Resource Economics

Pricing agricultural GHG emissions: *impacts on emissions leakage*

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Report for He Waka Eke Noa

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Contents

1 Introduction

1.1 Background

Emissions leakage occurs when actions to reduce emissions in one country result in emissions rising in another. This can happen when producers of internationally traded goods face greenhouse gas (GHG) emissions pricing or other policies that increase their costs, and which causes the producers to lose market share to international competitors that do not face similar costs.[1] Production moves when the emission reduction is not associated with a proportional reduction in consumption of the commodity.

The emissions leakage problem has previously arisen in the context of inclusion of emissions intensive trade exposed (EITE) industries in the New Zealand Emissions Trading Scheme (ETS). It is part of the reason companies in EITE industries receive an allocation of New Zealand Units (NZUs) to partially compensate for their emission costs.[2]

In this report we outline the issues for agricultural emissions pricing and the production of agricultural commodities. This includes a discussion of the relevance of emission caps and of relative emission intensities. We first turn to these issues.

1.2 Likelihood of Production Loss

Emissions pricing is expected to result in output reduction when the total costs are significant compared with profits and when prices cannot be passed on to consumers because New Zealand producers are not price setters in commodity markets.

Modelling of the impacts of pricing agricultural emissions in New Zealand has suggested some reductions in production and output will result.[3] This includes the loss of production and reduction in emissions when changes in relative prices result in land use change, eg from farming to forestry.

The Interim Climate Change Committee (ICCC) noted the potential for New Zealand to differentiate its agricultural products on environmental grounds[4] and that a price premium might make the sector more resilient to cost increases, reducing production losses. However, although a potential price premium has been suggested in some international surveys,[5] pricing agricultural emissions alone, without significant changes to farm practices is unlikely to be regarded as sufficient to enable price premiums to be set.

The flip side to this is whether New Zealand, without doing anything to limit its agricultural emissions, would lose market share because of negative branding of its products. This is possible and has been raised previously in the context of impacts on water quality,[6] but the effects are again highly uncertain.

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[1] Climate Change Commission (2021a); Arvanitopoulos *et al* (2021)
[2] Ministry for the Environment (2021)
[3] Djanibekov et al (2019); Dorner et al (2018); Denne (2022)
[4] Interim Climate Change Committee (2019)
[5] See, for example Tait *et al* (2018, 2020)
[6] Denne (2020)

We presume for this study that modelling results, based on current prices, that suggest reductions in agricultural output in New Zealand below that projected without emissions prices, will result in increases in production and output elsewhere. The extent of the increase elsewhere will depend partly on the implications for marginal production costs[7] and thus commodity prices. Rising commodity prices from changes in the location of production might, in turn, lead to reductions in consumption of products compared to a future in which New Zealand maintains its production. This would offset some of the emission increases that otherwise might occur.

1.3 The Relationship Between Leakage and Emission Caps

1.3.1 Emission Caps

A difference needs to be drawn between emissions leakage (the shift of production and emissions from one country to another) and an increase in global emissions which might result. Emissions leakage will not always cause an increase in global emissions because of the interplay between sectoral emissions in any one country and emission caps in that country. However, since the introduction of New Zealand's split gas target (Box 1), this may play out differently in New Zealand[8] from in other countries that have only set targets for all GHGs combined.

Box 1 New Zealand's Split-Gas Emission Targets

National emission objectives set in Section 5Q of the Climate Change Response (Zero Carbon) Amendment Act 2019 require reductions in agricultural emissions. These are:

- Net zero emissions of all greenhouse gases (GHGs) other than biogenic methane (CH4),[9] but including nitrous oxide (N2O), by 2050; and
- 24 to 47 per cent reduction of biogenic methane emissions below 2017 levels by 2050, including a 10 per cent reduction below 2017 by 2030.

1.3.2 Offsets Between Sources of GHGs

Prior to the introduction of New Zealand's split-gas target, it had been argued that, because New Zealand and other countries would seek to achieve emission targets at least cost, they would be indifferent to which source reduced emissions and might use emission reductions in one sector to offset emission increases in another.[10] Consistent with this, losses of agricultural emissions from New Zealand might increase agricultural emissions in another country, but would not increase total emissions because emissions from other sources within that country's emissions cap would fall at the same time. Thus, the ICCC suggested:[11]

[7] Which depends on the supply cost curve and supply capacity of existing marginal (price-setting) producers.
[8] Despite this domestic split gas target, the target in the updated Nationally Determined Contribution (NDC) under the Paris Agreement is to "reduce net greenhouse gas emissions to 50 per cent below gross 2005 levels by 2030", with net emissions including all gases based on 100 year Global Warming Potentials (GWP_{100}) from the IPCC 5th assessment report (New Zealand Government, 2021).
[9] Biogenic methane is produced from biological (plant and animal) sources, and includes emissions from livestock and from waste decomposition. Methane (CH4) is treated differently from other gases because it is short-lived in the atmosphere. Approximately 90% of biogenic methane emissions in New Zealand are from agriculture.
[10] This was a major reason for the original design of the NZ ETS (Ministry for the Environment and The Treasury, 2007)
[11] And note the ICCC uses emissions leakage only when it results in an increase in global emissions

> *Whether emissions leakage occurs depends fundamentally on the nature of emission targets adopted by our competitors. If a competitor country has adopted an economy-wide emission target, while that target lasts, any increase in its agricultural emissions would be compensated by an equal reduction of emissions in other sectors*.[12]

The Climate Change Commission (CCC) repeated the comments of the ICCC when examining the supporting evidence for its deliberations. It noted the ICCC's findings that the risk of emissions leakage from reduced dairy sector emissions was unlikely to be high in the short-term because the main competitor countries (in Western Europe and North America) had economy-wide emission caps, but that there was some greater risk for meat and wool production "because not all competitor countries are advanced economies with economy-wide emissions reduction targets."[13]

This analysis is still relevant to the risks of emission leakage from industrial sectors and to N_2O and other long-lived gas emissions from agriculture, where there is scope for shifts in emissions between sectors, particularly when facilitated by the ETS. Consistent with this, the Ministry for the Environment (MfE) in its recent consultation document on industrial allocation, suggests:[14]

> *If our emissions were exported to countries without a hard emissions cap in place, leakage would undermine New Zealand's commitment to reduce global emissions.*

If this argument is correct, offsetting between sectors may reduce the risk of leakage producing increases in global emissions. Below we explore how offsetting might play out differently for long-lived gases (N_2O and CO_2) and methane.

Long-Lived Gases

The New Zealand Government is required to set five-year emissions budgets for 2022-2035 and to produce an Emissions Reduction Plan (ERP) by 31 May 2022,[15] that will set a path for how the climate targets (Box 1) will be met. This first ERP will focus primarily on meeting the first emission budget (2022-2025) while also laying the foundation for second and third year budgets.

New Zealand faces relatively high costs for emission reduction and is thus motivated to achieve its targets at least cost. This means we would expect emission reductions in one sector to be used to offset emissions in another. This is achieved in practice for emissions from sources included in the ETS, where there is explicit trading of allowances between sources allowing emissions effectively to shift. But, also of note, the ETS and associated emissions, along with long-lived agricultural emissions, sit underneath the national emissions cap (the 2050 target for GHGs other than biogenic methane) that will be defined into five-year budgets via the ERP. And any reductions in emissions in the agriculture sector, including those that result from reductions in production, will allow other sectors to emit more than otherwise they would, within the overall national cap. The mechanisms for

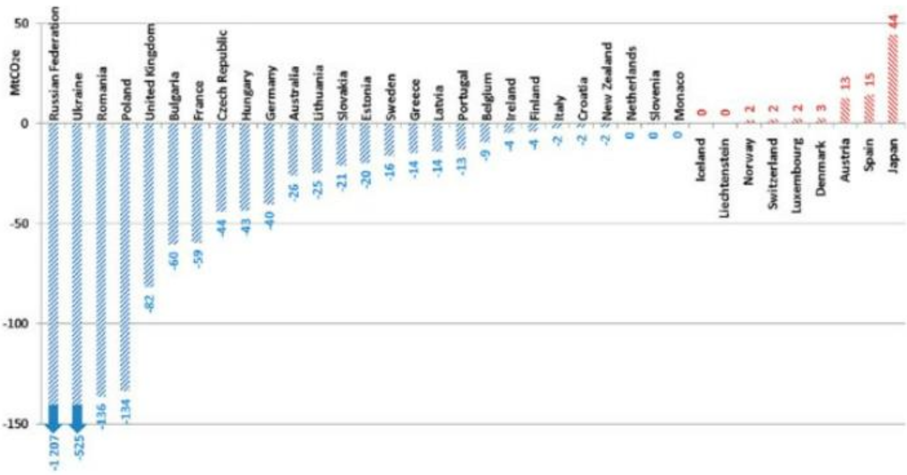
[12] Interim Climate Change Committee (2019), p4
[13] Climate Change Commission (2021b)
[14] Ministry for the Environment (2021a)
[15] Ministry for the Environment (2021b)

how this might play out would include via changes to allocations of units to the ETS or the stringency of other policies outside the ETS.

Thus, in theory, New Zealand would be expected to meet its targets but importantly, just to meet its targets. And this would be assumed to apply to other countries with hard caps also, ie that emissions rising or falling in one sector would be offset by emissions rising or falling in another.

However, these conclusions assume that, in countries with caps, emission reduction policy is efficient, so that targets are just met. In practice meeting an emissions target is not a precise art, even if most of a country's emissions are covered by an ETS. The experience of the Kyoto Protocol first commitment period is illustrative. Many countries met their target, but generally they over-complied, often significantly (those with negative values in Figure 1). The gap between required and actual compliance is relevant here because marginal changes in emission levels in agriculture may not result in offsetting reductions elsewhere if there is a large enough compliance buffer (the gap between emissions and target) and/or if agricultural emissions are not included in a national ETS. And for many countries, agricultural emissions have not to date been central or overly important to their emission reduction plans.

Figure 1 Relative difference between the average annual emissions of Annex B-2012 countries in 2008-2012 and their respective Kyoto targets including LULUCF



Source: Shislov et al (2016)

A recent review of countries' emission reductions against targets set under the Kyoto Protocol (1997), the Copenhagen Accord (2009) and the Paris Agreement (2015) identifies that compliance with targets is mixed, but that countries with targets reduce emissions more than those without and that pricing mechanisms (carbon taxes and ETSs) have led to material reductions in emissions.[16] This is consistent with a view that sees an emission target as policy tool that sets a direction for change more than providing a strict limit (and from a cynical perspective, setting targets historically may partly have reflected the ease of meeting them).

[16] Tenreyro and de Silva (2021)

However, Nationally Determined Contributions (NDCs) or targets set under the Paris Agreement are expected to be more stringent for many countries and more closely complied with, because of the greater pressure to act and the increasing scrutiny placed on governments to comply. Counter to this, concerns about food security might over-ride pressure to reduce agricultural emissions, for some countries at least.

Some imprecision in matching emissions with targets is likely to continue, such that individual countries may under or over comply with their targets. And this introduces uncertainty over the extent to which marginal changes in emissions from individual sectors or gases are likely to be fully offset.

Methane

New Zealand is unique in using a split-gas approach with a separate national target for methane. This is in recognition of the different atmospheric lifetimes, potency and warming effect of the different GHGs.[17] The European Union (EU) and the United States (US) have recently announced a Global Methane Pledge which proposes that countries commit to a goal of reducing global methane emissions by at least 30% from 2020 levels by 2030.[18] However, this is expected to focus on reducing emissions from the oil & gas industry, gas pipe leaks and landfills, rather than it necessarily demonstrating any additional intent of these countries to address methane from agriculture.[19]

Given this split-gas approach, it is less likely that there will be offsetting changes in emissions in other sectors if New Zealand reduces its agricultural methane emissions more (or less) than targeted. Compensating increases in emissions would need to come from other biogenic methane sources, eg waste. If there are no offsetting increases within New Zealand, methane emissions that leak to other countries with emission caps for GHGs combined, may lead to a reduction in global emissions.[20]

1.4 National Targets

1.4.1 Nationally Determined Contributions

The discussion in Section 1.4 above noted the importance of whether countries meet emission targets to the outcomes of emissions leakage. The development of climate change policy in other countries is also relevant to the question of whether agricultural prices, set internationally, will start to reflect the costs of emissions, which will in turn affect the extent to which the New Zealand agricultural industry can absorb a price of emissions.

Under the Paris Agreement, Parties are to develop Nationally Determined Contributions (NDCs) including their intended achievements and emission targets, and reflecting their own level of ambition. Table 1 lists the NDC commitments of New Zealand and competitor countries, alongside agriculture's contribution to total GHG emissions using 100-year Global

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[17] Office of the Minister for Climate Change (2019)

[18] European Union and US Government (2021). As of 12th October 2021, 32 countries and the EU had joined the initiative (Schonhardt, 2021)

[19] See discussion in Frame and Macey (2021)

[20] This would occur if: (1) any rise in methane emissions in other countries is offset by reductions in emissions from other sectors, while (2) New Zealand's methane emission reductions would not enable a rise elsewhere because methane is isolated within its own target.

Warming Potentials (GWP_{100}).[21] All countries listed have absolute targets (binding caps) for emission reductions.

Table 1 National Commitments of Individual Countries

Country	GHG % from agriculture	Target
New Zealand	46%	NDC target: To reduce net greenhouse gas emissions to 50 per cent below gross 2005 levels by 2030. Domestic targets: Net zero GHG emissions other than biogenic methane (BM) by 2050; compared to 2017, reduce biogenic methane by 10% in 2030 and 24-47% in 2050.
Argentina	45%	Net GHGs limited to 359 Mt CO_2-e in 2030, 19% below peak in 2007.
Australia	16%	Compared to 2005, reduce GHGs by 26-28% in 2030 (net-net approach)
Brazil	46%	Compared to 2005, reduce GHGs by 37% in 2025 and 43% in 2030.
EU		Compared to 2005, reduce GHGs in the EU ETS by 43% in 2030.
France	18%	Compared to 2005, reduce GHG emissions outside ETS by 37% in 2030.
Germany	7%	Compared to 2005, reduce GHG emissions outside ETS by 38% in 2030.
Ireland	35%	Compared to 2005, reduce GHG emissions outside ETS by 36% in 2030. Compared to 2018, agriculture emissions to be reduced by 22-30% by 2030.
Netherlands	8%	Compared to 2005, reduce GHG emissions outside ETS by 30% in 2030.
Spain	11%	Compared to 2005, reduce GHG emissions outside ETS by 26% in 2030.
UK	9%	Compared to 1990, reduce GHG emissions by 68% in 2030.
USA	8%	Compared to 2005, reduce GHG emissions by 50-52% in 2030.

Source: Richards et al (2015); Ministerio de Ambiente y Desarrollo Sostenible, República Argentina (2020); Australian Government (2020); Brazil Government (2020); European Union (2020); Ireland Department of the Environment, Climate and Communications (2021); UK Government (2020)

The EU Member States' commitments are shown based on those in the EU NDC. However, individual countries may have additional commitments. For example, Ireland has agreed to introduce legislation that sets a target for all GHGs to be 51% below 2018 levels by 2030 and to net zero by 2050.[22]

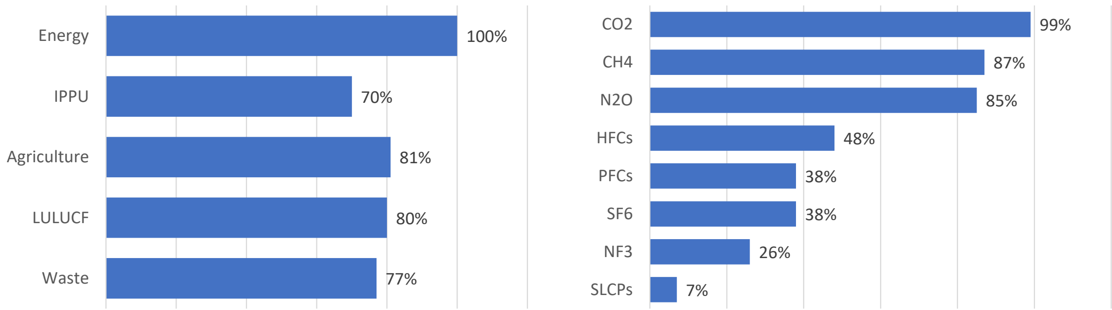
Most countries were compliant with the first commitment period under the Kyoto Protocol (Figure 1), and amongst those that were not, four of the nine are EU member states, and the Kyoto Protocol commitment was for the EU combined.[23] The non-compliant countries were Iceland, Japan, Norway, Switzerland and Liechtenstein. In addition, the US did not ratify the Protocol and Canada withdrew. However, as noted above, compliance itself is not necessarily important in defining whether leakage will result in emission increases, but the gap between emissions and allowed emissions (ie the efficiency of meeting commitments) and whether agricultural emissions can be readily offset within national policies.

[21] Emission estimates are based on national reports to the UNFCCC summarized by Richards et al (2015)
[22] https://www.gov.ie/en/press-release/22e97-government-approves-landmark-climate-bill-putting-ireland-on-the-path-to-net-zero-emissions-by-2050/
[23] As party to the Kyoto Protocol, the EU committed to reducing GHG emissions by 8% during the first (2008-12) commitment period. This target is shared between the Member States under the burden-sharing agreement, which sets individual emissions targets for each Member State (Council Decision 2002/358/EC of 25 April 2002).

1.4.2 Agricultural Emissions Commitments

The Secretariat to the UNFCCC tracks the extent to which sectoral sources of emissions are covered by the commitments of the individual countries. This is summarised in Figure 2. It suggests that 81% of agricultural emissions are covered by existing commitments and 87% of methane emissions.

Figure 2 Sectors and greenhouse gases covered in nationally determined contributions



Note: SLCPs = short-lived climate pollutants, eg black carbon, sulphur dioxide and non-methane volatile organic compound
Source: Secretariat to the UN FCCC (2021)

Henderson and Frezal (2019) produced a report for the ICCC on the status of emission policies affecting agriculture in different countries. It noted a wide range of current responses; we do not repeat this work. Rather, we note below how agriculture is included in national emission reduction policy efforts of a selection of countries in Table 1, noting that it is not included in the EU ETS.

Australia is currently forecasting that it will achieve its target to reduce all GHGs to 26-28% below 2005 levels by 2030.[24] It has no separate target for agricultural emissions (currently 15% of total emissions),[25] but these are forecast to be 6% below 2005 levels by 2030.

Emissions policy in Australia includes an Emission Reduction Fund (ERF) which provides funding for eligible activities that include those in the agricultural sector. ERF methods can be used to generate Australian Carbon Credit Units (ACCUs)[26] for sale via reverse auction to the Government or to third parties.[27] There is an additional dairy industry commitment to reduce GHG intensity by 30% below 2015/16 by 2030.[28]

In Ireland, policy relating to agriculture is coordinated in the *Ag Climatise* Roadmap that includes encouragement of reduced fertiliser use, replacing urea with protected urea, enhanced breeding programmes for low emission livestock, encouraging grass feeding,

[24] Australian Government Department of Industry, Science, Energy and Resources (2020)
[25] Australian Government Department of Industry, Science, Energy and Resources (2021)
[26] http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register/Historical-ACCU-data
[27] Approximately 16.5 million ACCUs have been issued to date (http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register/Historical-ACCU-data). Henderson and Frezal (2019) suggest the largest abatements have been from sequestration of carbon in soils.
[28] The target is 98 t CO_2-e/ML of milk manufactured and 0.72 kg CO_2-e/kg Fat and Protein Corrected Milk (FPCM) (https://www.sustainabledairyoz.com.au/reducing-environmental-impact). This is an update from the target reported by Henderson and Frezal (2019)

promotion of organic farming, and increased afforestation.[29] An enhanced Ag Climatise Roadmap has been proposed with the objective of achieving a 22-30% reduction in agriculture emissions by 2030 compared to 2018.[30]

The Netherlands has targeted a 14% reduction in agricultural and land use emissions by 2030 (3.5 Mt, including 1Mt from greenhouse horticulture).[31] Current projections suggest a 25% reduction in agricultural emissions below 1990 by 2030,[32] including a 5-11% reduction in livestock emissions via identified measures. These include precision fertilising dairy farming, low-emission dairy cattle and pig housing, selection of dairy cattle, scaling back pig farming, and fertiliser replacement.[33]

Historically it has been true to suggest that few countries were taking significant action to address agricultural emissions. This is changing and increasingly other countries are adopting emissions policy measures for agriculture and including agricultural emissions within national emission reduction plans.

1.5 Previous Analyses

The CCC notes that the risk of emissions leakage is difficult to quantify precisely for the food and fibre sector,[34] and there has been little analysis to quantify the expected levels of emissions leakage resulting from emissions pricing in New Zealand.

One example is a study undertaken for the OECD[35] using a global computable general equilibrium (CGE) model, to assess the potential effects of agricultural GHG pricing on emissions leakage rates.[36] An emissions charge of US$100/t CO_2-e applied to agriculture emissions in Australia and New Zealand resulted in a mix of emission reductions using mitigation technologies and reductions in output, such that 55% of the 2050 reduction in emissions leaked to other countries. There are limitations to this analysis including the over-estimated New Zealand emissions intensities as noted by the authors and the use of US EPA mitigation cost curves. And the authors note that, without mitigation technologies, modelled leakage rates would be significantly greater.[37] This is relevant to the pursuit of 2030 targets for which relatively few mitigation technology options are expected to be available.

The authors also noted the importance of demand responses in the analysis. Displacement of production from one country that leads to higher production costs elsewhere, and to higher commodity prices when marginal production costs increase, would be expected to see reductions in total consumption to offset some of the emission impacts of leakage.

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[29] Ireland Department of Agriculture, Food and the Marine (2020)
[30] Ireland Department of the Environment, Climate and Communications (2021)
[31] Netherlands Government (2019)
[32] PBL Netherlands Environmental Assessment Agency (2020)
[33] Netherlands Government (2019)
[34] Climate Change Commission (2021b)
[35] Henderson and Verma (2021)
[36] Leakage rates are defined as the increases in agricultural emissions in one country divided by the sum of the reductions in agricultural emissions in another country (or countries) that implement mitigation policies. Thus, a leakage rate of less than 1 signifies a net reduction in global GHG emissions from agriculture.
[37] They modelled the absence of mitigation technologies for the OECD as a whole and estimated, without mitigation technologies, leakage rates increased from 31% to 64%.

Changes in consumption would include switches to less emissions-intensive products, eg to chicken rather than red meat.[38]

To analyse the potential impact of emissions pricing on leakage, Sense Partners (2018) analysed the impacts of the NZ ETS and found no real evidence of a reduction in firms' competitiveness, although this included the impacts on industries estimated to be EITE and therefore provided with NZU allocations to partially offset their surrender obligations. They examined potential effects of emissions pricing on agriculture, noting that some of the cost impact in New Zealand is likely to be absorbed into the price of land[39] and that the extent of leakage could be farm-specific because of the wide range of emission intensities across New Zealand farms.[40]

The previous analyses do not provide quantitative data that can be used here but do point to sources of uncertainty in any analysis.

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[38] This is a point also made by Sense Partners (2018)

[39] Emissions pricing might result in some farms with high debt levels becoming unprofitable, but farming may continue on the same land under different ownership. This still has a significant short-run impact, but means leakage may be lower than initially suggested.

[40] Their analysis of the expected effects used emission intensities from Opio et al (2013) to suggest that a range of outcomes is possible depending on whether emissions are displaced from low or high emissions intensive farms in New Zealand.

2 Analysis

2.1 Scope of Analysis

The analysis in this report is limited to animal-based sectors: dairy plus sheep and beef farming. Horticulture industries, including production of fruit and vegetables, have not been included because of the expectation that they will be much less affected by emissions pricing. For fruit production, economic modelling indicates a price on fertiliser (the main source of emissions) is unlikely to drive reductions in production or fertiliser use (beyond good management practice). Vegetables are produced for domestic supply and many crops cannot be directly substituted with imports such that increased cost to growers would be expected to be passed on to domestic consumers to the extent possible given price elasticities of demand.

Horticulture industries using glasshouses can face more significant costs from emissions associated with energy use, and some are already treated as EITE and are provided with NZU allocations to partially offset their surrender obligations.[41]

2.2 Agricultural Production and Exports

2.2.1 Current Activity

New Zealand is a significant producer and exporter of several agricultural products (Table 2), with exports comprising 28% and 9% of global consumption of whole milk powder (WMP) and of skim milk powder (SMP) by weight respectively. It is also a very large contributor to global trade in sheep meat (38% of global trade by weight).

Table 2 New Zealand Contribution to World Trade in Selected Commodities (2018-20)

Commodity	Global Consumption (kt)	Global trade (kt)	NZ Exports (kt)	NZ exports (% of global Consumption)	NZ exports (% of global trade
Beef	70,281	10,410	623	0.9%	6.0%
Sheep	15,901	1,169	438	2.8%	37.5%
Whole Milk Powder	5,102	2,645	1,439	28.2%	54.4%
Skim Milk Powder	4,545	2,669	406	8.9%	15.2%

Source: Data from OECD/FAO (2021)

By export value, New Zealand is ranked highest by value globally as an exporter of milk products, second behind Australia as a source of sheep meat and seventh as a source of beef (Table 3).[42] New Zealand exports are 30% by value of global sheep and lamb meat exports, 5% of global beef exports and 22% of global dairy product exports.

[41] https://www.epa.govt.nz/industry-areas/emissions-trading-scheme/industrial-allocations/decisions/

[42] These comparisons assume equivalent products, although we note for example, India's exports of beef are dominated by buffalo.

Table 3 Value of sheep meat, beef and milk (top 10 countries) exports - (2020)

Country	Sheep (US$ million)	Country	Beef (US$ billion)	Country	Milk (US$ billion)
Australia	$2,600	Brazil	$7.4	New Zealand	$6.5
New Zealand	$2,500	Australia	$6.9	Germany	$2.9
UK	$560	USA	$6.6	USA	$2.3
Ireland	$390	India	$2.8	Netherlands	$2.2
Spain	$207	Argentina	$2.7	France	$1.8
Netherlands	$196	Netherlands	$2.6	Belgium	$1.5
Uruguay	$73	New Zealand	$2.4	Australia	$0.9
Belgium	$62	Canada	$2.2	Poland	$0.8
India	$48	Ireland	$2.2	Ireland	$0.8
France	$47	Uruguay	$1.6	UK	$0.7

Source: https://www.worldstopexports.com/top-sheep-and-lamb-meat-exports/, https://www.worldstopexports.com/top-beef-exporting-countries/ and https://www.worldstopexports.com/top-milk-exporting-countries/ using data from CIA World Factbook

New Zealand currently exports dairy, meat and wool products to over 100 countries. The main destinations are shown in Table 4. China is now the major destination of exports.

Table 4 Destination of New Zealand dairy and meat and wool exports (% by value; year to end of March 2021)

Country	Dairy	Country	Meat and Wool
China	39%	China	38%
Australia	6%	USA	20%
USA	4%	EU excl UK	9%
Japan	4%	Australia	4%
Indonesia	4%	UK	4%
Malaysia	3%	Japan	4%
Philippines	3%	Taiwan	3%
UAE	3%	Canada	3%
Saudi Arabia	3%	S Korea	2%
Thailand	3%	Singapore	2%
All other	30%	All other	11%

Source: MPI (2021)

2.2.2 Market Growth

The recent OECD-FAO Agricultural Outlook discusses where future growth in output and trade is expected to be for a range of agricultural commodities. Table 5 summarises the projected major contributors to growth in exports for beef and sheep meat, WMP and SMP. The growth percentage figures are the increase in projected exports from individual countries as a percentage of the positive increase in total exports.[43]

[43] For example, Brazil is projected to increase exports of beef by 728 kt, which is 40% of the total of all countries projected to increase their exports. Several countries are projected to decrease exports, partly as their production will increasingly be used for domestic consumption, eg India is projected to reduce exports by 725kt. The estimated positive growth in exports of WMP (245 kt) is less than the total estimated net growth (258kt)

Table 5 Projected contributors to global growth in commodity exports (2021-2030)

Beef		**Sheep**		**WMP**		**SMP**	
Growth (kt)[1]	1,811	Growth (kt)[1]	84	Growth (kt)	245	Growth (kt)	532
Net growth (kt)[1]	873	Net growth (kt)[1]	16	Net growth (kt)	258	Net growth (kt)	390
Brazil	40%	Australia	85%	New Zealand	44%	United States	61%
Australia	16%	EU	11%	EU	27%	EU	36%
Argentina	11%	Pakistan	2%	Argentina	12%	New Zealand	2%
United States	9%	Argentina	1%	United States	7%	Argentina	1%
Canada	9%			Brazil	4%		
Paraguay	8%			Paraguay	1%		
EU	4%						
Mexico	1%						

[1] kt cwe (carcass weight equivalent)
Source: Data from OECD/FAO (2021)

We use these data below when considering which countries might be marginal exporters that would increase production if New Zealand reduced its exports. The OECD/FAO expects New Zealand to continue to increase its production and exports of WMP and SMP but to reduce production and exports of beef and sheep meat (Table 6) because of an assumed ongoing shift in land use to dairy.[44]

Table 6 Projected change in production and exports from New Zealand (2021-2030)

	Production change (kt)	**% change**	**Exports change (kt)**	**% change**
Beef	-28	-4%	-27	-4%
Sheep	-23	-5%	-13	-3%
WMP	108	7%	108	8%
SMP	8	2%	8	2%

Source: Data from OECD/FAO (2021)

2.3 The Relevance of Emission Intensity

Emissions intensity of production, which is measured by emissions per kg of output/production, matters in the analysis, depending on the extent to which changes in emissions from one source are offset by changes to emissions from another. The options are shown in Table 7 and explained below.

Table 7 Matrix of response scenarios

New Zealand	**Other country optimises emissions**	**Other country does not optimise emissions**
Offsets agricultural emission losses with increases in other sectors	Scenario 1: no change to global emissions	Scenario 2: global emissions rise determined by emissions intensity of other country
Does not offset agricultural emission losses with increases in other sectors	Scenario 3: global emissions fall, determined by emissions intensity in New Zealand	Scenario 4: global emissions rise or fall determined by relative emissions intensity

- If reductions in agricultural emissions in New Zealand are fully offset by increases in emissions in New Zealand from other domestic sources, then:

[44] OECD/FAO (2021)

- Scenario 1: global emissions would not rise if the country in which agricultural emissions rise adjusts its emissions downwards in other sectors; and
    - Scenario 2: emissions might rise in another country if it does not adjust its emissions in other sectors. Global emission increases will be determined by the absolute emissions intensity of production in the other country.

- If reductions in agricultural emissions in New Zealand are not offset by increases in emissions in New Zealand from other domestic sources, then:
    - Scenario 3: global emissions would fall if the other country adjusts its emissions in other sectors. The impact on global emissions would be determined by New Zealand's emissions intensity; and
    - Scenario 4: emissions would rise in another country if it does not adjust its emissions in other sectors. Global emission increases (or decreases) will be determined by the relative emissions intensity of production in New Zealand and the other country.

The extent to which emissions increases and decreases are offset depends on the efficiency with which countries match emissions with targets. Historically there have been significant inefficiencies, observed in the gap between targets and measured emissions (above and below). However, this is expected to narrow significantly as countries increasingly adopt ETSs and include more sources within them. They would be expected to be more widespread as the costs of emission reduction increase and pressure rises to adopt least cost policy mechanisms.

The notable current exception to the greater inclusion of emissions in ETSs is the exclusion of agricultural emissions, both in New Zealand and elsewhere. This leaves some uncertainty over the extent to which agricultural emissions (rising or falling) will lead to offsetting adjustments.[45]

Scenario 4 in Table 7 is most likely where leakage involves small marginal changes to emission levels, but other Scenarios are likely to be relevant when the quantities are significant and/or as countries become more efficient. It is also likely that countries will not fit neatly into one of the matrix squares, ie emission changes might be partly offset but not fully.

2.4 Emissions Intensity

Although agricultural production in New Zealand is trade-intensive, ie a large proportion of production is traded, previous analyses have suggested that the fact that some is traded, combined with emissions intensity, has the greatest influence on whether there is leakage.[46]

Several studies have estimated the relative emissions intensity of agricultural products produced in different locations. This has been used to assess the change in agricultural emissions if production was to shift from New Zealand to some other country.

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[45] The comparisons of relative emission intensities of agricultural products between New Zealand and other countries in life cycle assessments (See Section 2.4 below) include emissions from transport and processing also, many of which will be included in ETSs, but life cycle emissions are dominated by those on-farm.
[46] Denne (2011)

Life cycle assessment (LCA) estimates GHG emissions throughout all stages of the production and consumption of food, ie to measure the product's 'carbon footprint'.[47]

2.4.1 Sheep and Beef

Two recent AgResearch reports for the Meat Industry Association (MIA) and Beef + Lamb New Zealand have analysed the emissions intensity of New Zealand beef relative to that in other countries.[48] The results of comparative LCAs are shown from cradle to grave per kg of meat (Table 8), including emissions from production, processing, shipping, local transport, warehousing, retail, consumption (as roast meat, hot-pot or frying, depending on the export destination) and waste disposal.

Table 8 Life cycle emissions intensities (kg CO_2-e/kg meat) calculated by individual studies

Country	Boundary	Farm type	Farm	Pro-cessing	Post pro-cessing	Total
Beef						
Australia	USA warehouse	Beef grass	25.49	0.98	0.76	27.22
Australia	USA warehouse	Beef medium-fed grain	21.62	0.98	0.76	23.36
Australia	USA warehouse	Beef long-fed grain	23.82	0.98	0.76	25.56
Mexico	Retail	Extensive system	20.37	1.13	0.24	21.73
Mexico	Retail	Intensive system	19.87	0.25	0.48	20.60
Italy	Food consumption	Organic beef	20.98	1.27	2.22	24.47
USA	Food consumption		27.00	0.39	3.43	30.82
USA	Grave	Pasture + Feedlot	30.67	0.59	3.84	35.10
NZ	Grave (various)	NZ average	20.10	0.50	1.68	22.30
NZ	Grave (USA)	NZ average	20.90	0.52	0.66	22.08
NZ	Grave (Japan)	NZ average	20.90	0.52	0.36	21.79
NZ	Grave	NZ average	19.70	0.52	0.36-0.66	20.59-20.88
Sheep						
Australia	to USA warehouse	Conventional	14.40	0.76	0.76	16.07
NZ	Grave (UK)	NZ average lamb	14.97	0.57	4.13	19.66
NZ	Grave (UK)	NA average mutton	13.20	0.57	4.13	17.90
NZ	Grave (UK)	NZ average	13.32	0.52	0.96	14.81
NZ	Grave (China)	NZ average	13.32	0.52	0.92	14.77
NZ	Grave (USA)	NZ average	13.32	0.52	0.77	14.62
NZ	Grave	NZ average	13.32	0.52	0.77-0.96	13.69-13.88

Source: Ledgard *et al* (2021)

The conclusions included:

- The main emission of GHGs for both beef and sheep product systems occurred on the farm. This accounted for 90 to 95% of total life cycle emissions.
- For beef and sheep meat, the NZ farm-related emissions were at the low end of the published range for beef and sheep meat produced in other countries, while

[47] FAO (2016a,b,c)

[48] Ledgard et al (2021); Mazzetto *et al* (2021b)

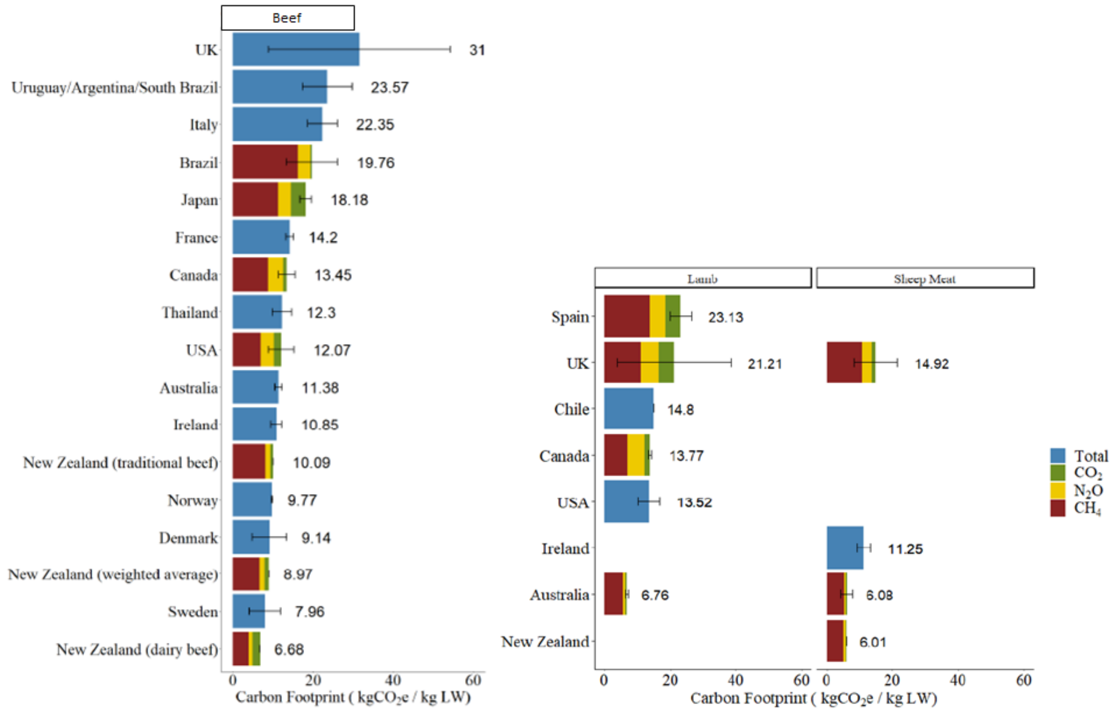
processing emissions were intermediate, and post-processing emissions within the wide range reported by others.

- Shipping represented 1-4% of the total carbon footprint. Thus, despite the long shipping distances sometimes involved, this study indicated that NZ beef and sheep meat supplied to widespread international markets have a full life-cycle carbon footprint at the lower end of the range of other published estimates.

- All post-processing stages made up only 1.7-3.0% and 5.3-6.5% of the cradle-to-grave carbon footprint for the beef and sheep supply chains, respectively.

An analysis by Mazzetto *et al* compiled average carbon footprint estimates for meat (beef and lamb/sheep meat) production in different countries using liveweight (LW) (Figure 3) and meat production (Table 9).

Figure 3 Cradle-to-farm-gate carbon footprint for beef production from different countries using liveweight (LW)



Source: Mazzetto et al (2021b)

Table 9 Cradle-to-grave carbon footprint (kg CO_2-e per kg meat) for beef and lamb production

Country	Beef	Lamb
Australia	20.66	16.1
Portugal	20.19	
Mexico	21.16	
New Zealand	21.86	14.7
Italy	24.46	
USA	32.72	
Tunisia		26

Source: Mazzetto *et al* (2021b)

For beef, the LW analysis places New Zealand (weighted average for dairy and traditional beef) at the bottom of the range of countries (bar Sweden), including being less emissions intensive than Australia. In contrast, the meat weight analysis (Table 9) suggests New Zealand is slightly more emissions intensive than Australia.

For lamb and sheep meat, the analyses all show New Zealand to be less emissions intensive than other countries.

Expected Marginal Comparison

If there is a loss of production and exports from New Zealand, any net increase in global emissions will depend on which is the expected marginal producer of the individual commodities. To better understand this, we have received inputs from MPI and New Zealand industry bodies, in addition to the OECD/FAO expectations of the sources of export growth (Table 5).

For beef, Brazil and Australia are the countries expected to contribute most to increases in exports, with additional significant contributions from Argentina, the US, Canada and Paraguay (Table 5). Using data for Australia and the US suggests a range of 20.7 – 35.1 kg CO_2-e/kg meat for Australia and the US, compared to 20.6 – 22.3 kg CO_2-e/kg in New Zealand. If Brazil is the source of additional production, the impacts may be greater (as suggested by the liveweight analysis in Figure 3) but we do not have the comparative data on a kg of meat basis.

For sheep, Australia, and to a lesser extent the EU, are expected to be the main sources of growth in exports (Table 5). Assuming Australia as the main expected competitor, suggests an emissions intensity of 16.1 kg CO_2-e/kg sheep meat compared to a range of 13.7 – 14.7 kg CO_2-e/kg in New Zealand.

2.4.2 Dairy

Mazzetto et al (2021a) compared New Zealand's carbon footprint for dairy cow milk with that of other countries and regions. Comparisons took account of differences in methodologies used to calculate the footprint. The results are based on emissions per kg of fat-and-protein corrected milk (FPCM). This is not a common measure of production in New Zealand but was used because it was a widely used measure in the literature.[49] Ledgard *et al* (2020) estimate an average relationship for New Zealand of 13.0 kg FPCM/kg MS.[50] Using this conversion factor suggests an emissions intensity of 10.0 kg CO_2-e/kg MS, which is slightly less than the 10.8 kg CO_2-e/kg MS for farm-level emissions estimated by the CCC in its analysis[51] (equivalent to 0.83 kg CO_2-e/ kg FPCM).

When the ICCC examined the risks of leakage from agriculture it suggested the risk of leakage from the dairy industry was low because any decrease in dairy production would be likely to be offset by increased production in Western Europe or North America, that those locations have similar emission intensities, have economy-wide emissions caps, and their

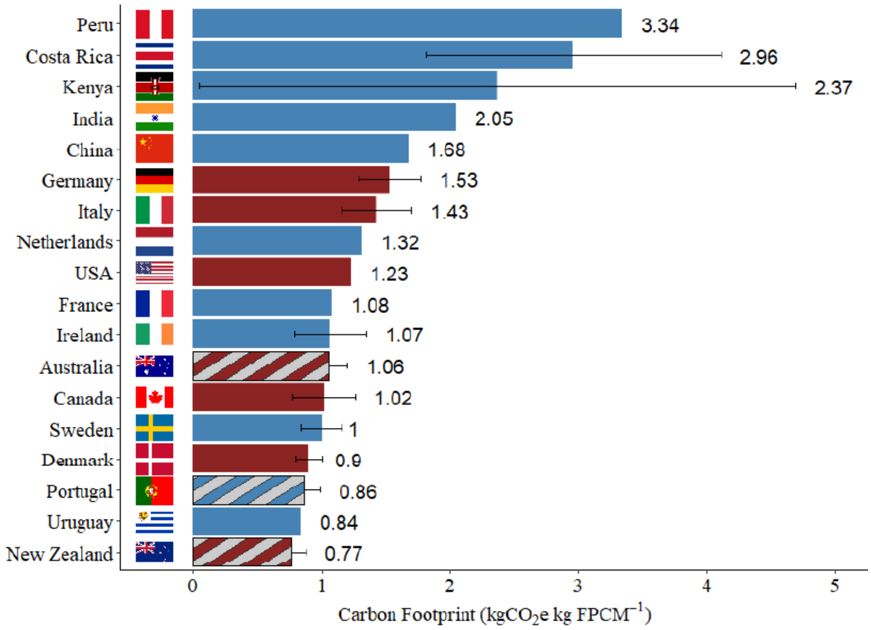
[49] André Mazzetto, pers comm

[50] Which is a very similar ratio to that for Ireland also (O'Brien et al, 2015)

[51] This is based on 2018 data (the latest for which national emissions inventory data are available) in Climate Change Commission (2021c)

farm businesses also face environmental regulations on nitrate, ammonia and phosphorous pollution which would constrain production.[52]

Figure 4 Carbon footprint of milk production (kg CO_2-e/kg FPCM) in different countries (after correction to common GWP, functional unit and allocation methodology)



Source: Mazetto et al (2021a)

The OECD/FAO assumptions (Table 5) also suggest the US and the EU as the main alternative sources to New Zealand of export growth in WMP and SMP. Because the EU producers are expected to face similar costs on emissions and other environmental regulations, the marginal producer is more likely to be the USA, or possibly Eastern Europe.[53]

Using the USA as marginal producer, suggests a comparison of 1.23 kg CO_2-e/kg FPCM compared to 0.77 kg CO_2-e/kg FPCM for New Zealand. This is equivalent to a comparison of 10.0 kg CO_2-e/kg MS with 16.0 kg CO_2-e/kg MS assuming the conversion factor of 13.0 kg FPCM/kg MS (as above).

2.4.3 Summary of Impacts

Using the numbers from the above LCAs and the suggested marginal producers, we estimate the impacts of production loss on GHG emissions in other countries and globally. Table 10 shows the estimated increase in global emissions per lost unit of output (kg of meat or kg of milk solids). We include three scenarios: (1) there are small marginal changes in output and emission changes are not offset in either country via changes in other emissions; (2) there will be partial adjustment, and we have arbitrarily assumed 50%; and (3) emission increases in other countries are fully offset (as assumed by the ICCC) and that there is no growth in global emissions.

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[52] Interim Climate Change Commission (2019)

[53] Kimberly Crewther, Dairy Companies Association of New Zealand (DCANZ), pers comm

Table 10 Estimated impact of loss of production on emissions

Product type	Unit	Assumed marginal producer	NZ footprint	Inter-national footprints	Difference using relative EI (% of NZ)	Difference using 50% of relative EI (% of NZ)	Emission increases fully offset
Beef	kg CO_2-e/ kg meat	Aus, US	20.6 -22.3	20.7 - 35.1	6.5 (30%)	3.3 (15%)	0%
Sheep	kg CO_2-e/ kg meat	Aus	13.7 - 14.7	16.1	1.9 (13%)	1.0 (7%)	0%
Dairy	kg CO_2-e/ kg MS	US	10.0	16.0	6.0 (60%)	3.0 (30%)	0%

There is considerable uncertainty in making any predictions of leakage rates. This includes uncertainties in:

- the data used in analysis;
- the assumptions over which countries are the marginal producers likely to increase output;
- the extent of any impact on commodity prices and any associated demand response;
- the extent to which emissions policy will be extended to agricultural emissions in other countries, better enabling New Zealand to absorb cost increases; and
- the extent of offsetting between agricultural emissions and those from other sources, both in New Zealand and other countries.

Using the 50% scenario from Table 10 suggests that, for every tonne of emissions reduced in New Zealand from the beef sector from reductions in output, emissions would be expected to rise elsewhere by 1.15 tonnes, an overall increase in global emissions of 15%. The equivalent estimates for sheep and dairy production are emissions increases of 7% and 30% respectively. The 50% assumption is obviously arbitrary and actual leakage rates if pricing was introduced to New Zealand are highly uncertain.

3 Conclusions

The analysis in this report has assessed the interaction between loss of production in New Zealand and gains in other countries, where the implications for emissions might differ with the emission targets employed and the extent to which New Zealand and other countries manage emissions collectively based on GWPs.

Many countries have established targets for emission reductions under the Paris Agreement that are based on GHGs in aggregate. In theory these allow trade-offs to be made between emissions from different sources and sectors, such that any increases in agricultural production and emissions in another country with a hard cap would be offset by reductions in emissions elsewhere in the economy. However, we suggest that management of emissions is not a precise art and that agricultural emissions may not be fully offset. This suggests that, for small marginal changes in production and emissions, emissions will rise globally.

We have deliberately not defined "small marginal changes" as this too is imprecise. But we suggest it is reasonable to assume lost agricultural production from New Zealand will lead to emissions leakage and increases in global emissions.

The development and recent review of industrial allocation policy under the ETS addressed the risk of leakage without attempting to quantify it because of uncertainties in analysis.[54] Quantification has been undertaken in this report based on the results of LCAs and simplifying assumptions about marginal producer countries and the extent of offsetting emissions between sectors as governments seek to achieve national emissions targets; the analysis also does not assume any demand response to changes in product prices that could result. Using these assumptions, with partial (50%) offsetting of emissions, there could be a 15% increase in global emissions for every tonne of emissions reduced in New Zealand from lower output of beef, so if emissions reduced by one tonne in New Zealand, they might increase by 1.15 tonnes in another country. The equivalent estimates for sheep and dairy production are emissions increases of 7% and 30% respectively.

The numbers are illustrative only; this analysis indicates that there is likely to be some leakage but how much is uncertain.

The potential for emissions leakage to erode some of the global benefits of agricultural emissions pricing suggests the benefits of policy options that incentivise emission reductions via efficiency improvements and mitigation technologies, while disincentivising output reduction in New Zealand. This includes pricing options that use output-based rebates in the same way as output-based allocations of NZUs have been used for EITE industries in the ETS, or those that use revenue collected from an emissions charge to fund emission reductions limited to those not achieved by output reductions.

[54] See Ministry for the Environment (2021a), Denne (2021)

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