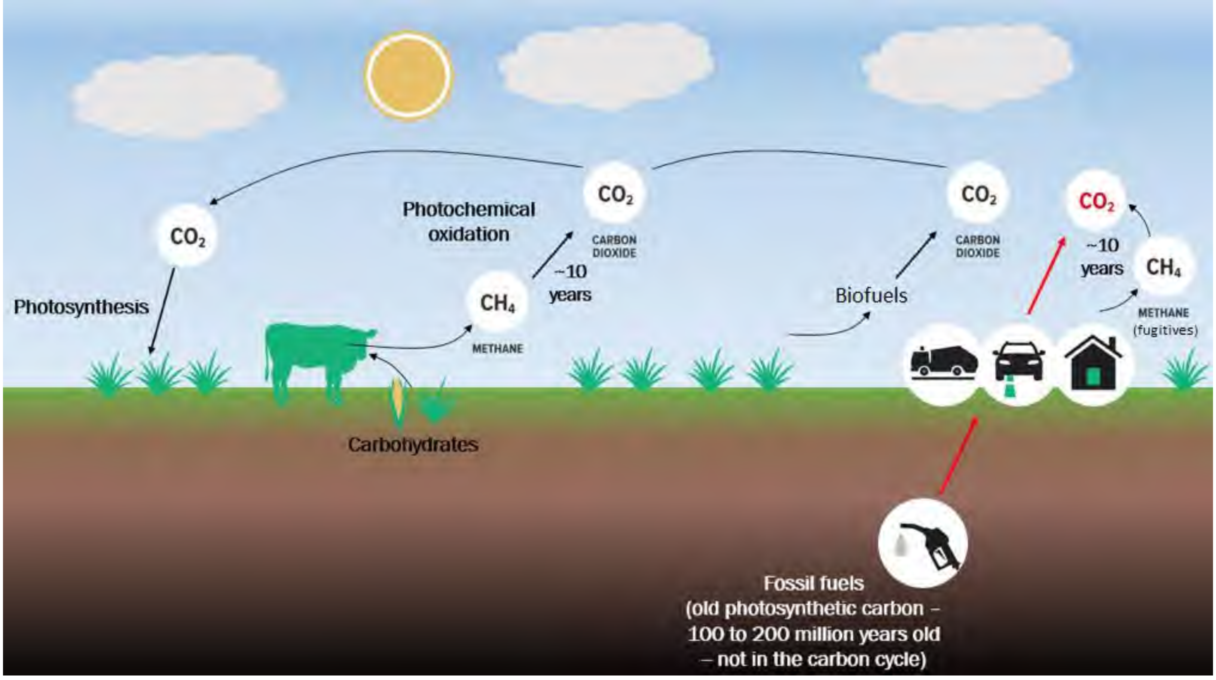
Gas	Chemical formula	Atmospheric lifetime (average)	GWP_{100} (AR5)	Share of Australia's emissions (CO_2-e) b
Carbon dioxide	CO_2	Up to millenia	1	70.0%
Methane	CH_4	12 years	28-30 **a**	23.3%
Nitrous oxide	N_2O	121 years	265	4.4%
Hydrofluorocarbons	HFCs	5.2–47.1 years	677–4,800	2.2%
Perfluorocarbons	PFCs	2,600–50,000 years	6,630–11,100	<0.0%
Sulphur hexafluoride	SF_6	3,200 years	23,500	<0.0%

Note: **a** NZPC (Box 9.3) say GWP for fossil is 30. According to Guardian, 30 is fossil. **b** Australia's GHG inventory currently published in AR4 units (could provide GWP100 for AR4 too). Australia's NGGI is scheduled to use these AR5 estimates from 2020–21 (DISER, p.22, DISER p.23). Could split methane into biogenic and fossil (but not sure if all waste is fossil).
Source: Greenhouse Gas Protocol 2016; NZPC Table 9.1, AGEIS.

Because methane is integral to many biological and geological processes, there are sources and sinks of methane emissions which are not human-induced (anthropogenic). These are not included in global climate mitigation commitments, although they can be indirectly affected by human activities, and impact climate change through feedbacks (Global Methane Budget).

There are two categories of anthropogenic methane emissions: *biogenic*, which is produced from organic matter, for example through digestion by animals or decomposition in landfills; and *fossil*, which derives from the extraction and use of fossil fuels (organic material from the geological past) (Figure 1). Importantly, the CO_2 produced from the atmospheric decay of biogenic methane is offset by the carbon sequestered in plants from which the methane is derived. This means that there is a *net zero CO_2 effect of biogenic methane* emissions. In contrast, fossil-derived methane will degrade into CO_2 which is not offset by sequestration, hence producing both short-lived methane and long-lived CO_2, both of which contribute to global temperatures.

Figure 1 Biogenic and fossil methane cycle



Source: adapted from Place (2019).

Comparing the effects of short- and long-lived gases – GWP_{100}

To estimate the combined impact on global warming of all anthropogenic GHG emissions, the Intergovernmental Panel on Climate Change (IPCC) use a metric which measures the global warming potential (GWP) of each greenhouse gas over 100 years, converted to CO_2 equivalents (CO_2-e). This metric is called GWP_{100}, and is used in IPCC guidelines for national greenhouse gas inventories, which are the basis for the Kyoto Protocol and Paris Agreement (IPCC 2007, 2014).

The CO_2-e estimate for methane has changed slightly as scientific understanding of atmospheric processes has improved. These changes are reflected in each update of the IPCC Assessment Report. Australia's current (2019) national greenhouse gas inventory (NGGI) is based on the Fourth Assessment Report (AR4, IPCC 2007), and uses a conversion of 1t CH_4 =25t CO_2. Table 1 summarises the GWP_{100} estimates for major GHGs based on the Fifth Assessment Report (AR5, IPCC 2014), in which methane has 28 and 30 times the warming potential of CO_2 (based on biogenic and fossil methane, respectively). A Sixth Assessment Report (AR6) is due for release in 2022, which may update these estimates.

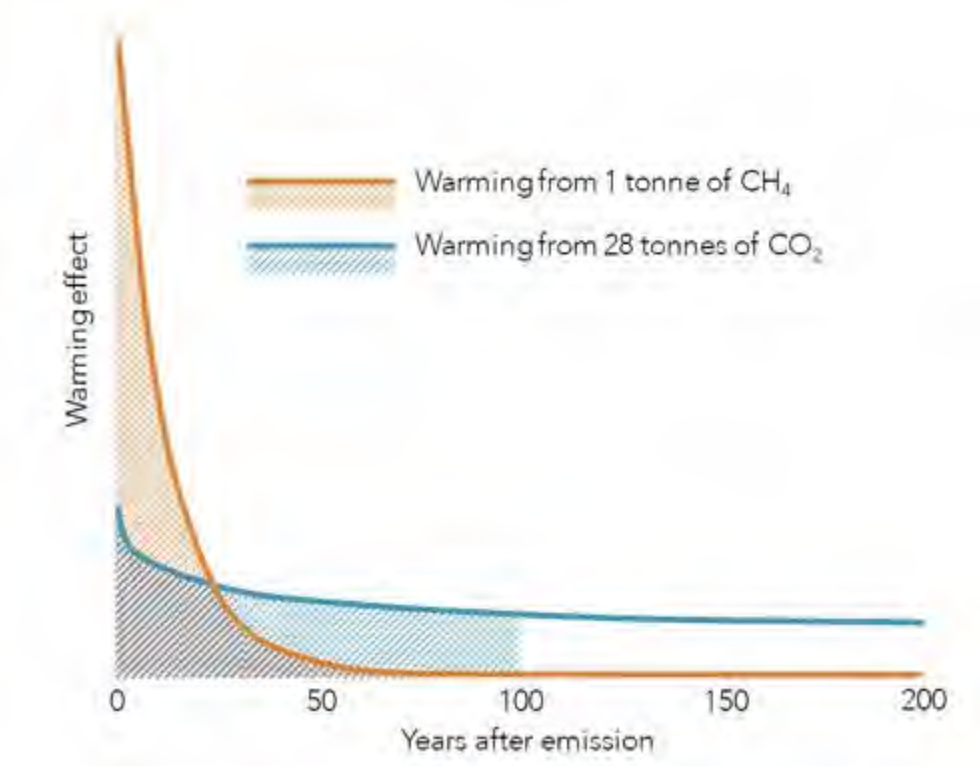
Despite its short-lived residence in the atmosphere, methane has a stronger warming impact than CO_2, and the intertemporal impact of the gases is very different (Figure 2). While the warming impact of methane is much higher than CO_2 initially, it decreases rapidly over time, following an exponential decay curve (Reisinger 2018). Although the average duration of methane in the atmosphere is only 12 years, some decays much faster than this, and some remains in the atmosphere 50 years after the original emission. In contrast, CO_2 declines only slightly over its residence in the atmosphere, and persists beyond the 100 year assumption used in GWP_{100}.

Figure 2 illustrates, in a simplified way, what the GWP_{100} conversion factors for CO_2 and methane represent: over 100 years, the area under the CH_4 curve (representing the aggregate warming effect of one unit of methane) equals the area under the curve representing 28 units of CO_2 (using the GWP_{100} conversion factors from IPCC AR5).

The implication of the GWP_{100} metric is that every emission of greenhouse gas contributes to global warming, and hence the emission of all greenhouse gases must be reduced to zero, or offset by CO_2 removal (sequestration), in order to achieve global temperature stability. This is the fundamental objective of the Paris Agreement (see Box 1).

However, this is also a limitation of GWP_{100}.

Figure 2 Comparing the warming effects of CO_2 and CH_4



Source: NZPC 2018, adapted from Reisinger and Strrombergen 2011. Based on IPCC AR5 conversion of CH_4 to CO_2-e.

Potential limitations of GWP_{100}

The GWP_{100} metric described above uses simplifying assumptions to compare the relative warming impacts of different greenhouse gases. The implication of GWP_{100} emissions accounting is that all GHG emissions must be reduced to net zero to achieve climate stability, and the GWP_{100} value represents the relative priority for abatement of each greenhouse gas.

However, there are alternative ways to achieve global temperature stability that cannot be recognised using GWP_{100}.

Because each emission of CO_2 results in a permanent (>1000 years) warming effect, from a scientific perspective it is imperative that these emissions be reduced to net zero. Delays in abating CO_2 emissions can lock in permanently higher global temperatures due to the compounding impact of CO_2 (Climate Analytics 2019) – although sequestration activities such as revegetation can reverse this, provided they remain permanent sinks.

Box 1 The Paris Agreement

The Paris Agreement provides a common framework for all countries to tackle climate change. It aims to limit the increase in the average global temperature to well below 2°C, and ideally to 1.5°C, to avoid more significant climate change risks.

To achieve that goal, global emissions need to peak as soon as possible and then fall to 'net zero' in the second half of the century (UNFCCC 2015; IPCC 2018). This means that all GHG emissions need to be reduced to zero or offset by sequestration activities in order to stabilise global temperatures. To estimate the path to net zero, emissions of each GHG is summed using the GWP_{100} conversion factors set out by the IPCC Assessment Reports.

The Agreement establishes that common goal. But each country is responsible for determining its targets and policies. National commitments must be formalised, regularly reviewed, and made progressively more ambitious.

Recent analysis finds that aggregate commitments are currently short of what is needed to reach the Paris goals. Without more ambition, the result is expected to be around 3.2°C of global warming, rather 1.5°C or 2°C (UNEP 2019). However the Agreement requires the level of ambition to be progressively increased, and countries are expect to update their commitments in 2020 (UNFCCC 2015).

In that context, a growing number of countries are announcing a commitment to target net zero emissions by 2050 (Energy & Climate Intelligence Unit 2020), including the EU, the UK, and others such as New Zealand (with a separate target for biogenic methane). As is implied by a net zero target, policy discussions in those countries include options for reducing or offsetting emissions associated with agriculture.

In 2015, Australia announced an economy-wide target to reduce GHG emissions by 26 to 28 per cent below 2005 levels by 2030. No industry-specific targets have been set under this goal.

In contrast, a one-off emission of short-lived gases like biogenic methane results in only a temporary increase in global temperatures (though climate feedbacks may complicate this, as discussed below). Hence, when a unit of biogenic methane is emitted, global temperature will (in theory) increase for a finite period, before falling to the original level. A pulse of methane has an average residence in the atmosphere of 12 years, and after around 50 years of exponential decay, only 2% of the original emission is estimated to remain (Reisinger 2018).

The implication of this is that, rather than requiring net zero emissions, global temperature stability can be achieved with stable, but positive, biogenic methane emissions.

However, note that an emission of fossil methane will, in contrast, result in a large temporary CH_4-induced effect on temperature, followed by a smaller permanent CO_2-induced effect after the methane decays. Hence, fossil methane emissions still need to achieve net zero for climate stability.

An alternative metric to compare warming impacts – GWP*

There are alternative ways to estimate the warming impacts of different GHGs, and taking into account their longevity in the atmosphere. Recently, the metric GWP* has been suggested (Lynch et al. 2020; Cain et al. 2019; Cain 2018; Frame et al. 2018; Allen et al. 2018) as a replacement to GWP_{100}. GWP* reports emissions as carbon dioxide warming equivalents (CO_2-w.e.) instead of radiative forcing equivalents (CO_2-e) used in GWP_{100}. This means that the GWP* calculation is better linked with the temperature change contribution of each gas.

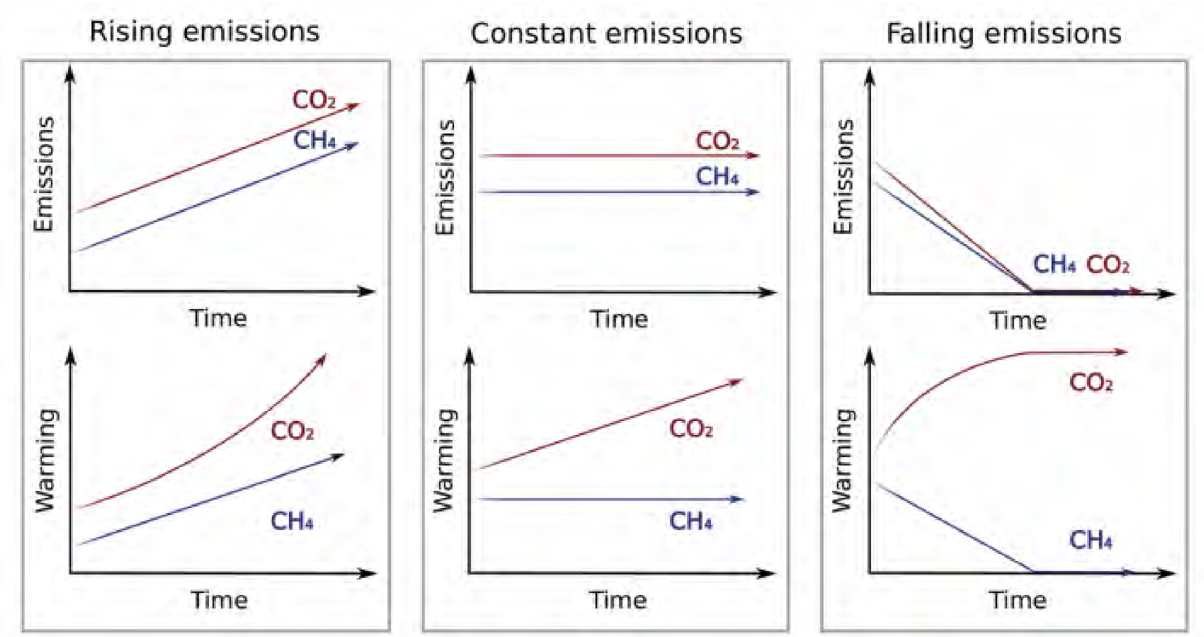
GWP* calculates the carbon dioxide warming equivalents of short-lived climate pollutants (SLCPs) primarily by relating the change in their rate of emissions over 20 years to a one-off release of a set quantiy of CO_2. This reflects the fact that SLCPs do not accumulate in the atmosphere in the same way that CO_2 does (Lynch et al. 2020).

The key consequence of GWP* is that global temperature can be stabilised by maintaining the atmospheric concentrations of short-lived gases at constant levels, by matching their inflow rates (emissions) to their outflow rates (decay) (see Figure 3). Hence, the centre column shows that constant CO_2 emissions continue to contribute to rising temperatures; while constant CH_4 emissions are associated with stable temperatures. Note also that declines in biogenic methane emissions are associated with lower global temperatures (right-hand column), because lower emissions will lead to declining atmospheric methane concentrations.

These conclusions are different to the GWP_{100} metric, under which it is assumed all GHGs (including biogenic methane) must achieve net zero emissions to stop warming.

Nevertheless, under both the GWP_{100} and GWP* metrics, emissions of long-lived GHGs like carbon dioxide must be reduced to zero to achieve climate stability.

Figure 3 Graph of alternative emission scenarios and contribution to global temperatures under GWP*



Source: Oxford Martin Programme on Climate Pollutants

Proponents for adoption of GWP* in climate commitments

There is sound and accepted scientific basis for GWP*. However, the existing global climate negotiations and commitments, using GWP_{100}, are also based on scientific assessments of the global warming impacts of GHGs. While based on a more simplified framework, these GWP_{100} emissions targets still provide a practical and effective way of mitigating climate change through emissions abatement.

The key concern in the context of global climate change policy is whether GWP_{100} results in an unfair mitigation burden on biogenic methane emitters – that is, whether the requirement to

reduce net emissions to zero under GWP_{100} places a cost on these emitters which is not consistent with their contribution to global warming, relative to other sectors of the economy.

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One of the key sources of biogenic methane is the livestock industry.

New Zealand has the highest proportion of methane in total GHG emissions across all OECD countries, 95% of which is biogenic methane (Table 2). This led the New Zealand government to introduce the Climate Change Response (Zero Carbon) Amendment Bill, which imposed a target to reduce all greenhouse gases (except biogenic methane) to net zero by 2050. Separately, the Bill includes a 10% reduction target for gross emissions of biogenic methane by 2030, and a 24 to 47% reduction by 2050 (relative to 2017 levels) (New Zealand Ministry for the Environment (MFE) 2019).

While New Zealand is currently leading efforts to establish separate mitigation targets for biogenic methane, Europe is also examining alternative ways of dealing with methane emissions (European Commission 2020). Table 2 illustrates that many European countries are among the top 10 methane shares in the OECD (the European Union has an average 10% methane share across all 28 countries).

Table 2 Top methane emitting countries by share of total emissions, 2017

Rank	Country	Methane emissions	Total emissions (CO_2-e)	Methane % of total emissions (CO_2-e)	% Biogenic methane	% Fossil methane
1	New Zealand	34,132	80,853	42%	95%	5%
2	Ireland	14,034	60,744	23%	87%	13%
3	Australia	103,602	554,127	19%	72%	28%
4	Latvia	1,805	11,306	16%	67%	33%
5	Lithuania	3,257	20,417	16%	77%	23%
6	Denmark	6,920	49,226	14%	87%	13%
7	Portugal	9,477	70,546	13%	92%	8%
8	Canada	92,848	715,749	13%	47%	53%
9	Iceland	581	4,755	12%	98%	2%
10	Slovenia	2,102	17,454	12%	55%	45%

Note: Measures total methane divided by total CO2e emissions. Need to clarify which conversions used. Australia may differ from NGGI. Biogenic methane calculated from gigagrams of methane emitted in 2017 from agriculture and waste sectors.Could include EU28 as one region.
Source: OECD, FAOSTAT

Australia's biogenic methane emissions

Australia has the third highest share of methane in GHG emissions across the OECD, although 28% of this is fossil-derived. In response to the scientific debate, livestock groups such as the Cattle Council of Australia suggest that GWP* demonstrates that the existing GWP_{100} model may overstate livestock's impact on global temperatures. Following New Zealand's lead, these groups suggest Australia should investigate the feasibility of switch to a GHG accounting framework that does not place an unfair burden on their industry.

Australia's latest GHG emission inventory estimates that 23% of total national emissions are from methane, with over two-thirds of this biogenic methane (Table 3).

The major sources of Australia's anthropogenic methane emissions are agriculture (47%), energy (31%), landuse change (13%) and waste (10%). Agriculture is one of the most methane-intensive industries in Australia's emissions profile – methane represents over three-quarters of CO_2-e emissions. Waste is even more methane-intensive (95% of emissions).

All methane from the energy industries are fossil-derived, and are emitted via transport, direct combustion and fugitives.

In Australia, all biogenic methane emissions are attributable to three sectors: agriculture (68% of total biogenic methane), landuse change (18%) and waste (14%) (Table 3). All methane emissions from these sectors are considered biogenic.

One of the reasons livestock industries are concerned about the potential over-representation of their industries in climate change mitigation commitments is that the emission of non-CO_2 greenhouse gases, such as methane and nitrous oxide, are intrinsic to many natural systems within which agriculture operates. Hence, the complete elimination of these emissions is not possible (Reisinger and Clark 2017; CCC 2019), and the cost of reducing these emissions can be higher than in other sectors of the economy. s. 33(a)(iii)

Table 3 Australia's biogenic and fossil methane emissions, by sector, 2018

	Greenhouse Gas Emissions (CO_2-e) based on GWP_{100}			Biogenic methane emissions	
Sector	**Biogenic methane**	**Fossil methane**	**Total emissions (all GHGs)**	**Share of industry methane emissions (%)**	**Share of total emissions (%)**
Electricity	-	598	183,170	0.0%	0.0%
Direct combustion	-	992	97,155	0.0%	0.0%
Transport	-	358	100,796	0.0%	0.0%
Fugitives	-	37,107	54,450	0.0%	0.0%
Industrial Processes	-	77	34,197	0.0%	0.0%
Agriculture	58,388	-	75,588	100.0%	77.2%
LULUCF	15,768	-	-20,601	100.0%	n.a.
Waste	12,012	-	12,691	100.0%	94.6%
Total Australia	86,168	39,132	537,446	68.8%	16.0%

Note: All emissions based on GWP_{100} AR4. Assumes all agriculture methane is biogenic, and all LULUCF and waste methane is biogenic. LULUCF share of biogenic not estimated as total emissions are negative.
Source: AGEIS.

Potential limitations of adopting GWP*

The treatment of biogenic methane in global plans for climate change mitigation using GWP_{100} has led some countries to consider alternatives like GWP*. s. 33(a)(iii)

However, while there is agreement on the science behind GWP*, there are a number of factors which may make its implementation in global abatement plans more difficult. These may mean that the emission abatement burden faced by biogenic methane emitters will not necessarily be lower under such a scheme.

Changes to burden of mitigation across countries and industries

While GWP_{100} is a less scientifically sophisticated concept, it does provide a clear path to global temperature stabilisation: all GHG emissions must be reduced to net zero (Figure 4a). GWP*, however, introduces additional complications and would require new targets to be negotiated, both across countries and between industries within countries.

For instance, using GWP* to advocate constant methane emissions would change the relative burden of GHG mitigation across industries, in favour of those with larger proportions of methane. If methane emissions remain constant, temperatures will rise at a faster rate than estimated under a scenario where all GHGs trend to net zero. Hence, emissions of CO_2 (and other long-lived gases) would have to reduce to net zero faster than currently negotiated in order to achieve the same temperature goals (Figure 4b). Compared to existing commitments, this would impose additional costs on fossil fuel industries in particular, in order to manage global warming.

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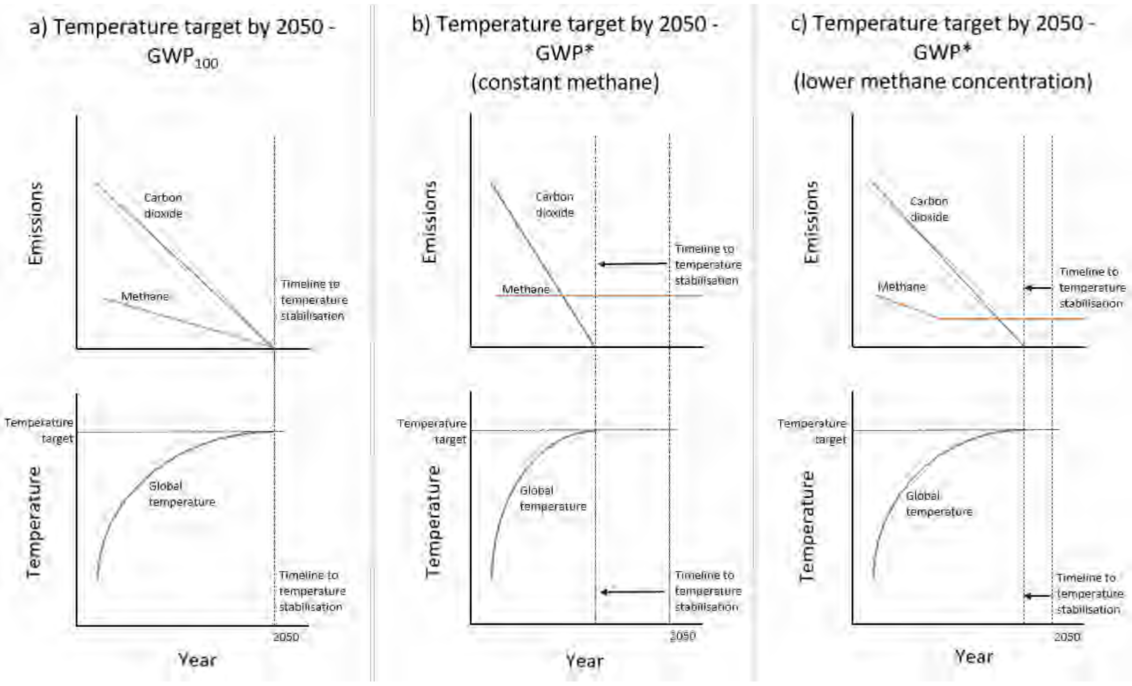
Figure 4 Warming impacts of different emission scenarios under GWP100 and GWP*



Note: Trends in emissions, temperatures and timelines indicative only. For simplification, only two greenhouse gases are presented.

However, GWP* does not necessarily imply that biogenic methane emissions should remain constant. In fact, GWP* can also show that reductions in methane emissions can rapidly reduce atmospheric methane concentrations (inflows < outflows), and hence contribute to relatively significant and rapid reductions in global warming potential. This would slow temperature rises, and allow more time for emissions of CO_2 and other LLCPs (including fossil methane) to transition to net zero (Figure 4c). s. 33(a)(iii)

The right to constant emissions

Some proponents of GWP* argue that this accounting metric demonstrates that biogenic methane emitters can maintain a constant level of emissions without having an impact on global temperatures. The implication of this argument is that they do not contribute to climate change, and therefore should not have to undertake any abatement.

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However, this interpretation of GWP* is also incorrect, because the GWP* science does not indicate the 'correct' level of atmospheric methane concentrations, or how emissions should be allocated. While it is true that a steady rate of biogenic emissions over time does not contribute to further warming, it is also true that each emission of biogenic methane prevents the atmospheric concentration of methane from declining: the marginal warming contribution of each methane emission remains positive. Without current emissions of methane, the atmospheric concentration of this gas would naturally decline as methane decays, thus providing a global cooling effect that would partly counter-balance the warming effect of other GHG emissions. Hence, as noted above (Figure 4c), a permanent decline in atmospheric methane concentrations would allow more time to reduce emissions of CO_2 or other long-lived GHGs.

Implicit in the argument that current methane emitters can continue emitting without cost is that these emitters have a 'right' to the current atmospheric concentrations of methane. That is, for example, when a livestock operation emits 1 tonne of methane, that same operation is entitled to the 'offset' of the decay of 1 tonne of methane currently in the atmosphere. While this could be negotiated in future GHG abatement targets, there is no scientific or economic basis to this argument.

Regardless of this, atmospheric methane concentrations are not currently stable. In fact, methane emissions have increased significantly in recent years, according to the Global Methane Budget, as a result of global agricultural and mining emissions. The stabilisation of global temperatures is therefore unlikely to be compatible with current levels methane, and the atmospheric concentration of methane, currently at 1875ppm, will have to be reduced.

Climate feedbacks

The relatively rapid and large temperature impact of methane emissions has indirect effects on global temperatures, which means that the consequence of constant emissions is not necessarily neutral.

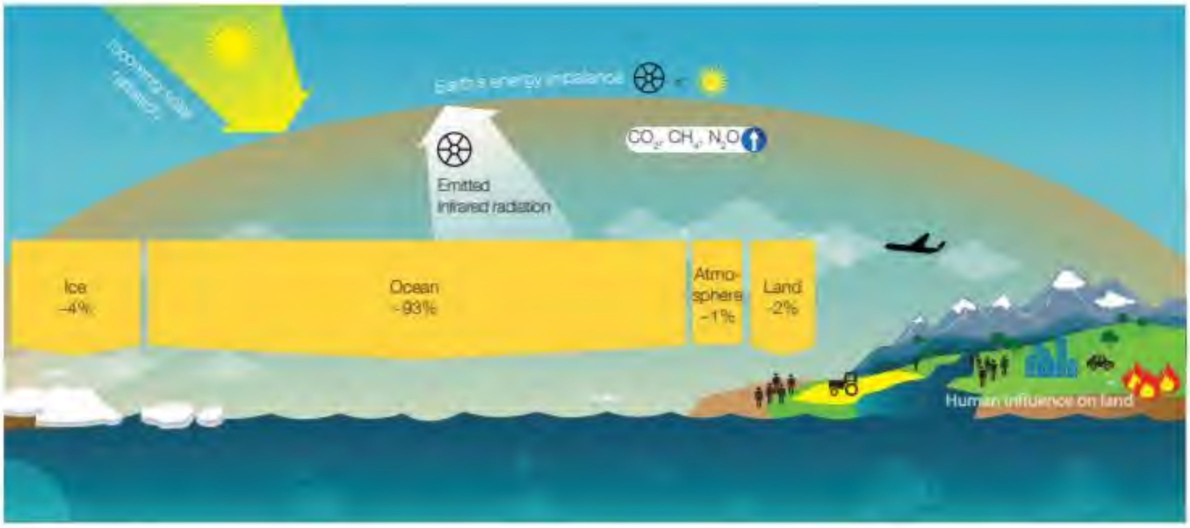
While methane only persists in the atmosphere for around 12 years on average, the warming impact is not limited to this time due to climate feedbacks in the Earth's system.

Since at least 1970 there has been more energy entering the Earth's atmosphere than escaping it due to human induced greenhouse gas emissions. While some of this energy has been warming the atmosphere and land, and evaporating water and ice, more than 93% of the excess warming

since the 1970s has been absorbed into the ocean (Reid 2016, Figure 5), causing it to warm (Rhein et al. 2013). Heat accumulated in the ocean is not locked away indefinitely and this excess heat can be released back into the atmosphere (Reid 2016). Increasing ocean temperatures are also having other impacts including increasing sea level rise, intensification of El Niño events, increased occurance of extreme weather events, warming adjacent land masses and deoxygenation (Reid 2016).

Hence, despite the short lifetime of methane in the atmosphere, the indirect impact of its warming can continue for hundreds to thousands of years (Zickfeld et al. 2017, Eckard and White 2019).

Figure 5 Flow and storage of energy in the Earth's climate system



Note: Schematic representation of the flow and storage of energy in the Earth's climate system. Around 93% of the excess energy goes into the ocean and the remainder goes into the atmosphere, land, and melting ice and snow.
Source: Reid 2016.

Constraints on industry growth and flexibility

Proponents of GWP* argue that this metric will allow the maintenance of constant emissions into the future, implying that industry activity can also remain constant. s. 33(a)(iii)

Over the last decade, Australia's beef cattle numbers have fluctuated between 22.3 and 26.5 million head, without exhibiting a trend in either direction. Livestock numbers vary from year to year as a result of changes to climate conditions, which affect survival and birth rates, and markets, which affect farmers' decisions about turn off and live export. Livestock emissions are highly correlated to animal numbers.

As a result, livestock numbers and emissions can change significantly each year, generally moving in the same direction (Figure 6). For example, after falling in 2010, livestock numbers rebounded strongly, by almost 2 million head, in 2011. And after declines in livestock numbers in 2015 and 2016, numbers increased by over 1 million head in 2017. Emissions followed a similar trend in these years.

Hence, emissions from livestock are never constant, s. 33(a)(iii)

In the case of

livestock, a framework for allowing constant emissions could be based on long-term average livestock numbers, which would allow annual fluctuations but restrict any trend growth in livestock numbers. Alternatively, baseline emissions could be based on an individual base year (such as 2015), which may be detrimental to livestock farmers if it constrains stock rebuilding.

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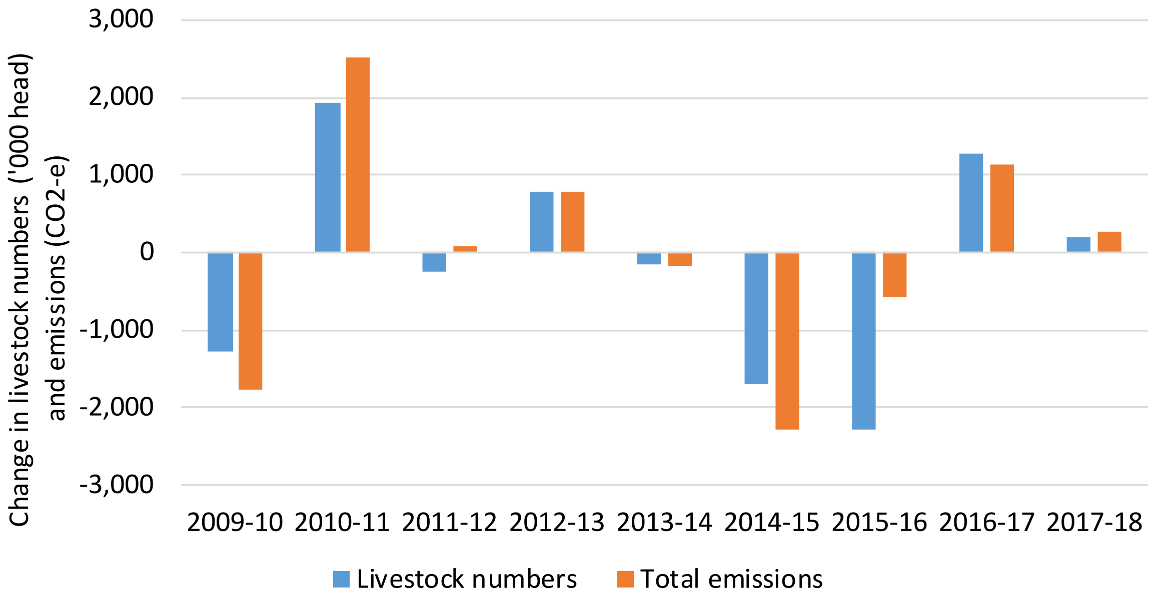
Figure 6 Annual changes in livestock numbers and total GHG emissions, beef cattle



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Conclusions: policy implications

GWP* is justified scientifically, and does improve the representation of long- and short-lived gases on global temperature change. There are simplifications in the GWP_{100} metric which could result in higher global temperatures if CO_2 mitigation is delayed.

But GWP* does not offer an easier path to climate mitigation. s. 33(a)(iii)

and concrete action is still required to achieve global temperature stability. Contrary to the public discussion around GWP*, this method does not justify the maintenance of current methane emission levels at zero cost. Instead, it highlights the imperative of reducing emissions of long-lived gases to zero, and the balancing role that can be played by short-lived gases in managing global temperatures while the transition to net zero emissions is navigated.

It is important to recognise that the net zero emissions target that has been endorsed by the Paris Agreement has provided incentives for all sectors of the economy, including livestock industries, to consider their role in this transition. The national commitments made under the Paris Agreement recognise the intrinsic nature of methane emissions to many biological processes inherent in agriculture, and the high costs of abatement faced by the industry as a result. Hence, under this GWP_{100} framework, many agricultural industries have been provided flexibility to investigate alternative paths to net zero, and identify existing gaps in technology and policy that must be overcome to achieve it.

The IPCC has also recognised this, and has identified a range of 24-47% global agricultural methane emission reductions by 2050, relative to 2010, in emission pathways that keep warming to 1.5°C (NZAGGRC 2019)

But rather than representing an excess burden on these industries, this framework has provided incentives for research into new technologies and policy development. Research is underway in many countries to unlock methane abatement opportunities, particularly through feed supplments and forages. Much of this research is being undertaken in Australia, incentivised by the prospect of increasingly environmentally-conscious consumers and investors. Importantly, many of the technologies to reduce emissions have co-benefits for agricultural productivity, which could help spread adoption ahead of market or policy incentives.

For example, the opportunities of this transition to net zero has led Australia's Meat and Livestock Association (MLA) to develop a goal to be carbon neutral plan by 2030 (CN30), and to establish pathways to the target via existing management practices and investment in new technologies to reduce methane emissions, including use of existing and prospective livestock and land management practices (Mayberry et al. 2018).

Other agricultural industries, not necessarily involved in methane emissions, have also endorsed zero emissions goals which support their environmental reputation. GrainGrowers supports a net zero goal for agriculture by 2050 and is aiming to release a grain-specific target for 2030. Other sectors are also acting, and the National Farmers' Federation's *2030 Roadmap* aims to see the whole sector trending towards carbon neutrality by 2030. A number of individual red meat producers have also claimed carbon neutral certification.

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s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Wednesday, 13 October 2021 2:55 PM
To: s. 22(1)(a)(ii); s. 22(1)(a)(ii), s. 22(1)(a)(ii)
Cc: s. 22(1)(a)(ii) Greenville, Jared; s. 22(1)(a)(ii)
Subject: Re: Ag subsidies and emissions [SEC=OFFICIAL]
Attachments: ABARES GWP Brief - Sep2020.docx

Thanks s. 22(1)(a)(i appreciate your insights as always.

Continuing on the topic of methane, following a conversation with our SES it looks like GWP is coming back into focus and becoming a topic for us to be prepared to brief on. This is reinforced with current government meetings taking place.

You have previously circulated the attached deep dive on the issue which has been a great resource. We haven't shared this brief as requested, but I was hoping to get approval to share elements of it going forward? This would be a great way to get our SES and broader network up to speed on the issue so we can be better prepared for incoming requests.

Happy to discuss.

Kind regards
s. 22(1)(a)(ii)

s. 22(1)(a)(ii)

Assistant Director | Climate and Adaptation Policy | (02) 627s. 22(1)(a)(ii)

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Australian Government
Department of Agriculture, Water and the Environment

September 2020

GWP* – policy implications for an alternative measurement of livestock greenhouse gas emissions

Key Points

- The Paris Agreement to reduce GHG emissions uses the GWP_{100} greenhouse gas accounting system. The GW_{100} has been criticised for not taking into account the differences between long-lived gases (e.g. CO2) and short-lived gases (such as biogenic methane that breaks down relatively quickly, of which livestock is a major source).
- GWP* is an alternative accounting methodology that takes into account how long a gas resides in the atmosphere and reduces the warming impact associated with short-lived gases. it reduces the burden on livestock owners to reduce emissions and provides an argument for biogenic methane emissions to be allowed to stabilise (rather than fall) at a constant level equal to its rate of decay.

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Summary

- Under the Paris Agreement, climate change impacts of all greenhouse gases are aggregated using a metric called GWP_{100}. Under this, all GHG emissions must be reduced to net zero to stabilise temperatures, using the GWP_{100} multipliers (e.g. 1t biogenic CH_4 = 28t CO_2 IPCC AR5).
- GWP* is an alternative metric which identifies different impacts of short- and long-lived gases. Under GWP*, short-lived GHG emissions can remain constant without contributing to rising temperatures; while long-lived GHG emissions must still be reduced to net zero.
- CO_2 is a long-lived gas, lasting for over 1000 years in the atmosphere. Methane is a short-lived gas, lasting only 12 years on average before decaying into CO_2. *Biogenic* methane is produced from organic matter, which has sequestered CO_2 during its growth.
- Livestock is a major source of biogenic methane emissions, and some industry groups propose the adoption of GWP* in GHG abatement targets. For example, New Zealand has proposed a separate biogenic methane budget (and reduction target) in its Climate Change Response Act.
- However, there are some important implications of using GWP*:

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- GWP* does not mean that biogenic methane emissions have no impact on warming. While matching methane emissions to decay rates will result in neutral warming impacts, each emission of methane also prevents the atmospheric methane concentration from declining: the marginal warming impact of each methane emission remains positive.
- The high, short-term warming impact of methane can be stored in the ocean; hence the warming effect can persist beyond the atmospheric lifetime of the gas.

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- The Paris Agreement provides indirect incentives for emission abatement in agriculture, without imposing immediate cost burdens. This is evident in Australia, with some red meat producers acquiring carbon neutral certification, and MLA setting a target for carbon neutrality by 2030, and pursuing an R&D program to bring technologies to market to achieve this.

Warming impacts of short- and long-lived greenhouse gases

The main anthropogenic greenhouse gases (GHGs) in the atmosphere are carbon dioxie (CO_2), methane (CH_4), nitrous oxide (N_2O) and synthetic gases (Table 1). These gases prevent the sun's heat from escaping the atmosphere, hence causing the climate to warm. Each GHG has a different source, warming potential and residence time in the atmosphere.

Carbon dioxide is known as a long-lived climate pollutant (LLCP) as it remains in the atmosphere for hundreds to thousands of years (Table 1) – although CO_2 can also be removed from the atmosphere, such as through sequestration by plants and soils.

In contrast, methane is known as a short-lived climate pollutant (SLCP) as it only persists in the atmosphere for an average of 12 years, before breaking down into CO_2 and water; some atmospheric methane is also removed through uptake in soil (Jackson et al. 2020; McSweeney 2020). The CO_2 produced from decayed methane will then itself contribute to global temperature and become a LLCP.

Table 1 Estimated lifetime of major greenhouse gases and warming potential under GWP_{100}

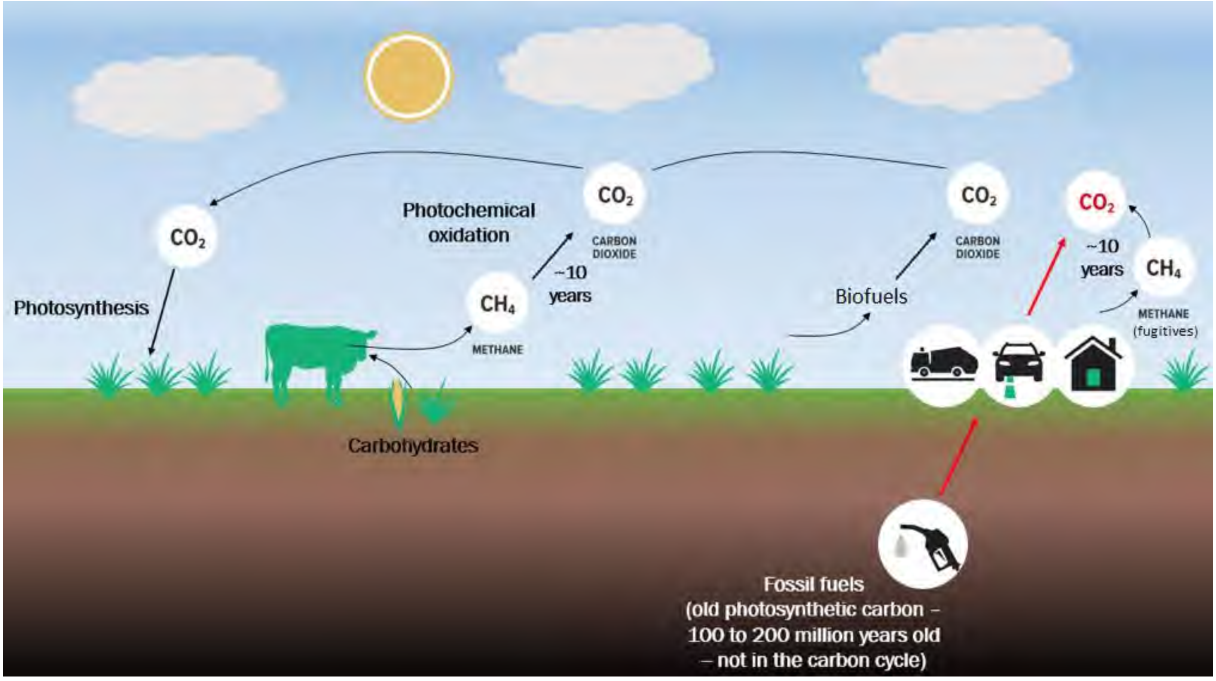
Gas	Chemical formula	Atmospheric lifetime (average)	GWP_{100} (AR5)	Share of Australia's emissions (CO_2-e) b
Carbon dioxide	CO_2	Up to millenia	1	70.0%
Methane	CH_4	12 years	28-30 **a**	23.3%
Nitrous oxide	N_2O	121 years	265	4.4%
Hydrofluorocarbons	HFCs	5.2–47.1 years	677–4,800	2.2%
Perfluorocarbons	PFCs	2,600–50,000 years	6,630–11,100	<0.0%
Sulphur hexafluoride	SF_6	3,200 years	23,500	<0.0%

Note: **a** NZPC (Box 9.3) say GWP for fossil is 30. According to Guardian, 30 is fossil. **b** Australia's GHG inventory currently published in AR4 units (could provide GWP100 for AR4 too). Australia's NGGI is scheduled to use these AR5 estimates from 2020–21 (DISER, p.22, DISER p.23). Could split methane into biogenic and fossil (but not sure if all waste is fossil).
Source: Greenhouse Gas Protocol 2016; NZPC Table 9.1, AGEIS.

Because methane is integral to many biological and geological processes, there are sources and sinks of methane emissions which are not human-induced (anthropogenic). These are not included in global climate mitigation commitments, although they can be indirectly affected by human activities, and impact climate change through feedbacks (Global Methane Budget).

There are two categories of anthropogenic methane emissions: *biogenic*, which is produced from organic matter, for example through digestion by animals or decomposition in landfills; and *fossil*, which derives from the extraction and use of fossil fuels (organic material from the geological past) (Figure 1). Importantly, the CO_2 produced from the atmospheric decay of biogenic methane is offset by the carbon sequestered in plants from which the methane is derived. This means that there is a *net zero CO_2 effect of biogenic methane* emissions. In contrast, fossil-derived methane will degrade into CO_2 which is not offset by sequestration, hence producing both short-lived methane and long-lived CO_2, both of which contribute to global temperatures.

Figure 1 Biogenic and fossil methane cycle



Source: adapted from Place (2019).

Comparing the effects of short- and long-lived gases – GWP_{100}

To estimate the combined impact on global warming of all anthropogenic GHG emissions, the Intergovernmental Panel on Climate Change (IPCC) use a metric which measures the global warming potential (GWP) of each greenhouse gas over 100 years, converted to CO_2 equivalents (CO_2-e). This metric is called GWP_{100}, and is used in IPCC guidelines for national greenhouse gas inventories, which are the basis for the Kyoto Protocol and Paris Agreement (IPCC 2007, 2014).

The CO_2-e estimate for methane has changed slightly as scientific understanding of atmospheric processes has improved. These changes are reflected in each update of the IPCC Assessment Report. Australia's current (2019) national greenhouse gas inventory (NGGI) is based on the Fourth Assessment Report (AR4, IPCC 2007), and uses a conversion of 1t CH_4 =25t CO_2. Table 1 summarises the GWP_{100} estimates for major GHGs based on the Fifth Assessment Report (AR5, IPCC 2014), in which methane has 28 and 30 times the warming potential of CO_2 (based on biogenic and fossil methane, respectively). A Sixth Assessment Report (AR6) is due for release in 2022, which may update these estimates.

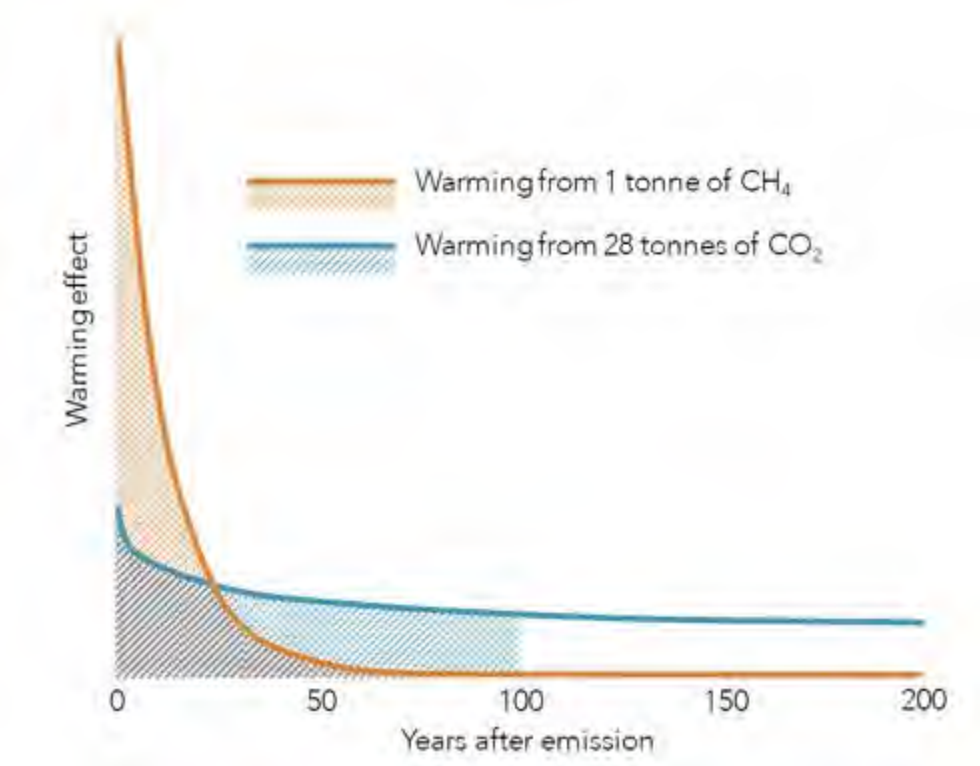
Despite its short-lived residence in the atmosphere, methane has a stronger warming impact than CO_2, and the intertemporal impact of the gases is very different (Figure 2). While the warming impact of methane is much higher than CO_2 initially, it decreases rapidly over time, following an exponential decay curve (Reisinger 2018). Although the average duration of methane in the atmosphere is only 12 years, some decays much faster than this, and some remains in the atmosphere 50 years after the original emission. In contrast, CO_2 declines only slightly over its residence in the atmosphere, and persists beyond the 100 year assumption used in GWP_{100}.

Figure 2 illustrates, in a simplified way, what the GWP_{100} conversion factors for CO_2 and methane represent: over 100 years, the area under the CH_4 curve (representing the aggregate warming effect of one unit of methane) equals the area under the curve representing 28 units of CO_2 (using the GWP_{100} conversion factors from IPCC AR5).

The implication of the GWP_{100} metric is that every emission of greenhouse gas contributes to global warming, and hence the emission of all greenhouse gases must be reduced to zero, or offset by CO_2 removal (sequestration), in order to achieve global temperature stability. This is the fundamental objective of the Paris Agreement (see Box 1).

However, this is also a limitation of GWP_{100}.

Figure 2 Comparing the warming effects of CO_2 and CH_4



Source: NZPC 2018, adapted from Reisinger and Strrombergen 2011. Based on IPCC AR5 conversion of CH_4 to CO_2-e.

Potential limitations of GWP_{100}

The GWP_{100} metric described above uses simplifying assumptions to compare the relative warming impacts of different greenhouse gases. The implication of GWP_{100} emissions accounting is that all GHG emissions must be reduced to net zero to achieve climate stability, and the GWP_{100} value represents the relative priority for abatement of each greenhouse gas.

However, there are alternative ways to achieve global temperature stability that cannot be recognised using GWP_{100}.

Because each emission of CO_2 results in a permanent (>1000 years) warming effect, from a scientific perspective it is imperative that these emissions be reduced to net zero. Delays in abating CO_2 emissions can lock in permanently higher global temperatures due to the compounding impact of CO_2 (Climate Analytics 2019) – although sequestration activities such as revegetation can reverse this, provided they remain permanent sinks.

Box 1 The Paris Agreement

The Paris Agreement provides a common framework for all countries to tackle climate change. It aims to limit the increase in the average global temperature to well below 2°C, and ideally to 1.5°C, to avoid more significant climate change risks.

To achieve that goal, global emissions need to peak as soon as possible and then fall to 'net zero' in the second half of the century (UNFCCC 2015; IPCC 2018). This means that all GHG emissions need to be reduced to zero or offset by sequestration activities in order to stabilise global temperatures. To estimate the path to net zero, emissions of each GHG is summed using the GWP_{100} conversion factors set out by the IPCC Assessment Reports.

The Agreement establishes that common goal. But each country is responsible for determining its targets and policies. National commitments must be formalised, regularly reviewed, and made progressively more ambitious.

Recent analysis finds that aggregate commitments are currently short of what is needed to reach the Paris goals. Without more ambition, the result is expected to be around 3.2°C of global warming, rather 1.5°C or 2°C (UNEP 2019). However the Agreement requires the level of ambition to be progressively increased, and countries are expect to update their commitments in 2020 (UNFCCC 2015).

In that context, a growing number of countries are announcing a commitment to target net zero emissions by 2050 (Energy & Climate Intelligence Unit 2020), including the EU, the UK, and others such as New Zealand (with a separate target for biogenic methane). As is implied by a net zero target, policy discussions in those countries include options for reducing or offsetting emissions associated with agriculture.

In 2015, Australia announced an economy-wide target to reduce GHG emissions by 26 to 28 per cent below 2005 levels by 2030. No industry-specific targets have been set under this goal.

In contrast, a one-off emission of short-lived gases like biogenic methane results in only a temporary increase in global temperatures (though climate feedbacks may complicate this, as discussed below). Hence, when a unit of biogenic methane is emitted, global temperature will (in theory) increase for a finite period, before falling to the original level. A pulse of methane has an average residence in the atmosphere of 12 years, and after around 50 years of exponential decay, only 2% of the original emission is estimated to remain (Reisinger 2018).

The implication of this is that, rather than requiring net zero emissions, global temperature stability can be achieved with stable, but positive, biogenic methane emissions.

However, note that an emission of fossil methane will, in contrast, result in a large temporary CH_4-induced effect on temperature, followed by a smaller permanent CO_2-induced effect after the methane decays. Hence, fossil methane emissions still need to achieve net zero for climate stability.

An alternative metric to compare warming impacts – GWP*

There are alternative ways to estimate the warming impacts of different GHGs, and taking into account their longevity in the atmosphere. Recently, the metric GWP* has been suggested (Lynch et al. 2020; Cain et al. 2019; Cain 2018; Frame et al. 2018; Allen et al. 2018) as a replacement to GWP_{100}. GWP* reports emissions as carbon dioxide warming equivalents (CO_2-w.e.) instead of radiative forcing equivalents (CO_2-e) used in GWP_{100}. This means that the GWP* calculation is better linked with the temperature change contribution of each gas.

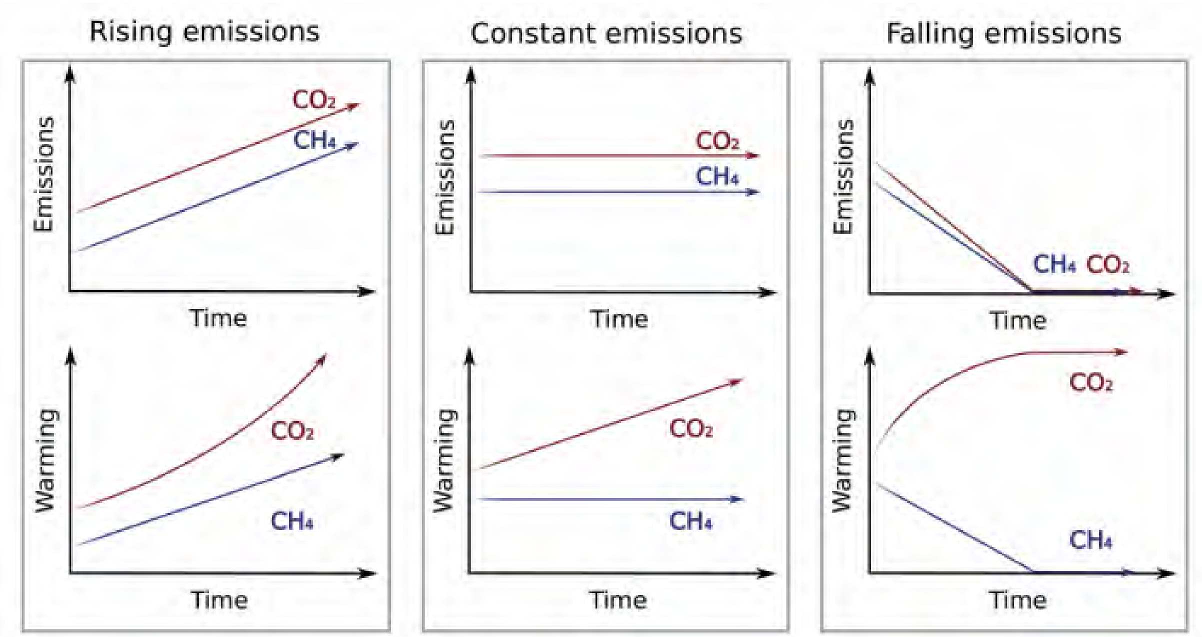
GWP* calculates the carbon dioxide warming equivalents of short-lived climate pollutants (SLCPs) primarily by relating the change in their rate of emissions over 20 years to a one-off release of a set quantiy of CO_2. This reflects the fact that SLCPs do not accumulate in the atmosphere in the same way that CO_2 does (Lynch et al. 2020).

The key consequence of GWP* is that global temperature can be stabilised by maintaining the atmospheric concentrations of short-lived gases at constant levels, by matching their inflow rates (emissions) to their outflow rates (decay) (see Figure 3). Hence, the centre column shows that constant CO_2 emissions continue to contribute to rising temperatures; while constant CH_4 emissions are associated with stable temperatures. Note also that declines in biogenic methane emissions are associated with lower global temperatures (right-hand column), because lower emissions will lead to declining atmospheric methane concentrations.

These conclusions are different to the GWP_{100} metric, under which it is assumed all GHGs (including biogenic methane) must achieve net zero emissions to stop warming.

Nevertheless, under both the GWP_{100} and GWP* metrics, emissions of long-lived GHGs like carbon dioxide must be reduced to zero to achieve climate stability.

Figure 3 Graph of alternative emission scenarios and contribution to global temperatures under GWP*



Source: Oxford Martin Programme on Climate Pollutants

Proponents for adoption of GWP* in climate commitments

There is sound and accepted scientific basis for GWP*. However, the existing global climate negotiations and commitments, using GWP_{100}, are also based on scientific assessments of the global warming impacts of GHGs. While based on a more simplified framework, these GWP_{100} emissions targets still provide a practical and effective way of mitigating climate change through emissions abatement.

The key concern in the context of global climate change policy is whether GWP_{100} results in an unfair mitigation burden on biogenic methane emitters – that is, whether the requirement to

reduce net emissions to zero under GWP_{100} places a cost on these emitters which is not consistent with their contribution to global warming, relative to other sectors of the economy.

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One of the key sources of biogenic methane is the livestock industry.

New Zealand has the highest proportion of methane in total GHG emissions across all OECD countries, 95% of which is biogenic methane (Table 2). This led the New Zealand government to introduce the Climate Change Response (Zero Carbon) Amendment Bill, which imposed a target to reduce all greenhouse gases (except biogenic methane) to net zero by 2050. Separately, the Bill includes a 10% reduction target for gross emissions of biogenic methane by 2030, and a 24 to 47% reduction by 2050 (relative to 2017 levels) (New Zealand Ministry for the Environment (MFE) 2019).

While New Zealand is currently leading efforts to establish separate mitigation targets for biogenic methane, Europe is also examining alternative ways of dealing with methane emissions (European Commission 2020). Table 2 illustrates that many European countries are among the top 10 methane shares in the OECD (the European Union has an average 10% methane share across all 28 countries).

Table 2 Top methane emitting countries by share of total emissions, 2017

Rank	Country	Methane emissions	Total emissions (CO_2-e)	Methane % of total emissions (CO_2-e)	% Biogenic methane	% Fossil methane
1	New Zealand	34,132	80,853	42%	95%	5%
2	Ireland	14,034	60,744	23%	87%	13%
3	Australia	103,602	554,127	19%	72%	28%
4	Latvia	1,805	11,306	16%	67%	33%
5	Lithuania	3,257	20,417	16%	77%	23%
6	Denmark	6,920	49,226	14%	87%	13%
7	Portugal	9,477	70,546	13%	92%	8%
8	Canada	92,848	715,749	13%	47%	53%
9	Iceland	581	4,755	12%	98%	2%
10	Slovenia	2,102	17,454	12%	55%	45%

Note: Measures total methane divided by total CO2e emissions. Need to clarify which conversions used. Australia may differ from NGGI. Biogenic methane calculated from gigagrams of methane emitted in 2017 from agriculture and waste sectors.Could include EU28 as one region.
Source: OECD, FAOSTAT

Australia's biogenic methane emissions

Australia has the third highest share of methane in GHG emissions across the OECD, although 28% of this is fossil-derived. In response to the scientific debate, livestock groups such as the Cattle Council of Australia suggest that GWP* demonstrates that the existing GWP_{100} model may overstate livestock's impact on global temperatures. Following New Zealand's lead, these groups suggest Australia should investigate the feasibility of switch to a GHG accounting framework that does not place an unfair burden on their industry.

Australia's latest GHG emission inventory estimates that 23% of total national emissions are from methane, with over two-thirds of this biogenic methane (Table 3).

The major sources of Australia's anthropogenic methane emissions are agriculture (47%), energy (31%), landuse change (13%) and waste (10%). Agriculture is one of the most methane-intensive industries in Australia's emissions profile – methane represents over three-quarters of CO_2-e emissions. Waste is even more methane-intensive (95% of emissions).

All methane from the energy industries are fossil-derived, and are emitted via transport, direct combustion and fugitives.

In Australia, all biogenic methane emissions are attributable to three sectors: agriculture (68% of total biogenic methane), landuse change (18%) and waste (14%) (Table 3). All methane emissions from these sectors are considered biogenic.

One of the reasons livestock industries are concerned about the potential over-representation of their industries in climate change mitigation commitments is that the emission of non-CO_2 greenhouse gases, such as methane and nitrous oxide, are intrinsic to many natural systems within which agriculture operates. Hence, the complete elimination of these emissions is not possible (Reisinger and Clark 2017; CCC 2019), and the cost of reducing these emissions can be higher than in other sectors of the economy. s. 33(a)(iii)

Table 3 Australia's biogenic and fossil methane emissions, by sector, 2018

	Greenhouse Gas Emissions (CO_2-e) based on GWP_{100}			Biogenic methane emissions	
Sector	**Biogenic methane**	**Fossil methane**	**Total emissions (all GHGs)**	**Share of industry methane emissions (%)**	**Share of total emissions (%)**
Electricity	-	598	183,170	0.0%	0.0%
Direct combustion	-	992	97,155	0.0%	0.0%
Transport	-	358	100,796	0.0%	0.0%
Fugitives	-	37,107	54,450	0.0%	0.0%
Industrial Processes	-	77	34,197	0.0%	0.0%
Agriculture	58,388	-	75,588	100.0%	77.2%
LULUCF	15,768	-	-20,601	100.0%	n.a.
Waste	12,012	-	12,691	100.0%	94.6%
Total Australia	86,168	39,132	537,446	68.8%	16.0%

Note: All emissions based on GWP_{100} AR4. Assumes all agriculture methane is biogenic, and all LULUCF and waste methane is biogenic. LULUCF share of biogenic not estimated as total emissions are negative.
Source: AGEIS.

Potential limitations of adopting GWP*

The treatment of biogenic methane in global plans for climate change mitigation using GWP_{100} has led some countries to consider alternatives like GWP*. s. 33(a)(iii)

However, while there is agreement on the science behind GWP*, there are a number of factors which may make its implementation in global abatement plans more difficult. These may mean that the emission abatement burden faced by biogenic methane emitters will not necessarily be lower under such a scheme.

Changes to burden of mitigation across countries and industries

While GWP_{100} is a less scientifically sophisticated concept, it does provide a clear path to global temperature stabilisation: all GHG emissions must be reduced to net zero (Figure 4a). GWP*, however, introduces additional complications and would require new targets to be negotiated, both across countries and between industries within countries.

For instance, using GWP* to advocate constant methane emissions would change the relative burden of GHG mitigation across industries, in favour of those with larger proportions of methane. If methane emissions remain constant, temperatures will rise at a faster rate than estimated under a scenario where all GHGs trend to net zero. Hence, emissions of CO_2 (and other long-lived gases) would have to reduce to net zero faster than currently negotiated in order to achieve the same temperature goals (Figure 4b). Compared to existing commitments, this would impose additional costs on fossil fuel industries in particular, in order to manage global warming.

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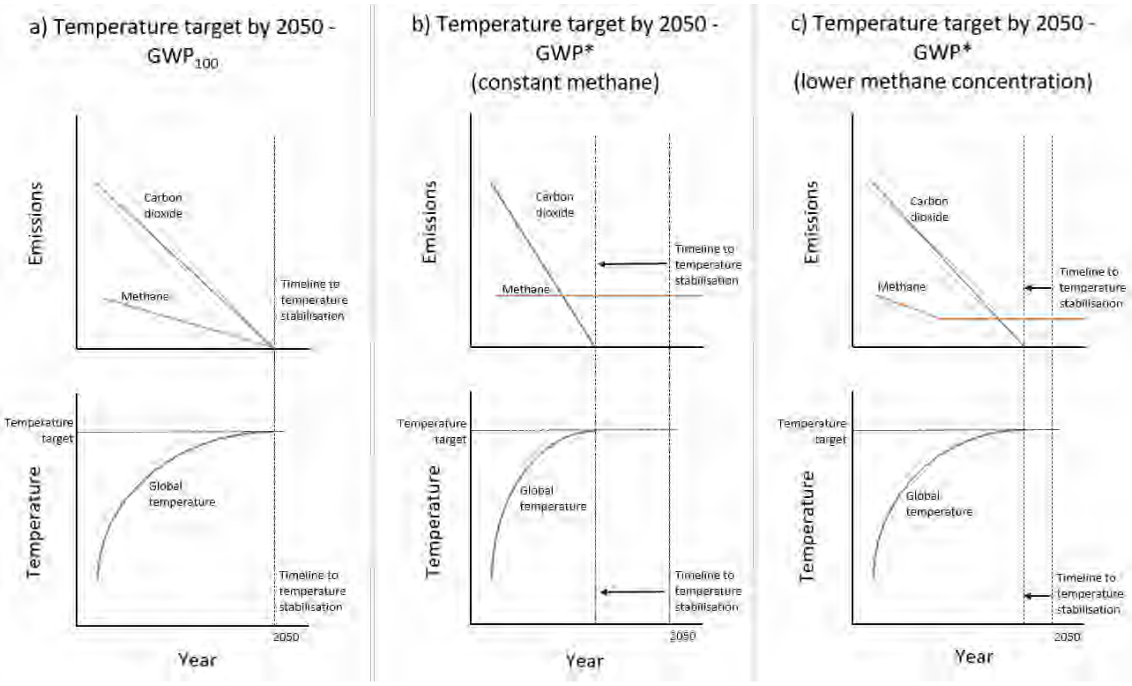
Figure 4 Warming impacts of different emission scenarios under GWP100 and GWP*



Note: Trends in emissions, temperatures and timelines indicative only. For simplification, only two greenhouse gases are presented.

However, GWP* does not necessarily imply that biogenic methane emissions should remain constant. In fact, GWP* can also show that reductions in methane emissions can rapidly reduce atmospheric methane concentrations (inflows < outflows), and hence contribute to relatively significant and rapid reductions in global warming potential. This would slow temperature rises, and allow more time for emissions of CO_2 and other LLCPs (including fossil methane) to transition to net zero (Figure 4c). s. 33(a)(iii)

The right to constant emissions

Some proponents of GWP* argue that this accounting metric demonstrates that biogenic methane emitters can maintain a constant level of emissions without having an impact on global temperatures. The implication of this argument is that they do not contribute to climate change, and therefore should not have to undertake any abatement.

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However, this interpretation of GWP* is also incorrect, because the GWP* science does not indicate the 'correct' level of atmospheric methane concentrations, or how emissions should be allocated. While it is true that a steady rate of biogenic emissions over time does not contribute to further warming, it is also true that each emission of biogenic methane prevents the atmospheric concentration of methane from declining: the marginal warming contribution of each methane emission remains positive. Without current emissions of methane, the atmospheric concentration of this gas would naturally decline as methane decays, thus providing a global cooling effect that would partly counter-balance the warming effect of other GHG emissions. Hence, as noted above (Figure 4c), a permanent decline in atmospheric methane concentrations would allow more time to reduce emissions of CO_2 or other long-lived GHGs.

Implicit in the argument that current methane emitters can continue emitting without cost is that these emitters have a 'right' to the current atmospheric concentrations of methane. That is, for example, when a livestock operation emits 1 tonne of methane, that same operation is entitled to the 'offset' of the decay of 1 tonne of methane currently in the atmosphere. While this could be negotiated in future GHG abatement targets, there is no scientific or economic basis to this argument.

Regardless of this, atmospheric methane concentrations are not currently stable. In fact, methane emissions have increased significantly in recent years, according to the Global Methane Budget, as a result of global agricultural and mining emissions. The stabilisation of global temperatures is therefore unlikely to be compatible with current levels methane, and the atmospheric concentration of methane, currently at 1875ppm, will have to be reduced.

Climate feedbacks

The relatively rapid and large temperature impact of methane emissions has indirect effects on global temperatures, which means that the consequence of constant emissions is not necessarily neutral.

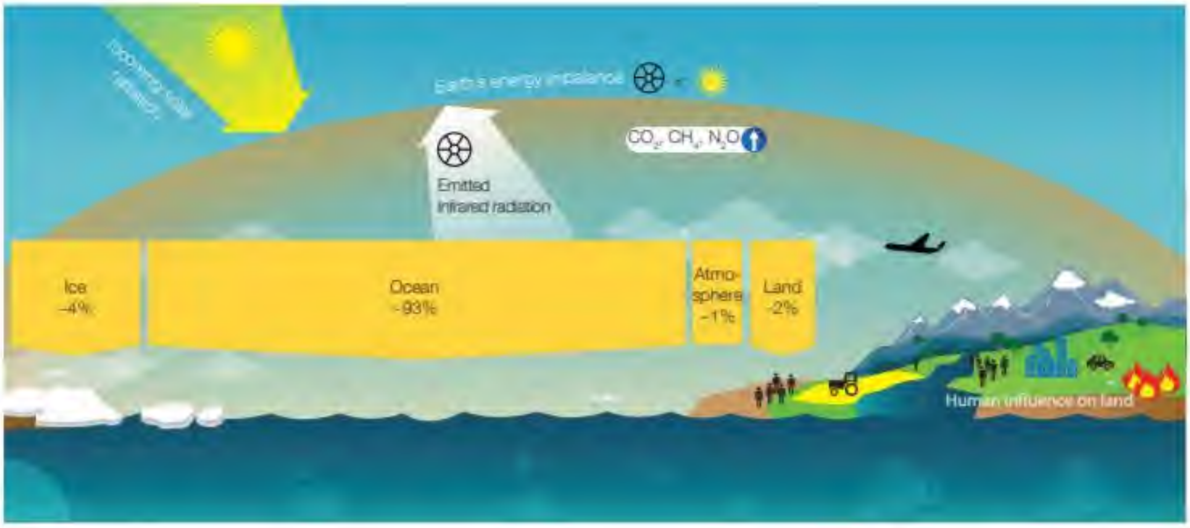
While methane only persists in the atmosphere for around 12 years on average, the warming impact is not limited to this time due to climate feedbacks in the Earth's system.

Since at least 1970 there has been more energy entering the Earth's atmosphere than escaping it due to human induced greenhouse gas emissions. While some of this energy has been warming the atmosphere and land, and evaporating water and ice, more than 93% of the excess warming

since the 1970s has been absorbed into the ocean (Reid 2016, Figure 5), causing it to warm (Rhein et al. 2013). Heat accumulated in the ocean is not locked away indefinitely and this excess heat can be released back into the atmosphere (Reid 2016). Increasing ocean temperatures are also having other impacts including increasing sea level rise, intensification of El Niño events, increased occurance of extreme weather events, warming adjacent land masses and deoxygenation (Reid 2016).

Hence, despite the short lifetime of methane in the atmosphere, the indirect impact of its warming can continue for hundreds to thousands of years (Zickfeld et al. 2017, Eckard and White 2019).

Figure 5 Flow and storage of energy in the Earth's climate system



Note: Schematic representation of the flow and storage of energy in the Earth's climate system. Around 93% of the excess energy goes into the ocean and the remainder goes into the atmosphere, land, and melting ice and snow.
Source: Reid 2016.

Constraints on industry growth and flexibility

Proponents of GWP* argue that this metric will allow the maintenance of constant emissions into the future, implying that industry activity can also remain constant. s. 33(a)(iii)

Over the last decade, Australia's beef cattle numbers have fluctuated between 22.3 and 26.5 million head, without exhibiting a trend in either direction. Livestock numbers vary from year to year as a result of changes to climate conditions, which affect survival and birth rates, and markets, which affect farmers' decisions about turn off and live export. Livestock emissions are highly correlated to animal numbers.

As a result, livestock numbers and emissions can change significantly each year, generally moving in the same direction (Figure 6). For example, after falling in 2010, livestock numbers rebounded strongly, by almost 2 million head, in 2011. And after declines in livestock numbers in 2015 and 2016, numbers increased by over 1 million head in 2017. Emissions followed a similar trend in these years.

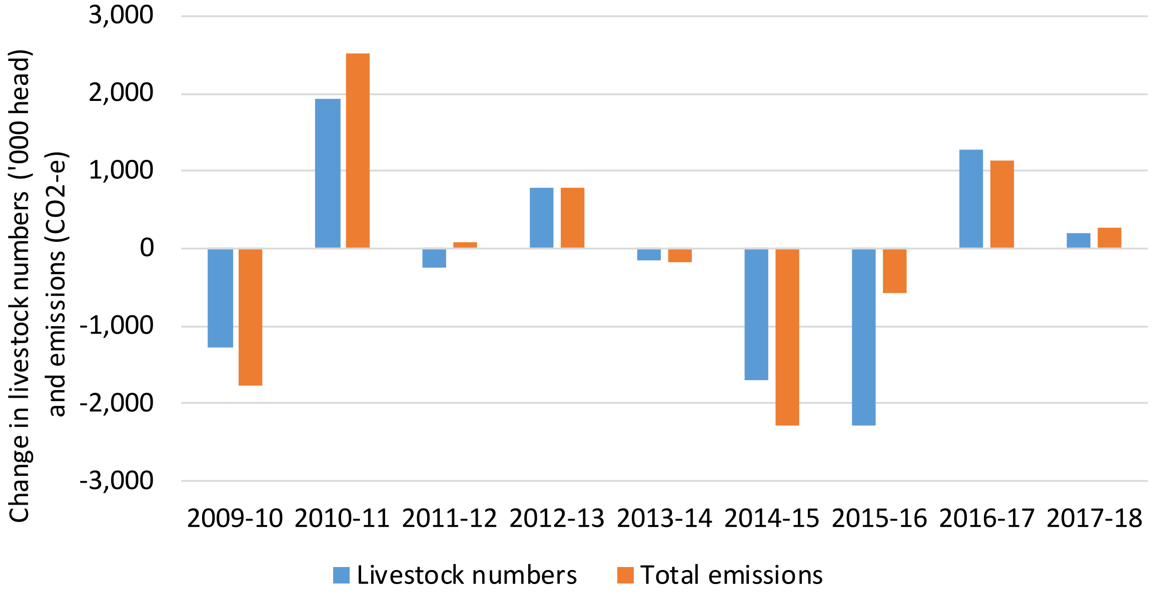
Hence, emissions from livestock are never constant, s. 33(a)(iii)

In the case of

livestock, a framework for allowing constant emissions could be based on long-term average livestock numbers, which would allow annual fluctuations but restrict any trend growth in livestock numbers. Alternatively, baseline emissions could be based on an individual base year (such as 2015), which may be detrimental to livestock farmers if it constrains stock rebuilding.

s. 33(a)(iii)

Figure 6 Annual changes in livestock numbers and total GHG emissions, beef cattle



Note: note sure how to present data

Conclusions: policy implications

GWP* is justified scientifically, and does improve the representation of long- and short-lived gases on global temperature change. There are simplifications in the GWP_{100} metric which could result in higher global temperatures if CO_2 mitigation is delayed.

But GWP* does not offer an easier path to climate mitigation. s. 33(a)(iii)

and concrete action is still required to achieve global temperature stability. Contrary to the public discussion around GWP*, this method does not justify the maintenance of current methane emission levels at zero cost. Instead, it highlights the imperative of reducing emissions of long-lived gases to zero, and the balancing role that can be played by short-lived gases in managing global temperatures while the transition to net zero emissions is navigated.

It is important to recognise that the net zero emissions target that has been endorsed by the Paris Agreement has provided incentives for all sectors of the economy, including livestock industries, to consider their role in this transition. The national commitments made under the Paris Agreement recognise the intrinsic nature of methane emissions to many biological processes inherent in agriculture, and the high costs of abatement faced by the industry as a result. Hence, under this GWP_{100} framework, many agricultural industries have been provided flexibility to investigate alternative paths to net zero, and identify existing gaps in technology and policy that must be overcome to achieve it.

The IPCC has also recognised this, and has identified a range of 24-47% global agricultural methane emission reductions by 2050, relative to 2010, in emission pathways that keep warming to 1.5°C (NZAGGRC 2019)

But rather than representing an excess burden on these industries, this framework has provided incentives for research into new technologies and policy development. Research is underway in many countries to unlock methane abatement opportunities, particularly through feed supplments and forages. Much of this research is being undertaken in Australia, incentivised by the prospect of increasingly environmentally-conscious consumers and investors. Importantly, many of the technologies to reduce emissions have co-benefits for agricultural productivity, which could help spread adoption ahead of market or policy incentives.

For example, the opportunities of this transition to net zero has led Australia's Meat and Livestock Association (MLA) to develop a goal to be carbon neutral plan by 2030 (CN30), and to establish pathways to the target via existing management practices and investment in new technologies to reduce methane emissions, including use of existing and prospective livestock and land management practices (Mayberry et al. 2018).

Other agricultural industries, not necessarily involved in methane emissions, have also endorsed zero emissions goals which support their environmental reputation. GrainGrowers supports a net zero goal for agriculture by 2050 and is aiming to release a grain-specific target for 2030. Other sectors are also acting, and the National Farmers' Federation's *2030 Roadmap* aims to see the whole sector trending towards carbon neutrality by 2030. A number of individual red meat producers have also claimed carbon neutral certification.

s. 33(a)(iii)

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s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Thursday, 14 October 2021 11:51 AM
To: s. 22(1)(a)(ii); s. 22(1)(a)(ii)
Cc: s. 22(1)(a)(ii) Greenville, Jared; s. 22(1)(a)(ii) s. 22(1)(a)(ii)
Subject: RE: Ag subsidies and emissions [SEC=OFFICIAL]
Attachments: ABARES GWP Brief - Oct2020.docx

Hi s. 22(1)(a)(ii), see attached – we noticed a couple of typos on the first page of the Brief. Feel free to share all or part as you wish, and happy to discuss any other briefing needs going forward.
s. 22(1)(a)(i

From: s. 22(1)(a)(ii) @agriculture.gov.au>
Sent: Wednesday, 13 October 2021 2:55 PM
To: s. 22(1)(a)(ii) @agriculture.gov.au>; s. 22(1)(a)(ii) @agriculture.gov.au>
Cc: s. 22(1)(a)(ii) @agriculture.gov.au>; Greenville, Jared <Jared.Greenville@agriculture.gov.au>; s. 22(1)(a)(ii) @environment.gov.au>
Subject: Re: Ag subsidies and emissions [SEC=OFFICIAL]

Thanks s. 22(1)(a)(i appreciate your insights as always.

Continuing on the topic of methane, following a conversation with our SES it looks like GWP is coming back into focus and becoming a topic for us to be prepared to brief on. This is reinforced with current government meetings taking place.

You have previously circulated the attached deep dive on the issue which has been a great resource. We haven't shared this brief as requested, but I was hoping to get approval to share elements of it going forward? This would be a great way to get our SES and broader network up to speed on the issue so we can be better prepared for incoming requests.

Happy to discuss.

Kind regards
s. 22(1)(a)(ii)

s. 22(1)(a)(ii)

Assistant Director | Climate and Adaptation Policy | (02) 627s. 22(1)(a)(ii)

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Australian Government
Department of Agriculture, Water and the Environment

October 2020

GWP* – policy implications for an alternative measurement of livestock greenhouse gas emissions

Key Points

- The Paris Agreement to reduce GHG emissions uses the GWP100 greenhouse gas accounting system. The GWP100 has been criticised for not taking into account the differences between long-lived gases (e.g. CO2) and short-lived gases (such as biogenic methane that breaks down relatively quickly, of which livestock is a major source).
- GWP* is an alternative accounting methodology that takes into account how long a gas resides in the atmosphere and reduces the warming impact associated with short-lived gases. it reduces the burden on livestock owners to reduce emissions and provides an argument for biogenic methane emissions to be allowed to stabilise (rather than fall) at a constant level equal to its rate of decay.

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Summary

- Under the Paris Agreement, climate change impacts of all greenhouse gases are aggregated using a metric called GWP_{100}. Under this, all GHG emissions must be reduced to net zero to stabilise temperatures, using the GWP_{100} multipliers (e.g. 1t biogenic CH_4 = 28t CO_2 IPCC AR5).
- GWP* is an alternative metric which identifies different impacts of short- and long-lived gases. Under GWP*, short-lived GHG emissions can remain constant without contributing to rising temperatures; while long-lived GHG emissions must still be reduced to net zero.
- CO_2 is a long-lived gas, lasting for over 1000 years in the atmosphere. Methane is a short-lived gas, lasting only 12 years on average before decaying into CO_2. *Biogenic* methane is produced from organic matter, which has sequestered CO_2 during its growth.
- Livestock is a major source of biogenic methane emissions, and some industry groups propose the adoption of GWP* in GHG abatement targets. For example, New Zealand has proposed a separate biogenic methane budget (and reduction target) in its Climate Change Response Act.
- However, there are some important implications of using GWP*:

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- GWP* does not mean that biogenic methane emissions have no impact on warming. While matching methane emissions to decay rates will result in neutral warming impacts, each emission of methane also prevents the atmospheric methane concentration from declining: the marginal warming impact of each methane emission remains positive.
- The high, short-term warming impact of methane can be stored in the ocean; hence the warming effect can persist beyond the atmospheric lifetime of the gas.

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- The Paris Agreement provides indirect incentives for emission abatement in agriculture, without imposing immediate cost burdens. This is evident in Australia, with some red meat producers acquiring carbon neutral certification, and MLA setting a target for carbon neutrality by 2030, and pursuing an R&D program to bring technologies to market to achieve this.

Warming impacts of short- and long-lived greenhouse gases

The main anthropogenic greenhouse gases (GHGs) in the atmosphere are carbon dioxie (CO_2), methane (CH_4), nitrous oxide (N_2O) and synthetic gases (Table 1). These gases prevent the sun's heat from escaping the atmosphere, hence causing the climate to warm. Each GHG has a different source, warming potential and residence time in the atmosphere.

Carbon dioxide is known as a long-lived climate pollutant (LLCP) as it remains in the atmosphere for hundreds to thousands of years (Table 1) – although CO_2 can also be removed from the atmosphere, such as through sequestration by plants and soils.

In contrast, methane is known as a short-lived climate pollutant (SLCP) as it only persists in the atmosphere for an average of 12 years, before breaking down into CO_2 and water; some atmospheric methane is also removed through uptake in soil (Jackson et al. 2020; McSweeney 2020). The CO_2 produced from decayed methane will then itself contribute to global temperature and become a LLCP.

Table 1 Estimated lifetime of major greenhouse gases and warming potential under GWP_{100}

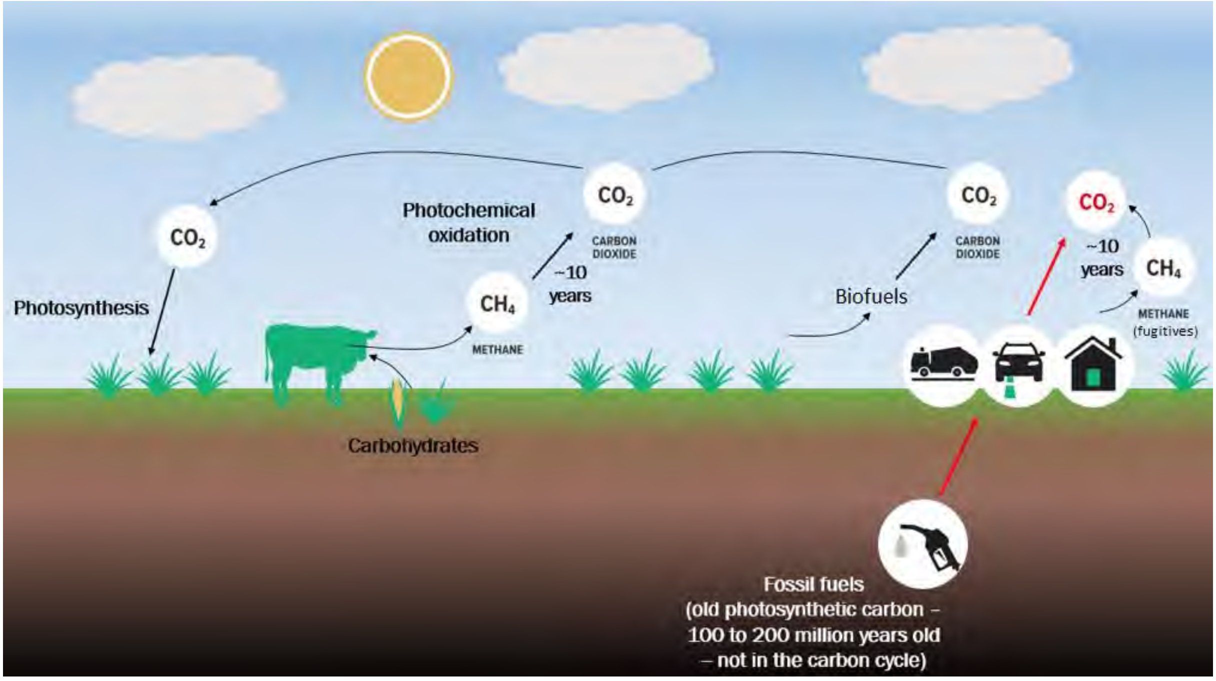
Gas	Chemical formula	Atmospheric lifetime (average)	GWP_{100} (AR5)	Share of Australia's emissions (CO_2-e) b
Carbon dioxide	CO_2	Up to millenia	1	70.0%
Methane	CH_4	12 years	28-30 **a**	23.3%
Nitrous oxide	N_2O	121 years	265	4.4%
Hydrofluorocarbons	HFCs	5.2–47.1 years	677–4,800	2.2%
Perfluorocarbons	PFCs	2,600–50,000 years	6,630–11,100	<0.0%
Sulphur hexafluoride	SF_6	3,200 years	23,500	<0.0%

Note: **a** NZPC (Box 9.3) say GWP for fossil is 30. According to Guardian, 30 is fossil. **b** Australia's GHG inventory currently published in AR4 units (could provide GWP100 for AR4 too). Australia's NGGI is scheduled to use these AR5 estimates from 2020–21 (DISER, p.22, DISER p.23). Could split methane into biogenic and fossil (but not sure if all waste is fossil).
Source: Greenhouse Gas Protocol 2016; NZPC Table 9.1, AGEIS.

Because methane is integral to many biological and geological processes, there are sources and sinks of methane emissions which are not human-induced (anthropogenic). These are not included in global climate mitigation commitments, although they can be indirectly affected by human activities, and impact climate change through feedbacks (Global Methane Budget).

There are two categories of anthropogenic methane emissions: *biogenic*, which is produced from organic matter, for example through digestion by animals or decomposition in landfills; and *fossil*, which derives from the extraction and use of fossil fuels (organic material from the geological past) (Figure 1). Importantly, the CO_2 produced from the atmospheric decay of biogenic methane is offset by the carbon sequestered in plants from which the methane is derived. This means that there is a *net zero CO_2 effect of biogenic methane* emissions. In contrast, fossil-derived methane will degrade into CO_2 which is not offset by sequestration, hence producing both short-lived methane and long-lived CO_2, both of which contribute to global temperatures.

Figure 1 Biogenic and fossil methane cycle



Source: adapted from Place (2019).

Comparing the effects of short- and long-lived gases – GWP_{100}

To estimate the combined impact on global warming of all anthropogenic GHG emissions, the Intergovernmental Panel on Climate Change (IPCC) use a metric which measures the global warming potential (GWP) of each greenhouse gas over 100 years, converted to CO_2 equivalents (CO_2-e). This metric is called GWP_{100}, and is used in IPCC guidelines for national greenhouse gas inventories, which are the basis for the Kyoto Protocol and Paris Agreement (IPCC 2007, 2014).

The CO_2-e estimate for methane has changed slightly as scientific understanding of atmospheric processes has improved. These changes are reflected in each update of the IPCC Assessment Report. Australia's current (2019) national greenhouse gas inventory (NGGI) is based on the Fourth Assessment Report (AR4, IPCC 2007), and uses a conversion of 1t CH_4 =25t CO_2. Table 1 summarises the GWP_{100} estimates for major GHGs based on the Fifth Assessment Report (AR5, IPCC 2014), in which methane has 28 and 30 times the warming potential of CO_2 (based on biogenic and fossil methane, respectively). A Sixth Assessment Report (AR6) is due for release in 2022, which may update these estimates.

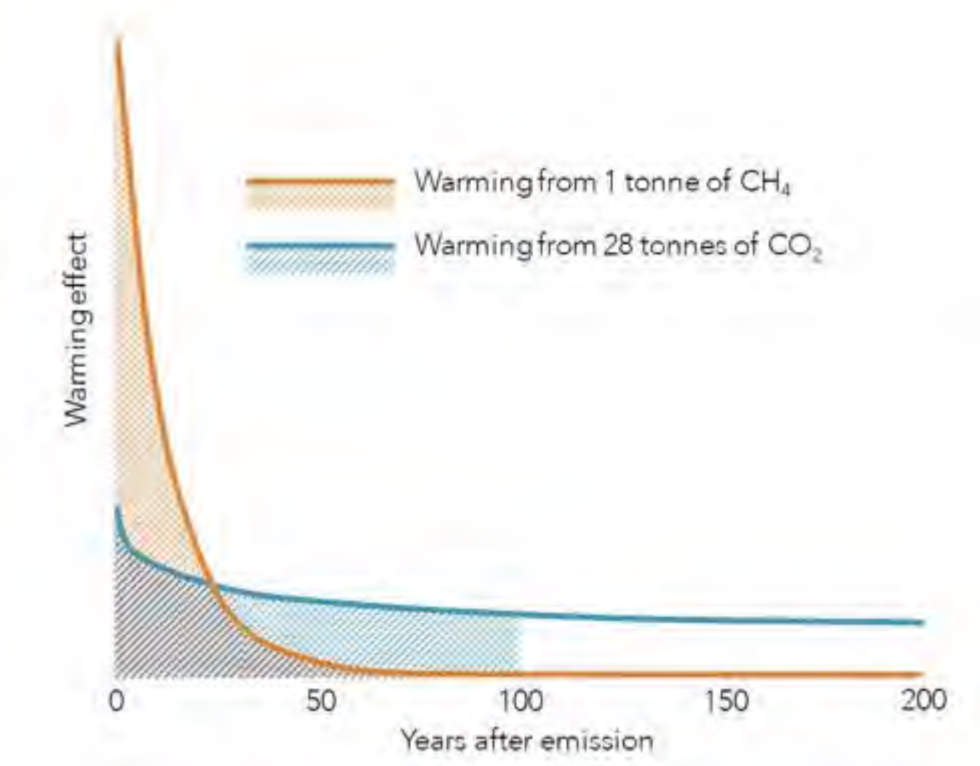
Despite its short-lived residence in the atmosphere, methane has a stronger warming impact than CO_2, and the intertemporal impact of the gases is very different (Figure 2). While the warming impact of methane is much higher than CO_2 initially, it decreases rapidly over time, following an exponential decay curve (Reisinger 2018). Although the average duration of methane in the atmosphere is only 12 years, some decays much faster than this, and some remains in the atmosphere 50 years after the original emission. In contrast, CO_2 declines only slightly over its residence in the atmosphere, and persists beyond the 100 year assumption used in GWP_{100}.

Figure 2 illustrates, in a simplified way, what the GWP_{100} conversion factors for CO_2 and methane represent: over 100 years, the area under the CH_4 curve (representing the aggregate warming effect of one unit of methane) equals the area under the curve representing 28 units of CO_2 (using the GWP_{100} conversion factors from IPCC AR5).

The implication of the GWP_{100} metric is that every emission of greenhouse gas contributes to global warming, and hence the emission of all greenhouse gases must be reduced to zero, or offset by CO_2 removal (sequestration), in order to achieve global temperature stability. This is the fundamental objective of the Paris Agreement (see Box 1).

However, this is also a limitation of GWP_{100}.

Figure 2 Comparing the warming effects of CO_2 and CH_4



Source: NZPC 2018, adapted from Reisinger and Strrombergen 2011. Based on IPCC AR5 conversion of CH_4 to CO_2-e.

Potential limitations of GWP_{100}

The GWP_{100} metric described above uses simplifying assumptions to compare the relative warming impacts of different greenhouse gases. The implication of GWP_{100} emissions accounting is that all GHG emissions must be reduced to net zero to achieve climate stability, and the GWP_{100} value represents the relative priority for abatement of each greenhouse gas.

However, there are alternative ways to achieve global temperature stability that cannot be recognised using GWP_{100}.

Because each emission of CO_2 results in a permanent (>1000 years) warming effect, from a scientific perspective it is imperative that these emissions be reduced to net zero. Delays in abating CO_2 emissions can lock in permanently higher global temperatures due to the compounding impact of CO_2 (Climate Analytics 2019) – although sequestration activities such as revegetation can reverse this, provided they remain permanent sinks.

Box 1 The Paris Agreement

The Paris Agreement provides a common framework for all countries to tackle climate change. It aims to limit the increase in the average global temperature to well below 2°C, and ideally to 1.5°C, to avoid more significant climate change risks.

To achieve that goal, global emissions need to peak as soon as possible and then fall to 'net zero' in the second half of the century (UNFCCC 2015; IPCC 2018). This means that all GHG emissions need to be reduced to zero or offset by sequestration activities in order to stabilise global temperatures. To estimate the path to net zero, emissions of each GHG is summed using the GWP_{100} conversion factors set out by the IPCC Assessment Reports.

The Agreement establishes that common goal. But each country is responsible for determining its targets and policies. National commitments must be formalised, regularly reviewed, and made progressively more ambitious.

Recent analysis finds that aggregate commitments are currently short of what is needed to reach the Paris goals. Without more ambition, the result is expected to be around 3.2°C of global warming, rather 1.5°C or 2°C (UNEP 2019). However the Agreement requires the level of ambition to be progressively increased, and countries are expect to update their commitments in 2020 (UNFCCC 2015).

In that context, a growing number of countries are announcing a commitment to target net zero emissions by 2050 (Energy & Climate Intelligence Unit 2020), including the EU, the UK, and others such as New Zealand (with a separate target for biogenic methane). As is implied by a net zero target, policy discussions in those countries include options for reducing or offsetting emissions associated with agriculture.

In 2015, Australia announced an economy-wide target to reduce GHG emissions by 26 to 28 per cent below 2005 levels by 2030. No industry-specific targets have been set under this goal.

In contrast, a one-off emission of short-lived gases like biogenic methane results in only a temporary increase in global temperatures (though climate feedbacks may complicate this, as discussed below). Hence, when a unit of biogenic methane is emitted, global temperature will (in theory) increase for a finite period, before falling to the original level. A pulse of methane has an average residence in the atmosphere of 12 years, and after around 50 years of exponential decay, only 2% of the original emission is estimated to remain (Reisinger 2018).

The implication of this is that, rather than requiring net zero emissions, global temperature stability can be achieved with stable, but positive, biogenic methane emissions.

However, note that an emission of fossil methane will, in contrast, result in a large temporary CH_4-induced effect on temperature, followed by a smaller permanent CO_2-induced effect after the methane decays. Hence, fossil methane emissions still need to achieve net zero for climate stability.

An alternative metric to compare warming impacts – GWP*

There are alternative ways to estimate the warming impacts of different GHGs, and taking into account their longevity in the atmosphere. Recently, the metric GWP* has been suggested (Lynch et al. 2020; Cain et al. 2019; Cain 2018; Frame et al. 2018; Allen et al. 2018) as a replacement to GWP_{100}. GWP* reports emissions as carbon dioxide warming equivalents (CO_2-w.e.) instead of radiative forcing equivalents (CO_2-e) used in GWP_{100}. This means that the GWP* calculation is better linked with the temperature change contribution of each gas.

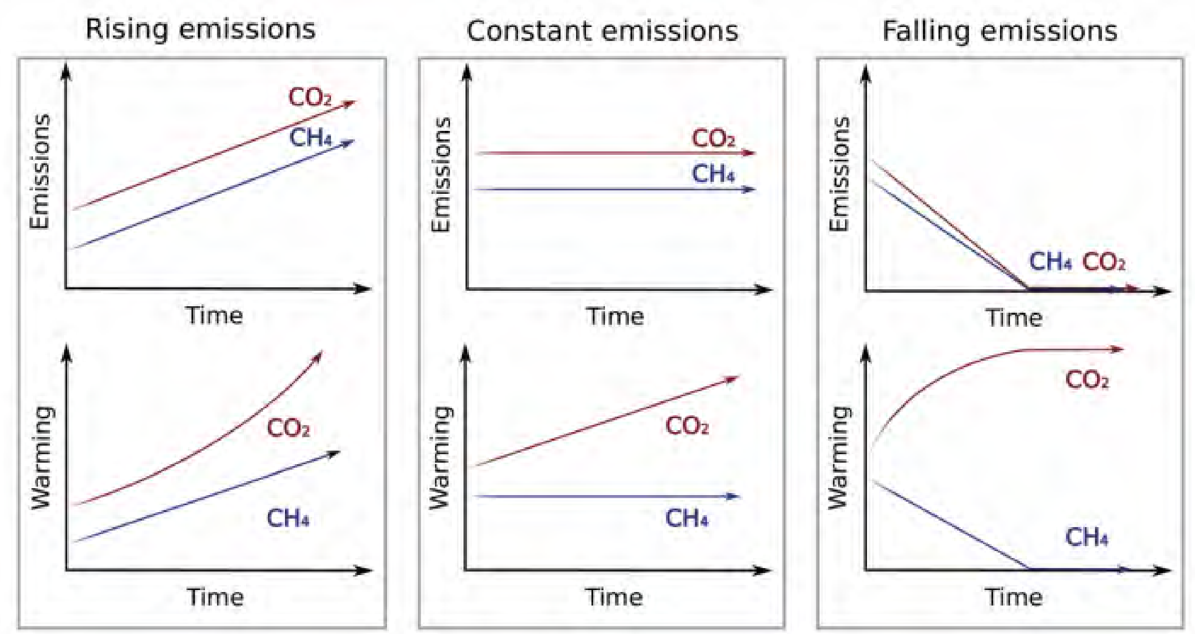
GWP* calculates the carbon dioxide warming equivalents of short-lived climate pollutants (SLCPs) primarily by relating the change in their rate of emissions over 20 years to a one-off release of a set quantiy of CO_2. This reflects the fact that SLCPs do not accumulate in the atmosphere in the same way that CO_2 does (Lynch et al. 2020).

The key consequence of GWP* is that global temperature can be stabilised by maintaining the atmospheric concentrations of short-lived gases at constant levels, by matching their inflow rates (emissions) to their outflow rates (decay) (see Figure 3). Hence, the centre column shows that constant CO_2 emissions continue to contribute to rising temperatures; while constant CH_4 emissions are associated with stable temperatures. Note also that declines in biogenic methane emissions are associated with lower global temperatures (right-hand column), because lower emissions will lead to declining atmospheric methane concentrations.

These conclusions are different to the GWP_{100} metric, under which it is assumed all GHGs (including biogenic methane) must achieve net zero emissions to stop warming.

Nevertheless, under both the GWP_{100} and GWP* metrics, emissions of long-lived GHGs like carbon dioxide must be reduced to zero to achieve climate stability.

Figure 3 Graph of alternative emission scenarios and contribution to global temperatures under GWP*



Source: Oxford Martin Programme on Climate Pollutants

Proponents for adoption of GWP* in climate commitments

There is sound and accepted scientific basis for GWP*. However, the existing global climate negotiations and commitments, using GWP_{100}, are also based on scientific assessments of the global warming impacts of GHGs. While based on a more simplified framework, these GWP_{100} emissions targets still provide a practical and effective way of mitigating climate change through emissions abatement.

The key concern in the context of global climate change policy is whether GWP_{100} results in an unfair mitigation burden on biogenic methane emitters – that is, whether the requirement to

reduce net emissions to zero under GWP_{100} places a cost on these emitters which is not consistent with their contribution to global warming, relative to other sectors of the economy.

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One of the key sources of biogenic methane is the livestock industry.

New Zealand has the highest proportion of methane in total GHG emissions across all OECD countries, 95% of which is biogenic methane (Table 2). This led the New Zealand government to introduce the Climate Change Response (Zero Carbon) Amendment Bill, which imposed a target to reduce all greenhouse gases (except biogenic methane) to net zero by 2050. Separately, the Bill includes a 10% reduction target for gross emissions of biogenic methane by 2030, and a 24 to 47% reduction by 2050 (relative to 2017 levels) (New Zealand Ministry for the Environment (MFE) 2019).

While New Zealand is currently leading efforts to establish separate mitigation targets for biogenic methane, Europe is also examining alternative ways of dealing with methane emissions (European Commission 2020). Table 2 illustrates that many European countries are among the top 10 methane shares in the OECD (the European Union has an average 10% methane share across all 28 countries).

Table 2 Top methane emitting countries by share of total emissions, 2017

Rank	Country	Methane emissions	Total emissions (CO_2-e)	Methane % of total emissions (CO_2-e)	% Biogenic methane	% Fossil methane
1	New Zealand	34,132	80,853	42%	95%	5%
2	Ireland	14,034	60,744	23%	87%	13%
3	Australia	103,602	554,127	19%	72%	28%
4	Latvia	1,805	11,306	16%	67%	33%
5	Lithuania	3,257	20,417	16%	77%	23%
6	Denmark	6,920	49,226	14%	87%	13%
7	Portugal	9,477	70,546	13%	92%	8%
8	Canada	92,848	715,749	13%	47%	53%
9	Iceland	581	4,755	12%	98%	2%
10	Slovenia	2,102	17,454	12%	55%	45%

Note: Measures total methane divided by total CO2e emissions. Need to clarify which conversions used. Australia may differ from NGGI. Biogenic methane calculated from gigagrams of methane emitted in 2017 from agriculture and waste sectors.Could include EU28 as one region.
Source: OECD, FAOSTAT

Australia's biogenic methane emissions

Australia has the third highest share of methane in GHG emissions across the OECD, although 28% of this is fossil-derived. In response to the scientific debate, livestock groups such as the Cattle Council of Australia suggest that GWP* demonstrates that the existing GWP_{100} model may overstate livestock's impact on global temperatures. Following New Zealand's lead, these groups suggest Australia should investigate the feasibility of switch to a GHG accounting framework that does not place an unfair burden on their industry.

Australia's latest GHG emission inventory estimates that 23% of total national emissions are from methane, with over two-thirds of this biogenic methane (Table 3).

The major sources of Australia's anthropogenic methane emissions are agriculture (47%), energy (31%), landuse change (13%) and waste (10%). Agriculture is one of the most methane-intensive industries in Australia's emissions profile – methane represents over three-quarters of CO_2-e emissions. Waste is even more methane-intensive (95% of emissions).

All methane from the energy industries are fossil-derived, and are emitted via transport, direct combustion and fugitives.

In Australia, all biogenic methane emissions are attributable to three sectors: agriculture (68% of total biogenic methane), landuse change (18%) and waste (14%) (Table 3). All methane emissions from these sectors are considered biogenic.

One of the reasons livestock industries are concerned about the potential over-representation of their industries in climate change mitigation commitments is that the emission of non-CO_2 greenhouse gases, such as methane and nitrous oxide, are intrinsic to many natural systems within which agriculture operates. Hence, the complete elimination of these emissions is not possible (Reisinger and Clark 2017; CCC 2019), and the cost of reducing these emissions can be higher than in other sectors of the economy. s. 33(a)(iii)

Table 3 Australia's biogenic and fossil methane emissions, by sector, 2018

	Greenhouse Gas Emissions (CO_2-e) based on GWP_{100}			Biogenic methane emissions	
Sector	**Biogenic methane**	**Fossil methane**	**Total emissions (all GHGs)**	**Share of industry methane emissions (%)**	**Share of total emissions (%)**
Electricity	-	598	183,170	0.0%	0.0%
Direct combustion	-	992	97,155	0.0%	0.0%
Transport	-	358	100,796	0.0%	0.0%
Fugitives	-	37,107	54,450	0.0%	0.0%
Industrial Processes	-	77	34,197	0.0%	0.0%
Agriculture	58,388	-	75,588	100.0%	77.2%
LULUCF	15,768	-	-20,601	100.0%	n.a.
Waste	12,012	-	12,691	100.0%	94.6%
Total Australia	86,168	39,132	537,446	68.8%	16.0%

Note: All emissions based on GWP_{100} AR4. Assumes all agriculture methane is biogenic, and all LULUCF and waste methane is biogenic. LULUCF share of biogenic not estimated as total emissions are negative.
Source: AGEIS.

Potential limitations of adopting GWP*

The treatment of biogenic methane in global plans for climate change mitigation using GWP_{100} has led some countries to consider alternatives like GWP*. s. 33(a)(iii)

However, while there is agreement on the science behind GWP*, there are a number of factors which may make its implementation in global abatement plans more difficult. These may mean that the emission abatement burden faced by biogenic methane emitters will not necessarily be lower under such a scheme.

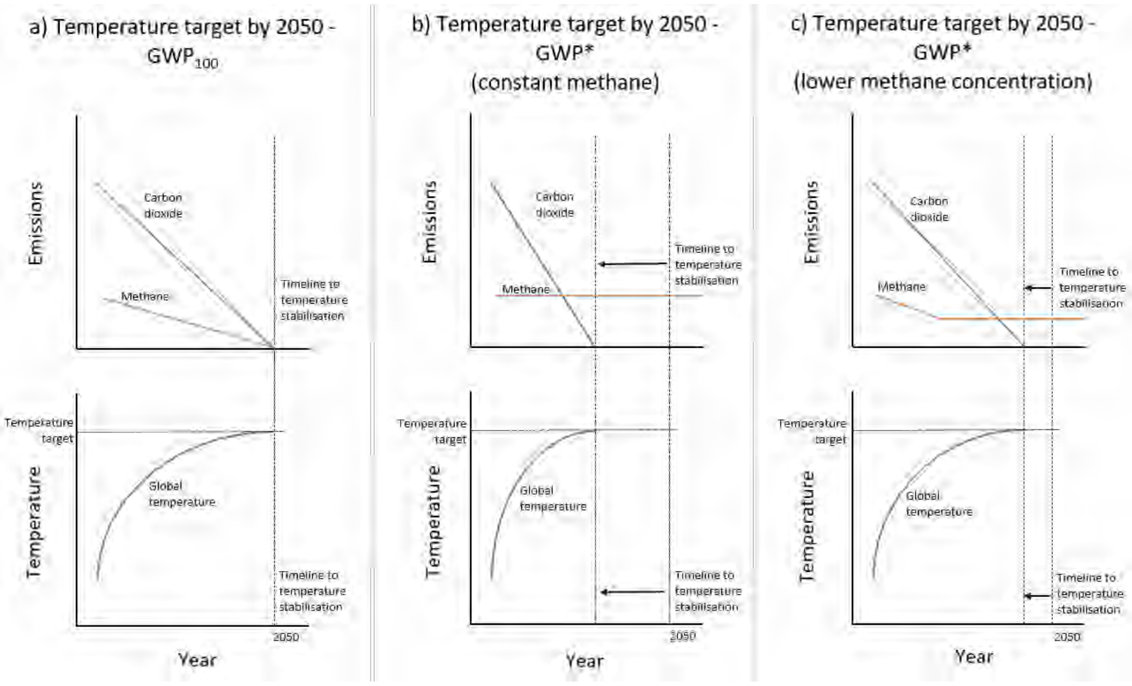
Changes to burden of mitigation across countries and industries

While GWP_{100} is a less scientifically sophisticated concept, it does provide a clear path to global temperature stabilisation: all GHG emissions must be reduced to net zero (Figure 4a). GWP*, however, introduces additional complications and would require new targets to be negotiated, both across countries and between industries within countries.

For instance, using GWP* to advocate constant methane emissions would change the relative burden of GHG mitigation across industries, in favour of those with larger proportions of methane. If methane emissions remain constant, temperatures will rise at a faster rate than estimated under a scenario where all GHGs trend to net zero. Hence, emissions of CO_2 (and other long-lived gases) would have to reduce to net zero faster than currently negotiated in order to achieve the same temperature goals (Figure 4b). Compared to existing commitments, this would impose additional costs on fossil fuel industries in particular, in order to manage global warming.

s. 33(a)(iii)

Figure 4 Warming impacts of different emission scenarios under GWP100 and GWP*



Note: Trends in emissions, temperatures and timelines indicative only. For simplification, only two greenhouse gases are presented.

However, GWP* does not necessarily imply that biogenic methane emissions should remain constant. In fact, GWP* can also show that reductions in methane emissions can rapidly reduce atmospheric methane concentrations (inflows < outflows), and hence contribute to relatively significant and rapid reductions in global warming potential. This would slow temperature rises, and allow more time for emissions of CO_2 and other LLCPs (including fossil methane) to transition to net zero (Figure 4c). s. 33(a)(iii)

The right to constant emissions

Some proponents of GWP* argue that this accounting metric demonstrates that biogenic methane emitters can maintain a constant level of emissions without having an impact on global temperatures. The implication of this argument is that they do not contribute to climate change, and therefore should not have to undertake any abatement.

s. 33(a)(iii)

However, this interpretation of GWP* is also incorrect, because the GWP* science does not indicate the 'correct' level of atmospheric methane concentrations, or how emissions should be allocated. While it is true that a steady rate of biogenic emissions over time does not contribute to further warming, it is also true that each emission of biogenic methane prevents the atmospheric concentration of methane from declining: the marginal warming contribution of each methane emission remains positive. Without current emissions of methane, the atmospheric concentration of this gas would naturally decline as methane decays, thus providing a global cooling effect that would partly counter-balance the warming effect of other GHG emissions. Hence, as noted above (Figure 4c), a permanent decline in atmospheric methane concentrations would allow more time to reduce emissions of CO_2 or other long-lived GHGs.

Implicit in the argument that current methane emitters can continue emitting without cost is that these emitters have a 'right' to the current atmospheric concentrations of methane. That is, for example, when a livestock operation emits 1 tonne of methane, that same operation is entitled to the 'offset' of the decay of 1 tonne of methane currently in the atmosphere. While this could be negotiated in future GHG abatement targets, there is no scientific or economic basis to this argument.

Regardless of this, atmospheric methane concentrations are not currently stable. In fact, methane emissions have increased significantly in recent years, according to the Global Methane Budget, as a result of global agricultural and mining emissions. The stabilisation of global temperatures is therefore unlikely to be compatible with current levels methane, and the atmospheric concentration of methane, currently at 1875ppm, will have to be reduced.

Climate feedbacks

The relatively rapid and large temperature impact of methane emissions has indirect effects on global temperatures, which means that the consequence of constant emissions is not necessarily neutral.

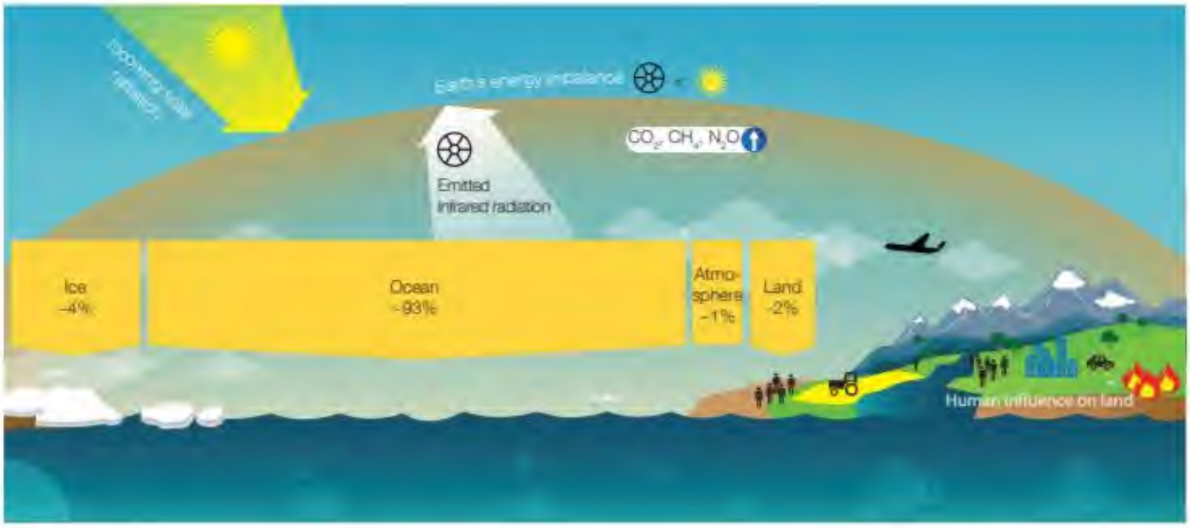
While methane only persists in the atmosphere for around 12 years on average, the warming impact is not limited to this time due to climate feedbacks in the Earth's system.

Since at least 1970 there has been more energy entering the Earth's atmosphere than escaping it due to human induced greenhouse gas emissions. While some of this energy has been warming the atmosphere and land, and evaporating water and ice, more than 93% of the excess warming

since the 1970s has been absorbed into the ocean (Reid 2016, Figure 5), causing it to warm (Rhein et al. 2013). Heat accumulated in the ocean is not locked away indefinitely and this excess heat can be released back into the atmosphere (Reid 2016). Increasing ocean temperatures are also having other impacts including increasing sea level rise, intensification of El Niño events, increased occurance of extreme weather events, warming adjacent land masses and deoxygenation (Reid 2016).

Hence, despite the short lifetime of methane in the atmosphere, the indirect impact of its warming can continue for hundreds to thousands of years (Zickfeld et al. 2017, Eckard and White 2019).

Figure 5 Flow and storage of energy in the Earth's climate system



Note: Schematic representation of the flow and storage of energy in the Earth's climate system. Around 93% of the excess energy goes into the ocean and the remainder goes into the atmosphere, land, and melting ice and snow.
Source: Reid 2016.

Constraints on industry growth and flexibility

Proponents of GWP* argue that this metric will allow the maintenance of constant emissions into the future, implying that industry activity can also remain constant. s. 33(a)(iii)

Over the last decade, Australia's beef cattle numbers have fluctuated between 22.3 and 26.5 million head, without exhibiting a trend in either direction. Livestock numbers vary from year to year as a result of changes to climate conditions, which affect survival and birth rates, and markets, which affect farmers' decisions about turn off and live export. Livestock emissions are highly correlated to animal numbers.

As a result, livestock numbers and emissions can change significantly each year, generally moving in the same direction (Figure 6). For example, after falling in 2010, livestock numbers rebounded strongly, by almost 2 million head, in 2011. And after declines in livestock numbers in 2015 and 2016, numbers increased by over 1 million head in 2017. Emissions followed a similar trend in these years.

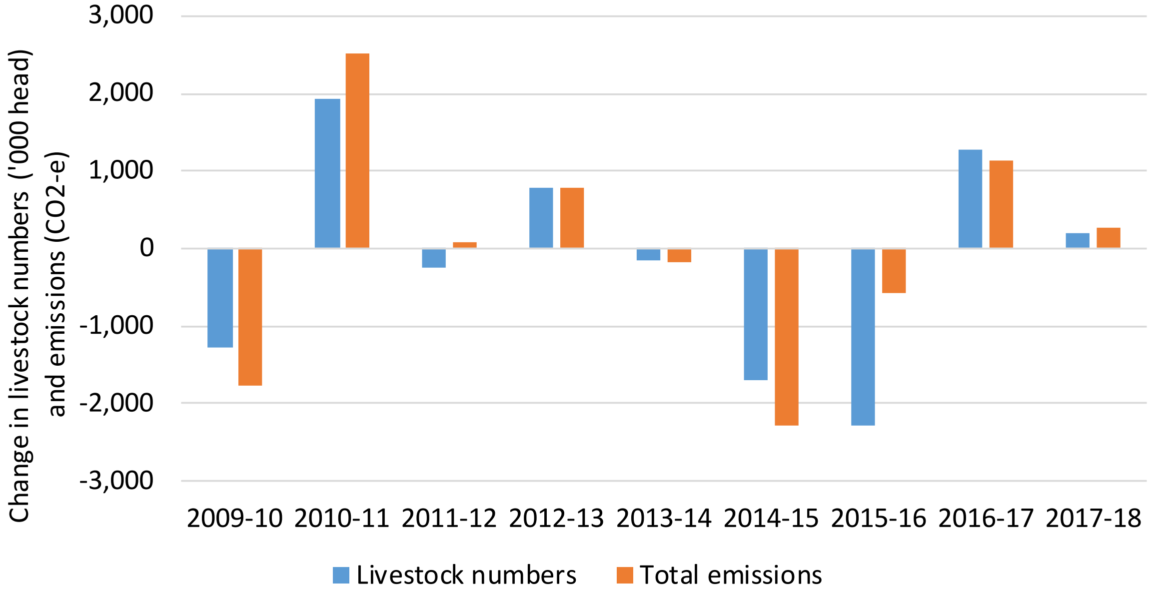
Hence, emissions from livestock are never constant, s. 33(a)(iii)

In the case of

livestock, a framework for allowing constant emissions could be based on long-term average livestock numbers, which would allow annual fluctuations but restrict any trend growth in livestock numbers. Alternatively, baseline emissions could be based on an individual base year (such as 2015), which may be detrimental to livestock farmers if it constrains stock rebuilding.

s. 33(a)(iii)

Figure 6 Annual changes in livestock numbers and total GHG emissions, beef cattle



Note: note sure how to present data

Conclusions: policy implications

GWP* is justified scientifically, and does improve the representation of long- and short-lived gases on global temperature change. There are simplifications in the GWP_{100} metric which could result in higher global temperatures if CO_2 mitigation is delayed.

But GWP* does not offer an easier path to climate mitigation. s. 33(a)(iii)

and concrete action is still required to achieve global temperature stability. Contrary to the public discussion around GWP*, this method does not justify the maintenance of current methane emission levels at zero cost. Instead, it highlights the imperative of reducing emissions of long-lived gases to zero, and the balancing role that can be played by short-lived gases in managing global temperatures while the transition to net zero emissions is navigated.

It is important to recognise that the net zero emissions target that has been endorsed by the Paris Agreement has provided incentives for all sectors of the economy, including livestock industries, to consider their role in this transition. The national commitments made under the Paris Agreement recognise the intrinsic nature of methane emissions to many biological processes inherent in agriculture, and the high costs of abatement faced by the industry as a result. Hence, under this GWP_{100} framework, many agricultural industries have been provided flexibility to investigate alternative paths to net zero, and identify existing gaps in technology and policy that must be overcome to achieve it.

The IPCC has also recognised this, and has identified a range of 24-47% global agricultural methane emission reductions by 2050, relative to 2010, in emission pathways that keep warming to 1.5°C (NZAGGRC 2019)

But rather than representing an excess burden on these industries, this framework has provided incentives for research into new technologies and policy development. Research is underway in many countries to unlock methane abatement opportunities, particularly through feed supplments and forages. Much of this research is being undertaken in Australia, incentivised by the prospect of increasingly environmentally-conscious consumers and investors. Importantly, many of the technologies to reduce emissions have co-benefits for agricultural productivity, which could help spread adoption ahead of market or policy incentives.

For example, the opportunities of this transition to net zero has led Australia's Meat and Livestock Association (MLA) to develop a goal to be carbon neutral plan by 2030 (CN30), and to establish pathways to the target via existing management practices and investment in new technologies to reduce methane emissions, including use of existing and prospective livestock and land management practices (Mayberry et al. 2018).

Other agricultural industries, not necessarily involved in methane emissions, have also endorsed zero emissions goals which support their environmental reputation. GrainGrowers supports a net zero goal for agriculture by 2050 and is aiming to release a grain-specific target for 2030. Other sectors are also acting, and the National Farmers' Federation's *2030 Roadmap* aims to see the whole sector trending towards carbon neutrality by 2030. A number of individual red meat producers have also claimed carbon neutral certification.

s. 33(a)(iii)

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s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Thursday, 25 November 2021 11:05 AM
To: Grainger, Joanna (DFAT); Greenville, Jared
Cc: s. 47F(1) ; s. 47F(1) ; s. 47F(1) ; s. 22(1)(a)(ii)@awe.gov.au; s. 47F(1)
Subject: RE: Question re methane claims and red meat [SEC=OFFICIAL]

Hi Jo, sorry about the late reply.
Thanks for bringing this article, and the growing debate, to our attention. There are a number of issues unique to climate change in agriculture that can mean generalisations, in arguments or policies, can be misleading. And proponents of certain industries can argue that these complexities mean that the policies are wrong, or that their industries are exempt from them. It will be interesting to see how these strategies play out over time, and how accounting systems and climate policies end up treating agricultural systems.

The article you link is actually reasonably good, and while it glosses over some details, there's nothing factually incorrect in it – despite the colourful language.

In terms of the methane debate you raised, the article makes legitimate points regarding the difference between biogenic methane emissions and those from fossil sources – either from the mining industry, or from the burning of fossil fuels in air and road transport. Methane breaks down into carbon dioxide after 10-12 years on average, but biogenic methane offsets this CO2 by sequestering it in plants (which are then consumed by animals which emit methane). Whereas the CO2 from fossil methane continues to contribute to warming for millennia. This isn't actually reflected in the IPCC Assessment Report guidelines – so in national inventories, all methane has a global warming potential (GWP100) of 28 (meaning it's 28 times more potent than CO2 over 100 years).

There is no specific mention of the GWP* debate in the article, although it's implied in the language about the distinction between methane and carbon-based emissions. The argument is that, because methane is a short-lived gas, livestock industries have a neutral effect on climate if production is unchanged (the volume of methane emissions equals the volume of methane removals/break-down). This is a legitimate issue, though it's often presented in a simplified way. The main problems with this argument are that (i) it imposes a large burden on other sectors to reduce emissions to achieve net zero, (ii) it constrains the livestock industry from growing, and (iii) there are positive feedbacks from methane emissions which mean the net effect is not neutral.

It's also important to note that, because methane does have a short residence in the atmosphere, it can have an important role in reducing GHG concentrations quickly, and hence meeting short-term temperature goals. Existing livestock producers do not have a 'right' to the methane already in the atmosphere – hence they cannot claim the breakdown of atmospheric methane against their current emissions, particularly when this breakdown may be part of a solution to avoiding short-term temperature rises.

There are other issues raised in the article that are also interesting:

- The article rightly holds up the RMAC/MLA CN30 initiative as one that demonstrates the industry is taking climate change seriously. The Australian government is supportive of this initiative, which relies on a range of technological solutions, practice change and landuse change. There is a great deal still to do however in this initiative in order to achieve the goal.
- The numbers quoted in terms of the reduction in agricultural emissions from livestock (>50% reduction since 2005) are often cited – they represent a point in time estimate, where sheep and dairy numbers were declining, and also combine landuse change with agriculture. But this is where the argument gets a bit more complex than presented in the article. Cattle numbers and emissions have been relatively steady over time – and hence the challenge of reducing emissions further will not be as simple as assuming the 2005-2015 trend will just continue.

- It is also misleading to claim that past reductions in emissions are sufficient to claim some sort of goodwill from consumers or investors. As we discuss in our Insights paper, consumer preferences and government policies (such as carbon border adjustment mechanisms) will be based on estimates of the *current* emissions intensities of products, not past reductions. And at present Australia's agricultural products are around the middle of our major trading partners in terms of emissions intensity. There are risks for the Australian agriculture in oversimplifying claims about the climate credentials of our products – arguing that business-as-usual is sufficient could see the sector left behind by our competitors. And, as emissions are reduced in the energy and transport sectors (as these are the current focus of mitigation policies), the share of agriculture's emissions will increase.
- There are several other points that are simplified in the article.
  - If the burden of emissions mitigation is reduced for agriculture, this will impose a greater burden on other sectors of the economy.
  - There are trade-offs with all landuses. So claiming that the pasture or feed used by livestock cannot be otherwise consumed by humans is not correct. This land can be used for a range of purposes, particularly for environmental and climate mitigation purposes. There is definitely an opportunity cost to using land for both livestock grazing and feed production.
  - Alternative protein sources do have lower emissions intensities than meat, based on current production systems. See Poore & Nemecek 2018.

Hope this helps, and happy to discuss any other issues raised by these reports.
s. 22(1)(a)(i

s. 22(1)(a)(ii)
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From: Greenville, Jared <Jared.Greenville@agriculture.gov.au>
Sent: Thursday, 18 November 2021 8:11 PM
To: Grainger, Joanna (DFAT) <Joanna.grainger@dfat.gov.au>
Cc: s. 47F(1) @dfat.gov.au>; s. 47F(1) O/S London s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 22(1)(a)(ii)@awe.gov.au; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: RE: Question re methane claims and red meat [SEC=OFFICIAL]

Hey Jo,

We will come back with a more detailed response as s. 22(1)(a)(ii) has some past briefing he will pull out. As always the truth sits in the grey. There is the consideration or who should be able to emit – for food production or electricity – and differences in the short versus long carbon cycle. The rub is often if you have to reduce emissions, and that methane has high warming impact, then no matter what the source is it will help. The issue of sustainability under BAU or otherwise is thus dependent on what 'space' is left for the emissions from the agriculture sector.

Will come back will less ramble and more considered response!

Cheers
Jared

Jared.Greenville@awe.gov.au

+61 2 6272 5098
s. 47F(1)

From: Joanna Grainger <Joanna.Grainger@dfat.gov.au>
Sent: Wednesday, 17 November 2021 4:55 PM
To: zz [External] jared.greenville@awe.gov.au <jared.greenville@awe.gov.au>
Cc: s. 47F(1) @dfat.gov.au>; s. 47F(1)
s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 22(1)(a)(ii)@awe.gov.au
Subject: Question re methane claims and red meat[SEC=OFFICIAL]

OFFICIAL

Dear Jared

As you may have seen articles like the one below are getting a lot of support from the red meat industry and MLA has got some pretty forward leaning claims about methane of late.

https://www.thomaseldermarkets.com.au/livestock/a-load-of-bulldust/

Before we start talking this concept up I wanted to check in with you about how credible we think this approach is.

I recall we talked about this a few years back and you indicated that research on the impact of methane was ongoing but wasn't clear whether it held water.

Welcome your view and also if there is a go to person in your team for this topic.

Cheers
Jo

OFFICIAL

s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Tuesday, 7 December 2021 6:34 PM
To: s. 22(1)(a)(ii)
Cc: s. 22(1)(a)(ii) Greenville, Jared
Subject: FW: Question re methane claims and red meat [SEC=OFFICIAL]

Hi s. 22(1)(a)(ii), thanks for sending a link to this article (Climate neutral livestock production – A radiative forcing-based climate footprint approach, Bradley Ridoutt). There are a number of variants to this argument going around, and some of our overseas posts have also recently noticed an uptick in reports arguing livestock industries don't contribute to climate change. See this article and the emails below:
https://www.thomaseldermarkets.com.au/livestock/a-load-of-bulldust/

This is all about trying to position agriculture to avoid some of the potential burden that emerging net zero plans may place on the industry – and their concerns are often quite legitimate.
Many use the argument that measuring gross warming potential (GWP) over 100 years doesn't reflect the transient nature of methane in the atmosphere. They hence propose a new metric (often called GWP*), which says that as long as livestock industries don't increase production, their methane emissions don't contribute to higher atmospheric methane concentrations, because the emissions offset the natural degradation of the atmospheric methane.

The paper you linked by Ridoutt is essentially the same argument, but doesn't mention GWP*, and instead focuses on a Climate Stabilization objective – if production does not contribute to increasing atmospheric concentrations of GHGs (measured in terms of radiative forcing), then it is Climate Neutral, and should be regarded as such by governments and consumers. The author claims that an ISO standard is being developed for this – but obviously this wouldn't apply to national obligations under the UNFCCC and Paris Agreement, and would essentially be for branding purposes to consumers.

There are a number of limitations to this approach, and we've briefed the department about these (see also my email below). An easy test to determine whether an activity is indeed climate neutral would be to consider whether the climate outcomes of maintaining production would be the same as ceasing production. It would be easy to show that, for sheep and lamb in this study, the climate would be warmer under the former compared to the latter – production maintains methane concentrations, while these concentrations would fall if production ceased. So production isn't climate neutral.

Anyway, thanks again for bringing it up. As these articles and papers seem to be increasing in visibility recently, and as governments start to consider how agriculture should be treated under carbon neutral pathways, we'll probably be asked to do more briefings in the future. So it's good to be aware of what's out there.
s. 22(1)(a)(i

From: Joanna Grainger <Joanna.Grainger@dfat.gov.au>
Sent: Thursday, 25 November 2021 6:10 PM
To: s. 22(1)(a)(ii) @awe.gov.au>; Greenville, Jared <Jared.Greenville@agriculture.gov.au>
Cc: s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 22(1)(a)(ii)@awe.gov.au; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: Re: Question re methane claims and red meat[SEC=OFFICIAL]

OFFICIAL

Dear s. 22(1)(a)(ii) and Jared

Thank you. This is really useful. s. 33(a)(iii)

Kind regards

Jo

OFFICIAL

From: s. 22(1)(a)(ii) @awe.gov.au>
Date: Thursday, 25 November 2021 at 01:06:43
To: "Joanna Grainger" <Joanna.Grainger@dfat.gov.au>, "Greenville, Jared" <Jared.Greenville@agriculture.gov.au>
Cc: s. 47F(1) @dfat.gov.au>, s. 47F(1) @dfat.gov.au>, s. 47F(1) @dfat.gov.au>, s. 22(1)(a)(ii) @awe.gov.au" s. 22(1)(a)(ii) @awe.gov.au>, s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: [EXTERNAL] RE: Question re methane claims and red meat [SEC=OFFICIAL]

CAUTION: This email originated from outside the organisation. Do not click links or open attachments unless you recognise the sender.

Hi Jo, sorry about the late reply.
Thanks for bringing this article, and the growing debate, to our attention. There are a number of issues unique to climate change in agriculture that can mean generalisations, in arguments or policies, can be misleading. And proponents of certain industries can argue that these complexities mean that the policies are wrong, or that their industries are exempt from them. It will be interesting to see how these strategies play out over time, and how accounting systems and climate policies end up treating agricultural systems.

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    - If the burden of emissions mitigation is reduced for agriculture, this will impose a greater burden on other sectors of the economy.
    - There are trade-offs with all landuses. So claiming that the pasture or feed used by livestock cannot be otherwise consumed by humans is not correct. This land can be used for a range of purposes, particularly for environmental and climate mitigation purposes. There is definitely an opportunity cost to using land for both livestock grazing and feed production.
    - Alternative protein sources do have lower emissions intensities than meat, based on current production systems. See Poore & Nemecek 2018.

Hope this helps, and happy to discuss any other issues raised by these reports.
s. 22(1)(a)(i

s. 22(1)(a)(ii)
Economist | ABARES
Email: s. 22(1)(a)(ii)@awe.gov.au
Phone: +61 2 627s. 22(1)(a)(ii)

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
Department of Agriculture, Water and the Environment
7 London Cct, Canberra ACT 2601 Australia / GPO Box 1563 Canberra ACT 2601 Australia

---

From: Greenville, Jared <Jared.Greenville@agriculture.gov.au>
Sent: Thursday, 18 November 2021 8:11 PM
To: Grainger, Joanna (DFAT) <Joanna.grainger@dfat.gov.au>
Cc: s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 22(1)(a)(ii)@awe.gov.au; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: RE: Question re methane claims and red meat [SEC=OFFICIAL]

Hey Jo,

We will come back with a more detailed response as s. 22(1)(a)(ii) has some past briefing he will pull out. As always the truth sits in the grey. There is the consideration or who should be able to emit – for food production or electricity – and differences in the short versus long carbon cycle. The rub is often if you have to reduce emissions, and that methane has high warming impact, then no matter what the source is it will help. The issue of sustainability under BAU or otherwise is thus dependent on what 'space' is left for the emissions from the agriculture sector.

Will come back will less ramble and more considered response!

Cheers
Jared

Jared.Greenville@awe.gov.au
+61 2 6272 5098
s. 47F(1)

From: Joanna Grainger <Joanna.Grainger@dfat.gov.au>
Sent: Wednesday, 17 November 2021 4:55 PM
To: zz [External] jared.greenville@awe.gov.au <jared.greenville@awe.gov.au>
Cc: s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 47F(1) @dfat.gov.au>; s. 22(1)(a)(ii)@awe.gov.au
Subject: Question re methane claims and red meat[SEC=OFFICIAL]

OFFICIAL

Dear Jared

As you may have seen articles like the one below are getting a lot of support from the red meat industry and MLA has got some pretty forward leaning claims about methane of late.

https://www.thomaseldermarkets.com.au/livestock/a-load-of-bulldust/

Before we start talking this concept up I wanted to check in with you about how credible we think this approach is.

I recall we talked about this a few years back and you indicated that research on the impact of methane was ongoing but wasn't clear whether it held water.

Welcome your view and also if there is a go to person in your team for this topic.

Cheers
Jo

OFFICIAL

s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Thursday, 1 April 2021 9:08 AM
To: ABARES-TradeAndGlobalChange_Program; Hockey, Kurt
Subject: OECD food system report focuses on 3 key policy questions [SEC=OFFICIAL]
Attachments: 2021 OECD - Making Better Policies for Food Systems.pdf

Hi team
OECD recently released a report on making better policies for the food system, which you may find interesting and relevant to your work.

Their report focuses on three questions:

- What has been the performance of food systems to-date, and what role did policies play?
- How can policy makers design coherent policies across the triple challenge (agriculture, health, and environmental)?
- How can policy makers deal with frictions related to facts, interests, and values, which often complicate the task of achieving better policies?

Better policies will require breaking down silos between agriculture, health, and environmental policies, and overcoming knowledge gaps, resistance from interest groups, and differing values. Robust, inclusive, evidence-based processes are thus essential to making better policies for food systems.

To save having to long into the OECD *i-Library* system, I've attached a copy to this email.
FYI if interested.

Cheers s. 22(1)(

From: Department of Agriculture, Water and the Environment <no-reply@agriculture.gov.au>
Sent: Wednesday, 31 March 2021 3:39 PM
To: s. 22(1)(a)(ii)@awe.gov.au
Subject: [BULK] Agricultural Trade Matters, March 2021 [SEC=UNOFFICIAL]

Agricultural Trade Matters March 2021

OECD releases food report on better policies for food systems

In January this year, the *Making Better Policies for Food Systems* report was released by the

Organisation for Economic Co-operation and Development (OECD).

This report recognises the ongoing stress on our food systems, which must address the triple challenge of providing nutritious food, livelihoods, and better environmental sustainability.

‘This report acknowledges the friction between facts, interests and values that governments and policy leaders have to juggle when developing policy for food systems’ said Simon Smalley, Minister Counsellor for Agriculture in London.

Read more…

Making Better Policies for Food Systems

OECD

Making Better Policies for Food Systems

OECD
BETTER POLICIES FOR BETTER LIVES

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The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Note by Turkey
The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union
The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

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Foreword

With only ten years left to meet the Sustainable Development Goals (SDGs), there is increasing recognition among researchers, policy makers, stakeholders, and civil society of the crucial role played by food systems. The convening of the UN Food Systems Summit in 2021 highlights the growing view that better policies for food systems are needed to deliver progress on all the SDGs

Food systems matter not only for food security and nutrition and for the livelihoods of those involved in these activities, but also for environmental sustainability. Even though these key objectives are interconnected, policy making and policy analysis have historically tended to deal with them in isolation. The concept of “food systems” draws attention to the important synergies and trade-offs that might exist between these different areas, and to the need for increased co-ordination between policy making communities.

The OECD has a long track record of providing data, evidence, and policy recommendations to improve the functioning of food systems, including on topics as diverse as obesity, water use, rural development, and global value chains. Much of this work has considered synergies and trade-offs and the challenges of policy coherence. In this sense, the OECD has worked on food systems for decades, albeit without using this terminology. This report focuses on three sets of questions. What has been the actual performance of food systems, and what has been the role of policies? How should policy makers go about designing policies that are coherent across different dimensions such as food security and nutrition, livelihoods, and environmental sustainability? What are common factors complicating the task of achieving better policies, and what can be done about them? In answering these questions, the report draws upon a wide body of research conducted by the OECD and others.

There is a clear need to reform those agricultural and fisheries support policies that are most distorting and which create negative environmental effects. Beyond that, food systems are highly complex and diverse, requiring the design of tailored and multidimensional policy recommendations. This report emphasises that processes matter for policy design in such circumstances. More specifically, better policies for food systems require robust, evidence-based, and inclusive policy processes. To develop effective policies, these processes must successfully overcome frictions related to facts, interests, and values, as explained in this report.

Marion Jansen
Director, Trade and Agriculture Directorate
Organisation for Economic Co-operation and Development

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The development of this work benefited from comments and suggestions by numerous colleagues across different OECD directorates including the Trade and Agriculture Directorate (TAD), the Governance Directorate (GOV), the Environment Directorate (ENV), the Science, Technology and Innovation Directorate (STI), the Economics Department (ECO), the Directorate for Employment, Labour and Social Affairs (ELS), the Centre for Entrepreneurship, SMEs, Regions and Cities (CFE), the Directorate for Financial and Enterprise Affairs (DAF), and the Office of the Secretary-General (SGE). In particular, extensive comments were gratefully received from Julio Bacio Terracino, Pauline Bertrand, Hélène Blake, Filippo Cavassini, Michele Cecchini, Claudia Chwalisz, Bertrand Dagallier, James Drummond, Sara Fyson, Jose Enrique Garcilazo, David Goessmann, Shivani Kannabhiran, Tomasz Kozluk, Carina Lindberg, Nick Malyshev, Neil Martin, Mariana Mirabile, Francesca Papa, Mariana Prats, Toni Rumpf, Rebecca Santos, Ernesto Soria Morales, Piret Tonurist, Daniel Trnka, and William Tompson. The development of this report also benefited from discussion in the OECD Food Chain Analysis Network meeting hosted by Wageningen University and the Dutch Ministry of Agriculture, Nature and Food Quality in September 2019. The chapter on the seeds sector benefited from comments and suggestions by the Technical Working Group Meeting of the OECD Seed Schemes, as well as Seed Scheme delegates and experts from the Netherlands, the European Commission, Switzerland, the Russian Federation, and the United States, and organisations including the International Union for the Protection of New Varieties of Plants (UPOV), the EU Community Plant Variety Office (CPVO), the World Farmers Organisation (WFO), the International Seed Federation (ISF), the International Food Policy Research institute (IFPRI), Consiglio per la Ricerca in agricoltura e analisi dell’ Economia Agraria (CREA), the European Forest Genetic Resources Programme (EUFORGEN), the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the American Seed Trade Association (ASTA). Furthermore, the report benefited from comments by Julian M. Alston (University of California, Davis), Ken Ash, Carmel Cahill, Jeroen Candel (Wageningen University), Keith Fuglie (USAID), Paul Heisey, Peter Kearns (Re-Imagine Europa – RIE), Jayson Lusk (Purdue University), Will Masters (Tufts University), Kelly Parsons (Hertfordshire University), and Matin Qaim (Goettingen University).

This report was declassified by the Working Party on Agricultural Policies and Markets, 24-26 November 2020.

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Executive summary

Food systems are expected to provide food security and nutrition for a world population which is projected to grow to nearly 10 billion by mid-century. Food systems are also central to the livelihoods of hundreds of millions of households around the world. Moreover, food systems are not only highly dependent on the environment, but also exert important pressures on it. In all three dimensions, the world is facing important challenges:

- Globally, about 2 billion people do not have regular access to sufficient, safe, and nutritious food; an even greater number are overweight or obese.
- At the same time, technical and structural change and the repercussions of COVID-19 are putting pressure on the livelihoods of people working on 570 million farms worldwide and along other stages of the food supply chain.
- The environmental damage from food production is also considerable. Around 80% of all threatened terrestrial bird and mammal species are in danger because of habitat loss due to agricultural expansion; food production (including pre-production and post-production activities) accounts for 21-37% of anthropogenic greenhouse gas emissions.

There have been increasing calls to adopt a “food systems approach” to simultaneously make progress on these three dimensions. A food systems approach asks that policy makers active in different areas (e.g. agriculture, fisheries, environment, public health) take a more holistic view on the set of objectives as well as on the set of possible policy levers, and coordinate to avoid incoherent policies. For example, agricultural policymakers have historically focused mostly on problems of primary agricultural production; a food systems approach places a greater emphasis on possible effects of agricultural policies on nutritional and environmental outcomes. Similarly, where environmental problems related to agriculture have in the past been considered an issue to be addressed mainly through agri-environmental policies, a food systems approach opens the possibility to use other instruments such as promoting changes in consumer behaviour or promoting voluntary standards among firms.

The growing demand for a more holistic “food systems approach” to policy making is based on the realisation that there are potential synergies and trade-offs between food security and nutrition, livelihoods, and environmental sustainability. Food systems are complex. For example, growing demand for some food products may benefit producers in poor countries but may also bring negative environmental consequences; and changes in food prices which benefit producers could simultaneously harm poor consumers. Adding to the complexity, food systems display heterogeneity, with important differences between smallholder quinoa farming in the Andes, extensive cattle grazing in Mongolia, and high-tech greenhouse vegetable production in the Netherlands. This complexity makes it hard to generalise, and highlights the importance of evidence: while it is easy to speculate about possible synergies or trade-offs, it is imperative for policy makers to scrutinise these hypotheses before using them as the basis for policy decisions. However, making better policies for food systems not only requires overcoming disagreements over facts, but also requires dealing with diverging interests and differing values. This can be achieved through inclusive policy processes which give stakeholders an opportunity to be heard, while avoiding capture by special interests.

This report contributes to making better policies for food systems by focusing on three sets of questions: What has been the actual performance of food systems around the world, and what has been the role of policies? How should policy makers go about designing policies that are coherent across different dimensions such as food security and nutrition, livelihoods, and environmental sustainability? What are common factors complicating the task of achieving better policies, and what can be done about them?

Chapter 1 describes the main expectations and achievements of food systems in terms of the "triple challenge" of food security and nutrition, livelihoods, and environmental sustainability. The actual achievements of food systems are not as black and white as is sometimes assumed, and there has been remarkable progress in some areas. At the same time, major shortcomings exist on all three dimensions. Much is already known about how better policies could contribute to improving outcomes. For example, agricultural policies around the world tend to use highly distorting measures, often creating incentives for overproduction and overuse of inputs. Such policies are inefficient ways to improve livelihoods or food security, and often have negative environmental effects. Reforming these policies would go a long way to meeting the triple challenge.

Chapter 2 gets to the heart of food systems approaches. It asks how policy makers can design coherent policies when faced with multiple objectives and multiple possible policy instruments where both synergies and trade-offs exist. Documenting and quantifying such potential spillover effects is an important first step, and can be facilitated by increased coordination between different policy making communities. Where synergies are found, one policy instrument will rarely be sufficient to meet all objectives; rather, a mix of instruments is usually needed. When trade-offs are found, experience shows that these can often be avoided by a smarter choice of policy instruments. But when trade-offs persist, the question is how society should choose between competing objectives – for instance, how to strike the balance between farmer livelihoods and climate change mitigation efforts. Robust evidence is needed to understand these trade-offs, but the final decision is not (only) a technical one.

Policies related to food systems have often shown themselves difficult to reform. Chapter 3 discusses the role of disagreements over facts, diverging interests, and differences over values. Although much is already known about which policy changes would be beneficial for food systems, information is still lacking on many issues. At the same time, any policy reform is likely to create both winners and losers, and groups with diverging interests will try to influence the policy process. It is essential to avoid policy capture (a situation where policy caters to a special interest rather than the public interest). Not all policy disagreements revolve around facts and interests, however. In many cases, there is no societal consensus on what the relative priorities should be, as people differ in the values they emphasise. To complicate matters, frictions in one area (e.g. differing values) can reinforce frictions in another area (e.g. by making people less willing to consider facts that go against their initial beliefs). The chapter identifies several good practices which can help prevent or manage such frictions around facts, interests, and values.

Case studies on the seed sector, the ruminant livestock sector, and the processed food sector provide an in-depth discussion of how these sectors can contribute to addressing the triple challenge, what kinds of synergies and trade-offs exist, and what kinds of policy processes have been used in different countries.

The seed sector makes an important contribution to meeting the triple challenge by supporting food security and nutrition, livelihoods, and sustainable resource use and climate change mitigation. However, there are several contentious issues. These include the role of private-sector investment in plant breeding; issues around access, benefit sharing and conservation of genetic resources; and the role of new plant breeding technologies. These issues are contentious because of the interplay of disagreements over facts, diverging interests, and differences over values. Implications for policy makers include the need for a better targeting of policies, greater support for competition, improvements in uptake of new technologies, better access to information and trust-building, improvements in communications tools, and strategies to support collaboration and coexistence.

Ruminant livestock is an important source of nutrition and livelihoods, but contributes to significant environmental problems, including climate change. The case study on ruminant livestock discusses its contribution to the triple challenge and illustrates how governments in Ireland, the Netherlands and New Zealand (countries with an important ruminant livestock sector) are navigating trade-offs and incorporate facts, interest and values in policy processes. Scientific facts, including from independent advisory groups, play an important role but are not always widely accepted by the public or stakeholders. Through consultation with stakeholders, policy makers hear from groups with different interests, including those with livelihoods at stake. Values play a role as well, including farmer identities and their sense of belonging to a rural community. Policy developments have also been influenced by court challenges and innovative mechanisms such as deliberative processes.

Processed food (defined as any food that has been altered in some way from its raw state) is essential to maintaining a steady global supply of safe, affordable, and nutritious foods, and the sector accounts for a significant share of income generation and employment. But some processing activities produce foods that are energy-dense and nutrient-poor and are associated with negative health effects when consumed in excess. To date, policies targeting the processed food sector have largely focused on improving health outcomes. Environmental impacts vary across different processed food products, and the processed food sector can influence the sustainability of diets through improving energy efficiency in processing, requiring stricter environmental standards of suppliers and conveying information on environmental sustainability performance to downstream consumers. Making better policies will require transparent engagement with industry stakeholders, protecting the integrity of scientific evidence, and strengthening the public's trust in public officials and scientific experts. Such processes can inform the design of policy interventions in order to minimise unwanted spill-overs, such as excessive regulatory burdens that impede industry innovations.

A recurring theme across these three case studies and the other chapters of the report is the importance of facts, interests, and values. Intuition can be a poor guide to policy making in food systems. Decisions should be based on the best possible evidence about the extent and characteristics of problems, their trade-offs and synergies, and the effectiveness and costs and benefits of different possible policy responses, including the status quo. Yet making better policies for food systems not only requires a rigorous understanding of how the world is, but also a shared view of how the world should be. The process thus inevitably involves not only facts, but also interests and values. In diverse societies, stakeholders may have diverging interests and differing values. Robust policy processes are needed to balance these diverging interests and to overcome value differences, while avoiding policy capture by special interests.

1 The triple challenge

This chapter describes the main expectations of food systems in terms of the "triple challenge" of providing food security and nutrition for a growing population; providing livelihoods for hundreds of millions of people involved in farming and along the food chain, and contributing to environmental sustainability. The achievements of food systems are not as black and white as is sometimes assumed, as there has been remarkable progress in some areas. At the same time, major shortcomings exist on all three dimensions. Much is already known about how better policies could contribute to improving outcomes. Agricultural policies around the world tend to use highly distorting measures, often creating incentives for overproduction and overuse of inputs. Such policies are inefficient ways to improve livelihoods or food security, and often have negative environmental effects. Reforming these policies would go a long way to meeting the triple challenge.

Key messages

- Food systems around the world face a triple challenge of providing food security and nutrition to a growing global population, providing livelihoods to those along the food supply chain, and contributing to environmental sustainability.
- Globally, about 2 billion people do not have regular access to sufficient, safe, and nutritious food; an even greater number are overweight or obese.
- At the same time, technical and structural change and the repercussions of COVID-19 are putting pressure on the livelihoods of people working on 570 million farms worldwide and along other stages of the food supply chain.
- The environmental damage from food production is also considerable. Around 80% of all threatened terrestrial bird and mammal species are in danger because of habitat loss due to agricultural expansion; food production (including pre-production and post-production activities) accounts for 21-37% of anthropogenic greenhouse gas emissions.
- Much is already known about how better policies could contribute to improving outcomes. Agricultural policies around the world tend to use highly distorting measures, often creating incentives for overproduction and overuse of inputs. Such policies are inefficient ways to improve livelihoods or food security, and often have negative environmental effects.
- A food systems approach to policy making is needed to exploit synergies and manage trade-offs between the different dimensions of the triple challenge.

1.1. Introduction

Food systems around the world are expected to deliver on a formidable “triple challenge”. The first requirement is to ensure food security and nutrition for all. The second is to provide livelihoods to farmers and others in the food chain, and promote rural development. The third is to do all this while ensuring environmental sustainability – i.e. using natural resources sustainably (including protecting valuable ecosystems and biodiversity) and reducing greenhouse gas emissions, as well as meeting other societal expectations such as animal welfare.[1]

The fact that these goals are a long way from being attained has led to charges of “systems failure”. Yet the scale of past achievements is as remarkable as what remains to be done:

- The world population has grown from 3 billion in 1960 to about 7.5 billion today, and there is more food available per capita than ever before.[2] Yet globally about 2 billion people do not have regular access to sufficient, safe and nutritious food, while an even greater number are overweight or obese.[3] These and other forms of malnutrition are associated with a rising public health burden.
- The process of technical and structural change has benefited many farmers who have been successfully absorbed in faster growing parts of the economy, while consumers have benefited from lower food prices. However, it has put pressure on the incomes of farmers who are not able to compete, and in some countries led to distress migration to urban areas.
- The tripling of agricultural production since 1960 was achieved primarily through improved yields and productivity growth, with only modest overall change in agricultural area. Had those productivity gains not been realised, the consequences for human development and for the environment would have been devastating. Nevertheless, production growth has imposed stresses on soils and water resources. The agricultural sector also directly accounts for 12% of GHG

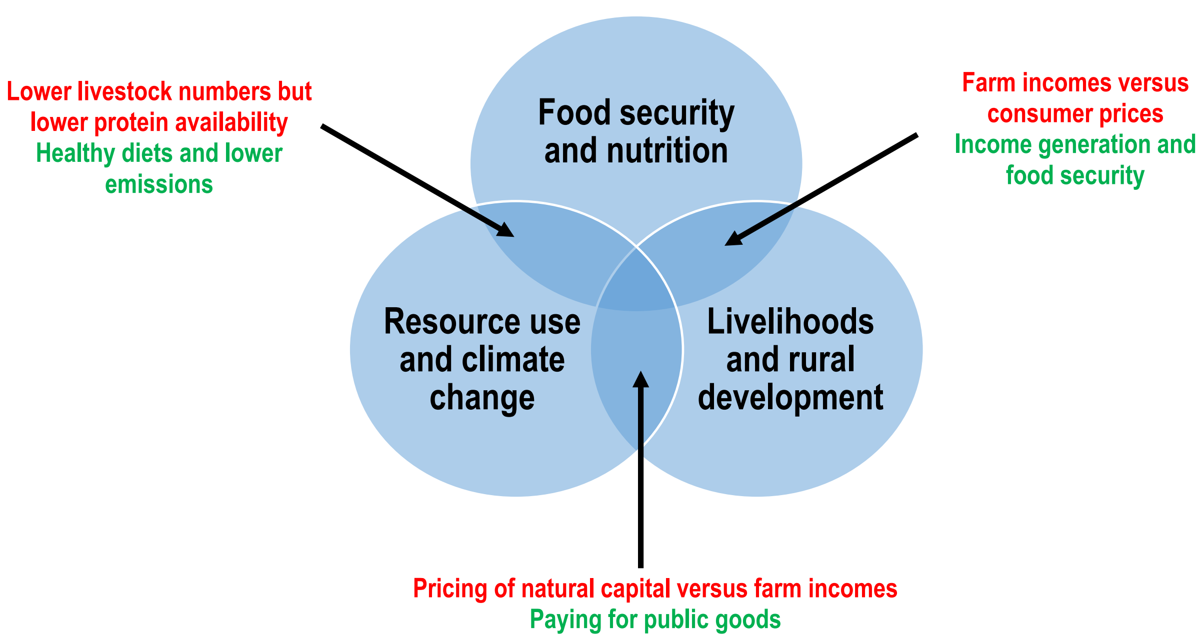
emissions, with that share more than doubling once land use change and the contribution of other segments of the food supply chain are factored in.[4]

The sudden outbreak of the COVID-19 pandemic in early 2020 created additional stresses on food systems, requiring interventions by policy makers to guarantee the continued functioning of supply chains and to ensure access to food for vulnerable consumers.[5] However, the triple challenge facing food systems around the world predates COVID-19, and will remain even as the disruption caused by this pandemic abates.

COVID-19 demonstrates the centrality and complexity of food systems, a term which covers "all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" (HLPE, 2017[1]). There is diversity in how these processes operate in different parts of the world: some are global, while others are highly localised. Food systems globally consist of a multitude of national and local food systems which shape and are in turn shaped by global processes, in the same way that the global economy consists of interactions between national and local economies.[6]

Policy makers need to be able to navigate that complexity so that their decision-making processes are no more cumbersome than necessary, yet reflect an understanding of how actions in one area may affect outcomes in another. The triple challenge provides a simplified organising framework for considering the most salient interactions (Figure 1.1).

Figure 1.1. Examples of synergies and trade-offs in food systems



Note: Examples of synergies are noted in green; examples of trade-offs in red.

As this framework suggests, some objectives can be pursued more or less independently (the non-intersecting parts of the diagram), but there may be important synergies and trade-offs between different dimensions of the triple challenge (the intersecting elements). For example, dietary guidelines in several countries suggest people should adopt diets with a limit on the consumption of red meat. Insofar as these guidelines reduce demand for ruminant meat, there could be a benefit in terms of lower emissions (a synergy). Conversely, policies that lead to lower livestock production could reduce protein availability in regions where intake remains low (a trade-off) and could negatively affect livelihoods (a trade-off). Similarly, policies to raise farm productivity could generate income growth in agriculture and beyond, and benefit consumers through lower prices, but this will involve trade-offs with regard to producers who are not able to raise their productivity. As another example, paying for public goods could benefit the environment and simultaneously support farm incomes, but pricing natural capital according to its social cost could lower incomes, at least in the short term. Policies in one dimension can thus have spill-over effects on another dimension, and in some cases there are complex synergies or trade-offs across all three dimensions (the kernel of Figure 1.1).

This chapter provides a summary assessment of the performance of food systems across these three dimensions of the triple challenge. As the chapter shows, the frequent claim that food systems are “broken” overlooks important achievements across all three dimensions, although important challenges exist and require urgent attention. A key contention is that much is already known about how better policies can improve outcomes in each of the three dimensions. However, the discussion also shows there are wide gaps between policies that would be effective in addressing the triple challenge and the policies currently adopted in many countries. These gaps may arise due to difficulties in identifying and addressing synergies and trade-offs, but they may also reflect disagreements over facts, diverging interests, or differences over values.

Synergies and trade-offs between the three dimensions could have important implications for the choice of policy instruments and for the calibration of how much intervention is needed. For example, a policy to promote healthier diets by changing the level and composition of food demand could contribute to lower emissions but is unlikely to reduce emissions as much as required, meaning that other measures will also be required to address the latter objective. Similarly, a policy to raise agricultural productivity could reduce resource stress, implying less need for agri-environmental measures, but it could lower food prices and so increase the need for policies to curb overconsumption of some products. When there are trade-offs across the triple challenge there is no unique mix of policies that will provide the ideal outcome for every objective. Choices have to be made, and priorities established, in a way that attracts broad support across society. Responsibilities over different relevant policy areas may also be fragmented across different jurisdictions, and across different government agencies and levels of government within a country.

All this raises the question of how policy-making processes should be designed to achieve policies which are not only coherent, but sufficiently ambitious to meet the triple challenge. Chapter 2 discusses how policy makers can design coherent policies when confronted with synergies and trade-offs, while Chapter 3 analyses frictions related to facts, interests, and values, and how these can be managed to achieve better policies. In-depth case studies apply this analytical framework to the seed, ruminant livestock, and processed food sectors. These sectors represent different stages of the food chain, and the most salient policy issues differ by sector. Yet in each case there are clear linkages to the triple challenge, as well as synergies and trade-offs.

This report builds on a wide range of earlier OECD work (including analysis of global food security, diets and nutrition, income generation and poverty reduction, resource use and climate change) and extends this work by drawing out the importance of synergies and trade-offs across these domains. It also incorporates findings from several other studies on the policy challenges facing food systems, and complements other initiatives to address these challenges, such as the Collaborative Framework for Food Systems Transformation (UNEP, 2019[2]) developed as part of the multi-stakeholder One Planet Network Sustainable Food Systems Programme.

The remainder of this chapter is organised as follows:

- Section 1.2 considers the performance of food systems in delivering *food security and nutrition* and assesses outstanding policy priorities.
- Section 1.3 examines how food systems have contributed to *livelihoods along the food chain*, and the evidence on policies needed to generate incomes and improve livelihoods.

- Section 1.4 focuses on how the development of food systems has affected *resource use and emissions,* and the policies required to improve environmental sustainability and reduce emissions.
- A concluding section summarises the insights of this chapter and draws implications for the design of coherent policies and potential obstacles to achieving better policies, previewing the arguments in Chapters 2 and 3.

1.2. Challenge 1: Food security and nutrition

Food security is a multi-dimensional concept. According to the definition adopted at the 1996 World Food Summit (FAO, 1996[3]), food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." As this definition makes clear, food security is not only a matter of food availability – people will only be food secure when they have access to it, and when it leads to good nutritional outcomes. A fourth requirement is stability of these dimensions over time. This section takes stock of the performance of food systems with respect to the four criteria and identifies the principal policy requirements.[7]

Food availability

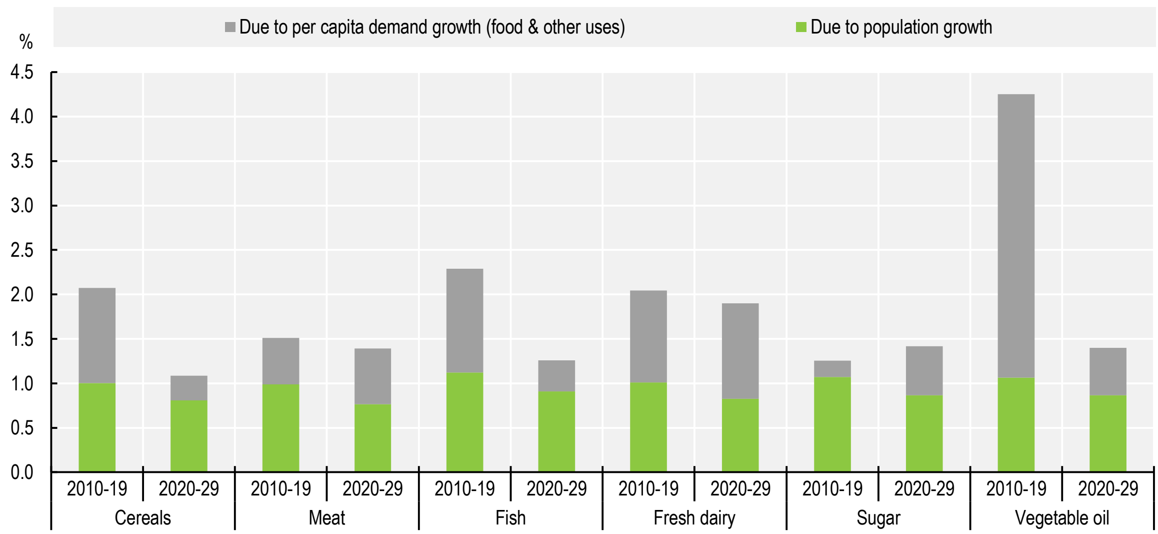
Despite occasional Malthusian fears, the overall availability of food has not historically posed a problem for global food security. Since 1960, world population has more than doubled, but food production per person has increased by more than 45%. There are few reasons to expect this trend to be reversed over the coming decades, although the longer term outlook is more uncertain if the extreme effects of climate change cannot be prevented (Brooks and Blandford, 2019[4]). The more pressing question is how food availability can be increased in an environmentally sustainable way.

Performance and outlook

The evolution of global food availability depends on the relative growth of demand and supply. The *OECD-FAO Agricultural Outlook* (OECD/FAO, 2020[5]) projects a marked slowing in the pace of demand growth over the coming decade, with global demand for cereals, meat and fish growing broadly in line with global population (Figure 1.2).

In most countries, per capita demand for cereals has reached consumption levels that are close to saturation. There is some scope for higher per capita meat consumption, which in turn will stimulate feed grain consumption, but that too is unlikely to grow as rapidly as in the past. Much of the increase in meat demand in recent years came from the People's Republic of China (hereafter "China"), but consumption there now compares with that in high income countries. In the medium term, it is unlikely that other regions can provide demand growth for meat comparable to that provided by China over the past two decades. For example, the latent demand for protein in India is likely to be met mostly by dairy products. Over the long term, a major stimulus to world food markets could come from per capita demand growth in Sub-Saharan Africa, although in many of these countries economic growth is currently not resulting in higher disposable income for the majority of the population. Globally, as incomes increase and lifestyles change, a growing preference for processed food products will tend to support the demand growth for sugar, dairy, and vegetable oil, albeit at slower rates than in the past. Furthermore, while biofuels contributed to demand growth for cereals, sugarcane and vegetable oil over the past two decades, the contribution of biofuels to demand for agricultural products will be much smaller in the coming years if current trends continue (OECD/FAO, 2020[5]).

Figure 1.2. Annual growth in demand for major agricultural commodities



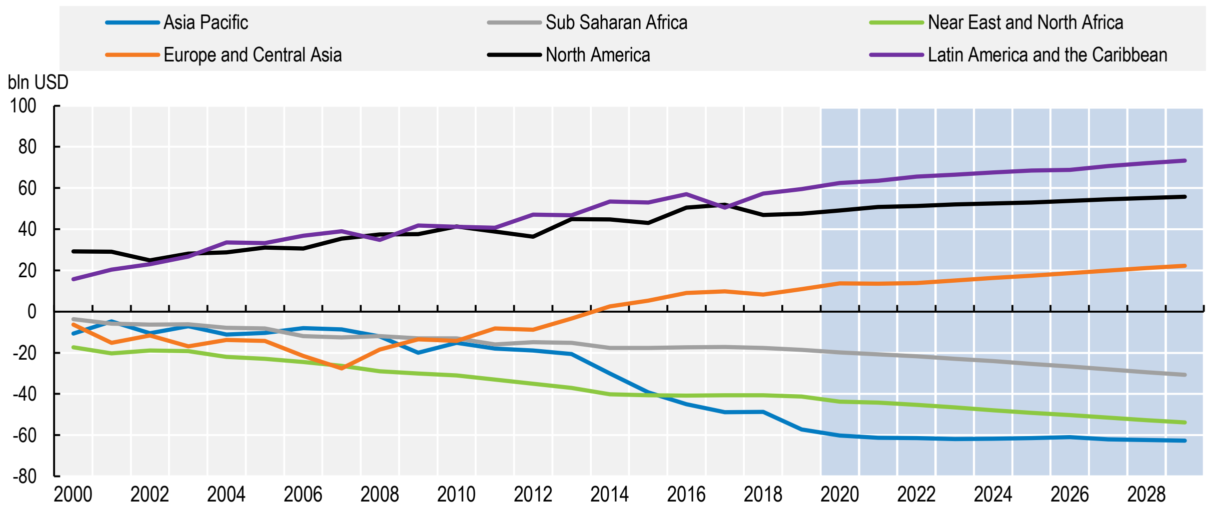
Note: Growth rates refer to total demand (for food, feed and other uses).
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

On the supply side, the growth in agriculture and food production in the past decades has increasingly come through higher yields rather than through the use of more land. The growth in yields in turn reflects the use of other inputs (such as fertilisers), but increasingly output growth is driven by efficiency gains, e.g. through better farm management practices (Section 1.4). Large yield gaps exist around the world, and some regions (notably Sub-Saharan Africa) have considerable scope to raise yields to meet rising demand. Further production growth in major exporting regions (such as North and South America, Russian Federation, and Ukraine) is also expected to contribute to supply growth.

As the regions experiencing the greatest increase in population and food demand are not those with the greatest potential for supply growth in the short-to-medium term, international trade will become increasingly important for global food security by balancing the deficits of net food importers with the surpluses of net food exporters (Figure 1.3) (OECD, 2013[6]). In some countries, food imports are high partly because of low agricultural productivity. Closing yield gaps in Sub-Saharan Africa could significantly reduce the region's food import bill. Cross-border and intra-regional trade has the potential to improve food availability, especially in countries where deeper integration with world markets remains difficult. Trade can only fulfil this role if imports are affordable for consumers, which depends on various domestic factors which can raise prices (from import tariffs to poor infrastructure), on consumers' disposable incomes, and on the evolution of agricultural commodity prices in international markets.

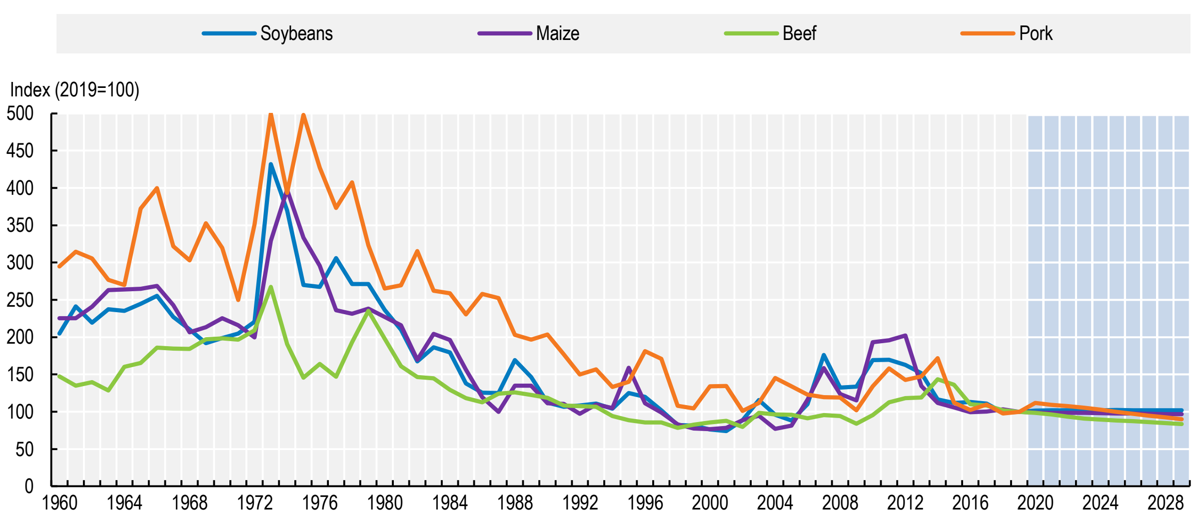
With global demand growth decelerating and broadly matched by supply growth, real agricultural prices are projected to remain flat to declining on average over the next ten years (Figure 1.4). However, markets are subject to shocks. In some instances, such shocks cause temporary periods of rising prices and high volatility, as seen on cereal markets in 2007-08, or disruptions in the functioning of global supply chains, as seen during the COVID-19 crisis. National markets can also be subject to catastrophic events such as harvest failures, which require effective risk management policies. International trade has an important role to play in buffering against such national risks. These issues are taken up below.

Figure 1.3. Agricultural trade balances by region



Note: Net trade (exports minus imports) of major agricultural commodities, measured at constant 2004-06 USD.
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Figure 1.4. Long-term evolution of real agricultural prices



Note: Historical data for soybeans, maize and beef from World Bank, "World Commodity Price Data" (1960-1989). Historical data for pork from USDA QuickStats (1960-1989).
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Yet overall, global food availability is not likely to be a constraint in absolute terms. Ongoing food shortages are most likely to derive from factors such as conflict and civil unrest; in some isolated areas, ensuring food availability may also be challenging because of high transport costs. At the global level, however, a relative abundance of supplies will probably keep food prices low, thereby also helping to improve the affordability of (and hence access to) food.

In short, it seems likely that food systems globally are able to meet the growing demand for food. The real question is how food availability can be increased sustainably. This can be done by policies that increase supply sustainably, and by policies that limit or reorient food demand.

Policies to increase food supply in an environmentally sustainable way

Increasing the supply of food through either agricultural land expansion or a more intensive use of other inputs (e.g. water, fertilisers) can have important negative environmental effects, as discussed in more detail in Section 1.4. What is needed instead is sustainable productivity growth, both in primary agriculture and throughout the food chain. Policy makers have an important role to play in achieving this outcome (OECD, 2019[7]).

Research and development (R&D) policies will play a key role in improving productivity in agricultural production, food processing, and delivery to consumers. This requires public investments as well as effective and predictable regulation of new technologies, including biotechnology and digital technologies. For example, new breeding techniques can accelerate the productivity and climate resilience of both crop and animal agriculture in the decades to come (see, for example, South et al. (2019[8]), Van Eenennaam (2017[9])), but private sector investment will be limited if there is uncertainty about the future regulatory environment. Public investments in agricultural R&D have historically had large positive effects on agricultural productivity (Alston et al., 2010[10]). Despite this strong track record and the clear need for innovative solutions to meet the triple challenge, public funding for agricultural R&D has been falling in real terms over the past decade in high-income countries (Heisey and Fuglie, 2018[11]). Public funding for research on food and agriculture is crucial in areas where private investment is missing. So are efforts by developed countries to share technology with developing countries.[8] Public policy can also stimulate private efforts, including through public-private partnerships (OECD, 2019[7]).

Innovation is only effective if new technologies are widely adopted, which requires education, training, and advisory systems. Especially in the developing world, there may be multiple barriers to obtaining and adopting new technologies by farmers, such as lack of credit, lack of reliable information, poor quality of the available technology, or barriers to business expansion (e.g. land tenure systems and gender barriers). The deeper integration of smallholders into domestic and potentially international value chains could help overcome some of these constraints (Swinnen and Kuijpers, 2019[12]). Digital technologies could also help in dealing with the risks created by climate change and in achieving sustainable intensification (OECD, 2019[13]).

New technologies make it possible to achieve more output with fewer inputs, but even with existing technologies much can be done to improve the sustainability and productivity of global agriculture. Many agricultural and economy-wide policies lead to a misallocation of resources and have negative environmental effects (Section 1.4). One example is policies which fail to correctly price water resources for farmers (Gruère, Ashley and Cadilhon, 2018[14]). Other policies keep farmers in low-income activities, stifle innovation, slow structural change, and weaken resilience. Rolling back these policies would contribute to sustainable productivity growth, but may also accelerate adjustment and consolidation at the farm level, along with the associated release of labour from the sector (Section 1.3).

Improving the overall efficiency of the food chain can help increase food supply by reducing losses that occur between the harvest and retail stages. These losses have been estimated at 14% of global food production, although rates seem to vary strongly even within the same region and commodity group (FAO, 2019[15]). Losses occur in both developed and developing countries, and the underlying causes are likely to be context-dependent. In developing countries, losses are likely due in large part to inadequate infrastructure such as poor transportation systems (roads, railways, ports, etc.), a lack of storage facilities (in particular refrigerated storage), and unreliable utilities (power and water). However, better monitoring and quantification is essential to develop more tailored policy interventions and to better understand the costs and benefits of different policy options (FAO, 2019[15]).

The above policies have the twin benefit of increasing food availability while improving economic efficiency, in contrast with other policies that may boost food availability but do so with highly inefficient instruments. In particular, high import tariffs and subsidies linked to production or to the use of agricultural inputs may boost domestic food supplies, but lead to a misallocation of resources, reduce overall national welfare, and generate negative spill-overs on international markets. They are also inefficient ways of raising farmers' incomes, are more difficult to target than direct payments, and can have negative environmental consequences (OECD (2002[16]), (2019[17])).

Policies to limit or reorient demand growth

On the demand side, several policy options exist to limit or reorient the demand for food, thus providing a complementary path to increasing food availability sustainably. Broadly speaking, four categories of policy lever exist: reducing overconsumption of food; reorienting diets towards more sustainable patterns; reducing food waste; and limiting the growth in "non-food" demand for agricultural commodities.

First, in many countries, both developed and developing, a significant share of the population consumes more calories than the medical evidence suggests is healthy. Bringing these consumption patterns in line with dietary recommendations would thus limit the growth in food demand.

Second, moving towards healthier diets will often involve not only a reduction in calorie intake but also a change in the composition of diets, which can in turn reduce pressures on the environment. A move towards healthier diets (e.g. as defined by national dietary guidelines) would for many countries imply more moderate levels of consumption of meat and dairy products (although in lower income countries, where per capita demand remains below recommended dietary limits, it would imply an increase in consumption). Healthier diets would typically also involve higher consumption of fruits and vegetables and reduced consumption of sugar and of vegetable oils that are high in trans fats (WHO, 2018[18]). Not all of these changes are unambiguously positive for the environment; for example, fruit production tends to involve relatively high pesticide use, and in some contexts increasing the production of fruits and vegetables may increase pressure on water resources. But on balance, a move towards healthier diets could reduce the pressure on resources needed by agriculture to meet future food demand. Another way to improve environmental sustainability is to increase transparency and traceability along the food chain to allow customers to identify and buy more sustainably-produced food. Advances in digital technologies may help in this regard (Jouanjean, 2019[19]).

Third, efforts to reduce food waste could significantly improve food availability without expanding production, thus avoiding additional environmental pressures (Bagherzadeh, Inamura and Jeong, 2014[20]). In developed countries, a significant amount of waste can occur in the retail and food service parts of the food system, as well as at the consumer level. In the United States, for example, an estimated 31% of the total supply of food was lost at the retail and consumer level in 2010 (Buzby, Wells and Hyman, 2014[21]). Sources of waste include cooking loss and spoilage due to inadequate storage after purchase, plate waste from meals consumed in restaurants or in the home, and restaurants over-ordering so that they can maintain a diverse menu. Yet, while food waste corresponds to a monetary loss for households, the fact that food continues to be wasted suggests that other factors, such as convenience, play an offsetting role in household decision-making. For example, while reducing food waste may save money it is likely to impose some non-monetary costs, such as an investment of time and energy in learning how to prepare meals from leftover food and recurring efforts to more carefully plan meals. As individual decisions do not take into account the true environmental cost of food waste, there is a rationale for public efforts to reduce waste (FAO, 2019[15]). Efforts to raise awareness and visibility and other policies that target consumer behaviour changes may be effective ways to reduce this type of waste without generating spill-overs across other dimensions of food security. At the same time, factors such as the time and effort needed for better meal planning suggest that behavioural change may not be straightforward.

A fourth way to reduce demand-side pressures is to limit growth in "non-food" demand for agricultural commodities. Over the past two decades, the main source of growth in this demand has come from the expansion of biofuels, stimulated by policies in many countries which mandated a minimum level of biofuels to be blended with conventional transport fuels. Biofuels from non-food agricultural sources are expected to be a necessary component of global efforts to combat climate change. However, policies that encourage the use of food or animal feed products as feedstocks for biofuels should be avoided in the absence of clear evidence of the gains in terms of reduced net GHG emissions (OECD, 2019[22]) (OECD, 2013[6]) (OECD, 2008[23]).

Finally, international trade can help improve the "matching" of supply and demand. Trade not only enables food to move from surplus to deficit regions, but will be necessary to ensure the efficient and sustainable use of global food and agricultural resources. However, import tariffs for agricultural goods remain higher than for industrial goods, creating distortions which limit this "matching" function of international agricultural trade (OECD, 2019[24]).

Access to food

In contrast to food availability, the determinants of access to food lie mostly outside the food system. Food prices clearly matter for the affordability of food, but overall real incomes remain a much more important factor: where incomes are extremely low, even cheap food may be out of reach, let alone a balanced diet necessary for a healthy and active life (Hirvonen et al., 2019[25]). In the early 2000s, when international food prices were at all-time lows, there were more than 800 million undernourished according to FAO estimates (FAO, 2020[26]). By contrast, income growth typically leads to a decrease in childhood stunting, an indicator of chronic childhood malnutrition (Headey, 2013[27]).

Conflict and civil strife can rapidly undermine access to food, as shown in recent years. Beyond that, resolution of the paradox of hunger amid plenty is fundamentally about raising the incomes of the poor rather than lowering food prices. For poor consumers in developing countries, much of this is about broad-based economic development. Food systems are implicated to the extent that they are a driver of economic development and a source of livelihoods (Section 1.3).

In some cases, there is a more direct link between food availability and access. While much of the world's food is produced by larger commercial farms (where the food security of the operators is not in question), the basic food security of many smaller farmers is contingent on the income they derive from agricultural production and the food they produce for own consumption (HLPE, 2013[28]).

The problem of food access is not confined to poor countries: food insecurity also exists in high-income countries, where in recent years an estimated 60 million people (or 7% of the population) used food banks (Gentilini, 2013[29]). In several high-income countries, remote and indigenous groups are particularly vulnerable (OECD, 2019[30]) (Davy, 2016[31]). The origins of this problem include low incomes, social exclusion, and remoteness. Policies designed specifically for food systems may thus not be sufficient to resolve the problem, and a broader set of policies may be needed.

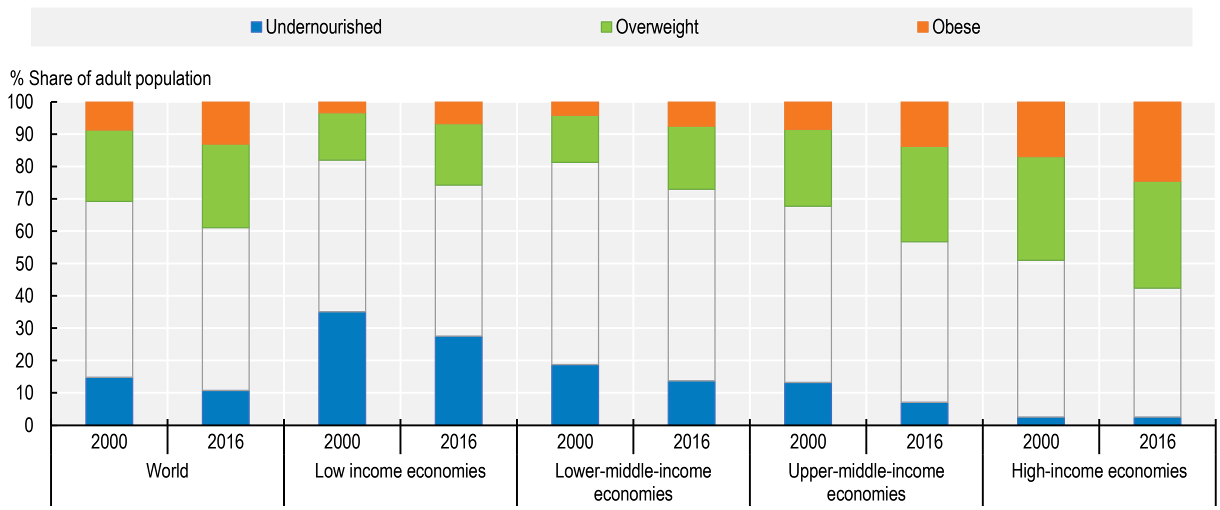
Nutrition in support of public health

Increased food availability and improved access are necessary conditions for improvements in food security and nutrition, but they are not sufficient to guarantee improved nutritional outcomes.

As countries develop economically, they typically pass through a "nutrition transition", under which higher incomes translate first into demand for more calories, and then into demand for more protein (usually from animal sources) as well as for other nutrients coming from nuts, fruits and vegetables. A parallel trend is for higher consumption of sugar, oils, and fats, via processed foods. These become more important as countries become wealthier and more urbanised (Popkin and Gordon-Larsen (2004[32]), Popkin (2017[33])).

Up to a certain point, the consumption of more food from more diverse sources improves nutrition. But many parts of the world are seeing a rising burden of overweight and obesity (Figure 1.5).

Figure 1.5. Undernourishment, overweight and obesity, 2000-2016



Source: WHO (2019)

Many developing countries have poor nutrition, with people who are undernourished (having insufficient calories), over-nourished (having too many), and malnourished (as a result of not having the right balance of nutrients). Many poorer countries lack the necessary complements to ensure effective nutritional outcomes, such as clean water, public health, and specific nutrition assistance, in particular for mothers and young children (Global Nutrition Report, 2018[34]) (Pingali and Sunder, 2017[35]).

Developed countries mostly have more stable food preferences, with incomes growing more slowly and consumption patterns that are less sensitive to income changes. These patterns typically include a high intake of meat and dairy products, as well as vegetable oils and sugar (due in part to the consumption of more processed food products). However, there is increasing over-consumption, which translates into a higher proportion of the population being overweight or obese: almost one in four people in OECD countries is obese (OECD, 2019[36]). Ultra processed foods that are low in nutritional content but dense in energy now make up 30-60% of total dietary energy consumed in high-income countries.[9]

Poor nutrition in all its forms leads to poor health outcomes (Afshin et al., 2019[37]). For example, poor diets contribute to type 2 diabetes (Ley et al., 2014[38]) and the nutrition transition has coincided with a strong increase in the prevalence of diabetes worldwide, with the strongest growth in low- and middle-income countries (NCD Risk Factor Collaboration, 2017[39]). Overweight and obesity are linked to a range of such non-communicable diseases and shorter lifespans (NIH, 2013[40]), imposing considerable costs on society (OECD, 2019[36]). A systematic analysis by the Global Burden of Disease Study suggests that 11 million deaths globally were attributable to dietary risk factors in 2017, with the three leading risk factors being high intake of salt, low intake of whole grains, and low intake of fruits (Afshin et al., 2019[37]). The same analysis finds that improved diets could prevent one in five deaths globally. In addition to causing preventable deaths and poor health outcomes, inadequate nutrition affects livelihoods by reducing labour productivity and hence incomes. Global economic losses due to various types of malnutrition (including undernutrition and obesity) have been estimated at 4%-5% of global GDP (FAO, 2013[41]).

Dietary guidelines around the world typically recommend consuming a variety of foods, including fruits and vegetables, legumes, and animal-source foods (meat, eggs, dairy), while limiting sugar, fat, and salt intake.

Recommendations on intake of dairy, red meat, fats and oils, and nuts are more variable (Herforth et al., 2019[42]). In developed countries, guidelines often recommend limiting the consumption of high-fat dairy products and meat, especially of processed and/or red meat.[10]

The causes of unbalanced diets, when the prerequisites of availability and access are met, are complex (OECD, 2019[36]) (Alston, MacEwan and Okrent, 2016[43]). Increased urbanisation and greater female participation in the workforce are two factors behind the increased consumption of processed food and growing tendency to eat outside the home (Bleich et al., 2008[44]) (Seto and Ramankutty, 2016[45]), while increased sedentariness is a further factor behind rising obesity trends (Graf and Cecchini, 2017[46]). A lack of affordable and healthy food options ("food deserts") or a high proportion of fast food outlets ("food swamps") have been suggested as contributing factors. Research in the United States suggests that lack of access to healthy food is not a major factor (Ver Ploeg and Rahkovsky, 2016[47]) although proximity to fast food outlets seems to be a better predictor of obesity rates (Cooksey-Stowers, Schwartz and Brownell, 2017[48]).

Recent OECD work suggests that a four-track approach can encourage healthier food choices in a way that is consistent with wider objectives for the food and agriculture sector, including objectives related to environmental sustainability and to the livelihoods of agents along the food chain (Giner and Brooks, 2019[49]).[11]

The first track would be to tackle unhealthy food choices via demand side public interventions such as the provision of public information and counselling, including through the use of digital tools (Baragwanath, 2021[50]). Such instruments do not introduce other distortions into the functioning of the food system. The evidence base suggests that such policies work and are cost-effective, but are unlikely to be sufficient. A particular need is to target groups with poorer diets, which requires an understanding of the socio-economic and demographic aspects of food choices (Placzek, 2021[51]).

A second supporting track is to work with industry at the supply-demand interface, e.g. in product reformulation or in introducing and testing labelling schemes.[12] There is an emerging evidence base that such policies can be effective, but that specific design features are critical for their success. Simplified labelling schemes offer considerable potential, with a need for international cooperation given the global nature of the food industry. A potential avenue for public-private collaboration is through behavioural nudges. The scope for testing the effectiveness of such approaches is enhanced by digital technologies and associated possibilities to collect information on consumers' food acquisition and intake, as well as on the food environment more generally (Baragwanath, 2021[50]) (OECD, 2019[13]).

As a third track, some firmer regulations may be needed to modify processors' and retailers' behaviour, as private incentives do not always fully align with public ones. Such measures could include rules on promotion and advertising for foods which are potentially unhealthy, such as those rich in sugar, salt and/or fat. Restrictions are especially relevant for products marketed to children. For example, UK Advertising Codes restrict promotion of products high in fat, salt, or sugar to children.[13] Regulations can also directly address product composition. The World Health Organization has called on governments to eliminate industrially-produced trans fats from the global food supply, and bans on trans fats are in place in a growing number of countries (Health Canada, 2018[52]).

A fourth track is fiscal measures, including consumption taxes on products that are "unhealthy" when consumed excessively.[14] Such policies may have some effect, but with low price elasticities of demand, taxes would need to be very high to have a sizeable effect on consumption. They are prone to slippage (e.g. with consumers sourcing from other markets) and may be regressive in terms of their higher impact and incidence on those with lower incomes. Given alarming trends in public health, and the fact that other instruments have so far not managed to reverse those trends, policy makers are giving increased consideration to such measures. A particular target has been sugar, where consumption levels often largely exceed those recommended by health experts, and where current trends are pointing in the wrong direction. The announcement in the United Kingdom of a levy on soft drinks resulted in several major companies reformulating their products ahead of the introduction of the tax (Davies, 2019[53]), suggesting that a credible threat of policy action can play an important role in prompting change and may be as important as the action itself.

Across these four different policy approaches, further research will be needed to determine which combinations of instruments are likely to be most effective. More information is needed, in particular, on products provided by the fast growing catering industry and on the characteristics of food consumed away from home.

Stability

Complete food security requires stability across the availability, access and utilisation dimensions. There is a need to build resilience into the food and agricultural system in order to manage a wide range of risks. Many of the core policies that are needed to help the system withstand short-term shocks are the same as those needed to improve long run productivity. But other measures can be taken to deal with short-term variations in food availability and prices.

On balance, domestic shocks tend to be more frequent and more severe than international shocks. For this reason, international trade plays an important role in reducing volatility by enabling countries to make use of world markets in the face of domestic shocks (OECD, 2013[6]). Improvements in infrastructure (transportation and storage) and transparency regarding supply, demand, stocks, and prices can contribute to the effectiveness of trade. International initiatives such as the G20-led Agricultural Market Information System (AMIS) can play an important role in the assembly and diffusion of accurate information.[15]

The buffering function of trade also requires that countries avoid the use of policy measures that undermine the efficient functioning of international markets. In 2007-08, in the face of rapidly rising food prices, a number of key grain exporting countries adopted export restrictions or bans in an attempt to reserve domestic production for local consumption. At the same time, several major grain importing nations reacted by increasing bids for import supplies, reducing pre-existing import restrictions such as tariffs and relaxing tariff rate quotas (Jones and Kwiecinski, 2010[54]). These types of actions contribute to instability in international markets, with consequent negative implications for global food security. In practice, many agricultural markets are “thin”, and world cereal trade achieves only a fraction of its potential risk pooling benefits (Liapis, 2012[55]). With climate change, and an increased likelihood of extreme events, the risk pooling effect of trade will become more important. There is thus a case for further trade liberalisation to “thicken” international markets and to enable trade to play its balancing and stabilising role.

Openness may not be sufficient to contain rare but severe international shocks, such as simultaneous harvest failures, or disruptions to global supply chains as during the COVID-19 crisis. Countries need mechanisms to manage such risks, but border measures are not a co-operative way to do so, and self-sufficiency policies increase risks to domestic food security from unforeseen variations in domestic production. Yet, trade policy instruments are often used by governments to try to influence the stability of domestic markets. Asian rice producing and consuming countries have a long history of using price policies and border measures to stabilise domestic prices (Timmer, 2010[56]). Interventions in Africa have often destabilised domestic markets (Jayne and Tschirley, 2009[57]). For the world as a whole, domestic trade policy interventions appear to have had little impact on reducing domestic price instability (Anderson and Nelgen, 2012[58]). The use of trade measures to insulate economies from shocks to world prices can, at best, transfer the risks associated with commodity production and trade. If many countries seek to transfer price risk to others, the outcome is likely to be ineffective (Martin and Anderson, 2011[59]).

Public stock policies can be used to help stabilise domestic food markets. It is important to distinguish between three major types of public stocks (Deuss, 2015[60]). Emergency stocks are only released in response to humanitarian emergencies. Social safety net stock schemes distribute food at subsidised prices in order to assist the impoverished and chronically food insecure. Buffer stocks aim to stabilise prices and/or affect the level of producer and consumer prices. However, it is not clear that such storage programs reduce domestic price volatility, and even if they do, this is often at a high cost. Moreover, public stockholding policies are almost always implemented via other policy instruments such as administered prices, trade policy instruments, and import and export monopolies, which create economic inefficiencies. Policies to support prices for farmers also often lead to the accumulation of stocks. There are also concerns about spill-overs on international markets through the impact of the accumulation and release of stocks.

In the rare but potentially disastrous scenario of a severe international shock, the priority is to ensure that poor countries are provided with the means to maintain food availability and access. Food assistance under the terms of the 2012 UN Food Assistance Convention may help with local availability in response to humanitarian emergencies.[16] For rare cases of aggregate calorie shortfalls when food import bills become unaffordable, there are under-utilized mechanisms for financial assistance to buy food (Brooks and Matthews, 2015[61]). These are, in most cases, preferable to physical food aid. Governments may also use option contracts to lock in future food import purchases, so that future import costs are known in advance. Increased international assistance – financial and technical – may be required to help put these mechanisms in place.

Well-regulated futures markets provide a means for food systems participants to reduce price risk through hedging or the purchase of options, and also provide an important source of information on prices for decision making by those participants (FAO et al., 2011[62]). Insurance products, e.g. crop insurance, can play a role in increasing resilience in the food system, particularly in the face of increasing climatic variability. Such products need to be actuarially sound, i.e. not become ways for governments to provide subsidies to farmers. Subsidised insurance has the potential to cause resource misallocation by promoting the production of climatically vulnerable products or production in areas subject to high climatic risk.

1.3. Challenge 2: Livelihoods

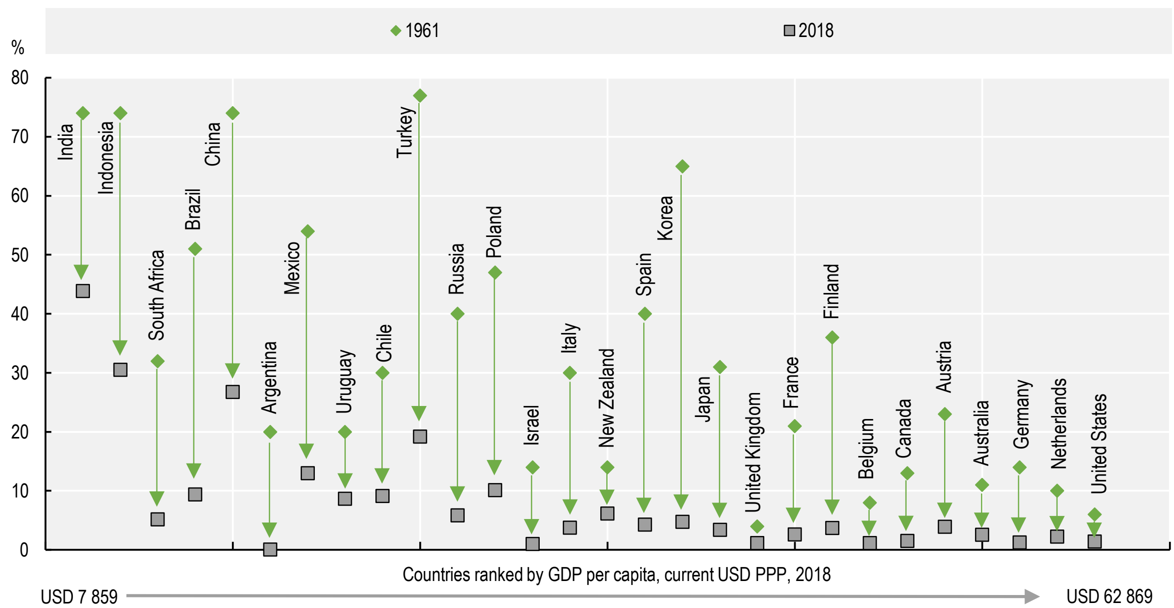
Economic development and the transformation of food systems

Food systems provide incomes and livelihoods to farmers and many others in the economy, ranging from input suppliers to those engaged in downstream processing and distribution, as well as the final stage of supermarkets, canteens, food stalls and restaurants. A multitude of service sectors are connected to the supply chain. Many of those services are provided locally, often giving a rural dimension to food systems development.

Primary agriculture is the basis of the food system, and employs a large number of people directly. Most of the world's farmers are smallholders: of the more than 570 million farms worldwide, an estimated 500 million (84%) are small farms of less than 2 hectares (Lowder, Skoet and Raney, 2016[63]). These small farms produce an estimated one-third of global food supply (Ricciardi et al., 2018[64]) with the remaining two-thirds produced by larger farms, most of which are family farms rather than corporate farms (Lowder, Skoet and Raney, 2016[63]). Livestock plays an important role in providing livelihoods for many rural households (FAO, 2018[65]); the case study on ruminant livestock explores this sector in more detail.

As economies develop, primary agriculture tends to account for a declining share of overall employment (Figure 1.6). Associated with this are often huge rural-to-urban migrations. There are two main reasons for this. On the supply side, labour-saving productivity growth in agriculture tends to consolidate farming, pushing farmers and farm workers out of the sector. On the demand side, faster rates of non-agricultural growth compared with agricultural growth pull agricultural labour into other sectors. The adjustment process is naturally easier to manage when those two forces are matched.[17]

Figure 1.6. Agriculture's share of total employment, 1961-2018



Source: Agriculture's share of employment from World Development Indicators; GDP per capita data from the IMF.

Smallholder farmers are directly implicated in the agricultural transformation. In agriculture-dependent economies, the development process has to start by exploiting the potential of existing structures, and productivity and income growth in agriculture can be essential in generating demand for manufactures and services (Timmer (2002[66]); Olmstead and Rhode (2008[67])). Over the longer term, however, the improvements in productivity needed to assure higher incomes go hand-in-hand with large reductions in the proportion of the population engaged in agriculture.

The specificities of this development process vary across countries. Some countries may retain a higher share of employment in farming than overall incomes would suggest because of their comparative advantage in agricultural production. For instance, dairy farming and processing alone account for 3% of GDP and employment in New Zealand (NZIER, 2018[68]). Some countries may also be relatively specialised in more labour intensive commodities such as fruits and vegetables. The speed of the development process also differs: the pace of non-agricultural growth in Southeast Asian countries has been so fast over recent decades that the absorption of labour from agriculture has occurred much more swiftly than it did in Europe or earlier developing regions. In some developing countries (particularly in Sub-Saharan Africa), that process is still at an early stage, and there are concerns about premature de-industrialisation thwarting a smooth transition.[18]

When jobs are created outside of agriculture, these are often still connected to the food system. For instance, as urbanisation and income growth contribute to a greater consumption of processed foods bought from both small and large retailers, employment opportunities are created in food processing and retailing (Reardon and Timmer, 2012[69]). Employment in the food chain thus tends to shift from agriculture to other segments of the food chain as countries develop. In low-income countries (e.g. in Eastern and Southern Africa), some 90% of the food-related employment is in agriculture. In middle-income countries such as Brazil, farming accounts for around half of the food-related employment, with the remainder split between food services (including, for example, logistics) and food manufacturing. In high-income countries such as the United States, around two-thirds of the food-related employment is in food services (World Bank, 2017[70]). The data also suggest that as economies develop, agriculture's share of GDP falls from

40% of GDP or more to below 10%, while the share of agribusiness (i.e. all other segments of the food chain) grows from less than 20% to more than 30%, before declining again as countries become more industrialised (World Bank, 2008[71]). However, even in industrialised countries food-related activities remain important: food and beverage manufacturing ranks as one of the top three manufacturing activities in terms of value added in 27 OECD countries (UNIDO, 2020[72]).

International trade and participation in global value chains (GVCs) are important drivers of agricultural employment and incomes around the world. Trade directly or indirectly accounts for around one-fifth of agricultural labour income globally, albeit with important variation among countries: in New Zealand, close to 73% of agricultural labour income depends on value added created by trade and GVCs, while this share is only 3% in Japan (Greenville, Kawasaki and Jouanjean, 2019[73]). These figures include both the direct effect of agricultural trade and the indirect effect of trade in products which rely on agriculture. Indeed, trade in agro-food products also generates income in other sectors, such as industry and services: globally, around one-fifth of the labour income created by agro-food exports goes to the services sectors supporting the production of primary and processed products, with another 6% going to labour used in industry (Greenville, Kawasaki and Jouanjean, 2019[73]).[19] Countries also do not necessarily need to move into food processing to generate higher value-added: participation in international trade and GVCs (i.e. through the export of primary products) can generate at least as much domestic value added as participation which relies on domestic processing (Greenville, Kawasaki and Jouanjean, 2019[74]).

Productivity improvements in agriculture have underpinned a long-term trend towards declining real agricultural prices. This has provided major benefits to consumers all over the world, but puts direct pressure on the incomes of poorer farmers. At the same time, consumers are shifting their spending from relatively unprocessed products bought in local markets to processed foods bought in supermarkets or meals consumed away from home. Spending on food must now not only cover the costs of agricultural ingredients but also the costs incurred by other actors in the food chain, from logistics providers to chefs, from employees in slaughterhouses to check-out clerks in grocery stores. In combination with declining real agricultural prices, this results in a declining "farm share" of food expenditures. This decline is sometimes interpreted as evidence that farmers are systematically disadvantaged relative to other actors in the food chain. However, the observed changes in the "farm share" largely reflect the structural changes described earlier. In the United States, for instance, the farm share of the food dollar was estimated at less than 15% in 2018. But nearly half of the US "food dollar" goes to paying salaries in sectors other than primary agriculture – notably in food service, retail, and food processing.[20] Rather than measuring market power, the "farm share" therefore mostly reflects structural changes occurring in the food system.[21]

A trend underlying much of the structural transformation occurring in agro-food systems in recent decades is the increasing importance of standards, labelling, and certification to create more differentiated products (Beghin, Maertens and Swinnen, 2015[75]). Meeting these standards imposes more stringent requirements on participants in the value chain (Fulponi, 2006[76]). On the other hand, if consumers are willing to pay a premium for these products, the resulting value can in principle be shared along the value chain – and such value-sharing with suppliers may be necessary to ensure a stable supply of products that meet the desired criteria (Swinnen et al., 2015[77]) (Sexton, 2013[78]). Some certification schemes, such as Fairtrade, explicitly aim to improve farmers' livelihoods. Empirical evidence on how these developments impact farmers is currently mixed.[22] However, it is possible that new digital technologies enabling greater transparency and traceability could make it easier for farmers to provide differentiated products to customers.

Policies to strengthen livelihoods across food systems

In broad terms, the process of labour adjustment has been positive (OECD, 2012[79]). Agricultural production continues to grow in most countries, implying continued economic opportunities within the sector, even if labour demand is declining relative to that in other sectors. Millions of people have left agriculture for higher paying jobs while their offspring have benefited from superior opportunities in other sectors. For educated children, the transition has frequently offered a large improvement in earning potential. But the process of adjustment has been far from seamless. It has involved stresses too, with less competitive farmers struggling to compete as productivity growth lowers real farm prices, and cases of distress migration from the fields to urban centres. Policies need to enable people to take advantage of the rising opportunities offered by agricultural development, but also protect those who are unable to do so.

OECD work has emphasised the need for a long-term strategy for development that acknowledges the inevitability of structural change while helping to smooth the adjustment process (OECD, 2012[79]). Such a strategy should offer multiple pathways that include (i) increasing productivity and competitiveness within agriculture; (ii) diversifying income sources, within or outside agriculture; and (iii) leaving the sector for off-farm employment. At the same time, governments will need to provide social protection for those unable to adjust.

OECD (2012[79]) provides recommendations on the instruments that can facilitate transition along these pathways, highlighting the role of productivity-enhancing investments for those who remain in the sector, and a role for agricultural risk management policies that underwrite those aspects of agricultural risk that neither farmers nor markets can cover (OECD, 2011[80]). Wider investments in human capital, hard and soft infrastructure can improve households' opportunities without biasing decisions on whether to remain in the sector or take advantage of opportunities outside agriculture, while labour market and regional policies can facilitate the absorption of labour into other sectors, including downstream processing sectors.

So far, the bulk of policy support to agriculture has not been calibrated in ways that correspond to the balance of economic opportunities across these pathways. Total support to agriculture (including support to farmers, general services to the sector and consumer subsidies) across the 54 countries covered by the 2020 *OECD Agricultural Policy Monitoring and Evaluation* report (OECD, 2020[81]) averaged USD 708 billion per year in 2017-19. A relatively low share of this support was provided in the form of "general services" to the sector, a category which includes public services such as R&D support and inspection services (Figure 1.10). Nearly three-quarters (USD 536 billion per year) was provided in the form of support to farm incomes, either via higher prices or direct payments, as opposed to the enabling environment through which those incomes are generated. Such support has the effect of providing a disincentive for farmers to diversify their income sources or leave the sector, thereby putting a brake on – rather than facilitating – adjustment pathways beyond agriculture.

Beyond the agricultural sector, many countries provide social safety nets, including conditional cash transfer programmes, but few have provided at-scale programmes to smooth the absorption of ex-farmers in the non-agricultural economy or to manage rural-urban migration.

1.4. Challenge 3: Environmental sustainability

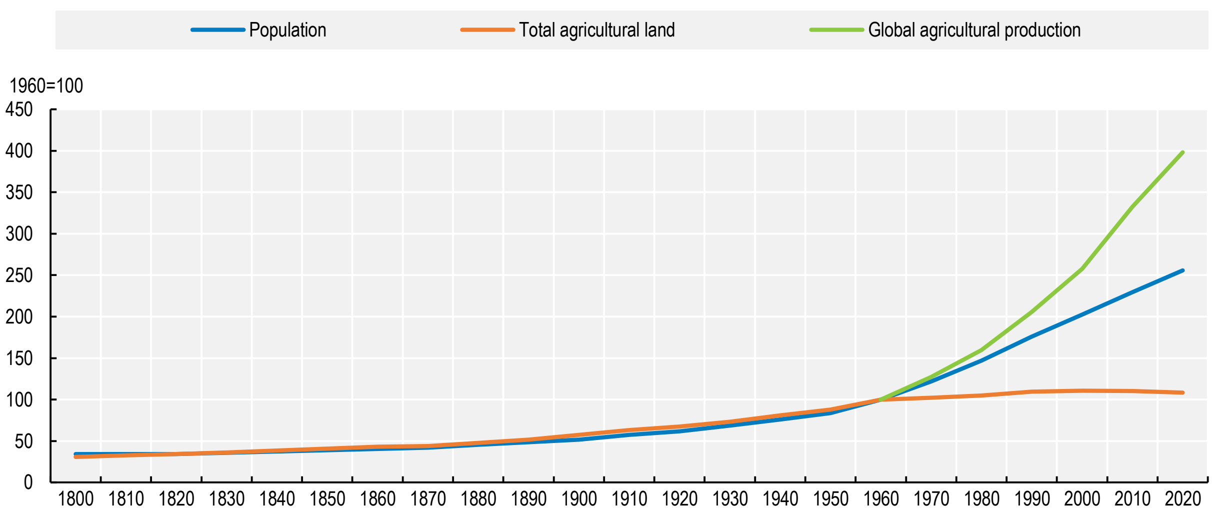
Food production has led to environmental changes such as deforestation, erosion and resource depletion since the rise of agriculture (Kirch, 2005[82]), but environmental pressures from agriculture have accelerated in the past two centuries as the world population grew from 1 billion in the early 1800s to more than 7.5 billion today. As a result, agricultural production is currently a major source of environmental pressures, not only in local ecosystems but also at a global level (Campbell et al. (2017[83]), IPBES (2019[84]), IPCC (2019[85])).

Due to its close link with the natural environment, much of the environmental damage related to food systems occurs at the agricultural production stage. This is true not only for impacts on land use, biodiversity, or water use, but also for greenhouse gas (GHG) emissions. Agricultural production and the associated land use changes account for an estimated 16-27% of total anthropogenic GHG emissions while all other stages of food systems (energy, transport, processing, etc.) contribute an estimated 5%-10% (IPCC, 2019[85]).

Broadly speaking, greater food production can come from three sources, with starkly different environmental implications: greater land use, greater use of other inputs, and greater efficiency in how these inputs are used.

Historically, most of the increase in food production came from increased agricultural land use, as growing populations expanded the global area under crops and the area used for grazing animals. However, after 1960, food production more than tripled while land use grew by only 10%-15% (Figure 1.7).

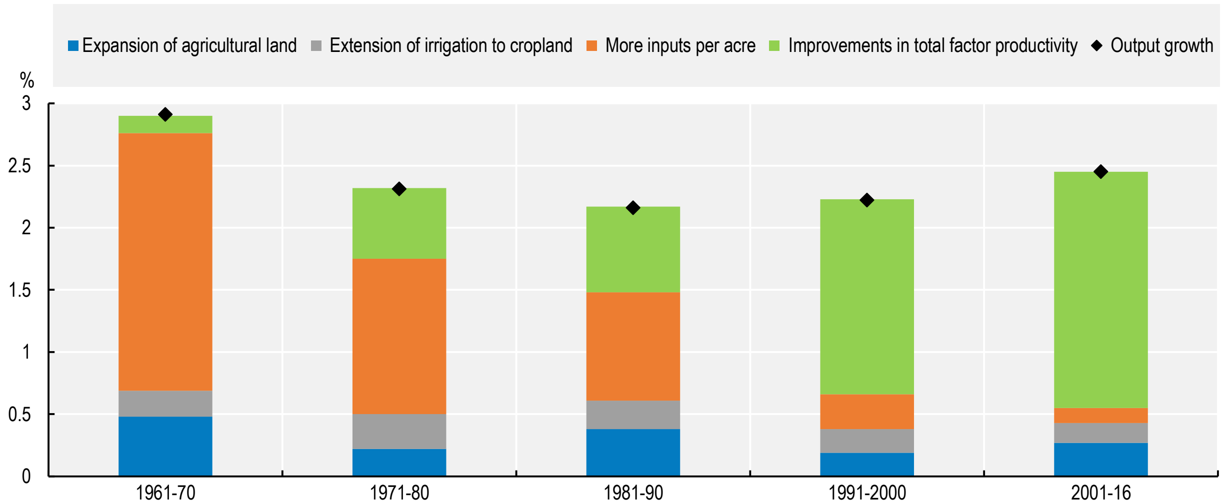
Figure 1.7. Population, food production and agricultural land use in the long run



Source: Population data from Maddison's historical statistics for 1820-1940; UN Population Division for 1950-2010; 1800 and 1810 extrapolated from Maddison. Agricultural (crops and pasture) land data for 1800-2010 from the History Database of the Global Environment (HYDE 3.2), Klein Goldewijk et al. (2017). Global agricultural production data for 1960-2010 from FAOSTAT (Net Agricultural Production Index); data for 2020 from OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

This "decoupling" of food production and land use was initially fuelled by more intensive use of inputs, such as synthetic fertilisers and irrigation water. In recent decades, production growth has increasingly come from greater efficiency, which makes it possible to produce more with fewer inputs. Figure 1.8 shows the contribution to global agricultural output growth of greater land use, the expansion of irrigation, more intensive use of inputs (including labour and machinery, but also fertilisers, pesticides, etc.), and growth in total factor productivity, which here captures the effects of better management practices, the adoption of improved varieties and breeds, and other efficiency improvements. From the 1960s to the 1980s, the intensification of input use contributed the most to global output growth. Over time, however, total factor productivity growth grew in importance, and since the 1990s it has been the major factor driving the growth of global agricultural production.

Figure 1.8. Sources of growth in global agricultural output, 1961-2016



Note: Each bar represents the annual average per cent growth over that period.
Source: USDA, Economic Research Service, International Agricultural Productivity statistics (November 2019 revision).

Box 1.1. Fish and the triple challenge

Like agriculture, the fish and seafood sector forms part of food systems and is intimately connected to the triple challenge (FAO, 2020[86]). First, fish and seafood are important for global food security and constitute a major source of protein and essential nutrients, especially in developing countries in Southeast Asia and Sub-Saharan Africa, as well as in small island developing states (Béné et al., 2016[87]). Global per capita consumption of fish and seafood grew from 9 kg to 20.5 kg between 1961 and 2018, in large part due to demand growth in China and other Asian economies (FAO, 2020[86]). This strong increase in fish and seafood consumption was possible thanks to the rapid rise of aquaculture, which saw its contribution to global food fish consumption rise from 4% in 1950 to more than half today (FAO, 2020[86]), with expectations for further growth in the future (OECD/FAO, 2020[5]).

The fish and seafood sector is also an important source of livelihoods, with an estimated 39 million people engaged in fisheries and 20.5 million in aquaculture globally, with the vast majority based in the developing world (FAO, 2020[86]). At the same time, there is a clear challenge for sustainability. Unsustainable production practices in both capture fisheries and aquaculture as well as climate change are damaging fish stocks, aquatic and ocean ecosystems, and biodiversity. These pressures reduce production capacity in the long run. FAO estimates that the share of the world's fish stocks fished at unsustainable levels has grown from 10% in 1974 to 34% in 2017, a global average which hides significant geographical variation (FAO, 2020[86]). Data from the 2020 *OECD Review of Fisheries* on the status of stocks assessed by 31 OECD countries and major fishing economies shows that 66% had a sustainable status and 23% an unsustainable status, with 12% undetermined. The countries covered in this review tend to have more capacity for stock management, and assessed stocks tend to be intensely managed; both factors contribute to having a better status than the global average. But even so, the data shows that stock status remains an issue of concern. Moreover, about half of the stocks with a sustainable status either do not have, or are not meeting, additional management objectives (such as maximising catch volume within sustainable limits) (OECD, 2020[88]).

Unsustainable practices are caused by weak governance, inadequate management, lack of scientific evidence to support decision-making and sometimes poorly targeted support policies. For example, over the period 2016-18 the 39 countries that report data to the OECD Fisheries Support Estimate database provided USD 4.6 billion per year in direct support to individuals or companies in the fisheries sector, accounting for 4.6% of the value of marine landings. About 70% of these transfers were directed at lowering the cost of inputs, e.g. through subsidies for vessel construction or modernisation, or through policies that lower the cost of fuel which constitutes 25% of total support. OECD work has shown that such policies are among the most likely to provoke overfishing, overcapacity, and illegal, unreported and unregulated (IUU) fishing, while at the same time favouring larger fishers. Re-directing support away from such policies that create incentives to fish more intensively could have significant benefits for the environment as well as for fishers' livelihoods. Further investing in science-based management and combatting IUU fishing could have similar positive impacts along all dimensions of the triple challenge. OECD analysis has demonstrated that when an effective management system is in place (e.g. with limits on total allowable catch), support policies are less likely to encourage unsustainable fishing and generally also lead to more benefits for fishers (Martini and Innes, 2018[89]).

While the rise of aquaculture made it possible to expand the supply of animal protein for a growing world population, the growth of the sector has also created new environmental challenges (WRI, 2014[90]). Several inputs (land, water, feed, and energy) have important environmental impacts; moreover, there are problems related to disease transmission, water pollution, and safety concerns. Improvements in efficiency may make it possible to reduce the environmental impact per unit of fish produced, especially when coupled with better public planning and regulation. The environmental impact of aquaculture also depends greatly on the species farmed; a shift in demand towards "low-trophic" species (e.g. tilapia, catfish, carp) would ease pressures on the environment.

The fish and seafood sector thus exhibits many of the same characteristics as other sectors of the food system, including a close link to each of the three dimensions of the triple challenge, a policy environment which is not always conducive to meeting that challenge, and a strong connection between efficiency gains and sustainable growth. New technologies may improve monitoring and traceability along the supply chain. Moreover, as with the livelihoods challenge in other sectors of the food system, a transition towards more sustainable fish and seafood production may require investments in alternative opportunities for vulnerable populations dependent on the sector for their livelihoods.

Environmental effects of agricultural land use

Agriculture presently uses up to half of the world's ice-free land surface, far more than any other human activity and considerably greater than urban land use and other infrastructure, which accounts for around 1% of the total (IPCC, 2019[85]). Agriculture's extensive land use has come at the expense of natural landscapes and has led to the clearing or conversion of an estimated 28% of tropical forests, 40% of temperate forests, 50% of shrub land and 58% of savannah and natural grassland (Ramankutty et al., 2008[91]).

Such land use changes are a major threat to biodiversity (Newbold et al., 2015[92]). As land use by humans expands, natural habitats may be lost or degraded, or populations may be fragmented. Worldwide, around 80% of all threatened terrestrial bird and mammal species are in danger because of agriculture-driven habitat loss (Tilman et al., 2017[93]). If cropland were to expand into all suitable natural areas, there could be a potential loss in biodiversity of 30% of species richness and 31% of species abundance in tropical areas in the Amazon and Africa (Kehoe et al., 2017[94]).

The expansion of agricultural land also depletes soil carbon. When forests are converted into agricultural land, the stocks of soil organic carbon decrease strongly, with declines of around 50% in temperate regions, 40% in tropical regions, and 30% in boreal regions (FAO and ITPS, 2015[95]). Since soils hold more carbon than the atmosphere and terrestrial vegetation combined, this is worrisome from a climate change mitigation perspective; it also threatens soil fertility. A particular difficulty is that while soil organic carbon can be lost rapidly, re-carbonisation is a slow process (FAO and ITPS, 2015[95]).

GHG emissions from land use changes are a major channel through which agriculture contributes to climate change (IPCC, (2019[85]); Blandford and Hassapoyannes (2018[96]), Smith et al. (2014[97])). An estimated 44% of agriculture-related emissions in 2007-16 were due to land use change (IPCC, 2019[85]).[23]

Given the detrimental effects of agricultural land use, the fact that global food production tripled since 1960 yet required only a 10%-15% increase in agricultural land use can be considered a major achievement.[24] However, this still reflects an increase of around 450 million hectares globally, an area twice as large as Greenland. The environmental consequences have been significant, especially since this agricultural expansion largely came at the expense of tropical forests (Gibbs et al., 2010[98]). Agriculture caused an estimated 73% of tropical and sub-tropical deforestation between 2000 and 2010 (Hosonuma et al., 2012[99]). While conversion of land to agriculture is a longstanding phenomenon across all continents, recent emissions from deforestation and peat land conversion have been caused to an important degree by the expansion of pasture for cattle in Latin America, and by the expansion of oilseeds production (notably palm oil) in Indonesia, as well as other countries in Asia and Latin America (Pendrill et al., 2019[100]). Still, the growth of agricultural output per unit of land has prevented an even worse outcome.

Direct greenhouse gas emissions

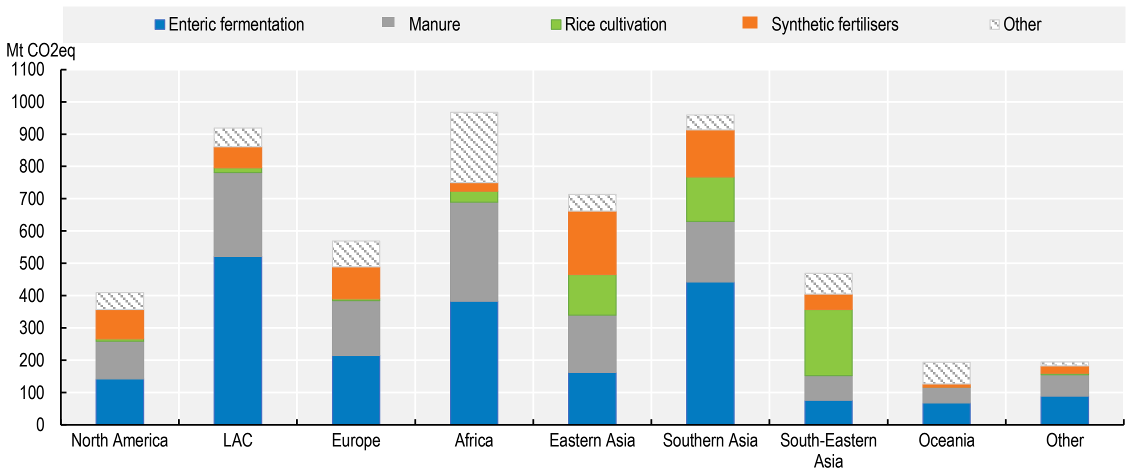
In addition to the important emissions from agricultural land use change mentioned earlier, agricultural production also causes important direct GHG emissions. These emissions account for 12% of global anthropogenic greenhouse gas emissions (IPCC, 2019[85]); agricultural production's share of global anthropogenic emissions is 44% for methane (CH_4) and 82% for nitrous oxide (N_2O).[25]

Two-thirds of the direct emissions from agricultural production are due to livestock. In a process known as "enteric fermentation", cattle and other ruminants such as sheep and goats produce methane as part of their digestive process. This process by itself has accounted for some 40% of direct emissions from agriculture in recent years. Emissions from manure contribute another 26% to direct emissions. Two other important contributors are synthetic fertilisers (responsible for 13% of direct emissions from agriculture) and rice cultivation (accounting for 10% of the total).[26]

Direct emissions from agriculture are not limited to one region or one agricultural production system (Figure 1.9). The sources of emissions tend to vary by region, although livestock-related emissions typically dominate, except in Eastern and South-Eastern Asia.

Between 1990 and 2016, direct emissions from agriculture grew by 0.5% per year. By comparison, global crop production grew by an estimated 2.5% per year over the same period, while livestock production grew an estimated 1.9% per year.[27] Emissions per unit of agricultural output have therefore fallen over time as agricultural productivity has grown, a trend which is true for most regions (Blandford and Hassapoyannes, 2018[96]). The emissions intensity of livestock in particular has fallen considerably since the 1970s (Smith et al., 2014[97]). However, beef continues to have by far the largest emissions footprint per unit of product among the major agricultural commodities (Gerber et al., 2013[101]). Emissions intensities for livestock vary considerably around the world and are highest in regions with low yields of animal agriculture (e.g. low milk yields, low slaughter weights, or a long time until animals are ready for slaughter). The quality of feed in particular is an important driver of productivity (and hence lower emissions intensities) (Herrero et al., 2013[102]).

Figure 1.9. Direct emissions from agriculture, by region and source, 2018



Note: 2018 or latest available. LAC is Latin America and the Caribbean. Manure includes manure applied to soils, manure left on pasture, and manure management. Other includes the FAOSTAT categories Burning - Crop Residues, Burning - Savanna, Crop Residues, and Cultivation of Organic Soils.
Source: FAOSTAT.

Environmental effects of intensification

The strong growth in agricultural output per unit of agricultural land is due in large part to a more intensive use of inputs. Since 1961, global consumption of nitrogen fertilisers grew almost nine-fold, while consumption of phosphorus and potassium fertilisers nearly quadrupled.[28] Over the same period, the share of global cropland under irrigation grew from 12% to 21%, and agricultural water use grew from 1 500 km^3 to 2 800 km^3 per year.[29] Between 1990 and 2015, global pesticide use grew from 2.7 million tonnes of active ingredients to 4 million tonnes.[30] Together with modern varieties and better management practices, the use of these inputs has contributed to unprecedentedly high crop yields, both in developed and developing countries. Intensive input use similarly contributed to growth in livestock production, e.g. through the use of concentrated animal feed.

Yet, this intensification of agricultural production has brought with it new challenges. For instance, the widespread use of synthetic nitrogen fertiliser and the large quantities of manure produced by intensive livestock systems not only contribute to global warming but can also cause severe damage to aquatic ecosystems (OECD, 2018[103]). Nitrogen pollution leads to the acidification of freshwater ecosystems, which harms invertebrates (such as crustaceans) and fish. Nitrogen also causes eutrophication, i.e. the proliferation of phytoplankton and algae. The subsequent decomposition of organic matter of these organisms consumes oxygen, leading to hypoxia (low oxygen levels in the water); one result is extensive deaths of both invertebrates and fish.[31] Eutrophication also directly stimulates the growth of toxic algae (Camargo and Alonso, 2006[104]).

As another example, pesticide use has been associated with declines in populations of wild bees (Brittain et al., 2010[105]) and insectivorous birds (Hallmann et al., 2014[106]) among others, and with harmful effects on broader ecosystem services (Chagnon et al., 2015[107]). A study of several European countries found that insecticides and fungicides had consistent negative effects on biodiversity (Geiger et al., 2010[108]). Exposure to certain pesticides can also have negative effects on human health, including acute toxicity, carcinogenicity, mutagenicity, or reproductive toxicity (WHO, 2010[109]) (Mostafalou and Abdollahi, 2017[110]), although there are currently no reliable estimates of the global health impact of pesticides (WHO, 2019[111]).[32]

Intensive use of inputs thus has had undesirable consequences. However, there are important differences among countries and regions. For example, agriculture accounts for some 70% of global water withdrawals, but agriculture's share is particularly high in South and Southeast Asia, the Middle East, and Africa. In North America and Europe, agriculture's share is smaller (although still sizeable). The impact of this water use also differs strongly. Water stress is particularly high in the Middle East and North Africa, given the low availability of water resources. But even in otherwise water-abundant countries, there could be local hotspots with water scarcity risks (World Resources Institute (2019[112]), OECD (2017[113])). As another example, application rates of synthetic nitrogen are especially high in East Asia (above 170 kg per hectare) and Western and Central Europe (around 150 kg per hectare), but lower in North America (around 73 kg per hectare).[33] Some developing regions (notably Sub-Saharan Africa) have low application rates and struggle with negative nutrient balances, meaning that fertiliser inputs are not sufficient to compensate for removals through harvest. At the same time, nitrogen leaching and runoff in Asia has been estimated at 15 million tonnes per year, or 64% of the global total (Liu et al., 2010[114]).

Over the past two decades, OECD countries have on average experienced declining nitrogen and phosphorus surpluses, despite growing agricultural production, which demonstrates that progress is possible (OECD, 2019[115]). Better policies, coupled with efficiency gains, offer considerable scope to limit or reduce environmental damage from intensive input use.

Poor policy choices often contribute to inefficient input use. In many countries, the use of irrigation water by farmers is insufficiently regulated and farmers do not pay the full price, leading to excessive water use. In the Middle East and North Africa, agricultural policy often stimulates the consumption and production of water-intensive but relatively low value crops such as wheat at the expense of horticultural crops which would generate greater value relative to their use of water (OECD/FAO, 2018[116]). Many countries continue to provide agricultural support through instruments which stimulate production and excessive input use; these instruments have been shown to be not only economically wasteful but also environmentally harmful, as discussed in more detail below.

In addition, evidence suggests that input use in many cases is inefficiently high. At the global level, nitrogen uptake by crops has been estimated at less than 60% of total inputs. Two-fifths of global nitrogen inputs are therefore lost into ecosystems, indicating considerable room for improving the efficiency of nitrogen use (Liu et al., 2010[114]). Data for France shows no clear link between pesticide intensity and productivity or profitability for the majority of farms, which suggests that pesticide use in some cases could be cut with little or no opportunity cost (Lechenet et al., 2017[117]) (Lechenet et al., 2014[118]). Similarly, the use of antimicrobials for growth promoting purposes in some livestock production can, with more sanitary farming practices, be eliminated with little or no adverse impact on the economic or technical performance of farms (Ryan, 2019[119]). These examples suggest both that smart environmental regulations in agriculture do not necessarily come at an economic cost, and that efficiency gains make it possible to increasingly "decouple" agricultural production from its environmental impacts.

Environmental effects of efficiency gains

In addition to land expansion and greater use of fertilisers, pesticides, and animal feed, other factors such as better management practices and better technology have played an important role in raising agricultural output and productivity both in the developing and the developed world. For example, modern crop varieties introduced during the Green Revolution accounted for 40% of crop production growth in developing countries between 1981 and 2000 (Evenson and Gollin, 2003[120]) while the development of better varieties through plant breeding is estimated to account for 59-79% of the seven-fold increase in US maize yields between 1930 and 2011 (Smith et al., 2014[121]).

Better genetics, better management practices and better technology can enable agricultural output growth without a corresponding increase in inputs. Data for the United States show how, relative to dairy practices in 1944, modern dairy practices make it possible to produce milk using only 21% of the number of animals, 23% of the feed, 35% of the water, 10% of the land, 24% of the manure output, 43% of the methane emissions, and 56% of the nitrous oxide emissions; the overall carbon footprint per kg of milk in 2007 was only 37% of that produced in 1944 (Capper, Cady and Bauman, 2009[122]), with further improvements between 2007 and 2017 (Capper and Cady, 2020[123]). Denmark and the Netherlands have reduced their use of synthetic nitrogen fertiliser since the 1980s, while agricultural output has been steadily expanding (OECD, 2019[115]). In the United States, nitrogen use per hectare of maize has been flat or declining over the same period, while maize yields have grown from around 6 tonnes per hectare in the early 1980s to more than 10 tonnes per hectare today.[34]

As these examples suggest, there is scope for efficiency gains which would allow production of the same agricultural output with less inputs, or a greater output with a less than proportional increase in inputs. Technological progress, better management practices and other increases in efficiency are also increasingly important drivers of global agricultural output growth. Continued investments in agricultural innovation are therefore key to achieve more productive, sustainable, and resilient food systems (OECD, 2019[7]).

Policies to limit or reorient demand growth hold the potential to improve the environmental footprint of food systems while meeting objectives of food security and nutrition, as discussed earlier. Such policies could thus also be seen as contributing to efficiency more broadly defined.

Alternative approaches to improving the environmental sustainability of the food system

In response to the environmental toll of intensive agriculture, alternative approaches have gained popularity, emphasising organic, local, and/or small-scale production. By reducing or eliminating the reliance on synthetic inputs (fertilisers and crop protection chemicals) or shortening supply chains, such approaches try to reduce the environmental impact of agricultural production. While some of the proposed practices can indeed help make agriculture more sustainable, alternative approaches have their own shortcomings and are not a panacea (OECD, 2016[124]).

The evidence suggests that organic agriculture achieves better environmental impacts *per unit of land used* (Seufert and Ramankutty, 2017[125]). These alternative approaches face a significant challenge, however, given the robust finding in the literature that organic farming produces considerably less food per unit of agricultural land. Meta-analyses summarising a wide range of comparisons concluded that organic yields are overall 19%-25% lower than yields in "conventional" agriculture, although yield gaps may vary depending on the specific crop and on management practices (de Ponti et al., (2012[126]); Seufert et al., (2012[127]); Ponisio et al. (2015[128])). All else being equal, a yield gap of 20% would imply that 25% more land is needed to produce the same output, which is problematic given the important negative consequences of expanding agricultural land use.[35] Because of this yield gap, organic agriculture requires more land, causes more eutrophication, uses less energy, and causes similar greenhouse gas emissions as conventional systems per unit of food (Clark and Tilman, 2017[129]).

Similarly, local agriculture does not in general minimise environmental impacts (Edwards-Jones et al., 2008[130]). The overwhelming majority of GHG emissions related to food occur through agricultural production and land-use change; all other stages of the food chain (including inputs, energy, processing, transport, etc.) account for only one-fourth of the total (IPCC, 2019[85]). Focusing on transport-related emissions or "food miles" without regard to how the food was produced will thus give a misleading picture. The environmental sustainability of food production differs strongly by region and by food product; depending on circumstances, locally-produced food may be more or less sustainable than imported alternatives, even after taking into account transport.

The environmental footprint of food systems is complex and multifaceted, and often depends on local circumstances. In turn, this means that no single approach will solve the environmental problems of the food system. This is true for alternative approaches such as organic or local agriculture, but it is equally true for a strategy of maximising yields through conventional agriculture in order to save land. In addition to the obvious risk that further intensification of agricultural production to achieve higher yields will exacerbate problems, such as nitrogen runoff or excessive use of pesticides, higher yields – even when due to efficiency gains instead of intensification – do not by themselves protect forests and other valuable areas from expanding agricultural land use.

While higher yields were "land saving" during the Green Revolution in Asia, Latin America, and the Middle East, simulations show that growth in agricultural productivity in Sub-Saharan Africa could increase the profitability of farming in the region and could thus lead to an expansion of production on the continent and reduced production in other regions (Hertel, Ramankutty and Baldos, 2014[131]). As yields in Sub-Saharan Africa would still be lower than in those other regions, the net result may well be an increase in global agricultural land use and GHG emissions, at least in the short run.[36] There is a need to spare land from agricultural expansion, but higher yields do not automatically lead to reduced agricultural land use. Other policies such as explicit conservation measures are needed.

The relative benefits of "land sharing" practices (e.g. adopting wildlife-friendly practices to increase on-farm biodiversity) as opposed to "land sparing" ones (e.g. aiming for high yields to reduce overall agricultural land use) are thus complex (Green et al., 2005[132]). A pragmatic approach is to assess which agricultural practices (e.g. crop rotations, biological pest control, cover crops) are beneficial under which circumstances, and with what trade-offs. This could imply specific roles for conservation agriculture, agro-ecological approaches, agricultural biotechnology and precision agriculture, among other farm management practices (OECD, 2016[124]). None of these constitute a "silver bullet" in terms of environmental sustainability of agriculture, but careful, context-dependent and evidence-based evaluation of specific practices and technologies could hold great potential. Examples of such pragmatic approaches include Integrated Pest Management (Ehler, 2006[133]) and Integrated Soil Fertility Management (Place et al., 2003[134]).[37]

Another shortcoming of the binary classification of "conventional" and "alternative" agricultural approaches is that it ignores the important potential of policies to improve environmental outcomes. Smart policies can make a difference for the environmental sustainability of agriculture.

The role of policies

Policy makers have looked at ways of containing the adverse environmental effects of agricultural production. For instance, with increased scientific understanding, regulatory procedures for pesticides have become more stringent and many harmful pesticides have been banned. Out of the ten best-selling pesticides in the United States in 1968, six are now banned, including DDT (Phillips McDougall, 2018[135]).

Similarly, several countries have taken steps to reduce problems related to fertiliser use. For instance, since the early 1990s, Denmark has reduced its nitrogen balance by 56% and its phosphorus balance by 58%, although its agricultural production has continued to increase over this period. Policy makers used a mix of instruments, including targets for reductions of nitrogen and phosphorus discharges, fertiliser accounting systems, nitrogen quota systems to regulate the use of fertilisers, bans on manure application on bare fields, fertiliser taxes for non-agricultural uses, taxes on phosphorus content in feed, as well as agri-environmental schemes and advisory services (OECD, 2019[115]).

Despite some success stories, however, policies have mostly failed to achieve significant improvements in environmental outcomes. An important factor is that many existing agricultural support policies exacerbate the environmental impact of agriculture. Coupled support measures such as import tariffs or output and input subsidies encourage farmers to expand production, to use more fertiliser and other inputs, and/or to expand agricultural land use, and hence have negative environmental impacts. By contrast, relatively less coupled payments, such as those based on historical entitlements, do not encourage intensification or an expansion of agricultural land use and are therefore less harmful to the environment

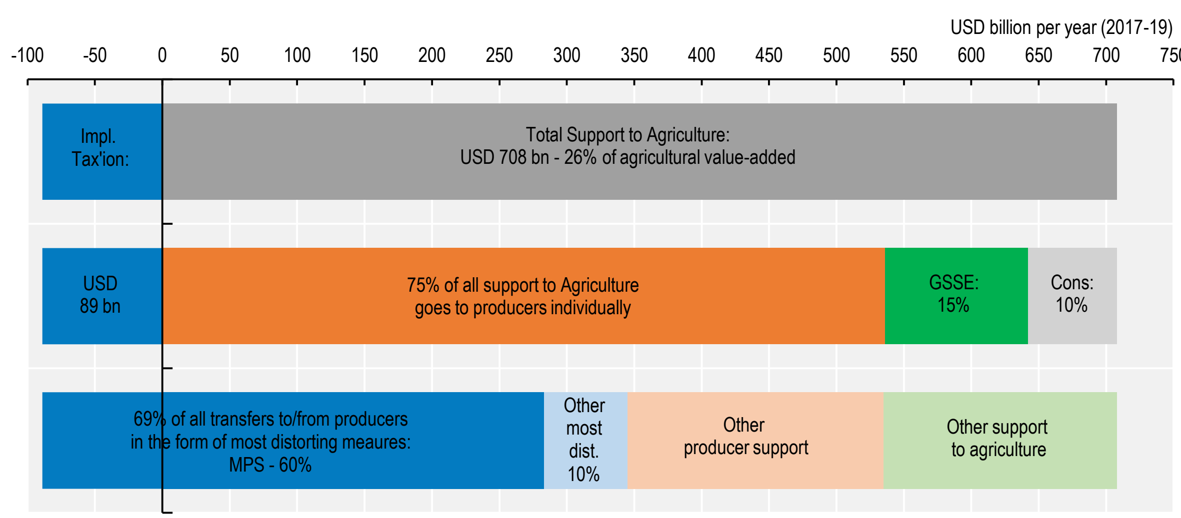
(OECD, 2019[17]) (Henderson and Lankoski, 2019[136]). Less coupled payments can still have indirect effects, however; for instance by keeping farmers in business who would otherwise have left the sector or maintaining production on marginal land. Nevertheless, less coupled payments are in general among the least environmentally harmful support policies. In addition to these environmental effects, less coupled forms of support are economically less distorting than coupled support.

As mentioned earlier, across the 54 OECD and non-OECD economies covered in the OECD's *Agricultural Policy Monitoring and Evaluation*, the agricultural sector receives USD 708 billion per year in support, of which USD 536 billion per year is support to individual producers through various support measures, including through higher prices paid by consumers Figure 1.10) (OECD, 2019[137]) (OECD, 2020[81]). Market price support and other coupled support account for much of the total; agricultural policy thus still relies to an important extent on the most distortionary and potentially most environmentally harmful instruments.[38] Market price support is measured as the policy-induced gap between domestic and border prices, and constitutes a transfer of resources from consumers to producers. Direct payments, on the other hand, are taxpayer financed, which means they can potentially be reallocated to other uses.

Based on the current profile of agricultural support policies around the world, a move to less coupled forms of support would likely reduce the environmental pressures from agriculture. Even with less coupled support, however, market price signals will typically not take into account environmental externalities associated with agricultural production. Decoupling on its own is therefore unlikely to fully resolve the environmental problems related to agriculture. Other policy instruments, such as environmental regulations or agri-environmental payments, are needed to tackle the negative environmental externalities of the food system.

Environmental regulations can play an important role in the policy mix. Existing studies show that the negative economic impact of such regulations is not necessarily as high as is often believed; some studies even appear to show a positive effect on economic efficiency.[39] As discussed earlier, evidence shows that agricultural inputs such as fertilisers are often used at inefficiently high levels. Regulations to reduce these levels can in such circumstances improve efficiency and environmental performance.

Figure 1.10. Support to agriculture, 2017-19



Note: "Impl. Tax'ion" is implicit taxation of producers, "GSSE" is General Services Support Estimate, "Cons" is the Consumer Support Estimate, "Other most dist." refers to the most distorting producer support measures other than market price support.
Source: Based on OECD (2020), *Agricultural Policy Monitoring and Evaluation 2020*.

On the other hand, the evidence regarding the effectiveness of agri-environmental schemes suggests considerable room for improvement. The objectives of such policies are sometimes ill-defined or may not be sufficiently ambitious. A lack of detailed scientific data may also make it difficult to develop effective policies. This problem is compounded by the heterogeneity of agricultural landscapes and production practices. As many policies focus on encouraging or discouraging specific practices, rather than focusing on environmental outcomes, there is a risk that policies will stimulate ineffective practices. An outcome-based approach with careful measurement and evaluation, and taking into account differing environmental conditions, is probably more effective. Finally, an overarching challenge in designing effective policies is that evidence about the environmental impacts is often lacking, making it difficult to judge the cost-effectiveness of policies.

Despite these shortcomings, agri-environmental policies have an important role to play in improving the environmental footprint of agriculture. However, an improved evidence base and a careful choice of policy instruments and their design features will be necessary to increase their impact.

Another possible lever for public policies to improve environmental sustainability is to stimulate improved transparency and traceability along the food chain. By making it easier for consumers to identify sustainably-produced items, governments may create incentives for producers to adopt sustainable practices and may point consumers towards a diet with a more favourable environmental footprint. Many environmental labelling and information schemes (ELIS) exist: one analysis found that more than 500 such schemes were introduced around the world between 1970 and 2012, across all sectors (Gruère, 2013[138]). Most of these schemes are voluntary, and are either initiated by a non-profit or by the private sector. One challenge in the use of such voluntary schemes is to avoid misleading or fraudulent claims. The private sector can increase the credibility of a voluntary scheme by third-party certification, but public policies can also help. Countries differ in how environmental claims are regulated, but in many countries misleading claims can be challenged under consumer protection laws (Klintman, 2016[139]). A range of other possibilities exist for public policies: e.g. mandating the disclosure of certain information; harmonising existing voluntary standards; stimulating the creation of new standards; overseeing certification; or creating a public standard (Rousset et al., 2015[140]). Developments in digital technology could open up new possibilities for increased traceability and transparency along supply chains, in addition to the opportunities they offer to improve agricultural policies through better data collection, processing and sharing (Baragwanath, 2021[50]) (OECD, 2019[13]).

These policy levers are focused on providing better market signals. Yet the importance of efficiency gains for sustainability also points to a more direct role for public policies to facilitate the uptake of more efficient and more sustainable practices and technologies, as well as to stimulate innovation. Both public and private efforts need to be strengthened, which requires public funding for food and agricultural research, and public-private partnerships (OECD, 2019[7]).

1.5. Conclusion

Across the dimensions of the triple challenge – ensuring food security and nutrition for all, providing livelihoods to farmers and others along the food chain, and using natural resources sustainably while reducing greenhouse gas emissions – food systems are sometimes accused of “systems failure”. As the summary assessment in this chapter shows, such claims overlook important achievements across all three dimensions, although important challenges exist and require urgent attention. Policies have not managed to keep up with rapid structural change across food systems and the problems these changes have induced, be they a rising incidence of obesity, continued adjustment pressures on farmers, or mounting GHG emissions.

Much is known about how policies can be reformed to achieve better outcomes. Existing agricultural support policies often exacerbate problems, and removing counterproductive measures would have important benefits. However, additional pro-active policy efforts are needed to effectively address the various components of the triple challenge in order to effectively contribute to the Sustainable Development Goals. While the complexity of food systems makes it impossible to provide an exhaustive overview, this chapter has highlighted that the existing wide range of analysis (by the OECD and others) can inform such efforts.

One contribution of a food systems perspective is to bring that analysis under a single organising framework in order to obtain a sense of relative policy priorities. The real value of a food systems perspective, however, is to highlight the synergies and trade-offs between policy domains which have historically often been treated in isolation. Some of these interactions are domestic, while others spill across international borders. An awareness of such interactions has several implications for policy makers. Any suggested policy could affect other dimensions of the triple challenge, so policy proposals need to be assessed with the possibility of such spill-overs in mind. Interactions could also offer new levers to address problems by exploiting synergies or adjusting policies with unwanted negative spill-over effects. All of this requires co-ordination between different policy-making communities. Some policy choices may simply be domestic matters, while others may need to be co-ordinated internationally, as one country's choices may affect the balance of synergies and trade-offs for other countries' choices. Chapter 2 develops these principles for policy coherence in more detail.

As the discussion in this chapter has shown, there are wide gaps between policies that the evidence suggests would be effective in addressing the triple challenge, and the policies that are currently adopted in many countries. Those gaps may arise due to difficulties in identifying and addressing synergies and trade-offs, but may also reflect issues such as disagreements over facts (e.g. a gap between popular beliefs and scientific evidence), diverging interests, or differences over values. As discussed in Chapter 3, policy-making processes should be designed to generate trusted evidence, to limit the influence of special interests, and to mediate between different values. Strong political leadership is needed to achieve policies which are coherent both domestically and internationally, and which are sufficiently ambitious to meet the triple challenge.

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Notes

[1] The challenges for food systems are a crucial aspect of the broader challenges facing humanity as a whole. Of the 17 UN Sustainable Development Goals (SDGs), nearly all link either directly or indirectly to food systems. Food security is linked to SDG2 (zero hunger) and SDG3 (good health and well-being). Livelihoods and rural development are reflected in SDG1 (no poverty), SDG6 (decent work and economic growth), and SDG10 (reduced inequalities). Sustainable resource use and climate change mitigation are contained within SDG12 (responsible consumption and production), SDG13 (climate action), SDG14 (life below water) and SDG15 (life on land). Other SDGs are important to the attainment of challenges facing food systems, including SDGs pertaining to education, institutions and gender equality. In the remainder of this report, the term "sustainability" is used to mean "environmental sustainability" unless explicitly indicated.

[2] Numbers based on FAO's Net Agricultural Production Index (1960-2010) from FAOSTAT.

[3] An estimated 1.9 billion people were moderately or severely food insecure in 2017-19 (FAO, 2020[26]). The World Health Organization estimates that more than 1.9 billion adults and more than 340 million children and adolescents were overweight or obese in 2016; see https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

[4] Agricultural production, land use and yield data from FAOSTAT (see Section 1.4); GHG emissions data from (IPCC, 2019[85]).

[5] Country policy responses to COVID-19 are discussed in *OECD Agricultural Policy Monitoring and Evaluation 2020*, while the medium-term impact on markets and trade is discussed in the *OECD-FAO Agricultural Outlook 2020-2029*. Information on supply conditions of major agricultural crops and on policy developments is available through the Agricultural Market Information System (AMIS) at www.amis-outlook.org. For a discussion of broader policy implications of COVID-19, see www.oecd.org/coronavirus/en/.

[6] For this reason, in some contexts it makes sense to talk about "the global food system" (singular) when emphasising, for example, global environmental challenges related to food and agriculture, or the importance of international trade in agri-food products. In line with common usage, this chapter mostly uses the term "food systems" (plural) to emphasise the heterogeneity and diversity of food production and consumption around the world, and to highlight the importance of taking into account this local context in designing effective policies. This, of course, does not diminish the importance of the global dimension, as food systems do not exist in isolation from each other or from global processes.

[7] This section builds on and updates material contained in OECD (2013[6]).

[8] An example of such efforts is the Global Research Alliance (www.globalresearchalliance.org), launched in December 2009, which focuses on research, development and extension of technologies and practices to create more productive and climate-resilient food systems without growing greenhouse gas emissions.

[9] The share of calorie intake coming from ultra-processed foods has been estimated at 30% in Mexico (Marrón-Ponce et al., 2018[184]), 35% in France (Julia et al., 2018[183]), 38% in Japan (Koiwai et al., 2019[182]), 48% in Canada (Moubarac et al., 2017[179]), 57% in the United Kingdom (Rauber et al., 2018[181]), and 59% in the United States (Baraldi et al., 2018[180]).

[10] These recommendations are based in part on studies suggesting that excessive consumption of processed and/or red meat is associated with higher risks of cardiovascular disease, stroke, various forms of cancer, as well as with overall mortality (Abete et al., 2014[166]) (Chen et al., 2013[167]) (Pan et al., 2012[168]) (Sinha et al., 2009[169]) (Etemadi et al., 2017[170]). A set of recent papers has argued that these effects may be overstated due to various methodological difficulties (Zeraatkar et al., 2019[171]) (Zeraatkar et al., 2019[172]) (Vernooij et al., 2019[173]) (Han et al., 2019[174]).

Although these reviews also tend to find an association between red and/or processed meat intake and various adverse health outcomes, the authors argue that the effects are small and that the underlying evidence is weak.

[11] This four-track approach for healthier food choices could easily be adapted to encourage more sustainable choices.

[12] A related approach focuses on food fortification and biofortification (the use of plant breeding to increase the micronutrient content of crops) to combat micronutrient deficiencies, especially in the developing world (Allen et al., 2006[185]) (Nestel et al., 2006[186]).

[13] See the UK Code of Broadcast Advertising (Art. 13.9-13.15) and the UK Code of Non-broadcast Advertising and Direct & Promotional Marketing (Section 15), available at www.asa.org.uk.

[14] At least 12 OECD countries have implemented federal health-related taxes, most commonly on soft drinks or sugar-sweetened beverages (Giner and Brooks, 2019[49]).

[15] See www.amis-outlook.org.

[16] Internationally, there has been a shift from food aid to food assistance (Cardwell, 2008[162]). Local procurement of food (e.g. within a given region) can reduce costs and improve timeliness. Better targeting of the needy can also reduce local market disincentives (depression of prices for farmers).

[17] For a discussion of the agricultural transformation, see OECD (2012[79]). Barrett et al. (2017[158]), and Jayne et al. (2018[159]) discuss recent experiences and prospects for transformation in Africa.

[18] The share of manufacturing in employment first peaks and then declines as countries develop, with productivity and income growth stimulating the growth of demand for manufactures. But there is evidence of the peak share becoming lower, and occurring at an earlier stage of income development (Rodrik, 2016[157]; Lawrence, 2017[189]). In some countries trade is a reason, but the common global factor is relatively rapid technological diffusion in manufacturing.

[19] See Greenville et al. (2019[74]) for a detailed discussion on services used to create value-added in agro-food exports.

[20] See https://www.ers.usda.gov/data-products/food-dollar-series/documentation/ (accessed 21 October 2020).

[21] Several reviews of the literature have concluded there is currently no evidence for large, systematic deviations from competitive conditions in food chains, although specific problems may exist in some markets, as is true for any economic sector (Sheldon, (2017[150]), Saitone and Sexton (2017[151]), McCorriston (2014[152]), Perekhozhuk et al. (2017[153]), Dillon and Dambro (2017[156])). Competition authorities can take a pro-active attitude to monitoring competition in the food chain, for instance by using their investigative powers to conduct market studies (OECD, 2018[155]). Policy makers can also play an important role in safeguarding competition by screening existing and proposed regulations for their potential anti-competitive effects (OECD, 2016[154]).

[22] A large literature has explored income and welfare effects of farmer participation in modern value chains, e.g. through participation in contract farming. While many studies find positive effects (Swinnen, 2007[176]), impacts appear to be context-dependent (Meemken and Bellemare, 2020[175]). Agricultural certification schemes (e.g. Fairtrade) similarly appear to have mixed effects (Oya, Schaefer and Skalidou, 2018[177]) (Meemken et al., 2019[178]).

[23] IPCC (2019[85]) estimates emissions from land-use changes related to food systems globally at 4.9 ± 2.5 Gigatonnes of CO_2-equivalent (Gt CO_2e) per year, with 6.2 ± 1.4 Gt CO_2e per year coming from direct agricultural emissions.

[24] Agricultural land use is not uniformly bad for the environment. In some regions, for instance, the revegetation of extensively grazed pastures could lead to the growth of woody bushes which increase the risk of wildfires (Collins

et al., 2015[163]). Still, there is little doubt that at the global level agricultural land expansion has on balance had negative environmental consequences.

[25] In addition to contributing to climate change, agriculture is one of the sectors most affected by it (FAO, 2016[164]) (Nelson et al., 2014[165]). It thus faces the double challenge of mitigation and adaptation.

[26] Emissions data cited in this paragraph are from FAOSTAT and refer to 2016.

[27] These growth rates refer to the compound annual growth rate between 1990 and 2014 in FAO's Net Production Index Number for crops and livestock, respectively.

[28] Data from the International Fertilizers Association's IFASTAT database (www.ifastat.org).

[29] Data on irrigated cropland as a share of the total from FAOSTAT. For estimates of water withdrawal and water consumption during the 20th century up to 1995, see Shiklomanov (2000[144]), who also forecast agricultural water withdrawal of 2 817 km^3 by 2010, which is nearly identical to the 2 833 km^3 suggested by the most recent FAO Aquastat data. (This figure is based on the most recently available data for each country; the average reporting year, weighted by agricultural withdrawal volume, is 2012).

[30] Data from FAOSTAT.

[31] A well-known example is the flow of excess nitrogen from the US Midwest contributing to a "dead zone" in the Gulf of Mexico (Goolsby et al., 2000[145]).

[32] A detailed analysis by Fantke et al. (2012[146]) has tried to quantify the total health impact and cost of pesticide use in Europe based on 133 pesticides applied in 24 European countries in 2003 which account for almost half of total pesticide use in that year. For these pesticides, the study estimated that annually some 2 000 disability-adjusted life years (DALYs) are lost due to pesticides, corresponding to a monetary cost of EUR 78 million. At the global level, one of the main channels through which pesticides affect human lives is by facilitating suicide; pesticide self-poisoning is one of the most commonly used methods of suicide worldwide, with an estimated 260 000 death annually, around one-third of all suicides (Gunnell et al., 2007[147]).

[33] Fertiliser consumption statistics from the International Fertilizer Association (www.ifastat.org); crop land data from FAOSTAT.

[34] Fertiliser data from United States Department of Agriculture (2019), "Fertilizer Use and Price", https://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx ; maize yields from FAOSTAT.

[35] In response to such arguments, proponents have argued that organic agriculture could feed the world without extra land use if coupled with reductions in food waste and reduced consumption of meat (thereby freeing up land now used for feed production) (Muller et al., 2017[149]). However, the same demand reduction measures would arguably result in even lower agricultural land use when combined with higher-yielding conventional agriculture, potentially freeing up land for afforestation.

[36] Recent research (Villoria, 2019[160]) shows that productivity growth between 1991 and 2010 had a negligible effect on land use in most countries, led to increased land expansion in major commodity exporting countries, and was land-saving only in a small number of countries which are relatively closed to international trade. At the global level, however, productivity growth was land-saving, as production was re-allocated internationally to more productive countries. Results show that a simultaneous 1% increase in agricultural total factor productivity in each country would reduce global cropland demand by 0.34%. A follow-up paper (Villoria, 2019[161]) showed that in the absence of productivity growth, 125 million hectares of additional agricultural land would have been needed in the decade from 2001-2010, which would have resulted in emissions of 17 to 84 gigatonnes of CO_2 equivalent (depending on where

the expansion would have taken place), in contrast with the 1 to 15 gigatonnes of CO_2 equivalent from observed land use change.

[37] An additional benefit of this pragmatic approach is that it avoids creating polarised attitudes to food and agriculture by seemingly forcing a choice between one of two competing systems or worldviews (Mehrabi, Seufert and Ramankutty, 2017[148]).

[38]Some countries also tax their agricultural producers using measures that depress domestic prices. These implicit taxes amount to USD 89 billion. The net transfer to agricultural producers is therefore USD 447 billion per year. These implicit taxes also create market distortions.

[39] See OECD (2021) “Exploring the Linkages between Policies, Productivity and Environmental Sustainability”, OECD Publishing, Paris forthcoming (COM/TAD/CA/ENV/EPOC(2019)4/FINAL).

2 Principles for policy coherence

A food systems approach has the advantage of creating awareness about synergies and trade-offs between policy domains which have historically often been treated in isolation, including interactions which spill across international borders. This chapter shows how policy makers can design coherent policies for food systems through better coordination across policy communities. Documenting and quantifying potential spillover effects is an important first step. Where synergies are found, one policy instrument will rarely be sufficient to meet all objectives; rather, a mix of instruments is usually needed. When trade-offs are found, experience shows that these can often be avoided by a smarter choice of policy instruments. But when trade-offs persist, the question is how society should choose between competing objectives. While those choices need to be based on the best possible evidence, they involve value judgments and need to be made in a way that commands broad support across society, is consistent with international obligations, and effectively addresses the triple challenge.

Key messages

- A food systems approach creates awareness about synergies and trade-offs across the different dimensions of the triple challenge. Synergies occur when making progress on one policy objective makes it easier to make progress on another. Trade-offs occur when making progress in one area leads to worse outcomes in another area.
- Coherent policies require increased coordination between different policy making communities (e.g. agriculture, fisheries, environment, public health), so that various policies are aligned to strengthen each other, or at least do not counteract each other.
- Documenting and quantifying potential spillover effects is an important first step. Not all hypothesised spillovers are large enough to matter for policy design.
- Where synergies are found, one policy instrument will rarely be sufficient to meet all objectives; rather, a mix of instruments is usually needed.
- When trade-offs are found, experience shows that these can often be avoided by a smarter choice of policy instruments.
- When trade-offs persist, the question is how society should choose between competing objectives. While those choices need to be based on the best possible evidence, they involve value judgments and need to be made in a way that commands broad support across society, is consistent with international obligations, and effectively addresses the triple challenge.

2.1. Introduction

Chapter 1 discussed how food systems around the world are facing a considerable “triple challenge” of simultaneously ensuring food security and nutrition, livelihoods, and environmental sustainability. Crafting effective policy responses is made more difficult by important interactions between the dimensions of the triple challenge: changes on one dimension can lead to unforeseen positive or negative changes on other dimensions, creating complex patterns of synergies and trade-offs. The question for policy makers is thus how to design effective policies in light of these interactions between different policy domains. The overarching ideal is that of *coherent policies* – where the design of different policies takes into account relevant interactions, and coordination and calibration takes place to achieve a desirable policy mix at the international, national and sub-national levels.[1]

The triple challenge facing food systems connects to several of the Sustainable Development Goals (SDGs). By their very nature, the SDGs call for coherence, given the broad range of policy domains involved and the transboundary nature of many of the challenges, and insights on policy coherence developed in the context of the SDGs are therefore useful for the triple challenge as well.[2] In 2019, the OECD Council adopted the *Recommendation on Policy Coherence for Sustainable Development* (OECD, 2019[1]), which contains principles to enhance such coherence falling under three pillars:

- *A strategic vision for implementing the 2030 Agenda and the SDGs in an integrated and coherent manner.* Three principles under this pillar are building political commitment and leadership; defining, implementing and communicating a strategic long-term vision; and improving policy integration.
- *Effective and inclusive institutional and governance mechanisms to address policy interactions across sectors and align actions between levels of government.* Three principles under this heading are ensuring whole-of-government coordination; engaging sub-national levels of government; and engaging stakeholders.

- *A set of responsive and adaptive tools to anticipate, assess and address domestic, transboundary and long-term impacts of policies.* This requires analysing and assessing the impact of policies and financing (in particular on developing countries); and strengthening monitoring, reporting and evaluation systems to collect evidence. [3]

Building on the OECD Recommendation, this chapter explores key principles for policy coherence in the context of food systems, taking into account the specificities of the triple challenge. Food systems are complex: not only is there a direct connection between food security and nutrition, livelihoods, and environmental sustainability, but many of these connections are global, e.g. through international trade in agricultural products or through global environmental externalities. This global dimension increases the "demand" for policy coherence (as the potential spillovers reach further) but at the same time makes it more difficult to "supply" policy coherence (as coherence needs to be defined across many jurisdictions, and hence is not limited to a single set of decision-makers). The complexity of achieving policy coherence at a global level is illustrated by the difficulties in completing multilateral trade negotiations in the World Trade Organization (WTO).

In addition to being complex, the interactions across the triple challenge are potentially contentious. Two ideas recurring throughout this chapter are therefore that pragmatic approaches are needed (based on the idea of making things "as simple as possible, but not any simpler")[4] and that policy design cannot be reduced to a technical exercise of quantifying interactions: when there are trade-offs, there remains a societal question of preferences in choosing among competing objectives.

2.2. The promise and challenges of policy coherence

When interactions exist between policy objectives, a policy focused only on a single objective might lead to unintended side effects (in the case of trade-offs) or might fail to realise all its possible benefits (in the case of synergies). When these interactions are not taken into account, the resulting policy mix will be less effective and may waste resources. Policymaking should therefore aim for *policy coherence,* defined for the purposes of this chapter as an outcome where various policies are aligned so that efforts in one policy area do not undermine efforts in another area, and even reinforce those efforts where possible (Parsons and Hawkes, 2019[2]).

Policy *incoherence* – the absence of policy coherence – can vary in scope and degree. The most serious types of incoherence can occur when general policy goals are misaligned. For example, a government setting ambitious but divergent goals for agricultural production and environmental performance will potentially create more complex problems of policy incoherence compared to a case where goals are aligned but the implementation details of a specific programme inadvertently end up encouraging certain environmentally harmful types of agricultural practices. In the latter case, a change to implementation rules may be sufficient to restore policy coherence; in the former case, a more serious realignment of policy goals and resulting instruments may be needed. Policy incoherence may also vary in degree, e.g. from merely failing to exploit synergies to slowing down or counteracting progress (OECD, 2019[3]). Several cases of policy incoherence of varying scope and degree have been documented in food and agriculture policies, as discussed below.

Ideally, policy coherence avoids misalignments at all levels; it should therefore take into account *all* relevant synergies and trade-offs between *all* policy objectives in designing the optimal policy mix across *all* possible policy instruments. Despite the potential benefits of policy coherence, actually achieving such a level of coherence may prove difficult.

First, achieving coherence is costly for policy makers. Coordinating across a large number of policy areas, and potentially across several levels of government, creates transaction costs. This in turn means that achieving coherence may require a significant amount of time, attention, and energy, or "political capital", of various policymaking communities. The transaction costs of achieving policy coherence are further increased by a lack of information about all potential interactions. The number of potential interactions between different policy areas is vast, and if information is not readily available, achieving coherence may require extensive research and consultation to identify potential interactions. To be sure, the benefits of improved policy coherence may be worth the higher transaction costs. But there is a risk that striving for *perfect* coherence might lead to slow decision-making or even paralysis, and it might therefore be more feasible to strive instead for “good enough” coherence (Vanheukelom, Mackie and Ronceray, 2018[4]). Such an approach would imply identifying and dealing with the most important synergies and trade-offs.

A second challenge with achieving coherence is that synergies and trade-offs between policy areas themselves depend on the specific policy instruments chosen by policy makers. For example, policies to reduce greenhouse gas emissions from agriculture could include a carbon tax, an abatement subsidy, policies to encourage shifts in diets away from ruminant livestock products, increased R&D efforts, and so on. Each of these policies will have different implications for food security and nutrition, for livelihoods, and for other dimensions of sustainability (OECD, 2019[5]). The choice of the number and type of instruments thus determines the pattern of synergies and trade-offs. This creates an additional challenge for coherence, as mapping potential interactions depends on all the different instruments that could be considered – thus increasing the analytical requirements. On the other hand, this fact can also present an opportunity, as a smart choice of instruments can help minimise trade-offs and maximise synergies.

A third challenge involves the problem of societal preferences and choice when faced with a trade-off. Designing a coherent policy may force a choice between two or more desirable but competing outcomes. For example, measures to improve animal welfare may raise the price of food, which tends to disproportionately impact poorer households.[5] A common trade-off also arises whenever a proposed policy requires public funds, as this typically implies either an increase in the tax burden or a reduction in spending on other programmes. These choices cannot be reduced to technical problems as they depend on a society’s priorities. In democracies, there will rarely be a unanimous view on how such trade-offs should be decided. Moreover, different interests will try to influence decision-makers to tip the scales in their favour. There is thus an important question of how societies make decisions: the processes they use to choose among conflicting objectives, and how this decision process can be well-informed while being insulated from “policy capture” by interest groups. Chapter 3 discusses these issues in more detail.

The above challenges are compounded in the case of transboundary spillovers. As long as spillovers occur within a single jurisdiction, both the costs and benefits of policy coherence are domestic and the choices can be made within one country’s decision-making processes. This typically makes it easier to obtain and exchange information on interactions, and to coordinate different policymaking communities. It also makes it easier to get representation of relevant stakeholders and make a political decision on societal trade-offs. If benefits accrue domestically, it is also easier to justify the transaction costs of achieving coherence. In an international setting, policy coherence becomes a common-pool resource, leading to collective action problems. Climate change mitigation is a case in point. Policy settings in one country may be acceptable from the point of view of domestic interests (e.g. by not imposing costly mitigation efforts) but may indirectly impose costs on stakeholders in other countries (who will suffer the consequences of climate change). These stakeholders are usually not represented in domestic policy-making processes, and at the international level, there is no single last arbiter or decision-maker. As a result, it is harder to address international cases of policy incoherence.

These challenges cannot necessarily be “solved”, but they can be managed more or less effectively. Building on OECD recommendations on policy coherence for sustainable development (OECD, 2019[1]), on regulatory policy and governance (OECD, 2012[6]), on the OECD Best Practice Principles on both Regulatory Impact Assessment (OECD, 2020[7]), on International Regulatory Cooperation (OECD, Forthcoming[8]), as well as on a broad range of OECD work on policy challenges in food and agriculture, the remainder of this chapter proposes principles for a pragmatic approach to ensuring policy coherence for food systems. This approach first seeks to reduce complexity. Where complexity remains, the proposed approach then seeks to rigorously test and quantify potential interactions, carefully calibrating the policy mix, and making societal and transboundary trade-offs explicit to facilitate conscious, transparent decision-making. (The question of how society should choose when faced with those trade-offs is explored in Chapter 3). The principles identified in this chapter (summarised in Figure 2.1 at the end of the chapter) can be translated into different practical approaches. As noted below, the principles could, for instance, be used for an *ad hoc* assessment of the coherence of existing policies, or could be embedded in routine processes for evaluating new policy initiatives, as is the case in several jurisdictions.

2.3. Reducing complexity

Assessing the need for policy intervention

A proposed first step in reducing the complexity of ensuring coherent policies for food systems is to ask whether and when policy intervention is needed.

The role of public policies in addressing the "triple challenge" can be assessed using the same principles applied to public policy in other policy areas. Communities, markets, and states have different strengths and weaknesses in meeting societal objectives, and, while different societies may opt for different mixes along the continuum, a long tradition of economic and public policy analysis has identified particular roles for government intervention in three areas. A first area is establishing framework conditions such as the rule of law, security, macroeconomic stability, and a rules-based international system; these framework conditions in turn allow markets and help communities to function. A second role for government is to correct specific market failures (including problems resulting from market power and asymmetric information, coordination issues, and externalities) and to provide public goods. Third, public policy can also address notions of social justice and an equitable distribution of incomes and opportunities across society (OECD, 2002[9]). Across all of these areas, it remains an empirical question whether and to what extent policy intervention could help in a given context, and which policy instruments are most fit for purpose, in line with general principles of good regulatory policy (OECD, 2012[6]) – in particular regulatory impact assessment (OECD, 2020[7]) and sound public governance (OECD, 2018[10]).

No policy intervention can be successful without defining the policy context and objectives, in particular the clear and systematic identification of the problem that provides the basis for action by government. In the context of food systems, specific policy interventions may be warranted in order to provide public goods and to address market failures. Agricultural research and development, education on what constitutes a healthy diet and lifestyle, and the provision of food safety regulation and testing are just some examples of investments in public goods with important benefits for society. Policy interventions can also help to correct externalities, where the social costs and benefits of agents' decisions diverge from the market signals that drive those decisions. Those externalities may be negative, such as GHG emissions and the public health burden of unhealthy food choices. They may also be positive, such as the contribution of agriculture to maintaining rural landscapes. Public policy can help private actors internalise the social costs and benefits of their actions, thus ensuring that private decisions are more aligned with societal objectives. Other policy measures can address problems of market power, asymmetric information, and coordination failures to ensure a better functioning of markets for the benefit of the population.

Market failures and public goods do not automatically imply a specific role for government intervention, however, and the existence of market failures and public goods does not necessarily mean that current levels and instruments of policy intervention are the most efficient in responding to these problems or in providing these benefits (OECD, 2002[9]). There exists a continuum along which some degree of intervention can be warranted – while keeping in mind that different forms of government intervention carry their own costs, including the cost of inaction. In some cases, direct government action is needed (e.g. through regulation or fiscal measures); in other cases, governments can play a coordinating role for initiatives by private stakeholders or can set non-binding standards which can nonetheless become an important reference in guiding others' action or behaviour, either at the national or international level (Box 2.1). Policy makers should therefore consider all plausible alternatives, from laws and regulations through to non-legislative solutions, and including the possibility of not taking any action.

The social justice argument for income redistribution is regularly conflated with the market failure/public goods rationale for government intervention in food systems, but from a public policy standpoint, it can be important to separate efficiency and equity arguments. Even when markets are functioning well, there is no guarantee that market processes will result in a socially desirable distribution of incomes. Conversely, concerns over income distribution do not necessarily imply that markets are not efficient. Moreover, while both factors could be a rationale for government intervention, the two concerns are not necessarily addressed with the same policies. Mixing the two makes it harder to design effective policies, harder to assess their effectiveness *ex post*, and reduces political accountability (OECD, 2002[9]). Achieving clarity on policy objectives is therefore an important precondition for developing effective policies (van Tongeren, 2008[14]). If both equity and efficiency are policy objectives, clearly distinguishing them is important to allow a transparent analysis of the different instruments which can be used, and the potential synergies or trade-offs between them.

Box 2.1. The OECD-FAO Guidance for Responsible Agricultural Supply Chains

Businesses can play a major role in meeting the triple challenge. At a minimum, they can minimise any adverse impacts of their operations, supply chains and other business relationships. Governments and international organisations can act as a catalyst or provide incentives of varying strength, e.g. by providing guidance on good practices, by promoting and monitoring their adoption by companies, and by incorporating them into public procurement standards.

The *OECD-FAO Guidance for Responsible Agricultural Supply Chains* (OECD/FAO, 2016[11]) provides a common framework to help agri-businesses and investors contribute to sustainable development. By implementing the due diligence recommendations of the *OECD-FAO Guidance*, companies can systematically identify, assess and mitigate potential negative impacts associated with their business. The *Guidance* is relevant for all enterprises across the entire agricultural supply chain, from the farm to the consumer, across food and non-food commodities. It covers a wide range of topics, including human rights; labour rights; food security and nutrition; health and safety; tenure rights over and access to natural resources; animal welfare; governance; environmental protection and sustainable use of natural resources; and technology and innovation.

In developing this *Guidance*, OECD and FAO worked closely with supply chain experts, business, civil society, unions and policy makers. The recommendations also incorporate long-standing standards for responsible business conduct (RBC), including the *OECD Guidelines for Multinational Enterprises* (OECD, 2011[12]) and the UN Committee on World Food Security's Principles for Responsible Investment in Agriculture and Food Systems (CFS, 2014[13]).

In addition to the standard itself, the OECD provides ongoing support towards the widespread uptake and implementation of the *OECD-FAO Guidance* with policy makers, business and relevant stakeholders.

The *OECD-FAO Guidance* demonstrates how the OECD and FAO together with national governments can use their convening power and expertise to encourage and support efforts by the private sector. In 2018-19, the OECD and FAO jointly implemented a pilot project with over 30 companies and industry initiatives. Several companies that took part in this pilot have started exploring how to collaboratively address systemic risks in common supply chains and markets. The OECD is also implementing a regional pilot in 2019-20 in Southeast Asia under the EU-ILO-OECD Responsible Supply Chains in Asia programme, with funding by the European Union.

Furthermore the OECD supports National Contact Points for RBC (NCPs), which are unique agencies for RBC established by governments. Their mandate is twofold: to promote the OECD Guidelines and related due diligence guidance including the OECD-FAO Guidance, and to handle cases of alleged non-observance of the Guidelines as a non-judicial grievance mechanism. To support NCPs in implementing their mandate, the OECD helps facilitate peer learning activities and voluntary peer reviews, and provides capacity building and practical tools to NCPs on promoting RBC and facilitating conciliation and mediation for access to remedy.

As this example shows, public-sector actors such as the OECD and FAO can facilitate a broad coalition of private and public stakeholders, with the support of civil society and worker representatives, to address transboundary impacts on people, the planet and society and meet global commitments on the Sustainable Development Goals (SDGs).

Choosing the right type and number of instruments

A second technique for reducing complexity is through smart choices of the *type* and *number* of policy instruments.

Trade-offs tend to be more severe when policy makers try to use a single instrument to achieve multiple policy objectives, or when an inappropriate policy instrument is used. For example, using support coupled to prices or production (e.g. import tariffs, output subsidies) as a means to transfer income to farmers can stimulate overproduction and lead to environmental problems and concerns about unfair competition from other producers. Within the context of this policy instrument, there is a trade-off between supporting farmers' incomes on the one hand, and economic efficiency, competition and environmental sustainability on the other. By contrast, more decoupled forms of income support (unrelated to current production) are less likely to lead to these problems: they can achieve income support to farmers with considerably smaller economic and environmental costs. Choosing the appropriate type of policy instrument can therefore weaken or even remove trade-offs between different policy objectives, which in turn makes it easier to achieve those different objectives.

When synergies exist between objectives, it will in general not be optimal to rely on a single policy instrument to achieve several objectives (a "silver bullet" approach).[6] The type and extent of policy interventions required to obtain one objective is unlikely to be the same as that required to achieve other objectives. For example, the optimal diet for human health is unlikely to coincide exactly with the optimal diet for environmental sustainability, and vice versa. In this example, other policies to improve the sustainability of food production are also likely to be needed.

Using a sufficient number of policy instruments thus reduces the risk of policy-induced trade-offs and increases the likelihood that different objectives can be achieved. As a rule of thumb, policy makers would therefore ideally need *as many instruments as objectives*. This principle is sometimes referred to as the "Tinbergen rule", after the Dutch Nobel-winning economist Jan Tinbergen (Tinbergen, 1952[15]).[7] When policy makers are faced with a trade-off between different objectives, one possible answer is therefore to reassess whether the existing policy instrument is fit for purpose, and search for new policy instruments which could replace or complement the existing policy instrument and help resolve the trade-off. When synergies are present, policy makers should keep in mind that "silver bullets" rarely exist; multiple objectives usually require multiple policy instruments. Even if one policy instrument has positive effects on a number of different objectives, complementary policy actions are usually needed to fully achieve those objectives.

One way to implement the "Tinbergen rule" is to choose policies which address market failures as directly as possible in order to avoid unintended secondary distortions (van Tongeren, 2008[14]). This may not always prove feasible, but searching for a targeted approach is nonetheless a good starting point. If the goal is to reduce environmental harm, such a targeted approach would seek to link incentives to the environmental outcomes. If a targeted approach is feasible, an additional benefit is that it makes it easier to assess whether the policy is achieving its goal and easier to adjust the policy when needed.[8] Indeed, some objectives for the food system could be pursued relatively independently if synergies or trade-offs are minor.

The need to distinguish clearly between different policy objectives, and to choose the appropriate type and number of instruments, is illustrated well by earlier OECD work on multifunctionality in agriculture (OECD (2001[16]), (2003[17]), (2008[18])). The starting point for that work was the observation that agricultural production is in some cases associated with the production of desirable "non-commodity outputs," including valued positive externalities or public goods (e.g. a pleasing landscape or certain eco-system services). This led to concerns that efforts to reduce production-linked support to agriculture could result in a lower supply of these outputs. OECD work emphasised the importance of first establishing the actual extent to which non-commodity outputs are linked to, or can be dissociated from, commodity production. If the two can be provided separately, a better policy approach is to provide *separate* incentives for the production of the non-commodity output – an instance of targeting. When a link exists, there may be ways to relax or weaken it, e.g. through changes in farming practices. Multifunctionality only becomes a policy issue when there is a strong link which cannot be altered, and when there is a market failure associated with the production of the non-commodity output. Even then, more targeted policies (rather than relying on production-linked support) are often available.

The principle of targeting can also refer to the level or scale at which government action is taken. For example, measures to reduce nitrogen leakage could in principle target individual farms or even parcels. A study by Konrad et al. (2014[19]) of nitrogen leakage in the Odensje Fjord (Denmark) illustrates how targeting at the parcel level could help to reduce the economic cost of such measures. Using highly disaggregated spatial data on parcels, simulation results show that a targeted approach would involve implementing measures (a mix of reductions in fertiliser application, planting of catch crops, establishing wetlands, and other interventions) on only 15% of all arable land, with no intervention on the remaining parcels. By contrast, policies uniformly applied to all parcels would be considerably more costly. These findings suggest that a more targeted approach can achieve reductions in nitrogen runoff at a lower cost – hence weakening the trade-off between economic costs and environmental benefits in this example. However, this level of targeting itself comes at a cost to policy makers, both in terms of information requirements and in terms of administration. In some cases, the additional cost of targeting may outweigh the benefit. In these cases, policy makers may choose a less targeted approach, while acknowledging that there will be a higher risk of trade-offs.[9]

One perhaps surprising implication of the "Tinbergen rule" is that the co-existence of policies that seemingly work in different directions is not necessarily incoherent. For example, the same agricultural activity (e.g. keeping ruminant livestock) may create positive externalities in one dimension while creating negative externalities in another. Policy makers might end up simultaneously paying farmers for the positive externalities (e.g. landscape services) while taxing them for the negative externalities (e.g. emissions) of the same activity. From the point of view of an individual farmer, this may seem incoherent. However, this situation might make sense from a policy point of view, as one instrument provides incentives to increase the provision of the positive externalities while the other instrument incentivises farmers to find ways to reduce the negative externalities of that activity. Moreover, using separate policy instruments may make it easier to evaluate the effectiveness of policies *ex post*.

2.4. Accounting for interaction effects

The techniques described in the previous section can help to reduce complexity and simplify the challenge of coherent policies. At the same time, some complexities will remain. Policy makers need to be aware of the possibility of interactions among policies, and need to have the tools to identify the nature and extent of such interactions. In the case of synergies, even when as many instruments as objectives are used, there is a question of the amount of policy intervention required through each of the different policy instruments. When trade-offs exist, tough choices may exist between different, valued outcomes. Several lessons regarding good practices can help policy makers with these questions of identification, calibration, and mediation.

Identification

Being able to identify the existence, nature and extent of trade-offs or synergies is necessary for coherent policymaking. Identification has two distinct aspects. First, policy makers need to be aware of the *possibility* that a new policy initiative may have spillover effects, or that an existing set of policies may be incoherent. Various mechanisms such as whole-of-government processes, regulatory impact assessments or stakeholder consultation processes can help in this initial screening process.[10] Identifying spillovers requires a broad view: some interactions may affect wellbeing "here and now", but it is equally important to consider potential interactions "elsewhere" (i.e. transboundary effects) and "later" (i.e. inter-generational effects) (OECD, 2016[20]). For example, in the context of the Sustainable Development Goals, work by the OECD (2016[21]) and (2017[22])) has explored potential positive and negative interactions between SDG 2 (Zero hunger) and other SDGs across a range of policy areas.

Such a screening may uncover potential interactions, but it is important to scrutinise these in a second step to establish where actual interactions exist, and how important these are from a policy perspective. This is an analytical task, which may involve statistical or experimental evidence, simulations, further consultations with experts and stakeholders, and other types of evidence. In an interconnected world, it is easy to hypothesise plausible interactions; but what matters for policy is whether these interactions are important enough to warrant adjustments to policies. Evidence on the extent of interactions is thus an important prerequisite to making transparent policy decisions.

Research by the OECD has uncovered several instances of incoherence between existing policies affecting food systems.[11] Chapter 1 reviewed recent OECD work on the environmental impact of agricultural policies, which concluded that policy instruments differ in their environmental impacts. The most negative impacts are generally found for coupled support (e.g. import tariffs, output subsidies), while more decoupled forms of support generally have smaller environmental impacts (OECD, 2019[23]). Work by the OECD on synergies and trade-offs between climate change adaptation, mitigation and agricultural productivity similarly found that existing agricultural and agri-environmental policies may be sending conflicting signals on at least one of those three goals. In addition, the work showed that countries rarely assessed whether existing policies were effective in supporting all three objectives (Lankoski et al., 2018[24]). Despite negative spillovers, much of the support to farmers globally is still provided through coupled support. Agricultural policy around the world thus relies on the potentially most environmentally harmful instruments (OECD, 2019[25]). In many countries, farmers also benefit from fuel tax concessions and other advantages such as lower VAT rates applied to pesticides and fertilisers (OECD, 2020[26]). However, as both the level of agricultural support and the mix of policy instruments used varies around the world, specific analysis is needed to decide on the importance of this type of incoherence in a given country context.

Detailed country reviews by the OECD on policies for innovation, productivity and sustainability in food and agriculture also uncovered several instances of policy incoherence (OECD, 2019[3]). In some cases, potential conflicts could be found at the level of general policy goals (e.g. promoting agricultural production growth but also aiming for more sustainable land use; these goals are not necessarily incoherent but could come into conflict if pursued independently of each other). Numerous instances of potential policy incoherence were found *within* policy areas (e.g. when public research efforts are not directed towards the needs of the sector) and among policy approaches within an area (e.g. when different commodities receive different degrees of agricultural support). Similarly, recent OECD work on policies for sustainable land use found many instances of policy incoherence, often linked to a lack of institutional coordination and the fragmentation of responsibilities among numerous agencies (OECD, 2020[27]).

It is essential that potential direct and indirect interactions are identified, substantiated by evidence, and where possible quantified. Interactions which are plausible in theory may not materialise; interactions which have been demonstrated in one context may turn out to be less relevant in a different context; and interactions which were demonstrated at some point in the past may have weakened or disappeared since. Rigorous, relevant and up-to-date evidence is thus important.

One example is the changing landscape of agricultural trade and the role of policies (OECD, 2019[28]). Historically, high levels of support and protection in developed countries often led to production surpluses, which were subsequently released on international markets using export subsidies. This resulted in lower international prices, which put pressure on exporters and import-competing producers in developing countries (OECD, 2013[29]). However, important reforms have taken place in the past two decades. Although support for agriculture remains widespread (and, in some countries, very large as a percentage of farm gate receipts) and trade barriers remain more important for agriculture than for industrial goods, the sector overall has seen falling tariffs and reductions in trade-distorting producer support by a number of developed countries (OECD, 2019[28]). In particular, the WTO Ministerial Conference in Nairobi (2015) agreed on the elimination of agricultural export subsidies by developed countries.[12] For example, the European Union, which made frequent use of export subsidies in the past, has ceased using this instrument since 2015 (Matthews and Soldi, 2019[30]). In parallel with this development, developing countries have moved away from policies which generally taxed the agricultural sector, with some now also providing support to farmers using distortionary instruments (Anderson, Rausser and Swinnen, 2013[31]) (Bouët and Laborde, 2017[32]) (OECD, 2019[25]). Other important changes have taken place: in the past two decades, agro-food trade has grown strongly, with important flows among emerging and developing countries. Agro-food sectors are also increasingly connected to other sectors, both domestically and through global value chains (OECD, 2019[28]). The international environment thus has changed in important ways over the past two decades, and discussions on potential spill-over effects (e.g. of agricultural and trade policies) should be based on up-to-date evidence and analysis.

An example of how hypothesised interactions may not materialise is the potential link between agricultural support policies and rising obesity. Several commentators have suggested that policies to support agricultural incomes (such as farm subsidies) have been an important contributor to rising obesity (see, for example, Wallinga (2010[33]) and Elinder (2005[34])). However, empirical evidence suggests otherwise. Agricultural support is often provided through trade barriers and other policies which *raise* domestic prices, thus discouraging consumption. Detailed analyses for the United States find that agricultural support policies have had small and mixed effects on prices of primary agricultural commodities, which in turn only play a small role in influencing the consumer prices of different types of food products. Researchers therefore conclude that agricultural support policies in the United States have a negligible impact on the evolution of obesity (Okrent and Alston, 2012[35]; Rickard, Okrent and Alston, 2013[36]). International evidence also shows that countries with the highest levels of agricultural support tend to have higher agricultural commodity prices which are in turn correlated with lower rates of obesity (Alston, Sumner and Vosti, 2008[37]). Contrary to perception, agricultural support policies in OECD countries are unlikely to be a driver of rising obesity rates.

The implication here is not that agricultural policies never matter for nutritional outcomes: in some contexts, agricultural policies may well be an important contributing factor to negative nutritional outcomes. This could arguably be the case, for example, in developing countries where policies often feature a near-exclusive focus on staple grains such as rice, wheat or maize at the expense of other agricultural products which could contribute to a more diverse diet (Pingali, 2015[38]).

In contrast with agricultural support policies, there is evidence that public investments in agricultural R&D in the United States were a major driver of declining real prices of agricultural commodities and hence contributed to greater calorie intake (Alston, MacEwan and Okrent, 2016[39]). However, even when such interactions can be demonstrated, it may be far from optimal to exploit these in policy design. Estimates by Alston et al. (2016[39]) suggest that if there had been no increase in the public agricultural R&D "knowledge stock" in the United States between 1980 and 2004, agricultural commodity prices and food prices would have been much higher and calorie intake lower. This would indeed imply lower obesity-related public healthcare costs, but those savings would be dwarfed by a large increase in consumer expenditures for food. Alston et al. (2016[39]) conclude that although public R&D spending influences calorie intake (and hence obesity and associated healthcare costs), using this instrument would create a large trade-off in terms of consumer welfare relative to other potential policies. Hence, even if an interaction exists, other potential policies have a better "profile" in terms of effectiveness and associated costs and trade-offs. The identification of interactions is thus only a prelude to a process of calibration (the choice of the optimal combination of instruments) and mediation (the choice between conflicting societal objectives).

At the same time, policy making never happens in a context of full information, whether because scientific knowledge evolves continuously, or because gathering additional evidence is costly and time-consuming so that postponing a policy decision until more information becomes available is itself a potentially costly decision. As discussed in the next chapter, there are important knowledge gaps on food systems, including on the extent and characteristics of policy issues, their synergies and trade-offs, and the costs and benefits of potential policy options. Investing in robust processes to gather the best possible evidence is thus important. But as decisions are often made with incomplete information, it is important to make explicit the uncertainty over possible costs and benefits of policy options.

Calibration

For synergies, the key question is one of *calibration* – of choosing the optimal combination of policy instruments (and their "settings" or magnitudes) to reach the desired objective, taking into account the empirical evidence on the relative effectiveness and other strengths and weaknesses of different instruments.

This is essentially no different from the task policy makers face in *any* policy setting: to carefully choose the best policy instrument to reach a given policy objective, including considering the baseline of no policy action (OECD, 2012[6]). Yet it is worth making this principle explicit, as in the context of the food system there is often a tendency to present specific initiatives as "silver bullets" capable of resolving many challenges at the same time. As pointed out earlier, even if synergies exist, it will never be the case that a single policy instrument can achieve multiple objectives perfectly. It is therefore important that policy makers consider different policy instruments alone and in combination, and where possible quantify their effects to determine the best policy mix. It is also important to consider and evaluate the full range of policy instruments, including plausible alternatives to a legislative/regulatory option, which can vary in terms of their stringency.[13]

One application of this principle regards the use of demand-side measures as a possible instrument to address negative externalities on the supply side (e.g. when a reduction in demand for ruminant livestock products is suggested in order to reduce associated greenhouse gas emissions). A well-known result in economic theory holds that in a closed economy, the effects of a tax do not depend on whether it is levied on producers or consumers: the result is a similar decrease in quantities produced (and consumed). This might suggest that efforts to encourage more "sustainable" consumption patterns could under the right circumstances achieve the same impact as policies that tax production for this purpose – and conversely, that supply-side measures could be used to achieve demand-side goals (e.g. healthier diets). In practical terms, however, there are several difficulties that need to be considered.

First, externalities are rarely linked one-for-one to the level of production or consumption. In the case of greenhouse gas emissions, for example, what matters is not only the volume of production but also the *emissions intensity* of production. The ideal instrument would tackle emissions itself. A tax on emissions would not only reduce production overall, but would also favour less emissions-intensive production methods, thus reducing the average emissions intensity in the sector. Moreover, intermediate sectors (e.g. food manufacturers) would in turn have an incentive to substitute away from emissions-intensive inputs, including by developing new products and processes. By contrast, an undifferentiated production tax takes away this flexibility. The same is true for a policy which aims to reduce demand (unless the policy can differentiate between producers depending on their emissions intensity, e.g. through a labelling scheme – although this would bring additional issues and costs). These policies will reduce emissions in line with the average emissions intensity of production without having much effect on emissions intensity itself. As a result, these undifferentiated measures achieve a relatively poor targeting of the problem they aim to address. A targeted policy can achieve the same reduction in emissions with a smaller decline in production.[14]

The bottom line here is that even if in theory demand-side measures could, under the right circumstances, be used to address supply-side problems and vice versa, this may not be optimal in practice. Policies therefore ideally focus on targeting externalities as directly as possible. Thus consumption externalities are best corrected using demand-side policy interventions, while supply-side policies will typically be the most effective approach to address production-related externalities such as emissions. However, if there are synergies between these goals, this could reduce the amount of policy effort needed on the separate targeted policies.

Mediation

For trade-offs, *mediation* between conflicting objectives is necessary. While identification and calibration have a strong focus on technical analysis, trade-offs between societal objectives necessarily involve value judgments. Identifying trade-offs will often highlight fundamental differences of opinion about how different objectives should be weighed against one another. These differences could reflect conflicting views on what is in society's wider interests, or narrow resistance from interest groups to policies that disadvantage them. In some cases, interest groups can gain considerable influence on public policy-making processes, leading to policy capture (OECD, 2017[40]). In either case, avoiding gridlock may require making tough choices or striking a grand bargain to overcome opposition.

Trade-offs are not a purely technical matter. For example, Okrent and Alston (2012[35]) consider the potential of taxes and subsidies to combat obesity and find that a tax on calories would be a highly effective obesity policy. The tax raises food prices, which hurts consumers financially, but as this effect is smaller than the savings in public health care costs, the tax has a positive net welfare effect. However, this efficiency gain comes at a potential cost in terms of equity. Food represents a larger share of the household budget for poorer households: in the United States, households in the lowest 20% of the income distribution spend 35% of their income on food, a share which falls to 8% for households in the highest 20% of the distribution (USDA, 2019[41]). While the calorie tax would be an effective way to reduce calorie intake and address obesity, it might also proportionally inflict a greater financial burden on lower-income groups in society in the absence of mechanisms to financially compensate them. At the same time, other research has found that individuals with lower socio-economic status are also likely to see financial benefits from improved diets, including through lower out-of-pocket healthcare spending and improved labour market outcomes (Sassi et al., 2018[42]).[15] The trade-off in terms of equity effects could be weakened or eliminated if those effects are taken into account, again underscoring the importance of empirically assessing and quantifying interactions. But if a trade-off remains between equity and public health, then whether and how to trade off these different outcomes is not a question which can be settled by analysis alone.

In the particular case of the calorie tax, one solution to a potential trade-off is to rely on other instruments, either alone or in combination with a tax. Analysis by the OECD has proposed a "four-track policy approach" to encourage healthier food choices. In addition to fiscal measures, this includes demand-side public interventions (e.g. education programmes or providing dietary information), voluntary collaborations with the food industry at the supply-demand interface (e.g. food reformulation, food labelling), and firmer regulations when public-private incentives are misaligned (e.g. rules on advertising aimed at children) (Giner and Brooks, 2019[43]). Some combination of these instruments may help encourage healthier food choices without necessarily imposing the same financial burden on poorer households. An alternative solution might be to provide offsetting financial compensation to poorer households.

However, such solutions to soften or avoid trade-offs are not always available. In those cases, society faces a choice between two or more valued outcomes. As discussed in more detail in the next chapter, there is no simple decision rule available to unambiguously resolve such trade-offs.[16] Democratic deliberation could help, by allowing those involved in the deliberation to reflect on information and arguments as well as on their own preferences; deliberation can also create a context more conducive to compromise (Dryzek and List, 2003[44]).[17] But even such a deliberative approach may fail to address transboundary spillovers if foreign stakeholders are not represented, as discussed below.

Policy approaches

There are various ways to translate the principles identified in this chapter into specific policy approaches. In several jurisdictions, the development of new policies routinely requires policy makers to assess issues of policy coherence through regulatory impact assessments. Policy makers can also decide to use a more elaborate multi-stakeholder consultative process for major policy initiatives. Coherence can also be assessed for new policies, but also for existing policies through "stocktaking" exercises. Moreover, various degrees of "policy integration" (coordination between policy-making communities) can also be used to improve coherence, although integration comes at a cost and does not necessarily guarantee better outcomes.

OECD countries are increasingly using Regulatory Impact Assessments (RIA) as a routine "screening" of proposed new laws and regulations (OECD, 2018[45]). Such assessments document the efficiency and distributional effects of proposed policies and can help illuminate trade-offs. The OECD Council Recommendation on Regulatory Policy and Governance calls for RIAs to include economic, social and environmental impacts, including distributional effects over time, and identifying who is likely to benefit and who is likely to bear costs; assessments should also be quantitative whenever possible (OECD, 2012[6]). These principles are increasingly common in OECD countries. In the United States, for example, guidance by the Office of Management and Budget to federal agencies on the development of regulatory analysis explicitly requires such assessments to "look beyond the direct benefits and direct costs (…) and consider any important ancillary benefits and countervailing risks" (Office of Management and Budget, 2003[46]). Similarly, the European Commission's "Better Regulation" guidelines on impact assessment require a comparison of different policy options on the basis of economic, social and environmental impacts, quantified whenever possible. Impact assessments must also include a description of who will be affected and how, as well as potential impacts on competitiveness, small and medium-sized enterprises (SMEs). Moreover, impact assessments must explain the consultation process used (European Commission, 2017[47]). These and related approaches to RIAs in other countries improve policy coherence by requiring an *ex ante* evaluation of potential trade-offs and synergies, and allowing a comparison of different policy options taking into account these interaction effects.

Policy makers can go beyond the normal requirements of RIAs in developing major new policies, for example by setting up more elaborate multi-stakeholder consultation mechanisms than would normally be done. To develop its “Food Policy for Canada”, the Canadian government started a process of public consultations in 2017. These consultations included dialogues with Indigenous Peoples and organisations, as well as with people working in the food system, and people and organisations active on issues such as food security and food waste. Close to 45 000 people provided input via online surveys while hundreds participated in face-to-face regional consultation sessions, as well as a National Food Policy Summit held in Ottawa. The consultation process was organised collaboratively by several federal departments and agencies, and the various viewpoints and insights were published in a separate report (Government of Canada, 2018[48]). Based on these extensive consultations, the government announced the first-ever food policy for Canada in 2019, including funding for initiatives such as a “challenge fund” to support innovative food waste reduction ideas, and support for community-led projects to address food insecurity (Agriculture and Agri-Food Canada, 2019[49]). An important component of the Food Policy for Canada will be the creation of a Food Policy Advisory Council, which will explicitly aim to bring together a wide range of perspectives and expertise to help the government tackle complex and systemic issues related to food (Government of Canada, 2019[50]). The development of “A Food Policy for Canada” deliberately sought alignment with the various Sustainable Development Goals related to food, notably SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 12 (Responsible Production and Consumption) and SDG 13 (Climate Action).

Another multi-stakeholder approach to assess problems of policy coherence related to the food system is proposed by the “Collaborative Framework for Food Systems Transformation” developed by the One Planet Network’s Sustainable Food Systems Programme (UNEP/SFSP, 2019[51]). The framework can be used by national or local governments seeking to develop more coherent policies for their food systems. It emphasises the importance of preparing a holistic food systems assessment, including a stocktaking of existing policies and initiatives and their potential trade-offs and synergies. In addition, the framework calls for robust evidence, active involvement of stakeholders, and dialogue across policy communities throughout the whole policy cycle (including planning, implementation, and evaluation of results).

An example of such a stocktaking are the detailed country reviews by the OECD on policies for innovation, productivity and sustainability in food and agriculture (OECD, 2019[3]), mentioned earlier. Another example is provided by G20 countries’ peer reviews on support to fossil fuels (OECD, 2018[52]). In 2013, G20 Finance Ministers agreed to develop a framework for voluntary peer reviews of inefficient fossil fuel subsidies leading to wasteful consumption. Countries prepare a self-review which is then submitted to a review team consisting of representatives of other countries and international organisations such as the OECD. Preparing for these reviews has helped countries get a better understanding of their own existing policies, and provides a unique opportunity for cross-ministerial coordination and discussion on policy coherence. Fuel tax concessions for agricultural producers are common: a recent OECD review of taxation in agriculture across 35 OECD countries found that such concessions are used in nearly all the countries surveyed (OECD, 2020[53]). Because fuel tax concessions represent revenue foregone, they are less visible than budgetary transfers and not subject to the same scrutiny or frequency of review, underscoring the importance of stock-taking exercises such as the G20 peer reviews.

Responsibility over different policy domains often sits with different policy making communities (e.g. different ministries, departments, specialised agencies) or different levels of government (e.g. federal, provincial/territorial/state, municipal/local). In this case, dealing with both synergies and trade-offs will require some degree of “policy integration”, i.e. coordination between these policy communities (Parsons, 2019[54]). This can vary from *ad hoc* exchanges of views or collaboration on specific cross-cutting themes to complete functional integration, e.g. by placing all responsibility over a policy area within the same ministry. These mechanisms can help different institutions to align their mandates, objectives and policies, and to take into account synergies and trade-offs in their decision-making process (OECD, 2019[1]).

Since deeper levels of integration come at a cost, the existence of some interactions does not necessarily mean that all policy making related to the triple challenge requires complete functional integration. Among the different costs associated with deeper policy integration is the risk that stronger integration around one issue leads to weaker integration with other areas; the risk that leadership attention may be diverted towards coordination at the expense of programmes at the "subsystem" level; or the risk that integration conflicts with other values such as decentralisation or subsidiarity. In addition, successful policy integration is not automatically guaranteed, but requires leadership and specific analytical, operational, and political capacities (Candel, 2019[55]). A review of empirical evidence shows numerous examples of failed attempts at policy integration, underscoring the challenges involved (Candel, 2017[56]). Given these costs and risks of functional integration, the degree of coordination between policy communities should ideally match the strength of synergies and trade-offs between their respective policy domains.[18]

2.5. Transboundary effects

Policies in one country can have transboundary effects on one or more countries or on a global public good (OECD, 2019[57]). If countries decide on policies without regard to these spillovers, the likely result is frictions created by incoherent policies across countries and an underprovision of global public goods.[19] A lack of international economic cooperation not only creates uncertainty for market participants and imposes costs on those involved in international trade, but also means that important global challenges are not addressed, and that potential mutual gains are not realised.

Achieving international cooperation is far from easy, as countries have different interests, preferences, and policy-making approaches. These differences are unlikely to go away. On the other hand, there are also instances where national policies diverge purely because national governments and regulators were working in isolation (OECD, Forthcoming[8]).The goal of international cooperation is not to eliminate all differences in policies, but to strike a balance between domestic objectives and realising the benefits of international cooperation (von Lampe, Deconinck and Bastien, 2016[58]).

Some key principles for domestic policy-making can help reconcile these objectives. If domestic policy approaches are transparent, non-discriminatory, and not more trade restrictive than necessary to achieve their objective, then this can help avoid unnecessary costs of policy differences. Unnecessary costs can also be avoided by requiring ex ante assessments of transboundary effects of proposed policies, including their coherence with any international standards and other relevant frameworks (in line with the 2012 OECD Council Recommendation on Regulatory Policy and Governance and the forthcoming OECD Best Practice Principles for Regulatory Policy: International Regulatory Coordination). That is, even without explicit coordination, policy makers can improve global coherence by using good regulatory practices in their domestic policy contexts.

Another way in which domestic processes can improve global coherence is by routinely taking into account the potential impact of proposed policies on stakeholders outside of the national boundaries. The RIA process provides an opportunity to do so, in particular through the assessment of trade impacts and of impacts on foreign jurisdictions. This can be facilitated by organising consultation with these external stakeholders, e.g. through business platforms or chambers of commerce. Transparency in terms of compulsory notification of draft regulations to international forums also provides an important means by which to alert and draw inputs from foreign stakeholders. The WTO TBT and SPS Agreements provide such an opportunity through the single central government authority responsible for notifications (OECD, Forthcoming[8]).

There are also several other institutional mechanisms for reducing costs and frictions internationally. These range from dialogue and the exchange of information (which can prevent "accidental" frictions) to joint solutions through international organisations or binding international agreements.[20] Dialogue and the exchange of information may help avoid situations where countries end up with different policy approaches which achieve basically similar results domestically but accidentally impose trade costs or create other unwanted transboundary effects. Even when information is available and countries are aware of the actions of others, the result may be policy divergence and unnecessary costs if countries only take into account a short-term view of their own welfare. Negotiations to overcome this collective action problem may lead to a better set of policies across countries – although these do not necessarily imply a uniformity of policies. Other possible approaches might include recognising the equivalence of trading partners' standards and conformity assessment procedures, or working together to develop international standards (OECD, 2017[59]).

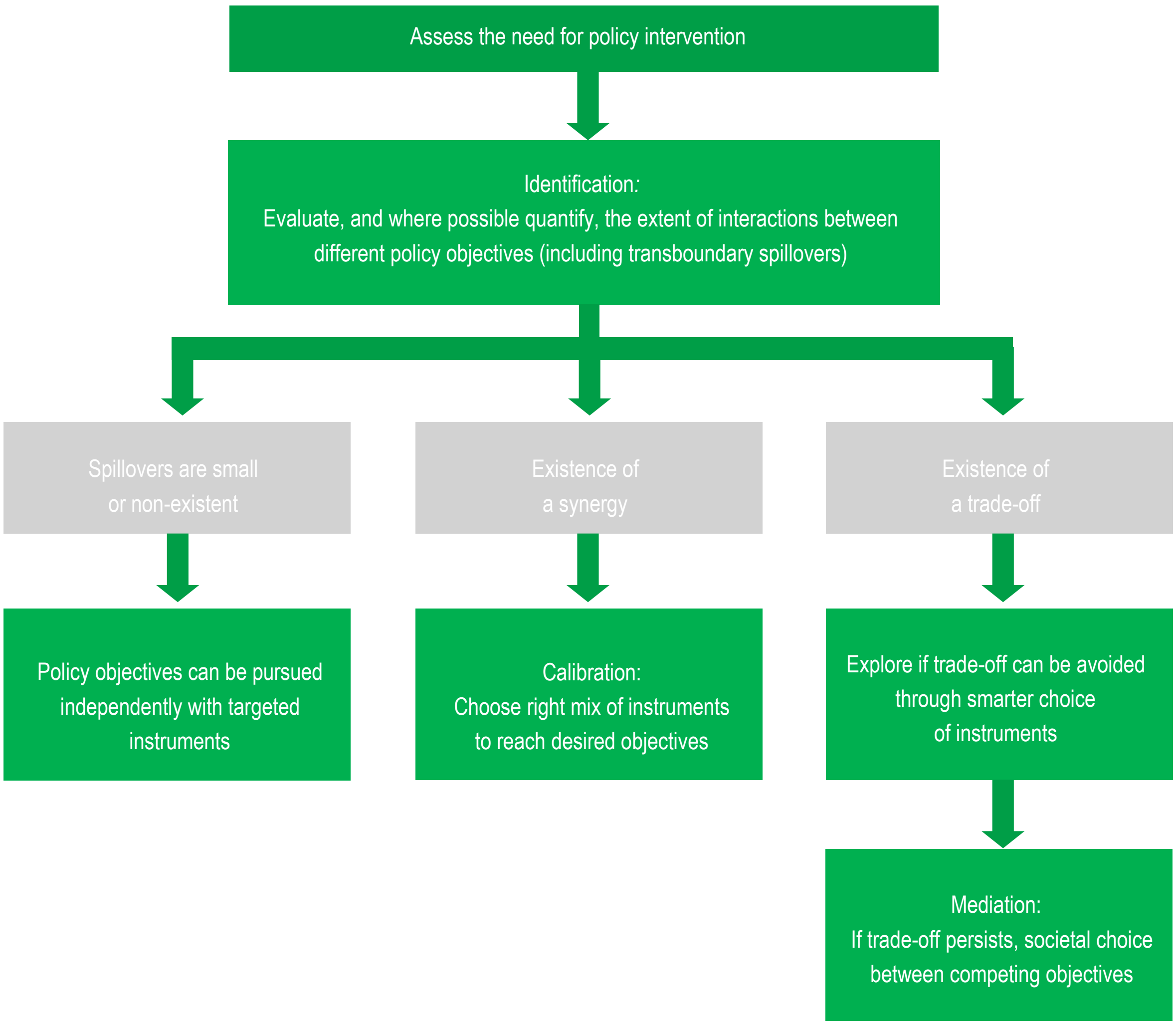
As with other policy issues explored in this chapter, international cooperation is not only a technical question but involves trade-offs. All countries can benefit from international cooperation, but any specific solution adopted will have different patterns of costs and benefits across (and within) countries. The same is true for policy cooperation in other areas. All countries can benefit from improved policy cooperation, but there will inevitably be a debate over the direction in which countries should converge, and over the specific policy packages to be adopted.

2.6. Conclusion

A systematic consideration of synergies and trade-offs across food and agriculture can contribute to more coherent policies. Given the large number of potential interactions, this chapter has proposed some key principles (summarised in Figure 2.1) which can help policy makers reduce complexity and scrutinise potential interactions – while at the same time recognising the difficulty of deciding on trade-offs between competing objectives, and the difficulty of achieving policy coherence at the global level.

While this chapter has emphasised the usefulness of greater policy coherence as a way to improve policy effectiveness, it is important to keep in mind that policy coherence as defined here may not be sufficient by itself, if policies lack the ambition needed to address the triple challenge. For this reason, the OECD Recommendation on Policy Coherence for Sustainable Development identified political commitment, leadership, and a strategic long-term vision as important principles to achieve the Sustainable Development Goals. The same is true for the triple challenge, which is closely related to the SDGs. Ambition and leadership are important because developing better policies for food systems may run into a host of obstacles. Scientific evidence (e.g. about interactions) may not always be available; there may be strong disagreement about which policy objectives deserve to have priority; or interest groups may organise to block policies which would be disadvantageous to them. Robust policy processes will be important in overcoming these obstacles, as explored in the following chapter.

Figure 2.1. Principles for policy coherence



Note: See main text for further information and specific policy approaches.

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Notes

[1] This chapter builds on insights from earlier work by the OECD, e.g. the OECD Ministerial Declaration on Policy Coherence for Development (OECD, 2008[73]), work on multifunctionality (OECD (2001[16]), (2003[17])) and the links between climate change adaptation, mitigation, and agricultural productivity (Lankoski et al. (2018[61]), Lankoski et al. (2018[62]), as well as between climate change mitigation and other objectives such as food security (OECD, 2019[5]); and on insights from the Collaborative Framework for Food Systems Transformation developed by UNEP (2019[51]).

[2] The 17 Sustainable Development Goals and 169 associated targets cover a wide range of policy areas. To achieve coherence across these policy areas, SDG Target 17.14 calls on all countries "to enhance policy coherence for sustainable development". For discussions on policy coherence related to food security and SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), see OECD (2017[22]) and OECD (2016[20]).

[3] The OECD also supports countries with the practical implementation of these Recommendations. In addition to serving as a forum for the exchange of experiences, the OECD provides a Policy Coherence for Sustainable Development Toolkit, which includes practical guidance, self-assessment checklists, good practice examples and tools to analyse, enhance and track progress on policy coherence in the implementation of the SDGs (see http://www.oecd.org/governance/pcsd/toolkit/). Moreover, an annual report on Policy Coherence for Sustainable Development reviews progress and highlights specific topics (OECD, 2019[64]).

[4] The quote "everything should be made as simple as possible, but not any simpler" is often attributed to Albert Einstein, although it is doubtful whether he indeed coined this phrase (Quote Investigator, 2011[76]).

[5] The impact of stricter animal welfare standards on production costs is clearly context-dependent, yet it is not uncommon for additional costs of some animal welfare standards to reach 30-40% of the "standard" production cost (Grethe, 2017[70]). The net impact on consumer prices will generally be smaller, as the final price for consumers includes other costs (e.g. for processing, transport) which are not much affected by stricter animal welfare standards. For a discussion of societal cost-benefit analyses taking into account animal welfare, see Lusk and Norwood (2011[71]).

[6] The phrase "silver bullet" is defined by Merriam-Webster as "something that acts as a magical weapon, especially one that instantly solves a long-standing problem." The phrase derives from the folklore belief that only a bullet made of silver could kill werewolves or other supernatural beings.

[7] For a graphical exposition of the principle, see Schaeffer (n.d.[60]).

[8] To be sure, assessing the effectiveness of a policy is never straightforward, as it requires not only accurate measurements of the current situation but also an assessment of what would have happened in the absence of the policy (i.e. the "counterfactual") (Angrist and Pischke, 2009[74]). But it is conceptually and statistically easier to assess whether a single policy instrument has made a positive impact on a single objective than it is to assess the effectiveness of multiple policy instruments in achieving multiple objectives. With multiple objectives, it is possible that some objectives are met while others are not, making it harder to unambiguously define success or failure; with multiple policy instruments, it is less clear which instruments were effective and which ones were not. This is not an argument

against the use of multiple instruments for multiple objectives *per se*; as noted, when synergies or trade-offs exist, this may be unavoidable. However, it does generally complicate the assessment of policy effectiveness.

[9] This example can be seen as an instance of the more general principle that policies and governance should be organised at the relevant geographic scale, as highlighted by the OECD Principles on Rural Policy (OECD, 2019[72]).

[10] On whole-of-government processes, see OECD (2018[10]) and OECD (2012[6]); on regulatory impact assessment processes, see OECD (2008[18]); on stakeholder engagement, see OECD (2017[67]).

[11] Other examples of studies on policy incoherence in food and agriculture are discussed in Parsons and Hawkes (2019[2]).

[12] The agreement also foresees the elimination of export subsidies by developing countries, albeit with some additional flexibility; for example, developing countries can cover marketing and transport costs for agriculture exports until the end of 2023 (WTO, 2020[75]).

[13] For example, the OECD Best Practice Principles on Regulatory Impact Assessment stipulate that all plausible alternatives, including non-regulatory solutions, must be taken into account during the policy process. A "do-nothing option" describing the assumed state of the world in the absence of the regulation (the "counterfactual," or "baseline") should always be included. RIAs should examine human welfare differences among alternative policies. Thus, RIAs should not just consider the preferred regulatory approach but should consider all plausible alternatives (OECD, 2020[7]).

[14] As discussed earlier, targeting may itself be costly. A tax on emissions may require detailed monitoring (e.g. measuring methane emissions on-farm). If monitoring activities are very costly, a less-targeted tax may be preferable, although there will be other trade-offs in terms of farm income and potentially nutrition.

[15] As noted by Sassi et al. (2018[42]), a full accounting of equity effects should include the benefits accruing to different households as a result of the reduction in unhealthy consumption patterns. These benefits may also be concentrated among lower-income households, and may include lower out-of-pocket medical expenses and higher earnings (as a result of longer life expectancy), in addition to the intrinsic value of better health outcomes. As shown in forthcoming OECD work, households with a lower socio-economic status tend to make less healthy food choices for a variety of reasons, including low levels of income and education, stress and time constraints related to being a single parent, and the prevalence and accessibility of unhealthy food options (Placzek, 2021[77]).

[16] Seminal work by Arrow (1951[68]) demonstrated that aggregating individual preferences to arrive at a consistent set of societal preferences is fraught with difficulties. A simple example can illustrate the problem. Imagine a society with three individuals using majority voting to decide between three alternatives A, B, and C. If individual 1 prefers A over B over C while individual 2 prefers B over C over A, and individual 3 prefers C over A over B, then majority voting will lead to instability: there will be a two-thirds majority choosing A over B, B over C, but C over A. This example (known as the Condorcet Paradox) was generalised by Arrow and gave rise to an extensive literature investigating the problem of "social choice"; see Arrow et al. (2002[69]).

[17] Dryzek and List (2003[44]) demonstrate formally how these effects of deliberation can soften or overcome the problems identified in the social choice literature following Arrow.

[18] In the field of complex systems analysis, a similar principle is known as Ashby's law, which states that a control system must be as complex as the system it is controlling (OECD, 2017[63]).

[19] For a discussion of the difficulties involved in measuring transboundary effects of policies in the context of the SDGs, see OECD (2019[57]).

[20] See, for example, OECD (2013[65]) and OECD (2016[66]) for a discussion of different mechanisms.

3 Achieving better policies

This chapter shows that achieving better policies for food systems often requires overcoming frictions related to facts, interests, and values. While much is known about how policies for food systems can be improved, in other areas there are substantial knowledge gaps. At the same time, policy reform creates both winners and losers, and groups with diverging interests will try to influence the policy process. But not all policy disagreements revolve around facts and interests. There is often no societal consensus on what the relative priorities should be, as people differ in the values they emphasise. To complicate matters, frictions in one area (e.g. differing values) can also reinforce frictions in another area (e.g. by making people less willing to consider facts that go against their initial beliefs). The chapter identifies several good practices which can help prevent or manage frictions around facts, interests, and values.

Key messages

- Achieving better policies for food systems is made difficult by disagreements over facts, diverging interests, and differences over values.
- On many policy issues, there is a lack of evidence about the extent and characteristics of problems; the magnitude of trade-offs and synergies; and the effectiveness and costs and benefits of various policy options. In other cases, there are gaps between the available scientific evidence and public perception.
- Policy reforms create winners and losers, so groups with diverging interests try to influence the policy process. It is thus imperative to avoid policy capture by a special interest.
- People often differ in the values they emphasise, and such differences over values can make it difficult to achieve societal consensus on policy priorities.
- Frictions in one area (e.g. differing values) can also reinforce frictions in another area (e.g. by making people less willing to consider facts that go against their initial beliefs).
- Good practices exist to design robust, inclusive, evidence-based policy processes which help to prevent or manage frictions related to facts, interests, and values.

3.1. Introduction

As the first two chapters of this report show, better policies offer significant potential to meet the "triple challenge" facing the food systems, especially when policy coherence can be achieved. Yet coherence by itself does not guarantee policies will be sufficiently ambitious to address these challenges. This chapter focuses on three sources of "frictions" which can occur during policy design and decision-making: disagreements over facts, diverging interests, and differences over values.[1] Many policy questions related to food systems encounter frictions on one or more of these dimensions, and the most controversial policy issues face frictions on all of them. In addition, frictions related to facts, interests, and values may influence each other in complex ways. The goal of this chapter is to draw on insights from diverse perspectives to provide policy makers with a better understanding of those frictions and a range of practical approaches to overcome them.

Chapter 2 discussed how policy makers can develop coherent policies when faced with potential synergies and trade-offs across different food systems objectives. As noted, a trade-off cannot be resolved on purely technical grounds, but involves an element of societal choice. In pluralist societies, people will typically have diverse interests and values, so that there will rarely be a unanimous view on how to strike the balance between competing objectives. Moreover, in some cases it may not be clear whether there is a trade-off and if so, what the exact consequences would be of different policy options. People may hold different views about these effects.

Such frictions around facts, interests and values are not unique to food systems, and are encountered to some degree in the design of any public policy. Yet there is reason to believe they are of particular importance in debates around food systems, where current policies are often not aligned to address the "triple challenge" and where policy developments have shown less progress than in other sectors. This is notably the case for agricultural trade liberalisation; despite progress over time, applied tariffs on agricultural goods remain higher than for industrial goods (OECD, 2019[1]), and agriculture remains a stumbling block in international trade negotiations (Jensen and Shin, 2014[2]). Likewise, despite agriculture's important contributions to global greenhouse gas (GHG) emissions, adopting effective strategies to mitigate agricultural emissions has proved especially challenging, as highlighted in the case study on ruminant livestock.

The discussion in this chapter complements existing OECD work on determinants of successful reforms. For example, work by the OECD (2017[3]) on the political economy of biodiversity policy reform highlighted the importance of the real or perceived economic costs of such regulations, distributional effects, and the role of vested interests and rent seeking behaviour, as well as the "political acceptability" of reform. The latter is a broad concept which includes factors such as public trust in government, the perceived effectiveness of proposed reforms, and whether the public understands and agrees with the proposed reforms. OECD work on the reform of water policies in agriculture (Gruère, Ashley and Cadilhon, 2018[4]) emphasised the importance of "windows of opportunity" created by crisis situations, such as droughts or floods or the current COVID-19 pandemic. Governments should thus prepare reforms early on to take advantage of reform opportunities when a window of opportunity opens (Gruère and Le Boëdec, 2019[5]).[2] Consistent with this view, many countries have announced their ambition to "build back better" following the COVID-19 pandemic, focusing economic recovery plans that improve sustainability and resilience.[3] Analysis by the OECD on fisheries policy changes confirms the importance of trusted evidence and the role of distributional effects and lobbying efforts, but also highlights other factors such as legal commitments to periodically evaluate and review policies (Delpeuch and Hutniczak, 2019[6]).

One conclusion of the existing work is that there is no "one size fits all" approach to policy reform (OECD, 2017[3]). Strategies which work in one context might backfire in another context; different countries have different institutional settings; and different sectors or policy problems have different characteristics, all of which affect the feasibility of different reform strategies.[4] That said, it is possible to identify some common factors, such as the three sources of frictions discussed in this chapter.

Policy design and political decision-making will naturally be easier if three criteria are met: if there is broad agreement in society on the basic facts of a policy question (such as the extent and nature of a problem and the types of policy instruments best suited to address that problem); if there is no major conflict between different interest groups and if all interests have the opportunity to voice their views – i.e. when there is no "policy capture" by special interests; and if there is agreement on the relative importance of different values. Policy questions which meet these three criteria will tend to be resolved without attracting much controversy. By contrast, difficult policy questions seem to be characterised by frictions in at least one area – facts, interests or values. Depending on which area is most problematic, different approaches are needed to move forward on policy issues:

- If frictions are limited to a disagreement about the facts, then what is needed is additional credible technical expertise, scientific evidence, or cost-benefit analyses to identify the best policy option, or better communication of the existing body of evidence.
- If frictions are due to diverging interests, then policymaking will involve an element of bargaining. Tensions between diverging interests (and hence interest groups) are unavoidable in diverse and pluralist societies, and much of political decision-making involves a search for compromises or grand bargains which can reconcile diverging interests in society. However, conflicts between diverging interests can become problematic if there is no "level playing field" – i.e. if one interest group has disproportionate influence over political decision-making. In such cases, achieving better policies will require efforts to ensure open and equitable access to policy-making processes, and to safeguard integrity in decision-making (OECD, 2010[7]).
- A third source of frictions are differences over values. In contrast with factual disagreements (which can in principle be adjudicated with additional evidence) and diverging interests (where it might be possible to "buy off" interest groups with compensatory measures), the source of friction here is that people may disagree over what constitutes the public good. In some cases, it may be possible to find creative solutions to reconcile differences over values by focusing on finding specific actions

which can be supported by people with different values. When such creative solutions are not available, deliberative approaches can help to build societal consensus.

The most difficult policy issues encounter frictions in all three areas. A particular difficulty occurs when frictions in one area spread to the other areas. For example, conflicts between diverging interests or differences over values can lead to motivated reasoning, whereby people interpret evidence in a way which is consistent with their interests or values. Interest groups may also deliberately distort facts. In the resulting policy controversies, opposing camps may hold different "worldviews", understood as incompatible sets of mutually reinforcing factual beliefs, interests, and values (Rein and Schön, 1993[8]).

Different authors have tended to emphasise different sources of friction. For Sunstein (2018[9]), politically contentious issues "are fundamentally about facts rather than values", and "[i]f we can agree on the facts, we should be able to agree on what to do – or at least our disagreements should be narrowed greatly." By contrast, a considerable literature on political economy has long emphasised the importance of tensions between the public interest and special interests (Rausser, Swinnen and Zusman, 2011[10]), while a third perspective emphasises the importance of values and differences over values (Thacher and Rein, 2004[11]) (Inglehart and Welzel, 2005[12]) (Stewart, 2006[13]) (Enke, 2020[14]). In reality, all three are likely to play a role, although their relative importance will vary by issue. An awareness of these distinct sources of friction, and their interactions, can help policy makers anticipate likely risks and develop ways forward in policy processes around food and agriculture.

This chapter focuses on policy design and decision-making. However, translating policy decisions into results is far from straightforward, and requires difficult processes of implementation, evaluation and adjustment of policies (Pressman and Wildavsky, 1973[15]). This chapter refrains from discussing implementation for several reasons. First, although some general principles of implementation hold across different policy areas, such as the importance of achieving clarity on priorities, of planning, and of measuring progress (Barber, 2015[16]), the specifics of how to achieve effective implementation will be highly context-dependent, and institutional aspects such as the degree of centralisation of political institutions also likely matter a great deal. The principles and approaches set out in this chapter offer a general guide, but the path and precise process will be different in each country and to set out how this should work in specific instances or issues risks being overly reductive of this diversity.

Fundamentally, implementation cannot be seen independently from the decision-making process. If decision-making is not based on a shared understanding of the facts, is tarred by (perceptions of) conflicts of interest, or fails to address differences over values, implementation will be difficult. Conversely, a decision-making process which successfully addresses frictions related to facts, interests, and values will greatly facilitate implementation. While this chapter outlines several approaches to build a shared understanding of the facts, balance diverging interests, deal with differences over values, and prevent or manage policy controversies, few of the approaches outlined in this chapter offer quick fixes. Rather, a recurring theme is the importance of building and maintaining the effectiveness, integrity and trustworthiness of public institutions. There is no rule of thumb on the precise choices different societies should make, but it is essential that processes and institutions for making these societal choices are transparent, ensure a level playing field, and promote accountability. Achieving such processes and institutions at the international level is also important, although no less challenging.

The remainder of the chapter is organised as follows. The next three sections discuss frictions related to facts, interests, and values respectively. Each section illustrates the relevance of these sources of frictions to food systems, and outlines possible policy approaches. Section 3.5 then discusses the particularly fraught case of policy controversies involving simultaneous frictions related to facts, interests, and values. In Section 3.6, international aspects are highlighted, while Section 3.7 concludes.

3.2. Building a shared understanding of the facts

Policy-relevant information is not always available about the existence or extent of a problem, its causal mechanisms, the effectiveness and distributional effects of various policy measures, or the magnitude of synergies and trade-offs between different policy goals. Several best practices exist to ensure that policies are based on the best available evidence, e.g. through the use of regulatory impact assessments, scientific advisory bodies and stakeholder consultations. Yet evidence by itself is rarely sufficient: on the one hand, societal choices always depend on the interests and values at stake; on the other hand, the role of interests and values also means that facts may become distorted or interpreted in ways consistent with people's prior views.

Relevance to food systems

For many policy issues facing food systems, developing an effective policy response is made difficult by a lack of knowledge. For example, the necessary evidence base to design policies for healthier food choices would need to combine information on the food environment (e.g. the role of food away from home, the role of fast-food outlets, the relative availability of healthier and less healthy food options in different areas), on food products (e.g. nutritional composition, prices), and on consumers' food choices (purchases, individual intake, household waste) and the determinants of those choices; the informational requirements are even greater if environmental sustainability is taken into account as well. Information on these elements is not always available, or exists in disparate databases with inconsistent definitions and methodologies and which are in many cases privately owned (Giner and Brooks, 2019[17]).

Policy discussions around food and agriculture are often also made complicated by instances of misconceptions and unreliable statistics used in public discourse (Box 3.1).

Box 3.1. Misconceptions and data gaps on food systems

Public debate around food systems often features claims which on closer inspection turn out to be misconceptions or based on unreliable statistics.

For example, it is often claimed that smallholder farmers produce most of the world's food. However, it is estimated that their contribution, although vital for global food security, is closer to one-third of world production (Ricciardi et al., 2018[18]).

Another example is the claim that due to soil erosion, the world only has "about 60 years of topsoil left" (World Economic Forum, 2012[19]), a claim repeated in major news outlets such as Scientific American (Arsenault, 2014[20]), The Guardian (Cosier, 2019[21]), and France24 (Bertsch, 2019[22]). There is no factual basis for this claim; for example, no evidence to back this statement can be found in the 2015 report "Status of the World's Soil Resources", a 600-page review prepared by the Intergovernmental Technical Panel on Soils (FAO and ITPS, 2015[23]). Moreover, translating the complexity and diversity of global soil conditions into a single "end-point" statistic is practically impossible, which is why such statistics are not found in the scientific literature (Wong, 2019[24]).

A similar claim that "[a]bout a third of the world's soil has already been degraded" (Arsenault, 2014[20]) is based on a single chart in FAO (2011[25]), where the results are explicitly described as "preliminary". Indeed, a more recent report "The Status of the World's Soil Resources" (FAO and ITPS, 2015[23]) mentions the "unreliability of some of the databases used" in this earlier exercise, and refrains from making any global assessment of "land degradation", instead presenting peer-reviewed evidence on a broad range of soil characteristics as well as detailed reviews by region. Yet, the "one-third" statistic is commonly found in discussions about food systems.

In other instances, the origin of some commonly cited statistics related to food systems is unclear. For example, it is often said that livestock contributes to the livelihoods of 1.3 billion (or in some versions, 1.7 billion) poor people. Such statistics are often found in policy discussions on the importance of the livestock sector. Yet despite their widespread use, it is unclear where these claims come from. The 2016 report of the High Level Panel of Experts on "Sustainable agricultural development for food security and nutrition: What roles for livestock?" (HLPE, 2016[26]) merely notes that "*it is often said* that 1.3 billion people depend on livestock for their livelihoods" (p. 35, emphasis added). The 2018 FAO report "World Livestock: Transforming the livestock sector through the Sustainable Development Goals" (FAO, 2018[27]) contains detailed and well-documented discussions of the contribution of livestock to poverty reduction, economic growth and employment (among other dimensions), but does not address the question of how many livelihoods depend on livestock. While there is no doubt that the contribution of livestock to livelihoods is significant, especially in lower- and middle-income countries, in the absence of a reliable source, caution is needed when citing precise figures.

In other cases, widely cited statistics rest on underlying data and methodology that may not be as robust as policy makers would wish. This is particularly the case for statistics on food loss and waste, where it is commonly said that one-third of the world's food is lost or wasted (see, for example, National Geographic (2014[28])). These estimates are based on an influential 2011 study (Gustavsson, Cederberg and Sonesson, 2011[29]); however, given the paucity of detailed studies at the time, the calculations involved several extrapolations and assumptions. Estimates of food loss and waste have also been plagued by inconsistent definitions and measures (Bagherzadeh, Inamura and Jeong, 2014[30]). A critical review by Xue et al. (2017[31]) highlighted the relatively limited evidence base on which many estimates of food loss and waste were based. In recognition of the limitations of these earlier estimates, researchers have made considerable efforts in recent years to harmonise definitions and methodologies. In the context of the Sustainable Development Goals and the One Planet Network's Sustainable Food Systems Programme, FAO and UNEP are collaborating to develop new estimates of food loss (along the supply chain) and food waste (at retail and consumer level). FAO (2019[32]) presents new estimates of food losses worldwide, while new estimates of food waste are under development.

In addition to a lack of information, there may also be gaps between public perceptions and the available evidence. A study by the Pew Research Center demonstrated substantial gaps between the views of US citizens and scientists on a range of scientific topics, with the largest gaps found in views on food safety. For example, while 88% of scientists agreed that genetically modified foods are safe to eat, only 37% of the broader US public thought so. Similarly, while 68% of scientists thought that food produced with pesticides is safe to eat, only 28% of the broader public agreed (Pew Research Center, 2015[33]). Such gaps between perceptions and evidence are likely to create tensions when policy makers attempt to design evidence-based policies, as discussed in the case study on seeds.

Finally, what matters for policy design is finding the *relevant* facts and correctly interpreting the policy implications of available evidence. Even when data are available on certain aspects of an issue, the data may miss policy-relevant aspects of the problem or may lend itself to misinterpretation. For example, internationally comparable data on pesticide use typically only cover total use or total sales, without distinguishing different toxicity levels. Yet, the health effects of pesticides differ greatly and depend on application rates (Fantke, Friedrich and Jolliet, 2012[34]). Moreover, as regulations have become more stringent, and as newer, less toxic products have replaced older, more toxic ones, the average toxicity of pesticides used has fallen over time.[5] Statistics showing levels of total pesticide use could thus hide important differences in terms of potential health effects. Similarly, direct emissions from ruminant livestock consist mainly of methane (CH_4) and nitrous oxide (N_2O) which differ from each other and from carbon dioxide (CO_2) in their ability to absorb energy and in their lifetime in the atmosphere. As discussed in the ruminant livestock case study, there are different ways of converting these gases into a common unit, with potentially different policy implications. More generally, discussions on food systems often invoke aggregate or average figures (e.g. at the global level) which ignore the heterogeneity of food systems across regions and countries highlighted in Chapter 1.

Approaches

As these examples illustrate, it is essential for policy makers to invest in the generation and communication of trustworthy and policy-relevant evidence which can serve as the basis for a shared understanding of the facts by all stakeholders. A number of approaches can improve the evidence base underlying policy decisions. These include regulatory impact assessments, input from scientific advisory bodies, stakeholders, and policy research organisations, as well as more experimental approaches through "learning by doing".

The OECD Council Recommendation on Regulatory Policy and Governance calls on policy makers to integrate Regulatory Impact Assessments into the early stages of the policy process (OECD, 2012[35]). As highlighted in the previous chapter, these assessments should cover economic, social and environmental impacts, ideally in a quantified and monetised form. A range of methods can be used to collect evidence and information relevant to such *ex ante* assessments.

Scientific and technical input into policy processes typically comes from three main sources (OECD, 2015[36]): scientific advisory bodies that are mandated to address specific issues, either permanent ones such as the Joint Research Centre of the European Commission or ad hoc ones such as the US committee on dietary guidelines (Dietary Guidelines for Americans, 2020[37]); academic institutions that provide information (which may or may not have been requested explicitly by the government), such as the Centre for Food Policy at the City University of London; or individual advisors in formal or informal roles. In the European Union, the European Commission Group of Chief Scientific Advisors recently commissioned a systematic review on sustainable food systems from SAPEA (Science Advice for Policy by European Academies) (2020[38]), a consortium of European academies of science.

The success of science advisory processes depends on three factors. First, an effective and trustworthy process must have a clear objective and well-defined roles and responsibilities. Second, such a process must involve the relevant actors; this not only includes scientists from all the relevant disciplines but also, where necessary, non-scientific experts and/or civil society stakeholders. There should be a transparent process for their participation, and strict procedures for declaring, verifying and dealing with conflicts of interest. Third, the advice should be sound, unbiased, and legitimate – which in turn means that it should be based on the best available scientific evidence, clearly describe scientific uncertainties, and be protected from political or other interest-group interference (OECD, 2015[36]).

Another important source of information is stakeholder consultation, which can be a powerful tool for policy makers to learn about policy issues and about how proposed policies might affect different groups in society (UNEP, 2019[39]). Examples in a food systems context include Canada's open consultation on dietary guidelines (Health Canada, 2018[40]) and the consultative process used to develop the first Food Policy for Canada (see Chapter 2), as well as France's "Estates General of Food" (Etats généraux de l'alimentation, also known as Egalim) (Ministère de l'Agriculture et de l'Alimentation, 2020[41]) Stakeholder consultation is not without its complexities, however, as not all stakeholders are equally organised or vocal. There is a risk that consultations will ignore a "silent majority" or disproportionately focus on certain well-organised groups. Moreover, stakeholder views are not necessarily factually accurate. The OECD Council Recommendation on Regulatory Policy and Governance therefore advises governments to hold open and balanced public consultations, actively engage all stakeholders, and design the consultation process to maximise the quality of information received. One way of doing so is by using impact assessments as part of the consultation process (OECD, 2012[35]). The OECD is currently developing best practice principles for stakeholder engagement (OECD, 2017[42]). These best practices emphasise the importance of transparency and inclusiveness.

Policy research organisations such as think tanks, foundations associated with political parties, movements, or interest groups, and government policy research departments occupy an intermediate place between scientific advice and stakeholder input. These organisations are often an important source of information and specific policy ideas, but may also be pushing a particular viewpoint. The relative role of private and public organisations in this field differs strongly according to national historical contexts (Campbell and Pederson, 2014[43]).[6] Research from an authoritative, non-partisan institution which is trusted across the political spectrum can have an important impact. International organisations such as the OECD play a role through collecting internationally comparable data and providing research and recommendations (Tompson, 2009[44]) (OECD, 2010[45]). For instance, to obtain trusted information on the extent of producer support in agriculture, governments preferred that data would be gathered by a respected international institution at arms' length from domestic policy makers and trade negotiators, leading to the OECD's efforts in measuring Producer Support Estimates and other indicators of agricultural policies (Legg, 2019[46]) (OECD, 2020[47]).

In addition to these methods to collect information *ex ante*, another method for resolving disagreements over facts is to engage in a form of "learning by doing", e.g. through the use of pilot projects. For example, in France a network of experimental farms was set up to explore possibilities to reduce pesticide use; this network, known as Dephy, currently counts around 3 000 farms spread across France.[7] In these cases, mechanisms to allow for timely feedback to be collected and for any necessary course corrections can be important. More broadly, adopting a culture of experimentation is fundamental to helping better inform policies, as well as to build evidence of "what works" before implementing a policy at full scale (OECD, 2019[48]).

Whichever method is used to collect evidence, achieving a reliable shared understanding of policy issues is an important precondition for developing successful policies (OECD, 2010[45]). Uncertainty can greatly complicate policy-making. Clarity on the likely distribution of costs and benefits is of particular importance, as uncertainty is likely to create resistance to reform (Tompson, 2009[44]). However, such detailed assessments are not always undertaken; in the context of fisheries policy, for example, impact assessments have often tended to focus on biophysical effects, and where socio-economic impacts are considered these are often limited to the overall societal balance of costs and benefits without exploring distributional effects (Delpeuch and Hutniczak, 2019[6]). At the same time, waiting for more data can lead to "paralysis by analysis" as complete information is rarely available, in part because scientific insight continues to evolve.

Limitations

While evidence describes the way things are, policy debates inevitably also involve a consideration of how things should be. The importance of evidence-based policymaking should thus not obscure the fact that evidence alone is never sufficient to make policy choices, which almost always involve some trade-off between competing interests and values (Parkhurst, 2017[49]). A *technocratic* approach to policymaking, which sees policy issues as essentially technical problems which can be solved through evidence and expertise, is thus insufficient.[8] Not only can facts by themselves not decide a policy issue, but the availability of information, and the types of facts that are considered relevant in a policy debate, depend themselves on the interests and values at stake in a policy issue (Parkhurst, 2017[49]). For example, data on gender implications of a policy decision are likely to be collected only if at least some participants in a policy debate consider gender issues important. Statistical indicators presented as evidence in a policy debate may also implicitly include some value judgments, especially when different variables are aggregated into a composite indicator – for example, when various aspects of environmental performance are aggregated into an overall index of sustainability. The selection of variables, and the relative weights of these variables in the overall index, implicitly depend on a judgment of which aspects of a problem are most important, and how a good performance on one dimension can compensate for a worse performance on another dimension.[9] Some aspects of a problem may also lend themselves more easily to quantification and measurement. In some contexts, an appeal to evidence-based policymaking could thus be an attempt to circumvent a debate over interests and values (Parkhurst, 2017[49]).

Interests and values also affect the role of evidence in other ways. Research in psychology has long documented how people exhibit “motivated reasoning”: faced with evidence and arguments, people tend to arrive at the conclusion they prefer to arrive at (Kunda, 1990[50]) (Nickerson, 1998[51]) (Bénabou and Tirole, 2016[52]) (Flynn, Nyhan and Reifler, 2017[53]).

People’s worldviews can influence this process. Beliefs on unrelated issues tend to “cluster” in ways which are difficult to explain rationally but which make sense given individuals’ worldviews (Kahan and Braman, 2006[54]). For example, researchers studying risk perceptions have suggested that people attracted to a more egalitarian worldview find it easier to believe that economic activities are causing societal harm, whereas people with a more individualist worldview are more likely to dismiss such claims (Kahan et al., 2010[55]). Moreover, while people recognise that others’ beliefs are not consistent with the facts, they may not recognise the same mechanisms at work in influencing their own beliefs (Cohen, 2003[56]). These mechanisms affect not only stakeholders, but also experts and policy makers (World Bank, 2015[57]).

One implication of these findings is that information by itself may not be sufficient to change people’s minds, especially on issues which have become strongly polarised. It is therefore imperative to prevent the needless polarisation of debates around the challenges facing food systems. Some approaches have been suggested to overcome or avoid these problems (Kahan, 2010[58]) (Kahan, Jenkins-Smith and Braman, 2011[59]) (Flynn, Nyhan and Reifler, 2017[53]). A first approach is to present information in a way which affirms the values held by the audience. For instance, people with an egalitarian worldview would probably be more positive about new technologies if information is provided on how these technologies could help in environmental protection (and not only on their potential use in, for example, reducing costs) (Kahan, 2010[58]). A second approach is to ensure that information is communicated by experts with diverse values; this increases the probability that people will hear the message from someone they identify as a trusted source (Cohen et al., 2007[60]).

Interests and values affect not only how people interpret evidence, but can also lead to distortions in communication around evidence. Interest groups may deliberately spread misinformation or biased information to influence policy debates.[10] Interest groups may also sponsor their own “scientific” studies, raising doubts about the impartiality and credibility of the resulting findings, as discussed in the section on “policy controversies” below. For these reasons, the task of building a shared understanding of the facts is often made difficult by diverging interests and differences over values.[11]

3.3. Balancing diverging interests

Most public policies have distributional consequences. Even if a policy reform would increase overall economic welfare, there are likely to be some who stand to lose; conversely, a policy which has important negative effects on society as a whole may benefit some sectors or some groups in society.

Groups with a strong stake in a policy outcome may organise to try to influence the policy process. It is probably not possible, and perhaps not even desirable, to have a political process which is completely immune to such influence. Interest groups, from businesses to civil society organisations, are critical actors in the policy-making process: by expressing their needs and by sharing their expertise, evidence, and policy proposals, they can provide valuable information to policy makers, and the political system can act as a mechanism to balance these diverging interests. But problems arise when some special interests achieve a disproportionate influence, leading to policy capture – the situation where public policy is used to benefit a special interest at the expense of others in society (OECD, 2017[61]).

Relevance to food systems

In the context of the food system, influence over policies has been ascribed to farm lobby groups, agricultural input suppliers, food processing companies, and NGOs, among others. In some cases, disproportionate influence has been well-documented in the scientific literature; in other cases, the available evidence is more anecdotal.

Policies affecting the incomes of agricultural producers in both the developing and the developed world show a number of systematic patterns which are difficult to explain as a socially optimal response to market failures, but are best understood as the result of pressures exerted by various interest groups (Anderson, Rausser and Swinnen, 2013[62]) (Swinnen, 2018[63]). For example, poorer countries have historically tended to tax the agricultural sector while richer countries have tended to support it, and as poorer countries developed economically, they have tended to reduce taxation or even moved to supporting agricultural producers. This "development paradox" (Swinnen, 2018[63]) can be explained in large part by the impact of economic development on interest group competition and the political incentives of policy makers. In rich countries, food is a smaller share of consumers' budgets, which reduces consumer opposition to policies to raise the price of food. Development also reduces the relative number of farmers, which lowers the cost to society of increasing farm incomes. Furthermore, it is easier to organise a small group of farmers for whom a sizeable amount of support is at stake than to organise a large group of consumers for whom the cost of that support is relatively small. This logic of collective action (Olson, 1965[64]) is further strengthened when farm incomes lag behind incomes in other sectors, as this makes lobbying more attractive to agricultural producers. The impact of these structural economic factors on policy outcomes is however mediated by the role of political institutions and governance mechanisms, as well as by ideology and other factors such as inequality or the role of mass media (Swinnen, 2018[63]). Similar processes have been documented for fisheries policies, with lobby groups exerting a surprising degree of influence despite the sector's small share of economic activity and employment in most countries (Delpeuch and Hutniczak, 2019[6]).[12]

Other actors in the food system similarly exert pressure to influence policies. As discussed in the case study on processed foods, for example, food and drinks companies engage in a variety of "corporate political activities" such as disseminating information; providing financial incentives to politicians, political parties and other decision makers; proposing voluntary initiatives or self-regulation as an alternative to public policies; or challenging proposed policies in court (Mialon, Swinburn and Sacks, 2015[65]). Corporate political activities have also been documented for many other actors in the food chain, such as retailers or biotech firms (Clapp and Fuchs, 2009[66]). Many of these activities are not illegitimate; neither are they unique to the agro-food sector. Yet there exists a "grey area" between legitimate advocacy activities on the one hand and illegal influence-seeking activities such as bribery on the other. In this grey area, advocacy activities can lead to increased risks of policy capture (OECD, 2017[61]).

As these examples suggest, several mechanisms can lead to policy capture. Work by the OECD (2017[61]) identified a number of direct and indirect channels of influence on public officials. Direct channels include actions designed to create a sense of reciprocity (ranging from legal activities such as political campaign donations to illegal actions such as bribery or threats) or leveraging personal ties (e.g. as a result of family ties or "revolving door" practices where former government officials end up working in industry or advocacy organisations). Indirect channels of influence build on strategic communication (e.g. press releases, media articles, participation in public hearings) and expertise (e.g. providing research and analysis), discussed in more detail in Section 3.5. Influence can also come simply from repeated interactions between public officials and members of an interest group (e.g. contacts between energy regulators and energy companies, or between environmental regulators and environmental services firms). Other, more subtle channels may exist: for example, members of an interest group and public officials may have similar educational or social backgrounds, causing public officials to unconsciously identify and sympathise with members of the interest group (Kwak, 2014[67]).

There is no doubt that such mechanisms exist and can lead to policies favouring special interests at the expense of the public interest. As pointed out by Carpenter and Moss (2014[68]), however, "observers are quick to see capture as the explanation for almost any regulatory problem," even though many claims about policy capture in the literature turn out to be poorly supported by the evidence. An excessive pessimism about the existence of policy capture could undermine public trust in government and lead to unwarranted fatalism about the scope for policy interventions. Hence, as with other claims regarding food systems, claims of regulatory capture should be scrutinised. What complicates such an analysis is that policies could have positive efficiency effects yet at the same time lead to important gains for some groups at the expense of others.[13] Where risks of capture exist, several approaches discussed below can help to strengthen the integrity of public decision-making.

Even where some of the stronger claims about regulatory capture may turn out to be exaggerated, it is undeniable that not all interests in society are represented equally well in the policy process. In particular, smaller groups with more concentrated interests at stake tend to be better organised than larger groups with more diffuse interests. In fact, the latter may even be "rationally ignorant" when the costs to an individual of being informed and politically engaged about a policy issue outweigh the potential benefits (Downs, 1957[69]). In the context of agriculture, policies in high-income countries often raise the price of agricultural commodities. In those cases, producers naturally have a strong incentive to be informed about policy developments which affect their revenues, while consumers will typically have a smaller incentive given the relatively low share of household budgets spent on food (although this share is higher for lower income households within high-income countries). Similarly, major policy reforms tend to impose clearly identifiable costs on specific groups in society while benefits may be less certain and spread out over the wider population. In such a context, groups which stand to lose could block the proposed reforms (Tompson, 2009[44]). Successful reform may then require compensating those who lose, or mobilising a countervailing coalition.

Approaches

To prevent policy capture, OECD (2017[61]) recommends four mutually reinforcing strategies:

- *Levelling the playing field* by engaging stakeholders with diverging interests to ensure a more inclusive decision-making process that is harder to capture by specific interests. This requires policies to foster integrity and transparency in lobbying activities; policies to ensure transparency in political finance; and policies to promote stakeholder engagement and participation, as described by the draft OECD Best Practice Principles on Stakeholder Engagement in Regulatory Policy (OECD, 2017[42]) and the OECD Council Recommendation on Open Government (OECD, 2017[70]).[14] As mentioned earlier, however, stakeholder engagement has its limitations, especially when some interests are not well-organised or difficult to represent (e.g. future generations).[15]
- *Enforcing the right to know*, i.e. creating transparency about how policy decisions are made and who was consulted during the policy process. Such information has to be timely, reliable, accessible, and available in a user-friendly format. Examples of transparency measures include making information available on meetings with external stakeholders, disclosing private interests of relevant public officials, publishing background studies, stating explicitly the rationale underlying a policy decision, and publishing evaluation reports and stakeholder comments. For example, in the case of the Canadian dietary guidelines mentioned earlier, Health Canada made available not only a summary of comments from stakeholders (Health Canada, 2018[40]) but the content of all correspondence between lobbyists and the government.[16]
- *Promoting accountability* through independent oversight and control bodies such as supreme audit institutions or an *ombudsman* (Zuegel, Cantera and Bellantoni, 2018[71]). Competition authorities and regulators also have an important role to play in mitigating the risks of capture by ensuring that companies are exposed to competition and by regulating markets where competition is not possible

or desirable, such as natural monopolies. Because of their importance these agencies are themselves at risk of policy capture. To prevent this requires appropriate institutional design to guarantee the agencies' independence of political influence, sufficient powers, resources and staff to fulfil their role, and internal strategies to promote a culture of integrity and accountability.

- *Identifying and mitigating capture risk* through organisational integrity policies requires internal control mechanisms, clear standards of conduct, and efforts to promote a culture of integrity.

While these strategies can help in mitigating risks of policy capture, they may not be sufficient to implement reforms where a politically powerful minority stands to lose but where benefits are diffused widely.

Surveying a set of major policy reforms in OECD countries, Tompson (2009[44]) found that successful reforms typically found a way to win over potential opponents, for instance by exempting some groups from the reforms (that is, "grandfathering" their acquired rights); by providing long transition periods; by providing concessions; by involving potential opponents in the post-reform system (e.g. by allowing trade unions to administer pension funds in the case of pension reforms); or in some cases by adopting policies in other domains to offset the cost of reform for some groups. As described in the case study on ruminant livestock, the New Zealand "zero carbon" policy adopted in 2019 will price agricultural emissions, but provides for a five-year transition period and foresees that 95% of carbon credits at the farm level will be allocated for free. A number of supporting measures are also put in place, such as tools for estimating farm-level emissions (to help farmers plan ahead), increased farm advisory efforts, and incentives for early adopters. In several other cases where agricultural support policies were abolished, producers received compensation (Alston, 2007[72]). However, compensation measures can also impede reform if they mask the market signals that are needed to spur adjustment (Martini, 2007[73]).

Tompson (2009[44]) notes that there is often little mobilisation of interest coalitions in *support* of reform, consistent with the earlier point that benefits are often diffuse and uncertain while costs are concentrated and visible. A notable exception is created through the principle of reciprocity in trade negotiations. If countries choose their trade policies unilaterally, producers in import-competing industries will have strong incentives to lobby the government for protectionist tariffs. These producers will tend to form a relatively small group with important and clearly identifiable gains from protection.[17] Even though the costs to society of protectionism outweigh the benefits to these producers, those costs are diffuse and spread out over a large number of consumers, making it difficult to mobilise a coalition in support of reforming protectionist trade policies. However, the reciprocity principle in trade negotiations implies that domestic exporters can get improved market access abroad only if foreign producers are granted more market access at home. This creates a countervailing interest group of exporters, facilitating trade liberalisation (Irwin, 2015[74]). Historically, the adoption of reciprocity as a basic principle in US trade policy fundamentally changed the political dynamics around this issue, leading to greater political support for trade liberalisation (Bailey, Goldstein and Weingast, 1997[75]). A related strategy is *issue linkage*, where negotiations on various topics form part of a package deal where "nothing is agreed until everything is agreed". This approach was taken during the Uruguay Round, during which developed countries agreed to an unprecedented reduction in barriers to agricultural imports in exchange for greater market access for their industrial and service exporters. Agricultural interests in developed countries were opposed to liberalisation, but industrial and service firms lobbied their governments to compromise. Issue linkage thus created countervailing interest groups in favour of agricultural trade liberalisation (Davis, 2004[76]).

Outside of trade negotiations, mobilising such a countervailing coalition may be difficult for policy makers. However, civil society actors committed to change can try to create such a coalition, for example through awareness-raising campaigns among the broader public.

3.4. Dealing with differences over values

Disagreements over facts and diverging interests are not the only possible sources of friction in policy design. Even if there is a shared understanding of the facts, and there is no undue influence of special interests, people differ in the values they emphasise, and such differences can create difficulties in designing policies. Some people may emphasise equality while others emphasise freedom; some may emphasise progress while others emphasise traditions; some may emphasise economic growth while others emphasise the environment; and so on. As noted by Stewart (2006[13]), differences over values are a relatively neglected aspect of policymaking, and some authors dismiss values as merely convenient covers for the pursuit of self-interest. Yet, there is growing evidence on the importance of values in policymaking.

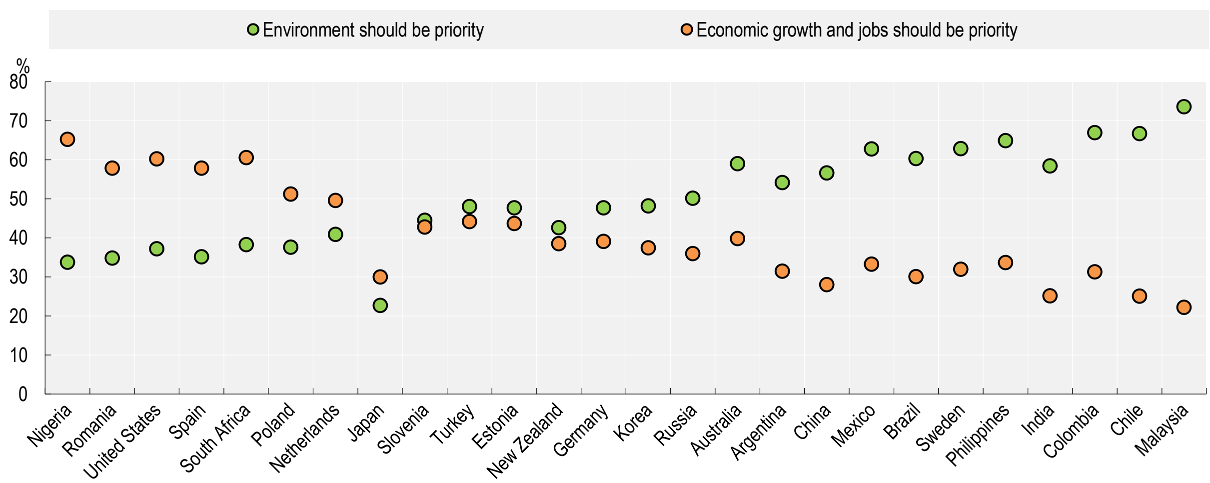
Relevance to food systems

Food and agriculture are intimately connected to people's values. This is the case for religiously prescribed food consumption patterns or behaviours (e.g. dietary restrictions or fasting), but the role of values also holds for new phenomena such as organic foods (Paarlberg, 2013[77]). People differ in the values they hold relative to food and agriculture, and these value differences correlate with their behaviour as consumers and as citizens. For example, research has shown that people who attach a greater value to naturalness, fairness and the environment are more likely to buy organic food (Lusk and Briggeman, 2009[78]) and that consumers can be willing to pay a price premium for local and organic food in part because of a concern with farmers' incomes (Toler et al., 2009[79]) (Chang and Lusk, 2009[80]). In the United States, people with a preference for maintaining family farms and for preserving the environment tend to favour government intervention in agriculture (Moon and Pino, 2018[81]); other research shows that people's policy preferences on food and agriculture are correlated with their overall political outlook (Lusk, 2012[82]). The cultural importance of fisheries was highlighted by policy makers as a crucial factor in shaping processes of policy change (Delpeuch and Hutniczak, 2019[6]). It has also been suggested that the negative attitudes of non-experts towards genetically modified food are to an important extent value based, reflecting a preference for "naturalness" (Scott et al., 2018[83]).[18]

There appear to be some systematic patterns in the values people generally emphasise. Drawing on cross-cultural research in moral psychology, Haidt (2012[84]) distinguishes six "moral foundations": *care versus harm*, *liberty versus oppression*, *fairness versus cheating*, *loyalty versus betrayal*, *authority versus subversion*, and *sanctity versus degradation*. Individuals, cultures, and political traditions differ in the relative importance they attach to these moral foundations.[19] The moral foundations also appear to be relevant to food and agriculture. Mäkiniemi et al. (2013[85]) asked people in Finland, Denmark and Italy to engage in a word-association task, where they wrote down the first five words, ideas or concepts that came to mind when thinking of "ethical food" or "morally right food" on the one hand, and "unethical food" or "morally wrong food" on the other hand. These answers revealed a particularly strong influence of the "care versus harm" foundation (e.g. the suffering of animals), the "sanctity versus degradation" foundation (e.g. chemical free, pure, clean, natural), and the "fairness versus cheating" foundation (e.g. fair trade, good working conditions, human rights). The study also found systematic differences in response by gender, country, and political orientation.

Value differences similarly exist around broader societal issues with relevance to the food system. This is illustrated in Figure 3.1 using data from the World Values Survey, a large-scale project to quantify cross-country differences and trends over time in people's values and attitudes. While specific questions about food and agricultural policy are not available, one of the questions included in the 2011-14 World Values Survey asked respondents whether they think protecting the environment should be the priority, or whether economic growth and jobs should be prioritised. In some countries (e.g. Nigeria, Romania, the United States, Spain) a majority of respondents prioritises economic growth and jobs, while in some other countries (e.g. Colombia, Chile, Malaysia) a majority of respondents prioritises the environment. In yet other countries (e.g. Slovenia, Turkey, Estonia, New Zealand) the shares of respondents are roughly evenly matched. Interestingly, there is only a weak correlation between countries' overall level of economic development and the share of respondents prioritising economic growth over protecting the environment. Moreover, even in countries with a clear preference for either option, there is typically a large minority choosing the other option; a national consensus is rare.[20]

Figure 3.1. Prioritisation of environment versus economic growth within and across countries



Note: Respondents in nationally representative surveys were asked to indicate which of the following two statements comes closer to their personal view: "Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs" or "Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent". Chart is showing responses for selected countries only. In Japan, 47% of respondents either gave a different answer or stated they did not know. Surveys were conducted between 2011 and 2014.
Source: Inglehart, R., et al. (eds.). 2014. World Values Survey: Round Six - Country-Pooled Datafile Version: http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp. Madrid: JD Systems Institute.

Values are important for agriculture and food policy, and policy decisions often involve a trade-off among several values. As there is rarely unanimity in society on how values should be prioritised, the design of policies for food systems is thus likely to encounter differences over values. Such differences are harder to resolve than situations where interests diverge: while those who lose financially from a policy change could in principle be compensated, the violation of cherished values is much more difficult to "compensate". The remainder of this section first discusses the distinction between interests and values, before turning to different approaches which have been used to deal with value differences in policy settings.

Interests versus values

The distinction between interests and values is not always clear-cut, but a first characteristic which distinguishes interests and values (at least as the terms are used in this chapter) is that interests are self-regarding while values are other-regarding. For example, people may vote to pay higher taxes out of a conviction that tax revenue will be used to help others in society; people may thus vote against their own material interests because of their attachment to certain values. This other-regarding nature of values is also obvious for the "moral foundations" mentioned earlier. Other-regarding values are not necessarily altruistic or cosmopolitan: moral foundations such as loyalty versus betrayal, or authority versus subversion, are other-regarding but could lead to e.g. nationalist or ethnocentric attitudes.

The distinction between interests and values may sometimes be hard to ascertain in practice; e.g. a high earner may vote for lower taxes out of self-interest or out of a conviction that hard work should be rewarded; a citizen may vote for more redistribution because of a belief in fairness and equality, or because of an expectation that he or she will personally benefit from a more equal income distribution. Yet, even if it can be hard to disentangle motivations, in each case the conceptual distinction can be made between self-regarding interests and other-regarding values.

There is a considerable and growing body of evidence demonstrating that, despite traditional economic assumptions of self-interest as main motive of behaviour, other-regarding motivations are in fact important drivers of decision-making (Fehr and Schmidt, 2006[86]) (Cooper and Kagel, 2016[87]). In real-world settings, scholars studying voters' preferences on international trade have argued that these preferences do not solely reflect voters' economic self-interest but to an important extent include considerations of how trade liberalisation would affect others, or their country in general (Mansfield and Mutz, 2009[88]) (Rho and Tomz, 2017[89]). Opinion surveys also often find strong support among the public for agricultural subsidies and tariffs, despite the fact that these economically harm them as consumers (Naoi and Kume, 2011[90]) (Jensen and Shin, 2014[91]) (Moon and Pino, 2018[81]). This could be due to "rational ignorance" as discussed in the previous section; alternatively, it could reflect a belief in the importance of supporting farmers or of the public goods produced by agriculture, or a lack of understanding of the impacts of support on other groups about which they might also be concerned (e.g. producers in poor countries).

A second distinction between values and interests is that interests are usually interpreted in the material sense (e.g. income and wealth, economic opportunities, the cost of living) while values are usually interpreted as non-material ideals which cannot easily be translated into an equivalent in material terms (e.g. gender equality, fairness, democracy). This makes interests "commensurable" – that is, stakeholders could be compensated, or might be willing to give up something in return for achieving a desired outcome – while values are in principle "incommensurable". To illustrate the distinction, Winship (2006[92]) describes efforts to build a dam in Arizona which would have had considerable economic benefits but which would have flooded the ancestral lands of the Yavapai Indians. The government was willing to pay compensation, but the Yavapai were not interested at any price, arguing that selling the land would be akin to selling one's mother.

In a conflict involving interests, numerous solutions may be possible, as stakeholders usually have several interests and hence could be compensated in one domain in return for compromising in another. By contrast, in a value-laden debate, "[c]ompromise, in its most pejorative sense, means abandoning deeply held beliefs, values, or ideals. To negotiate away values is to risk giving up one's identity" (Susskind, 2006[93]). It is thus important to correctly identify whether a policy disagreement revolves around interests or values. As Goldgeier and Tetlock (2008[94]) observe, "the very willingness to consider certain categories of trade-offs is taken as a sign in many political cultures that one is not adequately committed to core cultural values and identities." They distinguish three types of trade-offs, depending on whether the trade-off involves commensurable interests or incommensurable values.[21] A *routine* trade-off involves a choice between two interests, as is often the case in private economic decision-making or negotiation. A *taboo* trade-off pits values (e.g. human rights, the environment) against interests (e.g. profits). A *tragic* trade-off, meanwhile, pits two values against each other.

The difference between commensurable interests and incommensurable values bears some similarities to the distinction between goods which have a market price and those which do not, although the mapping is not exact. A good may have a market price, yet its owner may not be willing to accept any compensation to part with it; the case of the Yavapai Indians is an example. On the other hand, some desirable goods without a market price (e.g. reductions in crime or pollution) can be valued in monetary terms indirectly, by assessing consumers' implicit willingness to pay for additional "units" of the good (or willingness to accept compensation to part with one unit). For example, real estate prices will tend to be lower in areas with higher crime rates. While people dislike crime, they do not avoid these neighbourhoods entirely; their behaviour reveals that a lower price for housing can compensate for higher crime rates, and this information can be used to estimate the economic value of reductions in crime levels. Hence, some desirable ends could at least partly be translated into a monetary equivalent.

Such analytical techniques are commonly used in cost-benefit analyses and have the advantage of translating diverse outcomes into a common metric, which facilitates comparisons between different policy options.[22] If all costs and benefits of a policy can be expressed in monetary terms, then it is possible to identify the policy option with the highest net benefit; and if net benefits of a policy are positive, it should in theory be possible to design a set of transfers from those who gain to those who lose, thus ensuring that everyone is at least as well off as before.[23] However, there is no consensus on the scope and limits of these techniques, which strike some as requiring "a questionable philosophical leap of faith" (Smith, 2006[95]) in assuming that all policy-relevant aspects of a problem can be translated into monetary terms (Wolff and Haubrich, 2006[96]).[24] In its strongest form, cost-benefit analysis can be seen as an attempt to translate all policy problems into *routine* trade-offs (between commensurable interests); but this attempt strikes many as a *taboo* trade-off (between commensurable interests and incommensurable values).

Yet even where a monetary equivalent is hard to define, people may be forced by circumstance to prioritise or trade off different desirable ends in their personal lives. The resulting choice can be seen as a "revealed preference", or an implicit ranking or comparison of the outcomes involved. A similar logic holds for some policy choices involving seemingly incommensurable values (tragic trade-offs, in the terminology of Goldgeier and Tetlock (2008[94])). For example, the allocation of scarce resources across different medical treatments forces policy makers into uneasy comparisons between treatments in terms of number of people affected, number of life-years spared, the health-related quality of life which can be gained, fairness considerations, and so on. It may be impossible, or taboo, to translate the different options into monetary equivalents, but concrete policy dilemmas may still force a choice.

The distinction between those aspects which are commensurable and those which are not is thus best thought of as a continuum. In general, policy decisions will be easier if there is a greater degree of commensurability; conversely, where highly incommensurable values are at stake, the resulting differences over values will be more difficult to resolve.

Approaches

There are several ways of dealing with differences over values, not all of them wholly satisfactory. Stewart (2006[13]), building on Thacher and Rein (2004[11]), identifies six mechanisms which are used in practice to deal with value differences in policymaking:

- *Structural separation*, whereby responsibilities for different values are assigned to different institutions or departments (i.e. a "silo" approach).
- *Hybridisation*, where policies or practices with different underlying values coexist, often because a new set of policies is layered on top of existing policies with different underlying values.
- *Casuistry*, where choices are made on a case-by-case basis instead of making a general decision on how different values should be prioritised; in this approach, decisions might be made by reference to how earlier cases were decided (Thacher and Rein, 2004[11]). This is the approach taken in some legal systems, where precedents are used to guide decisions in court cases.
- *Incrementalism*, where small, gradual steps are made instead of enacting larger changes. This approach can help in signalling the intent to accommodate new values without generating too much opposition.
- *Bias,* where institutions and policy processes implicitly privilege some values over others. Dominant paradigms among policy advisors and decision-makers may imply that some values or policy options are simply never considered.
- *Cycling*, where policy makers focus sequentially on different values. The result may be that policies "oscillate".

In the past, agricultural policymaking often relied on structural separation and bias. In most developed countries, the post-war period was characterised by "agricultural exceptionalism", with agricultural policies made by closed policy networks consisting of agriculture ministries and farm groups and with a near-exclusive focus on raising farm income and productivity to the exclusion of other considerations. This suppressed some values while privileging others, giving the impression that value differences had been resolved (Daugbjerg and Swinbank, 2012[97]). Similar dynamics have historically been at work in fisheries policy (Delpeuch and Hutniczak, 2019[6]).

While perhaps common in practice, the approaches listed above suffer from obvious shortcomings. In particular, most are unlikely to lead to policy coherence, with the result that value differences will simply show up as incoherent policies. This is particularly the case for structural separation and cycling. Some other approaches such as casuistry and bias may lead to more coherence but not necessarily to policies which are seen as acceptable by all stakeholders.

More promising approaches exist to deal with value differences, however. Meijer and De Jong (2019[98]) identify the two complementary approaches of *problem-solving* (where policies are re-designed in an attempt to accommodate the different values at stake) and *deliberation* (where stakeholders discuss why certain values are important in an attempt to clarify and potentially resolve value differences).[25] These approaches hold the promise of a coherent approach, either because tension is removed through a creative solution or because agreement is reached on how different values should be prioritised. A further approach can be to try to identify another common value which all or most parties share, or to identify how a different approach could still satisfy the same value as the basis for problem-solving; for example, when the value of "fairness" is invoked in a policy debate about support to farmers, "fairness" can also be appealed to in seeking to avoid harm to other countries or producers.

Policy decisions rarely pit values against each other directly; decisions are typically about actions, which are interpreted by stakeholders in terms of values. Ideally, modifying the specifics of a policy can increase its compatibility with different values through creative problem-solving (Winship, 2006[92]) (Rein, 2006[99]). One example of how such an approach could work is suggested by empirical work by Ehrlich (2010[100]), who found that many voters are opposed to free trade not because of how it would affect them personally, but because of sincere concerns about labour and environmental conditions abroad. If opposition to free trade is motivated by such values, conventional approaches to provide compensation (e.g. job training, a stronger welfare state) will not be effective. Yet correctly identifying the source of voters' opposition to free trade also points the way to alternative policy solutions such as greater support for development programmes aimed at improving labour conditions, or attaching labour or environmental side agreements to trade agreements, or supporting private initiatives such as fair trade labelling schemes. Ongoing work by the OECD is identifying factors which can help arrive at such innovative solutions to complex societal problems (OECD, 2017[101]).

Where such creative adjustments are possible, they are clearly preferable, but not all differences over values will lend themselves to such an elegant solution. In principle, one approach to deal with persistent disagreement is to use decision rules such as voting mechanisms to translate individual preferences into a societal choice. However, such mechanical decision rules have severe shortcomings. First, as shown originally by Arrow (1951[102]) and confirmed by a large subsequent literature (Arrow, Sen and Suzumura, 2002[103]), such decision rules can lead to inconsistent societal choices or other undesirable outcomes even if people are well-informed, which is rarely the case on complex policy issues. Second, with contentious issues it may be desirable to achieve consensus, or at least widespread support; a decision based on numerical strength could foster resentment and may make it harder to implement the chosen policy afterwards (Susskind, 2006[93]). An alternative approach therefore emphasises *deliberative mechanisms* (Bächtiger et al., 2018[104]). Rather than taking people's beliefs, values and preferences as given, this approach focuses on the process of discussing policy options, where participants can exchange their views, argue in favour or against courses of action, and persuade or be persuaded (Dryzek and List, 2003[105]). Ideally, deliberation helps to resolve value differences by building consensus or at least finding compromises with widespread support.

Existing democratic systems combine elements of both voting and deliberation: parties compete for votes, and elected officials subsequently discuss and negotiate over policies in the legislative and executive branch, although countries obviously differ in their precise institutional setup (Lijphart, 2012[106]). However, a growing number of jurisdictions have been experimenting with forums where citizens can deliberate about important policy issues (OECD, 2020[107]) (Van Reybrouck, 2016[108]). Many initiatives use random selection or other approaches to ensure that participants represent the larger population to guarantee an inclusive process and to avoid disproportionate influence of stakeholders with vested interests (OECD, 2020[107]).

Proponents of citizen deliberations argue that these experiences demonstrate that ordinary citizens are willing and able to engage in high-quality deliberation. Other potential benefits include the potential to overcome polarisation and populism, and the ability to generate innovative solutions and move beyond impasse (Dryzek et al., 2019[109]). Empirical research on deliberative practices finds qualified support for many of these claims, although successful deliberation is often difficult to achieve (Ryfe, 2005[110]) (Thompson, 2008[111]). The quality of deliberations is improved when they include the provision of balanced information, expert testimony, and oversight by a facilitator (Dryzek et al., 2019[109]). The use of citizen deliberations can also create greater legitimacy for decisions and should in principle reduce the risk of policy capture if random selection is used. Work by the OECD has explored a wide variety of innovative citizen participation initiatives and has identified good practices to ensure high-quality processes that result in useful recommendations and meaningful opportunities for citizens to shape public decisions (OECD, 2020[107]).

Many deliberative initiatives have covered food and agricultural policies (Ankeny, 2016[112]). A prominent recent example is the Irish Citizens' Assembly. Established in 2016, this body consists of a chairperson and 99 citizens, randomly selected to be representative of the Irish population. The Citizens' Assembly has considered a number of issues, such as legalisation of abortion; population ageing; and climate change. As explained in the case study on ruminant livestock, the Irish Citizens' Assembly made several recommendations on how Irish agriculture could contribute to climate change mitigation, including a tax on agricultural emissions with revenues to be reinvested in climate friendly agriculture and incentives paid to farmers for sequestering carbon. A committee with representatives from Ireland's political parties considered these recommendations, but did not endorse taxing agricultural emissions. In France, the *Convention Citoyenne pour le Climat* similarly used random selection to bring together 150 citizens to define initiatives to reduce greenhouse gas emissions. Several of the decisions of the Convention related to food systems, such as encouraging a shift towards a diet with less meat and dairy and more fruits and vegetables, as well as providing consumers with information on the environmental impacts on food products (Convention Citoyenne pour le Climat, 2020[113]). At the international level, Food Systems Dialogues form another example of deliberative approaches to food and agricultural policies. This initiative was established in 2018 by EAT, the Food and Land Use Coalition, the Global Alliance for Improved Nutrition, the World Economic Forum (WEF) and the World Business Council for Sustainable Development (WBCSD). So far, more than 40 dialogues have been convened in 23 countries with over 2 500 participants; Food Systems Dialogues will also be used during the preparations for the 2021 United Nations Food Systems Summit.[26]

In both problem-solving and deliberation approaches, it is often essential to rely on trusted, independent facilitators. Susskind (2006[93]) outlines a "consensus building process" in which a trusted neutral facilitator plays a key role in identifying the underlying issues and conflicts and in organising sessions where stakeholders can review information, brainstorm possible solutions, and discuss with outside experts. In this approach, the neutral facilitator then proposes decisions.

An important concern is that some people are considerably more interested and more vocal than others. This is the case for food and agriculture, where "foodies" may see themselves as more knowledgeable than the general public (Ankeny, 2016[112]). Moreover, people who take an interest in food policy are also likely to have more social and economic power, creating "subtle forms of social domination" which can undermine the attempts to foster deliberation (Ankeny, 2016[112]). This problem is particularly pronounced where participants are recruited on a voluntary basis, as "foodies" are considerably more likely to volunteer for deliberative processes around food policies.

Another method, increasingly used by civil society actors, is litigation. As explained in more detail in the case study on ruminant livestock, lawsuits demanding more ambitious climate action have been filed in at least 28 countries. In the Netherlands, civil society actors have sued the Dutch government over its climate policies and, in a separate case, over its nitrogen policy. In both cases, the courts ruled in favour of the civil society groups, forcing the government to adopt more stringent measures to combat climate change and nitrogen oxide emissions. The increased use of litigation to settle political and policy issues has been referred to as the "judicialisation of politics" (Hirschl, 2009[114]), a term which encompasses not only the spread of legal and rights-based discourse and procedures in society, but also an increasing use in some countries of "administrative review" (whereby courts can review policy decisions by administrative bodies) as well as a growing tendency for courts to decide on major political controversies. Hirschl (2009[114]) warns that even though political controversies often have constitutional aspects, they are not exclusively or even mostly legal dilemmas. This makes it doubtful whether courts are the proper forum for deciding on such matters, rather than settling these issues through public deliberation in the political sphere.

As is clear from these descriptions, successful reconciliation and deliberation approaches require careful preparation and are neither easy nor cheap. Such mechanisms may therefore not be practical for all policy decisions, although they could be a powerful tool to move forward in the face of important differences over values– at least when their recommendations are taken to heart by policy makers.

3.5. Managing policy controversies

The most sensitive policy issues concerning food systems combine disagreements over facts, diverging interests, and differing values. For example, as argued in the case study on the seed sector, policy controversies over the proper regulatory approach to genetically modified organisms (GMOs) are not merely about the technical question of benefits and risks of the technology, but also involve claims that biotech firms or NGOs have disproportionate influence over policy processes. The debates also involve differing values, e.g. on the role of technology, small farmers, or corporations. As another example, controversies over the role of animal agriculture involve values (such as ethical aspects of eating animals, or the humane treatment of animals), interests (such as those of farmers and industry) as well as facts (such as the contested health effects of eating red and/or processed meat, or the precise contribution of ruminant livestock to global warming); several of these aspects are explored in more detail in the case study on ruminant livestock.

Mutually reinforcing beliefs

With policy controversies, friction in one area (e.g. differences over values) may reinforce frictions in another area (e.g. disagreement over the facts) through a number of mechanisms. One such mechanism, motivated reasoning, was discussed earlier: people tend to interpret evidence and arguments in a way consistent with their prior beliefs, so that diverging interests and differing values can lead to persistent disagreements over facts as well.

Another example is the deliberate spread of biased, misleading or wrong information by certain interest groups in an attempt to influence public opinion and the policy process, for example through funding and dissemination of research.[27] A considerable body of evidence from various sectors shows that industry-funded research leads to results and conclusions more favourable to the funder (Lundh et al., 2017[115]). Industry funding has also been shown to affect research priorities (Fabbri et al., 2018[116]). These dynamics also appear at work in industry-funded research on nutrition and health. A review of more than 200 nutrition-related articles showed that industry-funded studies were four to eight times more likely to report results favourable to the industry (Lesser et al., 2007[117]).[28] Mandrioli et al. (2016[118]), studying reviews on the effects of beverages with artificial sweeteners (e.g. saccharin) on weight outcomes, found that industry-sponsored reviews were more likely to have results and conclusions favourable to the industry compared with non-industry sponsored reviews, while all reviews sponsored by competing industries (e.g. the sugar industry) found unfavourable conclusions. Bes-Rastrollo et al. (2013[119]), studying reviews on the effects of sugar-sweetened beverages on weight gain or obesity, found that among reviews without any reported conflict of interest, about 80% concluded that sugar-sweetened beverages could be a potential risk factor for weight gain. Among reviews disclosing a financial conflict of interest with the food industry, by contrast, 80% concluded that the scientific evidence was insufficient. Similar results were found by Massougbodji et al. (2014[120]). The damage done by industry influence extends beyond these specific topics; it may lead citizens to dismiss *any* scientific study which contradicts their prior beliefs, making it difficult to engage in evidence-based discussions. As highlighted in the case study on seeds, one possible reason why consumers in many countries remain sceptical about GM crops may be that the public trusts environmental NGOs more than scientists and the private sector, as NGOs are perceived as not having a hidden agenda (Qaim, 2020[121]). As discussed in the case study on processed foods, industry funding is not problematic *per se*; it can enable important research and innovations, especially in a context of scarce public funding. But clear governing principles are needed to manage the relationship between industry and the research community to avoid the production and dissemination of biased information and to safeguard the public interest. In addition to rules requiring researchers to disclose funding sources and potential conflicts of interest, these can include requirements by scientific journals for transparency regarding, for example, the data and methods used by researchers. An example are the Transparency and Openness Promotion guidelines of the Center for Open Science.[29]

Diverging interests can also influence the values emphasised in a policy debate. In attempts to influence policy debates, interest groups are likely to advocate a policy position with reference to broader values, and not only with reference to the expected gains for the interest group. Thus, farm groups are likely to describe their goal as a *fair* income rather than simply a higher income for their members. Similarly, agricultural input firms are likely to describe their activities as aiming at improved sustainability, better lives for farmers and healthy food for consumers, rather than in terms of financial goals.[30] In other cases, interest groups have deliberately sought to emphasise certain values (e.g. consumer choice, freedom) in an attempt to oppose policy initiatives. For example, the American Beverage Association has organised a campaign “Your Cart, Your Choice” in response to initiatives to impose taxes on sugar-sweetened beverages, with the message that “[e]lected officials and pro-tax advocacy groups should not be dictating what you can and can’t eat or drink. These choices are yours – and yours alone.”[31] Even though these interest groups are clearly invoking values for self-serving reasons, the values in question are real, and are held by at least part of the public.[32] Efforts to frame a policy discussion in terms of values can thus help interest groups to move a policy debate in a desired direction.[33]

The distinction introduced earlier between routine trade-offs (between interests), taboo trade-offs (between interests and values) and tragic trade-offs (between values) is again relevant here. Opponents may try to frame a policy they oppose as involving a taboo trade-off, e.g. surrendering a deeply held value for money or convenience, which has the effect of portraying proponents of the policy as unprincipled or immoral (Goldgeier and Tetlock, 2008[94]).

Uncertainties or disagreements over facts can also worsen conflicts over interests and differences over values. Uncertainty over the distribution of gains and benefits of a policy reform is likely to lead to greater resistance (Tompson, 2009[44]) (Fernandez and Rodrik, 1991[122]). Conversely, *creating* uncertainty over the facts is often a useful tactic for interest groups trying to block proposed policy initiatives (Stauber and Rampton, 1995[123]). Disagreement over facts and differences over values can also reinforce each other through framing – for example, whether farmers are seen as "stewards of the land" or "polluters" will influence how people feel about agricultural and environmental policy issues.[34]

Finally, values can affect stakeholders' effectiveness in organising to protect their interests. As noted earlier, efforts to influence public policymaking may suffer from a "free rider" problem: organising to influence policies is costly, and it is difficult to exclude those who did not contribute to the lobbying effort from the benefits of a policy. This logic of collective action means that individual stakeholders may find it hard to organise themselves to successfully lobby for their preferred policy. However, a sense of solidarity, community and fairness may help overcome this problem; this has been suggested as a potential explanation for the lobbying strength of fishers (Delpeuch and Hutniczak, 2019[6]).

These interaction effects between facts, interests and values can create complex problems, which Rein and Schön (1993[8]) have labelled "policy controversies". Policy controversies often involve two or more competing "frames" which combine facts and theories, interests, and values to make sense of a complex reality. This distinguishes them from mere disagreements over policy, where there are frictions related to facts, interests, or values but not all three at once. In such cases, there remains some common ground which can help establish rules for resolving disagreement. Policy controversies and their competing frames are more problematic, as they involve fundamentally different ways of looking at the world.[35]

An example of such contrasting worldviews relevant to food and agriculture is offered by Mann (2018[124]), who distinguishes between the worldviews of "wizards" and "prophets". Wizards emphasise technological progress and innovation as a way to achieve environmental sustainability, while prophets emphasise the need for reductions in consumption (including through efforts to limit population growth). In Mann's telling, the two worldviews are diametrically opposed: prophets see wizards' faith in technology and innovation as unthinking, arrogant, and a recipe for environmental disaster, while wizards see prophets' insistence on reducing consumption as backwards, indifferent to the poor, and unnecessarily apocalyptic. Moreover, prophets accuse wizards of prioritising corporate profits, while wizards accuse prophets of racism (as poverty, hunger and population growth are concentrated in non-Western countries). To the extent that participants in debates around food systems indeed hold such diametrically opposed worldviews, constructive policymaking may be difficult.[36]

Approaches

Unfortunately, the political science literature does not offer much practical advice on how to manage policy controversies stemming from opposing worldviews. Rein and Schön (1993[8]) themselves advocated for "frame-reflectiveness", i.e. an awareness among policy analysts and participants in policy debates of the different frames that are being used, a willingness to identify their sources and consequences, and an openness to reassess these worldviews. However, the authors noted that "there are very few examples of such processes" (Rein and Schön, 1993[8]). Another strategy is to search for "frame-robust" policies that are acceptable to stakeholders with different frames, an approach similar to the creative problem solving outlined earlier.

These ideas can be applied to the distinction between "wizards" and "prophets". As Chapter 1 has argued, the actual performance of food systems in terms of the triple challenge is less black-and-white than these two opposing worldviews suggest; there have been remarkable achievements, but serious challenges exist. The impact of technology, too, has not been unambiguously good or bad. For example, the increasing use of synthetic inputs after World War II has contributed to enormous gains in agricultural production, but also to environmental problems; however, where technological progress has led to overall efficiency gains (as in more recent decades), environmental sustainability has generally improved, at least per unit of food produced. Acknowledging the evidence on both the successes and challenges of food systems can hopefully establish common ground between different worldviews. Rather than deriving policy prescriptions from a single worldview, Chapter 1 has also argued for a pragmatic approach based on assessing which practices are beneficial under which circumstances and with which trade-offs, emphasising careful, context-dependent and evidence-based evaluations. Such an approach is inherently eclectic, and can thus borrow insights and policy ideas from different worldviews, which may again help in finding common ground.

Success in bridging different worldviews is not guaranteed, however. The scarcity of practical solutions to policy controversies is in some sense not surprising – if solutions were readily available, policy controversies would not be a major concern. The difficulty of resolving policy controversies thus underscores the importance of *preventing* policy controversies from emerging in the first place.

This imposes a responsibility on participants in policy debates to commit to using rigorous evidence, to be forthcoming about potential conflicts of interest, to acknowledge different values at stake, and so on. But individual responsibility is unlikely to be sufficient. Rather, the various approaches outlined in the earlier sections – trusted, independent science; a commitment to consider evidence on a wide range of potential effects as part of impact assessments in the policy process; strict rules to prevent conflicts of interest and undue influence; mechanisms such as deliberative practices to deal with differences over values; and so on – need to be embedded institutionally. A large literature confirms the importance of institutions (the "rules of the game") in shaping political and economic outcomes ((North, 1990[125]) (Ostrom, 1990[126]) (Williamson, 1998[127]) (Acemoglu, Johnson and Robinson, 2005[128]) (Rausser, Swinnen and Zusman, 2011[10]) (Lijphart, 2012[106])); this institutional view of policymaking suggests that it is possible "to improve the *substance* of public policy choices by improving the *procedures* used to make these choices" (Immergut, 2006[129]). As noted throughout this chapter, numerous best practices and principles exist which can help build a shared understanding of the facts, balance diverging interests while maintaining a level playing field, and provide a forum for dealing with differences over values, e.g. through deliberative practices. To the extent that guidelines such as the Recommendation of the Council on Regulatory Policy and Governance (OECD, 2012[35]), best practices for preventing policy capture (OECD, 2017[61]), best practice principles on stakeholder engagement (OECD, 2017[42]) and the like are firmly embedded in the policy-making process, the obstacles described in this chapter should be greatly diminished. Robust processes should also contribute to public trust, reducing the suspicion that for example evidence provided in a policy debate is biased by conflicts of interest.

As noted at the outset, disagreements around facts, diverging interests and differing values are not specific to policy debates around food systems, so neither are the relevant best practices. The analysis in this chapter thus suggests that those concerned with achieving better policies for food systems should in the first place lend their support to these general principles of good governance and policy-making.

3.6. International aspects

Many of the challenges facing food systems require policy responses primarily at the national or local level. This is often true for problems related to nitrogen pollution or excessive water use, as well as for many problems related to nutrition. But a number of policy issues have international spillovers, notably those involving agricultural support and trade and international externalities such as agriculture's contribution to climate change. Coherent policies then require some degree of international coordination, as discussed in the previous chapter. As with domestic policymaking, achieving better policies at the international level can be complicated due to disagreements over facts, diverging interests, and differing values.

International organisations often play an important role in building a shared understanding of the facts at the global level. The OECD's estimates of producer support and FAO estimates of food loss, for example, were mentioned earlier. Other notable examples include the Intergovernmental Panel on Climate Change (IPCC); the High Level Panel of Experts of the UN Committee on World Food Security; the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES); the

International Food Policy Research Institute (IFPRI) and other CGIAR centres; and the long-standing research efforts by the World Bank to estimate living conditions and poverty around the world. The UN Food and Agriculture Organization plays an important role in collecting and disseminating information and analysis, as does the High Level Panel of Experts on Food Security and Nutrition (HLPE), the science-policy interface of the UN Committee on World Food Security (CFS). On several issues there is arguably a better evidence base on global conditions than on national or local conditions: a lack of data for one country (e.g. on poverty rates) may not affect overall global estimates, although such data are of course essential for national policy makers.

The role of interests and values is harder to assess at the international level, as the behaviours of national governments derive from complex domestic policy processes as well as strategic interactions with other states (Putnam, 1988[130]). As a result, it is not always easy to interpret whether a country's position on an international issue reflects its assessment of what would maximise domestic welfare; the lobbying of domestic interest groups; deeply held values of its population; or a complex mix of these different motivations. Moreover, governments may act strategically, for example by taking a strong position on one international issue to gain leverage in negotiations on another.

One illustration of these complexities was offered earlier: while interest groups are often seen as obstacles to achieving mutually beneficial outcomes, in a trade context the reciprocity principle helps to mobilise interest groups of exporters in favour of trade liberalisation, thus offsetting pressures for protectionism by import-competing interest groups. In other policy areas (e.g. global public goods such as climate change mitigation), domestic interest groups who stand to lose may have a less beneficial effect, although strong civil society groups may have an important role to play in offsetting the lobbying efforts of such interest groups. Even where contributing to global public goods is not a country's main policy objective, more domestically oriented motivations may still enable international cooperation, e.g. where a country's comparative advantage is in sustainable production (Keohane and Victor, 2016[131]).

Values play an important role in shaping citizens' attitudes towards international policy issues (Rathbun et al., 2016[132]). For example, Kertzer et al. (2014[133]) show that the "moral foundations" are strongly and systematically associated with foreign policy attitudes, with the dimensions of harm versus care and fairness versus cheating linked to cooperative attitudes. Values also matter as a determinant of a government's policy priorities. People around the world differ in the relative importance they assign to different values (Inglehart and Welzel, 2005[12]), although there can also be commonalities of view in communities that cross borders, including in contexts where such views may not be dominant in the domestic policy debate. One could expect this diversity to be an additional source of friction, especially regarding sensitive issues such as food and agriculture. For example, people may differ in their degree of risk aversion in policy areas such as food safety, hygiene or biosecurity. Such differences could in turn explain differences in regulatory approaches around the world, which have led to international friction. However, as noted earlier, it is often difficult to disentangle the relative contribution of attitudes and values on the one hand, and interests on the other.

At the same time, value differences should also not be exaggerated; as Rein and Schön (1993[8]) pointed out, at a sufficiently abstract level it is usually possible to find agreement. For example, despite their differences, all 193 members of the United Nations General Assembly have adopted the Sustainable Development Goals (SDGs). Even if countries will inevitably have their disagreements over how these should be achieved, the SDGs provide at least some common ground.

3.7. Conclusion

The challenges facing food systems are considerable, and better policies are urgently needed to meet the "triple challenge" of ensuring food security and nutrition for a growing population, providing livelihoods for actors along the food chain, and ensuring environmental sustainability. Because of the complexity of food systems, and the various synergies and trade-offs which exist between different dimensions of the triple challenge, such policies need to be coherent, and the previous chapter has outlined a pragmatic approach to increase the coherence of policies for food systems. Yet coherence by itself is of little value if policies are not sufficiently ambitious. Policies regarding food and agriculture have often proved to be difficult to reform, however. Policy makers can expect to encounter several obstacles on the path to better policies. [37] This chapter has identified frictions around facts, interests, and values as common obstacles. Disagreements over policy usually involve frictions in one of these three areas; the most problematic policy controversies may involve frictions in all of them. Achieving better policies thus requires building a shared understanding of the facts, balancing diverging interests (or finding ways to compensate those who stand to lose from a policy reform), and resolving differences over values. Good practices (summarised in Table 3.1) can help with each of these tasks. For example, rigorous *ex ante* Regulatory Impact Assessments should bring together the best available scientific and technical information to inform policy decisions. These assessments could then be used as input in a stakeholder consultation process to gather further insights. To prevent policy capture by special interests, governments need to ensure all interests have the opportunity to voice their views (for example by designing inclusive stakeholder consultation processes) and take the necessary steps to promote transparency and accountability. Differences over values can sometimes be resolved by focusing on specific actions rather than general principles. In other cases, deliberative approaches can help to resolve thorny societal dilemmas. Ideally, such approaches can help to build societal consensus or at least find compromises with widespread support.

Table 3.1. Three sources of friction and potential policy approaches

	Types of friction	Potential policy approaches
Facts	• Lack of data/evidence about the extent, causes and characteristics of policy issues; about the synergies and trade-offs with other issues; and about the effectiveness of different policy options • Gaps between public perception and scientific evidence	• Build a shared understanding of the facts through the use of Regulatory Impact Assessments, incorporating insights from scientific advisory bodies etc. • Stakeholders can be a source of information, but not all stakeholders equally well represented, and stakeholders' views not necessarily evidence-based; therefore good to use regulatory impact assessment as input in stakeholder consultation
Interests	• Most policies create winners and losers, leading to political frictions • Interest groups can provide valuable information to policy makers, and the political system can act as a mechanism to balance diverging interests • However, there is a risk that special interests capture policy processes	• Institutions and policy processes should promote transparency, accountability and a level playing field to minimise the risk of policy capture • It may be necessary to mobilise a countervailing coalition
Values	• Many food system issues are marked by differences over values (e.g. genetically engineered organisms, animal welfare). In contrast with interests, it is hard to "buy off" value-based opposition with compensation	• Creative problem solving: policies can sometimes be adjusted so they are acceptable to people with different values (i.e. focus on actions, not values) • Making difficult decisions through deliberative processes so that choices have legitimacy; ideally, this builds societal consensus or at least widespread support
All of the above	• A *policy controversy* combines all of the above and is difficult to resolve due to incompatible worldviews (e.g. "wizards versus prophets")	• Difficult to solve, although some approaches can help (e.g. ensure communication by experts with diverse values to reduce polarisation) • Important to prevent the emergence of policy controversies by embedding the best practices for facts, interests and values into institutions and policy processes, thus building trust

Note: See main text of the chapter for detailed discussion on each of these items.

None of these approaches offer quick fixes. Rather, achieving better policies will require embedding the best practices highlighted in this chapter into institutions and policy processes. This can build trust and confidence in the approaches used to gather and assess evidence, to balance diverging interests, and to resolve differences over values, which in turn should make it less likely that friction in one domain spills over into others, creating intractable policy controversies.

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Notes

[1] The OECD wishes to thank Béatrice Cherrier (CNRS) for bringing this parsimonious triad to its attention. The discussion in this chapter draws on a voluminous literature on public policies, with notable contributions from political science (surveyed by, for example, Weible and Sabatier (2017[154]), Moran et al. (2008[155]) and Dodds (2018[156])) and economics (surveyed by, for example, Mueller (2003[157]), Persson and Tabellini (2000[158]), Rausser et al. (2011[10])). The "triad" of facts, interests and values usefully captures and synthesises many of the insights from these literatures, although different traditions have tended to emphasise different elements of this triad. This chapter uses the term "frictions" as shorthand to refer to the ways in which disagreements over facts, diverging interests, and differences over values can complicate the policy-making process.

[2] As an example, New Zealand underwent major reforms to its economic policies in the 1980s, including to agricultural support policies. The magnitude of these reforms was considerable: New Zealand's Producer Support Estimate stood at 20% in 1986, but was reduced to about 3% in 1988 and fell further to around 1% by the early 1990s. These reforms were made possible by an "atmosphere of crisis" and considerable budgetary problems, and a new government brought to power after the 1984 election (Atkinson, 1997[170]).

[3] See http://www.oecd.org/coronavirus/policy-responses/making-the-green-recovery-work-for-jobs-income-and-growth-a505f3e7/.

[4] For a detailed discussion of how the dynamics of public policy differ across economic, social, education, or environmental policymaking, see Dodds (2018[156]).

[5] As noted in Chapter 1, of the ten best-selling pesticides in the United States in 1968, six are now banned, including DDT (Phillips McDougall, 2018[176]); toxicity of pesticides used in US agriculture has fallen considerably since the 1960s (Fernandez-Cornejo et al., 2014[177]). Similarly, Fantke et al. (2012[34]) report that 33 of the 133 pesticides in their study, accounting for 20% of the health impacts in the EU in 2003, were banned by 2012. The situation is likely different in many low- and middle-income countries, which often still allow pesticides that have been banned in high-income countries (Schreinemachers and Tipraqsa, 2012[178]).

[6] The dynamics of this "ideas industry" (Drezner, 2017[134]) have been changing in recent years due to a waning trust in expertise (Nichols, 2017[135]) as well as growing political polarisation and a growing role of philanthropists funding think tanks.

[7] See https://ree.developpement-durable.gouv.fr/themes/economie-verte/activites-de-l-economie-verte/pratiques-agricoles-respectueuses-de-l-environnement/article/vers-la-transition-agro-ecologique.

[8] Technocratic approaches assume that ends are given and that the only relevant questions concern the optimal choice of means. Such approaches are thus inappropriate in a context where there is disagreement over the ends. Recently, Friedman (2020[153]) has argued that technocratic approaches often fall short even on their own terms (in finding the optimal means to given ends) as it is impossible to predict how people will react to policies.

[9] Recent attempts to construct indices have sometimes allowed users to adjust the weights to see how overall rankings are affected. This approach is used in the OECD Better Life Index (www.oecdbetterlifeindex.org). The Global Food Security Index by The Economist Intelligence Unit similarly allows users to download a spreadsheet where the weights can be modified (https://foodsecurityindex.eiu.com/). As an example of how the mathematical formula for aggregating information can play a role, since 2010 the Human Development Index combines sub-indices of life expectancy, education, and income using a geometric mean (i.e. multiplying the three sub-indices, then taking the cubic root) rather than an arithmetic mean (which would add the three sub-indices and divide by three). Using a geometric mean implies that a low score on one dimension is much harder to compensate with a high score on another dimension. For instance,

if a country would score zero on one dimension, the overall Human Development Index would be zero regardless of the score on the other dimensions.

[10] Recent work by the OECD distinguishes between *misinformation* (when false information is shared but no harm is meant), *disinformation* (when false information is knowingly shared to cause harm), and *malinformation* (when genuine information is shared to cause harm) (Matasick, Alfonsi and Bellantoni, 2020[183]).

[11] The emphasis on pragmatic, rigorous, evidence-based approaches throughout this report also extends to the *ex post* evaluation of the effectiveness of existing policies. But just as with debates over new policies, the evaluation of existing policies rarely involves only facts. Despite the importance of feedback and learning, policy evaluations may be used to apportion blame or praise, leading to a "politics of policy evaluation" (Bovens, 't Hart and Kuipers, 2006[164]). Nevertheless, such *ex post* evaluation is important, as policies may have outlived their original rationale. For example, many countries provide reductions on excise taxes for fuels used in agricultural production. Such measures go against any sustainability logic, but have often been in place for a long time; in the United Kingdom, the lowering of fuel duties originated during the Second World War to increase production. Despite international pressures to reform fuel subsidies, only a handful of countries (e.g. Austria, the Netherlands) have reformed these policies (OECD, 2020[169]).

[12] Agricultural policies tend to be complex, with large variations by commodity even within a single country (OECD, 2020[47]). This can be seen as another consequence of the logic of collective action, i.e. the observation that lobbying is more difficult for larger groups because members have an incentive to try to benefit from the resulting policy without contributing to the lobbying effort ("free riding"). An interest group representing all agricultural producers is necessarily heterogeneous and large, and hence vulnerable to free riding behaviour. Moreover, not all producers within the group necessarily share the same interests and there may be trade-offs. Smaller groups representing more narrowly defined producer interests (e.g. dairy, sugar, rice) can thus often be effective in pursuing specific interests, including when they are also linked to a concentrated geographical region. This leads to different levels of support across commodities – which in turn leads to greater economic distortions (OECD, 2020[47]).

[13] This can be the case, for instance, for official food standards (Swinnen et al., 2015[179]). Compared to traditional trade instruments such as import tariffs, the economic analysis of official/government standards is considerably more difficult. For a small open economy, welfare analysis shows that a positive tariff (on a good for which the country is a net importer) restricts trade and benefits domestic producers at the expense of domestic consumers, leading to a net welfare loss. For public standards, these effects can go in different directions. For example, standards can act as a barrier to trade (e.g. by imposing costs on foreign suppliers) but can also act as a catalyst to trade (as the standard could reassure domestic consumers, and hence expand total demand, including imports). Empirically, some standards appear to simultaneously raise costs yet expand trade because of this demand-enhancing effect (Cadot, Gourdon and van Tongeren, 2018[181]). Moreover, while in the traditional analysis, domestic (import-competing) producers benefit from higher tariffs while consumers lose, there is no simple relation between the level of stringency of standards and its welfare effects on producers and consumers; this depends on factors such as implementation costs and whether consumers' utility from products with a higher quality standard is offset by higher prices. For detailed discussions, see Swinnen et al. (2015[179]); Beghin et al. (2015[180]); Swinnen (2018[63]).

[14] The importance of inclusive multi-stakeholder approaches is also emphasised in the Collaborative Framework for Food Systems Transformation (UNEP, 2019[39]).

[15] A further limitation of stakeholder engagement is that it may have a "status quo" bias: policy reforms might create new businesses, new employment opportunities etc., but these potential new interest groups are typically not yet organised, or at least not as well-organised as existing interests.

[16] Health Canada's policy regarding transparency of stakeholder communications is outlined on https://www.canada.ca/en/services/health/campaigns/vision-healthy-canada/healthy-eating/transparency-stakeholder-communications-healthy-eating-initiatives.html.

[17] In many instances, these benefits may be perceived rather than real, or may be offset by long-term costs, especially in the context of global value chains (GVCs). For example, Greenville, Kawasaki and Jouanjean (2019[173]) found that protectionist policies in agro-food sectors have a negative effect on the long-term growth of the sector they seek to protect, as they limit participation in GVCs. Other research across all sectors in turn suggests that stronger participation

in GVCs leads to lower tariffs, consistent with the argument that GVCs reduce industries' incentives to lobby for protectionist tariffs (Bown, Erbahar and Zanardi, 2020[175]) (Blanchard, Bown and Johnson, 2017[174]).

[18] For a clear discussion of value differences in a different public policy setting, see Ford (2013[161]) on forest management for Australian native forests.

[19] For an application of Haidt's moral foundations to US politics, see Enke (2020[14]). The "moral foundations" approach is not wholly undisputed; for a critique, see Scott Curry (2019[172]), who instead distinguishes seven "moral domains": family, group, reciprocity, heroism, deference, fairness, and property. Other research suggests that as societies modernise and provide greater economic and physical security, they undergo cultural changes leading to a greater emphasis on egalitarian social norms, a greater openness to new ideas, and a reduced emphasis on traditional cultural norms (Inglehart and Welzel, 2005[12]) (Inglehart and Welzel, 2010[141]) (Inglehart, 2018[142]).

[20] Among the 59 countries for which the World Values Survey collected this information in 2011-14, the most unanimous response was found in Haiti (not shown in the chart) where 93% of respondents prioritised economic growth and jobs, with only 4% prioritising the environment. The next country is Egypt, where 69% of respondents prioritised economic growth and jobs; but even here, more than 30% of respondents prioritised the environment.

[21] Goldgeier and Tetlock (2008[94]) themselves use the terms "secular values" and "sacred values", which broadly correspond to interests and values as used in this chapter.

[22] For an introduction to these and other "non-market valuation" techniques, see Baker and Ruting (2014[184]).

[23] This idea is known in economics as the Kaldor-Hicks criterion.

[24] See Sunstein (2018[9]) for a recent defence of cost-benefit analysis. In debates on the role of cost-benefit analysis, it is important to distinguish between the claim that policy making should be based on a comprehensive, well-researched and where possible quantified analysis of likely impacts, and the stronger claim that any policy decision should be based only on "net benefits". The first claim is uncontroversial and a cornerstone of sound regulatory policy and good governance (OECD, 2012[35]). The second claim, by contrast, introduces additional ethical assumptions about how impacts in different policy domains and affecting different stakeholders should be weighed against each other.

[25] Meijer and De Jong (2019[98]) use the term "reconciliation" instead of problem-solving; however, the former term is avoided here as it is also used to denote processes to overcome traumatic national events (e.g. South Africa's Truth and Reconciliation Commission).

[26] See https://foodsystemsdialogues.org/

[27] A classic exposé of such practices is Stauber and Rampton (1995[123]).

[28] Similar results were reported by Chartres et al. (2016[139]), although the authors themselves conclude that the findings were not statistically significant. However, their results show that favourable conclusions were 1.31 times more likely in industry-sponsored studies, with a 95% confidence interval from 0.99 to 1.72. Despite the authors' cautious interpretation, the data thus strongly suggest a correlation between industry funding and favourable conclusions.

[29] See https://www.cos.io/initiatives/top-guidelines.

[30] A subtle form of this mechanism in the context of food systems is the promotion of what has variously been called "the agrarian myth" (Brooks, 1996[185]) or the "rural idyll" (Bell, 2006[186]), a widespread positive perception of rural

landscapes, communities, and lifestyles, including family farming. Such myths combine both factual beliefs (which may or may not be accurate) and values.

[31] Americans for Food and Beverage Choice (2020), “Your Cart, Your Choice”, https://yourcartyourchoice.com/your-cart-your-choice/ (consulted 4 June 2020).

[32] For a discussion of the ethical issues involved in taxing sugar-sweetened beverages and other proposed interventions, see for example Dawson (2016[166]), Véliz et al. (2019[167]) and Goiana-da-Silva et al. (2020[165]).

[33] For a similar argument in the context of trade policy, see Ehrlich (2010[100]), who warns that protectionist interests might “hijack” sincere concerns of citizens about labour and environmental standards abroad.

[34] In New Zealand, reference is often made to farmers’ “social licence to operate”, a concept which denotes the social acceptability of farming activities (as opposed to merely its regulatory acceptability). For a discussion of the concept (which is also used in reference to other sectors), see Edwards and Trafford (2016[171]).

[35] The concept of a policy controversy is thus closely related to that of a “wicked problem”, first described by Rittel and Webber (1973[162]). A wicked problem is one which cannot be definitively described, and where there is no undisputed solution, not only because of the technical complexity of the issue but also because there is no consensus on what would constitute a good outcome.

[36] Other authors have identified different worldviews relevant to food and agriculture. For example, Thompson (2017[163]) identifies a “productionist” worldview (which emphasises increasing food production above all else), an “agricultural stewardship” worldview (inspired by the ideas of the American essayist Wendell Berry and emphasising not only agricultural sustainability but healthy rural communities, a sense of connectedness to place, and a scepticism of large-scale and industrial processes), a “true cost of food” worldview (which corresponds roughly to the viewpoint of many economists that externalities should be priced); and “holistic” approaches (including the “holistic management” approach of Allan Savory and the “natural systems agriculture” ideas of Wes Jackson, which both emphasise that sustainable agricultural practices should mimic natural ecosystems). Some of these worldviews also reflect elements of] bear a resemblance to the “agrarian myth” or “rural idyll” discussed earlier.

[37] This chapter has mostly addressed policy makers, although civil society actors are playing an increasingly important role in shaping the future of food systems, not in the least by creating awareness about issues. The analysis in this chapter suggests several other areas where civil society and other actors can contribute to the policy process. First, civil society actors, along with academics and researchers, can play an important role in building a shared understanding of the facts, such as by sponsoring or conducting original research and by giving voice to otherwise underrepresented stakeholders. Second, civil society groups can help in counteracting the influence of certain special interests, for example by highlighting instances where there has been an undue influence of other interest groups, or by building “countervailing” coalitions. Third, civil society actors can play an important role in facilitating dialogues with various stakeholders, clarifying values and worldviews, and building a consensus, for example by adopting the role of “food systems champions” (UNEP, 2019[39]). Such initiatives are best seen as complements, rather than substitutes, for public efforts. While civil society can play an important role, civil society actors are also likely to have predetermined agendas and may have fundraising models that can rely on campaigns and can thus also themselves be a form of special interest: for example, many local food policy initiatives appear to be organised by groups opposed to “industrialised” food or genetically modified organisms and/or in favour of organic, local, or vegetarian/vegan food (Ankeny, 2016[112]).

4 The contribution of the seed sector to the triple challenge

The seed sector makes an important contribution to meeting the triple challenge facing food systems by supporting food security and nutrition, livelihoods, and sustainable resource use and climate change mitigation. But contentious issues related to plant breeding arise in debates around food systems. These include the role of private-sector investment in plant breeding; issues around access, benefit sharing and conservation of genetic resources for plant breeding; and the role of new plant breeding technologies. Building on the framework developed in this overall report, this chapter argues that many of the contentious issues derive from the interplay of disagreements over facts, interests, and values.

Key messages

- The seed sector will play an important role in both maintaining and increasing yields to feed a growing global population, while adapting to climate change and environmental pressures.
- However, the seed sector is struggling to navigate a number of contentious issues related to plant breeding that are based on scientific facts, the interests of specific groups and personal values.
- Whether an issue is based on facts, interests or values will affect how it is addressed by policy makers.
- Implications for policy makers include the need for a better targeting of policies, greater support for competition and development of strategies to support collaboration and coexistence between different approaches to plant breeding.
- In addition, to build trust and improve the uptake of new technologies, better communication tools are needed increase access to accurate information.

4.1. Introduction

As a key agricultural input, seeds play a fundamental role in meeting the triple challenge of improving food security and nutrition, supporting the livelihoods of farmers and rural communities, and contributing to sustainable resource use and climate change adaptation and mitigation. Efficiency gains and innovation are essential to improve the productivity, sustainability and resilience of food and agricultural production (OECD, 2019[1]), and innovations in plant breeding can play a particularly powerful role in addressing the triple challenge.[1]

Since the beginning of agriculture, farmers and breeders have been selectively saving seed that performs well to enhance breeding results, enabling gradual changes in agricultural crops to strengthen desirable traits such as yield, disease resistance, storage aptitude and other processing qualities (e.g. fibre length, oil content, flour quality) (Kingsbury, 2009[2]) (Rhode and Olmstead, 2008[3]) (Kloppenburg, 1988[4]).[2] Plant breeding has also enabled certain crops to adapt to broader climatic and geographic zones, expanding their cultivation and increasing their importance in food systems. The advent of modern plant breeding has dramatically accelerated the breeding process and enabled strong yield growth. High yielding varieties formed part of the new technologies developed and adopted by farmers during the Green Revolution beginning in the 1960s (Evenson and Golin, 2003[5]).[3] In recent decades, plant breeding has enabled agricultural crops to rapidly adapt to climate change, the evolution of pests and diseases and market preferences. This potential for adaptation and genetic improvement, driven by plant breeding, can help meet the triple challenge.

Progress in plant breeding, however, has not been entirely uncontested. Contentious issues include the perceived dominance of a handful of agribusiness firms; questions about access to and benefits from genetic resources; and the appropriate regulatory approaches to genetic engineering. Some stakeholders consider that the increasing privatisation of plant breeding, the development of intellectual property protection on plant varieties, and the high prices of modern varieties have negatively affected farmer livelihoods. Others have voiced concerns about the potential environmental effects of intensive farming practices (such as irrigation, crop protection chemicals and fertilisers) required by some of the high yielding varieties introduced during the Green Revolution, as well as about the potential biosafety of transgenic organisms. At the same time, many believe that the accessibility of high-quality seed is vital to support the livelihoods and resilience of farmers, and therefore advocate for government policies that enable the availability of a diversity of crops and varieties for growers, including those developed using the latest technologies.[4] Proponents of new plant breeding techniques such as gene editing also argue that these tools could play a key role in reducing carbon emissions and the use of agro-chemicals, thus supporting more sustainable agriculture. And while some emphasise the importance of developing formal seed markets, others have pointed out that informal farmer seed networks continue to play an important role in the developing world.[5]

Over the past few decades, disagreements over these contentious issues have been playing out in science, the media, and politics. There is no clear resolution to many of these disagreements, posing challenges for the seed sector to help meet the triple challenge. Sections 4.2 to 4.4 discuss in more detail how plant breeding and the seed sector more broadly can help food systems meet this challenge. Section 4.5 then discusses a number of contentious policy issues. Section 4.6 provides an interpretation of why seed policy questions are often contentious and explores potential policy approaches.

4.2. Food security and nutrition

The seed sector directly influences three dimensions of food security and nutrition: food availability, access, and stability. The seed sector contributes to food security and nutrition through productivity growth, improved resilience and quality improvement, allowing a greater availability of nutritious food at lower prices.

Historically, improvements in varieties have underpinned large gains in agricultural productivity and food availability around the world (Huang, Pray and Rozelle, 2002[6]). Experts estimate that between 1981 and 2000, improved varieties were responsible for 40% of the growth in crop production in developing countries (Evenson and Golin, 2003[5]) while in the United States, improved maize varieties were responsible for more than half of the sevenfold increase in yield between the 1930s and the present (Fernandez-Cornejo, 2004[7]). In the United Kingdom, increases in cereal yields since 1982 were mostly due to better varieties (Mackay, 2011[8]). Recent findings suggest that there is still considerable scope to increase crop yields through genetic improvement.[6]

In addition to the availability of calories, nutrition also depends on various micronutrients (FAO, 2019[9]). Increased yields due to plant breeding have contributed to the increased affordability of many nutritious crops, including fruits and vegetables. However, despite considerable advances in plant breeding and increases in yields, malnutrition remains a problem for poor communities in both developing and developed countries. One way plant breeding could help combat this is through biofortification (Osendarp et al., 2018[10]), a process that increases the density of vitamins and minerals (e.g. zinc, iron, and vitamin A) in a crop using either conventional breeding methods or genetic engineering. Current biofortification programmes target foods widely consumed by low-income families globally (such as beans, rice, maize, sorghum, sweet potato, cassava) (WHO, 2020[11]), including those in Africa, Asia, and Latin America. More than 15 million people in developing countries now grow and consume biofortified crops (Saltzman et al., 2017[12]). Future efforts in the area of biofortification are focused on strengthening the supply of, and the demand for, biofortified staple food crops and facilitating targeted investment to those crop–country combinations that have the highest potential nutritional impact (Saltzman et al., 2017[12]).[7]

Crops are vulnerable to various stresses, such as fungi, insects, or adverse weather conditions. Pests and diseases in particular are problematic, as these evolve over time to develop resistance to the natural defences of crop varieties. Spielman and Smale (2017[13]) argue that consistent varietal turnover rates are needed to sustain and stabilise yields over time by protecting crops from changing biotic and abiotic stresses.[8] As such, even where yields remain relatively constant, plant breeders play a crucial role in preventing yield decline caused by pests and disease and climate shocks. Rhode and Olmstead (2008[3]) have shown the historical importance of breeding in preventing a decline in wheat yields in the United States in the 19th century; they estimate that without the breeding of new pest and disease resistant varieties, wheat yields would have been 46% lower in the second half of the 19th century due to increasing pest pressures. Plant breeding and varietal turnover to protect against crop pests and diseases will only become more important in the future, given predicted changes in climate and the increasingly globalised trade in agricultural products. While trade makes an important contribution to food security, it also means that crop pests and diseases can readily cross international borders and multiply quickly (FAO, 2018[14]).

Plant breeding will also play a critical role in climate adaptation strategies (Rosegrant et al., 2014[15]). Changes in weather patterns are already affecting growing seasons and crop production, particularly in tropical regions (Access to Seeds Index, 2019[16]). These problems are expected to worsen as temperatures and extreme weather events increase (Challinor et al., 2016[17]). In addition, as the impacts of climate change become more severe and further threaten food security, it is likely that the poorest populations will suffer the most. For these communities, plant breeding that can create crop varieties with a greater resilience to extreme weather conditions will be particularly important.

Plant breeding innovations are only the first step in a long journey to the farm and finally to the fork. New characteristics need to be available to farmers in high performing varieties that are generally well adapted to the agro-ecological region where they will be grown. This requires not only breeding facilities, but also multiplication and distribution infrastructure for registered varieties. It also requires the provision of authentic, high-quality seed typically ensured through variety registration, seed certification (Box 4.1), and phytosanitary measures. Moreover, while plant breeding is an essential component of agricultural productivity growth in the developing world, complementary actions are required to ensure productivity growth, including improvements in fertilisers and pesticides, improved agronomic and livestock practices (in relation to crops used for feed), and major public investments in irrigation, roads, marketing systems, and land reforms (Hazell, 2009[18]).

Box 4.1. The OECD Seed Schemes

Since the 1960s, the OECD Seed Schemes has been certifying the varietal identity and purity of seed lots destined for international trade. As of 2020, 61 countries (both developed and developing) participate in the OECD Seed Schemes.

The Schemes facilitate the movement of high quality agricultural seeds across borders by harmonising certification standards and procedures. This harmonisation helps to improve domestic production, develop export markets, and provides farmers, plant breeders and authorities with reassurance as new markets open up. As such, many participating countries have now adopted OECD rules and regulations as part of their national laws.

The ultimate goal of the seed schemes is to ensure that farmers can trust the seed they are buying. In 2016-17, the OECD Seed Schemes certified 1.2 billion kg of seed, roughly a third (28%) of the total global exports of field crops (pulses, cereals, industrial crops and forages). Currently, over 60 000 varieties of agricultural crops are registered under the OECD Seed Schemes.

The OECD Seed Schemes form a key part of the international regulatory framework governing the seed sector and works in close co-operation with other international seed-related organisations.

Expanding farmers' access to breeding innovations remains a challenge. It is estimated that the 13 leading global seed companies together reach no more than 10% of the world's 500 million small farms (Access to Seeds Index, 2019[16]). Therefore, despite their potential, innovations may not immediately translate into increased farm productivity unless accompanied by policies that improve access, such as a better infrastructure in rural areas and a supportive environment for innovation and business (World Bank., 2019[19]). There is also a growing trend of participatory approaches to ensure that the improved varieties are meeting the needs of farmers (Westengen and Winge, 2020[20]).

4.3. Livelihoods

Numerous studies have shown that increases in the incomes of smallholder farmers can have an important impact on extreme poverty and that improvements in agricultural productivity therefore not only improve food security and nutrition, but also socio-economic development (Qaim, 2016[21]).

Under suitable production conditions, improved varieties can help increase farm income as the gains from greater production (or lower costs for other inputs) offset the cost of the seed itself. Access to new varieties of food staple crops is a well-documented method for increasing individual agricultural productivity, improving the quality of crops and ensuring resilience to pests and disease, thereby improving rural livelihoods (Spielman and Smale, 2017[13]). Some varieties, bred using genetic engineering or new plant breeding techniques, have the potential to also reduce the need for agricultural inputs such as fertilisers and pesticides, and to reduce harvesting costs by controlling plant height and ripening times, which affect the amount of labour/mechanisation used per hectare (Heisey and Fuglie, 2018[22]). Breeding can also have an important impact on the demand for agricultural products and prices paid to farmers: if new varieties are able to produce agricultural crops that meet certain quality standards (size, taste, colour), they can provide farmers with access to new markets and hence additional income.

Plant breeding can also help to increase resilience to environmental stress. Varieties with greater drought tolerance in particular can help farmers adapt to changes in water availability. Drought-tolerant sugarcane cultivars are being developed in several countries, including Brazil, India, and Indonesia. The Water Efficient Maize for Africa (WEMA) project is developing drought-tolerant varieties with the intention to make these available royalty-free to smallholder farmers through African seed companies (Oikeh et al., 2014[23]). However, it is worth noting that increased resilience to adverse growing conditions may come at the cost of lower yields under good growing conditions.

Despite the potential benefits, the world's poorest farmers may be reluctant to adopt new varieties as the costs of modern varieties and complementary inputs (e.g. irrigation, pesticides and fertilisers) may be significantly higher than their previous production practices and agricultural inputs, and as they may be concerned about risks (e.g. crop failure).

It is also worth noting that widespread agricultural productivity growth does not necessarily boost aggregate farm incomes, as higher productivity also tends to lower prices. Due to global productivity growth outstripping global demand growth, there has been a long-run decline in real cereal prices since at least the early 20th century, albeit interrupted by occasional periods of volatility (OECD/FAO, 2019[24]). Historically, the main beneficiaries of productivity growth in agriculture have therefore been consumers, who enjoy lower food prices due to the decline in commodity prices. The overall impact on farmers is more ambiguous, as declining commodity prices present a challenge for farmers who fail to achieve productivity growth (Alston, 2018[25]). On the other hand, as economic development reduces the number of people working in agriculture, remaining farmers who manage to increase productivity may see gains. Moreover, in poor countries farmers and others working in agriculture may often be net buyers of food, and may hence benefit from lower food prices.

In summary, plant breeding can deliver important gains for farmers, boosting productivity and improving resilience to climate shocks, pests and disease. However, the effect on farmers' livelihoods is more ambiguous: productivity growth reduces prices, putting pressure on farmers who do not achieve productivity gains.

4.4. Environmental sustainability

As discussed in Chapter 1, crop production can be increased in three main ways: through greater land use, through greater use of agricultural inputs, or through improved agricultural productivity. Agricultural expansion onto new lands and the increased use of agricultural inputs can have considerable, negative environmental consequences depending on the land, inputs and context. Plant breeding is one of the main tools available to the agricultural sector to achieve greater agricultural productivity, and hence deliver positive outcomes for sustainable resources use and climate change mitigation.

By helping farmers achieve greater yields, plant breeding may help reduce the expansion of agricultural land, thereby reducing land use change (LUC) and the resulting greenhouse gas emissions and preserving natural biodiversity. This is particularly important in regions where the expansion of agricultural land involves the conversion of carbon rich and biodiverse landscapes (IPCC, 2019[26]). Plant breeding and genetic modification of grazing crops also has the potential to improve the quality of pasture and feed and the feed conversion efficiency of ruminant livestock. This leads to a decrease in methane emissions while reducing the need for more land use for the production of animal protein (Herrero, M. et al., 2016[27]).

Studies have shown that increases in productivity attributed to the Green Revolution were land saving at the global level, helping to protect millions of hectares of natural habitat (Villoria, 2019[28]). However, yield growth is necessary but not sufficient for land saving. For example, yield growth in lower-yielding countries may stimulate extra investment in agriculture, perhaps leading to a partial relocation of production from relatively higher-yielding parts of the world to those lower yielding countries. This may paradoxically result in increased deforestation and environmental damage if the right environmental safeguards, such as capping or regulating land use and training in Good Agricultural Practices (GAP), are not put in place (Hertel, Ramankutty and Baldos, 2014[29]).

The high yielding varieties of the Green Revolution work best with well-irrigated and fertilised soils. Some of the varieties developed during the Green Revolution were also more susceptible to pests and diseases, and farmers used additional pesticides to ensure maximum yield (Foley et al., 2011[30]). The intensive use of these inputs in some regions led to biodiversity loss as well as soil and water pollution (Khoury et al., 2014[31]) (Pingali, 2015[32]).[9] However, when suitable incentives exist, new plant breeding offers important opportunities for reducing water, fertiliser and pesticide use by improving input efficiency (Voss-Fels et al, 2019[33]).[10]

The seed sector also has an important role to play in the conservation of plant genetic resources (Euroseeds, 2020[34]). Genetic diversity is an important element for populations to adapt to changing environments, such as climate change (López-Noriega et al., 2012[35]) (FAO, 2015[36]).[11] These conservation issues are discussed in more detail in Section 4.4.

Although COVID-19 is currently creating disruptions in the sector (Box 4.2), the seed sector has an important role to play in meeting the triple challenge. The FAO Commission on Genetic Resources for Food and Agriculture recommends strengthening both formal and informal seed systems to improve the availability of and access to quality seeds of a diverse range of adapted crop varieties to achieve food and livelihood security, especially in developing countries. The role of the seed sector will differ by region or country, depending on differences in level of development, regulatory frameworks, infrastructure, and access to markets. Developing countries are increasingly involved in the global seed industry as both producers and users of new varieties.

Box 4.2. The impact of COVID-19 on the seed sector

A seed lot can be expected to travel through several countries for multiplication, production, processing, and packaging before it reaches a farmer. It is also time sensitive, with defined periods for sowing and harvesting different crops. As such, the necessary restrictions on movement and transport put in place by governments to protect their people from COVID-19 have the potential to seriously affect the production, certification, distribution and cost of seed. This presents a problem for all countries, but is likely to have a greater impact in developing countries, which may be particularly hard hit by the economic down-turn and relatively more reliant on agriculture.

The classification of the agriculture sector as "essential" in all countries is important in order for the continued production and movement of seed, and avoiding changes to regulatory frameworks is critical at a time when relevant authorities are short staffed and under pressure (OECD, 2020[37]). In order to successfully support the seed sector through this unprecedented crisis, policy makers need greater visibility over seed breeding, production, certification and trade.

OECD's Trade and Agriculture Directorate, in collaboration with the Japanese government, is in the process of analysing the resilience of the international seed market during the COVID-19 pandemic, including a case study of the Asian seed market. In addition, following in the footsteps of the Agricultural Market Information System (AMIS) developed in response to the global food price hikes in 2007/08 and 2010, OECD will work to develop a digital seed information system that provides countries with greater visibility over seed production, certification, and potentially flows.

4.5. What are the contentious issues?

As highlighted in the previous section, plant breeding plays a critical role in meeting the triple challenge. However, the seed sector is struggling with a number of contentious issues. These issues are closely interconnected, but for the purpose of this case study, they will be explored under the following headings:

- Sources of investment in plant breeding
- Access, benefit sharing and conservation of genetic resources for plant breeding
- Modern plant breeding technologies.

As discussed in Chapters 1 and 2, in designing coherent policies for the global food system, one challenge lies in mediating trade-offs. In the case of the seed sector, an additional challenge is that there is debate over whether some issues pose a trade-off or not. For example, certain stakeholders perceive that genetic engineering of plants creates risks to human and environmental health, as well as increasing corporate control over the food chain (Bonny, 2017[38]). From this perspective, the use of transgenic crops comes with important (and to some, unacceptable) trade-offs. This perspective is far from universally shared, however. Contentious issues in the seed sector thus illustrate that there is not necessarily a consensus on what constitutes a trade-off in the global food system. Whether an issue is seen as a real trade-off or not will in turn affect how it is addressed by policy makers.

Much of the information in this section was provided by the National Designated Authorities to the OECD and observer organisations to the OECD Seed Schemes.[12] Stakeholders were invited to provide feedback on an OECD questionnaire.

Sources of investment in plant breeding

Historically, the public sector played a dominant role in plant breeding, but considerable shifts in funding have taken place over the past 60 years. Despite significant and demonstrated benefits to society, actual public sector spending on agricultural research is decreasing, particularly in developed countries (OECD, 2019[39]) (Heisey and Fuglie, 2018[22]) (Clancy, Fuglie and Heisey, 2016[40]). At the same time, intellectual property rights protections and other incentives put in place by governments have stimulated private sector R&D in plant breeding (OECD, 2019[39]) and research in high-income countries is increasingly undertaken by companies (Heisey and Fuglie, 2018[22]).[13] A review of agricultural innovation systems undertaken by the OECD in 2019 found that funding mechanisms for agricultural research have also changed, with processes for obtaining public funding becoming more competitive and with an increased emphasis on public-private collaboration (OECD, 2019[39]).[14]

As an illustration of the relative importance of private and public investments, in 2017, Monsanto's annual research budget was USD 1.6 billion (Monsanto, 2017[41]), while the CGIAR (formerly the Consultative Group on International Agricultural Research), one of the main intergovernmental initiatives to support agricultural innovation and breeding for developing countries, had an annual budget of USD 849 million (CGIAR, 2017[42]).[15]

A potential trade-off associated with this shift from publicly to privately financed R&D is that private-sector investments are likely to be skewed towards crops with larger commercial markets; to traits preferred by manufacturers, retailers and consumers; and to qualities that are conducive to intellectual property protection such as hybridisation. Investment in crops with larger markets potentially comes at the expense of investments in crops with smaller markets, or traits that are useful but more difficult to monetise. A different concern is the legal uncertainty associated with the regulatory frameworks to stimulate private-sector innovation, such as Plant Variety Protection (PVP) and seed marketing regulations. Any uncertainty around the application of PVP may affect farmers' ability to save seed, particularly in developing countries where farmers may rely on saved seed to reduce input costs and because of limited access to formal seed markets (FAO, 2018[14]). [16]

OECD country reviews of innovation, agricultural productivity and sustainability systems have identified a number of intellectual property mechanisms that support private sector investments in innovation, including PVP, patents, trade secrets, trademarks, and geographical indications (OECD, 2019[39]). This case study will look specifically at the benefits and challenges presented by PVP and patents.

The direction of plant breeding

The public and private sector dominate in different regions and crops (Areal and Riesgo, 2014[43]) (Gustafson, 2016[44]). For example, while maize breeding is usually led by the private sector, many grains with small markets are the domain of the public sector. The public sector increasingly focuses on fundamental research, or on crops for which little private sector interest exists (Heisey and Fuglie, 2018[22]). For example, the Swiss market is small and fairly specific due to the country's size and topography, limiting private sector investments in plant breeding tailored to the needs of Swiss farmers. In response, the government developed a new strategy for plant breeding to support information and technology exchange and breeding of key crops (Federal Office for Agriculture, 2015[45]).

As governments have put in place PVP frameworks to incentivise the private sector to assume a greater proportion of breeding, private research efforts have naturally shifted to those crops that deliver the greatest profits at the expense of those crops that do not.

Larger commercial markets tend to attract more investment and are hence likely to witness faster innovation. Analysis of European seed markets found that a 10% increase in total market size (as measured in revenues) was associated with an increase of 4-5% in the number of new varieties introduced per year (OECD, 2018[46]).[17] For example, if the market for barley seed in Germany grew by 10%, this would on average be expected to raise by 4-5% the number of new barley varieties introduced each year in the market. This finding also implies that if the commercial market for a crop is smaller, it will receive less R&D and hence see less innovation over time.

Crops with smaller markets may not receive much private investment or plant-breeding effort, despite their importance in terms of genetic diversity and their potential in terms of food security or livelihoods in some parts of the world. Such crops have been labelled "underutilised," "neglected," "minor" or "orphan" crops. For example, root, tuber and banana crops have received limited attention from researchers, extension service providers and policy makers, but are important staple crops in some of the world's poorest regions. Strengthening research in such neglected and underutilised crops could thus have a significant impact on malnutrition. In some cases, the commercial potential of such crops goes unrealised because of a lack of scientific knowledge or recognition of the potential benefits of the crop downstream (e.g. food security and nutrition), a lack of knowledge of how to adapt the crop to consumer markets, or market imperfections and failures (Gruère, Giuliani and Smale, 2006[47]).

The same is true for investments in developing specific traits. For example, a surprisingly large share of agricultural R&D is undertaken by consumer goods manufacturers such as PepsiCo, Kraft Heinz and Nestlé.[18] Such firms made up 44% of the total developed-country private agricultural R&D in 2011. Pardey et al. (2016[48]) and Gopinath et al. (1996[49]) suggest that these companies are keen to invest in agriculture because abundant, low cost raw materials deliver productivity growth in food processing. R&D funded by these firms is thus likely to focus on the development of varieties that feed into their processed food supply chains. By contrast, private-sector investment is less likely for traits with hard-to-monetise benefits, such as those that would improve environmental sustainability of farm production.

Moreover, even in otherwise profitable markets some geographic or agronomic niches may be too small for profitable private-sector involvement. For example, even though the US maize market is the largest seed market in the world and attracts considerable commercial investment, there are several niches that receive little attention. This is the case for silage maize in New York, Pennsylvania or Wisconsin and for white kernel maize in Texas.[19]

A particularly pressing concern is that current levels of private-sector investment may not be sufficient to provide the innovation needed for crops in developing countries. Knowledge spill overs from developed countries to developing countries are limited due to variations in agro-environmental conditions: breeding for temperate climates will have fewer applications in tropical climates, and vice versa. In addition, the kind of production constraints experienced by farmers in developing countries are very different from those in developed countries (Heisey and Fuglie, 2018[22]).

Smaller, national or regional companies in developing countries may be better placed in terms of breeding of crops to meet the needs of local farmers due to better knowledge of local conditions and crops and closer relationships with local and regional research and development organisations (Gustafson, 2016[44]).

The Access to Seeds Index highlights the relative absence of seed company activity in certain countries, attributing this absence to poor infrastructure and a weak enabling environment for businesses (Access to Seeds Index, 2019[16]).[20] However, some of the leading multinationals are increasingly active in the emerging commercial seed markets in Africa, in particular through purchasing and investing in local companies (African Centre for Biodiversity, 2015[50]). In recent years the seed industry also seems to have demonstrated a more responsive approach toward smallholder farmers (Access to Seeds Index, 2019[16]). In India, the commercial seed sector is growing at more than 10% per year (Spielman, D. et al., 2014[51]). Despite this growing interest, large multinationals may fail to cater to developing country needs and local markets, limiting themselves to certain crops (e.g. maize) and breeding strategies (e.g. hybridisation) that offer greater profits and biological means to protect intellectual property.[21] In India, private-sector investment has focused on cotton, maize, pearl millet, sorghum, and vegetable crops where hybrids are possible (Spielman, D. et al., 2014[51]).

Even though investment in agricultural R&D is still highest in developed countries, this trend is shifting. World Bank figures show that public and private expenditures on agricultural R&D in high-income countries fell from 69% of the global total in 1980 to 55% in 2011. Meanwhile, middle-income countries (including the Peoples Republic of China – hereafter “China”, Brazil and India) were responsible for 43% of global spending on agricultural R&D; up from a share of only 29% in 1980 (Pardey et al., 2016[48]). Heisey and Fuglie (2018[22]) argue the world may become more dependent on the public sector research of countries like China, India, and Brazil when it comes to the innovation needed to address food and environment challenges, and plant breeding in these emerging economies may enable greater spill overs to developing countries that have similar climatic zones.

One risk associated with underinvesting in plant breeding for certain varieties and climatic zones is vulnerability to pests and diseases. An example is the emergence of new virulent strains of wheat stem rust in Uganda in the late 1990s, and their subsequent spread throughout Kenya, Ethiopia, South Africa and elsewhere in Africa. Years of previous success in keeping the disease at bay meant that research funding was no longer targeted at the disease, leaving only a few researchers left to tackle the crisis (Pardey et al., 2016[48]).

A number of mechanisms have been put in place across OECD countries to capitalise on the benefits of both private and public sector funding and ensure more equitable benefits from innovation (OECD, 2019[39]). The central challenge is that while PVP and patenting may incentivise private funding of plant breeding, broad and easy access to the innovation is subsequently limited by higher prices. On the other hand, if R&D is financed by the public sector, the innovation could be made available more cheaply, but this requires the use of public funds and raises the question of whether innovation will be demand-driven. Public-private partnerships (PPPs) can under the right circumstances combine the best of both approaches. Moreddu (2016[52]) finds that PPPs are essential to increase the efficiency with which public funds are used, and improve the adaptation of innovation to demand, leading to wider diffusion. Intellectual Property Rights (IPRs), governance and implementation issues need to be carefully considered to ensure success. Areal and Riesgo (2014[43]) found that in Europe, PPPs mainly focus on strategic crops for the European market and on strategic traits (e.g. climate change adaptation, food security and biofuels). That said, PPPs also tend to focus on foundational technologies and pre-breeding and do not follow through to the development of new varieties. They may also pay limited attention to minor crops. For Canada, Phillips, Boland and Ryan (2013[53]) found that PPPs in plant breeding often required extended public sector funding, as it takes about 15 years to generate an independent cash flow (e.g. through royalties).

Heisey and Fuglie (2018[22]) explored the potential role of private sector levies in better addressing the needs of farmers. In Canada, the Saskatchewan Pulse Growers (SPG) scheme includes over 18 000 pulse producers. The scheme imposes a mandatory 1% levy on the value of the gross sale of all pulse crops and uses revenues to fund various research projects, provide royalty-free seed and carry out agronomic research. The SPG has been very successful at working with both academic and private plant breeding institutions. As such, pulse yields have increased by 40% in two decades and the internal rate of return on SPG investments has been estimated at 20% per year. Levy-funded research holds some important benefits compared to completely private or completely public R&D, including encouraging adoption by farmers. The levy is based on farmers’ total output (regardless of the varieties used). In the case of new varieties, the levy may be zero, to encourage farmers to experiment and adopt new, improved varieties more quickly and at a lower cost than with the private system. As farmer associations direct the work, farmers have a greater voice in the process, which helps ensure they will benefit. While this may ensure that research responds to farmer needs, it may assign a lower priority to innovations which mainly benefit consumers or the environment.

Farmers

Ensuring access to improved varieties in developing countries often proves difficult for a range of reasons, including poor infrastructure and distribution channels; weak regulatory frameworks for seed companies; low private and public investment (as discussed above); lack of harmonised legislation to facilitate the movement of seeds between countries; a lack of complementary inputs (e.g. fertiliser); or a lack of capacity to make use of agricultural technologies (Access to Seeds Index, 2019[16]). A persistent concern is whether the privatisation of plant breeding limits agricultural innovations from reaching the world's poorest farmers.

Many farmers in the developing and developed world rely on informal systems of seed exchange among farmers, rather than the formal seed sector (i.e. public and private plant breeding and seed production) (van Etten, 2017[54]). The use of improved varieties (mostly channelled by the formal seed sector) is closely linked to the development of the agriculture sector as a whole, including adoption of modern agronomic practices by farmers. A number of developing countries have undertaken policy and regulatory reforms to strengthen the formal seed market, and such efforts have been supported by the private sector, developed country governments and aid organisations. These reforms encourage investment by plant breeding companies and can improve farmers' access to new varieties in developing countries.

However, in the context of the triple challenge, policy and regulatory reforms may, at least initially, be a poor fit for domestic smallholder agriculture and be better adapted to large-scale, export-oriented sectors. In this case, immediate benefits may be seen at the national level with regard to trade and export earnings but improved productivity from new high-yielding and disease-resistant varieties may be slower to materialise for the majority of domestic farmers who continue to use informal seed systems. It takes time for the benefits to trickle down to local farmers and this raises questions regarding how policy reforms can be better tailored to maximise their impact for those most in need.

Some stakeholders have voiced concerns that IPR frameworks designed to increase private sector investment in plant breeding limit farmers' access to seed through restrictions on farm-saved seed (FAO, 2018[14]). IPR protection for new plant varieties has emerged gradually. Historically, plants were not covered by any form of patent and were considered products of nature. However, developing a new variety is a costly and time-consuming process: a common rule of thumb in the industry is that it takes more than ten years to develop a new field crop variety, with even longer processes for tree crops. In the absence of government subsidies or grants, plant breeders need an effective intellectual property protection system to enable them to capture the financial benefits from their investments. Over time, this has led to the emergence of a system of IPR protection for plant varieties. The system of IPRs for new plant varieties is mostly *sui generis*, that is, a system distinct from the patent system governing most other innovative industries. As with other IP systems, PVP presents a trade-off between providing incentives for innovation (which would suggest allowing the inventor to charge users) and stimulating adoption (which would suggest making the invention available as cheaply as possible).[22]

An international PVP system was established by the International Union for the Protection of New Varieties of Plants (UPOV) through successive revisions of its International Convention for the Protection of New Varieties of Plants, or UPOV Convention. [23] The original convention (adopted in 1961) was revised in 1972, 1978 and 1991. There are currently 76 members of UPOV, mostly in the developed world, but the differentiated implementation of the various UPOV Acts by countries can create confusion. The first UPOV Convention (the 1961 Act) and the 1978 Act allowed governments to permit farmers to save seeds of varieties covered by Plant Breeders' Rights (PBR), as long as it was not done for the production of seed for marketing. The 1991 Act of the UPOV Convention further clarified permission through two exemptions. The first allows for private and non-commercial use of seeds by subsistence farmers (who only produce enough food for their own consumption) and hobby gardeners, whose activities are considered private and non-commercial. The second exemption allows countries adhering to the UPOV Convention to permit seed saving by farmers "within reasonable limits and subject to the safeguarding of the legitimate interests of the breeder" (FAO, 2018[14]) (ISF, 2012[55]). In the United Kingdom, for example, farm-saved seed is allowed, but an industry-wide system exists for the collection of royalty payments on farm-saved seed. Royalty levels for farm-saved seed are lower than royalty rates on certified ("new") seed. The system applies only to newer varieties (BSPB, 2014[56]).

Despite the private and non-commercial use exemption in the UPOV convention, NGOs have voiced their concern that plant breeders' rights modelled after the UPOV Acts may be preventing the world's poorest farmers from having access to new varieties. A related concern is that, without further clarification of the private and non-commercial use exception, such legislation may prevent farmers from saving, using, exchanging and selling farm-saved seeds. Such concerns were for instance expressed by Oxfam during an FAO symposium (FAO, 2018[14]). Oxfam also expressed concern that the UPOV Convention prevents its adherents from aligning their PVP law with other international obligations under the Convention for Biodiversity and the International Treaty for Plant Genetic Resources for Food and Agriculture.[24] Oxfam called on UPOV to "establish a proper and explicit balance between Farmers' Rights and Plant Breeders' Rights in order not to obstruct the practice of seed exchange and trade amongst smallholder farmers", for example by "providing a clear interpretation of the private and non-commercial use exemption… to assist (prospective) member states to include such interpretation in their national legislation" (FAO, 2018[14]). Following the symposium, Oxfam, Plantum and Euroseeds developed a flowchart to help users understand whether or not an activity using self-produced seed is covered by the exception (Oxfam, Plantum and Euroseeds, 2019[57]).[25]

While the TRIPS Agreement requires WTO members to implement a *sui generis* plant variety protection system, there is no obligation to adopt the UPOV convention or to adopt the most recent (1991) Act. Alternative PVP systems have emerged in some countries, including India, Ethiopia, Thailand and Malaysia, while Norway decided to remain an adherent to the 1978 Act of the UPOV Convention (rather than updating to the 1991 Act) as it was considered to be more supportive of Farmers' Rights (Government of Norway, 2018[58]), while in India, PVP and Farmers' Rights are addressed in the same Act (Ramanna, 2006[59]). Alternative systems may also include a requirement for the disclosure of information on the geographical origin of genetic resources as a way to fulfil policy objectives linked to monitoring the utilisation of genetic resources.

Notwithstanding the concerns of some NGOs, an impact study carried out by UPOV identified a number of positive changes that took place following adoption of PVP across a range of countries (Argentina, China, Kenya, Poland and Korea). These changes included availability of new foreign plant varieties; diversification of agriculture and horticulture systems; stimulation of commercial breeding activities in domestic public research institutes and domestic seed companies, leading to an increase in the number of domestic breeders; an increase in domestic breeding and domestically bred varieties; and rapid adoption of new protected varieties by farmers. The study also noted an increase in collaboration between national research institutes and foreign seed companies and more public / private partnerships for plant breeding (UPOV, 2005[60]).

Plant breeders

Intellectual property rights enable firms to recover their investment by preventing competitors from making use of an innovation for a limited period of time. The challenge however is to provide incentives for private investment in innovation, without compromising the sharing of knowledge and further innovation. In most countries, there are two main types of IPRs used in plant breeding: patents for genetic traits and PVP. The UPOV system of PVPs addresses the issue of innovation through the "breeder's right". It gives the developer of a new variety the right to exclude others from commercialisation, but allows researchers to use the variety for further breeding research. Genetic traits such as herbicide resistance, however, are subject to patents, which generally provide less opportunities for further research.

Patents on genes, genetic processes, and genetically engineered plant varieties have been concentrated among a handful of large multinational companies (Clancy and Moschini, 2017[61]). Markets for genetically engineered traits are considerably more concentrated than the underlying seed markets (OECD, 2018[46]) (Deconinck, 2020[62]). This raises concerns about the impact of market concentration on innovation as well as market power and unequal benefit distribution (Stone, 2010[63]). It has also led to broader worries about the influence of a relatively small group of companies on food supply chains and public sector processes, such as risk assessments (Fernandez-Cornejo and Just, 2007[64]).

There is relatively little evidence available on the impact of market concentration on innovation in the seed industry (OECD, 2018[46]). This presents a barrier to overcoming public concern, as an informed policy debate requires detailed information. OECD (2018[65]) emphasises the importance of having precise data when discussing issues of market concentration and power, noting that publicly available data is often highly aggregated and may present a misleading picture in view of important variations by crop and by country. However, detailed data on market shares in different countries and market segments are typically not available in the public domain.

IPRs, combined with the large amount of knowledge and expertise required to set up a breeding company and the long development period for new varieties, creates a barrier for new companies to enter the plant-breeding sector. However, new plant breeding techniques (discussed in more detail below) may enable smaller companies to enter the market because of their speed and lower costs. For example, there are an increasing number of CRISPR biotechnology companies emerging from academic institutions (Brinegar et al., 2017[66]). Institutional innovations can also help facilitate access to intellectual property in the sector. For example, a number of vegetable breeding companies founded the International Licencing Platform (ILP), under which they grant each other access to patents to encourage innovation (ILP, 2020[67])

Access, benefit sharing and conservation of genetic resources for plant breeding

Maintaining crop genetic diversity is important both as an input into plant breeding (to ensure there is sufficient genetic material from which to select) and as an output (to ensure crop adaptation potential in the face of climate change, pests and diseases). Most countries now grow food crops which originated in other countries or continents (Khoury, C. et al, 2016[68]). Wild ancestral relatives or landraces which could be useful in plant breeding are therefore likely to be located outside of national borders (ISF, 2012[55]) (BSPB, 2014[56]). This raises questions about how to ensure access to genetic resources, how to stimulate the preservation and sustainable use of genetic diversity, and how to organise benefit-sharing arising from the use of genetic resources, some of which may be the result of centuries of cultivation efforts by farmers.

Bioprospecting is the process of searching for and discovering biological resources such as plants, animals or fungi that can then be used to develop valuable commercial products, such as new plant varieties or medicines. However, this may also be referred to as biopiracy when it is felt that researchers and companies have made use of biological resources without official agreement or sufficient compensation, particularly from developing countries and rural communities that have been conserving them. To ensure fair access and benefit sharing from plant genetic resources, a number of international policies and regulations governing the conservation, exchange and use of genetic resources have emerged over the past 70 years. These have created a complex regulatory landscape. The two main international agreements are the Convention on Biodiversity (CBD) (and its supplementary agreement, the Nagoya Protocol) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

The CBD entered into force in 1993 and recognises sovereign rights over genetic resources and the authority of national governments to determine access to those resources, as well as tasking governments with the responsibility of preserving that genetic diversity.

The Nagoya Protocol is a supplementary agreement to the CBD, which entered into force in 2014 and establishes a framework for “fair and equitable sharing of benefits arising out of the utilization of genetic resources". Those countries that have adopted the Nagoya Protocol commit to setting up a transparent, non-arbitrary process for access to genetic resources and sharing benefits domestically. The Nagoya Protocol also sets up an "Access and Benefit Sharing Clearing-House" to share information on topics such as domestic regulatory ABS requirements.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) entered into force in 2004. This treaty focuses on setting up a system of access and benefit sharing for a specific list of 64 crops (known as "Annex I" crops) used in food and agriculture. These 64 crops include the major food crops (e.g. rice, maize, wheat, potatoes) but exclude some other major agricultural commodities, notably soybeans.

In terms of access, countries ratifying the ITPGRFA agree to make available their genetic diversity as well as information about the crops stored in gene banks. Under the ITPGRFA, material in local, national and international gene banks, including the collections of the CGIAR, are put in a Multilateral System for Access and Benefit-Sharing. Genetic material is made available to users (e.g. plant breeders) under terms and conditions of a Standard Material Transfer Agreement (SMTA). This is a private contract with standard terms and conditions that ensures that the relevant provisions of the International Treaty are followed.

Both the Nagoya Protocol and the ITPGRFA target conservation and sustainable use of plant genetic resources as well as the equitable sharing of benefits arising from their use. The ITPGRFA is recognised as a specialised instrument in the Nagoya Protocol and is limited in scope to the specific list of crops mentioned earlier, while the Nagoya Protocol extends to all other plant genetic resources for food and agriculture.

Article 9 of the ITPGRFA specifically recognises the contribution that farmers have made towards the conservation and development of plant genetic resources. An Ad hoc Technical Expert Group on Farmers' Rights, established by the governing body of the ITPGRFA, has produced an inventory of examples on how to strengthen the implementation of Farmers' Rights and is currently developing options for encouraging, guiding and promoting the realisation of Farmers' Rights.

Access and benefit sharing

Given that access to genetic resources is key to plant breeding, both civil society and industry groups have expressed concern that the different legal frameworks are not working in harmony. While PVP and plant breeders' rights have been integrated into national laws and international trade, there is concern that aspects of the ITPGRFA (and in particular the concept of farmers' rights) have not.

During the period from 2013 to 2019, the Contracting Parties of the ITPGRFA discussed options to enhance the multilateral system of Access and Benefit Sharing. They considered proposals, among others, to make all use of material from the system conditional on mandatory monetary benefit sharing, and to expand the coverage of the system. The International Seed Federation (2012[55]) in particular has suggested delegating the Access and Benefit Sharing responsibilities for all genetic resources for plant breeding to the authority managing genetic resources under the ITPGRFA, arguing that it makes the process more user-friendly. One possibility could be to expand the list of crops in Annex I to cover all crops where breeding occurs, as well as other genetic resources used in breeding these crops (ISF, 2012[55]). However, no consensus was reached at the last session of the Governing Body.[26]

Since its introduction, the ITPGRFA has enabled 4.2 million exchanges of genetic material through almost 60 000 Standard Material Transfer Agreements. The largest share of genetic resources (2.1 million accessions) are from Latin America and the Caribbean, and most of the genetic resources have gone to Asia (1.3 million accessions) (FAO, 2017[69]).[27] All regions are both recipients and sources of germplasm, illustrating the interdependence among countries in terms of genetic resources.

The CBD and ITPGRFA are designed to protect biodiversity and communities, and ensure fair access and benefit sharing. However, the complex interactions between the different treaties and conventions are difficult to navigate and may be particularly burdensome for farmers, breeders and regulators in developing countries. This may jeopardise the international exchange of plant genetic resources.[28]

Another challenge comes from technological developments. While current governance of genetic resources is based on access to physical material, the treaties do not cover genetic information. For example, digital sequence information (DSI) uses computational models to predict and identify when certain genes are expressed. This can significantly improve the efficiency of selection, and can also be used to explore the presence of beneficial genes in underexploited gene banks. However, these new technologies present new challenges to policy makers. The terms and conditions for access to genetic resources and benefit-sharing mechanisms under existing frameworks do not apply to DSI, when DSI is not associated with a physical resource. (Halewood, M. et al., 2018[70]) (Welch, E. et al, 2017[71]). The application of these existing legal access and benefit-sharing frameworks to DSI could create significant costs for plant breeders, and act as barriers to much needed research (Marden, 2018[72]).

Conservation

There is additional concern that, as farmers around the world transition from local varieties to bred varieties with improved productivity and resilience, varietal diversity for certain crops will decrease. This in turn could impact the genepool available for future breeding (Access to Seeds Index, 2019[16]). Although there is limited evidence that genetic diversity of cultivated plants has consistently decreased, genetic uniformity on the field may increase as farmers cultivate the same varieties over large areas (Bonnin et al., 2014[73]) while "genetic erosion" may threaten those crops for which there is limited breeder interest (van de Wouw, M. et al., 2010[74]).

Globally, a significant amount of genetic diversity exists in farms and gardens where crops are cultivated and even more in natural landscapes where wild crop relatives occur. This diversity conserved *in situ*, as well as genetic resources conserved *ex situ* in gene banks, is of inestimable value for humankind. It is challenging to identify, characterise and give value to this diversity as the benefit of these genetic resources may only be revealed in the distant future (Smale, 2005[75]; Gepts, 2006[76]).

At a global level, the gene banks of the CGIAR Research Centres in particular play a significant role in conserving and providing access to the world's genetic resources. As a subset of the ITPGRFA resources, these gene banks contain at present 750 000 accessions[29], about 12% of all plant genetic resources conserved in gene banks. Between 2012 and 2016, the different gene banks of CGIAR distributed almost 600 000 samples of their accessions. Given the overwhelming benefits of these initiatives, continued funding should be an important priority for policy makers (Koo, Pardey and Wright, 2003[77]). The FAO Commission on Genetic Resources for Food and Agriculture also plays an important part in the conservation and sustainable use of genetic resources and the fair and equitable sharing of benefits derived from their use.[30]

Maintaining or increasing diversity conserved on farms and in agricultural systems (*in situ*) is more complex but none the less important. However, the varieties that are planted are often based on demand for the final product, as well as variables such as seed prices, the genetic attributes and physical quality of the seed, costs of other inputs (for example fertiliser), and farmers' expectations and preferences for specific traits and varieties (Spielman and Smale, 2017[13]). Initiatives such as European GenRes Bridge are seeking to strengthen the conservation and sustainable use of genetic resources both *in situ* and *ex situ* across plant, forest and animal domains (GenRes Bridge, 2020[78])

Marketing legislation of seed can also influence the degree of *in situ* genetic diversity in agricultural systems. For example, EU legislation requires that only officially certified seed of agricultural crops (registered varieties) can be marketed to farmers. Current procedures and regulations for variety registration require Distinctness, Uniformity and Stability (DUS) and discourage the registration of heterogeneous plant material.[31] In several jurisdictions, variety registration is seen as a critical component of the seed quality assurance system and was originally introduced to prevent fraudulent claims. However, variety registration systems could indirectly influence the conservation of genetic diversity by limiting the diversity of seed legally available to farmers (Louwaars and Burgaud, 2016[79]). In 2013, it was proposed to develop a new plant reproductive material law in the EU which would create more flexibility, e.g. by making it easier for farmers to use traditional varieties or heterogeneous plant material, which do not fulfil the DUS criteria (EU, 2013[80]). Although this proposal did not move forward, discussions are ongoing regarding what role the variety registration system could take in supporting the conservation of genetic diversity *in situ*.[32]

Modern plant breeding technologies

For centuries, breeders have sought to enhance the genetic make-up of crops though traditional breeding techniques, such as crossing. In more recent times, chemical or radiation-induced mutagenesis has also been used to create genetic variation from which to select sought-after traits. These methods have been successful in changing the genetic make-up of crops but do not deliver predictable outcomes and often result in unwanted mutations. The trial and error involved in these techniques is part of the reason why bringing a new variety to market takes so long. It takes many crosses before a breeder can deliver a variety with the desired combination of genes and the necessary uniformity and stability features needed for agricultural use (EC, 2017[81]). On average, it takes more than ten years from the first cross before a new product gets to market (KWS, 2017[82]).

Among the many technological innovations introduced in plant breeding over the centuries, two in particular are relevant for current policy debates: genetic engineering and the so-called new plant breeding techniques (NPBTs).

Genetic engineering

The discovery of recombinant DNA techniques in the 1980s made it possible to create more specific changes and avoid some of the unwanted mutations that were produced using traditional crossing and hybridisation, leading to the emergence of genetic engineering (GE) technology (see Box 4.3 for a discussion on terminology). This transfer of genetic material can be done using natural vectors such as bacteria or viral components, or by a number of other genetic engineering techniques. In principle, the genetic material transferred could be from the same species (*cisgenic*) or from a different species (*transgenic*). As most of the early applications were transgenic, in practice genetic engineering is often interpreted as meaning “transgenic”.

GE techniques can be used to enhance input traits (e.g. resistance to droughts or herbicides); to improve output traits (e.g. crops with more micronutrients such as Vitamin A); or to create crops for non-traditional uses (e.g. for pharmaceuticals or bio-fuels) (Fernandez-Cornejo, 2004[7]). However, in practice, the most common GE crops are those with enhanced input traits, mainly herbicide tolerance, insect resistance, or the two features combined. The main GE crops produced globally are soybeans (95.9 million hectares in 2018), maize (58.9 million hectares, 2018), cotton (24.9 million hectares 2018) and canola (10.1 million hectares in 2018) (ISAAA, 2020[83]).

The first GE plant was developed in 1982, and the first commercialisation of GE plants took place in 1994 (the Flavr Savr tomato). Since then, GE seeds have had a dramatic impact on the structure and evolution of seed and biotechnology markets (Deconinck, 2020[62]) (OECD, 2018[46]). In 2017, the countries with the largest GE area were the United States (75 million hectares, or 40% of the global total), Brazil (50 million hectares, 26%) and Argentina (24 million hectares, 12%). Developing countries accounted for 53% of the global total of GE crops, and this figure is expected to grow further (ISAAA, 2020[83]).

Box 4.3. Terminology related to genetically engineered organisms

Genetic engineering is a process by which genes are inserted into the genome of an organism. A genetically engineered organism is an organism into which genes coding for desirable traits have been inserted through the process of genetic engineering.

The inserted genes could be from the same species (cisgenic) or a different species (transgenic). Strictly speaking, the inclusion of foreign genetic material is thus not a pre-requisite for genetic engineering. However, many of the first genetically engineered organisms were transgenic, and most of the genetically engineered crops currently available on the market are transgenic. As a result, the terms “genetically engineered” or “genetically modified” are often used as synonyms for “transgenic”. Other terms with a similar meaning are “genetically modified organism”, “living modified organisms” (LMOs) or “biotech crops” (OECD, 2016[84]).

Terminology around modern plant breeding technologies is often contested, and different actors have different preferred terms to describe products of “modern biotechnology” (OECD, 2016[84]). Several countries have legal definitions of relevant terms, that govern which techniques or organisms are subject to regulation. In addition, as discussions have moved out of the scientific literature and into the media, the terminology has taken on new meaning and significance for the public.

Much of the terminology related to genetically engineered organisms is discussed and defined in the Cartagena Protocol on Biosafety (CBD, 2000[85]) and UN FAO Codex (WHO and FAO, 2009[86]) and the Convention on Biological Diversity (CBD, 1993[87]). In 2000, the OECD Working Group on Harmonisation of Regulatory Oversight in Biotechnology settled on the use of “genetic engineering” and “genetically engineered organism” in official documents (OECD, 2000[88]). This case study follows OECD practice in using the following terms:

- *Genetic engineering* (GE) when referring to the insertion of genes with desirable traits from the same or different species.
- *Genetically engineered organism (GEO)* when refereeing to an organism that has been genetically engineered.
- *Transgenic* when referring to organisms that have been created by inserting genetic material from a different species.

This case study may at times make use of the terms Genetic Modification (GM) and Genetically Modified Organisms (GMO), e.g. when referring to studies on public perceptions of “GM”.

Finally, genetic engineering should not be confused with the more recent technologies related to genome (or gene) editing.

New plant breeding techniques (NPBTs)

Plant breeding methods and technologies have continued to evolve, allowing for considerable increases in precision and speed (Hickey et al., 2019[89]). Recent breakthroughs in the so-called NPBTs could potentially lead to significant reductions in the time needed and cost involved to develop new varieties (Scheben and Edwards, 2017[90]) (Schaart et al., 2015[91]). NPBTs cover a broad range of tools and techniques, including cisgenesis, intragenesis, genome editing through site-directed nuclease (SDN), RNA-dependent DNA methylation (RdDM), or reverse breeding. One of the best-known of these new techniques, the CRISPR/Cas9 nuclease system, has received significant attention because of its range of potential applications and relatively low cost.

Genome (or gene) editing is one of the most prominent of the NPBTs and refers to techniques in which DNA is inserted, modified, replaced, or deleted in the genome of a living organism at predetermined locations, offering higher-precision breeding possibilities. Gene editing distinguishes itself from genetic engineering by its high degree of specificity due to the use of specially modified enzymes that create site-specific breaks in the DNA, which are then repaired using the cell's own repair systems Many of the genome-edited crops do not involve the integration of foreign DNA, and the resulting crops are hence not transgenic. The proceedings of an OECD conference on genome editing provide a review of these techniques and their vast potential for future agricultural developments (Friedrichs et al., 2019[92]).

The site-directed nucleases (SDN) such as CRISPR have the potential to dramatically speed up the breeding process and deliver rapid and targeted development of new varieties (Friedrichs et al., 2019[92]). The ability to more rapidly and cost effectively target development in a specific direction promises to speed up the process of innovation. Possible traits include pest and disease resistance, higher resilience to abiotic stresses such as heat, drought, flooding and soil salinity, and higher nutrient use efficiency, product quality and longevity. The SDN technologies could also enable the domestication of neglected crops and faster plant breeding (Qaim, 2020[93]). SDNs can also be useful for certain vegetatively propagated crops, such as banana and cassava, which are difficult to improve through traditional cross breeding techniques; these crops are important staples in developing countries where poverty, malnutrition and climate change present major threats (Qaim, 2016[21]). Many of the gene edited crops that have been developed so far do not carry any transgenes (Shan-e-Ali Zaidi et al., 2019[94]) and cannot be distinguished from non-genome edited varieties.

Divergent risk management approaches

The various techniques used in modern plant breeding are complex and rapidly evolving. There are important differences between techniques, which matter for their potential benefits and risks.[33] Yet in popular debate, terms such as new breeding techniques, gene editing, transgenics and genetic engineering are often used synonymously. This is unfortunate, as it creates the perception that all modern technologies and products carry the same level of risk.

From a policy perspective, a key question on NPBTs is under which regulatory regime these techniques (or the products which result from them) should fall (Laaninen, 2016[95]). The industry has called for legal certainty and predictability for plant breeding innovation to enable plant breeders to reliably plan their breeding programs, their product development and market potential (ISF, 2018[96]). Some of the concerns expressed by consumers and NGOs about transgenic organisms have now been expressed regarding NPBTs. As a result, plant breeders may be reluctant to adopt a technology which, although deemed safe by risk assessors, could result in a public backlash by consumers and food producers (Friedrichs et al., 2019[92]). It is therefore important for policy makers to not only provide sufficient safeguards to protect public health and the environment, but also ensure that those safeguards are trusted so that important innovations are not slowed or stalled.

When recombinant DNA technologies emerged in the 1980s, little was known about the safety of the products they produced when released into the environment or used for food and feed processing.

Beginning in the mid-1980s, the OECD, and later the World Health Organization (WHO) and Food and Agriculture Organization (FAO), began seeking harmonised international approaches for risk/safety assessments for products of modern biotechnology. On the basis of these deliberations, as well as the processes they described and their application, environmental risk and food/feed safety assessment approaches have been applied to genetically engineered organisms derived through the use of rDNA technology (Jeffrey, 2019[97]). In cooperation with WHO, FAO, and other relevant international organisations and stakeholders, the OECD developed a series of basic concepts, instruments and key documents that set up the founding principles of the safety assessment of genetically-engineered organisms that are still in use today (Box 4.4).

The Codex Alimentarius Commission, a joint FAO/WHO body, also developed principles for risk analysis and guidelines for food safety analysis of foods derived from modern biotechnology.[34] The work of Codex Alimentarius is of particular importance to international trade, as its standards and guidelines are used as an international reference in the context of the World Trade Organization, as discussed below.

Ongoing work at the OECD on biosafety and on the safety of novel food and feed products aims to assist countries in evaluations of potential risks of modern biotechnology products for both environmental and human/animal health in order to ensure high standards of safety. Work at the OECD contributes to limiting duplicative efforts and reducing the potential for non-tariff barriers to trade by sharing updated scientific information in an attempt to harmonise the regulatory frameworks for biotechnology products. The focus is on a science-based risk assessment that is common across countries, even if regulatory approaches are different. Particular attention was paid to agricultural products, especially crop plants as these were the early products, but some work also relates to the biosafety of animals and micro-organisms (Kearns, 2019[98]).

Box 4.4. OECD work on regulatory oversight in biotechnology

From the mid-1980s, the OECD developed the founding principles of the safety assessment of genetically-engineered organisms. For instance the OECD's "Blue Book" on Recombinant DNA Safety Considerations, published in 1986, still constitutes a major reference tool to address the risk/safety assessment issues (OECD, 1986[99]). The document covers scientific considerations on the applications of recombinant DNA techniques, human health and safety, industrial large-scale applications, as well as environmental and agricultural safety considerations. At the same time as the "Blue Book" publication, the OECD adopted the "Recommendation of the Council concerning Safety Considerations for Applications of Recombinant DNA Organisms in Industry, Agriculture and the Environment (OECD/LEGAL/0225)" (OECD, 1986[100]). This Recommendation remains in force as an OECD legal instrument, and is currently under review.

Examples of basic principles developed in these early years, which are still used in current biosafety practice, are *case-by-case risk assessment* and the *comparative approach between conventional and modified varieties*. The *case-by-case approach* holds that assessments should be carried out on an appropriate case-by-case basis for each specific product proposed for release, whereby environmental considerations should take into account the deep knowledge of the plant biology and its history of safe use, the trait incorporated and the environment of interest and other elements for building the proper risk assessment process for potential impact on the environment. The *comparative approach* is also used for the assessment of the novel foods and feeds derived from these transgenic plants and is based on a comparison of compositional elements important for food and feed safety (nutrients, anti-nutrients, toxicants, allergens where applicable) to confirm similarities or identify differences of possible concern relative to conventional varieties. The standard-setting body Codex Alimentarius developed a standard addressing the safety assessment of foods derived from recombinant-DNA plants in 2003, completed in 2008 (Codex Alimentarius Commission, 2003; Annexes II and III adopted in 2008[101]).

Using approaches and practices that have been harmonised as much as possible helps to build mutual trust between regulatory authorities in OECD countries or partners. To date, the OECD programmes on the Harmonisation of Regulatory Oversight in Biotechnology and the Safety of Novel Foods and Feeds cover the risk/safety issues for products derived from these innovations. In addition to sharing information on regulatory principles and practices of participating countries, "consensus documents" are developed on the biology or the composition of a range of plants and other organisms and on traits that can facilitate the biosafety and food/feed safety assessment of genetically-engineered organisms. Amongst other things, the OECD consensus documents continue to support the comparative approach and other concepts related to the risk/safety assessment of transgenic organisms and/or products derived from them.

Taking into account the diversity of regulatory situations worldwide, the approach adopted is not constraining; rather, the tools and guidance developed by the programmes are publicly available for regulatory authorities wishing to use them in their biosafety and food/feeds safety frameworks. The consensus documents, in particular, are recognised internationally as key resources and used in many countries. While not legally binding, this OECD work contributes to harmonising approaches and practices and to improve public understanding.

The consensus documents and other key publications can be consulted on the BioTrack website at www.oecd.org/env/ehs/biotrack/.

There is, however, an important difference between risk assessment (where scientific evidence is used to evaluate potential threats) and risk management (which uses the findings of risk assessment processes to mitigate potential risks, e.g. preventing the cultivation of certain transgenic crop varieties in regions where wild relatives occur and genetic drift presents a greater risk). Despite significant work on the harmonisation of risk assessment approaches, risk management mechanisms for biotechnology differ considerably and it remains unclear whose responsibility it is to determine a safe level of risk in different countries.[35] The complexity and lack of harmonisation among countries' risk management mechanisms can create a number of issues, including market fragmentation and barriers to international trade, market entry challenges for SMEs and entrepreneurs, and a reduced uptake of biotechnology in some developing countries.[36]

The different regulatory approaches in the European Union and the United States illustrate this divergence. In the European Union, specific laws were introduced for genetically engineered organisms, which require separate testing and approval by specially established institutions. Subsequently, officials from the European Commission and EU Member countries are given final approval rights and can reject a genetically engineered organism based on the precautionary principle (Qaim, 2016[21]). In the United States, by contrast, although transgenic crops are assessed in detail by three regulatory agencies (USDA, APHIS and EPA) prior to an authorization, if the transgenic crop passes the required tests, then there are no further regulatory requirements for commercialisation and there is no political involvement in the process.

In addition to the divergence between the United States and the European Union, developing countries tend to have less stringent regulations, while EU countries, as well as Japan, tend to have more restrictive GEO regulations; however, even within the European Union there are important differences in GEO rules (Vigani, Raimondi and Olper, 2012[102]).[37] These divergent approaches among countries have resulted in market fragmentation and challenges for international trade (Isaac, Perdikis and Kerr, 2004[103]). Vigani et al. (2012[102]) show that not only the stringency, but also the divergence of GEO regulations reduces trade.[38]

The potential for divergent risk management approaches to restrict international trade has led to disputes in the context of the World Trade Organization (WTO). In particular, the question has been raised whether some regulatory approaches violate the WTO Agreement on Sanitary and Phytosanitary (SPS) Measures. To avoid countries using food safety or animal and plant health regulations as protectionist measures, this agreement allows countries to set their own standards but requires these to be science based, to be applied to the extent necessary to protect human, animal or plant life or health, and to not discriminate between countries where similar conditions prevail. Countries are also encouraged to use international standards and guidelines, as this can help to harmonise approaches. As mentioned earlier, standards developed by the Codex Alimentarius Commission are explicitly recognised by the WTO as an international reference.

In 2003, a WTO dispute panel was established following a complaint by the United States, Canada and Argentina regarding measures put in place by the European Commission. The measures included an alleged *de facto* moratorium on approvals of biotech products, and safeguard measures prohibiting the import/marketing of specific biotech products within the territories of these member states (WTO, 2008[104]). The panel found that the measures put in place by the European Commission were not in line with the SPS Agreement.[39]

The divergence and stringency of GEO regulations have also affected the adoption of biotechnology in emerging economies and developing countries that have been argued to potentially have much to gain from the technology (Hundleby and Harwood, 2019[105]). Many countries in Africa and Asia are hesitant to promote GEO crops because of opposition to such crops in export markets. European attitudes and policy approaches are particularly important, given their longstanding trade connections with African and Asian countries (Smyth, Kerr and Philips, 2013[106]) (Tothova and Oehmke, 2004[107]) (Anderson and Jackson, 2004[108]) (Anderson, 2010[109]). GE-free private standards responding to consumer preferences likely play an important role as well (Vigani and Olper, 2014[110]) (Gruère and Takeshima, 2012[111]).

In addition, the regulatory approval process itself may impact innovation and competition. Smart et al., (2017[112]) found that the regulatory approval process for genetically engineered organisms in both the European Union and the United States is long, roughly 1 800 days and 2 500 days respectively. The associated costs of the approval process are also high. Kalaitzandonakes, Alston and Bradford (2007[113]) estimate between USD 6 million and USD 15 million in the case of genetically engineered maize, while an industry commissioned study by Phillips McDougall (2011[114]) estimated USD 35 million for a new GE crop. Other industry executives suggest costs as high as USD 100 million (Schenkelaars, de Vriend and Kalaitzandonakes, 2011[115]). These numbers are estimates, many of which are sourced from industry, and it is difficult to allocate costs to specific activities or distinguish single country approval from global approval. Yet the costs of regulatory compliance are undoubtedly high given the complexity of the technology and the wide range of factors to be assessed. Miller and Bradford (2010[116]) argue that these costs are prohibitively high for smaller markets, such as certain specialty crops, and have discouraged investment in these areas. As large firms find it easier to bear high regulatory costs, these costs may contribute to other phenomena in the seed sector such as the high level of concentration in markets for genetically engineered traits, and the associated perceptions of corporate power (OECD, 2018[46]).

Regulatory approaches to NPBTs

There is concern that the perceived biosafety risks of transgenic crops will negatively impact the acceptance and uptake of NPBTs. The use of these relatively new technologies does not have a long-established safety record; that said, it is argued that new types of risk are not expected because the point mutations that have so far been developed for commercial use are genetically indistinguishable from natural mutations.[40] In addition, it is argued that the frequency of off-target effects is much lower than for transgenic GEOs and traditional mutagenesis (Grohmann et al., 2019[117]) (Holme, Gregersen and Brinch-Psersen, 2019[118]). Against this background, there is a lack of clarity and consistency in the way that policy makers are approaching the task of regulating NPBTs.

Speakers at an OECD conference on genome editing in 2018 identified three main regulatory approaches to the governance of genome editing:

- *Process-driven regulatory trigger* (e.g. Australia, New Zealand, European Union, and India).[41,]These jurisdictions regulate new technologies based on their development process (Royal Society Te Aparangi, 2019[119]). Many of the countries listed are now reviewing the scope of their regulatory definitions to clarify whether all forms of genome editing fall under their existing GE regulatory framework.

- *Product-driven regulatory trigger* (e.g. Canada and the United States).[42 43] In these jurisdictions, the novelty of the trait in question is considered on a case-by-case basis, irrespective of the technology used to develop it.
- *Product or technology specific regulations* (e.g. Argentina). In these jurisdictions, the regulatory agency responsible assesses a new technology to determine on a case-by-case basis whether it falls in or out of the national biotech regulatory framework.

In many countries, plant breeders and policy makers are operating in a regulatory and policy framework that was established two or three decades earlier. These historical frameworks may *de facto* impose strict standards on new technologies irrespective of intrinsic risks. For example, in many jurisdictions, traditional mutagenesis induced through chemicals or radiation (which creates multiple, uncontrolled changes in DNA) is less strictly regulated than newer, more precise techniques – a situation which has been likened to “saying that electric cars should attract a greater penalty than petrol cars, because electric cars were not [yet] invented in 1998” (New Zealand Office of the Prime Minister's Chief Scientific Advisor, 2019[120]).

A number of jurisdictions, including the United States, do not regulate gene-edited crops as transgenic crops. Rather, gene-edited crops are regulated in the same way as conventionally-bred crops unless they contain DNA from other species. Australia does not regulate gene-edited crops as GMOs if no nucleic acid template was used to guide repair of SDN activity, while all others are regulated as GMOs. In Switzerland, the classification of new breeding technologies such as CRISPR/Cas9 is still a contentious issue with ongoing legal evaluation procedures and discussions.[44]

In 2015, Argentina passed a resolution on NPBTs that exempted some genome-edited products from being classified as genetic engineering. Along with passing this resolution, officials offered developers the chance to consult regulators at the design stage, and anticipate any new molecular and phenotypical characteristics. This approach seems to have made the regulatory process more affordable and accessible for small and medium-sized plant breeding companies. Previously, applications mostly came from multinationals, with almost no applications from national public research institutes and local SMEs. Under the new regulation, the situation has almost reversed: half of all applications so far have come from national public research institutions and SMEs and only a small number from multinationals (Friedrichs et al., 2019[92]).[45]

The United States is also seeking to streamline regulation around agricultural biotechnology. A presidential order from 2019 (Executive Order 13874) seeks to modernise the regulatory framework by basing the regulatory decisions on scientific and technical documentation and reviewing regulatory applications in a timely and efficient manner. The intent is for the federal agencies USDA, EPA, and FDA to ultimately streamline the regulatory process for agricultural biotechnology.

Risk perceptions among the public

From the point of view of proponents, the regulatory framework surrounding transgenic crops has become needlessly polarised and politicised. Qaim (2020[93]) argues that complex biosafety and food safety regulatory procedures are driven by “overly precautious regulators, highly politicised policy processes, and extensive lobbying efforts of anti-biotech activist groups”, as three decades’ worth of risk assessments have so far not found any evidence that transgenic products are more risky than conventional varieties (EASAC, 2013[121]) (NAS, 2016[122]) (Leopoldina, 2019[123]).

This body of scientific evidence has had little influence over the risk perceptions of the broader public, however. If the public does not perceive a technology to be safe, the political process is likely to lead to more stringent regulation (Zerbe, 2007[124]). More stringent regulation in turn is likely to feed risk perceptions of the broader public. Even without such a regulatory response, a lack of consumer acceptance may limit adoption of the technology by firms. Gruère and Sengupta (2009[125]) showed that GE-free private standards influenced the decisions of policy makers because of perceived trade losses, while Vigani et al.

(2012[102]) found that downstream traders' and food retailers' private decisions not to purchase GE products were more important than cultivation bans for GE organisms.

Consumer attitudes to genetically engineered products vary across countries. For instance, one study found that US consumers rated "GMO-free" as the 17th most important characteristic for food, while Italian consumers ranked it as the 5th most important characteristic and Japanese consumers as the 7th most important characteristic (McGarry et al., 2012[126]).

The gap between consumer perceptions and scientific views appears to be particularly large in the case of genetically engineered organisms. A study by the Pew Research Center (2015[127]) showed that the views of US citizens differed considerably from those of scientists on a range of scientific topics, with the largest difference found in views on the safety of "GM" foods: while 88% of scientists (and 92% of biomedical researchers) considered "GM" foods safe to eat, only 37% of the broader US public agreed (Pew Research Centre, 2016[128]). [46]

A number of factors may explain these perceptions. First, risk perceptions differ depending on the use of the technology, which can entail different cost/benefit calculations. For example, there is likely to be much less resistance to using genetic engineering to cure deadly diseases, while similar techniques would be evaluated very differently in a context of food safety and security (New Zealand Office of the Prime Minister's Chief Scientific Advisor, 2019[120]). For wealthy consumers who can afford higher food prices, existing genetic engineering technology might seem to hold little or no benefit, so that perceived health risks to consumers or perceived issues about longer-term environmental impacts weigh more heavily than potential effects on agricultural productivity. Consistent with this hypothesis, it is often highly educated and affluent consumers that are the most reluctant to purchase and consume foods that have been produced using GE technology (McCluskey, Swinnen and Vandemoortele, 2015[129]) (Curtis, McCluskey and Swinnen, 2008[130]).[47]

People's views about the safety of foods with "GM" ingredients are also closely related to their perceptions of expert consensus. Non-experts need to make decisions without full information, and therefore rely on experts' claims – and of course there are limits to even expert knowledge. Real or perceived disagreements among experts may also force non-experts to err on the side of caution. Public acceptance and adoption of new technologies is thus related in part to the quality of communication and information received by the public, and to broader trust in institutions. Lusk (2015[131]) highlights the risks of misinformation in a study that found that while a large majority (82%) support mandatory labels on "GM" organisms, a similar proportion (80%) would also support mandatory labels on "foods containing DNA".

Scientific literacy is critical to consumer views on new technologies. In Canada, a study found that people's first impressions of biotechnology are generally positive or neutral (88% combined), and that Canadians generally feel that biotechnology will have a positive impact on their future. However, when the same question was asked of some specific biotechnology applications, such as "genetically modified" plants and animals, this proportion falls below half (Nielsen Consumer Insights, 2017[132]). Both the quantitative and qualitative parts of the research made it clear that people did not have a solid understanding of what gene editing is or, more specifically, how it differed from genetic engineering. Following detailed explanations of gene editing, consumer sentiment was generally quite positive (Nielsen Consumer Insights, 2017[132]).

The quality of information available to consumers is important in shaping public risk perceptions. Lusk et al. (2014[133]) argue that media can frame food technologies by emotionalising an issue and increasing its importance through repetitive messaging. Heiman and Zilberman (2011[134]) find that both positive framing and negative framing affected the likelihood of purchasing "GM" products, but that negative framing had a stronger impact. [48]

Another factor which helps to explain divergent views between scientists and the broader public relates to communication styles, and the persuasive effect of everyday language and the use of individual stories rather than technical terms or scientific evidence.[49] In a variety of contexts, including in relation to the debates over benefits and potential side effects of vaccination, public agencies can struggle to counter over-simplified messaging as they may not be allowed to adopt similar tactics (Fischhoff and Kadvany, 2011[135]).

The broader public is also influenced by the stated positions of policy makers and NGOs. The fact that some policy makers express concern about transgenic organisms may itself reinforce widespread public beliefs that the technology is inherently dangerous (Herman, Fedorova and Storer, 2019[136]). According to Qaim (2020[93]), an important reason why "GM" crops are still feared by some consumers is because the public may trust environmental NGOs more than scientists and the private sector, as NGOs are perceived as not having a hidden or profit-driven agenda. This may in part be due to the context in which GE crops rose to prominence as a public policy issue (Bonny, 2017[38]). In the second half of the 1990s, confidence in institutions and in certain technological advances had suffered as a result of several crises, including mad cow disease (notably in the United Kingdom) and blood transfusions contaminated with HIV (in France), as well as broader food safety crises around E. coli, salmonella and listeria. This led to widespread distrust in both the public and private sectors, who were believed to have disregarded health risks in favour of economic or political interests (Joly and Lemarie, 1998[137]) (Vogel, 2003[138]). This history may also have contributed to concerns that "facts" presented in policy discussions have been distorted by ideology or self-interest.

Moreover, the debate around plant breeding technologies is affected by debates on a number of other issues, which in turn may affect risk perceptions about breeding technologies.

Firstly, one of the dominant transgenic crop applications to date (herbicide tolerance) facilitates the use of broad-spectrum herbicides such as glyphosate. The use of transgenic crops has thus become associated with pesticide use in agriculture – even though the other major GE trait, insect resistance, has allowed important reductions in insecticide use (Qaim, 2020[93]). Many large seed and biotechnology companies also have their origins in the chemical and agrochemical industry (Bonny, 2017[38]), which has fuelled concerns that transgenic crops would promote increasing pesticide use.[50]

A second issue often linked to plant breeding technologies is that of corporate power. Patents on genes, genetic processes, and transgenic plant varieties have been dominated by a handful of large multinational companies. Concerns about corporate power, political influence and lack of accurate information are reflected in consumers' trust in different stakeholder groups and their preferences for stakeholder involvement in policy making when it comes to biotechnology. For example, the majority of Americans want scientists to have a say in policy decisions related to "GM" foods, and majorities also support roles for small farmers (60%) and the general public (57%). However, fewer Americans say that food industry leaders should have a major role in policy decisions related to "GM" foods (42%), and only 24% believe elected officials should have a major role (Pew Research Centre, 2016[128]).

A third issue relates to ethical concerns with human intervention with the building blocks of life, and the ethics of patenting life and genetic materials, with many voicing the opinion that humans "should not play God" or that nature should not be patented (Qaim, 2016[21]). In Canada, it was found that the biotechnology applications viewed less positively tend to be ones in which the science has the potential to upset the 'natural order' (Nielsen Consumer Insights, 2017[132]). Stone (2010[63]) highlighted the views of opponents that genetic engineering was transgressing realms that belong to God, and the related narrative put forward by NGOs portraying "GM" crops as "frankenfood."

4.6. What makes these issues contentious, and what can be done?

A well-functioning seed sector is essential for meeting the triple challenge. For this reason, it is critical to build a policy and regulatory environment that facilitates both innovation and access to seed. Yet as the previous section has illustrated, the seed sector is characterised by a number of highly contentious issues, which may make it difficult to design effective policies. This section offers an interpretation of why plant breeding tends to be so contentious, and what can be done to develop effective and socially acceptable policies.

Sources of friction: Facts, interests, and values

The contentious issues discussed in this case study are not simply disagreements over the most efficient way to meet the "triple challenge" of food security and nutrition, livelihoods, and sustainable resource use and climate change mitigation. If they were, it would be difficult to explain why policy discussions have become so highly polarised. An alternative interpretation is that policy debates in the seed sector are so contentious because they also involve (real or perceived) conflicts between private interests and the public interest, and disagreements over values. In other words, contentious issues in the seed sector form a "wicked problem" (Rittel and Webber, 1973[139]). A wicked problem is one where: stakeholders have differing and sometimes competing definitions of the problem; there are no widely accepted solutions; the problem involves normative judgments which depend on stakeholder values and preferences; and debates about the problem are dependent on and embedded in social dynamics and contexts. Wicked problems cannot be solved by more research, data and experts, but may require a dialogue around societal goals and normative questions to move towards consensus.

The access and benefit sharing mechanisms that govern genetic resources illustrate some of these issues. Genetic resources are a global public good which can be conserved at a modest cost *in situ* and *ex situ* but which can potentially be used around the world to create new varieties. From a pure economic efficiency point of view, these genetic resources should therefore be made available as cheaply and easily as possible, to maximise their use in breeding programmes around the world. The public interest in this case is thus not necessarily in contradiction with the private interests of the plant breeding industry. Yet at the same time, existing genetic resources often represent the efforts of countless generations of farmers and local communities carefully saving and selecting seed. This fact is irrelevant from an efficiency standpoint, but it matters from the point of view of fairness, as many would object to plant breeders earning profits from genetic material selected and curated by local communities without compensating these communities for their historical stewardship.[51] The existing regulatory frameworks for access and benefit sharing seek a balance between principles of fairness on the one hand, and economic efficiency and encouraging innovation by plant breeders on the other hand.

The question of whether and when farmers have the right to save seed provides another illustration of disagreements over values and interests. As noted earlier, new plant varieties are difficult to develop but often easy to replicate, which threatens to undermine incentives for plant breeders to invest in the lengthy process of varietal improvement. From an economic efficiency point of view, PVP thus needs to strike a balance between providing incentives to plant breeders and allowing farmers' access to improved varieties. If farmers can freely save and reproduce seed, this may stimulate them to adopt new varieties more quickly (because they do not have to pay royalties or pay for new seeds each season), but it may also reduce the rate of innovation by undermining incentives for plant breeders. There is thus a question of designing an IPR regime that reconciles the highest possible rates of both innovation and adoption. But intellectual property regimes also have distributional consequences: they influence how much farmers effectively pay for seed, which affects profits for both farmers and plant breeding firms. The IPR regime which maximises profits for either one of these groups is not necessarily the regime which maximises overall innovation and social and economic welfare, and vice versa. Moreover, discussions about IPRs on genetic material again touch on moral questions about whether nature should be "privatised", whether corporations wield too much influence over farmers, and about what kind of agricultural system is most desirable (Stone, 2010[63]) (Schurman and Kelso, 2003[140]) (Goodman, 2003[141]) (Lewontin, 2000[142]) (Magdoff, Bellamy Foster and Buttel, 2000[143]).

The confluence of disagreements over facts, interests and values is also illustrated by debates over plant breeding technologies. Much of the controversy over genetic engineering and NPBTs is about the presence or absence of biosafety risks, but many other factors are at play in these debates. Risk management is never merely about scientific evidence on the magnitude or probability of harmful consequences; it inevitably involves a value judgment about the types and magnitude of risks which are deemed (un)acceptable by society. Even if access to accurate information was equal and the perception of risk among the general public was the same, people may still differ in their values and risk appetite (Fischhoff and Kadvany, 2011[135]).[52]

What complicates these matters further is that risk perceptions of the broader public can diverge from expert judgment. This is true in general and it is also the case for genetic engineering, as noted earlier.

It is possible to identify "clusters" of facts, interests and values in seed policy debates. For example, critics of private-sector plant breeding and modern breeding techniques seem likely to also believe that a handful of multinationals exert too much power over farmers and the overall direction in which the food system is evolving; that GEOs are more risky than the available evidence suggests; and that private-sector plant breeding will not deliver socially optimal outcomes in terms of innovation and genetic diversity. Those with these beliefs are probably also more likely to emphasise the value of diversity as opposed to homogeneity (e.g. monocultures). In terms of interests, they are likely to champion the interests of poor farmers and local communities and may share a wider scepticism about the benefits of globalisation. [53]

By contrast, proponents of private-sector plant breeding and modern breeding techniques seem more likely to emphasise that modern techniques are needed to feed a growing population; that traditional and informal seed systems are insufficiently effective; that scientific risk assessments have demonstrated that GEOs are safe; and that private-sector investments in R&D can deliver societally relevant benefits. Proponents are also likely to advocate for science and technological progress. Taken to an extreme, this view argues that all domestication of nature is in fact genetic modification (Fedoroff, 2003[144]) (Pinstrup-Andersen and Schioler, 2000[145]), and that the term genetic modification itself is only a political construction (Herring, 2008[146]). In the case of plant breeding firms, there are also economic interests related to plant breeders' rights and regulatory approval of new technologies.

Siegrist et al. (2000[147]) explain such clustering of beliefs as a mental shortcut which takes place when people who are not technically trained to evaluate risks and benefits of a technology on their own put their trust in others who have been shown to hold similar values and interests to them. It can subsequently become difficult to express beliefs "inconsistent" with this clustering, affecting the ability to find a middle ground in public debates. For example, when Urs Niggli, Director of the Swiss Research Institute of Organic Agriculture (FiBL), expressed support for the potential role of NPBTs in organic agriculture, he was heavily criticised by the organic movement which has been outspoken against genetic engineering (Maurin, 2016[148]) in Shao, Punt and Wesseler (2018[149])).

The clustering of facts, interests and values makes it difficult to settle debates on contentious issues with reference to facts or evidence alone. It may also make it harder for people to accept evidence contradicting their prior beliefs, especially if there is a lack of trust in the credibility of research conducted at universities or regulatory agencies (prompted, for example, by concerns about conflicts of interest).

Implications for policy makers and key stakeholders

If the above interpretation is correct, controversies over specific seed policies may often reflect much deeper disagreements between clusters of facts, interests, and values. As emphasised in Chapter 3, there are unlikely to be easy solutions to such policy controversies. However, it might be possible to find some "no-regret" actions (which are acceptable to diverse stakeholders), as well as some ways of moving the policy process forward. In doing so, it is important to address not only plant breeders and farmers upstream but also the values and interests of consumers and citizens. At the same time, in order to be most effective, policies need to be informed by science and facts.

Targeting

A first step is to acknowledge that seed policy debates touch on a wide range of issues, but that not all of these issues need to be resolved through seed policy and regulations. As in other areas of the global food system, policies targeting one objective may have trade-offs and synergies with other objectives. However, ideally policy makers should use as many policy instruments as there are objectives to avoid or minimise trade-offs (Chapter 2). For example, concerns around the environmental consequences of monocultures linked to certain plant-breeding technologies could probably be addressed more effectively through targeted agri-environmental policies, allowing for more precise management of trade-offs, rather than through the blunt instrument of restricting the use of those plant-breeding technologies.

A second step is to explore where existing policies have negative spillovers, which could be addressed without compromising the original objectives of those policies. For example, blanket restrictions and excessive regulatory hurdles on NPBTs likely limit innovation and market entry for small firms and new breeders, and the experiences in Argentina mentioned earlier suggest that reform of these regulations can lead to improved market access for national public research institutions and SMEs. Given the concerns about the impact of competition on market concentration and innovation, when pro-competitive adjustments are possible while providing sufficient safeguards on health and environment, they should be pursued.

Enabling competition

Competition helps lower prices, increase variety, and stimulate innovation; given the centrality of the seed sector for the triple challenge, stimulating competition in the sector is thus essential. Moreover, vigorous competition in the seed sector could also help attenuate concerns about corporate power. This requires enforcement by competition agencies, but several complementary options exist to stimulate competition. These include avoiding regulatory barriers, facilitating access to intellectual property and genetic resources, and stimulating both public and private R&D (OECD, 2018[46]).

The regulatory environment can have important effects on competition. OECD Good Regulatory Practices (OECD, 2012[150]) argue for the simplification of regulatory systems where necessary, to make regulations clearer, more transparent, easily accessible, and more coherent across jurisdictions.[54] As discussed earlier, this issue is of particular importance for NPBTs, where policy makers should take care to design a regulatory approach which does not exclude small and medium-sized enterprises (SMEs).

Simplification of public R&D and innovation funding can also help smaller companies access critical funds. For example, OECD work on innovation, agricultural productivity and sustainability found that some policy measures to stimulate R&D such as tax rebates might primarily benefit large firms, which suggests that better targeting could improve effectiveness (OECD, 2015[151]). Strengthening the capacity of smaller domestic companies to engage in research and innovation, possibly using incentives targeted to their needs, is important for the performance of the whole sector (OECD, 2019[39]).

Uptake of new technologies

The potential benefits of plant breeding technologies on the triple challenge are only realised if the technologies are taken up and are meeting local needs of farmers in different agroecological conditions. Uptake involves a wide range of stakeholders along the whole supply chain for food, including policy makers, teachers, researchers, advisors and brokers of innovation, farmers, agri-food companies, co-operatives, non-profit organisations (NGOs), and consumers (OECD, 2019[39]). It is important therefore that these stakeholders find consensus on a way to move forward.

Renewed policy attention is being given to improving the adoption of innovation in farms and firms through improvements in the enabling environment. Farm advisory systems and extension services play an important role in ensuring more effective participation in innovation networks and adaptation to new technologies (OECD, 2019[39]). OECD work on innovation systems shows that countries have higher rates of adoption of innovation at the farm level when training and extension is diverse and services are widely accessible, e.g. through specific programmes focusing on facilitating adoption (OECD, 2015[151]).

Access to information and re-building trust

Although some seed policy debates inevitably involve value judgments which cannot be settled by science alone, credible scientific evidence is essential to clarify the trade-offs and synergies involved and to help achieve coherent policies. In order to ensure smart policies, additional data is needed on innovation, market concentration and access. Fernandez-Cornejo and Just (2007[64]) argue that reliable analysis on market concentration, for example, requires time-series data on firm market shares, R&D investment, output quantities, and prices. Although such data are often considered private and confidential, concerns about market power should make greater public observation and oversight by competition authorities appropriate. Private investment in food and agriculture R&D is also difficult to track in many countries and is often missing or incomplete in official statistics (OECD, 2019[39]). The evaluation of programmes that support research and innovation in private companies should be strengthened to ensure they are efficient and reach their intended beneficiaries.

Initiatives have emerged to improve access to both information and innovation in the crop biotechnology space. For example, the Public Intellectual Property Resource for Agriculture (PIPRA) (PIPRA, 2020[152]) initiative was established to improve transparency and access to IPRs, particularly patents, in plant biotechnology for staple crops in developing countries and specialty crops. Sharing patent and licensing information from major public sector organizations supports better commercialization of agricultural biotechnology innovations from the public sector. Recently PIPRA has increased provision of educational services, capacity building, and professional training.

Related to the issue of data is that of transparency. The review of Innovation, Agricultural Productivity and Sustainability in the Netherlands (OECD, 2015[153]) found that transparency is essential when there is co-operation between science and business, but trust remains an issue for the image of scientists working for or with businesses. A key challenge is to ensure “facts” remain unpolluted to the maximum extent possible by “interests” and “values” and that there is trust in the process – that is, ensuring that scientific research by universities and public agencies is of the highest quality and integrity, avoids conflict of interest problems, and is trusted by the public. While removing all bias is difficult, maximum transparency helps others to make their own assessments as to the credibility of the information.

It is similarly essential that special interests do not obtain excessive influence over public policymaking processes. In the context of seed policies, interest groups include farmers, plant breeders, consumers, and civil society. Within these groups, interests are not necessarily homogeneous; for instance, the global seed industry consists of a small group of major multinationals and a much larger group of small and medium national and regional companies, and these may not always have the same interests (Spielman and Smale, 2017[13]). Interest groups (such as associations or lobby groups) can fulfil an important role in the policy process, as they can provide information on how proposed rules affect various stakeholders. But if some stakeholders can wield disproportionate influence, the resulting policies may benefit special interests at the expense of others in society. Even the perception of such disproportionate influence can undermine trust in the public sector.

Evidence from various sectors has shown that industry-funded research can lead to results and conclusions more favourable to the funder (see Chapters 3 and 6). While industry funding can enable important research efforts and is not inherently problematic, clear governing principles and standards of scientific integrity along with full transparency of research funding and methods are needed to avoid the spread of biased, misleading or wrong information that influences public opinion and the policy process. In the contested area of research and facts in the seeds debate, both industry and NGOs have disseminated research to affect public opinion, with a considerable impact on the GE debate (Paarlberg, 2014[154]).

Ensuring transparency and a level playing field for different interests (e.g. through transparent and participatory processes involving all relevant stakeholders) can help, such as the European Union's better regulation initiative that seeks to engage citizens and stakeholders (EU, 2020[155]). The disclosure of funding sources for scientists and NGOs as well as conflict of interest policies may also help improve transparency. Considerable improvement can also be made in outreach science and communication.

Communication

While scientific evidence on risk assessment can clarify the likelihood and possible magnitude of harmful consequences, different people (and different societies) are still likely to disagree on what constitutes an acceptable risk, particularly when the level of risk may vary between one region and another. This is why communication tools are critical to achieve a good understanding of risks and to ensure coherence in how different risks are managed – e.g. to avoid that an objectively less risky technology is treated with more scrutiny than an objectively riskier technology merely because of misperceptions; or, in the context of international trade, to avoid that unnecessarily restrictive measures are introduced under the pretence of safety standards.

In 1988, the US Environmental Protection Agency developed the *Seven Cardinal Rules of Risk Communication* (EPA, 1988[156]). It includes a range of recommendations for managing public communication including being *honest, frank and open*. In the context of the seed sector, this could include ensuring that information on the seed variety, the breeding techniques used to obtain them, as well as its safety for the environment and human health is easily available and communicated in a form that can be easily understood. This should also include efforts to clarify the use of terminology in the media.

Collaboration and co-existence

Many of the issues discussed go beyond problems of economic efficiency and raise broader questions related to rights, ethics, power and equitable development. There are a number of initiatives to develop policies which address and balance the needs of different "clusters of beliefs" involved in plant breeding debates. The principle of access and benefit sharing for genetic resources is an example. This principle simultaneously acknowledges the importance of easy access to genetic resources, while also acknowledging the historical stewardship of local communities. Other examples might include policies to strengthen public sector R&D and stimulate public-private partnerships, and policies to facilitate the licensing of patented genetic material.

It is critical to develop long-term strategies for breeding that consult a broad range of stakeholders early and often, clarify the role of different organisations, improve co-ordination across research and other organisations, and implement comprehensive evaluation systems. At the 2018 OECD Conference on Genome Editing, Friedrichs et al. (2019[92]) observed that while some experts argued against prohibitive increases in regulatory requirements surrounding NPBTs and genome editing, others argued that each community should first set its policies based on its values and objectives, so that regulation reflects societies' boundaries and not what is scientifically possible. Participants acknowledged that "[e]ffective public acceptance could not follow a 'one size fits all' approach; it requires well-tuned consideration of the prevalent socio-political disposition of each community" (Friedrichs et al., 2019[92]).

In Canada, Value Chain Round Tables (VCRTs) bring together industry leaders along with federal and provincial government policy makers to build long-term strategies, discuss challenges and opportunities and identify research opportunities, as well as policy, regulatory and technical requirements (OECD, 2019[39]). The Netherlands is also working to integrate social issues into its strategic knowledge and innovation agenda (OECD, 2015[153]) and has worked with stakeholders to define concrete goals for a wide range of policy instruments.

Such approaches can be challenging, however. The *Haut Conseil des Biotechnologies* in France (HCB, 2020[157]) is an independent body established by the Genetically Modified Organisms Act (GMO Act) of 25 June 2008 to inform public decision-making. The council reports to the ministries responsible for the environment, agriculture, research, health and consumer affairs. The council is made up of a Scientific Committee (SC) and an Economic, Ethical and Social Committee (EESC) and assesses not only the environmental and health risks of GEOs but also their socio-economic impact. Despite the establishment of such an initiative, perceptions of genetic engineering have not changed much.

Bauer, Allum and Miller (2007[158]) highlight the potential for "institutional neurosis". They use the example of the 2003 UK GM Nation public debate. Following the debate, the public remained sceptical of "GM" foods and crops and the government responded by blaming environmental NGOs or insisted on continuing the debate until the public changed their minds. If government and companies enter into the consultation process expecting the public to change and not expecting that they might have to, they risk effectively missing the point of a public consultation, which is to value the opinion of the public and take in to consideration their concerns and appetite for risk when making decisions.

It may be possible to find common ground in the face of new challenges. There is a broad and growing consensus around the importance of making progress on the SDGs and on the "triple challenge" of providing food security and nutrition, ensuring livelihoods, and using natural resources sustainably and contributing to climate change mitigation. Efficiency gains through improved varieties could play an important role. Moreover, as new techniques are more precise, the benefits perceived from new plant breeding technologies may be seen as larger than the risks. Yet, it is unlikely that full consensus will ever be achieved on all contentious issues.

An alternative possibility is a system where multiple agricultural systems co-exist in parallel. For example, the formal recognition of orphan crops and heterogeneous material may help ensure a more level playing field for alternative approaches. In the case of genetically engineered crops, the global picture is to a large extent one of coexistence. As a result of divergent regulatory approaches, some countries have high adoption rates of GE crops while others have little or none. Moreover, "GM-free" labels have emerged even in countries where genetic engineering is widely used. If some consumers have a preference for "GM-free" products while others are indifferent, such coexistence would seem a logical outcome. But coexistence based on the principle of consumer choice brings its own difficulties.

First, consumers need to be able to make an educated choice based on clear, accurate, science-based information, for example through the use of product labels. A diverse range of labelling regimes for GE products have emerged across countries (Vigani and Olper, 2013[159]). Labelling may be one step in allowing consumers to make an informed choice, but it assumes that consumers have sufficient scientific literacy to understand the differences between different technologies and agronomic techniques, which may not be the case in practice. Gruère (2006[160]) finds that labelling GE products may also indirectly act as a hazard warning: labelling a product as "free of ingredient X" might give ill-informed consumers the impression that "ingredient X" is risky or bad, even when there is no scientific basis for this claim. Hence, labelling is rarely a neutral communication tool. Design of labelling is also by no means straightforward, including in terms of international coherence.

Second, segregating the supply chains of GE and non-GE products creates significant additional costs in food supply chains. For example, processors may incur a loss of flexibility as they need to dedicate equipment to either GE or non-GE production (Bullock and Desquilbet, 2002[161]).

Third, the coexistence approach can work if the effects of a consumer's choice only affect that consumer. But the controversy around GE involves perceived externalities, such as risks to the environment. In addition, the controversy involves strongly held values that extend beyond personal consumption choices.

For example, if opponents of GE feels that it is fundamentally unethical to manipulate nature, or that the technology represents a dangerous power grab by a powerful corporate entity, then coexistence will not be a satisfactory solution to them.

4.7. Conclusion

In a recent paper, Qaim (2020[93]) concludes by asking the reader a number of questions regarding the seed sector. How can we ensure that newly developed crop varieties with desirable traits are used sustainably as part of diverse agricultural systems? How can market power by a few multinationals be prevented? How can we facilitate the development of new crops and traits that may not have huge commercial potential but may be particularly beneficial for poor farmers and consumers? How can we ensure that suitable new crop technologies will actually reach the poor through favourable technology transfer mechanisms? What is the appropriate level of IPR protection in industrialised and developing countries?

Policy makers will have to face these questions if plant breeding is to play its critical role in meeting the "triple challenge". In addition, policy makers must deal with the globalised and diverse nature of the seed sector, striking a balance between facilitating international trade and technology exchange through harmonisation and providing a policy environment adapted to highly diverse local contexts, including developing countries and those who will be most affected by climate change and natural resource constraints.

The diversity of the global seed sector also extends to the viewpoints of various stakeholders, making debates on seed policy uniquely contentious. While considerable work has been done to develop policies and regulations which act "upstream" in the plant breeding process, comparatively little has been done to address the concerns of consumers and concerned citizens downstream. Consumer concerns regarding plant breeding technologies can be addressed directly through innovative educational and communication programmes. In addition, concerns about the environment or corporate dominance in the food sector affect citizens' and consumers' perceptions of plant breeding technologies. Addressing these concerns directly, through improved environmental regulations or through policies that support a competitive market and address concerns regarding the impact of market power on innovation and access, is likely to be more effective than trying to address these issues through seed policy (consistent with the principles on policy coherence developed in Chapter 2). Moreover, tackling these issues head on could also help address citizens' and consumers' value-based concerns with new plant breeding technologies.

Certain seed policy debates involve value judgments, which cannot be settled by science alone. Acknowledging the importance of values and ensuring that a range of stakeholders have both access to accurate information as well as input in policy making processes can help ensure that decisions are not only evidence-based but also acceptable to the broader society. At the same time, effective policy development should be clearly targeted, making sure that the appropriate instrument is used for an issue.

It is crucial that to the maximum extent possible facts remain unpolluted by interests, including by promoting full transparency. Plant breeding technologies have suffered from association with both private and public actors who are perceived by the public to have disregarded health risks in favour of economic or political interests. Maintaining the highest standards of transparency and integrity is therefore essential to establish trust in scientific evidence and in the regulatory process.

Finally, policy makers can seek common ground and develop smart policies which facilitate innovation and technology while addressing and balancing the views of different "clusters of beliefs" in seed policy debates. An acknowledgement of the huge progress that must be made to meet the triple challenge may help de-polarise discussions. There are also examples of successfully balancing the interests of different stakeholders, such as the principle of access and benefit sharing or the coexistence of traditional breeding techniques alongside genetic engineering in the same country or region; but considerable effort is needed to develop and implement workable regulations by governments and the private sector as well as more of these mutually acceptable solutions.

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Notes

[1] The OECD has developed a wide body of literature on the broader topic of agricultural innovation, including a framework for analysing the role of government in agricultural innovation systems (OECD, 2013[187]) as well as 12 country reviews and a synthesis report (OECD, 2019[39]).

[2] A note on terminology. A seed is the physical "carrier" of genetic information of a variety. Farmers choose between different varieties when buying seed, and plant breeders aim to develop improved varieties. A variety developed or selected through human intervention is also referred to as a cultivar ("cultivated variety"). Strictly speaking, the term "seed market" or "seed industry" encompasses both the development of varieties (plant breeding) and the physical production ("multiplication"), distribution and sale of seeds. The focus of this study is primarily on plant breeding.

[3] In the 1950s and 1960s, a set of technological innovations and transfer initiatives took place, known as the Green Revolution. These innovations have been attributed with significant increases in agricultural production worldwide, as well as increased use of fertilisers, pesticides, mechanisation and irrigation (Evenson and Golin, 2003[5]).

[4] The term "quality" refers here to seed that has high purity (i.e. the seed sold corresponds to the variety it is claimed to be, and does not have foreign elements such as weed seeds, dirt, and seed of other varieties) and high germination rates, is free from pests and diseases, and has a low moisture content (to prevent early germination and quality losses). These quality parameters are guaranteed by official certification systems in formal seed markets, but are not guaranteed in the case of farmer varieties exchanged in informal settings. However, FAO's Quality Declared Seed System (FAO, 2006[200]) can be used as an intermediate solution, as it provides certain guarantees for the quality of seed and is applicable to local varieties.

[5] For example, Coomes et al. (2015[195]) emphasise the important role of farmer seed networks, where seed is shared among farmers through gifts, barter or purchase outside of the commercial seed sector and formal regulations. While such networks are often described as "informal" (as opposed to formal seed systems, which convey certified seed or registered varieties to farmers), these networks are often governed by social rules and norms, and there is permeability between the informal and formal systems. These farmer networks can be responsive to changes in local conditions, and resilient to environmental and price shocks; they therefore play an important role in ensuring long-term access to diverse crop planting material.

[6] In a number of important agricultural crops, the photosynthetic process (conversion of light to chemical energy) is relatively inefficient, limiting growth. Genetic engineering has recently been used to modify the photosynthesis process to deliver a 41% increase in biomass. Currently this has only been carried out in tobacco plants (chosen as a model species as it is easy to modify) but it has been suggested that similar yield gains could be achieved in staple crops such as soybeans, rice and wheat (South et al., 2019[172]).

[7] Biofortification is not the only means to improve the intake of micronutrients; other policy interventions to improve dietary diversity can play an important role.

[8] *Biotic* stresses are caused by other organisms such as fungi or insects, while *abiotic* stresses include, for example, adverse weather conditions.

[9] There have also been concerns that the Green Revolution contributed to a loss of crop genetic diversity, although evidence on this question is mixed (Pingali, 2017[196]). In general, a loss of genetic diversity could pose risks to global food security by undermining the resilience of agricultural systems to pests, pathogens and climate change (IPBES, 2019[197]).

[10] See Chapter 1 for a discussion on the suitability of incentives and the impact of agricultural support policies and agri-environmental policies on environmental sustainability.

[11] Genetic diversity is related to, but distinct from, biodiversity. While biodiversity refers to the variation at the genetic, species, and ecosystem level, genetic diversity is the total number of genetic characteristics in the genetic makeup of a species.

[12] There is considerable variation in agricultural innovation systems between countries, particularly in terms of ambitions, institutional set-up, and funding mechanisms (OECD, 2019[39]). As such, experiences and perspectives may differ between countries. This case study seeks to summarise the key contentious issues being debated at the national and international level.

[13] The private sector is taking on an increasing role in other agricultural areas too. In 2011, the private sector was carrying out 52.5% of the research on crop breeding, informatics, fertilisers, pesticides and food technologies in developed countries, compared to 42% in 1980 (Pardey et al., 2016[48]).

[14] Public breeding programmes may also benefit from intellectual property systems, which can generate revenues to support future R&D. Examples of public sector plant variety protection and patenting have been seen in Argentina (UPOV, 2017[190]) but comprehensive data on the ratio of public vs private patents is not available.

[15] In 2016, Monsanto was acquired by Bayer and the sale was completed in 2018. From that point, the Monsanto name was discontinued.

[16] Seed marketing regulations define the quality standards that must be met for seed production of agricultural plant species and seed lots if the seeds are to be commercially marketed.

[17] Evidence for the French seed industry similarly suggests that the number of new varieties introduced each year is positively correlated with market size, although this correlation disappears for hybrid crops (Charlot, 2015[173]).

[18] Agricultural R&D may include plant breeding but also other types of research and development initiatives.

[19] Paul Heisey, personal communication.

[20] During the 1980s, agricultural policy reforms in developing countries assumed that seed system deregulation and privatisation would generate investment (Tripp and Rohrbach, 2001[176]; Tripp and Louwaars, 1997[175]; Tripp and Louwaars, 1997[175]). However, many private companies refrained from investing because of continued market failures (Spielman and Smale, 2017[13]). Gilbert (2010[163]) suggests that contractual and reputational risks are also harder to manage in developing country contexts.

[21] A hybrid variety is obtained by crossing two (or more) inbred parent lines. Hybrid varieties often demonstrate more favourable traits (e.g. higher yields) relative to the parent lines, a phenomenon known as “hybrid vigour”. However, if the seed resulting from a hybrid variety is planted again, the next generation loses its uniformity and does not display the same vigour or desired traits. As a result, farmers have less of an incentive to save part of the harvest of a hybrid variety to re-use as seed. Hybridisation is not available for all crops, because hybrid varieties are easier to obtain from plant species which cross-pollinate naturally, but selected hybrid varieties are nowadays common for many staple crops such as maize, cotton, sunflower, rice, as well as fruits and vegetables.

[22] There has been a long-standing tension in policy discussions between the desire to provide intellectual property rights protection to stimulate the development of new varieties on the one hand, and on the other the view that genetic resources are “common heritage of mankind,” in the words of the 1983 International Undertaking on Plant Genetic Resources. The implication that modern varieties are private property while traditional varieties are freely available has contributed to a sense of unfairness in developing countries (Bjornstad, 2004[198]). A similar tension is at work in discussions on access and benefit sharing (Section 4.5). See also Section 4.6 for a discussion of the role of such differences over values and interests in policy discussions.

[23] The International Union for the Protection of New Varieties of Plants (UPOV, after its French name, *Union internationale pour la protection des obtentions végétales*) was established by the International Convention for the Protection of New Varieties of Plants. UPOV's mission is to provide and promote an effective system of plant variety protection, with the aim of encouraging the development of new varieties of plants, for the benefit of society.

[24] The precise relationship between the UPOV Conventions and the ITPGRFA is complex. For example, the ITPGRFA expressly acknowledges that the implementation of a system that allows farmers to “save, use, exchange and sell farm saved seed” is the responsibility of national governments “subject to national law and as appropriate”.

[25] While plant breeders' rights only cover new varieties, seed marketing legislation covers all varieties marketed to farmers. As discussed in the context of the in situ conservation of genetic diversity below, in many countries varieties can only be marketed to farmers if they meet criteria of distinctness, uniformity and stability (DUS). Such systems were originally introduced to prevent fraudulent claims, but they can result in a de facto ban on the sale of traditional or heterogeneous plant material, unless special provisions are made.

[26] The "Annex I" list was originally developed to clearly define and limit the scope of the international treaty. Negotiations on the scope of the list reflect how perspectives on access and benefit sharing differed between regions (Visser, 2013[191]). Many developing countries viewed the multilateral system as an experiment that had to show its effectiveness and its value in terms of monetary benefit sharing and were therefore cautious in terms of the content of the list. Developed countries saw the access to genetic resources as a major benefit in itself and favoured the inclusion of all plant genetic resources on the list.

[27] Despite the large number of successful exchanges, problems remain. Bjørnstad, Tekle and Göransson (2013[178]) sent seed requests to 121 countries that are Contracting Parties. They received no response from 54 countries, mainly in Africa and Latin America and the Caribbean, and concluded that the "facilitated access" promised by the ITPGRFA is not straightforward.

[28] To facilitate the implementation of access and benefit sharing in domestic policy processes, FAO has developed "ABS Elements" (FAO, 2019[199]).

[29] An accession is a sample of seeds that represents a variety, breeding line or a population and is distinct and uniquely identifiable. It is maintained in storage for conservation and use.

[30] The Commission produces regular global scientific assessments (State of the World reports) of genetic resources for food and agriculture. Based on the trends, gaps, and challenges identified in these assessments, the Commission aims to develop consensus on policy measures that are summarised in Global Plans of Action (GPAs) and other documents through which governments commit to take action to conserve and sustainably use genetic resources for food and agriculture.

[31] Heterogeneous plant material is a group of plants (or seeds) that comes from a single botanical taxon of the lowest known rank (genus or species). The group, however, is characterised by a high level of genetic and phenotypic diversity (hence it is heterogeneous) (Regulation (EU) 2018/848).

[32] In France, the "catalogue des espèces et variétés de plantes cultivées" (see https://www.geves.fr/catalogue/) contains specific lists for conservation varieties that are adapted to local and regional conditions and threatened by genetic erosion, however, these varieties cannot be marketed. The list also recognises old vegetable varieties whose seeds can be marketed in limited quantities in France for commercial production under specific growing conditions.

[33] The biosafety concerns regarding genetically engineered organisms differ depending on the organism (e.g. plants, trees, animals, micro-organisms), the engineering that has taken place and its potential use (e.g. industrial processes, agriculture, food, feed). In the context of agriculture, key concerns include those of gene transfer (the transfer of genetic material from a genetically engineered plant to a naturally occurring plant), potential impacts on non-target organisms, increased use of pesticides such as herbicides and increase in resistance among pests. A number of these issues may also be experienced when using non-GEOs.

[34] The relevant documents are *Principles for the Risk Analysis of Foods Derived from Modern Biotechnology* (CAC/GL 44-2003) and guidelines for the conduct of food safety assessment of foods derived from recombinant-DNA plants (CAC/GL 45-2003), micro-organisms (CAC/GL 46-2003), and animals (CAC/GL 68-2008); see http://www.fao.org/3/a-a1554e.pdf (accessed 11 September 2020).

[35] The separation of risk assessment and risk management roles has been adopted into law in Europe in order to clearly distinguish between the roles of science and politics (Food Safety News, 2013[186]). While this distinction may help clarify the process of science-based policy-making, the precise roles and responsibilities of risk assessors and managers may still create confusion.

[36] A further distinction is between regulations that govern the use of GE seed and those that govern food and feed derived from GE crops. To approve a transgenic seed for environmental release in most countries requires the technology to pass a number of biosafety requirements that are not needed for food or feed commercialisation. For example, only one transgenic crop is currently authorised in the European Union for commercial cultivation (insect-resistant maize grown in Spain and Portugal, see ISAAA (2018[166])) while more than 70 GE soybean, maize, and oilseed rape varieties are authorised for import in the European Union as commodities for feed use (Biotrack, 2020[167]).

[37] Tothova and Oehmke (2004[107]) observed the formation of 'clubs' at the country level in terms of GE regulation. They identify two trading blocs: one in favour, the other against GEOs. Countries in between face a choice between lower production costs (through the adoption of GE crops) or maintaining key export markets by restricting GEO production.

[38] In addition to national regulations, several international bodies and regulatory frameworks govern GE crops. These include the Cartagena Protocol on Biosafety and the Nagoya-Kuala Lumpur Supplementary Protocol on Liability and Redress, as well as Codex Alimentarius and the World Trade Organization (WTO).

[39] The most recent communication from the European Union notes that although mutually agreed solutions have been found with states with Argentina and Canada, discussions with the United States continue (WTO, 2020[201]).

[40] It is worth noting that the same technology could also be used to develop *transgenic* organisms, which can be distinguished from natural mutations (in contrast with cisgenic organisms).

[41] In the European Union, it was initially unclear whether NPBTs fell under the existing legislation on "genetically modified organisms" (EU Directive 2001/18/EU). This legislation exempts a number of techniques, including mutagenesis. However, the text does not precisely define mutagenesis, while the definition of a "genetically modified organism" itself is also somewhat ambiguous (Eriksson, D. et al, 2018[180]). On 25 July 2018, the European Court of Justice clarified the interpretation of the Directive. The Court ruled that varieties obtained using the new plant breeding techniques are Genetically Engineered Organisms and hence fall under the same regulatory framework (Court of Justice of the European Union, 2018[181]).

[42] In March 2018, the United States Department of Agriculture announced that it would not regulate "plants that could otherwise have been developed through traditional breeding techniques," provided that they are not "plant pests or developed using plant pests" (USDA, 2018[179]). This statement implies that new plant breeding techniques such as genome editing will not fall under the same regulatory framework used for genetically engineered organisms.

[43] In September 2020, Health Canada published a Notice of Intent to develop and publish new guidance for the Novel Food Regulations, focussed on plant breeding. (Health Canada, 2020[193]).

[44] According to the Swiss Federal Council (Motion 19.4050) CRISPR/Cas9 mutations are included within the scope of application of the Gene Technology Act and therefore considered as genetic engineering but considerable work is being done on the analysis of the conceptual problem. In 2020, the Swiss Federal Council will publish a proposal for an appropriate modification of this legislation and after a public consultation submit the proposal to the parliament for discussion and adoption.

[45] In addition to facilitating innovation by SMEs and thus potentially stimulating competition, this regulatory approach could also help local farmers by allowing more locally adapted varieties.

[46] These differences extend to other areas of agriculture and food safety: 68% of scientists (70% of biomedical researchers and 81% of chemists) consider food produced with pesticides safe to eat, only 28% of the broader public agreed (Pew Research Center, 2015[127]).

[47] Interestingly, farmers' perceptions of GE appear to be influenced by other factors. A study of farmers in the European Union showed that economic issues such as the promise of a higher income and the reduction of weed control costs were the most important factors for potential adopters of genetically engineered herbicide tolerant crops (Areal, Riesgo and Rodrıguez-Cerezo, 2011[192]).

[48] Several studies suggest that commonly available sources of information have tended to disproportionately emphasise negative aspects of genetic engineering. An analysis of media reports on agricultural biotechnology in five major newspaper sources in the United States and the United Kingdom concluded that "sensationalism and bias" have historically been present in reporting on "GM" biosafety (Marks and Kalaitzandonakes, 2001[168]). Durant and Lindsey (2000[169]) also found that a number of journalists focused on risks, and expressed standpoints opposed to "GMOs", sometimes entering into opposition movements themselves.

[49] For example, Ryan (2014[170]) highlights the use of techniques including imagery, metaphors and celebrity endorsements to encourage momentum against genetic engineering technologies.

[50] A related issue is whether a greater use of herbicides would in turn accelerate the emergence of resistant weeds. For example, the use of herbicide tolerant crops in North and South America induced many farmers to narrow down their crop rotations and ultimately grow these crops as monocultures, often against the recommendation of seed retailers. This in turn led to weeds developing resistance to glyphosate-based herbicides (Fernandez-Cornejo et al., 2014[171]). These agronomic problems are not inherent to transgenic crops (indeed, glyphosate was widely used as a herbicide before transgenic crops were introduced) and are the result of inappropriate use of pesticides, but are now associated with transgenic crops.

[51] Stone (2010[63]) reviews selected articles related to the role of farmers and communities in conserving genetic resources, including Kloppenburg (2004[182]) who places the question of ownership of plant genetic resources within a broader discussion on the appropriation of biological resources from the global south, and Brush (1993[183]) and Cleveland and Murray (1997[184]), who examine the spread of new IPRs and the impact of biotechnology on indigenous peoples, while McAfee (2003[185]) considers IP regimes in the context of the of the Convention on Biodiversity. The issue is closely related to broader discussions about the principle of free, prior and informed consent of indigenous peoples; see Tamang (2005[194]) for an overview.

[52] In terms of the “expected utility” framework in economic theory, scientific evidence can help to assess probabilities and outcomes, but individual consumers differ in their degree of risk aversion.

[53] As an example of this clustering of beliefs, opposition to “GMOs” was first taken up by various environmentalist organisations such as Greenpeace or Friends of the Earth, as well as supporters of Green political parties and organic agriculture associations. The anti-“GMO” movement later expanded to other groups such as farmer's unions and anti-globalisation organisations, adding an “economic” dimension (Bonny, 2003[177]).

[54] See also the OECD Competition Assessment Toolkit (OECD, 2020[188]) and related OECD work on pro-competitive policy reforms (OECD, 2020[189]).

5 The contribution of the ruminant livestock sector to the triple challenge

Ruminant livestock is an important source of protein and livelihoods, but is a significant contributor to environmental problems, including climate change. This chapter reviews its contribution to the triple challenge and illustrates how governments in Ireland, the Netherlands and New Zealand (countries with important ruminant livestock sectors) are navigating trade-offs and incorporate facts, interest and values in their policy process. Scientific facts, including from independent advisory groups, play an important role but are not always widely accepted by the public or stakeholders. Through consultation with stakeholders, policy makers hear from groups with different interests, including those with livelihoods at stake. Values play a role as well, including farmers' sense of belonging to a rural community, the importance of reducing climate change emissions in all sectors, as well as animal welfare, preserving landscapes, and the ethics of eating meat. Policy developments have also been influenced by court challenges and innovative mechanisms such as deliberative processes.

Key messages

- Ruminant livestock are an important source of protein and income, but are also a significant source of environmental problems, including climate change.
- Ireland, the Netherlands and New Zealand – large producers of ruminant livestock products– have policies that target the reduction of methane emissions from enteric fermentation and improving water quality.
- Ireland has used an innovative deliberative process to navigate the facts, interests and values conversation for its climate policy approach, including the consideration of how to tackle agricultural greenhouse gas emissions.
- Climate litigation in the Netherlands will have significant impacts on policy responses that target the ruminant sector.
- New Zealand has agricultural specific commitments to reduce GHG emissions and it has established a public/private partnership to achieve this.

5.1. Introduction

Ruminant livestock – a category of animals that includes cattle, sheep, goats and buffalo – play an important role in global food security and nutrition, as well as in the livelihoods of farmers and others along the food chain. Ruminants provide a diverse range of products, such as meat, milk, hides, wool, heat and energy, and play an important role in animal-powered mechanisation on farms.[1] At the same time, ruminant livestock production systems raise a number of concerns around environmental sustainability, in particular because of their impact on greenhouse gas (GHG) emissions (Gerber, 2013[1]), water use and water quality, and biodiversity (Steinfeld et al., 2006[2]). This case study summarises the main linkages between elements of the triple challenge and discusses policy responses in three countries where livestock are a significant part of the agricultural sector (Ireland, the Netherlands, and New Zealand).

Ruminants are raised in three main production systems: extensive grazing on pasture; mixed systems that combine grazing with supplementary feed; and intensive systems including feedlots used to finish cattle for slaughter. Production systems vary worldwide in terms size, livestock numbers, stocking densities, technology, and capital and labour intensity. Mixed systems rely on pasture as well as feeding supplements such as hay, silage and grains. Extensive and mixed grazing represent the majority of ruminant production systems, accounting for 87-94% of worldwide beef production (Mottet et al., 2017[3]). Herrero et al. (2013[4]) estimate that in 2000, 69% of milk and 61% of meat sourced from ruminants worldwide were produced in mixed systems. Capital-intensive feedlot systems involve high animal density and the use of concentrated feed and, in the case of beef, aim to minimise the time required to prepare animals for slaughter (Tarawali et al., 2019[5]). Globally intensive livestock operations have been on the rise with feedlot systems for beef production growing in prevalence (FAO, 2018[6]). Intensive feedlots account for between 7% and 13% of the world's total beef production (Mottet et al., 2017[3]).

Ruminant livestock are the largest user of land worldwide with an estimated one-third of the earth's surface used for livestock grazing (direct use) and feed production (indirect use) (Herrero et al., 2013[4]). Land conversion from natural habitats to grazing land reduces biodiversity and ecosystems services and releases large amounts of CO_2 (Steinfeld et al., 2019[7]). Grazing to manage pasture ruminant livestock, however, can also play an important role in contributing to landscapes, habitats and biodiversity, and can control and prevent the incursion of weeds and other invasive plant species.

Livestock productivity varies considerably around the globe. Gaps between actual and potential milk yields are evident in sub-Saharan Africa, Latin America and South Asia (Steinfeld et al., 2019[7]). For instance, in 2015 average milk yields in North America were 9.9 tonnes per animal per year, compared with 4.7 tonnes in Oceania, 1.9 tonnes in Central and South America, 1.4 tonnes in South Asia, and 0.5 tonnes in Sub-Saharan Africa (Bizzarri and Gapon, 2019[8]). Milk yields, slaughter weights and feed conversion ratios depend on many factors including genetics, animal husbandry practices, the quality of pasture, and supplementary feed. For example, feed conversion ratios can be improved through enhanced feed quality and the addition of concentrates, i.e. moving from an exclusive grazing system to a mixed system. Optimal feed strategies depend on whether ruminant animals are producing milk or meat, or are part of the breeding herd being raised until such time as they are productive. The breeding herd for ruminants contributes the bulk of emissions (Gerber, 2013[1]).

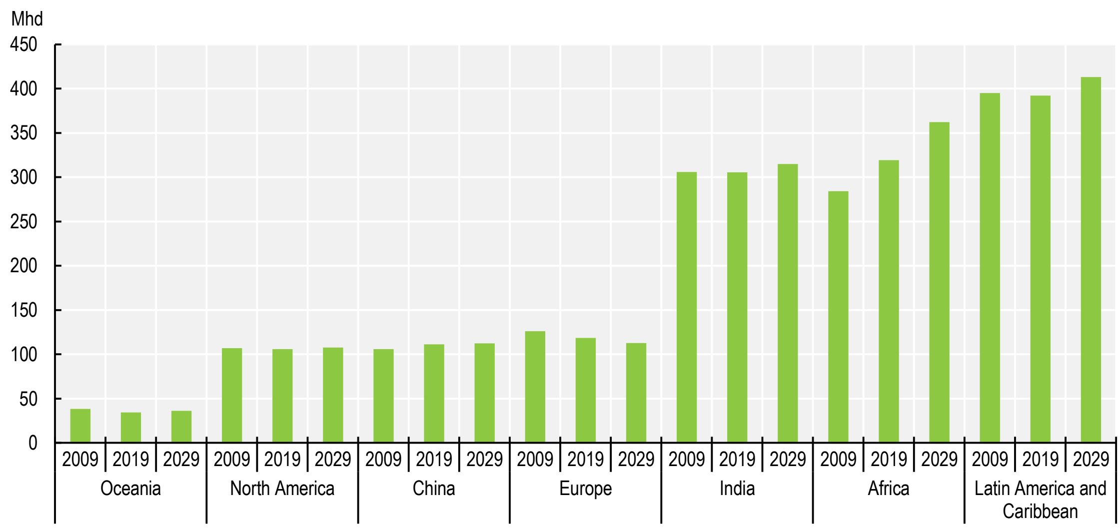
Reducing productivity gaps in a manner that avoids unintended consequence for land use is important not only for increasing food availability in regions with fast growing populations and for reducing land pressures, but also for climate change mitigation.[2] GHG emissions per unit of product or per unit of protein are much lower in highly productive systems (Havlík et al., 2014[9]). The importance of addressing productivity gaps is underscored by the fact that the largest number of ruminants are found in regions where productivity is the lowest and therefore GHG emissions per head are the largest (Blandford and Hassapoyannes, 2018[10]).

Ruminant livestock currently plays a crucial role in global food security and nutrition. A third of global protein intake and 17% of calories come from animal sources, much of it from ruminants (FAO, 2018[11]). More than a quarter of the world's 570 million farm holdings keep at least one ruminant animal, which improves these families' livelihoods, food security, and nutritional outcomes, as well as providing a mode of traction. Ownership of cattle by women in developing countries enables their economic progression and empowerment; approximately 80 million women worldwide are involved in dairy farming (FAO, 2016[12]).

With the global population set to expand from 7.7 billion in 2019 to 8.5 billion in 2030, 9.7 billion by 2050 and 10.9 billion by 2100, increasing global incomes will mean that demand for ruminant proteins will continue to grow (United Nations Population Division, 2019[13]). Total beef production is set to increase by 9% over the next decade to 2029 and total milk production will increase by 20% over the same period (OECD/FAO, 2020[14]). Higher levels of production of milk and ruminant meat are expected to come mostly from the expansion of global cattle herds, from their current level of 1.6 billion to nearly 1.8 billion in 2029. As of 2019 the largest numbers of cattle (including cows, buffalos, bulls and veal) are found in the Latin American and African regions along with India (Figure 5.1). In the ten years to 2029 animal numbers are predicted to grow in Latin America (by 5% to 413 million head), Africa (by 13% to 362 million head), and India (by 3% to 315 million head).

The growing number of ruminants worldwide has had serious environmental consequences, notably through land use change (negatively affecting biodiversity and GHG emissions), direct GHG emissions, and negative effects on water use and quality, and air quality. Direct GHG emissions from ruminants are a by-product of the digestion process, where ingested plant material begins to be digested in the rumen (the large forestomach) by microbes. This process of enteric fermentation creates methane (CH_4), belched or expelled by the animal, which has a short-lifetime (on average 12.4 years) in comparison to CO_2 which can survive in the atmosphere for centuries to millennia (Intergovernmental Panel on Climate Change, 2013[15])). While enteric fermentation is the main source of methane from ruminants, animal manure is also a significant emitter of the gas, as well as of nitrous oxide. Many factors influence the quantity of methane produced by animals, and the GHG emission intensity per unit of product from ruminant livestock varies considerably with the production system and the location of production.

Figure 5.1. Cattle inventory by region 2009, 2019 and 2029



Note: Mhd = Million head.
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Because of these environmental consequences, countries have implemented different policy approaches to address the sector's use of natural resources and its contribution to GHG emissions. Countries' policy approaches to agricultural GHG emissions are discussed further in the sections below, where recent policy approaches taken by Ireland, the Netherlands and New Zealand (countries with significant ruminant livestock sectors) are described based on information provided by these same countries themselves. Broadly speaking, all three implement a mix of policies to increase efficiency in order to maintain production and reduce negative environmental outcomes. Coherent policy processes, engagement with stakeholders, and the use of scientific research are described to highlight how these countries are navigating the facts, interests and values paradigm and taking decisions to deal with the trade-offs and synergies from competing policy objectives in terms of the triple challenge. Subsequent impacts of policies on ruminant producers are explored, including governments' efforts to assist them with transition strategies towards low emission production models or to exit the sector altogether.

5.2. Food security and nutrition

Meat and milk from ruminant livestock are nutrient dense foods which are an important source of calories, high-quality proteins, and micro-nutrients (Mottet et al., 2017[3]). Under-consumption of animal proteins is linked to malnutrition and stunting with serious health outcomes globally (Adesogan et al., 2019[16]; FAO, 2018[11]). Consumption of products from ruminants is low in some regions (notably Sub-Saharan Africa) and unlikely to increase given predicted low income growth. This presents a serious nutritional challenge as the highest future population growth will take place in these regions. In OECD countries, consumption of meat and dairy is high, although demand for red meat is decreasing, while demand for dairy is stable to declining for fresh dairy products but increasing for cheese (OECD/FAO, 2020[17]). Overconsumption of red meat and processed meat has been linked to cancer and, although the science is inconclusive on the extent of the risks, national dietary recommendations for many countries advise limiting weekly intakes.

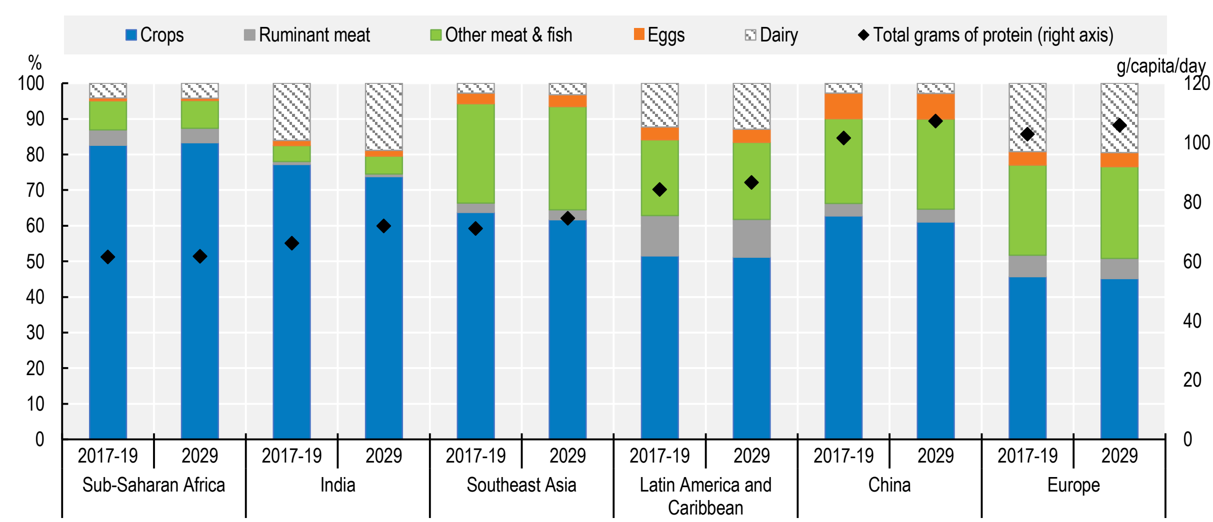
Consumption of ruminant livestock products around the world

Products produced from ruminant livestock are an important source of energy, high-quality protein and micro-nutrients, including vitamins A, B_{12}, and B_2, and calcium, iron and zinc minerals. Obtaining sufficient quantities of these nutrients from plant-based foods uniquely is challenging (Mottet et al., 2017[3]; FAO, 2018[11]). Seventeen per cent of calories and 33% of protein consumed worldwide comes from animal sources (FAO, 2018[11]).

Low intakes of animal products are associated with malnutrition leading to serious consequences globally (Adesogan et al., 2019[16]; FAO, 2018[11]). Health problems include anaemia and risks to pregnancy from lack of B_{12}. Even if calorie requirements are met, insufficient consumption of animal-sourced nutrition in the form of meat or milk by pregnant and lactating women, babies and young children can result in stunting. Stunting is linked to increased risk of infant mortality, but also lifelong consequences such as reduced IQ score, and reduced earnings of adults by 22%. Stunting is an indicator of chronic undernutrition, from which globally 151 million or nearly 25% of children under the age of five suffer (Adesogan et al., 2019[16]; FAO, 2018[6]). Children from households where women own livestock have better nutritional results than households without livestock (Adesogan et al., 2019[16]). This could be due in part to livestock's role in providing livelihoods, as discussed in the following section.

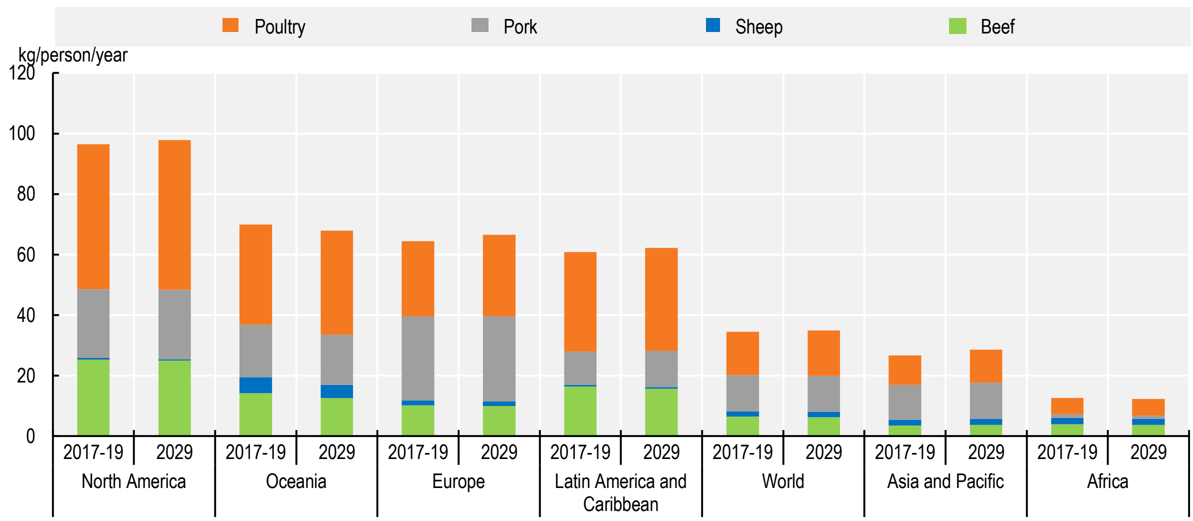
As is apparent from Figure 5.2 the importance of ruminant meat and dairy as a protein source varies by region. Populations in Sub-Saharan Africa and India get the majority of their daily protein from crops, while in other parts of the world animal proteins are the largest source of daily protein intakes. In Latin America, both ruminant meat and dairy are important sources of protein, whereas in Europe dairy is proportionally more important. In India, dairy proteins are important too.

Figure 5.2. Contribution of ruminant meat and other protein sources to total daily per capita availability



Note: Bars refer to the share of the food group in total daily per capita protein intake (left axis); Dots represent the total quantity daily per capita protein intake (right axis); Crops include arable food crops (cereals, edible oilseeds, pulses, roots and tubers, sugar)
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Figure 5.3. Per capita meat consumption by region



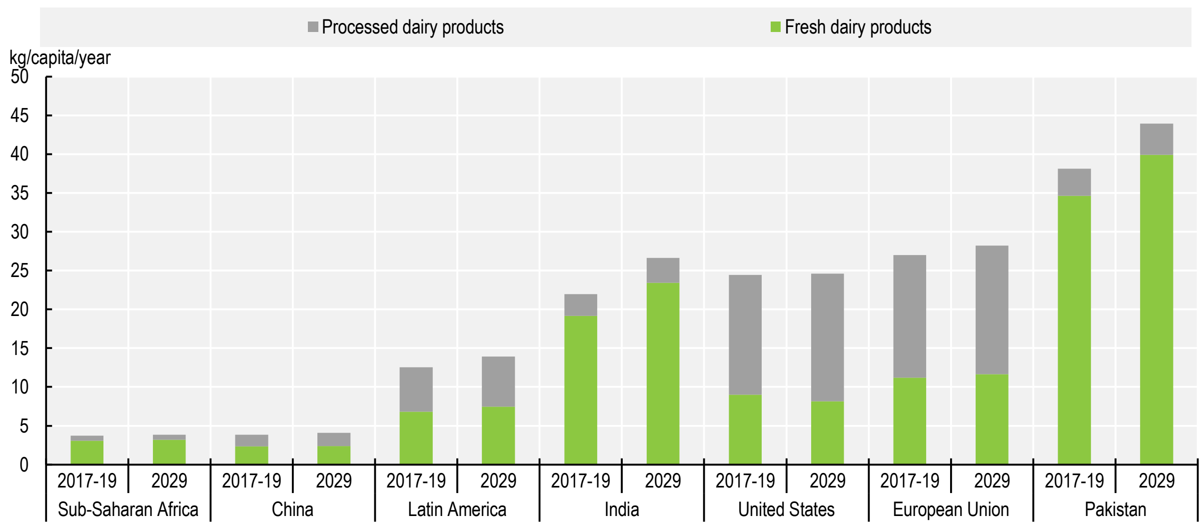
Note: Per capita consumption is expressed in retail weight.
Source: OECD/FAO (2019), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Consumption of (all types of) meat in Africa and in Asia and the Pacific is low (Figure 5.3). In terms of beef consumption, developed countries currently consume approximately three times as much as developing countries. While growing in developing countries, in particular Asia, the rate of beef consumption is on the decline in many OECD countries albeit from high consumption levels. This is particularly the case in the European and Central Asian region (OECD/FAO, 2020[14]). For example, per capita consumption of beef in New Zealand decreased from 23.3 kg per capita in 1992-94 to 15.7 kg in 2012-14 and is predicted to decrease by 11.3 kg in 2028-30. Beef consumption in Canada shows a similar decline, from 23.3 kg in 1992-94 to 19.7 kg in 2012-14, and it is predicted to decline to 16.8 kg per capita by 2028-30.

The importance of fresh dairy products to populations in Pakistan and India, and the predicted growth in demand in these countries, is evident from Figure 5.4. Low growth in dairy consumption is predicted for Sub-Saharan Africa, while demand for dairy in the European Union and the United States is predicted to remain relatively stable.

Weakening demand in developed countries for ruminant meat products is due to several factors, including concerns about the climate impact of cattle, dietary recommendations from governments to reduce red meat consumption, and animal welfare and the ethical considerations regarding eating animals. Climate and health concerns, rather than animal welfare, are behind the increasing interest in veganism observed in recent years in OECD countries (The Economist, 2020[18])

Figure 5.4. Per capita consumption of processed and fresh dairy products in milk solids by country and region



Note: Milk solids are calculated by adding the amount of fat and non-fat solids for each product; Processed dairy products include butter cheese, skim milk powder and whole milk powder.
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

Food versus feed and the impacts on food security

Producing livestock products requires animal feed, which in turn may compete directly with production of food for human consumption. For instance, arable land may be used for growing feed crops for animals rather than food (e.g. growing maize and soybean instead of wheat). Some land used for grazing livestock could also have been planted with food crops. Discussions of these trade-offs often focuses on beef production, emphasising the large quantities of grain fed in feedlot systems.

In feedlot production systems cattle can consume up to 20 kg of grain for each kilo of beef produced (Mottet et al., 2017[3]). However, feedlot systems are not the main method of producing beef. Grazing and mixed production systems are estimated to produce 87-93% of the world's beef. Ruminants under these production systems eat a large proportion of feed that is not edible for humans, such as grass, leaves, and crop residues (Mottet et al., 2017[3]). In 2010, of the 4.8 billion tonnes of dry matter consumed by ruminants worldwide (cattle and buffaloes, as well as small ruminants), 95% was inedible for humans (Mottet et al., 2017[3]). That said, 240 million tonnes of dry matter per year fed to livestock could have been consumed by humans (of which 210 million tonnes per year was grains) and 270 million tonnes of dry matter per year fed to ruminants was in direct competition with food production for human consumption (Mottet et al., 2017[3]).

About 560 million ha of the world's crop land is being used to produce feed crops of cereals and oilseeds instead of crops consumed directly as food (OECD/FAO, 2019[19]). Furthermore, more than 3 billion ha of land globally is used for grazing, of which 685 million ha could be used for producing crops for food (Mottet et al., 2017[3]). Inclusion of this land would increase global arable land by half (OECD/FAO, 2019[19]).

Potential negative effects on human health

Overconsumption of meat

Diet is linked to health outcomes and contributes to non-communicable diseases (NCDs). Worldwide 1.9 billion people do not have regular access to sufficient, safe, and nutritious food (FAO, IFAD, UNICEF, WFP, WHO, 2020[20]) and an even greater number are overweight or obese (WHO, 2020[21]). Afshin et al (2019[22]) investigated the dietary risk factors for the 2017 Global Burden of Disease study for the period 1990-2017 in 195 countries. According to their research, in 2017 dietary risk factors were the cause of 11 million deaths and 255 million disability adjusted life years (DALYs) globally. In terms of diet-related deaths from high processed meat and red meat consumption, these were ranked 13th and 15th out of 15 dietary risk factors attributable to deaths at the global level (Afshin et al., 2019[22]).

Many countries have national dietary guidelines providing evidence-based, context-specific advice on healthy diets and lifestyles, that take into account food production, consumption and accessibility, and socio-economic influences (FAO, 2020[23]). The dietary recommendations of developed countries often include limiting the consumption of high-fat meat products, in particular red meat and processed meats (Herforth et al., 2019[24]).

As an illustration, New Zealand's Eating and Activity Guidelines from 2015 (MoH, 2015[25]) recommend limited consumption of low and reduced fat dairy products and suggest consuming less than 500 g of cooked red meat per week. Ireland's 2017 Food Pyramid suggests that two to three servings of lean red meat (half the size of the palm of an adult hand) can be consumed weekly (FSAI, 2017[26]). Brazil's dietary guidelines from 2015 acknowledge that red meats are "excessively consumed in all of Brazil" (Ministry of Health, 2015[27]). While highlighting the benefits of red meat consumption in terms of micronutrients, Brazil's guidelines also refer to the high fat content of red meat and the link between overconsumption and the risks of heart disease, chronic diseases and bowel cancer (Ministry of Health, 2015[27]). The EU's "Farm to Fork" strategy highlights the need to reduce red meat consumption and move towards a plant-based diet to meet health and environmental objectives (European Commission, 2020[28]).

Such recommendations derive in part from epidemiological studies which have linked high levels of red meat and processed meat consumption with higher risks of cancers, cardiovascular diseases, and strokes (Abete et al., 2014[29]) (Chen et al., 2012[30]) (Sun, 2012[31]) (Sinha et al., 2009[32]) (Etemadi et al., 2017[33]). Some recent papers have challenged these findings, emphasising methodological limitations of previous studies (Zeraatkar et al., 2019[34]) (Zeraatkar et al., 2019[35]) (Vernooij et al., 2019[36]) (Han et al., 2019[37]). As with previous studies, these analyses generally find a correlation between negative health outcomes and the level of consumption of red and processed meat, but the authors state that the effects are smaller and the evidence weaker than previously found.

Antimicrobial resistance

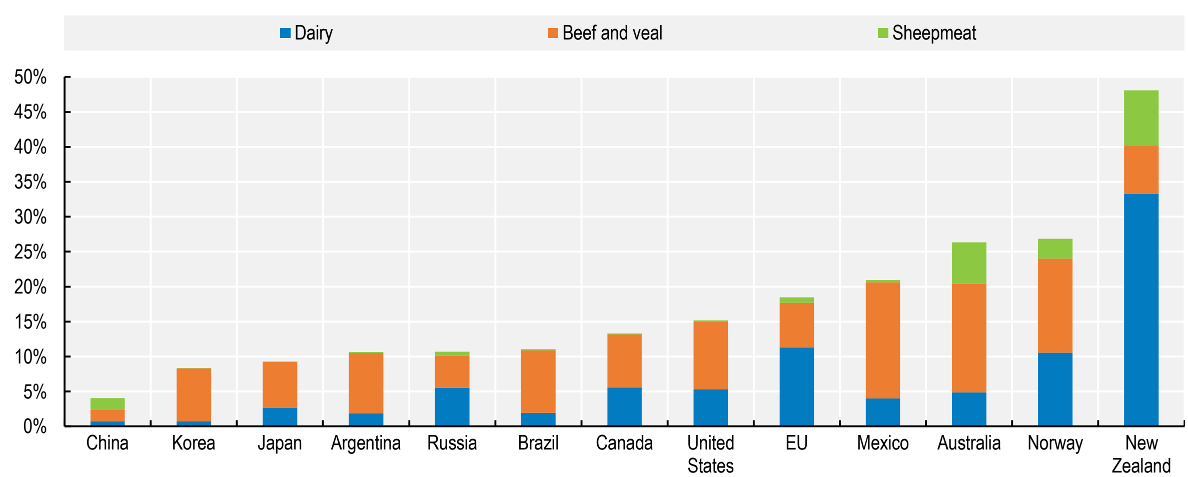
Concern is growing over the use of antimicrobials in food-producing animals and the emergence and transmission of resistant bacteria between animals and humans and vice versa (Rushton, Pinto Ferreira and Stärk, 2014[38]; Morel, 2019[39]; Ryan, 2019[40]; Godfray et al., 2018[41]). Antimicrobials are mainly used in intensive pig and poultry production systems (accounting for 80% of antimicrobial use) However, dairy cattle receive antimicrobial treatments during lactation and after calving on an individual basis. Antimicrobials are also added to feed in some intensive beef production systems to enhance growth and improve weight gain and feed efficiency (Rushton, Pinto Ferreira and Stärk, 2014[38]). However, the global use of antimicrobials as growth promoters in intensive beef production is declining. Bans on their use have been in place in the European Union since 2006, and the United States has been phasing antimicrobials for growth promotion and limiting their use for medical reasons since 2017. The European Union's "Farm to Fork" strategy includes the goal to reduce sales of antimicrobials for land animals (and for aquaculture) by 50% by 2030 (Eurostat, 2020[42]). A recent report from the World Organisation for Animal Health (OIE) indicates that as of 2018, 35 of 153 countries continue to use antimicrobials for growth promotion — down from 45 countries in the previous year (OIE, 2020[43]; Góchez et al., 2019[44]).[3]

5.3. Livelihoods

Many people are dependent on livestock for their livelihoods. Ruminant and non-ruminant livestock together contribute 40% to the global value of agricultural output and support the livelihoods and food and nutrition security of much of the world's population. More than one quarter of the world's 570 million farm holdings keep at least one milk-producing ruminant animal and only 0.3% of the world's dairy farms have more than 100 cows. Ruminant livestock is particularly important from a gender equality perspective. It is estimated that 80 million women are involved in dairy farming worldwide (FAO, 2016[12]). For rural women in developing countries, owning livestock is an important asset and one that is more readily obtainable compared to other assets (e.g. land) to which women may not have access (FAO, 2016[12]). Owning livestock provides women with opportunities to improve their economic empowerment and position in society; for example, through the ability to gain credit, increase income and exert greater decision-making power in the household and community. A quarter of the households with dairy cows (or 37 million farm holdings) are headed by women, and women are actively involved in animal husbandry, livestock management, and in selling milk (FAO, 2016[12]). Furthermore, ownership of livestock provides higher incomes and nutritional outcomes for households (Adesogan et al., 2019[16]).

Ruminant livestock plays an important role in many countries' economies (Figure 5.5). In New Zealand, dairy is the largest export earner, accounting for approximately 25% of total exports and employing 48 000 people (approximately 3% of total employment). Dairy farming and processing make up 3.1% of New Zealand's GDP (NZIER, 2018[45]). Irish dairy exports are valued at over EUR 5 billion in 2019 (with total agri-food exports worth EUR 14.5 billion in the same period) (DAFM, 2020[46]).

Figure 5.5. Relative importance of ruminant livestock in selected countries 2018



Note: Figures shows the estimated value of production of ruminant livestock commodities covered in the *OECD-FAO Agricultural Outlook*, as a percentage of total value of agricultural production.
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database). http://dx.doi.org/10.1787/agr-outl-data-en.

The ruminant livestock sector contributes significantly to the rural economy in some countries in terms of providing positive socio-economic outcomes. For instance, in the western half of Ireland suckler beef and sheep farming are the only food production systems suitable for the climate and terrain. In these rural areas ruminant livestock supports employment and social cohesion and preserves landscapes (DAFM, 2019[47]).

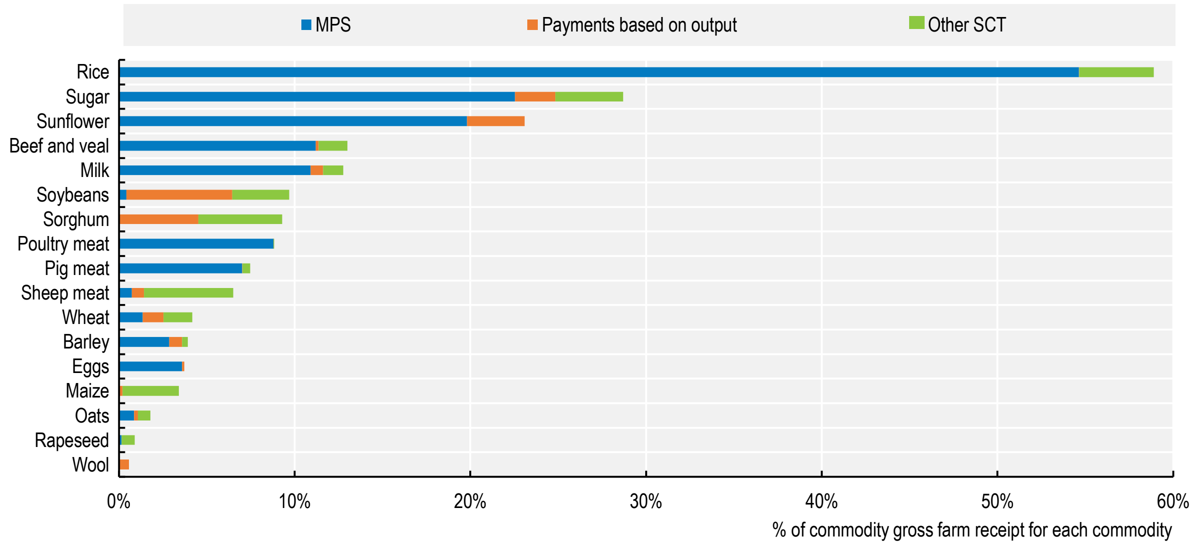
Farming as an occupation is also associated with a farmer's sense of identity, their community status, and their social and cultural capital based on their skills and perceived success (Burton, 2004[48]) (Burton, Kuczera and Schwarz, 2008[49]) (Wreford, Ignaciuk and Gruère, 2017[50]) (Burton, 2014[51]). Furthermore, remote rural communities are characterised as having highly specialised economies that make them more vulnerable to economic shocks (OECD, 2020[52]). Livestock production and meat processing activities based in rural areas create a concentration of people with a similar set of skills. This makes finding alternative employment, following for example, the closure of a meat processing plant challenging, potentially leading to out-migration. In New Zealand, many people employed in the red meat sector identify as Māori; ceasing meat industry activities could impact their communities disproportionately (Beef+Lamb NZ and MIA, 2020[53]).

Incomes of ruminant livestock producers are supported by some governments, particularly in developed countries. Among the 54 countries covered by the OECD's *Agricultural Policy Monitoring and Evaluation 2020* report, most provide income support to producers in the ruminant livestock sector (i.e. milk, beef and veal, and sheep meat) (OECD, 2020[54]). Over the period 2017-19, milk and beef and veal were among the commodities receiving the highest levels of support (Figure 5.6), mainly in the form of market price support, i.e. policies that increase domestic market prices through import restrictions or price floors. Such measures are particularly trade and production distorting. During the period 2017-19, effective prices received by producers were, on average, 13% higher than world prices for milk and beef (OECD, 2020[54]). The European Union provided the highest level of support for beef and veal on average over the period 2017-19, followed by China and Turkey. In terms of average support to milk over the same period the United States provided the highest level of support, followed by China and then Japan, and for sheep meat China provided the largest level of support followed by the European Union.

Trade in ruminant products is often restricted by tariff rate quotas for beef, cheese, butter and other dairy products, and tariffs on ruminant products are frequently among the highest compared with all other products. For instance, in the United States the highest average applied tariffs (above 100%) levied on agricultural products in 2016-2018 were for certain dairy products (WTO Secretariat, 2018[55]). In 2016, imports by the European Union of dairy products were charged the highest applied tariffs, with average applied tariffs for dairy products of 35%, and tariff peaks of 187% (WTO Secretariat, 2017[56]). Both the United States and the European Union maintain tariff rate quotas for beef and certain dairy products.

In addition to high tariffs, ruminant products are subject to non-tariff measures (NTMs) in the form of Sanitary and Phytosanitary (SPS) measures and Technical Barriers to Trade (TBT) (Greenville et al., 2019[57]). Traded ruminant products are perishable and meat and dairy are relatively high risk in terms of disease and foodborne illnesses (CDC, 2018[58]). SPS measures frequently applied to these products include certain restrictions based on an exporting country's disease status (e.g. for countries with Foot and Mouth Disease), product registration and approval, testing, certification of conformity, inspections, marking and packaging and labelling, and tolerance limits for residues (UNCTAD, 2019[59]). TBT measures (which cover different aspects of production and the supply chain) applied to ruminant products include labelling, marking and packaging requirements, and production process requirements. Standards can be trade creating as well as cost increasing – what matters is that they are science and risk based, transparent, non-discriminatory and efficient to reduce unnecessary trade costs.

Figure 5.6. Transfer to specific commodities (SCT), 2017-19



Note: Colombia became the 37th member of the OECD in April 2020. In the data aggregates used in this report, however, it is included as one of the 13 emerging economies.
Source: OECD (2020), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

5.4. Climate change and natural resource use

Climate change

Over the period 2007-16 emissions from agriculture, forestry and other land use (AFOLU) made up 23% of total net anthropogenic emissions of greenhouse gas (GHG) emissions. By adding in other stages of the food system (storage, transport, packaging, processing, retail and consumption) this reaches to 21-37% of total emissions (IPCC, 2019[60]).

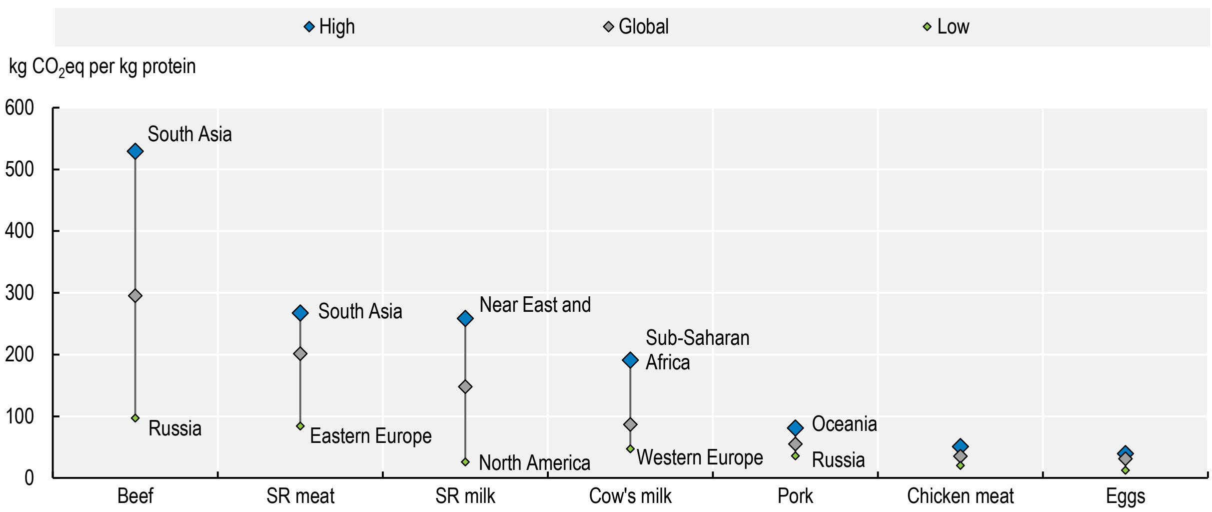
Direct emissions from agricultural production account for 12% of global anthropogenic emissions, and biological processes of ruminants are the largest source of these direct agricultural emissions (IPCC, 2019[60]). Globally, enteric fermentation accounts for 40% of direct emissions from agriculture and ruminant livestock also contribute to emissions from manure, which constitute 26% of direct emissions (other important sources are synthetic fertiliser and rice cultivation accounting for 13% and 10%). Among livestock-related direct emissions, cattle are responsible for 65%, buffaloes for 9%, and sheep and goats for 7% (Gerber, 2013[1]) (Steinfeld et al., 2019[7]). Enteric fermentation forms a significant part of direct agricultural emissions in most regions with the exception of South Eastern Asia (where rice cultivation is the major source of agricultural GHG emissions).

Over the period 1990-2014 global direct emissions from agriculture increased largely as a result of the growth in the number of ruminants and the subsequent increases in methane from enteric fermentation, expansion of extensive grazing of ruminants (increasing N_2O from manure deposited onto pasture), and the increased use of synthetic fertilisers (N_2O) (Blandford and Hassapoyannes, 2018[10]).[4]

Direct emissions of N_2O from agricultural soils are predicted to grow in significance and so this area is an important focus for ruminant livestock GHG emissions mitigation policies. Forecasts predict that emissions of N_2O from agricultural soils from synthetic fertilisers, soil cultivation, manure on pasture, and manure applied to soils will expand more rapidly than CH_4 emissions generated from livestock and rice cultivation or sources of CH_4 and N_2O emissions from manure management and burning of crop residues. As a result, in 2050 global emissions from enteric fermentation will be only 7% higher than emissions from agricultural soils, whereas in 1970 they were 60% higher (Blandford and Hassapoyannes, 2018[10]). This trend is already observed amongst OECD countries where higher agricultural soil emissions are responsible for most of the increases in GHG emissions over 2003-15 (OECD, 2019[61]).

According to life cycle assessments, emissions intensities of livestock products differ by product (Figure 5.7). Beef has the highest emissions intensity in terms of CO_2eq per kg protein produced, followed by meat from small ruminants (sheep), and milk from small ruminants. Cow's milk, pork, and chicken have global average emissions intensities of less than 100 kg CO_2eq per kg protein (Steinfeld et al., 2019[7]).

Figure 5.7. Global average emissions intensities for different livestock products



Note: Global average emissions intensities (Ei) for livestock stock products. SR: small ruminants
Source: Livestock Data for Decisions (2018) 'Livestock and Climate Change: Fact Check' based on data from FAO (2017), Global Livestock Environmental Assessment Model (GLEAM), www.fao.org/gleam/en

Globally, while GHG emissions from livestock have grown over time, their intensity in terms of GHG emissions per unit produced has been declining. Although high in terms of total emissions, the relative intensity of livestock's direct GHG emissions is lower in developed countries. For instance, the emissions intensities of beef in Europe are a third of those in Latin America and the Caribbean, and beef produced in Oceania and North America also have lower emissions intensities than those from this region (Blandford and Hassapoyannes, 2018[10]). Emissions intensities for ruminant livestock products are highest in Africa, India, and Latin America and the Caribbean, where the largest cattle herds are located (Gerber, 2013[1]) (IPCC, 2019[60]; OECD, 2019[61]) (Steinfeld et al., 2019[7]).

Advances in herd genetics, feed, and pasture quality and animal management have driven productivity gains over time, meaning the same level of production requires fewer animals and hence fewer emissions (Steinfeld et al., 2006[2]) (Gerber, 2013[1]) (Herrero et al., 2016[62]). For instance, the carbon footprint in the United States per kilogram of milk in 2007 was only 37% of the level in 1944 (Capper, Cady and Bauman, 2009[63]). Moreover, further efficiency gains in recent years have seen US milk production increase by nearly 25% over the years 2007-17, with total GHG emissions increasing by only 1% (Capper and Cady, 2019[64]).

Another important factor contributing to reducing emissions intensity is herd structure. Herds consist of productive animals producing meat or milk, and breeding herds, the replacement stock being raised until they are sufficiently mature to be productive. Breeding herds are necessary to maintain the main herd, but consume feed and produce emissions while not producing outputs; this is referred to as the "breeding overhead" (Gerber, 2013[1]). In specialised beef systems the breeding herd represents 69% of the total herd, whereas in dairy systems the breeding herd accounts for 52% (Gerber, 2013[1]) and the bulk of emissions come from these animals. Furthermore, since emissions intensities reflect animal productivity, dairy cows have lower intensities than beef because they produce both milk and meat whereas beef production systems produce only meat (Gerber, 2013[1]).

Globally, ruminants are responsible for indirect emissions from various sources, including producing feed, and producing fertiliser for application on feed crops, as well as emissions generated by processing and transporting feed, animals and livestock products. However, the most important indirect emissions are those from land use change. Pasture and arable land used for feed crops take up an estimated one-third of the earth's surface, accounting for the vast majority of total agricultural land use (Steinfeld et al., 2006[2]). Over time, demand for ruminant livestock products has led to increasing land conversion for pasture and for crops to produce animal feed (Steinfeld et al., 2006[2]). Deforestation and other habitat loss has resulted in significant biodiversity loss, as well as loss of ecosystems (i.e. pollination, pest control, and flood control) and increased CO_2 emissions from forest burning to clear land. Increased ruminant numbers have thus contributed to increased emissions and a reduced carbon absorption ability from forests (Steinfeld et al., 2019[7]). Other land-use effects include carbon emissions from desertification due to over grazing, and loss of soil organic carbon due to cultivation (Steinfeld et al., 2006[2]) (Steinfeld et al., 2019[7]). An estimated 44% of agriculture-related emissions in 2007-16 were due to land use change, much of this linked to ruminant livestock (IPCC, 2019[60]).[5]

Ruminant grazing and land management practices impact soil carbon stocks. The ability of soils to absorb carbon is not infinite and a saturation point is reached, and stocks can be easily diminished through ploughing techniques (Blandford and Hassapoyannes, 2018[10]). Furthermore, the higher temperatures from a changing climate could reduce the ability of soils to absorb carbon (WRI, 2019[65]).

Grazing by ruminants can increase or reduce soil carbon stocks (Steinfeld et al., 2006[2]) (Steinfeld et al., 2019[7]) (Henderson et al., 2015[66]) Pasture production responds positively to frequent grazing resulting in increased growth, and manure deposits add organic matter to soils (FAO, 2009[67]). However, over grazing of pastures leads to soil degradation through loss of vegetation cover, damaged soil structure (i.e. soil compaction), and increased risks of erosion (Steinfeld et al., 2006[2]) (FAO, 2009[67]; FAO & ITPS, 2015[68]). Potential for soil carbon sequestration depends also on factors such as location, soil type, land management practices, and other environmental factors (WRI, 2019[65]).

Countries are using innovative systems such as integrated livestock-crop, livestock-forest, or livestock-crop-forest to reduce the areas needed for livestock production and lower levels of emissions. An example of Brazil's Low Carbon Agriculture Plan (ABC Plan) which provides support to farmers who invest in such practices (Ministerio do meio ambiente, 2018[69]) (Henderson, Frezal and Flynn, 2020[70]) (OECD, 2020[71]). Argentina's National Forest Management Plan with Integrated Livestock (MBGI) programme aims to reduce forest degradation and livestock GHG emissions, while maintaining the productive capacity of the ecosystem and ensuring the welfare of farmers and communities (Ministerio de ambiente y desarrollo sustentable, 2016[72]).

Extensive versus intensive production systems

Emissions intensity of ruminant livestock products varies depending on whether animals are reared in extensive grazing, mixed systems, or intensive feedlots. Approximately 70% of milk and 60% of meat from ruminants globally are produced under mixed crop-livestock systems (incorporating supplementary feeds of grains, hay and silage) (Herrero et al., 2013[4]).

Several studies have examined which ruminant production system is least GHG emissions intensive and findings show generally favourable results for intensive production systems (Steinfeld et al., 2019[7]). There are a number of methodological choices which can influence results (Box 5.1) and the inclusion of cultivated feed crops tempers the extent of the efficiency gains (OECD, 2019[61]). Furthermore, feedlot beef production systems raise different issues including animal welfare concerns.

What is clear is that using energy dense supplementary feed improves feed digestibility. Shifting from a system of low inputs and low productivity based on extensive grazing to a mixed crop-livestock system incorporating the use of concentrates increases animal productivity and reduces total GHG emissions as long as the overall animal numbers and land use are reduced at the same time (Havlík et al., 2014[9]) (Herrero et al., 2016[62]; Gerssen-Gondelach et al., 2017[73]). However, in cases where grazing systems are already efficient, a low reliance on imported feed may reduce overall emissions intensity when all upstream and downstream emissions are taken into account (Styles et al., 2018[74]).

More intense production systems are associated with environmental challenges, such as managing the resulting manure which increases risks of air and water pollution. Intensification of livestock production reliant on concentrated feed, which may be imported, has led to nutrient oversupply in some regions and an inability to recycle surplus manure from animal production into crop production due to agricultural land limitations (Steinfeld et al., 2019[7]; OECD, 2019[61]).

Animal feeding strategies differ according to whether the animals are being fattened or milked, or whether they form part of the reproductive breeding herds. Meat and milk herds are more amenable to improved feeding practices that go with confinement (intensive production systems), or, in other cases cultivation of high quality pasture (for instance, in the Irish, New Zealand, and Dutch production models). The economics suit more extensive feeding practices; and while feed management still matters, the focus is on pasture rotations and feed quality with the inclusion of legumes (Drouillard, 2018[75]). However, other measures such as health, breeding, and husbandry can reduce mortality rates, improve fertility rates and, to some extent, growth rates, help to lower the breeding herd overhead and its associated emissions (Herrero et al., 2015[76]) (Gerber, 2013[1]).

Box 5.1. Measuring GHG emissions from ruminants

Greenhous gas (GHG) emissions heat the planet by absorbing energy and slowing the rate that the energy is released into the universe. Direct ruminant GHG emissions are mostly methane (CH_4) and nitrous oxide (N_2O), and these GHG gases along with CO_2 differ in their ability to absorb energy (measured by radiative efficiency, RE) and in their lifetime in the atmosphere.

- CO_2 has a relatively low radiative efficiency (RE), but a long average lifetime of centuries to millennia
- CH_4 has a higher RE, but an average lifetime of 12.4 years
- N_2O has an even larger RE and an average lifetime of 121 years (all values are based on the report by the Intergovernmental Panel on Climate Change (2013[15]).

These different GHGs need to be converted into a common unit to enable policy makers to make decisions on the aggregate effects of emissions or the overall effectiveness of mitigation strategies that target different gases. Comparisons are usually based on GWP_{100} (the 100-year Global Warming Potential of gases) which involves converting all GHG gas emissions into CO_2 equivalents, whereby one tonne of methane (tCH_4) equals 28 tonnes of CO_2 (tCO_2) over 100 years after their emissions (Intergovernmental Panel on Climate Change, 2013[15]). The GWP_{20} (the 20-year Global Warming Potential) conversion is used occasionally; under this metric, gases are evaluated based on their contribution to climate change over the first 20 years after their emission. This metric gives gases like CH_4 with short lifetime larger GWPs in comparison to gases with longer lifetimes (Reisinger and Clark, 2018[77]). Under GWP metrics, an assumption is made that warming from GHGs accumulates over time. However since CH_4 is a short-lived gas it does not accumulate in the atmosphere (in the same way as

CO_2) and so its emissions do not have to be reduced to zero to result in stabilisation of the climate (Reisinger and Clark, 2018[77]). This leads some researchers to contend that using the GWP metric and converting all GHGs emissions into CO_2 equivalent confuses long-term mitigation targets for the ruminant sector (Lynch et al., 2020[78]). Conversion metrics can also lead to different results when calculating the GHG emissions intensity for the same product (Reisinger, Ledgard and Falconer, 2017[79]). Other conversion metrics have been proposed to resolve this dynamic including the Global Temperature Change Potential (GTP) (Shine et al., 2005[80]) (Shine et al., 2007[81]), and the new GWP* metric (Cain et al., 2019[82]). However, these metric have limitations that can pose problems for policy makers. Researchers have recommended testing and disclosing conversion sensitivities for life cycle assessments of products (Levasseur et al., 2016[83]).

Quantifying the climate impact of ruminant production systems varies depending on where the assessment starts (and where it stops) and these different approaches also have implications for policy levers:

- *On-farm emissions* include CH_4 from enteric fermentation (the largest source), CH_4 and N_2O from manure, N_2O from fertilisers applied to soils, CO_2 from application of urea and lime, CO_2 from energy use (i.e. electricity and fuel), and CO_2 emitted or sequestered from land use and land use change.
- *Cradle to gate (and then to fork)* approaches include pre-farm gate emissions from, for example, the production of feed, fertilisers and other inputs used as part of the production process until the animals leave the farm. Adding in post-farm emissions from transporting and processing animals encapsulates a *Cradle to fork* or life cycle assessment approach. At what point the assessment ends is also an issue (e.g. should it capture the energy required for the manufacture of tractor tyres or the production of fertilisers?).

Water use, water and air quality, and biodiversity

Water use

Agriculture irrigation uses about 70% of global freshwater withdrawals (OECD, 2020[84]). While direct use of water by ruminant livestock is proportionally low, indirect water use for cultivating and processing feed crops and growing animal feed (including pasture) is the largest component the water use intensity for livestock products (Steinfeld et al., 2006[2]) (Gerbens-Leenes, Mekonnen and Hoekstra, 2013[85]) The environmental impact of water use by ruminant livestock varies and depends on the type of water used for the production of feed crops (rain water or surface and groundwater), and the type and scale of the system (extensive grazing, mixed or intensive feedlot).

Animal feed production requires more water than pasture. Cereal concentrates in particular require five times more water (per tonne of feed) than roughages (pastures) (Gerbens-Leenes, Mekonnen and Hoekstra, 2013[85]). With increasing global demand for animal protein, water use in livestock production, and in particular irrigation water for growing feed crops, is expected to rise (Herrero et al., 2015[76]). As grass is a significant feed input into ruminant livestock production systems, both under grazing and mixed systems, ruminant systems can be very water efficient under sustainably managed extensive grazing systems on unirrigated land that is not suitable for crop growing (Steinfeld et al., 2019[7]) (Herrero et al., 2015[76]).

Water availability varies around the world and within countries so the location of ruminant production systems and feed produced for these is important in considering the potential impact on water resources (Pfister, Koehler and Hellweg, 2009[86]). Agricultural production, markets and food security are also threatened by water insecurity, particularly water scarcity, in certain regions (OECD, 2017[87]).

Livestock production will be impacted as a result of reduced rain, or by increasing floods associated with a changing climate. Changes in the quantity of feed available and its quality, which are impacted by water availability, will influence livestock production. Animal health will be negatively impacted by heat stress, reducing the productivity of animals, and likely increasing the incidence of pest and diseases. Water demands mean that livestock will stay close to water sources, resulting in over grazing and land degradation (OECD, 2014[88]).

Water quality

Ruminant livestock production contributes to an increasing share of the nutrient balance in several OECD countries, resulting in environmental pressures. Surpluses of nutrients (i.e. nitrogen and phosphate) as measured by the nutrient balance indicator highlights the risks of soil, water and air pollution (from ammonia and GHG emissions). While nutrients are crucial for ruminant livestock systems to maintain and maximise pasture and crop growth, nutrients from livestock manure and application of fertiliser over and above utilisation requirements are undesirable. Cattle, in particular dairy cows, excrete higher rates of nitrogen and phosphate on a per kg per animal basis in comparison to other livestock species, i.e. pigs and poultry (Steinfeld et al., 2006[2]) (OECD, 2019[61]). Higher livestock densities for cattle increases nitrogen balances; this is supported by recent empirical work undertaken by the OECD which found a 1% increase in cattle density resulted in a 0.3% increase in the nitrogen balance (OECD, 2019[61]).

Nitrogen and phosphorus runoffs and discharge from animal manure and the use of synthetic fertilisers are major sources of water pollution for surface and ground water (OECD, 2018[89]). Nitrates in fresh and marine waters can result in eutrophication (or the spread of phytoplankton and algae) and acidification, harming fish and invertebrates (e.g. crustaceans) and can make drinking water unsafe if the nitrogen concentration is too high. Phosphorus pollutes surface water and promotes the growth of algae, which reduces oxygen and causes eutrophication (OECD, 2018[89]). Costs associated with treating agricultural pollution in water and damage to ecosystems are estimated to be in billions of euros (Gruère, Ashley and Cadilhon, 2018[90]).

Nutrient runoffs in extensive grazing systems can be influenced by stocking rates, how close to the water animals are located, the relative amount of rainfall, and the use of vegetative strips next to water bodies. Intensive grazing of stock on winter forage crops and holding stock for long periods in constrained areas can also negatively impact waterways (MPI, 2019[91]). Water quality is negatively impacted by ruminants directly accessing waterways. In these instances, there is a risk of pollution from soil particles (or sediment) and pathogens like E.coli from faeces (Steinfeld et al., 2006[2]). The trampling of stream banks can also lead to erosion and the destruction of habitat for freshwater plants and animals (MPI, 2019[91]).

In mixed and intensive systems, manure management creates risks for water quality. Collection, storage and application of manure can result in the leaching or draining of nutrients into water. The timing of manure spread and methods of application are crucial for reducing nutrient losses (Steinfeld et al., 2006[2]) (Herrero et al., 2015[76]) (Steinfeld et al., 2019[7]). Recycling of manure nutrients from intensive feedlot production systems can be difficult due to a lack of land on which to apply the manure, leading to nutrient pollution (Steinfeld et al., 2019[7]). Application of fertiliser used to stimulate pasture growth and the cultivation of feed crops can also lead to water pollution through nutrient run-off.

Air quality

The application of manure to soils results in the release of ammonia (NH_3). Environmental impacts of ammonia include reduced air quality from particulate matter, odour, and ozone formation that create risks to human health (asthma and respiratory problems), leaching, and run-off of nutrients into water which in turn create eutrophication, and reduce biodiversity from nitrogen deposition in the natural ecosystem (DAFM, 2019[92]; OECD, 2019[61]). Ammonia contributes to GHG emissions when it volatilises (or converts) into N_2O.

Biodiversity

The impact of livestock on biodiversity is both positive and negative (FAO, 2019[93]). In terms of habitat change, livestock contributes to habitat degradation and restoration. However, low intensity outdoor grazing of ruminant livestock can contribute to the agri-environmental public good of agricultural landscapes (OECD, 2015[94]). An example is Ireland which has 1 million ha of High Nature Value land grazed by cattle or sheep to maintain its biodiversity. Grazing pastures can also control and prevent the incursion of weeds and other invasive plant species. Livestock can play a role in recycling nutrients and contributes to soil carbon storage; however, it also contributes to nutrient pollution and emits GHGs (Steinfeld et al., 2006[2]) (FAO, 2019[93]).

Growth in demand for ruminant livestock products and the resulting increase in production has led to a substantial loss of remaining biodiversity via further land conversion for grazing and crop production. Conversion of remaining primary forests increases GHG emissions (with deforestation as the second most significant source of anthropogenic GHG emissions) and drives losses of ecosystems (IPCC, 2019[60]; Steinfeld et al., 2019[7]; Pendrill et al., 2019[95]).

During the period 2010-14, agricultural conversion and tree plantations led to net emissions of 2.6 Gt CO_2eq per year through losses of forests (Pendrill et al., 2019[95]). Cattle and oilseed production were the cause of half of these emissions. Products grown on land deforested during this period are exported mainly to China and Europe (Pendrill et al., 2019[95]).

One option to reduce biodiversity loss is the intensification of cattle production to reduce the area of land occupied by cattle (Steinfeld et al., 2006[2]) (Herrero et al., 2016[62]). However, intensive ruminant livestock systems require intake of feed crops produced off-farm and frequently imported, which may reduce biodiversity in other countries. As mentioned earlier, intensive systems also create issues with manure management that lead to negative water quality and soil outcomes (Steinfeld et al., 2006[2]) (Steinfeld et al., 2019[7]).

According to Herrero et al. (2016[62]), sustainable intensification can further avoid deforestation as it involves new technologies that use, for example, genetic modification of livestock and pastures varieties to reduce yield gaps, particularly in crop yields. Increased crop production would reduce feed costs and increase the use of grain as a supplement in ruminant feeding systems, leading to a decrease in land expansion pressure for grazing. The result would be less deforestation (Herrero et al., 2016[62]) but would not address animal welfare concerns and issues of manure management.

5.5. Policy responses

Three country examples are provided to analyse the trade-offs involved in the triple challenge. They focus on the implications for the ruminant livestock sector of the policy responses to climate change of Ireland, the Netherland and New Zealand. These countries were selected as they have large ruminant livestock sectors which are an important share of their agri-economies. They also provided information for inclusion in this chapter. Switzerland provided information concerning its new animal breeding strategy designed in collaboration with industry stakeholders to address the environmental impacts of its ruminant livestock sector (Box 5.2).

Policy development in these countries demonstrate how governments are navigating facts, interests, and values to determine policy direction. The climate change and water and nitrogen policy approaches described targeting the ruminant livestock sector have been politically difficult, and in the case of the Netherlands, have prompted farmer protests which are on-going.

Box 5.2. The contribution of Switzerland's ruminant livestock sector to the triple challenge and its 2030 Animal Breeding Strategy

Ruminant livestock are significant for Switzerland's agricultural sector. Of the over 50 000 farms, nearly 35 000 are cattle farms (dairy and beef), with over 8 000 being sheep farms and just over 6 000 goat farms (FOAG, 2020[96]). Grassland for grazing ruminant livestock uses over two thirds of the utilisable agricultural area, with the result of a minimum use of feed concentrates (FOAG, 2020[96]). In 2018, the contribution of the agriculture sector to the country's GDP was CHF 10.7 billion (or 0.7%) (FOAG, 2020[96]), to which the dairy sector contributed CHF 2.2 billion, cattle CHF 1.4 billion, and sheep and goats CHF 0.05 billion.

Switzerland's agricultural emissions in 2018 were 5.99 Mt CO_2eq, corresponding to approximately 13% of total emissions, with methane emissions from enteric fermentation contributing 55% and nitrous oxide emissions from agricultural soil contributing 25% (FOAG, 2020[96]) (FOEN, 2020[97]).

Ammonia emissions from agriculture are a major environmental challenge (Swiss Federal Council, 2016[98]). Agriculture is the main source of emissions, with approximately 93% of ammonia emissions from livestock (of which 77% are from ruminants) (FOAG, 2020[96]). The increase in herd numbers has resulted in ammonia emissions well beyond the long-term carrying capacity of the Swiss ecosystems (Kupper, Bonjour and Menzi, 2015[99]). In 2017, NH_3 emissions were approximately 51 550 tonnes, almost double the carrying capacity of 30 400 tonnes of NH_3 per year.

To address social requirements concerning animal welfare and health, maintaining genetic diversity, the environmental impact, and resource efficiency of livestock, the Swiss Federal Office for Agriculture (FOAG) developed the 2030 Animal Breeding Strategy (FOAG, 2018[100]) in collaboration with species and environmental experts, including from industry. Animal breeding is orientated towards:

- Food production meeting market requirements
- Preservation of animal genetic resources, and
- Vitality in rural areas.

Desired outcomes are elaborated for each key action areas and private actors, and government, will be able implement measures to achieve the objectives. The Strategy is to be implemented as part of the next Swiss Agricultural Policy. Producers will be compensated for results in relation to the breeding characteristics of their livestock.

While key actions from the Strategy are grouped around components of the triple challenge, i.e. the provision of food, livelihoods and biodiversity, how the impact of animal breeding on these outcomes is measured and how the policy will be evaluated is not yet clear.

Ireland

Ruminant livestock sector

The agri-food sector is Ireland's largest indigenous industry, accounting for almost 6.7% of Modified Gross National Income (GNI) in 2019 and employing 164 400 people (or 7.1% of total employment in 2019) (DAFM, 2020[46]). Two-thirds of Ireland's land area is used for agriculture and 81% of agricultural land is grass (silage, hay and pasture) used for grazing. There are approximately 137 500 farms with an average size of 32.4 hectares per holding, although farms in the southern and eastern regions are larger and more productive (DAFM, 2019[101]).

Ruminant livestock dominates Irish agriculture with beef and milk production accounting for over 61% of agricultural goods output in 2017 (Teagasc, 2019[102]). In 2020, the national herd of cattle was 7.3 million cattle, of which 1.6 million were dairy cows, while the sheep flock was 3.8 million head (CSO, 2020[103]) (DAFM, 2020[104]). The average herd size is 66 cattle (CSO, 2019[105]). Livestock are extensively grazed and fed supplements of grass silage, and while feed imports have been increasing due to the expansion of dairy production, grass and grass silage still constitute 90% or more of feed intake. Extensive beef and sheep operations are not as profitable as dairy operations, but play an important role in the rural economy (DAFM, 2019[47]). Despite their low profitability, surveys by the Irish Department of Agriculture, Food and the Marine indicate that 85% of beef and sheep farmers intend to continue farming (DAFM, 2019[47]).

Removal of the EU milk quotas in 2015 transformed the market and policy environment under which the Irish dairy sector operated — from being constrained by quota to not being limited and being able to react to market price signals. As a result, the number of dairy cows grew significantly. Milk production expanded by 54% between 2007-09 and 2018, with production in 2019 predicted to reach 8 billion litres for the first time. Annual exports of dairy products have increased from EUR 2 billion in 2007-09 to over EUR 5 billion in 2019, or about 35% of total agri-food exports (DAFM, 2020[46]).

The application of chemical fertiliser to stimulate pasture growth has been increasing in line with increasing livestock numbers. Furthermore use of nitrogen fertiliser is projected to continue to grow in coming years (DAFM, 2019[101]).

Challenges facing the ruminant livestock sector

The dominance of ruminant livestock poses important environmental challenges for Ireland, including in terms of GHG and ammonia emissions and in managing water quality. One difficulty is that Ireland is already one of the most efficient producers of dairy and beef in the European Union in terms of its carbon footprints and nitrogen efficiency, meaning that making improvements with the current herd numbers is complicated (Lanigan et al., 2018[106]; MacLeod et al., 2015[107]). Exacerbating environmental pressures are industry-set, government-adopted aspirational growth objectives for the ruminant sector.[6]

Agricultural GHG emissions make up a third of Irish emissions, setting Ireland apart from the rest of OECD countries, where agriculture accounts for 9% of total emissions (OECD, 2019[61]). Amongst OECD countries, Ireland is second after New Zealand in having the highest proportion of emissions from agriculture (OECD, 2019[61]). Unlike most other countries, Ireland has no heavy industry and agriculture forms a significant part of the national economy. In 2018, it was responsible for 19.95 Mt CO_2eq of GHG emissions, of which CH_4 emissions from enteric fermentation contributed nearly 58% (EPA, 2020[108]). Although the GHG emissions intensity of output from the bovine sector is low internationally, emissions have been increasing (DAFM, 2019[101]) and in 2016, 2017 and 2018, Ireland failed to meet its targets in the context of the EU Effort Sharing Decision (ESD) for agricultural GHG emissions (this was also the case for emissions from its transport, building, and waste sectors) (Climate Change Advisory Council, 2020[109]).[7] Non-compliance is predicted to continue due to the expanding dairy sector (EPA, 2019[110]).

Agriculture accounts for nearly all of Ireland's ammonia emissions, contributing to the eutrophication of surface waters and the acidification of soils (Government of Ireland, 2019[111]). OECD data indicates ammonia emissions have been on a slight declining trend during 2003-15 (OECD, 2019[61]). However, in 2016 and 2017, Ireland breached the ammonia emissions ceilings imposed by the EU National Emission Ceiling Directive (NECD). The NECD calls for additional reductions of Ireland's ammonia emissions to 1% below 2005 levels from 2020 onwards, and 5% below 2005 levels from 2030 onwards. Generated mainly from animal housing and the spreading of manure, if there is no abatement in ammonia emissions, these are projected to continue to increase to 2030 given the expanding dairy sector (DAFM, 2019[112]). Abatement options are outlined in a revised abatement cost curve (Teagasc, 2020[113]).

Water quality in Ireland has declined, with agriculture responsible for the deterioration of more than half of water bodies between 2013 and 2018 through primarily diffuse losses of nitrogen and run-off from phosphorous and sediment (EPA, 2019[114]). Latest reporting from the Irish Environmental Protection Agency (EPA) on compliance with the EU Water Framework Directive shows that 47.2% of the country's water bodies have moderate to bad ecological status, and that water quality is getting worse after a period of relative stability (EPA, 2019[114]). One-third of rivers and lakes and one-quarter of estuaries do not meet nutrient-based (nitrogen and phosphorus) quality standards, and over a quarter of monitored rivers have increasing phosphorus and nitrogen concentration (EPA, 2019[114]). Agriculture is responsible for 88% of nitrates and nearly 50% of phosphates reaching inland waters (ESRI, 2018[115]). Ireland did not meet its requirements under the EU Water Framework Directive to improve the ecological status of surface waters by 14% between 2009 and 2015 (DAFM, 2019[47]).

Climate change policy

Following the general election in February 2020, a three party coalition government (which included the Green Party) was formed in late June 2020. Subsequently, the government announced in its Programme for Government new climate ambitions. This included an average 7% per annum reduction in overall greenhouse gas emissions from 2021 to 2030, equivalent to a 51% reduction over the decade, and net zero emissions by 2050 (Fine gael, 2020[116]). In early October 2020, the Climate Action and Low Carbon Development (Amendment) Bill 2020 was introduced to parliament (Government of Ireland, 2020[117]). This Bill legislates the 2050 net zero target, along with the requirement to adopt five-year carbon budgets (for the years 2021-25, 2025-30 and 2030-35) setting maximum emissions for each sector (decarbonisation target ranges). These carbon budgets will be proposed to the Minister for Climate by the Climate Change Advisory Council (the Council), thereby strengthening its role. Carbon budgets will then considered by the Oireachtas Climate Committee (or Parliamentary Climate Committee), as well as by both the lower and upper houses of the Oireachtas (Parliament) as part of the approval process. Ministers with sector decarbonisation targets will be required to give an annual account of progress made to the Oireachtas Climate Committee (Government of Ireland, 2020[117]) (Government of Ireland, 2020[118]).

Actions to deliver carbon budgets and sectoral targets will be articulated in Climate Action Plans, revised annually. In late 2020, the next iteration of the Climate Action Plan will begin. This will build on the achievements and momentum of the 2019 All of Government Climate Action Plan (2019 Climate Action Plan) and will reflect the climate ambition of the new Amendment Bill and specific references it contains to the economic importance of agriculture and the special characteristics of biogenic methane (Fine gael, 2020[116]) (Government of Ireland, 2020[117]). The next section discusses the policy process leading to the adoption of the 2019 Climate Action Plan.

Policy process leading to the 2019 Climate Action Plan

Under the previous government, an All of Government Climate Action Plan was released in June 2019 (the 2019 Climate Action Plan).[8] It committed Ireland to meet the target of net zero greenhouse gas emissions by 2050 for all sectors, with the exception of agriculture. There was, however, a specific and legally binding reduction target for this sector. Cumulative emissions reduction targets for the agriculture, forestry and land use sector amounted to 16.5 Mt CO_2eq to 18.5 Mt CO_2eq between 2021 and 2030 and a further 26.8 Mt CO_2eq from land use removals. This is equal to a 10-15% reduction in emissions to reach a target of at least 19 Mt CO_2eq in 2030. These reduction targets are ambitious given that in 2018 agricultural emissions were equivalent to 19.95 Mt CO_2eq (EPA, 2020[108]).

Developing a broadly shared climate policy approach has motivated the involvement of a Citizens' Assembly, efforts to achieve cross-party consensus, and the establishment of an independent advisory group.

The 2019 Climate Action Plan was informed by engagement with Irish citizens through a Citizens' Assembly (Box 5.3). From its deliberations on climate change, the Citizens' Assembly agreed on 13 recommendations which were considered by an All Party Committee on Climate Action made up of representatives from Ireland's political parties (Joint Committee on Climate Action, 2019[119]). In March 2019, the Committee released their recommendations; reflecting a cross-party consensus, they did not endorse taxing agricultural GHG emissions, as recommended by the Citizens' Assembly.

Reviews undertaken by the independent Climate Change Advisory Council (the Council) established in 2016 under the Climate Action and Low Carbon Development Act 2015 have also informed climate policy development. Following a special assessment of climate change trends in the agriculture and land sector undertaken in 2019, recommendations from the Council to the Minister leading climate policy included, among other things, reducing the beef cattle rearing (or suckler) herd so as to mitigate agricultural emissions (Climate Change Advisory Council, 2019[120]) (Climate Change Advisory Council, 2020[109]).[9] With the Amendment Bill 2020, the Council has even greater responsibilities and, while current membership remains the same, in the future its composition will reflect a better gender balance and a higher number of scientific experts (Government of Ireland, 2020[118]).

Box 5.3. Ireland's Citizens' Assembly considers climate change

The Citizens' Assembly (hereafter, the Assembly) was established by the Irish government in 2016. It was a deliberative democratic process to have citizens consider legal and policy questions of significance to Irish society. Participants were selected in such a way that the composition of the Assembly reflected the age, gender, social class and regional make up of Irish society. The 99 members and Chairperson were mandated to consider five issues: legalising abortion; societal responses to an aging population; fixed-term parliaments; how referenda are held and climate policy. The Assembly met on 12 occasions from October 2016 to April 2018.

Over the course of two weekends in the last quarter of 2017, the Assembly met to consider how Ireland could lead in climate change policy. Their deliberations involved 26 hours listening to 15 experts and six stakeholders, as well as panel discussions and debate. As part of their preparation, Members read research papers and the summary of the 1 200 submissions it had received on topics covering all sectors of the economy. On agriculture, members heard from representatives of the agricultural, food and land use sector, followed by a panel discussion and a question and answer session.

The Assembly agreed on 13 recommendations by a majority vote. A tax on agricultural greenhouse gas emissions was recommended, with tax revenues to be reinvested in climate-friendly agriculture and incentives paid to farmers for sequestering carbon. Other recommendations pertaining to agriculture were the mandatory reporting and reduction of food waste throughout the food chain (distribution and supply), and support to plant forests and to support organic farming.

As part of its climate response, the All Party Committee on Climate Action (made up of representatives from Ireland's political parties) considered these recommendations, but did not endorse taxing agricultural emissions.

In a separate process on 15 November 2019, Ireland held a Youth Assembly on Climate with 150 delegates aged between 10 and 17 years. Of the ten recommendations from their deliberations, those pertaining to agriculture include the development of a climate labelling and pricing system for food, recommendations on increasing forestry on 10% of agricultural land, and a call to eliminate damage to ecosystems.

Source: (The Citizens' Assembly of Ireland, 2018[121]), (Government of Ireland, 2020[122]) (RTE, 2019[123]).

Figure 5.8. Process of engagement on the 2019 Climate Action Plan

Citizens' Assembly April 2018	• Topic : "How the State can make Ireland a leader in tackling climate change" • 13 questions posed and recommendations reached by majority vote • Recommended that GHG emissions from agriculture should be taxed, and revenue used to support climate friendly agricultural practices
Cross-party Committee on Climate Action March 2019	• Committee made up of representatives of Ireland's various political parties considered recommendations by the Citizens' Assembly • Report: "Climate change: A cross-party consensus for action" • 42 Priority Recommendations and 39 Ancillary Recommendations • Did not endorse taxing agricultural GHG emissions
Climate Action Plan June 2019	• All-of-government "Climate Action Plan to Tackle Climate Breakdown" • Defines sectoral targets and 180 actions • Strengthened governance structures and introduced quarterly reporting
Independent Climate Change Advisory Council July 2019	• Independent advisory body tasked with assessing and advising how Ireland transitions to a low-carbon economy by 2050 • 2019 Annual Review includes a detailed review on agriculture and land

Climate actions targeting the ruminant sector

Following public consultation, the *National Climate and Air Roadmap for the Agriculture Sector to 2030 and Beyond*, known as *"Ag-Climatise"*, is anticipated to be published in November 2020 (DAFM, 2019[47]). *Ag-Climatise* focuses on concrete actions to reduce emissions while maintaining incomes for farmers, including those producing ruminant livestock. It states that on-farm mitigation measures must be adopted urgently to achieve agricultural emissions reductions while maintaining a stable herd. It also states that if insufficient progress is made, more radical action will be required, especially from "sectors which are experiencing growth" (i.e. dairy) (DAFM, 2019[47]).

Central to its proposed actions included in the *Ag-Climatise* consultation document are those recommended in the Irish Agricultural and Food Development Authority, Teagasc's, Marginal Abatement Cost Curve (MACC) for GHG emissions (Lanigan et al., 2018[106]) (DAFM, 2019[47]) (the costs of abatement for ammonia emissions are also referenced in *Ag-Climatise* (Teagasc, 2020[113])). According to the MACC, cost-effective agricultural mitigations can achieve abatements of 1.73 Mt CO2eq per year from 2021 to 2030 if there is early adoption and high levels of uptake by producers (Lanigan et al., 2018[106]). Measures target on-farm improvements of nitrogen use, the use of low emissions fertilisers and manure spreading techniques, and improving cattle breeding genetics (DAFM, 2019[47]).[10]

Restricting cattle numbers, in particular dairy cow numbers, is not part of the current policy approach and is not supported by the Irish livestock sector, which believes this would damage the rural economy (DAFM, 2019[124]). Part of the rationale for this position is that if Ireland, with its comparatively low carbon footprint, restricts its dairy and beef production, other less efficient countries will increase theirs, resulting in a negative global result for the climate (Lanigan et al., 2018[106]).

Subsectors within the national herd may change, however, as a result of breeding programmes that are part of climate change mitigation. Increased herd fertility through breeding will reduce the number of replacement stock farmers need to keep. Sexed semen will increase herd productivity with pregnancies resulting in replacement animals (and not bulls) and improved genetics can increase feed conversion efficiency and general animal health.

In order to achieve the rapid uptake of technology and changes in farm management practices needed to reduce GHG emissions and to water quality without reducing output, ruminant livestock producers currently benefit from existing payments under the Rural Development Programme (RDP) of the EU's Common Agricultural Policy (2014-20) (Henderson, Frezal and Flynn, 2020[70]). Under the new Common Agricultural Policy (2021-27), Ireland will seek increased funding for abatement measures (Government of Ireland, 2019[111]).

Ruminant livestock farmers benefit from RDP payments under a number of different programmes described briefly here.[11] The Green Low-Carbon Agri-environment scheme (GLAS) incentivises farmers to use production methods that improve water quality, reduce GHG emissions and promote biodiversity. In 2017, 49 000 farmers were covered by the scheme, which is very popular with low-output sheep farms, which account for 52% of the participating farms (PER, 2019[125]) (DAFM, 2019[126]).

Capital investments in low emissions slurry spreading technology and farm nutrient storage are funded under the Targeted Agricultural Modernisation Scheme (TAMS II). As of July 2020, DAFM assisted approximately 2 400 low emission slurry spreading (LESS) machines under this programme. The Beef Data and Genomics Programme (BDGP) provides payments to the 25 500 participating farmers who must have the carbon profile of their farms analysed and undertake animal genotyping to accelerate the genetic improvement of their herds towards low emissions stock (DAFM, 2019[126]). Another programme, the Beef Environmental Efficiency Pilot (BEEP), was launched in 2019. Support is provided to suckler beef farmers and involves measuring the weaning efficiency of beef cows[12] to enable farmers to make culling decisions and improve beef production performance (DAFM, 2019[126]). Eligible beef farmers also received support in 2019 under the Beef Exceptional Aid Measure (BEAM) to compensate for beef price volatility and market uncertainties resulting from Brexit (DAFM, 2019[126]) (DAFM, 2019[127]). Applicants must commit to reducing production of nitrogen from livestock manure by 5% of 2018/19 levels (DAFM, 2019[128]).

Knowledge Transfer (KT) programmes promote on-farm climate mitigation management practices through farmer participation in discussion groups, facilitated by an agricultural advisor. Advisory services in Ireland have recently undergone extensive change and are now more focused on discussion groups where farmers are challenged by their peers, as opposed to receiving one-to-one advice. At present, there are approximately 18 600 participating farmers meeting in 1 100 groups, facilitated by 460 advisors (DAFM, 2019[126]). Another component of the KT programme is the mandatory Farm Improvement Plan for individual farms in consultation with an agricultural advisor (DAFM, 2019[129]). As part of the KT programme, 50 000 beef and 16 000 dairy farms have had their carbon profile assessed, with re-assessments taking place at 18-month intervals. Online tools allow farmers to compare their farm-level performance with similar farms; these comparisons highlight feed, animal and nutrient management practices that could be improved (Bord Bia, 2020[130]) (Teagasc & Bord Bia, 2019[131]) (Teagasc & Bord Bia, 2019[132]).

Complying with new regulatory requirements is expected to contribute to reducing GHG emissions and to improvements in water quality. For instance, from 1 January 2020 intensive dairy farms covered by the nitrates derogation are required to implement a set of measures that reduce their emissions profiles while contributing to reduced water pollution from nutrients, e.g. re-seeding grass with clover, reducing crude protein (or the nitrogen content) in concentrate feeds, and using Low Emission Slurry Spreading (LESS) equipment (DAFM, 2019[133]).[13] Under the nitrates derogation, granted by the European Union to its Nitrates Directive in 2018 and applicable until 2021 subject to meeting certain requirements, Irish farmers having a derogation can farm at higher livestock stocking rates (OECD, 2020[71]).[14] This nitrates derogation is critically important to the Irish dairy sector with its grass-based production system, as it enables a larger proportion of Ireland's total nitrogen application limit to come from livestock manure. The area farmed under this derogation increased by 34%, or 113 000 ha, from 2014 to 2018. Seven thousand farms that are intensively stocked (approximately 5% of all Irish farms) are covered by the nitrates derogation (DAFM, 2019[101]).

Voluntary on-farm actions included in the "Code of Good Agricultural Practice for reducing Ammonia Emissions" will also assist (DAFM, 2019[92]). [15] Improving nutrient use efficiency by recycling manure and replacing nitrogen chemical fertiliser use is an important focus of the Code, along with using low emissions manure spreading techniques (DAFM, 2019[92]).

One measure not proposed is the removal of tax subsidisation of fertiliser. No VAT is currently charged on the prices of chemical fertilisers (and pesticides) in Ireland (OECD, 2020[71]). Research indicates that charging the standard VAT of 23% would result in applications rates dropping by 33 000 tonnes per year. Furthermore, tax revenues that would be generated from applying VAT are estimated at EUR 35 million annually (ESRI, 2018[115]) (Breen et al., 2012[134]).

The Netherlands

Ruminant livestock sector

In 2018, there were an estimated 54 000 farms in the Netherlands, mostly owner-operated family businesses. Almost half (47%) of the agricultural enterprises were specialised in grazing livestock (cattle and dairy) (Wageningen University and Research, 2019[135]). As of April 2019, there were 3.8 million cattle in the national herd, of which 1.6 million were dairy cattle. Other ruminants (sheep, goat, horses/ponies) totalled 1.5 million (Wageningen University and Research, 2019[136]). In 2019, the gross production value of the dairy sector was EUR 5.5 billion, or over 19% of the total agricultural production value of the Netherlands. Given the prominent role of cattle in the agriculture sector in comparison to other ruminants, this section will focus on policies related to cattle.

The EU milk quotas constrained dairy cow numbers, so following the removal of the quota system in 2015, the national dairy herd expanded. However, since 2016, cattle numbers have contracted again as a result of the Netherland's phosphate emissions trading system, implemented in 2018 to protect water quality (discussed below). Cattle numbers in 2017 declined by 8% for dairy cattle and by 12% for non-dairy cattle (RIVM, 2020[137]). Farmers have been choosing to keep fewer calves and replacement heifers, and the average herd size per farm decreased from a peak of 160 cows per farm in 2016 to 153 in 2019, with dairy farmers keeping between 94 and 97 head of dairy cattle on average over the period 2014-18 (CBS, 2019[138]).

Challenges facing the ruminant livestock sector

As land is scarce, livestock systems in the Netherlands are efficient and intensive. High levels of input use from imported concentrated feed in the intensive dairy sector, and the resulting manure production poses environmental problems. Ground and surface water pollution, poor air quality, soil and biodiversity deterioration, and GHG emissions are the main environmental problems associated with ruminant livestock in the Netherlands (Hoes et al., 2019[139]). As a result, meeting its EU environmental commitments will be a challenge.

This challenge was one of the main drivers for the Cabinet to present in 2018 its holistic vision on the future of agriculture, nature and food in the Netherlands *'Valuable and Connected'* (MINLNV, 2019[140]) (MINLNV, 2019[141]). It addresses the triple challenge of feeding a growing population, providing a livelihood for farmers, and protecting the environment (including biodiversity). The premise is to bring agricultural models more in line with ecologically and economically vital production methods based on resource efficiency, in balance with nature and appreciated by society.

Acting on this, the programme for a Sustainable Livestock Sector was published in September 2019 (MINLNV, 2019[142]). It is based on three pillars: inspiring and experimenting, improving the conditions allowing farmers to farm sustainably, and private sector plans. The Dutch Dairy Association and dairy farmers, in partnership with other organisations, have since developed the Sustainable Dairy Chain which includes goals on climate neutrality, livestock health and welfare, preservation of grazing, and protection of biodiversity and the environment (duurzamezuivelketen, 2019[143]) (Dutch Dairy Association (NZO), 2019[144]) (OECD, 2020[145]).

Total GHG emissions in 2018 were 15% lower in the Netherlands than in 1990, but far from the 2020 target of reducing emissions by 25% below 1990 levels. Decreased GHG emissions are attributable mainly to reductions in methane and nitrous oxide, which in turn are due to reductions in cattle numbers (RIVM, 2019[146]). Long-term trends in OECD countries from 2003-05 to 2013-15 saw increases in agricultural GHG emissions attributable mainly to emissions from agricultural soils (due to fertiliser use), while enteric fermentation emissions decreased (OECD, 2019[61]). This trend is similar in the Netherlands, where in 2017 the agricultural sector was responsible for 86% of all ammonia emissions (RIVM, 2019[146]). Emissions in recent years have exceeded the ceiling under the EU National Emissions Ceilings Directive (NECD) for ammonia, as well as Dutch commitments under the Gothenburg Protocol (RIVM, 2020[137]). [16]

Moreover, various measures to increase agricultural production, such as the draining of wet areas, changes in crop choice, and use of chemical fertilisers has led to a deterioration of the country's biodiversity over the past century. As a result, the population of species that depend on agriculture continue to decrease, in particular breeding birds, insects and butterflies. Since the 1980s, various agri-environment schemes have been implemented in an attempt to reverse this trend, but these have not succeeded (Alterra, 2019[147]).

Diffuse agricultural sources negatively affect the water quality of 78% of surface water bodies. Nitrates generated by intensive livestock-rearing and dairy farming are an important source of water pollution. Nutrient concentrations in surface waters were identified by the European Commission in 2017 as a key issue in the Netherlands' implementation of EU environmental policy. Progress to reduce nutrient concentrations and eutrophication was made in 2019, but nitrate pollution is still problematic (European Commission, 2019[148]). The Netherlands is one of the few OECD countries to have reduced its nitrogen balance significantly over time and while still high compared to other OECD countries, the balance has gone from being over 300 kg/ha in 1990-92 to less than 150 kg/ha in 2012-14 (OECD, 2019[149]). Moreover, since 1990, the Netherlands has reduced its phosphate surplus while simultaneously increasing agriculture production levels (OECD, 2019[61]). To address water quality and meet the EU requirements, several regulations focussed on manure management and the nitrogen and phosphate content of manure have been implemented. These regulations effectively constrain dairy cow numbers to the previous level under the EU milk quotas.

Manure policy is based on the EU Nitrates Directive, and in addition to the four-year Nitrates Action Programmes (NAP) (the current NAP is the Netherland's sixth, covering the period 2018-2021) includes the following laws: the Manure Law, the Manure Law Implementing Decision, and the Manure Law Implementing rules. Implementing the Action Programmes also contributes to meeting the commitments under the EU Water Framework Directive.

The Netherlands has a derogation to the EU Nitrates Directive and is allowed to farm at higher livestock stocking rates, with a limit of 250 kg livestock manure per hectare (instead of the usual maximum of 170 kg per hectare). This translates into being allowed to farm two dairy cows per ha instead of only one. Continuation of the derogation is on the basis of the fulfilment of several conditions, including limiting phosphate from manure to 2002 levels. The current derogation was granted until 31 December 2019 (and a decision from the EC about its extension was due in March 2020) (RIVM, 2019[150]; European Commission, 2019[148]).

To stay within phosphate limits and retain the derogation, a phosphate emissions trading system was implemented for the dairy sector in January 2018. Free units were allocated to farmers on the basis of their July 2015 cattle numbers (Backus, 2017[151]). As a result, total phosphate emissions in 2019 from the dairy sector declined for the third consecutive year stand at 75 million kg, or 12% lower than the ceiling of 84.9 million kg set by the Dutch government for the dairy sector (CBS, 2020[152]).

Climate change policy

Agriculture accounts for nearly 10% of total emissions in the Netherlands, proportionally less than in the case of Ireland and New Zealand. Total agricultural emissions in 2018 were made up of 45% from enteric fermentation, 29% from N_2O from agricultural soils, and 25% from CH_4 and N_2O emissions from manure management (OECD, 2020[145]) (National Institute for Public Health and the Environment, 2020[153]).

At the end of June 2019, the Climate Act (*Klimaatwet*) and the National Climate Agreement were presented to the Dutch parliament and at the beginning of September 2019 the Climate Act came into force (Government of the Netherlands, 2019[154]). The Climate Act specifies a 49% reduction in overall GHG emissions by 2030 relative to 1990 levels, exceeding the EU target of 40% (under the EU's NDC submission for the Paris Agreement). A much more ambitious 95% reduction target is proposed for 2050. Under the Climate Act the government prepared a Climate Plan with specific measures to meet targets; this Act was submitted to Parliament at the end of 2019.[17]

The agriculture section of the National Climate Agreement is the basis for the Climate Plan for the sector. Achieving the agriculture emissions reduction target of 3.5 Mt CO_2eq by 2030, this will involve: reducing livestock CH_4 emissions (in particular dairy cattle and pigs, via manure and feed measures); increasing carbon sequestration in grasslands, agricultural soils, and forests; and reducing CO_2 emission in the greenhouse horticulture sector (via energy savings and sustainable production of energy). Measures proposed were developed in consultations with agriculture industry organisations and experts (OECD, 2020[145]; Klimaatakkoord, 2018[155]).

The livestock sector (dairy and pig farming) will jointly develop action plans under an "Implementation Agenda for Livestock-Climate". The Livestock Farming Development Group will monitor the sector's progress. Action plans for poultry, goat, sheep and veal sectors will also be developed (Government of the Netherlands, 2019[154]).

The Minister of Economic Affairs and Climate Policy has instituted an overarching committee to track progress, and maintain coherence and oversight of implementing actions under the Climate Act. Relevant Ministers, including the Minister of Agriculture, Nature and Food Quality, have responsibility for sector-specific implementing committees. Departments involved in developing the emissions reduction response for the ruminant livestock sector are: the Ministry of Economic Affairs and Climate Policy (Leads coordination); Ministry of Agriculture, Nature and Food Quality and Ministry of Environment.

To support climate policy development, the following institutions are undertaking data-intensive research: the Royal Dutch Meteorological Institute (KNMI), Emission Registration (ER) and Netherlands Environmental Assessment Agency (PBL). These report to the Ministry of Infrastructure and the Environment. Calculations undertaken by the PBL and the Netherlands Bureau for Economic Policy Analysis (CPB) on the effects of the commitment to a 49% GHG emissions reduction provided evidence of its feasibility.

Following court rulings on the climate policy upheld by the Supreme Court in December 2019 officials have revisited the climate change policy and in April 2020 the government announced additional measures Box 5.4).

Box 5.4. The Netherlands: Legal action against the government's climate policies

Legal action by groups demanding more ambitious climate responses has been taken against governments throughout the world. To date, climate lawsuits have been filed in 28 countries (LSE, 2019[156]).

In 2015, the District Court of the Hague (the Court) ruled against the Dutch government and required it to take stronger climate action. This lawsuit, initiated by the Urgenda Foundation, an environment group, along with 900 Dutch citizens, was the first example of a court ruling on the adequacy of a government's climate change commitments (Urgenda Foundation, 2019[157]). The Court concluded that given the State's duty to protect Dutch citizens, its climate change measures were insufficient (de Rechtspraak, 2015[158]). At the time, the Dutch climate change policy would have led to emissions reductions of 17% by 2020. The Court ordered that emissions be reduced by at least 25% below 1990 levels by 2020, as committed.

Obligated to comply with the ruling, upheld by both the Court of Appeal (in October 2018) and by the Supreme Court (in December 2019), the government has worked on a suite of measures in addition to those included in the national Climate Agreement. These were announced at the end of April 2020 (MINLNV, 2020[159]) and include a 75% scaling back of the country's three coal fired power plants operations (in operation since 2015). No additional measures for agriculture were introduced, as the Government had announced around the same time a package of measures for the agriculture sector to address the ruling of the Council of State on nitrogen. It is expected that these nitrogen measures will also contribute to GHG-emissions. Farmers will receive EUR 360 million in compensation for reducing livestock numbers. These measures and others were adopted by the government based on suggestions developed by the Urgenda Foundation in collaboration with 800 NGOs under its "54 Climate Solution Plan" (The Guardian, 2020[160]).

Source: (Climate Liability News, 2019[161]; New York Times, 2019[162]; Time, 2019[163]).

Impact on farmers of policies and their responses

Farmers have had to reduce dairy cow numbers to comply with regulations on manure management and the nitrogen and phosphate content in manure. This reduction has resulted in decreased agricultural GHG emissions, although total GHG emissions are still higher than reduction commitments. Following a ruling by the Dutch Supreme Court at the end of 2019 (Box 5.4), the government will need to take more action to cut total emissions by at least 25% below 1990 levels by 2020. This will be complicated, because, as of 2018, emissions were just 15% below 1990 levels (Climate Liability News, 2019[161]). Further reduction efforts may be required of the ruminant livestock sector.

Under the Dutch Rural Development Programme (RDP), there is funding for GHG mitigation activities by farmers. Funding activities that fall under the Agri-environmental and climate measures (AECMs) programme are a large part of the RDP budget (European Commission, 2019[164]). Furthermore, funding is being made available over the period 2020-2030 from the Climate Budget to support the ruminant livestock sector with the adoption of climate-friendly practices and innovation (Government of the Netherlands, 2019[154]).

Box 5.5. The Netherlands: Court ruling on nitrogen oxide emissions

In May 2019, the Council of State (Raad van State), the Netherland's highest administrative court, ruled that the Programmatic Approach to Nitrogen (Programmatische Aanpak Stikstof, PAS), the licensing mechanism for nitrogen-emitting activities, contravened the EU Habitats Directive. As a consequence, no new building permits have been issued since (including for intensive farm activities) if they result in an increase of nitrogen emissions (NH_3 and N_2O). To reduce such emissions, some politicians have called for the halving of livestock numbers and the withdrawal of farm emission rights. As of November 2019, the Dutch government has offered to buy old and inefficient farms and to assist other farms with subsidies to modernise. In February 2020, the government announced a suite of measures for the agriculture sector to address the ruling of the Council of State (MINLNV, 2020[165]) (MINLNV, 2020[166]). These include:

- Targeted buy-out by the government of livestock farms (on voluntary basis)
- Subsidies for innovation and the sustainability of animal housing
- A transition fund
- Facilitation of livestock farms near natural areas who want to switch to a more extensive way of livestock production
- Agricultural advisors to help farmers to implement measures to lower the emission of nitrogen and/or to advise them on other ways of production
- Establishment of a network of pilot farms

In October 2019 and February 2020, farmers demonstrated their opposition to the government measures. Protest actions included farmers driving their tractors to The Hague, creating huge traffic jams. The headquarters of the National Institute for Public Health and the Environment (RIVM) have been targeted by protesters who consider its reporting on nitrogen levels inaccurate. RIVM maintains that the agriculture sector accounts for 41% of nitrogen deposition on Natura 2000 protected areas established under the EU Habitats Directive. In mid-July 2020, Dutch farmers once again blocked roads to protest a proposal from the Minister of Agriculture to limit the protein content of concentrated feed.

Source: (Politico, 2019[167]; Arc2020EU, 2019[168]) (NL Times, 2020[169]).

New Zealand

Ruminant livestock sector

The ruminant livestock sector plays a major role in the economy of New Zealand. In 2019, revenue from dairy exports accounted for approximately a quarter of total national export revenues from all sectors (Statistics NZ, 2020[170]). The sector employs 48 000 people and accounts for around 3% of GDP (NZIER, 2018[45]). In addition, the meat processing sector employs 25 000 people and is responsible for approximately 13% of the country's total national exports revenues (Statistics NZ, 2020[170]).

As of June 2019 there were 6.3 million dairy cattle (an average dairy herd is 435 cows per farm), 3.9 million beef cattle, 26.8 million sheep and 810 000 deer (Statistics NZ, 2020[171]). These animals graze outside all year round.

Challenges facing the ruminant livestock sector

New Zealand has the highest proportion of emissions from agriculture of all OECD countries (OECD, 2019[61]) due to its high level of agricultural production, most of which is for export. It is also due to the country's lower proportion of emissions from electricity generation than most other countries, with 80% of New Zealand's electricity generated from renewable energy. New Zealand's gross GHGs emissions in 2018 were 78.9 Mt CO_2eq, 24% higher than 1990 levels due to methane emissions from dairy cattle and CO_2 from road transport (MfE, 2020[172]). Agriculture was responsible for 48% of all emissions in 2018, with dairy cattle accounting for 22.9%, sheep 11.9% and beef cattle 8.1%. Emissions from agriculture have increased by 17.1% in 2018 from the 1990 level (MfE, 2020[172]).

The increase is largely due to an increase in N_2O emissions from agricultural soils and an increase in CH_4 emissions from enteric fermentation. The 670% increase in the application of synthetic nitrogen fertiliser and an increase in dairy cow herd numbers by 85.6% over the period 1990-2018 are the key causes of increased agricultural emissions and the deterioration of water quality (MfE, 2020[172]) (MPI, 2019[91]). Over the same period, enteric fermentation emissions from sheep and non-dairy cows decreased, their numbers also declined by 53% and 19% respectively (MfE, 2020[172]). New Zealand's climate change policy and its implications for the livestock sector are discussed in the next sections.

In terms of water quality, nearly half of New Zealand's total river length is in areas with grazing farms (with 1% in urban areas). Over 70% of the total river length has nitrogen levels that may negatively affect the growth of some aquatic species and 82% of the river length in farming areas is unfit for swimming due to the risk of Campylobacter infection (MPI, 2019[91]).

Water policies announced in May 2020 (MfE, 2020[173]) strengthen policies that have been in place since 2011, and will have significant impacts on the dairy and sheep and beef industries as they aim to limit pollution from these sectors.[18] Key actions include: limits on nitrate and suspended sediment concentrations in waterways; restricting major agricultural intensification (MfE, 2020[174]); implementing stronger controls for feedlots as of 3 September 2020 and stockholding areas as of 1 July 2021 (MfE, 2020[175]); reducing excessive nitrogen use through a cap on synthetic fertilisers as of 1 July 2021; excluding stock from waterways as of 3 September 2020 (MfE, 2020[176]); and as of 1 May 2021 ensuring intensive winter grazing of forage crops meet standards (MfE, 2020[177]). These policies also aim to reduce soil loss by strictly managing activities such as: earthworks and land clearance; maintaining existing ecosystems by protecting streams and wetlands from draining or development; and controlling activities that can affect sources of drinking water (MfE, 2019[178]).

Requirements under the freshwater policy are also likely to have positive climate change outcomes. Given the costs for farmers of implementing the climate change and freshwater measures, policy makers will be focussed on avoiding the duplication of efforts.

Climate change policy

Given the significance of agriculture in the New Zealand economy, reducing agricultural emissions presents a unique challenge that requires a whole of government approach. New Zealand's overarching framework for climate change helped guide the co-ordinated policy development. This framework emphasizes international and domestic leadership on climate change, a productive, sustainable and climate-resilient economy, and a just and inclusive society.

In November 2019, the Climate Change Response (Zero Carbon) Amendment Act (the Act) passed into law with a cross-party consensus. The Act sets separate long-term emission reduction targets for long-lived and short-lived GHGs and includes a target for biogenic methane. Emissions reduction targets set out in the Act aim to:

- Reduce all GHG emissions except biogenic methane to net zero by 2050; and
- Reduce gross biogenic methane emissions by 10% by 2030 and by 24-47% by 2050 relative to 2017 levels.

The separate targets for methane recognise the different dynamics of long-lived versus short-lived GHGs. Long-lived gases (i.e. carbon dioxide and nitrous oxide) need to be reduced to net zero to limit global temperature increases, whereas methane needs to be reduced but, once stabilised, methane emissions can continue at a stable rate without adding to further warming (MPI, 2019[91]). In addition, the amount of methane reduction will depend on when technological developments are ready for farmers to use. At present, few practices and technologies are available to effectively reduce methane.

As of 2025, livestock emissions will be priced at the farm level, while fertiliser emissions will be priced at the processor level. A world-first partnership has been established between the government, the primary sector and iwi/Māori (indigenous groups) called *He Waka Eke Noa*.[19] The Joint Action Plan for Primary Sector Emissions will work towards building capability for farmers and growers to report, manage, and reduce emissions at the farm level (New Zealand Primary Sector, 2019[179]).

Supporting measures under the Joint Action Plan (to be administered by the Ministry for the Environment and Ministry for Primary Industries) include: integrating climate change component into farm plans (whole of business plans including management measures to meet water quality and biodiversity requirements) by 2025; creating tools for estimating farm-level emissions; increasing farm advisory capacity and capability; providing capacity-building tools and support for Māori landowners; providing incentives for early adopters; and potentially recognizing on-farm sequestration (e.g. small plantings, vegetation). If insufficient progress has been made in developing an appropriate farm gate emissions pricing mechanism by 2022, emissions will be priced at the processor level instead of at the farm level and will be included under the New Zealand Emissions Trade Scheme (NZ ETS).

Overall, pricing emissions at the farm level is intended to create an incentive for farmers to change their on-farm behaviour and to reduce emissions. Modelling suggests emissions reductions could be 2.45 Mt CO_2eq per year (or 6% of agricultural emissions) (Manaaki Whenua Landcare Research, 2019[180]). Issues yet to be worked through include the final design of the farm-level pricing scheme and the mechanism for the free allocation of carbon credits at the farm level (95% of emissions units will be freely allocated upon entry). Costs of implementing the farm-level scheme will depend on its final design.

Policy process leading to the commitment to price agricultural emissions

Political compromise and concessions were necessary to obtain cross-party support for the inclusion of agricultural emissions in the Climate Change Response (Zero Carbon) Amendment Act. Cross-party support was seen as crucial and was included in the Labour Party's pre-election manifesto (New Zealand Labour Party, 2017[181]). Unanimous support for the policy sends an important signal to farmers, business owners and investors that the regulations and legislation will not change with political cycles, providing them with certainty. This clear signal is significant because the time frame for implementation of 2025 was two elections away (with elections held in October 2020 and scheduled for 2023).

Under New Zealand's electoral system of Mixed Member Proportional (MMP) representation, political bargaining is essential. The previous government was a minority coalition between the Labour Party and New Zealand First Party, with support from the Green Party on key issues. Treatment of agricultural emissions in legislation was part of the coalition negotiations between the parties.[20]

Starting in May 2018, options to reduce agricultural emissions were informed by the independent Interim Climate Change Committee (ICCC). The ICCC was tasked with investigating whether or how agricultural emissions could be priced under the NZ ETS. Pricing emissions is consistent with the NZ ETS whereby emission costs are levied on sectors, including transport fuels, electricity production, synthetic gases, waste and industrial processes. Under current settings, agricultural processors (e.g. meat and dairy processors, nitrogen fertiliser manufacturers and importers) are required to report on their on-farm biological emissions under the NZ ETS, but do not pay for these.

Following consultations with farmers, growers, Māori landowners, primary sector industry organisations, NGOs, rural communities, and banks, the ICCC provided recommendations to Ministers in April 2019. It recommended farm-level pricing of livestock emissions, processor level pricing of fertiliser emissions by 2025 and, before 2025, the pricing of both at the processor level through the NZ ETS (ICCC, 2019[182]).

Farm groups were very critical of the recommended approach to include agricultural emissions in the NZ ETS, leading to the aforementioned Farmer organisations came up with an alternative proposal entitled *He Waka Eke Noa* in July 2019 (New Zealand Primary Sector, 2019[179]). Central to this proposal is that the sector does not pay for its emissions until 2025. Instead, a formal agreement should be developed between primary industry groups and government, including specific commitments to reduce agricultural emissions and move towards farm-level pricing by 2025 (rather than joining the ETS). This reflects the farmer position of wanting emissions to be counted at the farm-level in order to have control and to benefit from emissions reductions occurring on-farm.

Two options (a processor-level obligation in the NZ ETS and a formal sector-government agreement) were the focus of a four-week public consultation (through July and August 2019) (MfE, 2019[183]). Consultations included public meetings, special meetings with Māori for feedback on Māori-specific impacts, and technical workshops. Meetings were held in 18 urban and regional centres, with large attendance by farmers and industry organisations, despite it being calving season. In total, 3 976 submissions were received.

In late October 2019, the New Zealand government introduced the Climate Change Response (Emissions Trading Reform) Bill adopting a policy approach that was consistent with the proposal from farm industry organisations to work together with the sector and with Māori on a Joint Action Plan to support the implementation of farm-level pricing of emissions by 2025. Farmers will have to purchase only 5% of their emission credits with an initial 95% of credits allocated free of charge. In the future, larger shares of emissions credits will need to be purchased; this approach is consistent with that taken for other sectors. Starting from 2024, it will be mandatory for farmers to provide information on their farm-level livestock emissions. With this significant agreement reached in November 2019, the Climate Change Response (Zero Carbon) Amendment Act was passed into law with cross-party support.

By the end of 2022, the Minister for Climate Change and the Minister of Agriculture will need to report on the design of a mechanism to price agricultural emissions as an alternative to the NZ ETS. Issues that will need to be clarified are how emissions will be priced, the methodology for their calculation, the treatment of methane relative to other GHGs, and who will administer the system (New Zealand Government, 2019[184]).

Pricing of agriculture emissions will be applied at the processor level under the NZ ETS before 2025 (as initially recommended by the ICCC) should progress by the sector in preparing for farm-level pricing be considered insufficient. Monitoring progress under the formal primary sector-government agreement is the responsibility of the independent Climate Change Commission which will report back to the government in 2022.[21] The Minister for Climate Change will also report back in 2022 on an alternative farm-level emissions pricing scheme under the New Zealand Emissions Trading Scheme.

The decision appears to have satisfied the agriculture sector, yet environmental NGOs consider this response too slow and that agricultural emissions should be included under the NZ ETS. On a practical basis, a longer timeframe recognises that implementing a farm-level pricing scheme requires building farmer and grower capability. A survey undertaken by the Ministry for Primary Industries in 2018 found that only 14% of livestock farmers had estimated their livestock emissions and only 2% knew their last two years' on-farm emissions. Time is also needed to develop the emissions calculation tools as well as the administration system. Funding of NZD 122 million has been allocated over five years 2019-24 to provide information and practical assistance to farmers in terms of measuring and reporting on-farm emissions. Building capacity for measurement, reporting and verification (MRV) of on-farm GHG emissions is a useful step towards the implementation of a carbon price (OECD, 2020[145]).

Impact on farmers of policies and their responses

On-farm behaviour change has been taking place. The overall emissions intensity of the sector fell by an average of 1% per year over the period 1990-2014. Over 1990-2015, New Zealand reduced its emissions intensity, a ratio of GHG to agricultural gross value of production, by -34%, an achievement higher than the OECD average of -22% (OECD, 2019[61]). Declining emissions intensity is attributed to policies focussed on R&D and farm profitability in a responsive sector that does not receive distortionary support (OECD, 2019[61]). Some companies and industry organisations in the ruminant livestock sector have set their own GHG emissions reduction targets. However, more action is needed to meet the gross biogenic methane targets.

At this stage, the costs of implementing the farm-level scheme are not known, as these will depend on its final design. Feasibility considerations for farm-level pricing of emissions will be informed by the impacts on rural communities, including land values, profits, employment, demographics, social services and community resilience.

Economic opportunities associated with pricing agricultural emissions could include higher rates of innovation and the development of technology which could potentially be sold to other countries grappling with reducing agricultural GHG emissions. Benefits to farmers are likely to include productivity gains (MfE, 2019[185]).

Another benefit for farmers of pricing emissions is that it encourages more sustainable business models (MfE, 2019[185]). These would enhance farmers' "social licence to operate"; that is, the broad acceptance and trust of the sector and its operating methods by society, including consumers (MfE, 2019[185]). Pricing agricultural emissions can help to ensure future market access in valuable export markets.

Strict regulatory requirements in the new Essential Freshwater policy package target water pollution from the dairy sector. Complying with these regulations could lead to a reduction in cow numbers.

5.6. Conclusion

The ruminant livestock sector plays a key role in meeting the "triple challenge". The sector is a source of livelihood for millions of farmers and millions more along the value chain, providing employment in rural areas around the globe. Ruminant meat and dairy production contribute vital nutrients and vitamins to global food intake, which helps to combat malnutrition associated with the under consumption of animal proteins in the developing world. However, governments in many countries with high consumption levels recommend limiting the consumption of red and processed meat because of health risks associated with overconsumption. At the same time, the sector is facing important economic and environmental challenges through ruminant livestock's contribution to climate change and other problems such as water pollution. These challenges will only become more pressing, as global consumption of meat and dairy are projected to grow with the growing global population.

Ruminant livestock systems around the world are diverse, including in terms of productivity and environmental impact. India, Africa and Latin America are home to large herds but, in general, have lower animal productivity compared with the developed world. Improving the productivity of ruminant livestock in these regions (e.g. via animal and seed genetics, better feed quality, grazing and animal husbandry management practices) could help meet increasing demand for ruminant commodities while limiting the growth in herd numbers and the associated environmental damage, in particular GHG emissions.

Developed countries can make an important contribution by sharing knowledge and technologies to reduce productivity gaps.

Yet productivity growth alone will not suffice to reduce the environmental footprint of the agriculture sector; effective policies are needed. As the discussion of three country case studies (Ireland, New Zealand and the Netherlands) shows, introducing such policies is difficult when the ruminant livestock sector is an important source of livelihoods for farmers and those along the supply chain. Production systems are already highly efficient in these countries, thus limiting what can be achieved by closing productivity gaps (OECD, 2019[61]; Guerrero and Nakagawa, 2019[186]). Methane emissions from ruminants, however, make up a large part of their emissions profile and water quality has been negatively affected. The respective governments have struggled to address these issues, as seen by the difficulties that Ireland and the Netherlands are having to meet their EU obligations to protect water quality and reduce methane and ammonia emissions.

Different policy approaches are being taken in these countries to address these environmental challenges – which is the focus here rather than policies targeting food and nutrition security or the farmer livelihoods components of the triple challenge. To reduce manure production from dairy, the Netherlands is using a polluter pays approach through a phosphate trading scheme, which effectively constrains dairy cow numbers. A polluter pays approach is also being taken by New Zealand, with plans to price livestock emissions at the farm-level by 2025. Additionally, regulatory requirements under New Zealand's water policy will limit dairy intensification activities. Ireland, in contrast, is pursuing the rapid adoption of technology and changes in farm management practices to produce more with less GHG and ammonia emissions. Efforts are focussed on knowledge transfer and funding capital investments to improve nutrient use efficiency, along with genetic improvement of the national herd. The regulatory framework Ireland has in place for optimising nitrogen management across water, air and climate is reasonably well advanced in an international context and the Irish government has made it clear to farmers that if targets are not met, more radical action will be necessary. However, with an already highly efficient ruminant production system, it will be difficult to achieve further reductions in emissions while simultaneously maintaining livestock numbers and expanding production.

Given the important role of the ruminant livestock sector in these countries, developing effective policy responses to these challenges has not been easy, as seen in the case of their respective efforts to reduce GHG emissions. Ireland used an innovative deliberative process through its "Citizens' Assembly", whereby a representative group of 99 citizens recommended policy measures to respond to climate change, although their recommendation to tax agricultural emissions (although this was not adopted by the subsequent cross-political party process). Furthermore, an independent advisory group recently advised the government of the need to reduce the beef herd and to encourage farmers to exit this unprofitable sector as another way to reduce GHG emissions. In the new Climate Amendment Bill, this same advisory group is now be responsible for proposing carbon budgets for each sector, to be approved by a cross-party parliamentary committee.

In the Netherlands, legal challenges are driving policy changes. A court ruling that the Dutch government's climate change commitments were inadequate was a world first and has implications for ruminant livestock numbers as the Dutch government commits to making further reductions to GHG emissions as ordered. In another legal ruling, the country's approach to managing nitrogen emissions was found to be insufficient. However, measures to comply with this verdict are controversial with Dutch farmers, who have organised large-scale protests to demonstrate their opposition. Farm groups have also called into question the accuracy of nitrogen emissions as measured by the government's scientific institute.

In New Zealand, representatives from the primary industry organisations made a joint submission to the government requesting to be exempt from payments for emissions until 2025, and then have a phased in farm-level pricing of emissions, rather than becoming part of the Emissions Trading Scheme, so that farmers can benefit from the mitigation measures they implement on their farms. This approach was accepted on the proviso that sufficient progress is made by the sector in designing an allocation mechanism and preparing for its implementation.

These country examples demonstrate the difficulties for policy makers in addressing the triple challenge for the ruminant livestock sector, a sector of economic and political significance. Policy approaches that limit ruminant numbers or increase producers' costs are understandably unpopular with farm lobbies and politicians, although it may be difficult to reduce the environmental damage of the sector without such measures. Weakening consumer demand in developed countries for ruminant meat products for health and environmental reasons, along with requirements from increasingly urbanised consumers for more evidence of environmental stewardship by farmers will contribute to drive changes. It is nevertheless unlikely that these trends by themselves will suffice to address the negative environmental spillovers of the sector and so there is debate to be had over whether all ruminant livestock farmers should remain in the sector based on their competitiveness.

This raises a number of questions about possible ways forward to better policies. First, what is the role of information in creating a case for change? In terms of environmental impacts there are uncertainties around precise spillovers, the exact impacts of certain practices, and the degree to which each individual producer is responsible. These uncertainties can undermine momentum towards policy change. Countries surveyed for this chapter used several good practices to independently gather facts and information and to build a shared understanding, such as the establishment of an independent Interim Climate Change Commission in New Zealand and Ireland's use of a Citizens' Assembly, whereby participants were educated on the topic of climate change before deliberating and arriving at their recommendations. Work will continue on these advisory and extension services in all the three countries, e.g. to calculate on-farm GHG emissions and verifying farms' environmental performance and this, along with a more innovative model of advisory services, is critical for bringing about widespread and rapid change. But the ongoing difficulties with policy reform raise the question whether there are other mechanisms which could have strengthened this shared understanding. Polarisation of the debate in the context of evolving science means that the challenge is also in developing approaches and actions to address the issues fairly and in a balanced way with stakeholders all working together.

Policy interventions in the ruminant livestock sector are likely to harm producers financially by lowering their competitiveness and livelihoods, who understandably organise against such measures. In New Zealand, two methods used to reduce sector resistance were letting the sector co-determine how agricultural GHG reduction commitments will be delivered, and permitting a longer phase-in period than originally proposed. Another example is the recently announced (April 2020) financial compensation for reducing livestock numbers in the Netherlands in order to comply with court rulings. Are there other mechanisms which could be used to compensate those who stand to lose from policy reforms, thus making it less likely that producer interests mobilise against necessary policy measures?

Lastly, what is the role of values in facilitating the adoption of such policy measures? In all three countries, ruminant livestock has historically formed a major component of the rural economy and are a familiar presence in the landscape and, for many, an important element of their identity. Measures which end up limiting ruminant livestock numbers might thus also partly be resisted on non-material grounds. At the same time, it might be possible to reframe rural identities in ways that facilitate policy reform. For example, in New Zealand the case has been made that reform would support the sector's long-term economic sustainability and would enhance access to export markets. Public discourse in New Zealand considers farmers as stewards of the environment who have a "social licence" to operate based on society's trust and acceptance of their farming methods. Could such a positive framing facilitate the achievement of environmental goals?

The public may have preferences about how the trade-off between environmental goals and the presence of ruminant livestock should be struck, although information on these policy preferences tends to be scarce. Deliberative mechanisms such as the one used in Ireland could be one way to elicit these preferences, but as the Irish case illustrates, this may not by itself be sufficient to resolve the political question of to what extent and by what means the ruminant livestock sector should contribute to meeting environmental goals.

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Notes

[1] The emphasis in this chapter is on food from ruminants, and not fibre or hides or other uses derived from these animals.

[2] To avoid unintended consequences on land use pressure, policies aimed at increasing productivity need to be combined with land use measures (OECD, 2019[188]).

[3] The World Organisation for Animal Health ONE Health initiative and Global Action Plan on AMR monitors countries' use of antimicrobials using a global database and publishes an annual report (OIE, 2020[43]; Góchez et al., 2019[44]).

[4] Globally, numbers of ruminants (cattle, sheep and goats) have increased by 50% over the period 1968-2018 according to data from FAO Stats.

[5] Land-use change emissions stemming from the global food system are estimated by the IPCC (IPCC, 2019[60]) as being 4.9 ± 2.5 Gigatonnes of CO_2 equivalent (Gt CO_2eq) per year, with 6.2 ± 1.4 Gt CO_2eq per year coming from direct agricultural emissions.

[6] Food Harvest 2020 (released in 2010) and Food Wise 2025 (released in 2015) are sector strategies. The Food Harvest 2020 calls for increased growth in beef and milk production. The Food Wise 2025 sets targets for output growth for the entire agri-food sector and for the value of exports, jobs and value-added. The Food Wise 2025 does state that "sustainable growth should seek to increase the value added by the sector per unit of emissions (GHG or ammonia) produced" (Lanigan et al., 2015[191]; DAFM, 2010[197]; DAFM, 2015[198]). The next ten-year Agri-Food Strategy to 2030 is scheduled to be released in early 2021, public consultation on the direction of the Strategy was concluded in October 2019 (DFAM, 2019[190]). Public consultation was also undertaken on a Strategic Environmental Assessment of the yet to be published Agri-Food Strategy (DAFM, 2020[196]).

[7] As part of the obligations set out in the European Union's 2020 Energy and Climate Package and the 2030 Energy and Climate Framework, Ireland has committed to cut emissions from non-Emissions Trading Scheme sectors, including agriculture, by 20% by 2020 and by 30% by 2030 from 2005 levels (EPA, 2019[110]). However, emissions are predicted to be at best only 11% below 2005 levels in 2020 (Teagasc, 2019[192]).

[8] The 2019 Climate Action Plan has 180 economy-wide actions and many more sub-actions to achieve Ireland's emissions reductions in accordance with EU targets for 2030 (i.e. 30% reduction on GHG emissions based on 2005 levels).

[9] Recommendation 8.6 states *"Further expansion of the dairy herd will increase national emissions and may cause other environmental issues. Expansion is sustainable only if it takes place within a scenario in which overall agricultural emissions are declining. Accelerating decline in suckler cow numbers would be an important contribution to emissions reductions. Reductions should be facilitated by long-term and consistent supports and incentives to provide favourable environmental outcomes and alternative economic opportunities"* (Climate Change Advisory Council, 2019, p. 124[120]).

[10] An extensive literature review undertaken by the OECD found the MACC approach has limitations, and the cost-effectiveness of technical measures to mitigate GHG emissions in agriculture varied largely by location and farm type. This review also revealed there was a wide range of estimates for each mitigation practice investigated (MacLeod et al., 2015[107]).

[11] For a more detailed description of these programmes, see (OECD, 2020[145])

[12] Weaning efficiency is the calf weight at weaning relative to the cow's live weight (measured at 200 days of age) or the cost of getting the calf to weaning age. Higher live weights at weaning reduce the weight gain needed from weaning to slaughter, reducing feed costs.

[13] These mandatory requirements resulted from a review of the nitrates derogation plan undertaken by DAFM in 2019 (Government of Ireland, 2019[189]) (DAFM, 2019[101]) in advance of developing the fifth National Nitrates Action Programme (NAP) (2021-25) to implement the EU Nitrates Directive. The NAP sets annual limits on land application of manure and on levels of storage of livestock manure. These limits help prevent pollution of surface and ground water from agricultural sources. Limits also reduce N2O emissions and improve nitrogen use efficiency so contributing the reduction of GHG emissions.

[14] Farmers can farm at a 250 kg/ha livestock manure limit (beyond the usual limit under the EU Nitrates Directive of 170kg/ha annually) which in the Irish farming system is approximately three cows per ha rather than two cows, but farmers are required to meet certain conditions.

[15] To meet Ireland's requirements under the EU National Emissions Ceiling Directive (NECD) in November 2019 DAFM published a Code of Good Agricultural Practice for reducing Ammonia Emissions. Ammonia losses from slurry are significantly reduced by new protected fertiliser formulations, slurry application in the springtime and also the use of low emissions slurry spreading (LESS).

[16] Furthermore the Netherlands has committed to reduce its ammonia emissions from all sources by 13% between 2020 and 2029 and by 21% by 2030 (compared to 2005 levels) under its new NECD (2016) although it has already met these targets (Berkhout, 2019[187]). The Netherlands reduced its ammonia emissions by an average of-5.6% per annum over the period 1993-2005 and by an average of -2.4% per annum over the period 2003-15, making the largest average annual reductions per year of all OECD countries (OECD, 2019[61]).

[17] At the end of 2019, the Climate Plan was also presented to the European Commission as the Netherland's Integrated National Energy and Climate Plan (NECP).

[18] Under the new Essential Freshwater programme regulations are being introduced (MfE, 2020[173]). Public consultation on the proposed regulations was completed towards the end of 2019 (MfE, 2019[195]). Over 17 000 written submissions were received and while most supported the policy objectives, different views were expressed on how, and how fast, to meet them. New Zealand officials undertook further analysis to gain a more comprehensive understanding of their impacts of the proposals. An independent advisory panel was also set up to make recommendations to ministers alongside official advice.

[19] *He Waka Eke Noa* essentially translates to "we are all in this together".

[20] Including agricultural emissions in the New Zealand Emissions Trade Scheme (NZ ETS) is part of the 2017 Labour Party – Green Party agreement, while the 95% free allocation of emissions units upon entry of the sector to the NZ ETS is part of the Labour Party – NZ First Party Coalition Agreement (New Zealand Labour Party, 2017[194]; New Zealand Labour Party, 2017[193])

[21] The Climate Change Response (Zero Carbon) Amendment Act provides for the establishment of an independent Climate Change Commission to replace the Interim Climate Change Committee (which wound up in December 2019). The Commission is made up of a Chair and six Climate Change Commissioners, who are experts in climate science, adaptation, agriculture, economics, and the Māori-Crown relationship.

6 The contribution of the processed food sector to the triple challenge

This chapter provides an overview of the processed food sector as it relates to each dimension of the triple challenge. The term "processed food" is defined here as any food that has been altered in some way from its raw state. The processed food sector accounts for a significant share of income generation and employment and is essential to maintaining a steady global supply of safe, affordable, and nutritious foods and is thus key to supporting food security and nutrition. Despite broad benefits brought by food technology, some processing activities produce foods that are energy-dense and nutrient-poor and are associated with negative health effects when consumed in excess.

Key messages

- Processing (any alteration of food from its raw state) is a significant sector of the global economy, contributing to food security and nutrition as well as livelihoods.
- Processed food enables the supply of safe, affordable and nutritious foods.
- Excess consumption of processed foods high in salt, fat and sugar contributes to negative health impacts.
- Consultation with industry and public/private partnerships are crucial so that policies are practicable and regulations do not impede industry innovation; transparency and equal access are important to avoid policy capture.

6.1. Introduction

This chapter investigates how the processed food sector contributes to the triple challenges facing food systems: ensuring global food security and nutrition, providing livelihoods to farmers and others along the food chain, and using natural resources in a sustainable manner.

The consumption of foods that have been processed to varying degrees constitutes the final stage of the agro-food supply chain.[1] Processed foods, and the processed food sector more broadly, make important contributions to the economy and to dietary patterns worldwide. Indeed, food and beverage manufacturing ranks among the top three manufacturing activities in terms of value added in 27 OECD countries.[2] In 2019, the world's top ten food, beverage and tobacco[3] companies generated over USD 539 billion in revenues.[4]

Several types of food processing have a positive impact on the safety and quality of food products and are essential to supporting safe, affordable, and nutritious diets. Nevertheless, there is growing concern about the regular or excessive consumption of energy-dense and nutrient-poor processed food products to overall dietary quality and human health. According to the Global Burden of Disease Study (Afshin et al., 2019[1]), in 2017 poor diets were responsible for 11 million deaths worldwide, surpassing the number of deaths attributable to smoking. Conditions of over-nourishment (i.e. consuming too many calories) are rapidly increasing worldwide, with some 39% of adults categorised as either overweight or obese in 2016 (FAO, 2019[2]). Excessive consumption of sugars, salt, oils, and fats is associated with higher prevalence of overweight, obesity, specific forms of cancer, and other non-communicable diseases (NCD), contributing to the overall level of malnourishment and the global disease burden. In addition, several farm-level practices and manufacturing techniques involved in the production of processed foods contribute to environmental degradation. To overcome these problems, public policy can help support and complement the efforts of the processed food sector to improve food safety and quality, as well as the sustainability of food systems.

The processed food sector is at the interface of supply and demand, and has the potential to influence both on-farm practices and consumption patterns. Interventions that target the processed food sector offer opportunities to take advantage of important synergies across policy areas. For example, policies that incentivise the alignment of processed food composition or variety with dietary guidelines, while also stimulating sustainable production practices, have the potential to improve both public health and environmental outcomes. Policies that promote various labelling schemes for packaged products could similarly support the consumption of food products with improved nutritional, social, or environmental characteristics while potentially offering new value creation opportunities for actors along the agro-food value chain. This chapter looks first at how the processed food sector relates to each component of the triple challenge, and highlights the synergies and trade-offs across these policy areas. It then provides a policy perspective, examining both some of the issues that need to be navigated to develop more coherent policies, as well as existing or proposed policy mechanisms that target the processed food sector. The policy examples and insights from OECD country experiences presented build on the four-track approach developed in previous OECD work (Giner and Brooks, 2019[3]).[5]

6.2. Food security and nutrition

What is processed food?

Processed food, as used in this chapter, refers broadly to any food that has been in some way altered from its raw state. As such, this term covers a wide diversity of food products. Food processing encompasses a wide range of activities, and most foods are processed to some degree before consumed. For example, foods may undergo low amounts of processing via activities such as peeling, chopping, freezing, drying, or a number of other preparation or preservation techniques before they are purchased. Similarly, consumers may process food at home before they are consumed (e.g. by peeling, chopping, or boiling). Other food products are the result of multiple, sophisticated industrial procedures.

The term "processed food" is thus vague and unhelpful when used broadly, as it ignores the wide variation in processed food products. For this reason, several frameworks have been proposed to disaggregate the category of processed foods (Monteiro et al., 2019[4]). The NOVA classification is used most commonly in the scientific literature, and for this reason, it is described briefly here.[6] This system groups food into four categories based on the extent and purpose of industrial processing, from unprocessed and minimally processed foods (e.g. frozen or dried fruits and vegetables) to ultra-processed foods (Monteiro et al., 2017[5]; Monteiro et al., 2019[6]). Ultra-processed foods are defined as "formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes" (Monteiro et al., 2019[4]). Examples of food products included in this category are carbonated soft beverages and other sugar-sweetened beverages, sweet or savoury packaged snacks, confectionery, industrial packaged breads, buns, cookies, pastries, cake and cake mixes, breakfast cereals, cereal and energy bars, margarines and spreads, processed cheese, energy beverages, sugared fruit yoghurts, meat and chicken extracts, and instant sauces, infant formulas, follow-on milks and other baby products, 'health' and 'slimming' products such as powdered or 'fortified' meal and dish substitutes, and many ready-to-heat products including pre-prepared pies and pasta and pizza dishes, poultry and fish 'nuggets' and 'sticks', sausages, burgers, hot dogs and other reconstituted meat products, and powdered and packaged 'instant' soups, noodles and desserts. Food products falling under this category are often engineered to be highly palatable, affordable, and convenient (e.g. they are often sold ready-to-consume) (Monteiro et al., 2019[4]).

A classification system can be a helpful tool that allows for greater specificity when discussing the wide range of available processed food products and the processing techniques employed to make these products. However, this report recognises that the NOVA classification is not universally defined or employed, and further, that there is no universally agreed upon categorization system for the diverse array of products that come from the processed food sector. A detailed discussion of the merits and criticisms of the NOVA classification, and in particular the use of the term 'ultra-processed', is not a focus of this report (though a very brief overview of some of the common criticisms is provided in Box 6.1). This report only uses terms from the NOVA classification, such as "ultra-processed", for the sake of clarity when discussing the results of scientific literature that uses the NOVA classification.

Food that is processed does not by itself define the singular relationship of each food product to consumer health. While this section brings together conclusions drawn from several articles using the NOVA classification, as well as articles using other classification schemes, the discussion on nutrition and health focuses mostly on processed foods that are energy-dense and nutrient-poor – in particular products that are high in sodium, free sugars, and/or some fats – in order to distinguish them from the larger assortment of all other processed food products. It should be noted here that the use of food technology is not inherently problematic, and that indeed many food technologies bring important benefits that support food security and nutrition.

Box 6.1. Common criticisms of the NOVA classification

The NOVA classification groups foods into four categories according to the extent and purpose of industrial processing: (1) unprocessed or minimally processed foods; (2) processed culinary ingredients; (3) processed foods; and (4) ultra-processed foods.

The NOVA classification has been widely applied in the scientific literature examining the links between dietary patterns and health outcomes, and has been presented in publications by the United Nations Food and Agriculture Organisation (Monteiro et al., 2019[6]) and the Pan American Health Organisation (PAHO, 2015[7]). There is growing evidence across countries of an association between the excessive consumption of ultra-processed foods and a higher risk of developing conditions of overweight, obesity, and various NCDs. At the same time, there is considerable criticism of the NOVA classification, including:

- The NOVA classification is not universally used or defined, and the definition of "ultra-processed" foods has evolved since its initial introduction, resulting in situations where this classification is understood and applied inconsistently across studies and over time.
- The NOVA classification does not consistently generate groups of foods with similar nutrient profiles. Due to the focus on the degree of processing, foods with substantially different nutrient contents may be grouped together, while foods with similar nutrient contents fall into different NOVA categories. For example, fortified foods with high micronutrient contents can be grouped with other energy-dense and nutrient-poor foods, such as various confectionery.
- There is a lack of sufficient evidence to characterise ultra-processed foods as hyper-palatable with the effect of promoting over-consumption (Gibney et al., 2017[8]).

Traditional data sources on food intake (such as 24-hour dietary recalls and food frequency questionnaires) are typically not designed to collect detailed information on food processing activities. A lack of specific data on food processing could lead to misclassification of foods within NOVA (Poti, Braga and Qin, 2017[9]).

The processed food sector is essential to the provision of safe, nutritious, and affordable food across the globe

Food processing techniques play a key role in food safety, storage, transport stability, and trade (Knorr and Watzke, 2019[10]). Techniques such as drying, smoking, canning, freezing, pasteurization, and fermentation are used to preserve foods, and, as such, can increase the availability and stability (important dimensions of food security, in addition to access and utilisation) of the food supply across seasons and geographic regions, for example by enabling the trade of products that would otherwise perish or deteriorate in quality. This is the case, for instance, with exports of milk powder from New Zealand, a leading exporter of dairy products (OECD, 2016[11]), which depends upon dehydration processing techniques to remove water from liquid milk. Preservation and storage techniques are particularly important to increase resilience in rural or remote areas of developing and least developed countries that may experience intermittent shortages and/or drastic seasonal fluctuations in the availability of local foods. New and emerging non-thermal technologies, many of which are described by Knorr and Watzke (2019[10]), can improve the retention of various nutrients during processing operations, and thus preserve the nutritional quality of foods. Other processing activities can increase micronutrient contents, such as fortification for example the iodization of salt (Box 6.2). Another example is the use of pulsed UV light to increase vitamin D levels in mushrooms (Cardwell et al., 2018[12]).

While many processing activities make crucial contributions to the availability of safe, affordable and nutritious foods, the end-products of some processing activities can be energy-dense and nutrient-poor, and the excessive consumption of these foods can undermine population health objectives.[7] For example, using 2009-2010 National Health and Nutrition Examination Survey data and the NOVA classification to group dietary patterns in the United States into quintiles based on the energy contribution from ultra-processed foods, Steele et al. (2017[13]) found that diets with a higher energy contribution from ultra-processed foods are on average lower in protein, fibre, vitamins A, C, D, and E, zinc, potassium, phosphorus, magnesium, and calcium, and higher in carbohydrates, added sugar, and saturated fat contents. Another study, which used data from the United States 2000-2007 Homescan Panel and classified purchases of consumer packaged goods by degree of industrial processing and convenience, found higher saturated fat, total sugar, and sodium content among highly processed purchases compared to less processed purchases and ready-to-eat purchases compared to foods that required cooking or preparation (Poti et al., 2015[14]). This study also reported substantial variability in nutrient content within categories of consumer packaged goods, highlighting the potential importance of food choices within product categories. Several features of dietary patterns with excessive contributions from energy-dense and nutrient-poor processed foods correspond to some of the dietary risk factors listed in the 2017 Global Burden of Disease study (Afshin et al., 2019[1]). Some examples of these dietary risk factors include a diet low in fibre and calcium, and high in sodium and trans fatty acids. Other studies have also indicated that high sugar intake poses health risks (Box 6.2).

Economic development and income growth are associated with a dietary transition towards increased consumption of sugars and refined carbohydrates, salts, and oils and fats via some types of processed foods (Popkin, 2017[15]).[8] Several studies using the NOVA classification show that the consumption of ultra-processed foods accounts for a large share of total dietary energy intake among many high-income countries, and that their sales are growing rapidly in middle-income countries (Baker and Friel, 2016[16]; Monteiro et al., 2019[4]; Monteiro et al., 2013[17]; Sievert et al., 2019[18]; Popkin, 2014[19]). For example, national food consumption data for children and adults in the United States, Canada, Australia, and Chile reveal that ultra-processed foods are responsible for 60%, 48%, 42%, and 29% respectively of total dietary energy (Moubarac, 2017[20]; Baraldi et al., 2018[21]; Cediel et al., 2017[22]; Machado et al., 2019[23]).[9] Recent analysis of NutriNet-Santé cohort data from France revealed that ultra-processed foods contributed to 36% of dietary energy (Julia et al., 2017[24]). In the United Kingdom, ultra-processed foods accounted for 51% of calories purchased in 2008 (Monteiro et al., 2017[25]). Although processed foods high in sodium, free sugars, or fats are associated with adverse health effects when consumed in excess, it is important to note that other ingredients or additives can provide various positive functions, such as preservation or an increase in micronutrient content (in the case of fortification).

Problems associated with poor diet quality have become increasingly prevalent at the global level. For instance, the global prevalence of obesity among children aged 5-19 years increased more than five-fold between 1975 and 2016 (Abarca-Gómez et al., 2017[26]). In G20 countries, the rate of obesity among children aged 5-19 years increased from an average of 2-3% in 1975 to about 10% in 2016. Nearly one-quarter of people in OECD countries were categorised as obese in 2016 (OECD, 2019[27]), and conditions related to overweight and obesity account for approximately 8% of total health expenditure in OECD countries today (OECD, 2019[27]).

Shifts in dietary patterns are not solely responsible for these trends; other factors include level of physical activity, genetic characteristics, and microbiota (Graf and Cecchini, 2017[28]; Valdes et al., 2018[29]). Yet, it seems likely that the growing consumption of energy-dense and nutrient-poor processed food is an important contributing factor to the higher prevalence of overweight, obesity, and specific forms of cancer and other NCDs (WHO and FAO, 2002[30]; Fiolet et al., 2018[31]; Popkin and Gordon-Larsen, 2004[32]; Poti, Braga and Qin, 2017[9]; Schnabel et al., 2018[33]). A recent in-patient randomised controlled trial study demonstrated a causal relationship between the consumption of ultra-processed foods and excess calorie intake and weight gain, although further evidence based on a larger sample and over a longer period of time will be necessary to verify and support the results (Hall et al., 2019[34]).

Box 6.2. Effect of sugar, salt, and trans fat consumption on health

Sugars, salt and oils and fats are ingredients found in processed foods. To minimise health-related risks, the World Health Organisation (WHO) recommends limiting the intake of salt to less than 5g per day, of free sugar to less than 10% of total energy intake, and of saturated fat to less than 10%, and of trans fat to less than 1% of total energy intake. Overconsumption of each of these has been linked to various negative health outcomes (WHO, 2020[35]).

- High sodium intake (typically via salt intake) increases one's risk of hypertension, cardiovascular disease, and stroke (WHO, 2020[35]). Salt can be used in processed foods as a preservative, binding agent, and flavour enhancer. The 2017 Global Burden of Disease Study identified the high intake of sodium as among the leading dietary risk factors for deaths and disability-adjusted life-years (DALYs), accounting for 3 million deaths and 70 million DALYs worldwide (Afshin et al., 2019[1]).
- Free sugars are defined by the WHO as follows: "monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates." (WHO, 2015[36]). High intake of free sugar is associated with poor dietary quality, and a higher risk for overweight, obesity, specific forms of cancer and other NCDs, and dental caries (WHO, 2015[36]).
- Saturated fats that are mainly sourced from animal products, dairy and meat, salmon, egg yolks and some plant products (e.g. chocolate, cocoa butter) when consumed excessively have been associated with cardiovascular disease and coronary heart disease, ischemic stroke, and type 2 diabetes (The Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE), 2016[37]; de Souza et al., 2015[38]; SACN, 2019[39]; Dietary Guidelines Advisory Committee, 2020[40]; Health Canada, 2019[41]).

Trans fats or trans fatty acids are a type of unsaturated fat typically produced through an industrial process (partial hydrogenation). A large body of evidence links the intake of industrially-produced trans fatty acids to an increased risk of coronary heart disease and related mortality (Nishida and Uauy, 2009[42]; WHO, 2019[43]; The Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE), 2016[37]; de Souza et al., 2015[38]).

Processed foods have an important role in supporting food access

Food access is not equivalent to food availability. Food availability is a prerequisite for food access, and refers to the existence of a sufficient supply of food within a given location (FAO, 2006[44]). Food access takes into account additional characteristics of the food environment, including spatial factors such as travel distance to stores where food is purchased and access to transportation (e.g. access to a personal vehicle, access to public transportation), and embeds the concept of affordability (e.g. food prices, real incomes, cost of transportation) (Chenarides and Jaenicke, 2018[45]). The assortment of accessible foods varies across space, and, in turn, processed foods make varying contributions to overall dietary patterns across different food environments.

An emerging body of research, largely limited to North America at present, has begun to investigate the spatial relationships between public health outcomes and access to different types of foods.[10] The term “food desert” has emerged from this research. Presently, there is no consensus on the precise definition of a food desert, but the term generally refers to an area devoid of supermarkets with a resulting lack of access to nutritious and affordable foods (Ploeg et al., 2009[46]) (Walker, Keane and Burke, 2010[47]). Residents in such areas may have greater exposure to energy-dense and nutrient-poor processed foods due to the relative prevalence of convenience stores and fast-food outlets (Drewnowski and Specter, 2004[48]; Walker, Keane and Burke, 2010[47]). In line with this, a recent study using retailer scanner data from 2010-2015 in the United States found that consumers in areas with poor food access were also faced with fewer fruit and vegetable product options (referring to food items such as bagged produce, frozen fruits and vegetables, and shelf stable or canned fruits and vegetables) (Chenarides and Jaenicke, 2018[45]). In these areas, processed and shelf-stable options, such as frozen or dried fruits and vegetables among others, may be valuable for delivering many key micronutrients to consumers.

Existing evidence does not discern a clear causal relationship between food deserts and higher intake levels of processed foods. There is the possibility that local food environments reflect underlying food preferences. In line with this supposition, research has demonstrated that improving access to safe, affordable and nutritious food options by building new supermarkets in food deserts does not necessarily induce shifts towards dietary patterns that support population health objectives (Dubowitz et al., 2014[49]; Ver Ploeg and Rahkovsky, 2016[50]). Instead, taste preferences and other socio-economic factors may play a greater role in food choices.[11] Thus, eliminating food deserts by improving access to safe, affordable and nutritious food options may not be sufficient to curb intake levels of energy-dense and nutrient-poor processed food products.

An additional term that has emerged from research investigating food environments is “food swamp”. This refers to an area with a high density of foods that contribute to the excess intake of sodium, free sugars, and fats on a regular basis. This is distinct from the concept of a food desert in that safe, affordable and nutritious food options are accessible but outnumbered by an abundance of energy-dense and nutrient-poor food items. A US study suggests that food swamps may be stronger predictors of obesity than food deserts, and zoning policies are proposed as a way to address the over-abundance of energy-dense and nutrient-poor processed food options (Cooksey-Stowers, Schwartz and Brownell, 2017[51]). The food environment extends to “commuter corridors” and food options in the vicinity of people’s work places (Dornelles, 2019[52]) (Burgoine et al., 2014[53]). Public policy could help to encourage retail outlets to provide and promote safe, affordable and nutritious processed or unprocessed food options.

Remote and isolated communities may struggle with poor food access, which can increase their reliance on certain processed foods that are potentially unhealthy, such as those high in sodium, free sugars, and/or some fats. For instance, in many communities across northern Canada, fresh fruits and vegetables are either unavailable or unaffordable due to long travel distances and the high costs associated with transporting food items to remote communities (Council of Canadian Academies & Expert Panel on the State of Knowledge of Food Security in Northern Canada, 2014[54]). In such cases, lower-cost food items may include energy-dense and nutrient-poor processed foods. In recent decades, communities across northern Canada have experienced a dietary shift towards increased consumption of such processed foods.[12]

Food fortification as a means to address micronutrient deficiencies

In some cases where inadequate diets have resulted in micronutrient deficiencies within particular populations, food fortification has been employed as a corrective measure. Fortification refers to the deliberate addition of micronutrients to foods and has been used to address micronutrient deficiencies in both developed and developing countries. Efficient fortification programmes require co-ordination with the food processing industry, as well as the development of quality standards with monitoring to ensure that the levels of added micronutrients are effective while remaining below a determined intake level. International co-ordination is also important in order to prevent different stances that would result in unnecessary barriers to trade. Box 6.3 outlines a few examples of fortification programmes that have been implemented.

Similarly, "functional foods" have been suggested as a means to convey physiological benefits to consumers. However, unlike fortified foods, there is no consensus on the definition of a "functional food". Broadly speaking, the foods that might be referred to in some contexts as 'functional' typically contain particular ingredients (such as vitamins, minerals, and bioactive compounds) at levels high enough to potentially impart physiological benefits to consumers. Examining the regulatory environment surrounding health claims for these products and other food products will be an important area for future work, along with more research to better understand their health impacts. [13] International alignment on defining foods that might be considered 'functional' is also important.[14]

Box 6.3. Food fortification programmes and the processed food sector

Iodine fortification

Iodine deficiency is a major public health challenge that affects approximately two billion people worldwide (Biban and Lichiardopol, 2017[55]). Iodine is a mineral required for the synthesis of thyroid hormones; its deficiency can cause a range of adverse health outcomes, collectively referred to as iodine deficiency disorders. Adequate amounts of iodine can be difficult to obtain through diet alone due to the prevalence of iodine-poor soils used to grow crops. Universal salt iodization has been recommended and is endorsed by the WHO, but current voluntary and mandatory fortification programmes only reach approximately 71% of the global population. Despite well-documented improvements in public health outcomes, some countries prohibit the iodization of salt and the use of iodized salt in processed foods, with implications for trade in such products (Charlton and Skeaff, 2011[56]). On the other hand, with salt as the primary vehicle for iodine fortification, concerns have been raised over policies that aim to decrease dietary sodium. The potential impact of these policies is not yet clear, although much of the research to date suggests that the two objectives are compatible (Pastorelli, Stacchini and Olivieri, 2014[57]; Verkaik-Kloosterman, van 't Veer and Ocké, 2010[58]; Zimmermann, 2011[59]).

Folic acid fortification

Folic acid is the synthetic form of the water-soluble vitamin folate. Inadequate consumption of folate among women is associated with an increased risk of neural tube defects among newborns. Folic acid fortification programmes have been implemented in many countries and are considered to have been largely successful. For example, the United States and Canada implemented mandatory cereal grain fortification programmes in 1998, and Chile legislated mandatory folic acid fortification of wheat flour beginning in 2000 (Hertrampf and Cortes, 2004[60]; Crider, Bailey and Berry, 2011[61]; Ray, 2004[62]). All three countries have seen reductions in the prevalence of neural tube defects at birth. Other countries have employed voluntary fortification programmes. For example, the New Zealand Food Standard issued in 2012 permitted voluntary fortification of bread with folic acid (New Zealand Government, 2018[63]), and consultations are currently underway to introduce mandatory folic acid fortification (New Zealand Government, 2019[64]).

Vitamin D fortification

Vitamin D is important for regulating blood calcium levels and gene expression, and ensuring the proper growth and maintenance of bone tissue; inadequate intake is associated with rickets in children and osteomalacia in adults. Vitamin D is normally obtained via sun exposure and the consumption of animal-sourced foods (Pilz et al., 2018[65]). Its deficiency is a public health concern worldwide (Palacios and Gonzalez, 2014[66]) and many countries have either a voluntary or mandatory fortification programme in place; mass fortification programmes are in place in the United States, Canada, and Finland (Pilz et al., 2018[65]). A recent review of the Finnish fortification programme introduced in 2003 revealed substantial improvements in the vitamin D status of adults between the years 2000 and 2011 (Jääskeläinen et al., 2017[67]).

HarvestPlus

HarvestPlus[1] and its partners work towards improving human health and nutrition by developing and promoting biofortification technologies. In particular, HarvestPlus uses biofortification as a means to increase the zinc, iron, and vitamin A content in various staple crops. This method is effective in addressing micronutrient deficiencies (Bouis and Saltzman, 2017[68]). In contrast to industrial food fortification technologies, the biofortification of crops is accomplished through processes such as plant breeding, certain agronomic practices, and transgenic techniques (discussed in further detail in the seed sector case study). In this way, the fortification process actually takes place before any food processing. Food processors still play a key role in advancing food product value chains by including these crops as ingredients in their food products. This requires that the food processing sector provide for R&D spending towards the testing of biofortified crops in order to investigate, for example, vitamin and mineral retention by crops following various processing techniques.

1. More information on HarvestPlus can be found at https://www.harvestplus.org.

Marketing and R&D both play a major role in the processed food sector

Many food and beverage companies report substantial advertising expenses. For example, Coca-Cola Co. reported USD 4.1 billion in advertising expenses worldwide in 2018 (approximately 13% of net operating revenue) (The Coca-Cola Company, 2018[69]). Likewise, 2018 annual reports from the multinational companies PepsiCo and Kellogg Company show marketing and advertising expenditures of USD 4.2 billion and USD 752 million, respectively (approximately 6% of net revenue for each firm) (PepsiCo, 2018[70]; Kellogg Company, 2018[71]). In 2016, Nestlé spent USD 9.2 billion on all advertising (including television, in-store and social media), an amount equivalent to approximately 10.3% of that year's sales. Nestlé was ranked third globally in the top 100 companies spending the most on advertising in 2016 (AdAge, 2017[72]; Nestle, 2017[73]). Seven firms from the food and beverage sector (excluding restaurants and alcohol) were included in the top spending 100 firms with a combined USD 23 billion spent on advertising (AdAge, 2017[72]).

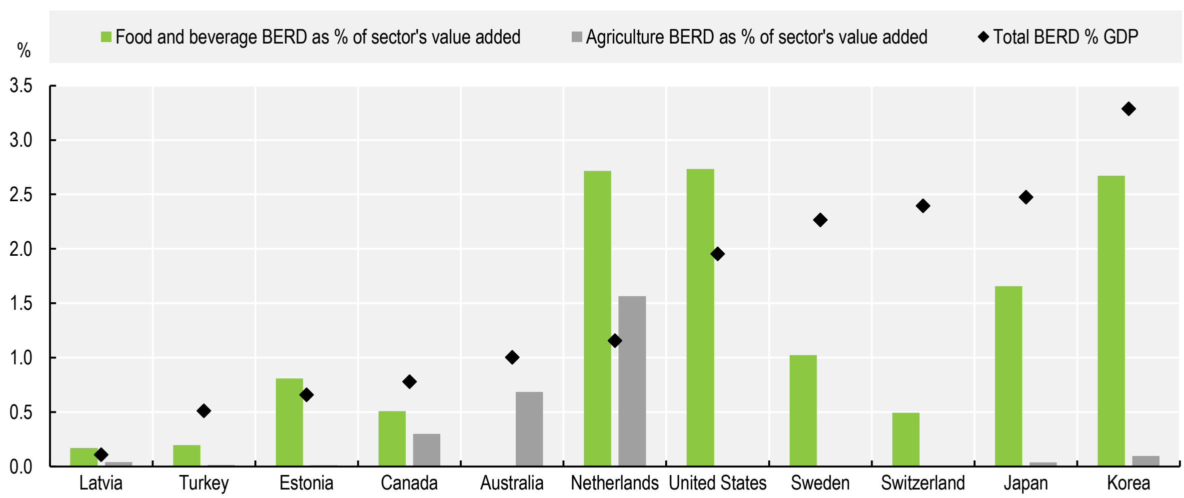
Marketing of processed food products is one way to communicate important information to consumers. However, there is growing concern about the exposure of children to the marketing of foods in so far as it contributes to excess intake of sodium, free sugars, and fats. These concerns stem from the evidence that such marketing can influence the preferences and consumption patterns of children (Cairns et al., 2013[74]; Sadeghirad et al., 2016[75]; Norman et al., 2018[76]; Boyland et al., 2016[77]; Harris, Bargh and Brownell, 2009[78]).

Evidence on the impact of food marketing on the consumption behaviour of adults is mixed. For example, a meta-analysis from Boswell and Kober (2015[79]) shows the association between visual food cues and subsequent eating behaviour and weight gain. Other research suggests that intense exposure to food advertising of products high in sodium, sugar, or fat does not influence food intake in adults but is associated with increased food intake in children (Boyland et al., 2016[77]). Voluntary self-regulation schemes have been favoured as a means to address the marketing of processed foods that are potentially unhealthy, such as those high in sodium, free sugars, and/or some fats, but there is little evidence to support their effectiveness (Moodie et al., 2013[80]; Stuckler and Nestle, 2012[81]).

While marketing strategies may influence preferences for existing processed food products, R&D expenditure influences the types of processed foods that will become available in the future, and hence plays an important role in shaping the food environment. Historically, public R&D investments have dominated total R&D expenditure in food and agriculture. However, the private share of worldwide agriculture and food R&D grew from 36% in 1980 to 44% in 2009, with recent data indicating continued expansion (Pardey et al., 2015[82]). Food processing accounts for more than half of private spending on food and agriculture-related R&D (Fuglie, 2016[83]; Pardey et al., 2015[82]; Bientema et al., 2012[84]). Business expenditures on R&D (BERD) as a percent of gross value added in the agriculture and food and beverage sectors are presented in Figure 6.1 for several OECD countries, as an indicator of the research intensity within those countries and sectors.

Figure 6.1. Research intensity in the agriculture and food and beverage processing industry, 2016

Business expenditures on R&D (BERD)[1] as a percentage of gross value added



Notes: * Or most recent available year; food and beverage data are not available for Australia; agriculture data are not available for Sweden, Switzerland, and the United States.
1. Business Expenditure on R&D (BERD) is the measure of intramural R&D expenditures within the business enterprise sector (regardless the sources of R&D funds).
Source: OECD (2019), Innovation, Productivity and Sustainability in Food and Agriculture: Main Findings from Country Reviews and Policy Lessons, OECD Food and Agricultural Reviews, OECD Publishing, Paris, https://dx.doi.org/10.1787/c9c4ec1d-en.

For all countries included in Figure 6.1 for which data were available for both sectors, research intensity was higher in the food and beverage sector than in the agriculture sector. Within the food and beverage sector, research intensity was highest in Korea, the Netherlands, and the United States. High research intensity within countries is linked with large multinational companies (Day-Rubenstein and Fuglie, 2011[85]). In cases where national food and beverage companies dominate, previous OECD work suggests that the associated low research intensity may be due to the high costs of conducting research locally, small local market size, regulatory burdens and inconsistencies, or intellectual property protection (OECD, 2019[86]).

These measures of research intensity, however, do not provide any indication of the objectives of R&D expenditures, e.g. is research directed towards increasing the palatability of food items or to test the retention of micronutrients following various transformations. More data are needed to understand how public and private R&D expenditure in the food and beverage sector can facilitate innovations that help the processed food sector maximise its contribution to meeting the triple challenge.

6.3. Livelihoods

The processed food sector offers opportunities for value addition and employment

Economic activities related to food processing account for an important share of income generation (value added) and employment worldwide. Value added from food and beverage manufacturing was an estimated USD 750 billion in 2015, accounting for approximately 1% of world gross domestic product (GDP), but this figure does not take into account the substantial informal sector in developing countries.[15] Moreover, the relative importance of the sector varies with the level of economic development.

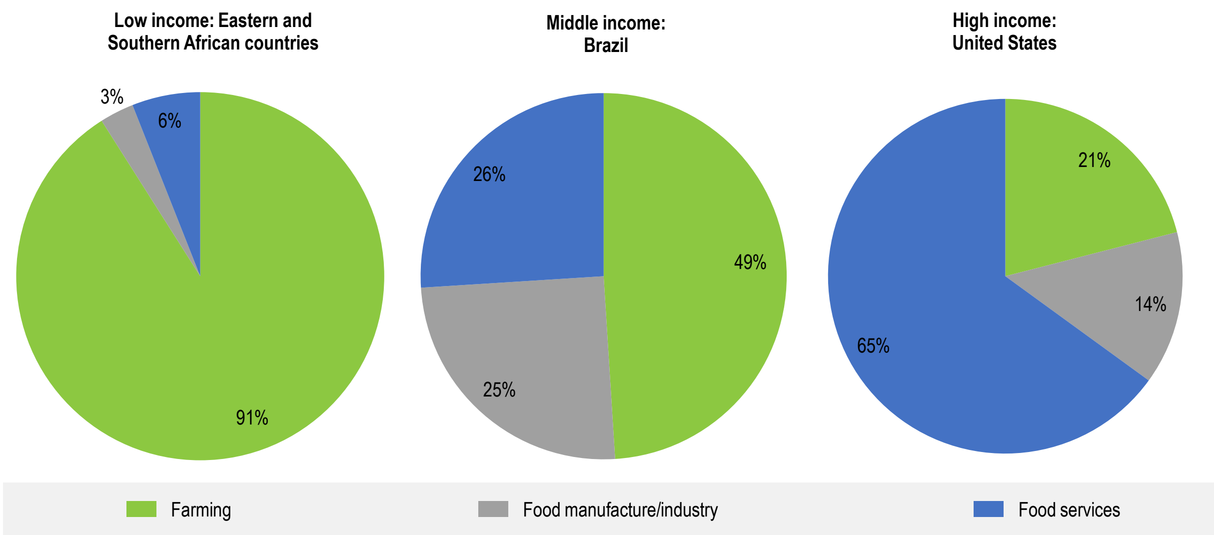
As discussed in Chapter 1, as economies develop the share of total employment in agriculture decreases and a growing share of workers seek employment in downstream sectors, both within and outside the agro-food value chain (Barrett, Carter and Timmer, 2010[87]; Brooks, 2012[88]; Reardon and Timmer, 2012[89]; The World Bank, 2017[90]). This agricultural transformation, alongside the increase in processed food consumption that comes with rising incomes and the need for the preservation of foodstuffs as countries become more urbanised (Popkin, 2017[15]; Wilkinson and Rocha, 2008[91]), lends increasing importance to downstream sectors in the food chain, including the processed food sector. While food manufacturing accounts for just 3% of food system employment across a sample of low-income eastern and southern African countries, this share increases to 25% in Brazil (a middle-income country) and declines to 14% in the United States (a high-income country) as more employment shifts towards food services (covering activities such as the distribution, marketing, and sales of food) (Figure 6.2).

Food and beverage is the leading sector in terms of manufacturing value added in 16 OECD countries and in 2017 ranked among the top three manufacturing sectors in 27 OECD countries (Table 6.1).[16] Across OECD countries that same year, the food and beverage manufacturing sector employed approximately 9.5 million people. Meat processing/preserving accounts for a relatively large share of employment in manufacturing across many OECD countries (Table 6.2).

The food and beverage sector is also the largest manufacturing sector and the leading employer in the European Union (FoodDrinkEurope, 2019[92]), accounting for a 12.3% share of value added in manufacturing and employing 4.7 million people in 2019, with SMEs responsible for most of this employment. In the United States, the Food Dollar Series maintained by the United States Department of Agriculture shows that food processing and packaging accounts for a substantial share of the final value of food products, contributing 17 cents of each dollar spent on food — second only to the food services sector. When considering only food consumed at home, food processing and packaging accounts for the largest share of value added (27.8%).[17]

At the global level, there has been increasing levels of vertical co-ordination of agro-food markets and an increased role for multinational companies (Swinnen and Maertens, 2007[93]; ILO, 2007[94]). The world's top ten food, beverage and tobacco companies generated over USD 539 billion in revenues and employed over 1.2 million people in 2019 (Table 6.3).

Figure 6.2. Composition of food system employment in low-, middle-, and high-income countries



Source: The World Bank (2017), http://documents.worldbank.org/curated/en/406511492528621198/pdf/114394-WP-PUBLIC-18-4-2017-10-56-45-ShapingtheFoodSystemtoDeliverJobs.pdf.

Table 6.1. Performance of the food and beverage manufacturing industry

Selected OECD countries, 2017

Country	Value added (million USD at current prices)	Value added share of manu-facturing (%)	Ranking within manu-facturing sector[1]	Value added share of GDP[2] (%)	Number of employees	Employment share of manu-facturing (%)	Labour productivity (value added USD per employee)[3]
Australia							
Total: Food, beverage, and tobacco	19 193	25.17	1	1.44	244 987	29.50	78 343
Food and beverage	..	..		..	..	..	..
Tobacco products	..	..		..	..	..	..
Canada							
Total: Food, beverage, and tobacco	32 824	17.81	1	1.99	281 780	17.6	116 488
Food and beverage	*31 545*	*17.12*		*1.92*	*279 723*	*17.47*	*112 772*
Tobacco products	*1 279*	*0.69*		*0.08*	*2 057*	*0.13*	*621 779*
Chile							
Total: Food, beverage, and tobacco	..	..	1	..	..	..	..
Food and beverage	*10 327*	*40.47*		*3.72*	*165 828*	*39.12*	*62 275*
Tobacco products	..	..		..	..	..	..
France							
Total: Food, beverage, and tobacco	45 190	17.58	1	1.75	..	..	..
Food and beverage	*44 498*	*17.31*		*1.72*	623 256	22.12	71 396
Tobacco products	*692*	*0.27*		*0.03*	..	..	..
Korea							
Total: Food, beverage, and tobacco	31 238	6.83	5	2.04	204 623	7.14	152 661
Food and beverage	*29 130*	*6.37*		*1.90*	*202 549*	*7.07*	*143 817*
Tobacco products	*2 108*	*0.46*		*0.14*	*2 074*	*0.07*	*1 016 393*

Country	Value added (million USD at current prices)	Value added share of manu-facturing (%)	Ranking within manu-facturing sector[1]	Value added share of GDP[2] (%)	Number of employees	Employment share of manu-facturing (%)	Labour productivity (value added USD per employee)[3]
United Kingdom							
Total: Food, beverage, and tobacco	42 647	18.96	1	1.60	482 625	19.13	88 365
Food and beverage	..	..		..	*482 245*	*19.12*	..
Tobacco products	..	..		..	*380*	*0.01*	..
United States							
Total: Food, beverage, and tobacco	403 896	16.18	2	2.07	1 610 898	14.29	250 727
Food and beverage	*368 195*	*14.75*		*1.89*	*1 597 654*	*14.17*	*230 460*
Tobacco products	*35 701*	*1.43*		*0.18*	*13 244*	*0.12*	*2 695 636*
OECD area							
Total: Food and beverage[4]	917 504	13.56		1.84	9 500 003	15.65	96 579

Notes: Where possible, estimates for food and beverages are shown separately from estimates for tobacco products. Not all countries have estimates for both of the categories 'food and beverage' and 'tobacco products'. Other countries have only an aggregate estimate for 'food, beverage, and tobacco'. Beverages include alcoholic beverage products.
1. Ranking is based on value added.
2. Author's calculations using World Bank Development Indicator estimates of GDP (USD at 2017 prices).
3. Author's calculations. Labour productivity is calculated as the ratio of value added to the number of employees for the year 2017.
4. Food and beverage value added and tobacco products value added estimates are aggregated for five OECD countries. Food and beverage employment and tobacco products employment estimates are aggregated for two OECD countries. Estimates for Latvia are from 2016 (the most recent year available).
Source: UNIDO Statistical Country Briefs (ISIC rev3), https://stat.unido.org/app/country/Emp.htm?Country=124&Group=null (accessed February 2020); the World Bank database of World Development Indicators, https://databank.worldbank.org/source/world-development-indicators (accessed February 2020).

Table 6.2. Employment within select sub-sectors of food manufacturing

Selected OECD countries, 2016

	Sub-sector Number employed (employment share of manufacturing, %)					
Country	Processing/ preserving of meat	Processing/ preserving of fruit, vegetables	Dairy products	Bakery products	Cocoa, chocolate and sugar confectionary	Vegetable and animal oils and fats
Australia	62 135 (7.4%)	14 510 (1.7%)	19 437 (2.3%)	70 361 (8.4%)	11 454 (1.4%)	1 628 (0.2%)
Canada	61 293 (3.9%)	18 632 (1.2%)	20 727 (1.3%)	47 344 (3.0%)	8 490 (0.5%)	3 259 (0.2%)[1]
Chile	28 885 (6.7%)	21 723 (5.1%)	13 503 (3.2%)	..	..	2 539 (0.6%)
France	120 462 (4.3%)	24 966 (0.9%)	60 113 (2.1%)	216 510 (7.7%)	19 293 (0.7%)	3 939 (0.1%)
Korea	36 364 (1.3%)	16 268 (0.6%)	10 016 (0.4%)	20 567 (0.7%)	4 465 (0.2%)	1 755 (0.1%)
United Kingdom	70 226 (2.7%)	33 909 (1.3%)	26 014 (1.0%)	94 667 (3.7%)	21 184 (0.8%)	1 410 (0.1%)
United States	479 511 (4.3%)	160 550 (1.4%)	135 821 (1.2%)	252 214 (2.3%)	60 281 (0.5%)	15 746 (0.1%)

Notes: Sub-sectors shown do not constitute the entire food manufacturing sector.
1. This value is the aggregate of 'vegetable and animal oils and fats' (ISIC 1040) and 'starches and starch products' (ISIC 1062).
Source: UNIDO INDSTAT 4 2019 (ISIC rev4), https://stat.unido.org/database/INDSTAT%204%202019,%20ISIC%20Revision%204 (accessed February 2020).

Table 6.3. Top 10 global food, beverage and tobacco manufacturing companies by revenues, 2019

Food, beverage, and tobacco company	Revenues (million USD)	Assets (million USD)	Employees	Headquarters
Nestlé	93 512.5	139 045.1	308 000	Switzerland
PepsiCo	64 661	77 648	267 000	United States
Archer Daniels Midland	64 341	40 833	31 600	United States
Anheuser-Busch InBev	54 619	232 103	172 603	Belgium
JBS	49 709.7	29 454.7	230 086	Brazil
Bunge	45 743	19 425	31 000	United States
Wilmar International	44 497.7	45 679.9	90 000	Singapore
Louis Dreyfus	40 571	18 440	16 785	Netherlands
Tyson Foods	49 052	29 109	121 000	United States
CHS	32 683.2	16 381.2	10 495	United States

Note: Beverages include alcoholic beverage products.
Source: Fortune Global 500 (2019), https://fortune.com/global500/2019/search/ (accessed February 2020).

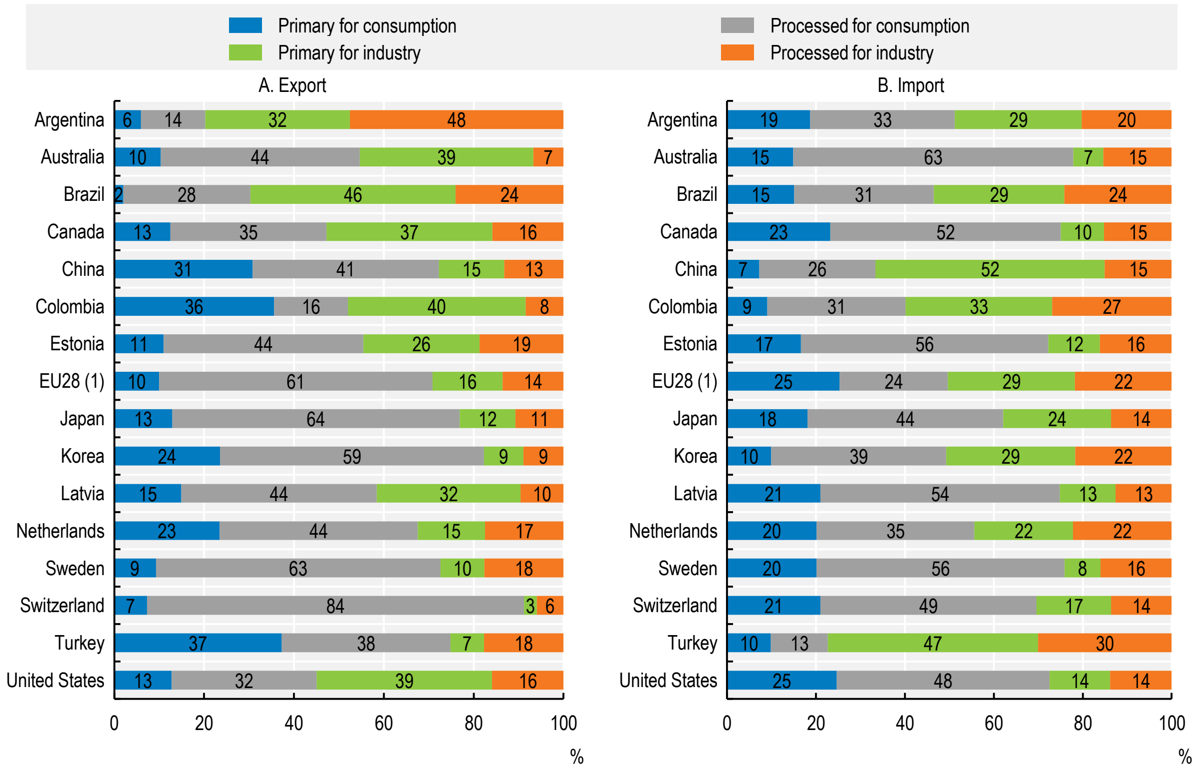
Evidence of consolidation and market concentration in food and beverage manufacturing has raised concerns around the potential for buyer power to negatively impact producer incomes in agricultural product markets. The food chain often exhibits an "hour-glass" shape, with many agricultural producers supplying a smaller number of processors and retailers who in turn provide products to many consumers. One concern is that high levels of market concentration could lead to monopolistic or monopsonistic behaviours. However, at present empirical evidence does not appear to support the hypothesis of systematic exploitation of buyer power by food processing firms (Perekhozhuk et al., 2016[95]; Sheldon, 2016[96]; Sexton and Xia, 2018[97]). However, it should be noted that studies to date do not provide comprehensive coverage across all geographic locations or agricultural product categories.

International trade in processed food products

Food processing plays a key role in the international trade of agro-food products. While some primary agricultural commodities are exported directly for consumption in foreign markets, many others are 1) exported as intermediates for processing in foreign markets, 2) processed domestically and exported for consumption in foreign markets, or 3) processed domestically and exported as intermediates for further processing in foreign markets. In this way, processed food products and intermediate products destined for further processing are dominant in agro-food trading activities in many OECD countries (Figure 6.3).

Current patterns of international trade in processed food products reflect the evolution of food processing technologies, consumer demand for year round access to a wider variety of foodstuffs, longer food chains, and increasing integration into global value chains (GVCs). The trade of processed food products and participation in GVCs has the potential to increase domestic value added and employment opportunities in the processing and agricultural sectors as domestic producers can take advantage of foreign demand for transformed and differentiated food products (Greenville, Kawasaki and Jouanjean, 2019[98]).[18] Evidence about the participation of SMEs in GVCs for agriculture and food products in South East Asian countries suggests that SMEs might struggle to integrate directly into GVCs as buyers or suppliers but they might be increasingly engaging in indirect exporting (selling to domestic firms which then export these products) (López González et al., 2019[99]).

Figure 6.3. Composition of agro-food trade, 2016



Notes: Numbers may not add up to 100 due to rounding. Agro-food definition does not include fish and fish products. Agro-food codes in H0: 01, 02, 04 to 24 (excluding 1504, 1603, 1604 and 1605), 3301, 3501 to 3505, 4101 to 4103, 4301, 5001 to 5003, 5101 to 5103, 5201 to 5203, 5301, 5302, 290543/44, 380910, 382360.1. Extra-EU trade.

Source: OECD (2019), *Innovation, Productivity and Sustainability in Food and Agriculture: Main Findings from Country Reviews and Policy Lessons*, OECD Food and Agricultural Reviews, OECD Publishing, Paris, https://dx.doi.org/10.1787/c9c4ec1d-en.

6.4. Environmental sustainability

Environmental impact of the processed food sector

As discussed in Chapter 1, much of the food system's environmental impact is associated with on-farm production and associated land use change. For example, greenhouse gas (GHG) emissions within the farm gate and from land use changes account for 16-27% of total anthropogenic GHG emissions, compared to just 5-10% from all remaining stages of the global food system together (IPCC, 2019[100]).

Yet complex linkages exist between the agriculture sector and its downstream sectors. As the food processing sector is at the interface of supply and demand, it can play a key role in shaping environmentally sustainable production and consumption patterns, e.g. by requiring improved sustainability monitoring and performance by suppliers and by providing consumers with information on performance (Poore and Nemecek, 2018[101]).To support this type of re-orientation, OECD-FAO (OECD/FAO, 2016[102]) outlined a framework to assist enterprises involved in food and agriculture to engage responsibly with their supply chains, as discussed in Chapter 2.

While farm level practices are responsible for much of the observed negative environmental impact of food systems, downstream sectors also make significant contributions. Overall, food processing accounts for an estimated 4.4% of GHG emissions, 2.4% of terrestrial acidification, and 1.7% of freshwater and marine eutrophication (Poore and Nemecek, 2018[101]). These negative environmental impacts – GHG emissions in particular – are due in part to the high energy requirements of the food processing sector (OECD, 2017[103]).

Improvements in efficiency could lower energy costs and reduce negative environmental impacts. Recent management practices and technological innovations have led to improvements in energy efficiency, leading to reductions in emissions. For example, the Food and Drink Federation in the United Kingdom reported a decrease in carbon dioxide emissions in 2017 of 53% from their 1990 baseline (Food and Drink Federation, 2018[104]).[19] There is scope, however, for further efficiency gains (Tassou et al., 2014[105]; Chowdhury et al., 2018[106]). OECD (2017[103]) identified several barriers to adopting energy efficient practices and technologies in the food supply chain, including structural barriers (e.g. lack of know-how), behavioural barriers (e.g. informational market failures that inhibit the pursuit of energy-efficient opportunities), availability barriers (e.g. inadequate access to energy-efficiency measures), and policy barriers (e.g. energy subsidies that distort market prices and fail to incentivise energy efficiency).[20]

Changes in dietary patterns and environmental sustainability: Implications for the processed food sector

Environmental impacts vary across different food groups, and a growing body of research is investigating the connections between dietary patterns and environmental degradation (Clark and Tilman, 2017[107]; Springmann et al., 2018[108]). The growing concern over the environmental impacts of dietary patterns has led to calls to incorporate sustainability concepts into dietary guidelines, recommendations, and benchmarks (Blackstone et al., 2018[109]; Willett et al., 2019[110]; Gonzalez Fischer and Garnett, 2016[111]). For example, the most recent version of the Dutch dietary guidelines recommends limiting weekly consumption of red meat to 300g or less, specifying that adherence to this limit is ecologically desirable (Health Council of the Netherlands, 2016[112]) (discussed in further detail in the ruminant livestock sector case study). Similarly, the EAT-Lancet reference diet aims to improve both health and environmental outcomes (Willett et al., 2019[110]).

Nutritional outcomes and environmental considerations are different globally. From the ruminant livestock sector case study it is apparent that in many developing countries crops are the main source of protein. For example, consumption of all types of meat is low in Sub-Saharan Africa, Asia and the Pacific. In these regions increased consumption of all proteins, including animal protein, would be optimal for human health and nutrition. However, in developed countries which are large GHG emitters and which consume on average three times as much beef as developing countries the situation is different.

In light of the growing interest in the environmental sustainability of diets, an important consideration in the context of processed foods is whether a transition to dietary patterns supporting population health objectives (e.g. through product reformulation or through substitution with different food options) would improve environmental sustainability.

While there may be synergies between health outcomes and environmental sustainability for some product categories, overall it appears there is only a weak correlation between these two dimensions in the case of highly processed foods. Ingredients common to some highly processed foods — such as sugars, salt, and grains — can have lower environmental impacts per calorie than fruits, vegetables, and animal-sourced foods (Vieux et al., 2013[113]; Garnett, 2016[114]; Drewnowski et al., 2014[115]; Tilman and Clark, 2014[116]). Sugar-sweetened beverages, for example, have a relatively low environmental impact (Clark et al., 2019[117]). Moreover, processing itself is typically not the major contributor to the environmental footprint of food products. Thus a reduction in the consumption of many highly processed foods would be unlikely to contribute to better environmental outcomes.[21]

An important exception is processed red meat; evidence suggests that a reduction in consumption could have environmental and health benefits, although the same evidence suggests similar effects for unprocessed red meat (Clark et al., 2019[117]). New forms of processed foods such as meat analogues and lab-grown foods are now emerging in response to growing concerns over the health and environmental implications of high intake levels of red and processed meats (Box 6.4). The contribution of such food products to the different dimensions of the triple challenge constitutes an interesting area for future research.

Box 6.4. Meat analogues and lab-grown foods: Emerging forms of processed foods

Animal-sourced foods provide energy and protein as well as an array of additional nutrients, and their consumption has historically held cultural and social significance (Macdiarmid, Douglas and Campbell, 2016[118]; Mottet et al., 2017[119]). Optimal nutritional outcomes in some countries, particularly least developed and those with high levels of malnutrition, involve increased consumption of all proteins, including animal protein. However, in developed countries, growing concerns over the health and environmental impact of animal-sourced foods (particularly of red and processed meats) and considerations for animal welfare have led to calls to reduce the consumption of animal-sourced foods and shift towards diets that feature plant-proteins (Aiking and de Boer, 2018[120]; Springmann et al., 2016[121]; Willett et al., 2019[110]). Changing consumer behaviour is challenging though, as consumers may be unwilling to change their consumption habits even when aware of the negative impact associated with certain dietary patterns (Macdiarmid, Douglas and Campbell, 2016[118]). This has fostered a growing interest in the development of substitutes for conventional animal-sourced foods, including plant-based meat analogues (products that imitate the aesthetic and nutritional qualities of meat but using plant-based ingredients), cultured meats (animal tissues produced *in vitro* via cell-culturing technologies; these are not yet commercially available), and dairy product analogues (products created *in vitro* using cellular and acellular culturing technologies).

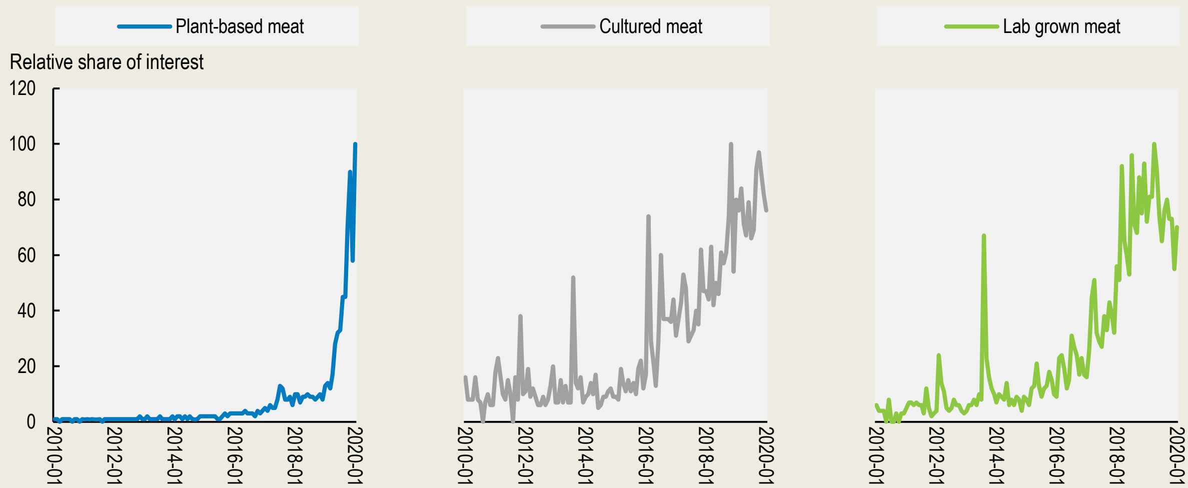
Google Trends data show increasing public interest in the search terms “plant based meat”, “cultured meat”, and “lab grown meat” (Figure 6.4). Companies that manufacture meat analogues and lab-grown foods include Beyond Meat,[1] Impossible Foods,[2] Eat JUST,[3] Solar Foods,[4] Mosa Meat,[5] Memphis Meats,[6] and Nestlé.[7]

Due to the novelty of meat analogues and lab-grown foods, there has been limited research in their market potential or their viability as nutritious, sustainable, and socially acceptable substitutes for animal-sourced foods, including at a global level. Beyond Meat commissioned a life cycle assessment of their *Beyond Burger*, which reported that it generated 90% less GHG emissions, 46% less energy, 99% less water use, and 93% less land use than did a quarter pound of beef produced in the United States (Heller and Keoleian, 2018[122]). Yet plant-based meat analogues can involve a high degree of processing; more research is necessary to understand the level of nutrient and phytochemical retention generated and the overall contributions of such foods to nutrition (Hu, Otis and McCarthy, 2019[123]).

Diets that feature unprocessed or minimally processed plant-based foods, rather than highly processed meat/dairy substitutes, may yield preferable environmental outcomes. A recent study found that, as mentioned above, high processing requirements limit the sustainability gains associated with meat alternatives (van der Weele et al., 2019[124]). Another study reported that plant-based meat analogues have land use requirements that are only marginally lower than requirements for egg and poultry meat production (Alexander et al., 2017[125]). This same study also suggests that cultured meats have similar conversion efficiencies to egg and poultry meat production, but higher energy requirements.

As product formulations and processing and cultivation technologies continue to evolve, further research will be necessary to understand how meat analogues and lab-grown foods will impact food systems.

Figure 6.4. Google keyword worldwide relative search volumes, 2010-2020



Note: Values represent the monthly relative share of interest, normalised to the peak interest for a search term.
Source: Google Trends, https://trends.google.fr/trends/?geo=FR (accessed February 2020).

Notes:
1. https://www.beyondmeat.com/.
2. https://impossiblefoods.com/.
3. https://www.ju.st/en-us.
4. https://solarfoods.fi/#vision.
5. https://www.mosameat.com/.
6. https://www.memphismeats.com/.
7. https://www.nestle.com/media/news/nestle-launch-plant-based-burgers-grounds-us-switzerland.

Even if reducing the consumption of highly processed food does not by itself lead to significant improvements in environmental outcomes, the sheer size and influence of the processed food sector suggests it can play an important role in improving overall environmental sustainability and nutritional quality. This could be achieved by product reformulation, and by requiring stricter environmental standards and the provision of reliable information to allow consumers to choose environmentally-friendly options. Furthermore environmentally harmful subsidies in the food sector which can contribute to negative sustainability outcomes should be addressed, but due to reasons discussed in Chapters 2 and 3 these policies are very hard to reform.

Monitoring changes in the composition of processed food products and the production practices that are associated with sourced ingredients, as well as the implementation of labelling schemes (Box 6.5), will be valuable for evaluating policies that are aimed at improving health and environmental outcomes. New digital opportunities to monitor and share information regarding the environmental impacts associated with various agricultural practices are constantly improving traceability within the agro-food supply chain (The World Bank, 2019[126]; OECD, 2019[127]; Jouanjean, 2019[128]) (Baragwanath, 2021[129]). Efforts to monitor the composition of a range of packaged foods have been undertaken by the global market research company Mintel,[22] and similar databases are being developed by government entities, including the Branded Food Products Database[23] in the United States and the Oqali database[24] in France. Moving forward, it would be helpful to expand such databases to include supply-chain data related to the environmental sustainability of production practices and processes associated with processed food products. Achieving more nutritious and sustainable processed food will also require further innovations in technologies and management practices; public policy can help incentivise such innovations.

Box 6.5. Measuring and communicating the environmental qualities of processed foods

Life cycle assessment

Companies increasingly seek to measure the environmental impacts of their products and services, both for their own use and to communicate these attributes to external users and other stakeholders (Gruère, 2013[130]; Gruère, 2014[131]). For example, companies may track and report carbon footprints (i.e. the quantification of GHG contributions made over the life-cycle of a product or service) or water footprints (i.e. the quantification of fresh water depletion and/or degradation over the life-cycle of a product or service), which involves the use of life cycle assessment (LCA).[1] LCA is a quantitative methodology used to understand the environmental impact of the collection of processes that model the lifecycle of a product within specified system boundaries (i.e. "cradle-to-cradle", "cradle-to-gate", "cradle-to-grave") (Scott Matthews, Hendrickson and Matthews, 2014[132]). In addition to assessing the overall environmental impact, this approach can be used to identify hotspots (i.e. the processes that make the greatest contributions to particular impact categories) in supply chains, which can help companies to prioritise mitigation and innovation efforts. From the policy makers perspective the environmental impacts may lie outside of the food and agricultural area and may be related, for instance, to transport, making things more complex.

Coca-Cola Co. is considered by many to have performed the first LCA in 1969 when making the decision between glass and plastic containers for their beverage products (Scott Matthews, Hendrickson and Matthews, 2014[132]). Since then, this approach has been used to understand the life-cycle impacts of many different food products. For instance, LCA has been used to compare the impact of processed foods against home-made equivalents. One LCA study that compared the carbon footprint of 40 commercial (processed) sandwiches to similar home-made sandwiches found that on average commercially produced sandwiches had carbon footprints twice that of their home-made counterparts (Espinoza-Orias and Azapagic, 2018[133]). Another study comparing the life-cycle environmental impacts of a typical processed ready-made meal with a home-made equivalent found higher GHG emissions associated with the ready-made option (Schmidt Rivera, Espinoza Orias and Azapagic, 2014[134]). Energy requirements for processing and refrigeration and the generation of food loss/waste made substantial GHG contributions for the processed food options in both studies, highlighting the need for further research efforts to reduce their environmental impact. At present, there do not appear to be any studies that have quantified the collective life-cycle impacts of processed food products consumed across the globe.

Environmental labelling and information schemes

Companies use many different schemes to communicate environment-related product/service attributes to users; these schemes are largely voluntary (OECD, 2016[135]). Ecolabel Index, a global directory that tracks ecolabels, lists 463 ecolabels for products and services across the world as of February 2020.[2] Previous OECD work compiled a dataset of environmental labelling and information schemes (ELIS) (Gruère, 2013[130]). This dataset lists 544 ELIS introduced between 1970 and 2012 worldwide. The data shows an increase over time in the number of traditional forms of ELIS (e.g. single-issue environmental seals) as well as the emergence of newer varieties of ELIS (e.g. environmental footprints based on life-cycle approaches). Notably, the majority of ELIS do not rely on LCA as life-cycle approaches are complex, expensive, and may be considered more risky to implement (i.e. there is greater uncertainty around how consumers may react to non-traditional forms of ELIS). The study also described a general lack of transparency in the standard-setting process for most ELIS.

The use of so many different forms of ELIS, especially alongside other types of information (e.g. product nutrition labels, product health claims) can be confusing for consumers, and the use of different methodologies makes it difficult to make valid comparisons across products (OECD, 2016[135]). Evidence also indicates that consumers have limited awareness of environmental labels on consumer goods and that these labels rarely factor into purchasing decisions (OECD, 2016[135]). This was also found to be the case in a study that examined labels such as Fair Trade or Rainforest Alliance used specifically on food products (Grunert, Hieke and Wills, 2014[136]). The influence of ELIS on consumers' food purchasing and consumption behaviour, as well as regulatory responses by governments to the multiplicity of ELIS applied to processed food and beverage products, constitutes an important area for future work.

Notes:
1. The International Organisation for Standardization (ISO) provides guidelines for carbon and water footprinting under ISO 14067 and ISO 14046, respectively (see https://www.iso.org/fr/standard/71206.html and https://www.iso.org/standard/43263.html).
2. See http://www.ecolabelindex.com/.

Waste generation associated with the processed food sector

Food loss and waste

An important share of all food produced for human consumption worldwide ends up as food loss (by actors along the food chain) or food waste (by consumers, retailers and food service providers) (FAO, 2019[137]).[25] Food loss and waste entail the unnecessary consumption of natural resources, represent a lost opportunity to decrease food insecurity, and add to total anthropogenic GHG emissions.

Many factors drive food loss at the processing and packaging stage, including insufficient processing capacity to accommodate seasonal variations in food quantities, technical malfunctions, lack of proper process management, and aesthetic standards (FAO, 2019[138]). While longer and increasingly complex supply chains for processed food products create more opportunities for a diverse market for ingredient suppliers, including at a global level, they can also create more opportunities for food loss/waste between production and consumption. On the other hand, food processing can extend shelf-life, which may help limit food loss and waste downstream. Furthermore, by-products from processing can be used to make other products.

At the processing and packaging stage, food loss varies greatly across different food categories and geographic regions. In the United States and Canada, per capita food loss per year in the food processing sector is estimated to be 47 kg and 43 kg, respectively (Commission for Environmental Cooperation, 2017[139]). According to ranges reported by the Food and Agriculture Organisation (FAO) of the United Nations, food loss at the processing and packaging stage for cereals and pulses could be as high as 16% in Eastern and South-eastern Asia and 20% in Sub-Saharan Africa (FAO, 2019[138]).[26] Food loss for fruits and vegetables during processing also shows geographic variability, with estimates of 0.25% in Central and Southern Asia, 37.5% in Eastern and South-eastern Asia, and 20.5% in Sub-Saharan Africa. Across the globe, approximately 14% of food is lost from post-harvest up to, but not including, the retail stage. It is clear that food loss and waste pose a global challenge. Previous OECD work indicates that many OECD countries address this problem within their waste prevention policies (OECD, 2015[140]).

Policies that influence packaging and date labelling practices (e.g. "use by" or "sell by" dates) used by food manufacturers can impact the quantity of processed food that is wasted at the consumption stage. A common criticism of date labels is that inconsistencies in terminology and information presented across different types of date labels can be confusing and may result in the premature disposal of food based solely on expiration dates (Newsome et al., 2014[141]; Wilson et al., 2017[142]; Wansink and Wright, 2006[143]). An investigation of the influence that different types of date labels and package sizes have on consumers' "willingness to waste" (i.e. anticipated food waste) found varying levels of anticipated waste across date labels and package sizes (Wilson et al., 2017[142]). In particular, higher anticipated food waste was associated with the "use by" label implemented for food safety and health objectives and a larger package size.

Packaging can extend shelf-life and reduce the amount of food loss and waste at various stages along the food supply chain. For example, FoodDrinkEurope reports that 32% of non-packaged produce becomes food waste, compared to 16% of packaged produce (FoodDrinkEurope, 2012[144]). Technologies such as modified atmosphere meat packaging have been effective for extending the shelf-life of meat and poultry products, and thus contribute to the reduction of food loss and waste of these products (Narasimha Rao and Sachindra, 2002[145]) At the same time, the use of packaging for food products can generate greater amounts of packaging waste.

Packaging waste

The generation and mismanagement of plastic waste from food packaging is problematic, in particular as much of it does not biodegrade. If current trends for the consumption and end-of-life management of plastics continue, an estimated 12 000 Mt of plastic waste will enter landfills and the environment by 2050 (Geyer, Jambeck and Law, 2017[146]). Food grade plastics, which must meet quality and purity standards, are challenging to recycle (Watkins et al., 2019[147]; OECD, 2018[148]). As such, a significant portion of the plastic waste stream comes from food packaging. For example, food packaging accounts for approximately 16% of plastic demand each year in the European Union (Schweitzer, Petsinaris and Gionfra, 2018[149]).

Plastic waste typically requires thousands of years to decompose. During this time, it can disrupt and accumulate in marine and terrestrial ecosystems and enter human food supply chains (de Souza Machado et al., 2018[150]; OECD, 2018[148]). Moreover, the production of plastics is energy-intensive and reliant upon fossil fuels (OECD, 2018[148]). In response to evidence on the health and environmental consequences of plastics, particularly single-use plastics, the European Commission released a proposal that included a ban on the use of several single-use plastics by 2021, as well as limitations on the use of plastic food containers and cups (European Commission, 2018[151]). There is also growing interest in developing more sustainable forms of food packaging to replace single-use plastics.[27]

6.5. Policy responses

As Chapter 2 shows, coherent policies require managing both synergies and trade-offs that can emerge across the different objectives for food systems. The following section provides an overview of programmes and policies that target the processed food sector in selected OECD countries in order to gain a better understanding of the approaches that countries have taken to navigate synergies and trade-offs across policy domains, as well as to highlight examples of public-private collaborations.

These examples are discussed within the context of the four-track policy approach developed by OECD (Giner and Brooks, 2019[3]). This approach can be used to reconcile health and nutritional objectives with wider food system objectives, including those related to environmental sustainability and to the livelihoods of agents along the food chain. The first track involves *demand-side public interventions*, such as policies that aim to promote nutritious or more environmentally or socially responsible food choices through the provision of public information. The second track involves *public-private collaborations*. For example, policies may focus on the voluntary reformulation of processed foods in order to provide consumers with more nutritious or sustainable product options. Food and beverage companies may also voluntarily adopt simplified labelling schemes in order to more effectively communicate food product attributes. The third track also focuses on the food industry but involves *stricter regulations*, such as mandatory restrictions on the marketing of foods that are potentially unhealthy, e.g. those that are high in sodium, free sugars, and/or some fats, or bans on the use of certain ingredients in processed food. The fourth track includes *fiscal measures*, e.g. taxes on sugar sweetened beverages. This four-track approach is used here in order to provide insights into the combinations of policy instruments that are likely to be the most effective in addressing the triple challenge with respect to the processed food sector.

Reformulation and orientation towards processed foods that support population health objectives

Measures such as reformulation or reorienting consumers towards processed food options that enable dietary patterns to support population health objectives (e.g. by using public information/education campaigns) have been promoted to address the adverse impacts associated with the consumption of energy-dense and nutrient-poor processed foods. These approaches can be voluntary or mandatory, and have typically focused on reducing dietary intake levels of trans fats, sugar, and salt, based on established links between their consumption and adverse health effects (Box 6.2).

Only a limited number of studies have evaluated the impact of actual reformulation actions undertaken by the processed food sector (Spiteri and Soler, 2017[152]; Poti, Dunford and Popkin, 2017[153]); the vast majority of studies have used simulations to assess the potential impact of hypothetical or proposed reformulation actions (Pearson-Stuttard et al., 2018[154]; Federici et al., 2019[155]; Bruins et al., 2015[156]; Dötsch-Klerk et al., 2015[157]; Hendriksen et al., 2013[158]). This is largely due to a general lack of detailed, product/brand-specific, and up-to-date data on processed food composition (Spiteri and Soler, 2017[152]; Ng and Popkin, 2012[159]). Moreover, existing studies have largely focused on measures for sodium reduction; less is known about the potential population health impacts of reformulation efforts or public information/education campaigns to reduce certain types of fat (i.e. trans fat or saturated fat) intake, sugar intake, and the intake levels of other important nutrients. A recent simulation study in the United States examined how reformulation of packaged foods would affect calories and four nutrients (saturated fat, total sugars, sodium, and dietary fiber), using up-to-date product and purchasing data (Muth et al., 2019[160]). Results showed that reformulation could potentially reduce caloric, saturated fat, sugar, and sodium intakes and increase dietary fibre intake. Detailed data on actual purchasing patterns combined with product/brand-specific food composition data would be particularly helpful to assess the impact of actual, rather than simulated, reformulation actions.

Amongst the criticisms of the reformulation approach is that it does not address overconsumption of foodstuffs – reformulation only addresses the intake of specific food components – and by honing in on specific food components, it overlooks the contributions from other ingredients in processed food products and ignores the potential adverse effects of the substitution of new ingredients (e.g. artificial sweeteners in lieu of sugar) (Scrinis and Monteiro, 2017[161]).

This section discusses OECD country examples of reformulation measures and initiatives to re-orient consumers towards processed food products that support population health objectives.[28]

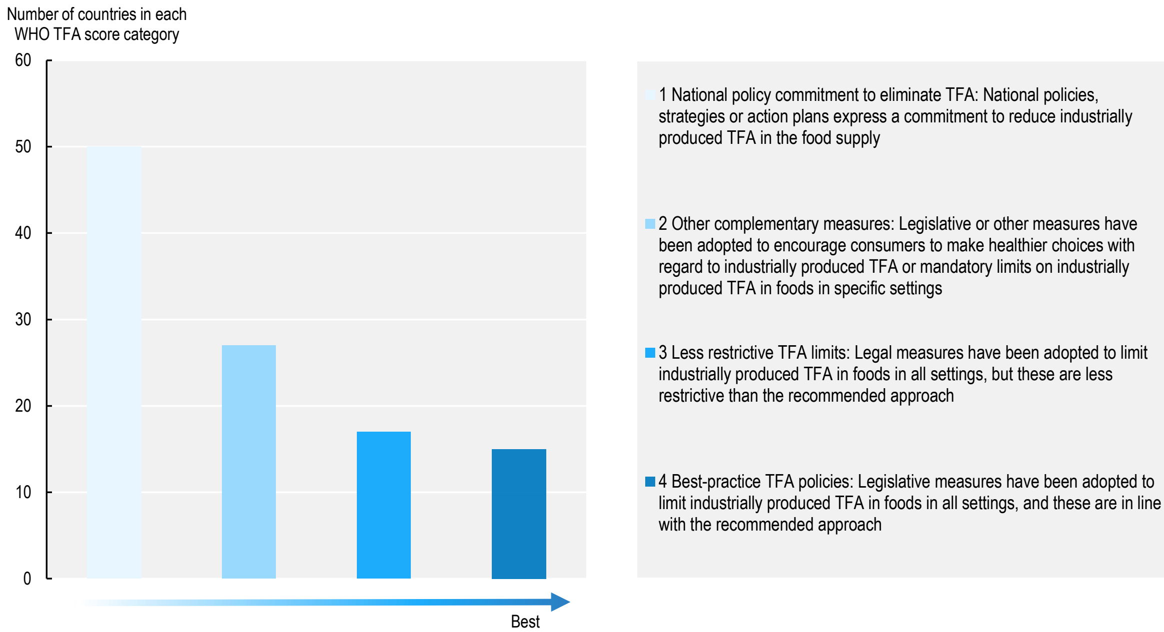
Policies to reduce and eliminate trans fats

Industrial trans fats are produced through partial hydrogenation and have been used, replacing saturated fats from animal products, as a low cost ingredient to prolong shelf life and enhance flavour and/or texture in processed foods such as baked foods, fried foods, snack foods, and spreads (WHO, 2019[162]). In response to the large health burden associated with the intake of trans fats, the WHO launched its REPLACE action package in May 2018 with the aim to "support governments to eliminate industrially-produced trans fats from the global food supply by 2023" (WHO, 2019[163]).[29]

To complement this action and to track progress towards the 2023 target, WHO developed a scoring system that groups trans fats elimination measures into four levels, with the fourth level comprising best-practice policies. Based on data available in the Global Database on the Implementation of Nutrition Action

(GINA), as of February 2020 only 15 countries have best-practice policies (Figure 6.5), while 27 countries have best-practice policies that have passed in legislature but are not yet in effect.

Figure 6.5. Progress towards reducing and eliminating industrial trans-fatty acids



Note: TFA stands for trans-fatty acid.
Source: WHO GINA database, TFA Country Scorecard, https://extranet.who.int/nutrition/gina/en/scorecard/TFA.

Two countries in the "best practice" category are Canada and the United States. A total ban on the sale of foods containing partially hydrogenated oils (and hence trans fats) was implemented in Canada in September 2020 (Health Canada, 2018[164]). This ban applies to domestic and imported foods, and to all food sold in all restaurants. The law was announced two years before its implementation to allow industry time to adapt.

In the United States, the Food and Drug Administration (FDA) ruled trans fats unsafe to eat in 2015 and set a June 2018 deadline by which foods containing trans fats were to be removed from the food system (US FDA, 2018[165]). According to the Grocery Manufacturers Association, 98% of trans fats were removed from the food supply between 2015 and 2018 (Dewey, 2018[166]). Nevertheless, due to concerns from the food industry with the various challenges of eliminating trans fats serving particular functions, it was requested that trans fats be permitted in some circumstances as flavour enhancers or greasing agents (Dewey, 2018[166]), and the ban was delayed. In 2018, a one-year extension to June 2019 was granted for the removal of trans fats from the food system (US FDA, 2018[165]).

More research is needed to gauge the success of the Canadian and United States' programmes. There is concern that such bans will prompt manufacturers to replace trans fats with sources of saturated fats (which are functionally similar to trans fats and have been associated with negative health effects) such as palm oil (Box 6.6) (Kadandale, Marten and Smith, 2018[167]). This highlights the need to monitor and better understand the potential adverse effects (e.g. health, environmental, and/or social) of substitute ingredients following reformulation efforts. Research in Canada (prior to the implementation of the trans fats ban) examining reformulation efforts by some manufacturers to reduce trans fat content in processed food found no increase in saturated fat content following reformulation, suggesting that these manufacturers did not turn to saturated fats as a replacement for trans fats (Ratnayake, L'Abbe and Mozaffarian, 2008[168]). However, more research is needed to better understand how manufacturers respond to total bans on industrially-produced trans fats, and how these responses differ across different country contexts.

Box 6.6. Palm oil and processed foods

Palm oil, a rich source of saturated fats, is a common ingredient in processed food products and many other consumer goods, with some 66 Mt produced in 2017 (Kadandale, Marten and Smith, 2018[167]). Indonesia and Malaysia are the world's main suppliers of palm oil and its production has helped to support the livelihoods of many farmers in these countries. Palm oil has a similar functionality to trans fats when included as an ingredient in various processed foods and there are expectations that manufacturers will increase their use of palm oil when faced with restrictions on the use of trans fats. This has raised concerns due to associations between consumption of palm oil and its adverse effects on health and the environment. Palm oil consumption is linked with higher ischaemic heart disease mortality rates (Chen et al., 2011[169]) and production practices (e.g. slash-and-burn) have additional negative health impacts for individuals living within palm oil production regions (Karthik et al., 2017[170]; The World Bank, 2016[171]). Palm oil production has also prompted large-scale deforestation (Kadandale, Marten and Smith, 2018[167]). A decrease in demand from food manufacturers to support health and/or environmental objectives could therefore have negative impacts on the livelihoods of many Indonesians and Malaysians. On the other hand, potential increases in demand in response to restrictions on the use of trans fats could further support livelihoods in palm oil-producing countries. This underscores the importance of efforts such as the Round Table on Sustainable Palm Oil (RSPO) to improve the environmental performance of the sector and to address concerns related to livelihoods and food security amongst rural populations in palm oil producing regions.

Sugar reduction programme in the United Kingdom

In the United Kingdom, one-third of children are overweight or obese by the time they have finished primary school. Obesity is a major cost to the national health care system (an estimated GBP 6.1 billion per year) (Public Health England, 2018[172]) and in response to this problem, Public Health England (PHE) instituted the Sugar Reduction Programme. This programme challenged the food industry to reduce sugar in their products by 20% by 2020, primarily by providing guidelines that stipulated the optimal quantity of sugar per 100g of a food product.[30] The major strategies suggested to programme partners were a reduction of overall sugar per 100g, a reduction in portion size, and/or reorienting customers towards low or zero sugar options (Public Health England, 2019[173]). Engaged stakeholders include manufacturers, retailers, and trade associates (Public Health England, 2019[174]).

The sugar reduction programme operates in tandem with a second programme targeting overall calorie intake. The latter is also working with and challenging the food industry to reduce the amount of calories in their products, in this case by 20% by 2024 (Public Health England, 2018[175]; Public Health England, 2018[176]). This is complemented by informational campaigns, i.e. the PHE's OneYou campaign which aims to make adults become more aware of the number of calories they consume on a daily basis and PHE's Change4Life campaign that provides online tools such as recipes, meal-time suggestions for parents to reduce their children's intake of sugary snacks and drinks replacing processed snacks with healthier alternatives.[31]

A recent modelling study found that meeting the targets of the sugar reduction programme would result in a gain of around 52 000 quality-adjusted life years and GBP 286 million in healthcare savings over a ten-year period (Amies-Cull, Briggs and Scarborough, 2019[177]). In support of this, recent work based on the OECD SPHeP-NCDs model indicated that a 20% reduction in the calorie content of energy-dense foods (across 42 countries included in the analysis) could avoid 1.1 million cases of NCDs and save

USD (PPP) 13.2 billion in healthcare expenditures per year (OECD, 2019[27]). PHE has assessed progress in the sugar reduction programme, and found that between 2015 and 2018 there was an overall reduction of 2.9% in sugar intake per 100g of food products, with different rates of progress by category of sugary food product (Public Health England, 2019[173]).[32] More assessments will be required to determine if the 2020 targets have been met, although the most recent available evidence indicates that in 2018 it remained far short of the targeted 20% reduction by 2020. Unlike the trans fat bans implemented in Canada and the United States, UK efforts do not involve binding laws but rely on the voluntary participation of stakeholders (falling in the second track of the four-track policy approach).[33]

Marketing regulation and labelling schemes for processed foods

Marketing of energy-dense and nutrient-poor processed food products, particularly marketing directed towards children, can shape preferences and contribute to poor dietary patterns. Alternatively, the implementation of labelling schemes can be used to communicate the various attributes of processed food products to consumers, helping to promote food choices for improved health or environment outcomes. An overview of different front-of-pack labelling schemes used in OECD countries is found in Giner and Brooks (2019[3]). This section discusses examples of marketing and labelling schemes applied to processed foods in selected OECD countries.[34]

Marketing and labelling laws in Chile

Chile has one of the highest prevalence of obesity and overweight of any OECD country: in 2016, 39.8% of its population was overweight and 34.4% were obese (OECD, 2019[178]). To address this situation, Chile implemented a set of laws between 2012 and 2015 to limit the marketing (especially towards children) of foods high in sugar, sodium, calories or saturated fats, and require these food products to present warnings indicating they contain high levels of these ingredients.[35] Warning labels ("high in sugar"; "high in sodium"; "high in saturated fats"; or "high in calories") are included on foods which surpass a certain threshold of sugar, sodium, or saturated fats. Any foods exceeding the deemed threshold quantity level of these nutritional values may not be advertised in nurseries, and elementary and secondary schools, nor in general to minors under the age of 14 years, and such foods may not be distributed for free (e.g through "gifts, contests, games, or other items that attract children"). Marketing of these products is restricted to the hours of 22:00 and 6:00 as long as the marketing does not target children.

These laws have met with challenges and push-back from the food industry (World Trade Institute, 2017[179]; FAO and PAHO, 2017[180]). The food industry had concerns regarding loss of profit, violation of property rights and freedom of speech, the inability to indicate warnings based on serving size rather than the mandated 100g/ml size, and the inability to choose the warning label for their products. A recent assessment of these regulations found a significant decrease – but not elimination – in children's exposure to televised advertising (e.g. the use of cartoon characters) of products high in sugar, sodium, saturated fats, and calories (Dillman Carpentier et al., 2019[181]). Further monitoring and evaluation will be important to ensure compliance by the private sector and to understand the long-term health impacts of these regulations on the population in general.

The Nutri-Score system in France

In March 2017, the French government adopted the Nutri-Score system as a new labelling practice in France (Giner and Brooks, 2019[3]) The basic idea behind Nutri-Score is a simplification – though not a replacement, since both systems now coexist – of existing labelling practices showing the nutritional values of food products. The system assigns a nutritional value (from a score of A for highest nutritional value to an E for relatively lower nutritional value) per 100g of a food product based on an addition of desirable nutrients, and a subtraction from the score based on the presence of harmful ones (Santé Publique France, 2020[182]). The system applies to all beverages and processed foods (with the exception of alcoholic beverages, coffee, tea, and herbs).

The basic purpose of the Nutri-Score label is to allow consumers to quickly and easily gain information on the product from a single aggregated score; a scoring system which can also be helpful to researchers as a tool to disaggregate the broad category of "processed foods". For example, Nutri-Score was used in a recent analysis of adolescent and children's exposure to food advertisements, which found that television advertisements for Nutri-Score D and E foods together represented more than half of food advertising seen by children and adolescents, respectively (Santé Publique France, 2020[183]).

Belgium and Spain have since adopted the Nutri-Score label as well (in 2018). Several other European countries have announced their plans to adopt the Nutri-Score label. Mandatory front of pack labelling in the EU by the end of 2022 is being proposed by the European Commission (European Commission, 2020[184]).[36] The Nutri-Score programme remains optional (track two of the four-track policy approach), although a growing number of companies are adopting it. Companies such as Danone, Auchan, and Fleury-Michon are major participants, with some 500 brands worldwide applying the labelling system as of September 2020.[37]

Fiscal policies

The use of fiscal measures is the fourth of the four-track policy approach (i.e. excise or sales taxes), such that prices for various processed food products more closely reflect their social cost. An example is the soft drinks industry levy implemented in April 2018 in the United Kingdom (Scarborough et al., 2020[185]). In order to address well-established negative health outcomes associated with high intake levels of sugar, a tax is now applied to UK manufacturers and importers for beverages that contain more than the threshold of 5g of sugar per 100ml. Importantly, the implementation of taxes on food or beverage items that are potentially unhealthy, such as those high in sodium, free sugars, or fats, can incentivise reformulation (Giner and Brooks, 2019[3]), and a recent assessment suggests that reformulation for reduced sugar content was one of the outcomes of the soft drinks industry levy in the United Kingdom (Scarborough et al., 2020[185]).

Newspapers and other media can also play an important role in influencing public reaction to and acceptance of health policies. A study analysing newsprint articles from prominent UK national newspapers between April 2015 and November 2016 suggest that media covering the health effects of sugar and sugar-sweetened beverage (SSB) consumption, the industry's role in promoting and enabling sugar consumption, and the need for government intervention helped to open a policy window for the development of fiscal approaches that sought to improve health outcomes by reducing sugar consumption (Buckton et al., 2017[186]).

Other fiscal policy approaches targeting energy-dense and nutrient-poor food have been imposed and subsequently revoked. For example, Denmark's tax on saturated fat, a world first, was implemented in 2011 but was abolished a year after its introduction in part due to the sustained and intensive pressure exerted by food industry associations (Bødker et al., 2015[187]).

6.6. Main challenges to more coherent policies

Developing coherent policies for the processed food sector that take into account potential trade-offs and synergies across the triple challenge domains requires co-operation and co-ordination amongst policy makers, scientific experts, and food and beverage manufacturers. However, these communities do not always relate to one another in a manner optimal to delivering coherent policies that are in the public interest. Focusing on the roles of each community, the following section discusses the key challenges to implementing coherent policies that are relevant to the processed food sector.

Data scarcity

The problem of insufficient data pertaining to the consumption and characteristics of processed foods is a major challenge in developing coherent policies. Funding and budget constraints are the usual underlying causes (Giner and Brooks, 2019[3]). In particular, the laboratory tests that are necessary to obtain detailed nutrient composition data are generally very costly. Incomplete and infrequently updated food composition data makes it difficult to monitor the evolution and composition of product- and brand-specific packaged food (Ng and Popkin, 2012[159]). Inconsistencies in product classifications prevent matching food products across different food information sources (e.g. matching products across food composition and food purchasing and acquisition databases) (Giner and Brooks, 2019[3]). Existing food information databases typically do not contain data on the product- and brand-specific sustainability performance of processed food items. Additionally, there are little data available on the composition of foods consumed away from home.

For these reasons, it is difficult to estimate the true nutrient intake levels and, more broadly, evaluate the impact of policy interventions aimed at addressing processed food sector-related objectives across the triple challenges. Policies to improve the characteristics of processed food consumed away from home may be especially important as its share of the food budget has increased over the past few decades, and recent research indicates that meals from full-service and fast-food restaurants are largely of low nutritional quality (USDA ERS, 2018[188]; Liu et al., 2020[189]). More granular data are also needed to better understand processed food consumption patterns across different socio-economic strata in order to allow for improved policy targeting (Placzek, 2021[190]). The co-operation of the private sector in sharing their data with policy makers and researchers is thus important.

Co-ordination across different policy-making communities

Co-ordination across different policy communities at the national level may pose a challenge to the development of coherent policies, as agricultural, environmental, health, economic, trade, and competition policy all touch in some way the processed food sector. Furthermore, the prominence of processed food products in international trade (and the role of trade in providing inputs for further processing), as well as the rise of transnational and multinational food and beverage corporations, necessitate co-ordination at an international level. For example, international co-ordination may be important to minimize potential unnecessary impediments to trade associated with inconsistencies in front-of-pack labelling schemes for packaged foods (Giner and Brooks, 2019[3]; Thow et al., 2017[191]). Such concerns give increasing importance to international standard-setting bodies such as the Codex Alimentarius that promote the harmonisation of requirements and approaches.[38]

Lack of trust and resistance to measures that restrict choice

A lack of trust on the part of consumers can undermine efforts to achieve objectives across the triple challenge with respect to the processed food sector. Erosion of consumer trust can stem from a general lack of coherence in public messaging. For example, marketing or informational campaigns by food industry actors with vested interests (e.g. the marketing of energy-dense and nutrient-poor food products, "greenwashing"[39] of food products) can conflict with and/or drown-out scientific evidence from experts (Mozaffarian and Forouhi, 2018[192])[40]. Private interest groups, civil society and even the scientists themselves may also undertake efforts to cast doubt on the integrity of scientific evidence (Nestle, 2015[193]). As such, confusion and distrust amongst consumers can stem from the difficulty in distinguishing between "facts" and private interests. Further distrust may arise with the evolution of food and nutrition science (which prompts shifts in dietary recommendations), uncertainties and lack of consensus on certain topics, and time-lags between the generation and implementation of new knowledge, all of which can be perceived as inconsistencies in the scientific evidence base on food and nutrition (Mozaffarian, Rosenberg and Uauy, 2018[194]; Mozaffarian and Forouhi, 2018[192]). To illustrate the case of the time-lag, Mozaffarian and Forouhi (2018[192]) provide the example of low fat food options, which remain an industry focus, regardless of new evidence indicating that total fat intake is not as important to diet quality as previously suspected: more important are the intake levels of specific types of fats.

Even when the evidence base on certain foods and nutrition is firmly established and generally trusted by the public, related policy interventions that place regulatory burdens on businesses or interfere with the range of choices available to consumers – measures that can be perceived as "paternalistic – can face resistance (Reeve and Magnusson, 2015[195]; Hanock, Barnes and Rice, 2017[196]; Véliz et al., 2019[197]). For example, the ban on the sale of large sugary beverages proposed in 2012 in New York City was met with widespread concern regarding compromised individual freedom and autonomy, and the ban was ultimately repealed (Véliz et al., 2019[197]). Another example is when the restaurant industry sued the city of New York in response to menu-labelling requirements in 2008 (Brownell and Warner, 2009[198]). At the same time, the threat of binding regulations can incite a range of responses from corporations that do not wish to have their activities restricted, including lobbying (see below). Such responses by civil society and private actors have led to the preferential use of voluntary measures over direct restrictions and bans, despite concerns with respect to their efficacy (Brownell, 2012[199]; Scott, Hawkins and Knai, 2017[200]).

Corporate political activity of food and beverage companies

Stakeholder consultation is a critical part of policy development, and formal consultations should promote fair and transparent participation in policy-making. Interest groups can use a range of other means to influence policy processes, such as industry-funded scientific research, and industry funding of organisations and non-profit groups to shape news and media coverage. These new approaches often lack the transparency that comes from traditional lobbying registers or disclosure requirements. Such "corporate political activity" (CPA) (Baysinger, 1984[201]) exists in many industries, including in the processed food sector.

By themselves, these activities are not necessarily harmful and can even play an important role in providing policy makers with useful information on the potential effects of proposed measures. But as in other sectors, the economic interests pursued by food and beverage companies (e.g. the pursuit of earnings growth, maximising value for shareholders) are not necessarily aligned with public interests, for example when public policies to improve environmental or health outcomes would reduce sales or profits for some firms.[41] A key task of policy making therefore consists in finding ways to balance the diversity of interests and avoid both over-representation or under-representation (or even exclusion) of specific interests. Policy makers need to avoid a situation where decisions reflect the interests of a narrow interest group at the expense of the broader interests of society, a situation referred to as "policy capture" (OECD, 2017[202]).[42]

Research from Mialon, Swinburn and Sacks (2015[203]) noted there is limited monitoring of CPA in health-related food areas and proposed an approach at the country level, building on a taxonomy for the tobacco industry CPA previously proposed by Savell, Gilmore and Fooks (2014[204]). The proposed framework for the classification of food industry CPA consists of six types of activity: information and messaging; financial incentive; constituency building; legal; policy substitution; and opposition, fragmentation and destabilisation.[43]

Making use of this framework and the information collected from the public domain, parallel studies were recently conducted in France analysing CPA by actors in the dairy industry (including Danone, Lactalis and the Centre National Interprofessionnel de l'Economie Laitière) (Mialon and Mialon, 2017[205]) and other major actors in the food industry (including Association Nationale des Industries Agroalimentaires/National Association of Agribusiness Industries, Coca-Cola, McDonald's, Nestlé, and Carrefour) (Mialon and Mialon, 2018[206]). Prominent practices identified included "information and messaging" (e.g. framing the debate on diet- and public health-related issues, shaping the evidence base on diet- and public health-related issues, promoting deregulation), "constituency building" (e.g. seeking involvement in the community), and "policy substitution" (e.g. developing and promoting alternatives to policies). Similarly, this framework was applied to food industry actors in Australia (including the Australian Food and Grocery Council, Coca Cola, McDonald's, Nestle, and Woolworths), and common practices identified included "information and messaging" and "constituency building" (Mialon et al., 2016[207]). The prominence of these practices in particular was supported by a second study that involved interviews with former policy makers, public health advocates, and academics who had interacted with the food industry in Australia (Mialon et al., 2017[208]). Based on such findings, some have argued that industry should be excluded from the development phase of health policies (Donovan, Anwar McHenry and Vines, 2014[209]).

However, the processed food sector can be a valuable source of information, practical knowledge and technical expertise to inform the development and implementation of workable policies. For example, public officials may need to interact with industry to gain access to data relevant to certain public decisions, such as information on specific technologies, consumer research, and other unique evidence sources (OECD, 2017[202]). Engaging with industry stakeholders early in the policy development process can be critical to avoid unintended consequences.

Yet such consultations create opportunities for industry actors to provide information that favours private interests, potentially at the expense of the public good (Helm, 2010[210]; OECD, 2017[202]). This tension is illustrated in the recommendations of the 2018 Australian Obesity Report, addressing the Australian Health Star Rating (HSR) system (a front-of-pack labelling system to rate packaged foods based on their respective nutrient profiles) (Select Committee into the Obesity Epidemic in Australia, 2018[211]).[44] Among the listed recommendations is the following: "Representatives of the food and beverage industry sectors may be consulted for technical advice but no longer sit on the HSR Calculator Technical Advisory Group". This recommendation recognises the potential need for technical information from industry, but also the potential for capture when industry actors are included in the development of programmes and policies.

The complexity of interacting with the processed food sector while preventing policy capture is evident in the case of lobbying, one of the sub-categories falling under the "information and messaging" group in the food industry CPA classification framework noted above. Lobbying, "the oral or written communication with a public official to influence legislation, policy or administrative decisions" (OECD, 2010[212]), is a legitimate practice for companies to share their needs and evidence about policy problems and how to address them. It can also be a valuable means to provide policy makers with information on which to base their decisions (OECD, 2017[202]). However, there is the risk that lobbying will result in powerful interest groups having undue influence in public decision-making, and transparency and integrity are needed to manage this risk (OECD, 2014[213]).

To enhance such transparency governments can require disclosures by lobbyists, including their employer's name and name of clients, and whether the lobbyist is a former public official, receives any government funding or contributes to any political campaigns.[45] Thirteen OECD countries have mandatory lobbying registers in place. Using this information, some databases have emerged that monitor lobbying activities and allow for their subsequent scrutiny by the public. An example is the publicly available database maintained by the Centre for Responsive Politics in the United States.[46] Information contained in this database indicates that in 2019 the food processing and sales industry in the United States had lobbying expenditures of USD 24.2 million, with the top five firms consisting of PepsiCo, Grocery Manufacturers Assn, WH Group, Tyson Foods, and Nestlé. Additionally, some 68% of lobbyists in the food processing and sales industry were categorised as "revolvers", which here refers to the concept of the "political revolving door" in which former public officials hold new positions in the industries that they previously oversaw (a practice falling under the "constituency building" category in the CPA framework noted above).

Similarly, consultations with stakeholders during policy development can be documented and made publically available. This was the case with the open consultation on Canada's Food Guide (i.e. the proposed recommendations for Canada's 2019 national dietary guidelines), where feedback from over 6 000 contributors, including 98 self-identified contributors from the food and beverage industry, was collected and synthesised into a publically-available report (Government of Canada, 2018[214]). This synthesis report indicates, for example, that many contributors from the food and beverage industry in Canada disagreed about the proposed recommendation to shift away from animal proteins. They also disagreed on the focus to reduce saturated fat consumption, were concerned that food taste and general food preferences were not being taken into account, and felt the recommendations should be based on food as a whole rather than their specific nutrients.

Corporate political activity can also affect the relationship between the food and beverage industry and the scientific research community, which in turn can impact public decisions. In particular, the scientific evidence base on the impacts of various food products on health can be shaped through industry funding of food and nutrition research, another activity that falls under the CPA category of "information and messaging" (Aveyard et al., 2016[215]; Mozaffarian, 2017[216]; Mozaffarian et al., 2018[217]; Mozaffarian and Forouhi, 2018[192]; Nestle, 2016[218]; Kearns, Schmidt and Glantz, 2016[219]; Nestle, 2016[220]; Lesser et al., 2007[221]; Chartres, Fabbri and Bero, 2016[222]; Nestle, 2015[193]). For instance, bias favourable to industry has been noted in the published conclusions of industry-funded research and reviews examining the association between sugar-sweetened beverage consumption, and weight gain, obesity and diabetes (Schillinger et al., 2016[223]; Bes-Rastrollo et al., 2013[224]). Similarly, bias has been identified in industry-funded reviews assessing the link between artificially sweetened beverage intake and weight outcomes (Mandrioli, Kearns and Bero, 2016[225]). Industry funding can enable important food and nutrition research and innovations (particularly where public funds are limited), but the establishment of clear governing principles is needed to manage the relationship between the food and beverage industry and the research community in a way that minimises the production and dissemination of biased information and safeguards public interest. Importantly, private sources of research funding are not necessarily problematic: the integrity of scientific evidence, rather than concern over the source of funding should be central in the establishment of such governing principles.

6.7. Conclusion

Policies targeting the processed food sector have an important role to play in addressing objectives across the triple challenge dimensions. Processed foods include a wide range of food products with differing health, environmental, and social implications. Processing techniques, such as preservation practices and fortification, have been important for improving food security and working towards various public health objectives. At the same time, there are well established associations between excessive intake of energy-dense and nutrient-poor processed foods and an increased risk of developing conditions of overweight, obesity, specific forms of cancer and other NCDs. Food processing accounts for an important share of income generation and employment in OECD, emerging, and less developed countries, including through participation in international trade and GVCs. Environmental impacts vary across different processed food products, and the processed food sector can influence the sustainability of diets through improving energy efficiency in processing, requiring stricter environmental standards of suppliers and conveying information on environmental sustainability performance to downstream consumers.

To date, policies targeting the processed food sector have largely focused on improving health outcomes. While further research is needed to better understand the impacts of these policies, existing evidence indicates that demand-side public interventions and voluntary measures targeting the processed food sector (tracks one and two of the four-track policy approach) have limited efficacy on their own. Mandatory measures and fiscal policies (tracks three and four of the four-track policy approach) may be more promising for achieving triple challenge objectives, particularly if they are able to effectively navigate and minimize potential resistance both from industry and the public. Strategies to achieve this could include transparent engagement with industry stakeholders during policy development (especially during early stages of policy development), protecting the integrity of scientific evidence, and strengthening the public's trust in public officials and scientific experts.

When developing policies in any of the four tracks, consideration should be given to the potential negative impacts that regulatory burdens can have on industry innovation and initiatives that aim to support nutritious, sustainable, and socially responsible food systems. Addressing data scarcity pertaining to the health, environmental, and social attributes of brand- and product-specific processed food items will also be important to designing policy interventions and anticipating potential interactions that could occur across triple challenge dimensions. Overcoming challenges to the design and implementation of coherent policies will require improved co-ordination amongst policy makers, scientific experts, and industry.

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Notes

[1] This chapter uses the term “processed food” to refer broadly to any food that has undergone any transformation from its raw form. This category encompasses a broad range of food products that have been processed to varying degrees and make varying contributions to each of the triple challenge domains.

[2] See https://stat.unido.org/app/country/Emp.htm?Country=124&Group=null.

[3] In this report, data for food, beverage, and tobacco are sometimes presented in the aggregate because many food and beverage companies also engage in tobacco processing activities and disaggregated data are typically unavailable. Where available, disaggregated data are presented.

[4] See https://fortune.com/global500/2019/search/

[5] The four-track approach consists of demand side public interventions, efforts to work with industry at the supply-demand interface, firmer regulations, and fiscal measures.

[6] For examples of other classification systems, see (Poti et al., 2015[14]) and (Eicher-Miller, Fulgoni and Keast, 2012[236]).

[7] Research on diet quality is evolving. A growing body of evidence is outlining the linkages between poor diets and negative health outcomes. Based on the current body of scientific evidence pertaining to health, nutrition, and the qualities that make up healthy dietary patterns, the World Health Organisation provides recommendations for the intake of whole foods, fats, salt, and sugar in the WHO Healthy Diet Fact Sheet (WHO, 2020[35]). In addition, national-level food based dietary guidelines are available for 90 countries globally (Herforth et al., 2019[233]).

[8] Rising national incomes typically lead to a declining share of disposable income spent on food (Engel’s law) and shifts towards higher caloric consumption and more diverse diets (Bennett’s law). Arguably, the rise of processed foods is a similar stylised fact. Technological innovations and shifts in living and working conditions make “ready-to-consume” foods or food away from home an attractive alternative to preparing meals at home (Rahkovsky, Jo and Carlson, 2018[226]). Factors such as increasing urbanisation and a greater number of women entering the labour force have fuelled the growing demand for convenient processed/preserved food products (Bleich et al., 2008[227]; Seto and Ramankutty, 2016[228]).

[9] Many types of processed foods have evolved in order to meet emerging consumer preferences for convenience and palatability, while remaining affordable (Gupta et al., 2019[229]; USDA, ERS, 2003[230]). This is partly achieved through a heavy reliance on low-cost and energy-dense ingredients such as sugars, fats, oils, and grains (Drewnowski and Specter, 2004[48]; Headey and Alderman, 2019[231]).

[10] Spatial overviews of food access in the United States by income levels and a community’s ability to access healthy food are downloadable at the USDA ERS Food Access Research Atlas and Food Environment Atlas websites. See https://www.ers.usda.gov/data-products/food-access-research-atlas/ and https://www.ers.usda.gov/data-products/food-environment-atlas/

[11] The socio-economic and demographic determinants of food choices are explored in greater detail in (Placzek, 2021[190])

[12]This dietary transition is particularly complex among Indigenous peoples in northern Canada, and can involve interactions between traditional/country food systems and market food systems, as well as various socio-economic factors. This is explored in detail in (Council of Canadian Academies & Expert Panel on the State of Knowledge of Food Security in Northern Canada, 2014[54]), and more recently in work from PROOF, an interdisciplinary research programme working to identify effective policy interventions to reduce household food insecurity in Canada, https://proof.utoronto.ca/

[13] The Codex Alimentarius Commission has established guidelines for the use of nutrition and health claims in food labelling (Codex Alimentarius Commission, 1997[240]). Many countries have national regulations for the use of nutrition and health claims.

[14] Health Canada is working on a regulatory framework for Supplemented Foods. A supplemented food is broadly defined as a pre-packaged product that is manufactured, sold or represented as a food, which contains added vitamins, minerals, amino acids, herbal or bioactive ingredients. These ingredients may perform a physiological role beyond the provision of nutritive requirements.

[15] The global estimate for value added from food and beverage manufacturing is from FAOSTAT, http://www.fao.org/faostat/en/#data/MK (accessed February 2020); Beverages include alcoholic beverage products.

[16] See UNIDO Statistical Country Briefs (ISIC rev3), https://stat.unido.org/app/country/Emp.htm?Country=124&Group=null (accessed February 2020).

[17] See https://www.ers.usda.gov/data-products/food-dollar-series/documentation/

[18] While participation in GVCs can provide domestic opportunities to transition along the value chain to the production of more "sophisticated" processed products, in some contexts just as much domestic value added can be generated via the export of a higher volume of primary agricultural products (Greenville, Kawasaki and Jouanjean, 2019[98]).

[19] Much of the energy consumed in food processing and manufacture goes towards heating and cooling procedures. Technologies such as the recirculation of air in dryers, waste recovery, and pre-cooling methods are particularly helpful for improving energy efficiency (OECD, 2017[103]).

[20] For a more detailed discussion of the poor alignment between energy taxes and the negative impacts of energy consumption, see OECD (2019[232]).

[21] Some life-cycle assessments suggest that ready-to-eat food has higher emissions relative to similar home-made products (Box 6.5).

[22] See the Mintel Global New Products Database: https://fr.mintel.com/gnpd-global-new-products-database.

[23] https://data.nal.usda.gov/dataset/usda-branded-food-products-database.

[24] https://www.oqali.fr/Base-de-donnees-Oqali.

[25] Previous FAO estimates from 2011 put total food loss and waste at one-third of global production by weight and around one-quarter by calories (FAO, 2011[239]). Given more recent advances in data and methodology, these estimates are currently being revised by FAO and the United Nations Environment Programme. Numbers cited here refer to FAO's revised estimates for food loss (FAO, 2019[138]).

[26] These data can be explored using the FAO Food Loss and Waste Database, (FAO, 2020[234]).

[27] For an overview of how policies can be used to incentivise sustainable plastic design, see (Watkins et al., 2019[147])

[28] For more examples and discussions on reformulation in terms of health and economic impacts in OECD countries, see (Goryakin et al., 2019[241]).

[29]See https://www.who.int/nutrition/topics/replace-transfat.

[30] Sugar here refers to the intake of free sugars, under the definition adopted by the Scientific Advisory Committee on Nutrition, "all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices" (SACN, 2015[235]). This definition is in line with the WHO definition (Box 6.2).

[31] See https://www.nhs.uk/change4life#5IfkYIFWdGz0hJdU.97

32 The major food product targets include breakfast cereals, yogurts, ice cream, confectionary, and cakes; although the Change4Life campaign also insists on the reduction of sugary drink intake.

33 For yearly summaries of stakeholder engagements, see https://www.gov.uk/government/publications/sugar-reduction-and-wider-reformulation-stakeholder-engagement

34 More information and comparisons across 52 countries in terms of life expectancy, health and labour market costs of different interventions, including FOP labelling and product reformulation, can be found in the technical notes to the OECD's 2019 report on obesity (OECD, 2019[27]) (OECD, 2019[242]).

35 Three laws enact these changes: Law 20.780 (a beverage tax law instituted in 2014), Law 20.606 (an advertising law instituted in 2012), and Law 20.869 (a food marketing law instituted in 2015).

36 See https://fr.openfoodfacts.org/nutriscore.

37 For a full list of participating companies, see https://world.openfoodfacts.org/label/nutriscore/brands.

38 See http://www.fao.org/fao-who-codexalimentarius/about-codex/en/; Proposed draft guidelines on front-of-pack nutrition labelling from the 2019 Codex Committee on Food Labelling are available at http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-714-45%252Fdocuments%252Ffl45_06e_final.pdf.

39 Referring the practice of using misleading or fraudulent claims pertaining to the environmental performance of products (Dahl, 2010[238]).

40 Sensational news media headlines can also add to the confusion and distrust.

41 Growing evidence and awareness of the negative health effects associated with certain categories of food products and certain ingredients used in processed food products can be understood by food and beverage companies as a business risk. For example, in Coca-Cola's 2018 annual report, one of the listed risk factors was as follows, "obesity and other health related concerns may reduce demand for some of our products" (The Coca-Cola Company, 2018[69]). Likewise, potential policy measures to improve public health outcomes and also environmental outcomes can be understood by food and beverage companies as risks. For example, the list of risk factors contained in PepsiCo's 2018 annual report included "the

imposition or proposed imposition of new or increased taxes aimed at our products could adversely affect our business, financial condition or results of operations", "significant additional labelling or warning requirements or limitations on the marketing or sale of our products may reduce demand for such products and could adversely affect our business, financial condition or results of operations", and "changes in laws and regulations relating to the use or disposal of plastics or other packaging of our products could continue to increase our costs, reduce demand for our products or otherwise have an adverse impact on our business, reputation, financial condition or results of operations" (PepsiCo, 2018[70]). Food and beverage companies that anticipate adverse impacts (e.g. threats to profitability) from various health (or environmental) initiatives may resist them (Nestle, 2013[237]).

42 As discussed in Chapter 3, previous OECD work provides four key recommendations to prevent policy capture: 1) levelling the playing field; 2) enforcing the right to know; 3) promoting accountability through competition authorities, regulatory agencies and supreme audit institutions; and 4) identifying and mitigating capture risk factors through appropriate organisational integrity policies (OECD, 2017[202]).

43 For a more detailed description of the types of practices falling under each of these six groups, see (Mialon, Swinburn and Sacks, 2015[203]).

44 See http://www.healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/Content/About-health-stars

[45] Governments can further enable scrutiny of lobbying activities by providing timely, reliable, accessible and intelligible public disclosures of reports on those activities. Moreover, creating open and user-friendly registers can facilitate public access to data on lobbying activities.

[46] See https://www.opensecrets.org/federal-lobbying/summary (monitored by the Centre for Responsive Politics).

7 Conclusion

This final chapter summarises the findings of the report and draws policy implications. While the performance of food systems in terms of the triple challenge has not been as black and white as some suggest, there are major shortcomings. Better policies for food systems are a powerful lever to improve food security and nutrition, livelihoods, and environmental sustainability. Coherence across these areas will require breaking down silos between agriculture, health and environmental policies, but will also require overcoming knowledge gaps, resistance from interest groups, and differing values. Robust, inclusive, evidence-based processes are thus essential to making better policies for food systems.

Food systems around the world can point to some impressive achievements. Between 1960 and today, world population more than doubled, yet global food production tripled, ensuring more food per person at lower prices. What's more, this was accomplished while only using about 10-15% more agricultural land, as food systems achieved a large increase in output per unit of agricultural land. The expansion of agricultural land has had important negative effects on forests and biodiversity, and led to large greenhouse gas emissions. If food systems had not managed to increase productivity, the consequences for human and environmental well-being would have been devastating. While production growth after 1960 was initially achieved mostly by using more inputs (e.g. fertilisers), which create their own set of environmental challenges, in recent decades efficiency gains have been the main source of production growth.

The scale of these past achievements is as remarkable as what still remains to be done. Food systems are expected to provide food security and nutrition for a growing population expected to approach 10 billion people by mid-century. Food systems are also relied on to provide livelihoods for those working on 570 million farms worldwide, and along other stages of the food supply chain. And food systems not only depend on natural resources, but are also expected to contribute to environmental sustainability.

Meeting this "triple challenge" is central to achieving the Sustainable Development Goals, but with only ten years left the world does not appear on track to meet these goals. The COVID-19 pandemic and the global recession it triggered constitute a major setback, with undernourishment on the rise as livelihoods have been disrupted. But even before the COVID-19 outbreak, food systems were inadequately addressing the triple challenge. After falling for many years, the number of undernourished has been increasing since 2014. An estimated two billion people do not have regular access to sufficient, safe and nutritious food while an even greater number are overweight or obese. Food production is also exerting major pressures on the environment, including through overfishing, nitrogen pollution, deforestation for agricultural expansion, and direct emissions from agriculture. Meanwhile, productivity growth in agriculture is often associated with a fall in agricultural employment, which can put pressures on livelihoods.

These problems have led some observers to talk about a "broken food system". Yet as Chapter 1 of this report has shown, the performance of food systems is not as black and white as that term suggests. There is no doubt that food systems face a daunting triple challenge requiring urgent policy responses. But the metaphor of a "broken food system" risks ignoring the enormous heterogeneity and complexity of food systems around the world, and falsely suggests that a single causal mechanism is at work behind the various problems, or that there is a single way of "fixing" these. Instead, effective policy responses need to be pragmatic and evidence-based, as emphasised in a significant body of work (by OECD and others) identifying policy options to create productive, sustainable and resilient food systems and to address poverty, hunger, and malnutrition. In particular, that work has shown that agricultural and fisheries support policies in many countries can exacerbate problems. Removing these counterproductive measures would have important benefits, but effectively addressing the triple challenge will also require additional pro-active policy efforts.

In developing better policies for food systems, policy makers must grapple with possible synergies and trade-offs across the dimensions of the triple challenge. A food systems approach has the advantage of creating awareness about interactions between policy domains which have historically often been treated in isolation, including interactions which spill across international borders. As discussed in Chapter 2 of this report, these interactions create both difficulties and opportunities. As any suggested policy could affect other dimensions of the triple challenge, policy proposals need to be assessed with the possibility of spill-overs in mind. This complicates the process of policy development, but it also creates opportunities, as such spill-overs might offer new levers to address problems by exploiting synergies or adjusting policies with unwanted negative spill-over effects. In other words, policy makers should aim for policies that are coherent with respect to the triple challenge, and should therefore coordinate across policy making communities. An important first step is to rigorously evaluate and where possible quantify the extent of interactions for proposed new policies, as well as for existing policies. Many plausible effects may not be large enough to warrant adjustments to policies. Where synergies exist, a single policy rarely delivers the optimal outcome across several dimensions: usually, a mix of policy instruments is needed. When there are trade-offs, no set of policies will provide the ideal outcome for every objective: choices must be made. While those choices need to be based on the best possible evidence, they involve value judgments and need to be made in a way that commands broad support across society, is consistent with international obligations, and effectively addresses the triple challenge.

Policies related to food systems have often proved hard to reform. Chapter 3 has shown that achieving better policies requires overcoming frictions related to facts, interests, and values. Although much is already known about which policy changes would be beneficial for food systems, for many policy questions there are still significant knowledge gaps about the extent and characteristics of problems; about synergies and trade-offs; or about the costs and benefits of various policy options. There may also be gaps between popular beliefs and scientific evidence, and policy debates may be hampered by myths, misperceptions, or outdated views. Yet facts are not the only source of friction in the policy process. Policies typically create winners and losers, creating diverging interests. If not all stakeholders are equally vocal or well-organised, the result may be suboptimal policies favouring special interests.

Moreover, differing values may come into play. For example, new plant breeding techniques (discussed in the case study on seeds) may be seen by some as a promising innovation which could lead to sustainable productivity growth, but may be seen by others as a “technological fix” pushed by corporations seen as concerned more about financial gain than about environmental or human health. Similarly, the ruminant livestock sector may be seen by some as providing essential animal-sourced proteins and contributing to livelihoods and rural landscapes, while others might object in principle to eating meat or dairy because of concerns with animal rights or climate change. And as discussed in the case study on processed foods, measures to reduce the sales of e.g. sugar-sweetened beverages may be seen by some as a reasonable policy to improve public health, but may be criticised by others as an unreasonable restriction of freedom of choice.

Such differences over values are ubiquitous and cannot be settled by facts alone. To complicate matters further, frictions in one area (e.g. differing values) can reinforce frictions in another area (e.g. by making people less willing to consider facts that go against their initial beliefs). As emphasised in Chapter 3, policy-making processes should thus be designed to generate trusted evidence, to avoid policy capture by special interests, and to mediate between differing values.

Making better policies for food systems thus requires overcoming data and knowledge gaps, resistance from interest groups, and differing values. In particular, there is a need to urgently reform those agricultural and fisheries policies which are most distorting and create negative environmental effects. Many of these policies also limit the flexibility of producers, and hence reduce the resilience of food systems to adapt to new technologies, changing consumer demands, and climate change; but the policies themselves have often proved hard to reform. Doing so will require political leadership, as well as cooperation and communication with stakeholders and across policy communities at the local, national, and international level.

Faced with this difficult task, the easy option for policy makers would be to maintain the status quo. But better policies for food systems hold tremendous promise for meeting the triple challenge of food security and nutrition, livelihoods, and environmental sustainability.

Making Better Policies for Food Systems

Food systems around the world face a triple challenge: providing food security and nutrition for a growing global population; supporting livelihoods for those working along the food supply chain; and contributing to environmental sustainability. Better policies hold tremendous promise for making progress in these domains. This report focuses on three questions. What has been the performance of food systems to date, and what role did policies play? How can policy makers design coherent policies across the triple challenge? And how can policy makers deal with frictions related to facts, interests, and values, which often complicate the task of achieving better policies? Better policies will require breaking down silos between agriculture, health, and environmental policies, and overcoming knowledge gaps, resistance from interest groups, and differing values. Robust, inclusive, evidence-based processes are thus essential to making better policies for food systems.

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s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Tuesday, 21 December 2021 10:13 AM
To: s. 22(1)(a)(ii)
Cc: s. 22(1)(a)(ii) Greenville, Jared
Subject: FW: FOR INFO/ACTION by OOB 14 Jan: [FAO LEAP Partnership] Draft guidelines on methane for review + updates [SEC=OFFICIAL]
Attachments: FAO Methane Assessment Technical Document DRAFT.pdf; Template_for_comments.doc

Hi, FYI. I'll respond to s. 22(1)(a) and will try and have a look at this sometime before the due date. So might send you my thoughts early in January, and we can hopefully clear a response by 14 Jan.

s. 22(1)(a)(i

From: s. 22(1)(a)(ii) @agriculture.gov.au>
Sent: Monday, 20 December 2021 1:01 PM
To: s. 22(1)(a)(ii) @agriculture.gov.au>
Cc: s. 22(1)(a)(ii) @agriculture.gov.au>; FAO <FAO@agriculture.gov.au>; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: FOR INFO/ACTION by OOB 14 Jan: [FAO LEAP Partnership] Draft guidelines on methane for review + updates [SEC=OFFICIAL]

Hello s. 22(1)(a)(ii)

I hope you've been well.

As you may already be aware, the FAO's Livestock Environmental Assessment and Performance (LEAP) have undertaken important work on methane assessment methodology this year (for further context see below), and the draft is now being shared with stakeholders for comment. Note Australia is not an official member of LEAP but Rome Post do attend LEAP Steering Committee meetings hence Australia has been approached for comment. Please also note that the LEAP team have requested that this document is not circulated widely at this stage.

I understand from s. 22(1)(a)(ii) and s. 22(1)(a)(ii) at Rome Post that you have been engaged in reviewing some methane reduction/impact recently – and may have an interest in reviewing/maintaining an awareness of this project. I'd also be interested to discuss with you whether you know of any CSIRO (or perhaps other RDC technical experts in this area) who may be capable of reviewing this paper and adding some value? Feel free to give me a call to discuss further if you like.

Should you have comments, kindly make use of the enclosed template and submit your feedback to DAWE's generic FAO team email by **OOB 14 January**: FAO@agriculture.gov.au and we will compile an Australian response. We understand the timing isn't great for Australian holiday period – and that this coincides with a likely period of leave for many, if you are unable to comment we understand there may be opportunity to comment on subsequent versions.

Very happy to chat about this – but if not, I hope that you have a decent break.

With thanks and kind regards

s. 22(1)(a)(ii)

s. 22(1)(a)(ii) (he/him)
A/g Assistant Director | Multilateral Economic Section | Trade Market Access and International Division

02 627s. 22(1)(a)(ii) | s. 22(1)(a)(ii)@awe.gov.au
Department of Agriculture, Water and the Environment
18 Marcus Clarke St, Canberra ACT 2601

Please note that I am working remotely

From: DeCamillis, Camillo (NSAL) s. 47F(1) @fao.org>
Sent: Thursday, 16 December 2021 6:00 PM
To: s. 47F(1) @esteri.it>; s. 47F(1) @ifif.org>; s. 47F(1) @itamaraty.gov.br>; s. 47F(1) @fao.org>; s. 47F(1) @blw.admin.ch; s. 47F(1) @diplomatie.gouv.fr>; s. 47F(1) @dfa.ie>; s. 47F(1) @am.gov.hu>; s. 47F(1) @ec.europa.eu>; s. 47F(1) @usaid.gov>; s. 47F(1) @wvi.org>; s. 47F(1) @hotmail.com>; s. 47F(1) t@fao.org>; s. 47F(1) @agriculture.gouv.fr>; s. 47F(1) @fao.org>; s. 47F(1) @gmail.com'; s. 47F(1) @fao.org>; s. 47E(@mrecic.gov.ar; s. 47E(d @mrecic.gov.ar; as. 47F(1) @wfo-oma.org>; s. 47E(d)@animaltaskforce.eu>; s. 47E(d) @dfat.gov.au>; s. 47F(1) @fao.org>; s. 47F(1) @meatnz.be>; s. 47F(1) @itamaraty.gov.br>; s. 47F(1) @dairysustainabilityframework.org>; s. 47F(1) @bsr.org>; s. 47F(1) @fil-idf.org>; s. 47F(1) @minrel.gob.cl>; s. 47E(d) @chinamission.it>; s. 47F(1) @mpi.govt.nz>; s. 47F(1) @inac.uy>; s. 47F(1) @thuenen.de>; s. 47F(1) @fediol.eu>; Cooperatives <ica@ica.coop>; s. 47F(1) @iwto.org>; s. 47F(1) @eeas.europa.eu>; s. 47F(1) @crea.gov.it>; s. 47F(1) @fao.org>; s. 47F(1) @gmail.com>; s. 47F(1) @diplomatie.gouv.fr>; s. 47E(d) @ec.europa.eu>; s. 47F(1) @fao.org>; s. 47E(d) @fil-idf.org>; s. 47F(1) @mfat.govt.nz>; s. 47F(1) @globaldairyplatform.com>; s. 47F(1) @novusint.com>; s. 47F(1) @agriculture.gov.ie>; s. 47F(1) @fao.org>; s. 47F(1) @politicheagricole.it>; s. 47F(1)@mrecic.gov.ar; Emma Cully <Emma.Cully@agriculture.gov.au>; s. 47F(1) @interbev.fr>; s. 47F(1) @interbev.asso.fr>; s. 47F(1) @agribenchmark.net>; Europa <Delegation-Rome@eeas.europa.eu>; s. 47F(1) @wwf.it>; s. 47F(1) @agricultura.gov.br>; s. 47F(1) @itamaraty.gov.br>; s. 47F(1) @inac.uy>; s. 47F(1) @gmail.com>; s. 47F(1) @worldbank.org>; 's. 47F(1) @teagasc.ie'; s. 47F(1) @bfh.ch>; s. 47F(1) @samsoft.ch; s. 47F(1) @meatnz.be>; s. 47F(1) @teagasc.ie>; s. 47F(1) @inac.uy>; s. 47F(1) @wfo-oma.org>; s. 47F(1) @politicheagricole.it>; s. 47F(1) @fao.org>; s. 47F(1) @ec.europa.eu>; s. 47F(1) @nzagrc.org.nz>; s. 47F(1) @globalresearchalliance.org>; s. 47F(1) @meat-ims.org) s. 47F(1) @meat-ims.org>; s. 22(1)(a)(ii) @agriculture.gov.au>; s. 47E(d) @mea.gov.in>; s. 47E(d)@internationalpoultrycouncil.org>; s. 47E(d) @foodsovereignty.org) s. 47E(d)@foodsovereignty.org>; s. 47F(1) ; s. 47F(1) s. 47F(1) ; s. 47F(1) ; s. 47F(1) ; s. 47F(1) ; s. 47F(1)

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Cc: s. 47E(d) @fao.org>
Subject: [EXTERNAL] [FAO LEAP Partnership] Draft guidelines on methane for review + updates
Importance: High

Dear LEAP Steering Committee participants, Further to a long series of virtual meetings held over 2021 by the 60 experts of the Technical Advisory Group (TAG) on methane, I am glad to inform that the leaders of TAG (Ermias Kebreab, UC Davis, USA; Michelle Cain, Cranfield University, UK; Jun Murase, Nagoya University, Japan) have shared today with the Secretariat the enclosed draft technical document *Methane Emissions in Agriculture – sources, quantification, mitigation and metrics.*

You are kindly requested to activate your technical services to review the draft document by 15 January 2022 COB. Should you have any comment, kindly make use of the enclosed template and submit your feedback to s. 47E(d) @fao.org
Kindly be reminded that any request for changes should be provided along with justification and, possibly, with alternative text.

The document is not yet for public review at this stage and should be kept confidential.
At this stage, the document is shared with pee-reviewers, the Steering Committee, colleagues from FAO OCB, and the Secretariats of GASL, GACSA, the Global Soil Partnership, GRA, UNEP-hosted Life Cycle Initiative that teamed up with LEAP for this technical guidance development. The document will also be shared for feedback with the Secretariat of the UNEP-hosted Climate and Clean Air Coalition project.

Further to this review step, the document will be revised by the TAG before being released for public review.
You will hence have another change to have your say also in a later stage.

Some more updates:

- Right today the European Commission has issued a legislative act about the use of the Product Environmental Footprint and Organization Environmental Footprint schemes. The LEAP guidelines are well cited in the technical annexes of the Communication.
- Thanks to those constituencies preparing and notifying financial pledges to LEAP4. Greatly appreciated. As highlighted in the past Steering Committee meeting, kindly be informed that LEAP will undertake in 2022 those activities already agreed for LEAP3 year 3 and not initiated due to shortage of funding (LEAP Navigator, translations, preparation of regional workshops) besides completing the guidelines on methane and arrange a couple of outreach events, should new financial contributions notified miss to meet LEAP4 budget requirements by 31/12/2021.

With kind regards,

Camillo De Camillis
LEAP manager

From: DeCamillis, Camillo (NSAL)
Sent: Friday, December 10, 2021 3:58 PM
To: s. 47E(d) @fao.org>
Subject: [FAO LEAP Partnership] Updates + Draft minutes of the 31st Steering Committee meeting
Importance: High

Dear all,

Last month, the importance of taking climate action and curb methane emissions was well highlighted at COP26 also through the Global Methane Pledge.
The working group on methane assessment initiated by LEAP in liaison with FAO CBD, GASL, GACSA, GRA, and the Life Cycle Initiative has now nearly completed the writing of the technical document reviewing sources of methane

in agriculture, and analyzing (a) methods to measure and model methane emissions, (b) metrics to assess methane, and (b) options to mitigate methane emissions from rice and livestock systems.
Further to the meeting of the metrics subgroup held last week, it was agreed to proceed with the review steps in the coming weeks.
To this end, the following experts have been identified for the peer-review:

- *Olivier Boucher*, Climate scientist, Director of the Institut Pierre-Simon Laplace Climate Modelling Centre, France (CV is enclosed)
- *Reiner Wassemann*, Climate change expert, emeritus leader of the International Rice Research Institute (IRRI) - CGIAR group – Reiner has coordinated the IRRI's research program on rice and climate change
- *Annie Levasseur* (University of Quebec, Canada) and/or *Francesco Cherubini* (Norwegian University of Science and Technology – NTNU, Norway), co-chairs of the UNEP hosted Life Cycle Initiative for climate change metrics

Should you have any objection to the appointment of these experts, kindly get back with a justification note by Tuesday 14 December COB.
Reviewers will go through the draft document in the first half of January 2021. In the second half, the draft document will be revised by the working group and we aim at releasing the document for public review in February. As soon as the draft document is shared by the working group, it will be distributed. Steering Committee participants will have a change to provide feedback in the first two weeks in January and during the public review period in February 2022.

On a separate note, kindly be informed that the professional editing of the FAO LEAP report about the global assessment of soil carbon stocks in grasslands is getting started.

In preparation of the coming months of the Partnership, please find attached the draft minutes of the 31st meeting of the FAO LEAP Steering Committee.
As far as the technical work on ecosystem services assessment is concerned, kindly note that it was a success the request for technical collaboration with GASL action networks to team up on this work stream and develop joint technical guidelines.

Finally, let me welcome in FAO LEAP new participants from Brazil and the Bill & Melinda Gates foundation.

Wish you all a very good weekend,

Camillo De Camillis
LEAP manager

From: Livestock-Partnership
Sent: Thursday, November 11, 2021 6:23 PM
To: s. 47E(d) @fao.org>
Cc: s. 47F(1) @fao.org>
Subject: LEAP Phase 4: request for input
Importance: High

Dear LEAP partners,

Reference is made to the outcomes of the 31st meeting of the LEAP Steering Committee, whose video recording is available for download from the link below.
Thanks to the 61 participants who joined our last virtual gathering and share their thoughts. The Secretariat is going to revisit the enclosed proposal presented by the Task Force for LEAP 4, work programme 2022-2024, and to circulate a revised version of the LEAP project document in the coming 3 weeks.

Should you have missed to provide your input to the LEAP4 task force so far, this is the last call to share your thoughts. Kindly get back to the Secretariat **by 23 Nov. 2021** at latest should you want LEAP to prioritize specific activities in our work plan 2022-2024.
As the ambition of LEAP4 is dependent on your engagement and the resources made available, countries, current donors and observers are invited to inform about their financial pledge, if any, to FAO LEAP by 31 December 2021.

In the last meeting, we discussed about developing technical guidance on ecosystem services assessment in liaison with the Global Agenda for Sustainable Livestock (GASL) and GACSA. Kindly be informed that in its last Guiding Group meeting, GASL welcomed collaboration with LEAP in this area and is eager to team up with its Action Networks.

As far as the LEAP side event at COP26 is concerned, I would like to thank IMS and IDF for having hosted us. The recording of the event is available from here. "*Accelerating climate action in the livestock sector: opportunities across different systems*" is something that is getting prominent in COP26 deliberations. Please find attached the slides relating to the speech by Dr Michelle Cain, co-chair of the Methane Technical Advisory Group, who introduced our work in this area and provided some insights about novel metrics for methane emissions assessment.

With kind regards,

Camillo De Camillis
LEAP manager

LEAP Steering Committee Meeting Recording:
https://fao.zoom.us/rec/share/HlsvIeWkhUzxMR8J54rQxYLYPlzZi7Tgz3oGeXmn0H7QVD_lErj_tlx0561Vv8gS.QEz9hFbmKvAMoFeI
Access Passcode: s. 22(1)(a)(ii)

Document 7a

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s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Wednesday, 23 March 2022 11:06 AM
To: s. 22(1)(a)(ii) @agriculture.gov.au>; s. 22(1)(a)(ii) @environment.gov.au>
Cc: s. 22(1)(a)(ii) @agriculture.gov.au>; s. 22(1)(a)(ii) @environment.gov.au>; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: RE: Cattle brief input - due by 4pm tomorrow please [SEC=UNOFFICIAL]

Hi s. 22(1)(a)(ii)

Looks ok to me.

Agree it's best to refer the GWP star and metrics to Minister Talyor.

s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii) @agriculture.gov.au>
Sent: Wednesday, 23 March 2022 10:07 AM
To: s. 22(1)(a)(ii) @environment.gov.au>
Cc: s. 22(1)(a)(ii) @agriculture.gov.au>; s. 22(1)(a)(ii) @agriculture.gov.au>; s. 22(1)(a)(ii) @environment.gov.au>; s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: FW: Cattle brief input - due by 4pm tomorrow please [SEC=UNOFFICIAL]
Importance: High

s. 22(1)(a)(ii) – I'm not sure if you/matt saw the attached brief when drafting. It goes to cattle council calls for alternative emissions reporting and also tax support for emissions reduction. Can you review my notes below and OK / suggest any required changes by 12? Thanks! s. 22(1)(a)(ii)

CCA requests tax incentives be provided assist producers with transitioning their production systems to utilise lower carbon practices and technologies.

- You announced $100m of concessions to ensure carbon and biodiversity credits are treated as on-farm income.
- MLA CN30 project Govt is supporting includes 'developing new scientific methods to generate carbon credits'.
- Developing the 'stacked' farm method for ERF is a 2022 priority for Minister Taylor, allowing separate ERF land-based activities to be combined.

CCA requests a red meat specific greenhouse gas inventory in the government's emission reporting, and to have it reported under the technical metric "GWP*" ("GWP Star"). This metric recognises that methane has a much shorter life in the atmosphere than carbon and so less methane emission reduction may stabilise global temperatures.

- Government (Taylor) is providing $1 million additional grant funding to MLA for their CN30 carbon neutral project. Activities supported include 'developing new measurement and reporting mechanisms to improve carbon accounting', and 'developing new measurement and reporting mechanisms to improve carbon accounting'.

- Industry is best to continue to raise these technical matters through Minister Taylor, as reporting needs to align with global standards.

s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii) @agriculture.gov.au>
Sent: Monday, 11 October 2021 8:30 AM
To: s. 22(1)(a)(ii) @agriculture.gov.au>
Subject: Fwd: Kyoto brief

Can you please start on the background re gwp100?

From: Maya Stuart-Fox <Maya.Stuart-Fox@environment.gov.au>
Sent: Monday, October 11, 2021 8:00 am
To: s. 22(1)(a)(ii); s. 22(1)(a)(ii); s. 22(1)(a)(ii)
Subject: Fwd: Kyoto brief

See attached and worth reading down the email chain. Can you get me some background on the GWP100 issue.

Thanks Maya
Get Outlook for iOS

From: s. 47F(1) @nff.org.au>
Sent: Monday, October 11, 2021 6:32:45 AM
To: Maya Stuart-Fox <Maya.Stuart-Fox@environment.gov.au>; s. 47F(1) @industry.gov.au>
Cc: s. 47F(1) @nff.org.au>
Subject: Kyoto brief

Good morning

You will probably have seen some media this morning around a proposal we are discussing with the Nats this morning. I have previously alerted you both that we are seeking to progress a solution to address farmers concerns around the acquisition of Kyoto credits without appropriate process and acknowledge of ownership. These credits are not being used, and seem unlikely to be, they should be transferred to the affected landholders by whatever mechanism we can agree to do so. The fundamental outcome in that they are transferred to landholders impacted by land clearing laws and therefore making unvalued, unknowing and unwilling contributions to Australia's overachievement.

The media release is below, and attached is the one page brief that underpins the discussion. Your respective Minister's offices have been furnished.

I imagine we might need a further discussion at some point.

Kind regards

s. 47F(1)

Farmers want Kyoto ledger squared

National Farmers Federation President Fiona Simson says while Australian farmers continue to lead the world in improved sustainability and emissions reduction it is time to address the inequities of the past.

"Farmers have been at the forefront of Australia's efforts to meet climate change targets for decades, although not always knowingly."

Ms Simson said in the 1990s and early 2000s, Queensland and NSW farmers were victims of land clearing legislation that removed their property rights, without compensation.

"The outcome of this was that landholders, unknowingly and without support, made a major contribution to meeting, and it turns out, substantially over achieving on Kyoto commitment targets. A significant proportion of more 400 million tonnes of excess carbon sequestration was delivered through this process.

"If done today, landholders would be eligible to participate in the Emission Reduction Fund or a secondary carbon market and receive income for this activity, but not then. It still hurts and now is the time to square the ledger."

Ms Simson and Agforce Queensland President Georgie Somerset, will this morning brief the federal Nationals party room, seeking a resolution to the festering sore created by the statutory theft.

"The rights to use this sequestered carbon should be vested in the landowner, not the government, nor an international accounting mechanism that 'doesn't count surpluses'. Appropriate redress must be provided.

"Fixing this will go a long way to ensuring farmers are enthusiastic participants and supporters of future emission reductions solutions."

Ms Simson said work to better understand soil carbon; invest in new technologies to reduce methane emission from ruminant livestock; streamline ERF methodologies and generally invest in technology innovation were vital and welcomed.

"Australian farmers are world-leaders in the adoption of new technologies and innovation, there is no reason to expect it will be any different in this context, but it has to make economic and production sense."

Ms Simson warned that farmers were not prepared to be the climate solution for other sectors.

"Government must not expect prime farm land to be converted to a massive carbon sink. Farmers have a job to feed and cloth the world and to power the nation's economy.

"Of course farming is also an integral part of rural and regional communities. The resilience of the regions is always paramount, and in these uncertain times it has been the farm sector that has been a consistent and reliable contributor."

The NFF supports an economy-wide aspiration of net zero emissions by 2050 with two important caveats: there is an economically viable pathway to net neutrality and farmers are not burdened by unnecessary regulatory impediment.

"The NFF is optimistic and constructive about the challenge. Farmers will play their part but the economics has to work, and other sectors must play their part too."

For farmers that means building on what they have been doing for decades – low and no-til farming, adopting new technology for animal production and maintaining vegetation on farm.

The recent Reisinger et al report outlines what the road ahead should look like for various gases. For agriculture it suggests the trajectory for enteric (livestock) methane is about 40% reduction by 2050 and 50-60% by 2100. For nitrous oxide it's about 20% reduction.

"There is still work to do, but this shows that we will need to see other sectors to also contribute as the real villain is carbon dioxide, and, as the Grattan Institute pointed out in their recent report, farmers extract (sequester) much more of that than they release (emit)," Ms Simson said.

"Agriculture has a great story to tell. Farmers positively contribute to emission reduction solutions, provide jobs and support communities. Today, we are calling for Government to right the wrongs of the past, so together we can work towards a lower emissions future and the NFF-led goal for agriculture to be Australia's next $100 billion industry," Ms Simson said.

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From: s. 22(1)(a)(ii) @awe.gov.au>
Sent: Sunday, October 10, 2021 8:50:39 PM
To: s. 47F(1) @nff.org.au>; s. 22(1)(a)(ii) @awe.gov.au>
Subject: RE: Further background [SEC=UNOFFICIAL]

Thanks s. 47F(1) I didn't properly appreciate the difference between GWP* and GWP100 when we were talking the other day – I was making the mental shortcut to another discussion I'd been aware of in the past about the move from AR4 to AR5 GWP values (e.g. Microsoft Word - Global-Warming-Potential-Values.docx (ghgprotocol.org)). I think I now appreciate the import – analogies involving bathtubs and plugs come to mind for me. s. 22(1)(a)(i

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From: s. 47F(1) @nff.org.au>
Sent: Wednesday, 6 October 2021 2:03 PM
To: s. 22(1)(a)(ii) @awe.gov.au>
Cc: s. 47F(1) @nff.org.au>
Subject: Further background [SEC=UNOFFICIAL]

Hi s. 22(1)(a)(i

Thank you for that discussion. I look forward to further delving into these important and timely issues with you. My address block is below and s. 47F(1) below that, we are at your disposal, anytime! I have your mobile as s. 47F(1)

For your background I attach two further documents for context:

- A paper by Reisinger et al (including Professor Mark Howden as a co author) which I referred to in the context of the role and commitment of enteric methane;
- I also attach the recently released CSIRO report into accounting metrics, it's a bit more comprehensive than the above, which discusses GWP 100, GWP* etc. good background to a complex area that seem to remain at least uncertain.
- Just so you have them to hand I attach recent NFF letters to Minister Taylor on GWP* and James Larsen on NFF priorities as well

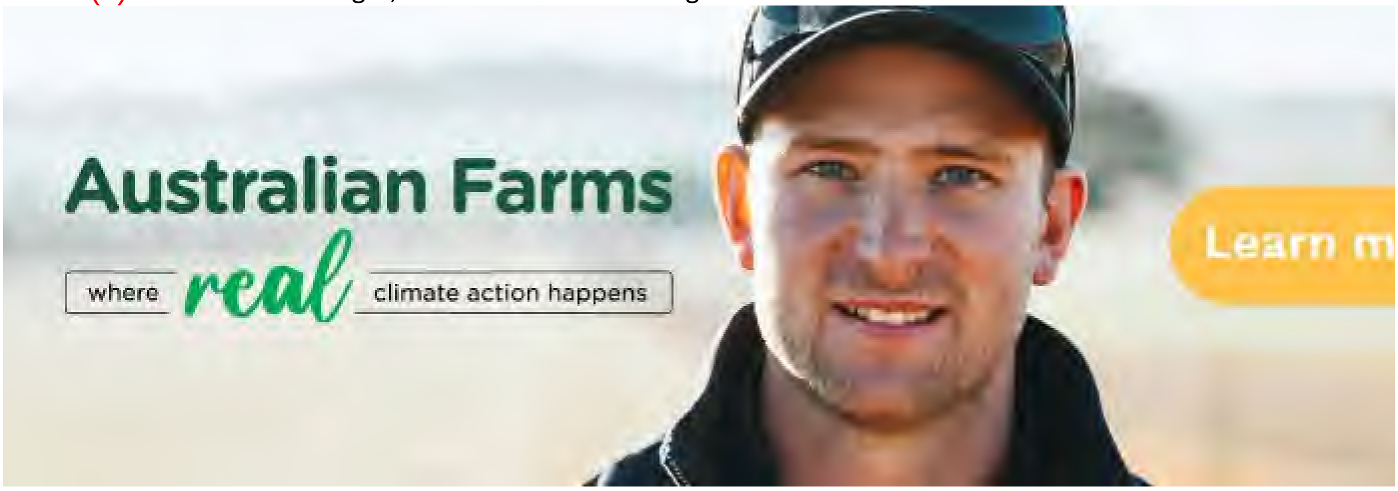
Finally, I encourage you to click on the 'learn more' link on the address block to view a bit of a campaign we have been running on farmer activity in the space.

Talk soon

Kind regards

s. 47F(1)

s. 47F(1) General Manager, Natural Resource Management



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s. 47F(1)
Chief Executive

s. 47F(1)

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BACKPOCKET BRIEFING: POST-BUDGET BRIEFING FOR LIVESTOCK INDUSTRIES ON CLIMATE CHANGE RELATED MEASURES

Tuesday, 8 June 2021, 11:00 am – 12:30 pm; Microsoft Teams and Department of Agriculture, Water and the Environment offices.

Chair: Nicholas Dowie, Assistant Secretary, Food and Supply Chains

Invitees

Industry bodies

- National Farmers Federation
- Red Meat Advisory Council
- Cattle Council of Australia
- Australian Pork Limited
- Australian Dairy Farmers
- Sheep Producers Australia
- Australian Meat Industry Council
- Australian Chicken Meat Federation
- Egg Farmers of Australia
- Goat Industry Council of Australia
- Australian Lot Feeders Association
- Australian Livestock Exporters Council
- National Indigenous Australians Agency

Research and Development Corporations

- Meat and Livestock Australia
- Australian Meat Processor Corporation
- Dairy Australia
- Australian Pork Limited
- Australian Wool Innovation
- Agrifutures
- Australian Eggs
- LiveCorp
- Indigenous Land and Sea Corporation
- Australian Wool Producers

Item 1: Welcome

- Welcome you all here today.
- Welcome to Country
- I'm Nick Dowie, the Assistant Secretary of the Food and Supply Chain Branch at the Department of Agriculture Water and the Environment.
- Among other things, my Branch has responsibility for Animal Products policy – including managing the government statutory funding agreements with the animal industry research, development and marketing organisations. Until recently, Soils Policy also fell within my Branch. Dairy doesn't sit within the branch but is nearby and it made sense to include dairy in the discussions today.
- Like the rest of the economy, livestock industries will face challenges in adapting to a low emissions future.
    - For the year until December 2020, the agricultural sector contributed around 14.6% of Australia's greenhouse gas emissions.
    - Around 68% of the sectors greenhouse gas emissions are from enteric fermentation and a further 9.7% from manure management (2018 inventory year).
- But they are also presented with opportunities to be part of that future.
- I think its fair to say that the government has recognised that challenge and is exploring and helping to facilitate some of those opportunities.

    - A range of initiatives are underway across government and our research and development corporations covering extensive and intensive production systems and the processing sector.
    - The interests and needs of industries vary – methane reduction in ruminant grazing industries, biomethane and energy efficiency in processing and intensive livestock industries, carbon sequestration in extensive grazing industries.
- This is a bit of an experiment. I know my colleagues in Climate and Adaptation Policy here at the department have conducted briefings for industry in the margins of the ABARES Outlook conferences in the past. I hope you find today useful. I know that there is a lot of consultation happening between government and different industry groups already, so I hope this is a useful value add. But if it's not – then, we can draw a line under it and move on…so genuinely open to your feedback here…..
- Overview and House keeping rules.
    - A range of presenters from the Department of Industry, Science, Energy and Resources, the Clean Energy Regulator and this department.
    - Short, sharp presentations on a range of programs related to reducing livestock emissions, reducing processing industry emissions and enabling carbon sequestration.
    - If you want to find out more, you can follow up with speakers separately off-line
    - Unless your speaking, please keep yourself on mute.
    - There will be opportunities to ask questions at the end of presentations and we can keep note of other questions that come up in the chat.

First presenter - s. 47F(1)

- One of the challenges that the red meat and dairy industries face is to reduce methane emissions from ruminant livestock.
- With that in mind – our first speaker today will be s. 47F(1) , Livestock, Waste and Industrial Section, Department of Industry, Science Energy and Resources to talk about Reducing livestock emissions grant programs
- Some of you may have attended an update on these grant programs given the Department of Industry a few weeks ago.

Second presenter – s. 47F(1)

- As I said in the welcome – livestock industries have a diverse range of interests in reducing their emissions.
- In the meat processing industry and the dairy processing industry, we have two of largest food manufacturing industries in Australia.
- So, with these industries interests in reducing energy usage in mind, I'd like to welcome our next speaker.
- s. 47F(1) Manager, National Energy Efficiency Policy, Department of Industry, Science Energy and Resources to talk about a range of energy efficiency programs that are now available.

Third presenter – the Clean Energy Regulator, s. 47F(1) **and** s. 47F(1)

- Next up we are going to be hearing from two speakers from the Clean Energy Regulator – s. 47F(1) and s. 47F(1) .

- The Clean Energy Regulator administers schemes legislated by the Australian Government for measuring, managing, reducing or offsetting Australia's carbon emissions.
- s. 47F(1) and s. 47F(1) are going to talk about two methods that are underway to establish the rules for emissions reduction or carbon storage projects that are of particular interest to the livestock industry relating to soil carbon and biomethane.

Fourth presenter – s. 47F(1)

- Moving to hear more about sequestration in soils and vegetation.
- s. 47F(1), Manager, Soils and Vegetation Section, Department of Industry, Science Energy and Resources.
- Today he is going to be talking about Soil Carbon programs administered by his department.

Fifth presenter – s. 22(1)(a)(ii)

- Moving to consider the role of native vegetation as a possible carbon sink.
- s. 22(1)(a)(ii), Director, Natural Capital and Markets, Department of Agriculture, Water and the Environment.
- s. 22(1)(a)(ii) is going to be talking about some of the Agriculture Stewardship packages that are currently underway.

Sixth presenter – s. 22(1)(a)(ii)

- As I said in my Introduction, Soils Policy was in my branch until recently and its fair to say that I learnt a lot about the importance of soils in the past few months.
- Soil contributes approximately $930 billion to our economy each year, with Australia's agricultural sector estimated to be worth $65 billion in 2020-21 alone.
- Improved soil knowledge will lead to improved management decisions, which will significantly increase our soil's sustainability and productivity and contributes towards the Australian Government's goal of making it agriculture a $100 billion industry by 2030.
- The National Soil Strategy released with the 2021-22 Budget sets out a twelve-point plan to value, better manage, and improve Australian soil for the next 20 years.
- The Australian Government has committed $196.9 million to a soil package in the 2021-22 Federal Budget that contributes to the Prime Minister's 'Caring for Country' priority.
- To talk a little bit more about the package I welcome s. 22(1)(a)(ii), A/g Director, Soils Policy, Department of Agriculture, Water and the Environment,

Wrap up

- Thanks to all our presenters today.
- Happy for you to follow up directly with any of them to learn more about some of the programs that were presented here today.

COORDINATION MECHANISMS

CRSPI (The Climate Research Strategy for Primary Industries)

Looks good on paper, but has made glacial progress.

- A collaborative partnership between RDCs, research organisations, Commonwealth state and territory governments.
- Partners have worked together for the past 10 years guided by a RD&E strategy, which is now in its third revision.
- CRSPI – provides a 'big picture' view, enabling all stakeholders with the sector to work together, by focusing research and development effort. It also helps avoid wasteful duplication of work among partners.

Agricultural Innovation Australia (AIA)

There hasn't been sufficient progress with the implementation of the Climate Initiative to discuss it at this briefing.

- On 1 October 2020 Agricultural Innovation Australia (AIA) was established to drive a new cross-industry approach to agricultural innovation.
- The Australian Government is providing $1.3 million (GST exclusive) to support Agricultural Innovation Australia's efforts to drive a new cross-industry approach to agricultural innovation.
- AIA identifies, develops and invests in strategies that address shared challenges and opportunities to deliver transformative outcomes that drive sustainability, productivity and profitability across Australian agricultural value chains.
- Activities undertaken by AIA will focus on areas with greatest impact across multiple agricultural industries on areas of national importance – like climate resilience, water and soil management and supply chain traceability.
- To avoid duplication of effort, when prioritising opportunities for investment, consideration will be given to existing RDC and industry strategies.

The Climate Initiative

- The Climate Initiative was originally developed by the fifteen Rural Research and Development Corporations, but is now being progressed by AIA.
- The Climate Initiative Investment Plan sets out an investment of approximately $11.5 million over three years to support the future evolution of the Climate Initiative by Agricultural Innovation Australia.
- The Initiative has been developed around three objectives:
  - Focus innovation and investment on enhancing the resilience and performance of agriculture, fisheries and forestry industries in the face of climate change
  - Enhance innovation system capabilities to address complex challenges and facilitate transformational change
  - Develop attractive investment opportunities with clear value propositions that will deliver impact.

RDC CLIMATE CHANGE STRATEGIES

The red meat industry's Carbon Neutral by 2030 Roadmap

Launched: November 2020

- The Australian red meat and livestock industry has set the ambitious target to be carbon neutral by 2030.
- CN30 is based on four key work areas:
    1. Green house gas emissions avoidance activities on-farm, feedlots and processing.
    2. Carbon storage on farm via trees, legumes and pastures
    3. Integrated management systems linking GHG emissions avoidance and carbon storage activities into farm system thinking.
    4. Leadership building to support growth in capacity and competency among individuals and organisations.

Dairy Australia's Climate Change Strategy

Launched: March 2021

GOALS	**2025 Outcomes**
ADAPT Australian dairy farming systems to thrive in a warmer and more unpredictable climate	Dairy businesses successfully adapting to (and continually evolving to meet) future climate challenges
PRESERVE our position in the Top 10 globally for low emissions intensity	Australian dairy industry's low carbon footprint recognised internationally, and within the Top 10 globally
EMBED climate action with the way we look after the environment	Requirements for managing the environment in the face of a changing climate known and being adopted by dairy businesses
INVEST and actively contribute to keep global warming to below 1.5°	Market and community recognition of the positive contributions of the dairy industry in addressing climate change

INDUSTRY CONCERNS

United Nations 2021 Food Systems Summit

- Being convened by the United Nations to launch 'bold new' actions to deliver progress on all 17 Sustainable Development Goals, each of which relive to some degree on healthier, more sustainable and equitable food systems.
- The department convened a series of webinars to help inform the Australian Government's input to the Future Food Systems processes.
- Livestock industries are concerned about 'anti-livestock industry' positions being pursued by other civil society groups as part of the Future Food Systems process.

GWP 100 Climate Metric

- The Australian Government currently uses the GWP 100 climate metric in its carbon accounting methods, consistent with its international agreements.
- Livestock industries support the emerging GWP* (GWP start) climate metric.
- The Australian Government is aware of discussions happening in the international arena about alternative climate metrics.
- The GWP 100 climate metric is used to convert the climate warming contributions of methane (28 x CO_2) and nitrous oxide (265 x CO_2) into carbon dioxide equivalents.
- Some researchers have noted weaknesses in this approach in that gases such as methane stay in the atmosphere for far shorter periods of time than CO_2.
- They have developed an alternative climate metric called GWP* (GWP star), which takes account of the shorter lifespans of methane. Using this alternative measure, the emissions reductions task of livestock industries is reduced.

Greenhouse gas emissions from Australian livestock production in 2018 assessed using GWP* and GWP 100 climate metrics (CSIRO 2021).

Industry	GWP* Mt CO_2-we	GWP100 Mt CO_2-e
Beef Cattle	32.4	49.6
Sheep meat	-2.85	10.3
Chicken meat	2.29	2.21
Pork	1.05	2.55
Egg	0.35	0.35
Milk	11.4	12.6

Emissions Reduction Fund method development

- The Clean Energy Regulator develops a limited number (5) of emissions reduction / abatement methods at any one time.
- There is likely to be pressure from the livestock industry that methane abatement products be listed as a method.
- Department of Industry can speak to the process for establishing the priority methods.

Recall note: Professor Richard Eckhardt, Uni Melbourne.

Script to guide consultation on sustainable livestock industries; Dec 2021.

Introductory talking points (tailor as needed).

- Thanks for meeting with us today.
- We work in the Animal Products section at the Department of Agriculture, Water and the Environment.
- We manage the government's relationship with livestock research and development corporations, such as Meat and Livestock Australia and Australian Pork Limited.
- We also provide advice to government on general issues facing Australia's livestock industries.
- As part of our forward looking / horizon scanning work, we are doing some quick research in to the sustainability of livestock production.
- This issue has been quite topical for a while now and recently in the lead up to The United Nations Food Systems Summit and COP26. Interest in this issue isn't likely to go away.
- So, its in that context that we reached out to you to explore your thoughts on the sustainability of Australia's livestock (or red meat or chicken) industries.

Segue to them…….

Angus Ireland, eco credentials manager AWI

We are market focused and we can see where the market signals are going.

We did an assessment of sustainability issues and it showed that GHG had a huge weighting / focus for regualtors / consumers.

Arm wool growers with the tools to meet demand for GHG low wool

Undersrand our current footprint and how to mitigate it.

Richard Eckhardt

I proiduce the GHG tools for the industry.

Back in the day, these tools were used to priorities investment. Now these tools are much popular. I host the GHG tools for various industries and their use has exploded. Corporate ag queries. Shareholders sitting in board rooms and are concerned about investing in animal ag. NAB and Rabobank want net zero GHG finance exposure by 2050. There are big things.

Major multinational companies have set targets. What government does is irrelevant, These big companies are setting their targets and producers have to hit it.

I started my research mostly lookingat N use in dairy.

Too many cows in New Zealand.

I can talk about impact of n loading.

Then moved in GHG for the past 20 years – what advice can we give industry on mitigation.

I would say I sit in the interface of collective research and government policy. I interpret the research and what its means for farmers.

Here are the hotspots that ill make a difference.

For MLA / RMAC / Dairy Australia / Australian Pork Limited

1. I know that the industry has seen this community interest coming for some time and has put together the Australian Beef Sustainability Framework / CN2030 / Australian Sheep Sustainability Framework / Pork Industry Sustainability Framework / Australian Dairy Industry Sustainability Framework.

   How is implementation of that framework going? Is it leading (or Will it lead) to investment being made in the right areas to make a difference?

   > **Background:** There are a range of industry sustainability frameworks around. Some of them a quite recent. We put quite a bit of weight in them in our briefing – but it's not clear they are driving change or just presentational tools.

My impression is yes.

I have surprised at farmer by in to these frameworks.

Are they going far enough yet – perhaps not, to mitigate trade restrictions.

As per Paris agreement – more ambition needed.

Take producers on the journey. If you cared about sustainability – you'd say we have a way top go to avoid future trade barriers etc.

CN30 has really worked to drive investment into that. That has worked really well.

I had exposure with NTCA 20 years ago, no they want me to go to meeting to talk about carbon farming. They were most resistant and now they are completely different.

Substantial moves in this area.

We are not alone. All our major competitors have similar targets. We have EU – how can they get info on standards Australian Livestockadhere to to compare it to EU standards.

The wool and meat – methane is the big issue there – but 20 years ago we didn't know this was a problem – now were moving fast.

Different in big ruminant indsutries eg dairy, a long way to go compared to extensive grazing when it comes to Nitrous emissions. NZ has a big probel here. There are no streams left in NZ with acceptable useful nutrient loads. The onkly reason dairyt gets away with it is there is no catchment in Aust that is all dairy.

We have got way with N use. All other developed countries regulate this. We have issues in cotton, sugar and dairy. From a sustainability perspective dairy is our mosy vulnerable industry.

As the wool industry – we haven't had the same level of guidance as MLA got from RMAC. The sheelp framework is motherhoody in its nature – general feel good aims.

It was a really good process. Got industry involved.

It is not the framework that is driving activity – its is the market every week a big wool user is coming out making carbon neutral commitments.

A risk for us is that they stick to their commitments and drop wool from their range.

A concerns given th

<u>For climate academics / CSRIO</u>

2. There seems to be different views on livestock industries contribution to methane emissions and how this best be assessed. I note work on GWP versus GWP* and also the amount of emissions versus climate forcing. What's your view on this? What is the take home message from this work?

   Background: There is scientific debate about the contribution of methane emissions from livestock to global warming. It would appear that the general view is that if warming is to be kept below 1.5°C, significant reduction in methane emissions from livestock will be required (or other sectors of the economy will have to reduce their emissions even more to make up for the livestock industries' inability to do so).

Alternative metrics are starting to come through.

GWP is being used in ways that it was not designed.

We can put energy into GWP*. But it will nbever be adopted – like turning the titanic.

NZ just set a non zero target for methane. They said long lived gases need t be zero by 2050, but methane needs to be 40% reduced. This was because it was shorter lived.

A 3% per year decline in methane by 2050 leads to no effect on climate forcing.

You have to get c02 to zero because it is long lived.

If you methane 12% per decade declkine you end out with the same outcome.

This is what GWP* is trying to calculate.

It will never be adopted.

The equation – if the national flock has declined you negative number. But we didn't intend that. If the flock increases – you get penalised severely for herd recovery.

The fracking industry would be severely penalised – no long term reductions and a very powerful sector.

My view is we could waste a lot of energy arguing or we could follow what NZ does – to be climate neutral.

Do you not using different metrics for different purposes?

Mark Hoden set me right – you need one metric across the board. There is no policy advantage in IPCC moving to GWP* - there might be advantages for the livestock industry.

Could be useful to say that methane is not as bad as we thought. The best thing to do is not set a zero target for methane.

GTP example.

As you get closer to zero the metric becomes irrelevant.

We can now offer 80% reductions in methane. In the future, if we can keep on investing we can reduce it to zero. Who cares about the metric.

3. There are a range of agriculture industry climate frameworks, such the red meat industry's Carbon Neutral 2030. There's also the Australian Government's long-terms emissions reduction plan – with its focus on soil carbon and methane emissions reducing feedstocks. What's your view on progress made by the agriculture sector to date? What more action is needed? (by government)?

    Background: This statement appears to be most true of the CN30 framework. Collaboration between RDCs and government agencies administering relevant programs should be encouraged (and is already happening in the case of DISERs methane programs).

There is a principle here that we are not alone.

NZ is investing millions. EU is ivesting millions in this area. Canada, US, Brazil.

What the Aust Govt has missed out on is that the NZ has committed funding to Euope union R&D.

There is an oopporunity for us not to do it all, but to participate in larger consortia.

We don't have to do it all ourselves.

The EU is doing seaweed – why do we need to hget involved.

Economies of scale wrt research investment.

When I looked at what NZ was investing to Eurogas – they got all their money back.

How can we do things better thatn doing it all ourselvesl.

Soil carbon.

30% methane pledgae out of COP26. 105 signed up to that. Yet we agreed to a soil carbon target.

Right now the 30% reduction in methane is acheievable through current research. Soil carbon is actually more difficult to achieve.

Rain = soil carbon. We can't control the rain. Therefore e can't control the soil carbon.

Soil carbon evalengalists got in the government ear.

As the supply chain get short of carbon suppliers – we will get caught short. You can't sell the soil carbon and claim to be a low carbon producer.

We need to deal with this. If we want to be carbon neutral – we will have sold our soil carbon and not be carbon.

Its fine to sell methane. But you can't sell a finite stock of soil carbon.

If you sell your soil carbon to government through the national account. It I still valid to allow the sector if the credits are retired. That could be fundamental to the industry getting low carbon and having an icnetive to do that.

4. Do you see opportunity for your industry from the growing interest in environmental sustainability?

    Background: The chicken meat industry has a smaller environmental footprint compared to the red meat industry. The more efficient productions systems could potentially reduce environmental impacts – but do give rise to concerns about animal welfare.

5. Are you aware of any studies that compare the life cycle analysis of Australian beef to our export competitors, like the United States or Brazil?

    Background: In the near future, sustainability is likely to be an important point of different / a requirement in export markets. I'm interested to know how Australian industry compares to our closest competitors. Robust life-cycle analysis has been required to support Australia's canola exports to the EU.

This is an interesting debate.

I have been in a number of countries in my career.

I have not seen anything to suggest we are any better than anywhere else.

We are in tenuous sintuation if we are pushed to show we are clean and green.

We are making progress. Most developed countries are. GHG per L of milk of Kg of carcas weight – pretty similar across the board.

You couldn't say NZ is more sustainable tham Aust wrt wool.

Sustainability – a generic term – in Australian, we have big water footprint due to the scarce nature of water availability. In some sense worse off than out competitors. Also use more land – a bigger footprint given low rates of productivity.

We should be lobbying that land that isn't used in another enterprise should be ok.

We can't grow market gardens at Bourke.

<u>Questions about the value of engagement in international livestock fora / bodies.</u>

6. Obviously, the Australian industry isn't isolated in confronting these sustainability challenges. What opportunities do you see from Australia's engagement in the *Global Sustainable Livestock Coalition,* the FAO Livestock Environmental Assessment and Performance Partnership, the Global Agenda for Sustainable Livestock or other international livestock industry fora? Should we engage more strongly with these bodies?

- What are industries views of the gaps in Australian engagement in various international/multilateral fora dealing with Livestock?
    - Are there gaps? What are risk/opportunities as perceived by industry re: livestock issues in global debates about sustainability?
- What are industry views on LEAPP? GASL? FAO Sub-Committee on Livestock? Any others?
    - What types of issues/challenges/positions/policy debates would industry see as valuable for Australia to be better engaged in internationally from the sustainable livestock perspective?
    - Is industry engaged in any international discussions/multilateral fora?

The risk of not engaging is very high.

It is just sensible engage in FAO LEAP.

This request we got from the EU. Very clearly they are looking at how we meet their important standards.

If we benchmark against EU standards – we should be fine.

WE fund a representative to FAO LEAP, dairy is there CSIRO is there. We could collaborate more and not double up.

Leave vaccines to NZ. Leave seaweed to Europe. Demonstrate a commitment to global frameworks.

In the whole we aim to meet EU standards so that should be problem.

We did a carbon audit for mark wooten. His farm was clearly cabon positive. He was abe to access carbon neutral markets and Europe and get a premium.

We will expect premiums until 2030 and then there will just be compliance.

A deadline for carbon neutrality. Afirst mover advantage right now. Also in the wine industry.

He is the most regernative farmer I know.

FACCE-JPI

ERA-gas

We should participate. NZ gets a seat at the table to discuss all the option being explored to address methane reduction.

Example of collaboration. I was on the assessment panel as Australia didn't have conflict of interest.

EM notes
Angus:

- Eco credentials manager at AWI.
- For AWI they are market focused when it comes to climate change and GHEs, they are looking at signals from the market.
- Cradle to grave livestock assessment in 2019. Biggest hotspot is GHEs at the farming stage.
- Legislators are looking at guiding consumers to less impactful products.
- Working to understand current carbon footprint.
- Identifying mitigation pathways for producers to follow.

Richard:

- Producers the greenhouse accounting tools for various industries.

- About 18 years ago the first accounting tools were produced, because people like Angus were being lobbied by stakeholders. He hosts accounting tools for many different ag industries.
- Audits across properties - requests coming in almost daily
- Investors are aware of investing in ag from a GHG exposure point.
- CBA want net zero emissions by 2050. 50% agridebt market with CBA.
- Rabobank - and Eurobank concerned about it as well.
- Dairy farmers->Fonterra->Unilever. All have to meet Unilever targets.
- Nitrogen use in dairy. Too many cows in NZ and they can't deal with the nitrate impact.
- Methane - what advice can be given to industry going forward - what Richard looks at.
- He works on enteric methane and abatement strategies, but he spends more time communicating the science and discussing with government.

What's your sense about the sustainability frameworks? Are they driving investment to where it needs to go to make a difference?

- His impression is yes. They were developed from the ground up, with farmer input.
- They perhaps aren't yet going far enough. They are a great starting point.
- If you were very concerned about sustainability - it has a way to go yet to avoid trade tarifs and barriers.
- MLA plan has driven investment in a level of sustainability to a level that we haven't seen in a long time. CN30 plan.
- NT Cattleman's association. 18 years ago never talked about climate change. Now they want Richard to speak at their conferences. Want to know how they can move themselves forward.
- Competitors are also embracing targets (NZ and Brasil). We're not unique in doing this.
- There are issues in some industries. Wool and meat industry - methane is the big issue there. 20 years ago we didn't know this is a problem. Now we have strategies coming through in the next 12-18 months to allow us to deal with this.
- Dairy - very intensive industry that occupies high rainfall areas of the eastern seaboard.
- Broadacre industry - higher methane, but lower nitrogen problem. Dairy has a big nitrogen problem.
- Australian diary industry gets away with nutrien loading that we have is because we don't have wall to wall dairy in catchments. They are a bit more spread out.
- Aus is the only developed country that doesn't regulate nitrogen fertiliser use.
- Dairy is the most vulnerable industry right now due to sustainability.
    - Angus:
    - AWI has not received the same level of guidance as MLA received from RMAC on CN30.
    - Sheep Sus Framework is more general than the beef one. It was a very good process though - to involve industry and bring them along on the journey.
    - It's not so much the framework that is driving activitiy - it's the market.
    - Brands are regularly making commitments to be carbon neutral by a certain timeframe. Industry has to meet this expectation, or they will lose market share. If wool can't keep up with the timeframe, then they will drop wool from their range.
- There's a principle here that we aren't alone in methane research. Other countries are involved in research in their own jurisdictions. Co-investing is happening in Europe and NZ. We can co-invest in existing research, rather than trying to re-invent the wheel.
- Is there research that we should be co-investing that we aren't concentrating on?
- FACCE - JPI Joint progress initiatve. Under that -JAAS program.The joint progress initiative out of the EU. NZ has snuck in the door, and Canada has as well.
- -irri-gas - methane projects that have been approved in the EU.

- Glasgow - pledge to reduce livestock methane by 30%. Australia did not sign up to that. But we agreed to soil carbon reduction. But methane reduction is more achievable.
- Latest research of soil carbon is 80% rainfall based. Aus is 22% more rainfall variable than other countries in the world. Why are we signing up to a target to increase soil carbon when it's a bit too unachievable. We can't control it due to rainfall. WHY?? What was the thinking process? Richard thinks that self-interested soil carbon aggregators got into government's ear and presented research that is not quite correct. Overstates how effective it is. Carbon soil evangelists.,.
- We are going to get short on selling soil carbon. The more we sell soil carbon, the harder it is to be carbon neutral in our own right. Double counting.
- Soil and tree carbon is a stock. It's a finite bank account.
- If you sell soil carbon to Microsoft and it leaves the country - you can't double count it. They could be taken by gov, and retire them, against the government's account. We should still be able to claim that. Not lose them from their farm account.
    - Angus
    - There's a lot of misinformation around about double counting. Once you sell your carbon credits, you are no longer carbon neutral.

There's a lot of research at looking at emissions from livestock industry - different metrics. GWP and GWP*, GHE vs enforcing. Take home message?

- GWP100 was never designed to be used the way it is today. * is not compatible with other GWP metrics in the ICC. It won't be adopted. * can give you a negative number if the national flock declines - but we don't intend for the flock to be smaller. When the herd recovers, the new sheep will be heavily penalised. Fracking system will be heavily penalised as well.
- Far easier to do what NZ has done. Don't fiddle with metrics. They just have a non-zero target for methane. Methane just needs to be 27-40% less than what it is today. NZ isn't focussing on short and long lived gasses.
- Methane only lasts 12 years in the atmosphere and a legacy.
- Get CO2 with zero, but you still have ongoing. Methane to 12% decade over a decade - you'll end up with the same outcome as radiative forcing.
- NZ - methane doesn't have to be zero to be climate neutral.
- Using different metrics for different purposes? - you have to have compatible metrics across the board, for policy making. There is no policy advantage to have different metrics. * would be good for industry communication. Quickest way to get the gains, or targets, is to not make methane a zero target, because it doesn't need to be.
- Keith Shine metric was better, but it hasn't been adopted.

Is there a risk of a clouded message to farmers about the need to change, with all of these different metrics.

- As you get closer to zero, the metric becomes irrelevant.

Where does Aus industry sit compared to competitors with sustainability of our practices?

- He hasn't seen anything in Aus systems that make us more sustainability than other countries.
    - Water impact in Aussie wool is a bigger impact than NZ wool as we have more scarcity.
    - Our environment makes us worse off. We use more land to grow 1kg of wool than NZ. It's a bigger footprint.
    - We need recognition that our land is suitable for livestock, and not crops.

We are interested in being more involved in FAO LEAP and other international forum engagement. What risks and opportunities?

- Risk of not engaging is very high. The FAO LEAP partnership is essential so that we aren't seen to be outside of the loop on this.
- To check that we meet standards for import/export.
- Trying to benchmark against the EU standards - very few standards we wouldn't meet then.

Market's expectation is growing. Are these increasing requirements providing us with opportunities, or just something that we have to do to participate? Price premiums or minimum requirement.

- Deadline for carbon neutrality. Premiums now, but it will become par for the course.

Quick Summary - Understanding methane emissions, accounting and Australia's global context

Methane summary

Methane is known as a short-lived climate pollutant (SLCP) as it only persists in the atmosphere for an average of 12 years, before breaking down into CO_2 and water; some atmospheric methane is also removed through uptake in soil (Jackson et al. 2020; McSweeney 2020). The CO_2 produced from decayed methane will then itself contribute to global temperature and become a LLCP.

Table 1 Estimated lifetime of major greenhouse gases and warming potential under GWP_{100}

Gas	Chemical formula	Atmospheric lifetime (average)	GWP_{100} (AR5)	Share of Australia's emissions (CO_2-e) b
Carbon dioxide	CO_2	Up to millenia	1	70.0%
Methane	CH_4	12 years	28-30 a	23.3%
Nitrous oxide	N_2O	121 years	265	4.4%
Hydrofluorocarbons	HFCs	5.2–47.1 years	677–4,800	2.2%
Perfluorocarbons	PFCs	2,600–50,000 years	6,630–11,100	<0.0%
Sulphur hexafluoride	SF_6	3,200 years	23,500	<0.0%

Note: a NZPC (Box 9.3) say GWP for fossil is 30. According to Guardian, 30 is fossil. b Australia's GHG inventory currently published in AR4 units (could provide GWP100 for AR4 too). Australia's NGGI is scheduled to use these AR5 estimates from 2020–21 (DISER, p.22, DISER p.23). Could split methane into biogenic and fossil (but not sure if all waste is fossil).
Source: Greenhouse Gas Protocol 2016; NZPC Table 9.1, AGEIS.

Because methane is integral to many biological and geological processes, there are sources and sinks of methane emissions which are not human-induced (anthropogenic). These are not included in global climate mitigation commitments, although they can be indirectly affected by human activities, and impact climate change through feedbacks (Global Methane Budget).

There are two categories of anthropogenic methane emissions: *biogenic*, which is produced from organic matter, for example through digestion by animals or decomposition in landfills; and *fossil*, which derives from the extraction and use of fossil fuels (organic material from the geological past) (**Error! Reference source not found.**). Importantly, the CO_2 produced from the atmospheric decay of biogenic methane is offset by the carbon sequestered in plants from which the methane is derived. This means that there is a *net zero CO_2 effect of biogenic methane* emissions. In contrast, fossil-derived methane will degrade into CO_2 which is not offset by sequestration, hence producing both short-lived methane and long-lived CO_2, both of which contribute to global temperatures.

Global context

New Zealand has the highest proportion of methane in total GHG emissions across all OECD countries, 95% of which is biogenic methane (Table 2). This led the New Zealand government to introduce the Climate Change Response (Zero Carbon) Amendment Bill, which imposed a target to reduce all greenhouse gases (except biogenic methane) to net zero by 2050. Separately, the Bill includes a 10% reduction target for gross emissions of biogenic methane by 2030, and a 24 to 47% reduction by 2050 (relative to 2017 levels) (New Zealand Ministry for the Environment (MFE) 2019).

While New Zealand is currently leading efforts to establish separate mitigation targets for biogenic methane, Europe is also examining alternative ways of dealing with methane emissions (European

Commission 2020). Table 2 illustrates that many European countries are among the top 10 methane shares in the OECD (the European Union has an average 10% methane share across all 28 countries).

Table 2 Top methane emitting countries by share of total emissions, 2017

Rank	Country	Methane emissions	Total emissions (CO_2-e)	Methane % of total emissions (CO_2-e)	% Biogenic methane	% Fossil methane
1	New Zealand	34,132	80,853	42%	95%	5%
2	Ireland	14,034	60,744	23%	87%	13%
3	Australia	103,602	554,127	19%	72%	28%
4	Latvia	1,805	11,306	16%	67%	33%
5	Lithuania	3,257	20,417	16%	77%	23%
6	Denmark	6,920	49,226	14%	87%	13%
7	Portugal	9,477	70,546	13%	92%	8%
8	Canada	92,848	715,749	13%	47%	53%
9	Iceland	581	4,755	12%	98%	2%
10	Slovenia	2,102	17,454	12%	55%	45%

Note: Measures total methane divided by total CO2e emissions. Need to clarify which conversions used. Australia may differ from NGGI. Biogenic methane calculated from gigagrams of methane emitted in 2017 from agriculture and waste sectors.Could include EU28 as one region.
Source: OECD, FAOSTAT

Australia's biogenic methane sources

Australia has the third highest share of methane in GHG emissions across the OECD, although 28% of this is fossil-derived. In response to the scientific debate, livestock groups such as the Cattle Council of Australia suggest that GWP* demonstrates that the existing GWP_{100} model may overstate livestock's impact on global temperatures. Following New Zealand's lead, these groups suggest Australia should investigate the feasibility of switch to a GHG accounting framework that does not place an unfair burden on their industry.

Australia's latest GHG emission inventory estimates that 23% of total national emissions are from methane, with over two-thirds of this biogenic methane (Table 3).

The major sources of Australia's anthropogenic methane emissions are agriculture (47%), energy (31%), landuse change (13%) and waste (10%). Agriculture is one of the most methane-intensive industries in Australia's emissions profile – methane represents over three-quarters of CO_2-e emissions. Waste is even more methane-intensive (95% of emissions).

All methane from the energy industries are fossil-derived, and are emitted via transport, direct combustion and fugitives.

In Australia, all biogenic methane emissions are attributable to three sectors: agriculture (68% of total biogenic methane), landuse change (18%) and waste (14%) (Table 3). All methane emissions from these sectors are considered biogenic.

One of the reasons livestock industries are concerned about the potential over-representation of their industries in climate change mitigation commitments is that the emission of non-CO_2 greenhouse gases, such as methane and nitrous oxide, are intrinsic to many natural systems within which agriculture operates. Hence, the complete elimination of these emissions is not possible (Reisinger and Clark 2017; CCC 2019), and the cost of reducing these emissions can be higher than in other sectors of the economy. These high costs of abatement are seen as a potential threat to the competitiveness of Australia's (export-oriented) livestock industries, particularly if the same costs are not imposed on similar industries overseas.

Table 3 Australia's biogenic and fossil methane emissions, by sector, 2018

	Greenhouse Gas Emissions (CO_2-e) based on GWP_{100}			Biogenic methane emissions	
Sector	Biogenic methane	Fossil methane	Total emissions (all GHGs)	Share of industry methane emissions (%)	Share of total emissions (%)
Electricity	-	598	183,170	0.0%	0.0%
Direct combustion	-	992	97,155	0.0%	0.0%
Transport	-	358	100,796	0.0%	0.0%
Fugitives	-	37,107	54,450	0.0%	0.0%
Industrial Processes	-	77	34,197	0.0%	0.0%
Agriculture	58,388	-	75,588	100.0%	77.2%
LULUCF	15,768	-	-20,601	100.0%	n.a.
Waste	12,012	-	12,691	100.0%	94.6%
Total Australia	86,168	39,132	537,446	68.8%	16.0%

Note: All emissions based on GWP_{100} AR4. Assumes all agriculture methane is biogenic, and all LULUCF and waste methane is biogenic. LULUCF share of biogenic not estimated as total emissions are negative.
Source: AGEIS.

s. 22(1)(a)(ii)

From: s. 22(1)(a)(ii)
Sent: Monday, 6 December 2021 1:52 PM
To: s. 22(1)(a)(ii) s. 22(1)(a)(ii)
Cc: s. 22(1)(a)(ii) s. 22(1)(a)(ii)
Subject: RE: Livestock industry methane contributions to global warming [SEC=OFFICIAL]
Attachments: ABARES GWP Brief - Oct2021 update.docx

Hi all

Apologies on missing the meeting. Following a quick catch up with s. 22(1)(a)(ii) it seems methane and Global Warming Potential (GWP) were topics raised. Please find attached a brief ABARES pulled together on the issue of methane in agriculture and considerations for alternative reporting metrics.

If you do have any follow up questions please don't hesitate to reach out.

Kind regards
s. 22(1)(a)(ii)

s. 22(1)(a)(ii)

Assistant Director | (02) 627s. 22(1)(a)(ii)

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-----Original Appointment-----
From: s. 22(1)(a)(ii) @agriculture.gov.au>
Sent: Thursday, 25 November 2021 2:00 PM
To: s. 22(1)(a)(ii) s. 22(1)(a)(ii) ; s. 22(1)(a)(ii) s. 22(1)(a)(ii) s. 22(1)(a)(ii)
Subject: Livestock industry methane contributions to global warming [SEC=OFFICIAL]
When: Monday, 6 December 2021 1:30 PM-2:00 PM (UTC+10:00) Canberra, Melbourne, Sydney.
Where: Microsoft Teams Meeting

Hi s. 22(1)(a)(ii)

Appreciate a quick reality check from your team on the livestock industry's contribution to global warming via methane emissions.

There seems to a bit of scientific debate about the contributions of livestock methane emissions to global warming (synthesised here). However, that recent report highlights the need for significant reductions from the sector to future emissions to limit warming to less than 1.5oC (or if not for other sectors of the economy to carry more of the reduction effort). However, MLA is putting a very positive slant on the industry's contributions.

I would like to better understand where the truth lies on this.

Cheers
s. 22(1)(a)(ii)

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Microsoft Teams meeting

Join on your computer or mobile app
Click here to join the meeting

s. 22(1)(a)(ii)

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