Ministry for the Environment
Manatū Mō Te Taiao

Comparable effort analysis of New Zealand's post-2020 contribution

Overview

Purpose

This paper summarises comparability analysis that will form the basis of final advice on New Zealand's post-2020 intended nationally determined contribution (referred to in this paper as target or INDC). Implied targets are provided for a range of indicators.

An appendix to this paper summarises some of the current state of knowledge on the global aggregate costs and benefits of different levels of global action (eg, action to limit temperature rise to below 2°C).

Assessing New Zealand's fair share

The New Zealand Government has a stated policy principle of doing its "fair share" on climate change. This principle can be ambiguous on how fairness is defined, and what it is defined relative to.

What is fair share defined relative to?

Two broad possibilities exist for what fair share is defined relative to:

- **2 degrees Celsius (2°C) above pre-industrial levels** – a global temperature limit that the Government endorsed as part of the Copenhagen pledge
- **Other countries' efforts -** this may include countries of similar circumstances to New Zealand, trade competitors, or some global "average" across all countries.

This paper considers fair share relative to both other countries, and to the 2°C global goal.

How is fair defined?

Four indicators have been prepared to indicate the target that may be expected of New Zealand based on different concepts of fairness, these are:

- **Equal cost between countries** – Countries take equivalent targets based on cost (ignoring second-order economic effects and co-benefits).
- **Equal per-capita emissions in 2050**[1] – Countries work towards having an equivalent level of greenhouse gas (GHG) emissions per person by 2050.
- **Equal effort based on historical responsibility**[2] - Countries reduce GHG emissions equivalent to their share of global GHG emissions from 1990 to 2012.

[1] Based on the contraction and convergence indicator.
[2] Based on the Brazilian proposal indicator.

- **Equal reduction from business as usual (BAU)** – Countries take targets that feature a proportional reduction in GHG emissions from a business as usual scenario without climate change measures.

A simplified explanation of each indicator is provided in Appendix 5 to this paper.

The Treasury have previously stated a position (in their advice on New Zealand's 2020 target) that the equal cost indicator is most appropriate when considering New Zealand's "fair share". This paper takes a neutral view across indicators, and recalls officials' three working objectives for New Zealand's contribution:

1) it is seen as a fair and ambitious contribution – both by international and domestic audiences,
2) costs and impacts on society are managed appropriately,
3) it must guide New Zealand over the long term in the global transition to a low emissions world.

Comparisons based on headline number.

It is also likely that some stakeholders will judge New Zealand based on the headline number of its target. For example, New Zealand taking a headline target of "-5 per cent" may be seen as less ambitious than the European Union taking a headline target of "-40 per cent" or Russia taking a headline target of "-25 to -30 per cent". **Comparisons based on headline number do not provide a fair reflection of effort**, and are not considered in this paper.

Converting to similar base-years or accounting rules does not necessarily provide a fair reflection of effort when looking solely at headline numbers. For example, New Zealand is severely disadvantaged by comparisons based on net-net accounting when using a 1990 base year; however this does not necessarily reflect greater policy effort by other countries vis-à-vis New Zealand.

Assumptions, uncertainties and limitations

Indicators are very sensitive to the model and assumptions used to calculate the indicator. Using different models or assumptions may significantly change results

Indicators neglect real-world factors such as the policy-effort already exerted by a country, the co-benefits accrued by each country, and different flow-on economic effects[3] in each country. Because of these factors, **comparability indicators are indicative only and should not be taken as a strict assessment of the target New Zealand should take** based on each concept**,** nor a strict assessment of the effort of particular countries.

Targets indirectly related to greenhouse gas emissions (eg, climate finance) are not incorporated in this analysis. This may mean that some of the effort by each country (eg,

[3] A stylised example of an economic flow-on effect can be observed if household income was impacted by a policy. This may result in the household buying less from the local supermarket, who in turn purchases less produce from local suppliers, who then pay their workers less. As real world economies are complex, diverse and highly integrated; flow-on economic effects can differ significantly between countries and for different policies.

research and development into clean energy, climate finance provision) is not accounted for when considering fair share.

Estimates featured in this paper are based on greenhouse gas emissions data from New Zealand's 1990-2013 inventory submission, and includes information about each country's accounting rules and targets available at the time of drafting. This version of the paper has been updated to incorporate Australia's 2030 climate change target, announced subsequent to the initial drafting of the paper.

This paper attempts to integrate each country's forestry accounting rules into the assessment of effort; however this has inevitably required assumptions when calculating indicators. For some countries, targets have been calculated based on net-net accounting. That is, targets are set relative to net emissions in the base year and met through net emissions. For others (such as Japan), targets have been calculated relative to gross emissions in the base year.

It is assumed that New Zealand applies an economy-wide target using absolute accounting of greenhouse gas emissions. New Zealand's target is applied excluding emissions and removals from forestry. Applying different accounting rules (eg, intensity accounting for a given sector) would change the targets recommended in this paper. This is due to the change in baseline (business as usual) greenhouse gas emissions that these rules create.

Table 1: Accounting rules for target assumed for comparisons to other countries

Country	Rules assumption	Data source for forestry emissions and removals
New Zealand	Gross-gross accounting	n/a
European Union	Gross-gross accounting	n/a
United States	Net-net accounting	"With Measures" scenario, United States 6th National Communication (UNFCCC, 2015)
Australia	Net-net accounting	Australia's emissions projections 2014-15 (Department of the Environment, 2015)
Canada	Net-net accounting	"With Measures" scenario, Canada 6th National Communication (UNFCCC, 2015)
Japan	Gross-net accounting	Japan draft INDC [Translated]
China	Forestry excluded	n/a
United Kingdom	Gross-gross accounting	n/a

All forestry mitigation potential is excluded from this paper. This is due to difficulties in sourcing data on forestry abatement potential across countries[4] and incorporating this with different forestry accounting rules sets. The practical effect of this assumption is that emissions or removals from forestry and land use are held constant for each country across all scenarios and increasing the carbon price cannot induce any further forest sequestration.

[4] Long-term emissions and removals from the land sector vary substantially between integrated assessment models based on the structuring of the model and the technologies available to mitigate GHG emissions (PricewaterhouseCoopers, 2015).

An assumption is made that all countries take the most cost-effective abatement available to achieve their target. This means that countries purchase international carbon offsets at the prevailing global carbon price where it is cost effective to do so. In reality it is likely that some countries may choose to pursue their target solely through domestic emission reductions. This is likely to result in higher costs of achieving targets for countries such as the European Union and United States than those compared against in this paper.

The equal cost indicator also assumes that countries use the most cost-effective measures available to it to achieve its target. In reality it is likely that countries may choose to use measures judged to be less efficient to achieve their targets (eg, renewable electricity subsidies), increasing the overall cost of their target.

Further information on uncertainties and limitations of the equal cost indicator are provided in Appendix 1 to this paper.

Assessment of fair share

This section assesses currently announced post-2020 targets using the fair share indicators. First, indicators are used to assess New Zealand relative to other countries targets. Second, indicators are used to assess New Zealand and other countries' targets relative to the 2°C global goal.

All indicators are presented for a 2030 target year to ensure consistency in comparisons made. Where countries have announced a 2025 target year, a 2030 target has been estimated by the author by linearly interpolating between the country's 2020, 2025 and 2050 targets.

Targets are calculated using data from a range of sources. Equal cost comparisons utilise the Ministry for the Environment's "*Comparing Emission Reduction Target Tool,*" updated as of May 2015.

Relative to other countries

Currently announced targets

As of 19 May 2015, 39 countries have tabled or announced post-2020 targets (for the period out to 2025/2030). These countries cover over 50 per cent of present day greenhouse gas emissions. Currently announced targets for the post-2020 period are presented in Table 1 below (not exhaustive).

Table 2: Selection of announced post-2020 targets

Canada	China	European Union	Norway	United States	United Kingdom
30% below 2005 levels by 2030	Carbon dioxide (CO_2) emissions peak by 2030	40% below 1990 levels by 2030	40% below 1990 levels by 2030	26-28% below 2005 levels by 2025	50% below 1990 levels by 2025[5]

Source: United Nations Framework Convention on Climate Change (2015); United Kingdom Government (2015).

Comparison to other countries

New Zealand's target is compared relative to the targets of the European Union, United States, China, Australia, Canada, Japan and the United Kingdom.

The equal cost indicator is portrayed as a range (shaded purple) for comparisons to the targets of other countries. This range is based on carbon prices ranging from $50 to $80 (2012 NZD). The carbon price range has been estimated based on the domestic abatement cost curves and announced post-2020 targets of the largest emitters (the United States, China and the European Union)[6]. The range has also been adjusted to account for different estimates of greenhouse gas emissions between official inventory reporting and data provided by Landcare Research.

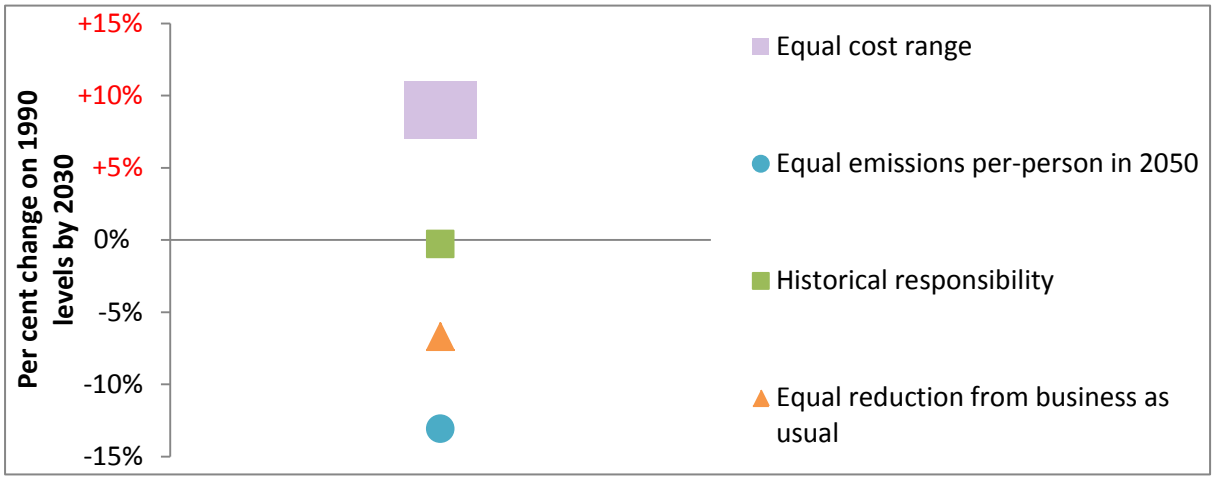
[5] Target has not been tabled to the post-2020 agreement, but is legally binding in domestic legislation.
[6] Using data provided by Landcare Research.

European Union

The European Union has a target of 40 per cent below 1990 levels by 2030. Based on each of the indicators, the target New Zealand would take is presented in Figure 1 below.

Based on the equal cost indicator, New Zealand would take a target of around 7 to 11 per cent above 1990 levels at 2030. The other fair share indicators suggest that New Zealand should take a more ambitious target, though all indicators suggest that New Zealand's target should be significantly less stringent in headline number than the European Union.

Figure 1: New Zealand's target equivalent to European Union's target based on fair share indicators



Source: Ministry for the Environment.

While the equal cost indicator suggests a fair comparative target for New Zealand would be an *increase* on 1990 levels, the cost of both the European Union and New Zealand's targets do not incorporate some of the sunk costs that have been borne by each country in reducing greenhouse gas emissions to date. For the European Union this includes renewable energy policies, carbon pricing, railway electrification, and energy efficiency measures.

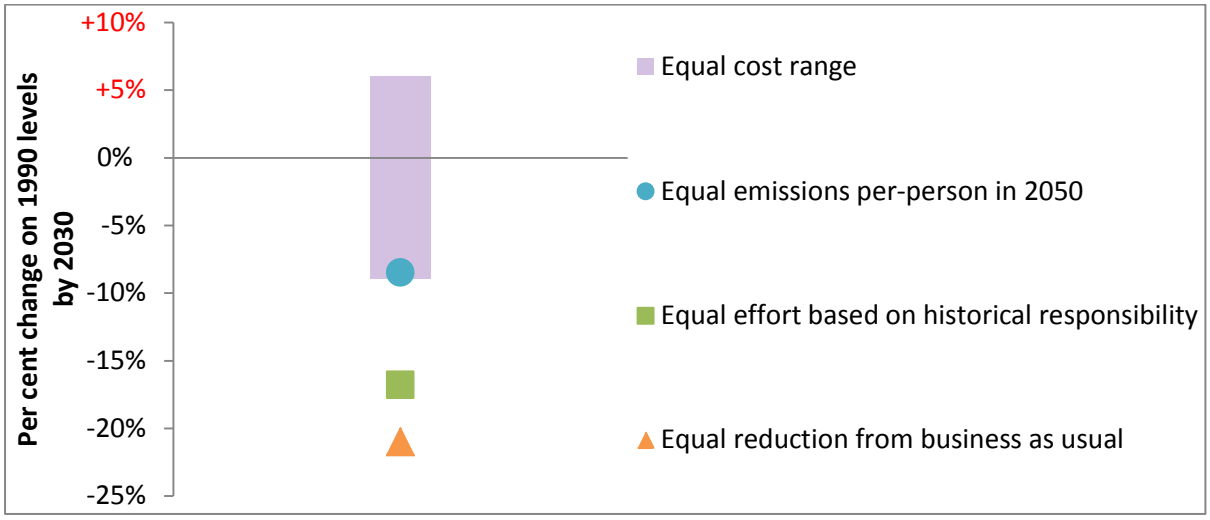
Analysis by the Ministry for the Environment (2015) suggests that the European Union's greenhouse gas emissions would have been 430 million tonnes of carbon dioxide equivalent higher than they actually were in 2011 if they did not put any policies and measures in place. In other words, instead of being 16 per cent below 1990 levels at 2011, they would have been 8 per cent below 1990 levels without policies and measures in place. This effort in reducing greenhouse gas emissions over the first commitment period of the Kyoto Protocol is not reflected in the equal cost indicator for the post-2020 period (nor is any past effort exerted by New Zealand).

United States

The United States has a target of 26 to 28 per cent below 2005 levels by 2025. It is assumed that the United States takes a target of 39 per cent below 2005 levels by 2030. This target is consistent with a straight line trajectory between their 2020, 2025 and 2050 targets.

Based on each of the indicators, the target New Zealand would take is presented in Figure 2 below.

Figure 2: New Zealand's target equivalent to the United States' target based on fair share indicators

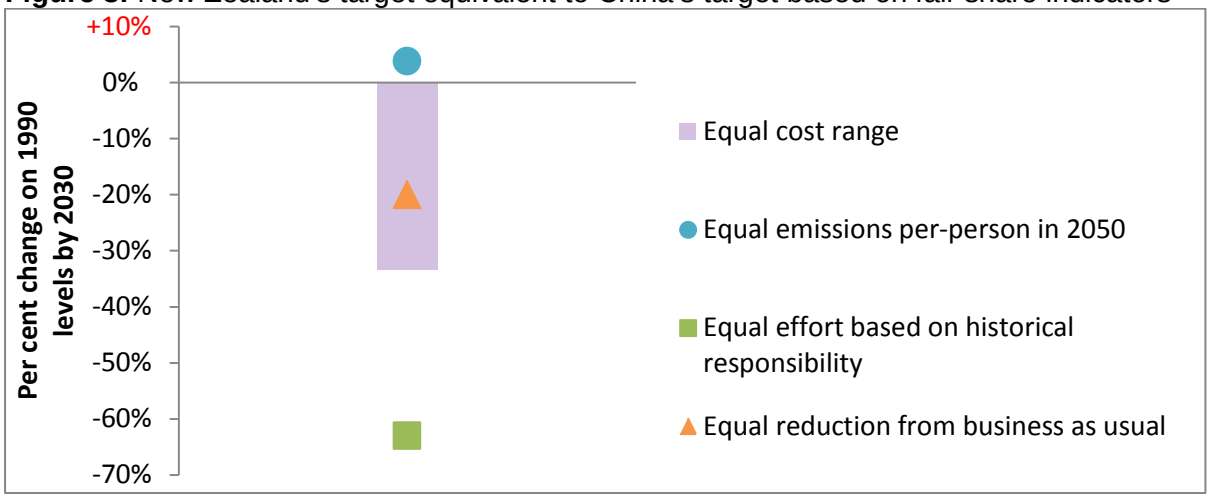


Source: Ministry for the Environment.

China

China has a target of peaking carbon dioxide emissions by 2030. Analysis of how this has been equated to an emissions reduction target is provided in Appendix 3 to this paper. Based on each of the indicators, the target New Zealand would take is presented in Figure 3 below.

Figure 3: New Zealand's target equivalent to China's target based on fair share indicators



Source: Ministry for the Environment.

It should be noted that China has a different level of economic development to New Zealand, with a GDP per person in 2012 of $6,100 compared with $38,700 in New Zealand (current USD).[7,8] This raises a valid question of whether indicators such as 'equal cost' are fair when comparing countries of different levels of economic development. In other words, should effort be *regressive* (relatively higher at low income levels), *progressive* (relatively higher at high income levels) or *flat* (proportional across income levels).

[7] International Monetary Fund (2014).

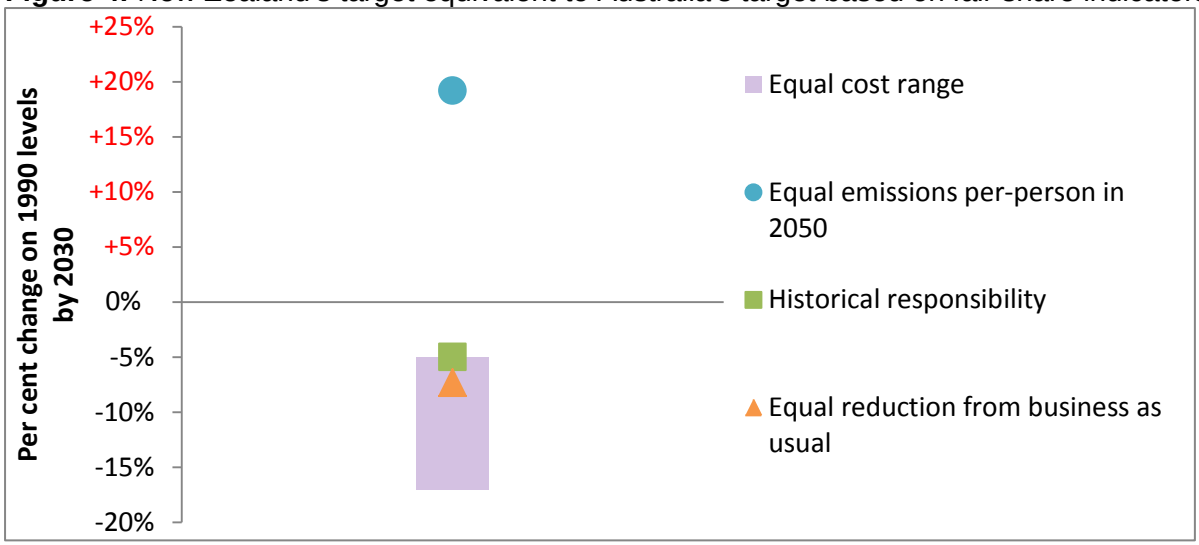
[8] Presenting GDP per person on purchasing power parity terms closes the gap between New Zealand and China, but the overall point remains the same.

A large range is provided for the equal cost indicator owing to large uncertainties in projections and historical levels of carbon dioxide emissions for China.

Australia

This paper has been updated to incorporate Australia's INDC, announced in August 2015. Australia has a target of 26 to 28 per cent below 2005 levels by 2030. Based on each of the indicators, the target New Zealand would take is presented in Figure 4 below.

Figure 4: New Zealand's target equivalent to Australia's target based on fair share indicators

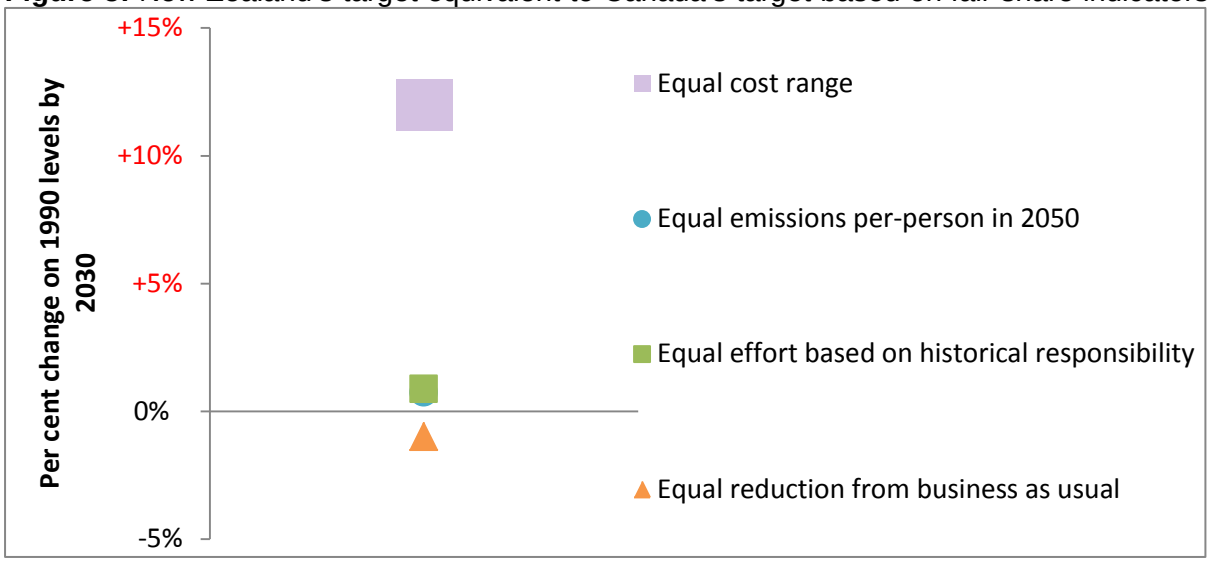


Source: Ministry for the Environment.

Canada

Canada has a target of 30 per cent below 2005 levels by 2030. Based on each of the indicators, the target New Zealand would take is presented in Figure 5 below.

Figure 5: New Zealand's target equivalent to Canada's target based on fair share indicators



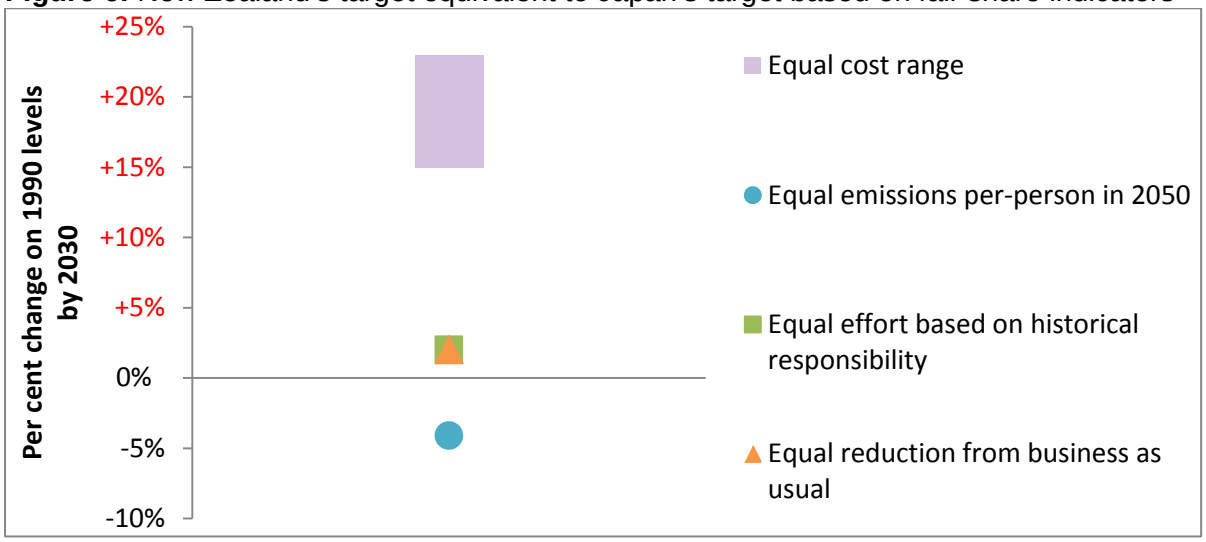
Source: Ministry for the Environment.

Japan

This section compares Japan's target to New Zealand. Japan has a draft target of 26 per cent below 2013 levels by 2030 (or 25.4 per cent below 2005 levels). Based on each of the indicators, the target New Zealand would take is presented in Figure 6 below.

It is worth noting that Japan's baseline GHG emissions are subject to an increased degree of uncertainty following the Fukushima earthquake in 2011. Baseline GHG emissions featured in this analysis see 2030 gross GHG emissions of approximately 1,330 million tonnes of carbon dioxide equivalent. Higher baseline GHG emissions projections for Japan would likely see more ambitious targets recommended for New Zealand based on equal cost and reduction from business as usual indicators.

Figure 6: New Zealand's target equivalent to Japan's target based on fair share indicators

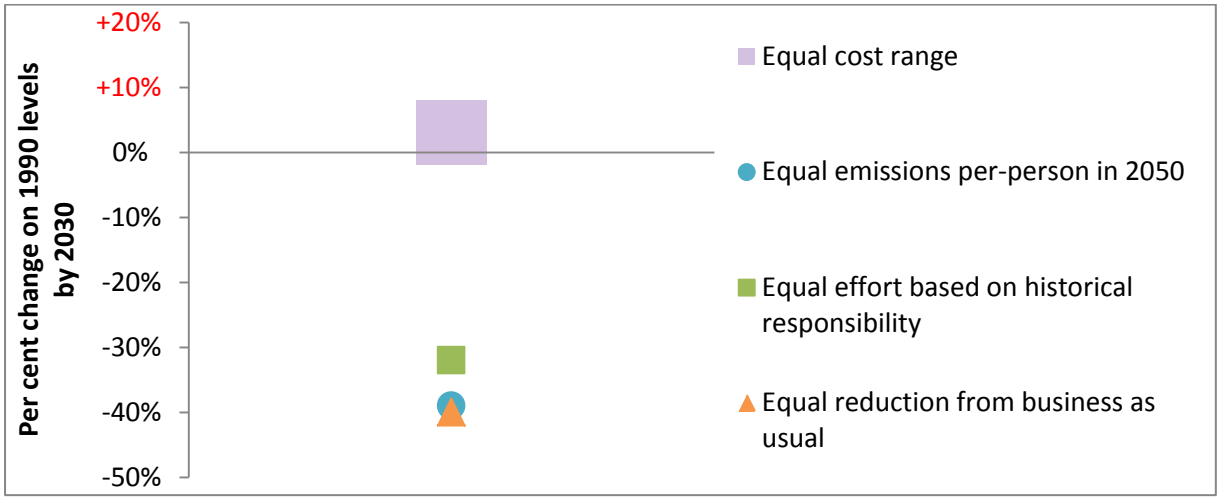


Source: Ministry for the Environment.

United Kingdom

The United Kingdom has a domestically legislated target of 50 per cent below 1990 levels by 2025, and a target at 2050 of 80 per cent below 1990 levels. This section compares an estimated target for the United Kingdom of 60 per cent below 1990 levels by 2030 to New Zealand. Based on each of the indicators, the target New Zealand would take is presented in Figure 7 below.

Figure 7: New Zealand's target equivalent to the United Kingdom's target based on fair share indicators

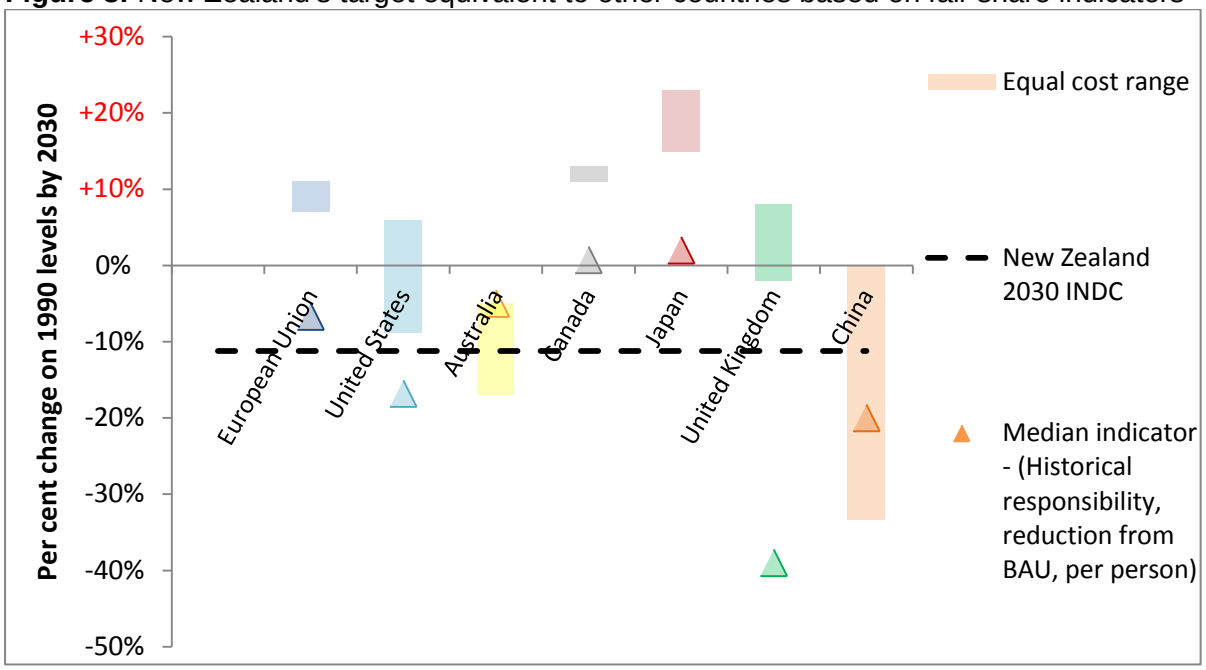


Source: Ministry for the Environment.

Summary

A summary of the indicators is presented in Figure 8 below showing the fair share target for New Zealand compared against the post-2020 targets of other countries.[9] This helps to demonstrate that effort between comparator countries varies based on the indicators observed. While the median indicator from the historical responsibility, equal per-person in 2050, and reduction from BAU indicators is shown – it should be noted that there can be significant variation between each of the indicators.

Figure 8: New Zealand's target equivalent to other countries based on fair share indicators[10]



Source: Ministry for the Environment.

[9] Noting that this is based on gross-gross accounting that excludes forestry abatement and forestry accounting rules for New Zealand.

[10] Information in this graph has been updated to incorporate New Zealand's 2030 INDC (shown as a black dashed line).

Relative to 2°C

Global effort

In 2010, **world leaders agreed on a target to limit global temperature increases to below 2 degrees Celsius (2°C).** This will require substantial and sustained reductions in greenhouse gas emissions by all countries. A compilation of the best science and economic modelling available today suggests that global greenhouse gas emissions will need to reach 40 to 70 per cent below 2010 levels by 2050, and net-zero or net-negative at 2100 to have a likely chance of limiting temperature rise to below 2°C.

A number of low-lying island countries have pushed for a global goal of limiting temperature rise to 1.5°C. New Zealand's close Pacific neighbours have been advocates of this goal. Limiting temperature rise to 1.5°C would require swifter reductions in global greenhouse gas emissions than what is required for 2°C.

The aggregate effort from currently announced INDCs is not in line with limiting temperature rise to below 2°C (IEA, 2015; Wolosin & Belenky, 2014; Boyd et al., 2015). An increase in effort *prior to 2030* is needed to ensure that the 2°C limit remains achievable (IEA, 2015). Early estimates (IEA, 2015; Wolosin & Belenky, 2014) of global greenhouse gas emissions out to 2030 based on current INDCs, put the world on a pathway consistent with temperature rises in the order of 2.5°C to 3.5°C at 2100, with **an 84 to 99 per cent chance of exceeding 2°C**.[11] For the potential impacts of this level of temperature rise, see Appendix 2 to this paper.

While current INDCs represent a pathway that is very unlikely to limit temperature rise to 2°C, they do put the world on a pathway for avoiding a "business as usual" pathway that could see temperature rise reach 4.5°C at 2100, with a 10 per cent chance of temperature rise reaching 7.8°C by 2100.[12,13]

Assessing other countries' effort

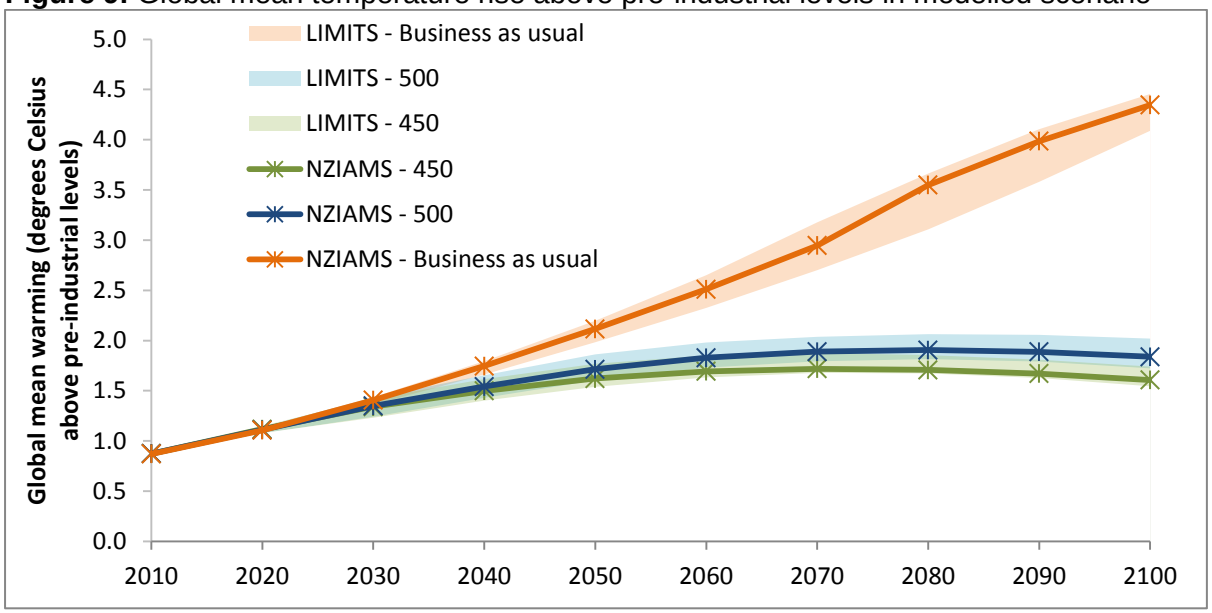
For comparing effort relative to 2°C, two cost-effective pathways are constructed to help assess each country's effort. This analysis utilises emissions pathways modelled by Landcare Research (2015) using the New Zealand Integrated Assessment Modelling System (NZIAMS) (Figure 8 below).

[11] Based on an emissions pathway consistent with representative concentration pathways (RCPs) 4.5 and 6 from the fifth assessment report of the Intergovernmental Panel on Climate Change (2014). Temperature outcomes are the mean outcome from scenarios with carbon dioxide equivalent concentration of 580-650 parts per million in 2100 (low estimate) and 720-1000 parts per million in 2100 (high estimate). The full range of temperature outcomes based on the 10th and 90th percentile of results from RCP 4.5 and 6 is 1.5^{o}C to 5.8^{o}C.

[12] Based on emissions pathways consistent with RCP 8.5 from the fifth assessment report of the Intergovernmental Panel on Climate Change (2014).

[13] Estimates of "business-as-usual" temperature rise at 2100 vary between literature sources due to different assumptions about emissions pathways, and ongoing updates to climate models. Temperature rise estimates also vary from region to region due to localised effects differing from the global average.

Figure 9: Global mean temperature rise above pre-industrial levels in modelled scenario

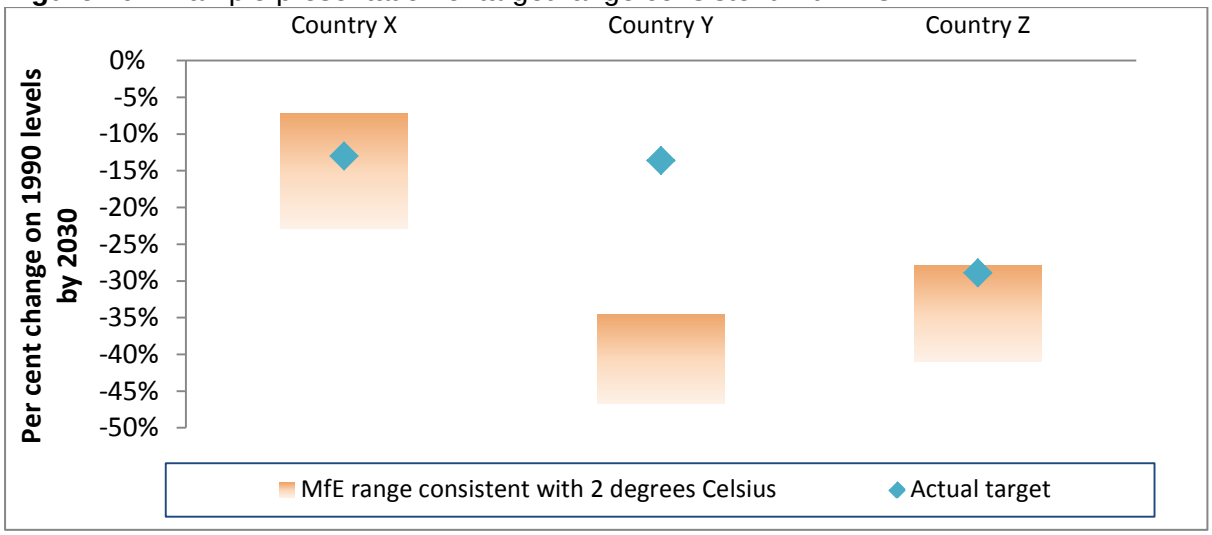


Source: Landcare Research, 2015; Kriegler et al., 2013.

Two emissions pathways are modelled. The weaker 2°C scenario is based on the "500" scenario of the LIMITS study (Krieglar et al., 2013). This scenario is consistent with a 41 to 66 per cent chance of limiting temperature rise to 2°C. The stronger 2°C scenario is based on the "450" scenario of the LIMITS study. This scenario is consistent with a 59 to 79 per cent chance of limiting temperature rise to 2°C. Both scenarios assume the availability of negative emissions technologies (eg, bioenergy with carbon capture and storage) in the second half of the century – however these technologies are not taken up in the NZIAMS scenarios.

Based on these cost-effective pathways, the fair share indicators are used to determine each country's target in the year 2030. Indicators are presented as a range, with dark orange signifying a target level roughly consistent with the "500" scenario, and light orange signifying a target level roughly consistent with the "450" scenario (see Figure 9 below). Actual announced targets are indicated with a light-blue diamond.

Figure 10: Example presentation of target range consistent with 2°C

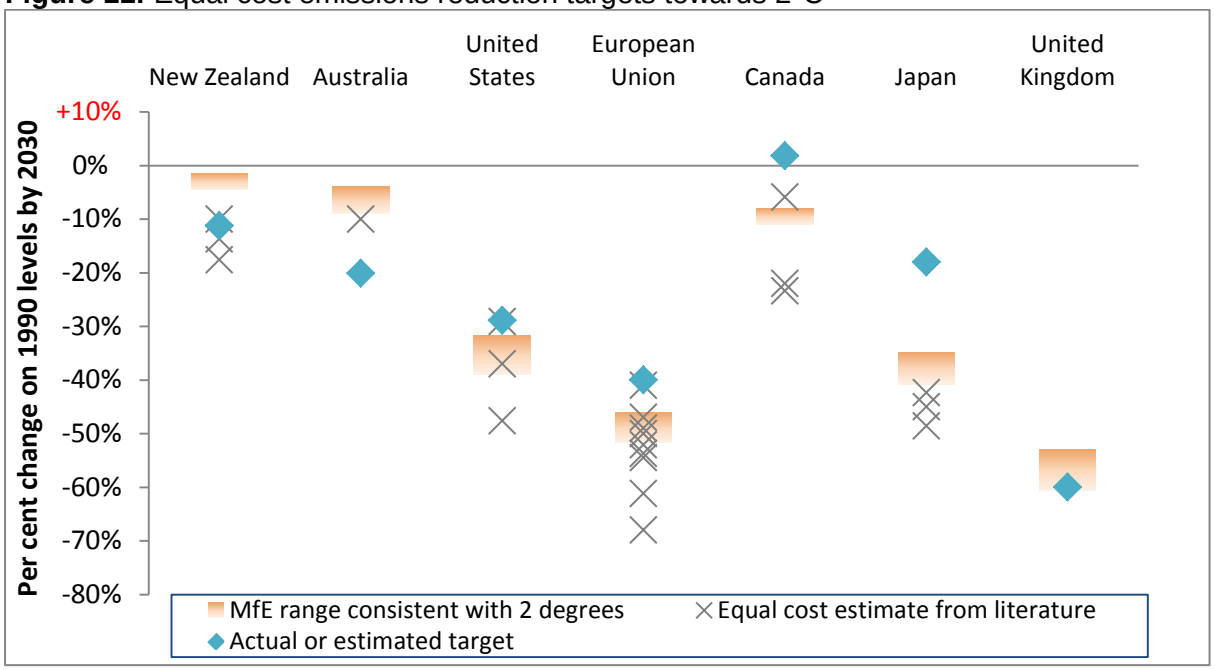


Equal cost indicator

Of the countries examined, only the United Kingdom and Australia's (hypothetical) targets are consistent with limiting temperature rise to below 2°C under the equal cost indicator.

There is strong evidence suggesting that the United States, Canada and European Union's targets are not consistent with 2°C under the equal-cost indicator. Multiple literature sources suggest that the European Union's target would need to be in the order of 45 to 60 per cent below 1990 levels by 2030 to be consistent with 2°C. For the United States, Japan and Canada, the equal cost indicator also suggests that more ambitious targets are needed.

Figure 11: Equal cost emissions reduction targets towards 2°C



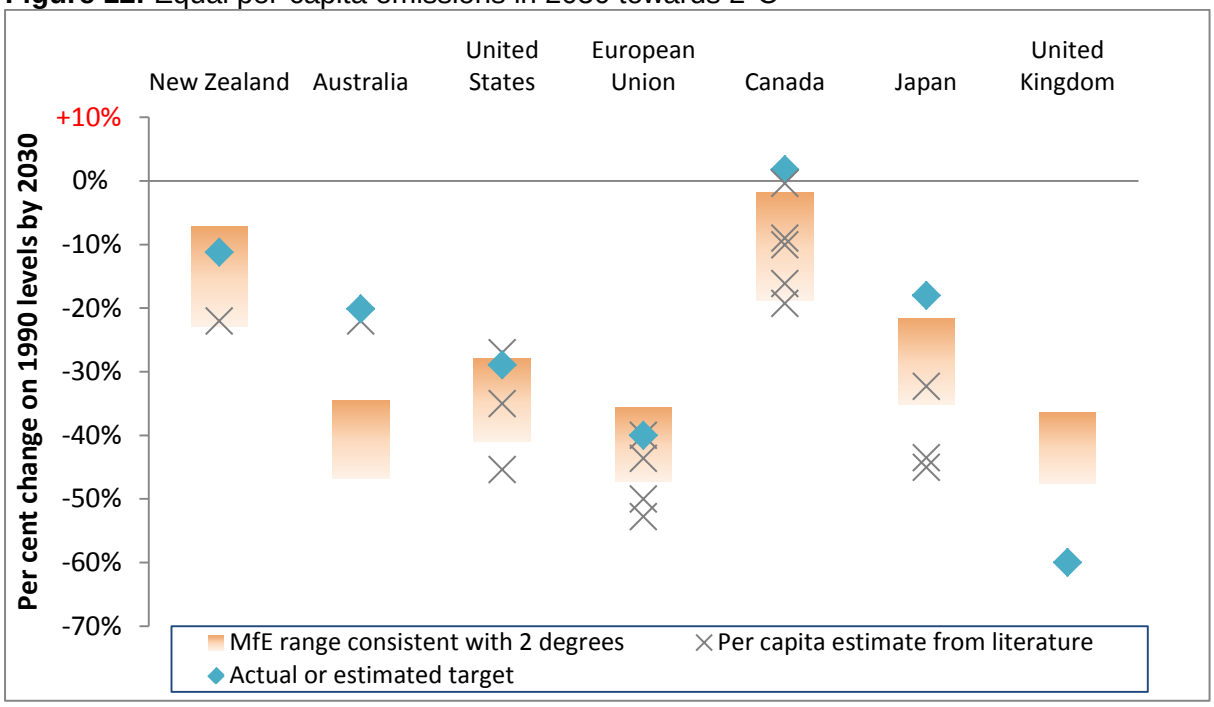
Source: Ministry for the Environment; Kriegler et al., 2013; Tavoni et al., 2013; Stern, 2013; Ecofys, 2013; PBL, 2012; Averchenkova, 2014.

While the Ministry for the Environment's range for each country (in orange) is relatively modest (including for New Zealand). It should be noted that this analysis presumes that *all* countries worldwide take a target featuring the same level of mitigation cost relative to their GDP in 2030. Other equal cost analysis (for example PBL, 2012) makes the assumption that high income countries spend up to three times as much as low income countries relative to their GDP, resulting in somewhat deeper targets recommended for high income countries including New Zealand.

Equal per-capita emissions indicator

Of the countries examined, the targets of the United States, United Kingdom, and European Union are within the range consistent with limiting temperature rise to below 2°C under the equal per-capita indicator. In contrast, Australia's target is significantly below what would be expected of it. Canada and Japan's targets are also below what would be expected of them based on this indicator.

Figure 12: Equal per-capita emissions in 2050 towards 2°C

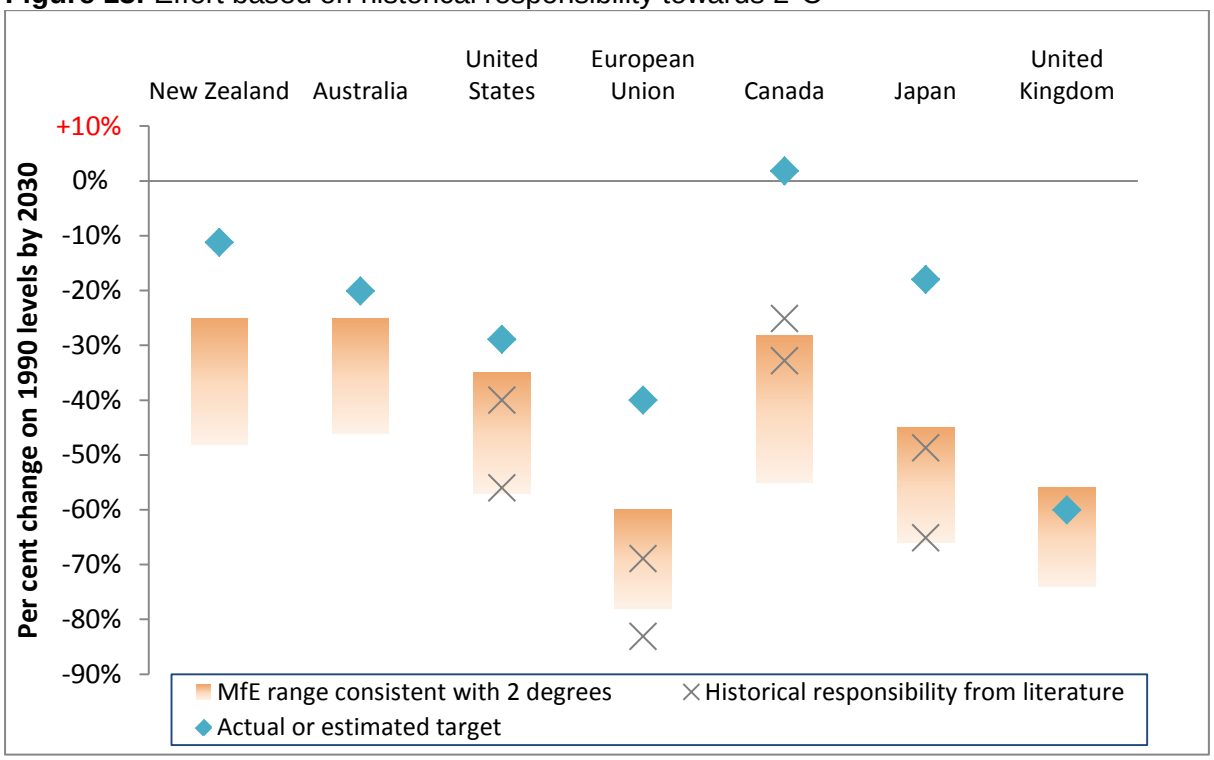


Source: Ministry for the Environment; PBL, 2012; United Kingdom Government, 2013, Averchenkova et al., 2014.

Historical responsibility indicator

Of the countries examined, only the United Kingdom's examined target is consistent with the range needed to reach 2°C under the historical responsibility indicator.

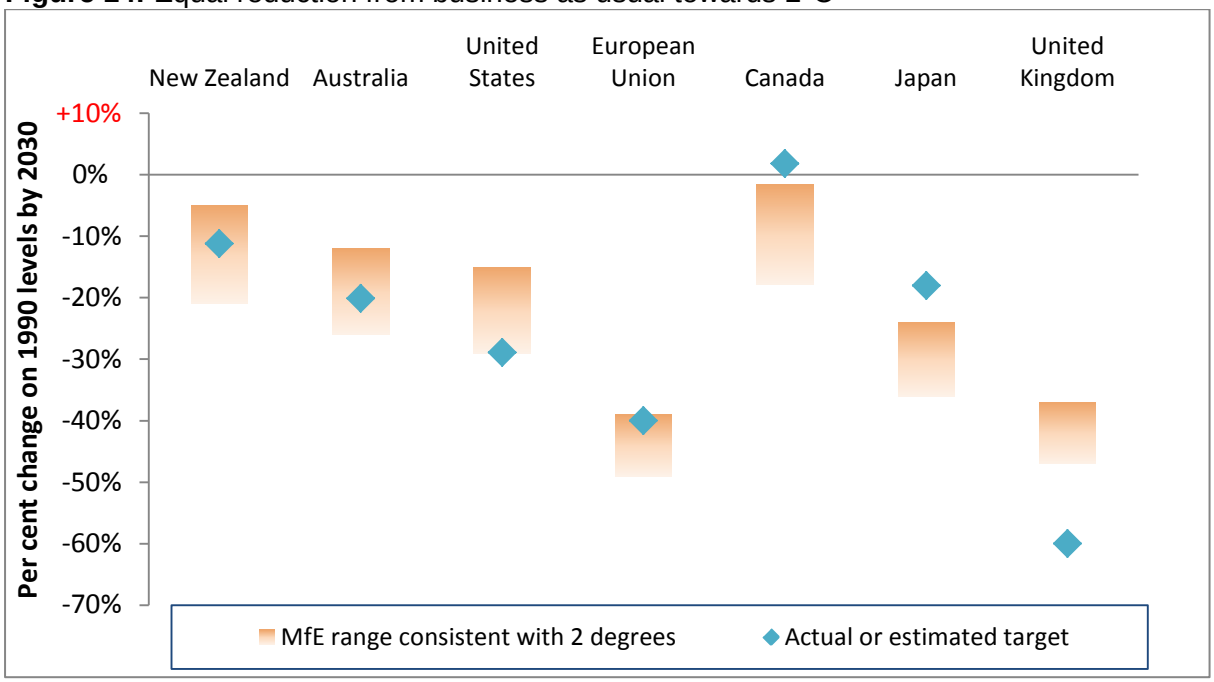
Figure 13: Effort based on historical responsibility towards 2°C



Source: Ministry for the Environment; Averchenkova et al., 2014.

Of the countries examined, the targets of the United States, Australia, European Union, and United Kingdom are consistent with the range needed to reach 2°C under the reduction from business as usual indicator. In contrast, Japan and Canada are below the range that would be expected of them. The target recommended for New Zealand is relatively low, reflecting New Zealand's growing baseline GHG emissions when climate change policies are not in place.

Figure 14: Equal reduction from business as usual towards 2°C

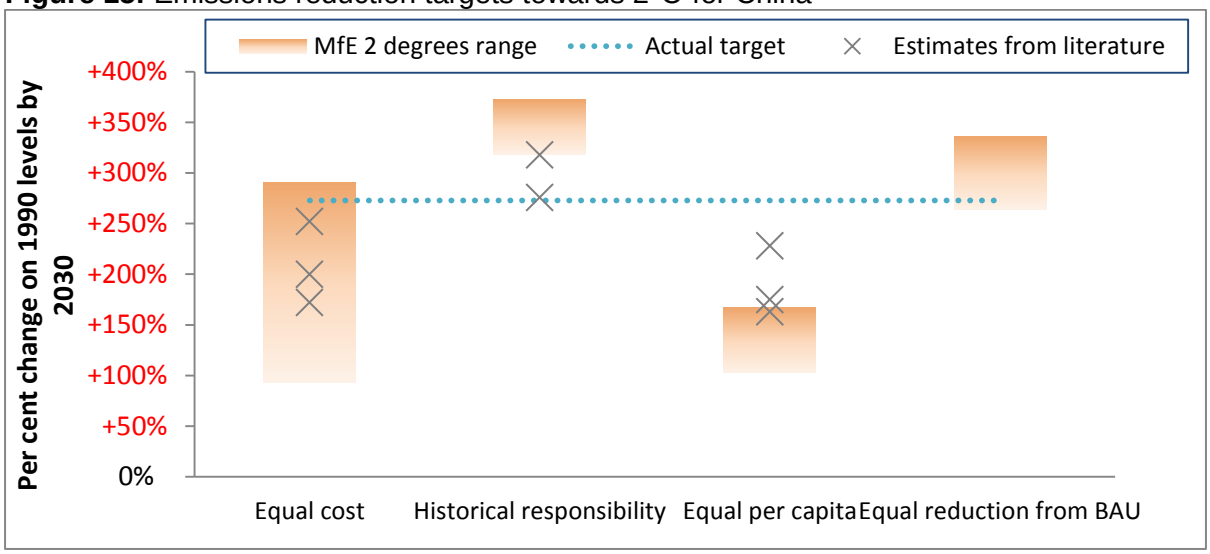


Source: Ministry for the Environment; Kriegler et al., 2013; Landcare Research, 2015; United Nations Framework Convention on Climate Change, 2015; Department of the Environment, 2015.

Assessing China's target

China's CO_2 target consistent with 2°C under each fair share indicator is shown in Figure 14 below. China's current target is assessed to be 273 per cent above 1990 levels (see Appendix 3). China's target is seen as ambitious against the historical responsibility and reduction from business as usual indicators. The equal per-capita indicator suggests that a deeper target is needed for China's target to be consistent with 2°C. However analysis of the per-capita indicator (Climate Change Authority, 2014) has found that it is particularly stringent on middle income and developing countries with rapidly rising greenhouse gas emissions, such as China.

Figure 15: Emissions reduction targets towards 2°C for China

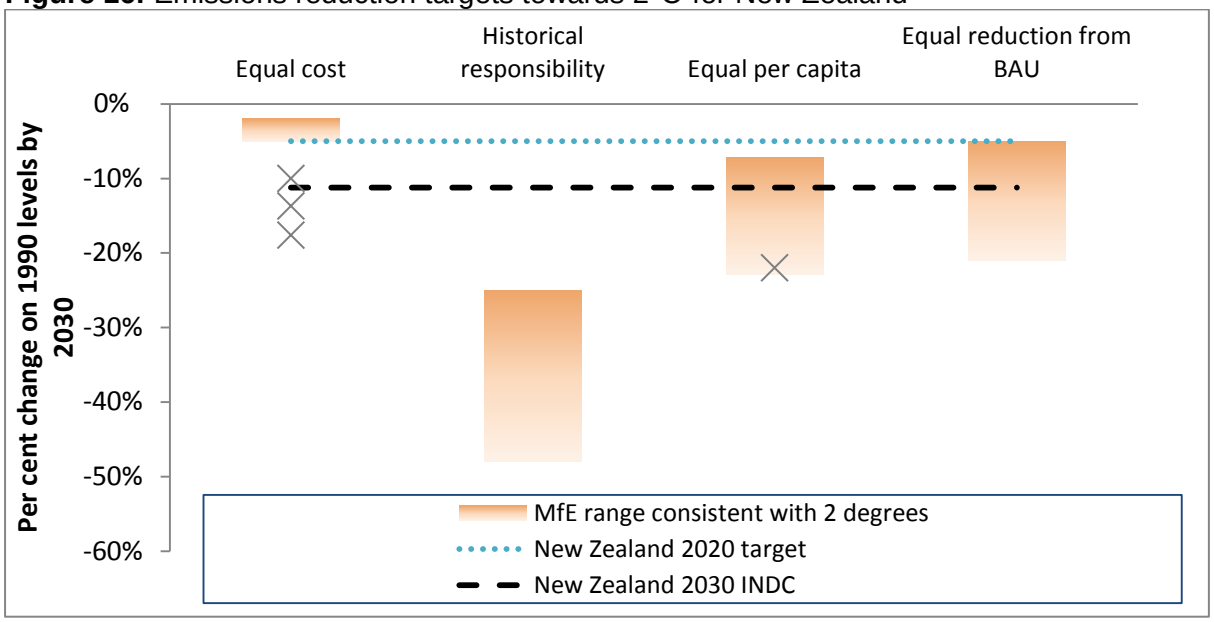


Source: Ministry for the Environment; Zhang et al., 2014; PBL, 2012; Averchenkova, 2014.

Assessing New Zealand's fair share

New Zealand's target at 2030 consistent with 2°C under different effort-sharing perspectives is shown in Figure 15 below. All indicators support the need for a headline number set below 1990 levels. However, only the historical responsibility indicator supports a target in the range of 40 per cent below 1990 levels (as previously recommended by a large number of stakeholders during consultation on New Zealand's 2020 target).

Figure 16: Emissions reduction targets towards 2°C for New Zealand[14]



Source: Ministry for the Environment; PBL, 2012.

[14] Information in this graph has been updated to incorporate New Zealand's 2030 INDC (shown as a black dashed line).

Other literature estimates of fair share

Communication of fair share indicators featured in this paper may help to justify New Zealand's target from the perspective of domestic and international stakeholders, and to help debunk the belief that high income countries should match the headline number of their peers. However it must be recognised that a number of assumptions are involved with any fair share indicator, and that these may be subject to criticism where stakeholders believe a particular assumption is unfair.[15]

Other engaged stakeholders (internationally and domestically) are likely to use different indicators to assess each country's fair share. New Zealand's target, regardless of the level, is unlikely to be seen as "ambitious" according to every indicator due to the wildly varying results produced by each indicator.

[15] For example, some stakeholders (Boyd et al., 2015) have critiqued the assumption of negative emissions technologies becoming available in the second half of the century.

References

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Appendices

Appendix 1: Additional uncertainties and limitations for equal cost analysis

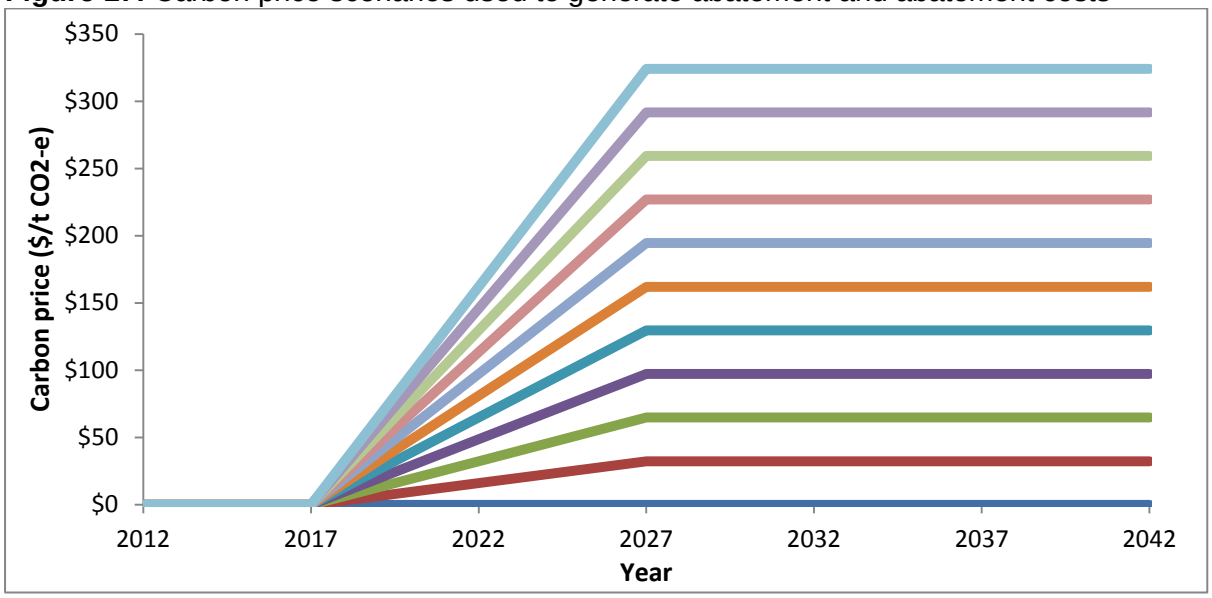
Indicators are very sensitive to the model and assumptions used to calculate the indicator. Using different models or assumptions may significantly change relative results. For example, in a six-model study of scenarios consistent with 2°C under an equal cost approach, the recommended target at 2030 for Europe (as a whole) varies from approximately 30 per cent to 60 per cent below 2010 levels depending on the model used (Tavoni et al., 2013, p. 18). For North America (as a whole), this range varies from approximately 30 per cent to 90 per cent below 2010 levels.

As the analysis of New Zealand's target in this paper uses *one* model, results and their interpretation are potentially subject to model-bias. The target range provided for each country should not be taken as an exhaustive range covering all possible results. Using alternative models may lead to results outside the range provided, and there are little grounds for determining which result is more "accurate."

Comparisons are also subject to bias due to the carbon price assumed. For example, fixing one country's target while moving the carbon price can result in a wide range of results for the comparator country's target. To overcome this limitation, targets based on equal cost have been provided as a range when comparing to other countries, based on carbon prices ranging from $50 to $80 (2012 NZD). For equal cost comparisons based on the 2°C global goal, a carbon price range of approximately $75 to $95 (2012 NZD) has been used based on modelling by Landcare Research (2015).

Abatement in a given year is also sensitive to abatement achieved in preceding years due to the long lifetimes of many forms of capital stock (eg, a hydro power plant). As a result, the cost of abatement in 2030 for each region is sensitive to the carbon price path assumed. Levels of abatement and the associated cost are based on data provided by Landcare Research (2015), and are built using the carbon price paths shown in Figure 17 below.

Figure 17: Carbon price scenarios used to generate abatement and abatement costs



Source: Landcare Research, 2015.

All equal cost comparisons **exclude forestry abatement potential**. If forestry abatement potential was included, the effect on the equal cost comparison would depend on the relative forestry abatement potential in each country. If New Zealand had proportionally greater cheap forestry abatement potential than the comparator country, this would lead to more stringent targets being recommended for New Zealand. If New Zealand had proportionally less cheap forestry abatement potential, this would lead to less stringent targets being recommended for New Zealand.

Equal cost comparisons also depend on the forestry rules assumed for each country. For New Zealand these rules have a significant effect due to the large size of forestry removals relative to gross greenhouse gas emissions.

It is unlikely that the stylised assumptions made to determine an “equal cost” target will hold in reality. For example, it is likely that technological development will differ from that modelled, which will have the effect of creating winners and losers, and negating the ability to empirically match other countries in terms of cost.

Appendix 2: A cost benefit analysis of 2°C

This section explores the expected costs and benefits of action to reduce greenhouse gas emissions in an attempt to contextualise the targets recommended by this paper.

This section does not seek to examine moral, cultural, environmental or other arguments for acting on climate change. The choice of "discount rate"[16] is also not explored, an issue on which a small change in the value used (eg, from a 5 per cent discount rate to an 8 per cent discount rate) can lead to vastly different conclusions. There is a wide body of literature on the use of discount rates for climate change policy analysis.

In 2010, **world leaders agreed on a target to limit global temperature increases to below 2 degrees Celsius (2°C).** This will require substantial and sustained reductions in greenhouse gas emissions by all countries. A compilation of the best scientific and economic modelling available today suggests that global greenhouse gas emissions will need to reach 40 to 70 per cent below 2010 levels by 2050, and net-zero or net-negative at 2100 to have a likely chance of limiting temperature rise to below 2°C.

Limiting temperature rise to below 2°C will involve mitigation costs over this century. Modelling by Landcare Research (2015) suggests that global aggregate costs could reach 1.4 to 2.3 per cent of GDP by 2030, and 3.8 to 5.0 per cent of GDP by 2050 in cost-effective pathways that limit temperature rise to below 2°C.

There are also co-benefits to some types of greenhouse gas emissions mitigation (eg, to air quality and energy security). These are not quantified within the models used to calculate the costs of mitigation, and may be substantial.[17] These models also neglect economic spill-over benefits, whereby the costs of greenhouse gas mitigation technologies reduce as a result of global action on greenhouse gas emissions (Aghion, 2014).

The primary economic benefit from acting on greenhouse gas emissions comes via a reduction in damages from climate change impacts, and a reduction in the costs of climate change adaptation (eg, building sea walls that would otherwise not be needed).

The economic damage of climate change impacts is very uncertain, but is estimated to increase rapidly at temperature increases beyond 2.5°C (IPCC, 2013). A number of impacts have not been fully quantified (eg, species extinction due to ocean acidification, and the potential for environmental tipping points). Incorporating these additional impacts can substantially increase the benefits of avoided damages (Lontzek et al., 2015).

There are many other costs and benefits from a changing climate and temperature that are not fully incorporated in any analysis of global damages from climate change impacts. For example, a shift in climate towards higher temperatures could see parts of New Zealand become less suitable for pastoral agriculture and more suitable for tropical or Mediterranean fruit and crops. Such a change would have a vast array of costs and benefits, including changes to regional employment levels, capital investment required, environmental externalities and impacts to New Zealand's terms of trade as examples.

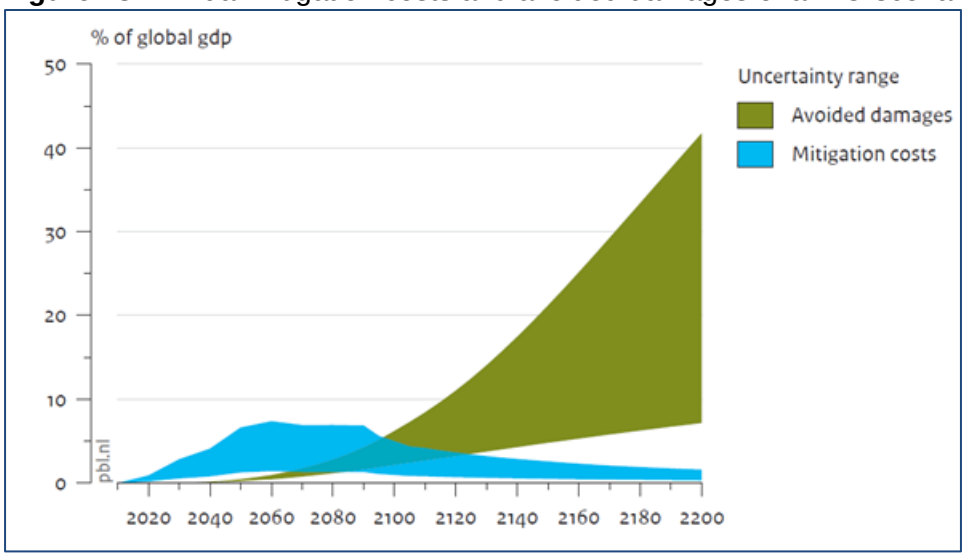
[16] The rate at which future costs are discounted, based on the idea that money in hand today is worth more than the same amount of money in hand in future.

[17] For example, benefits reaching up to 40% of mitigation costs for stringent scenarios towards 2°C (GEA, 2012; McCollum et al., 2013).

Costs and benefits of climate change to individual countries may differ substantially, and relative economic damage from climate change impacts are likely to be higher (on average) in least developed countries than the global average (PBL, 2014).

Though noting the limitations discussed above, the global benefits of avoided damages (undiscounted) are expected to significantly outweigh[18] the costs of mitigation in the long term (Figure 16).

Figure 18: Annual mitigation costs and avoided damages of a 2°C scenario



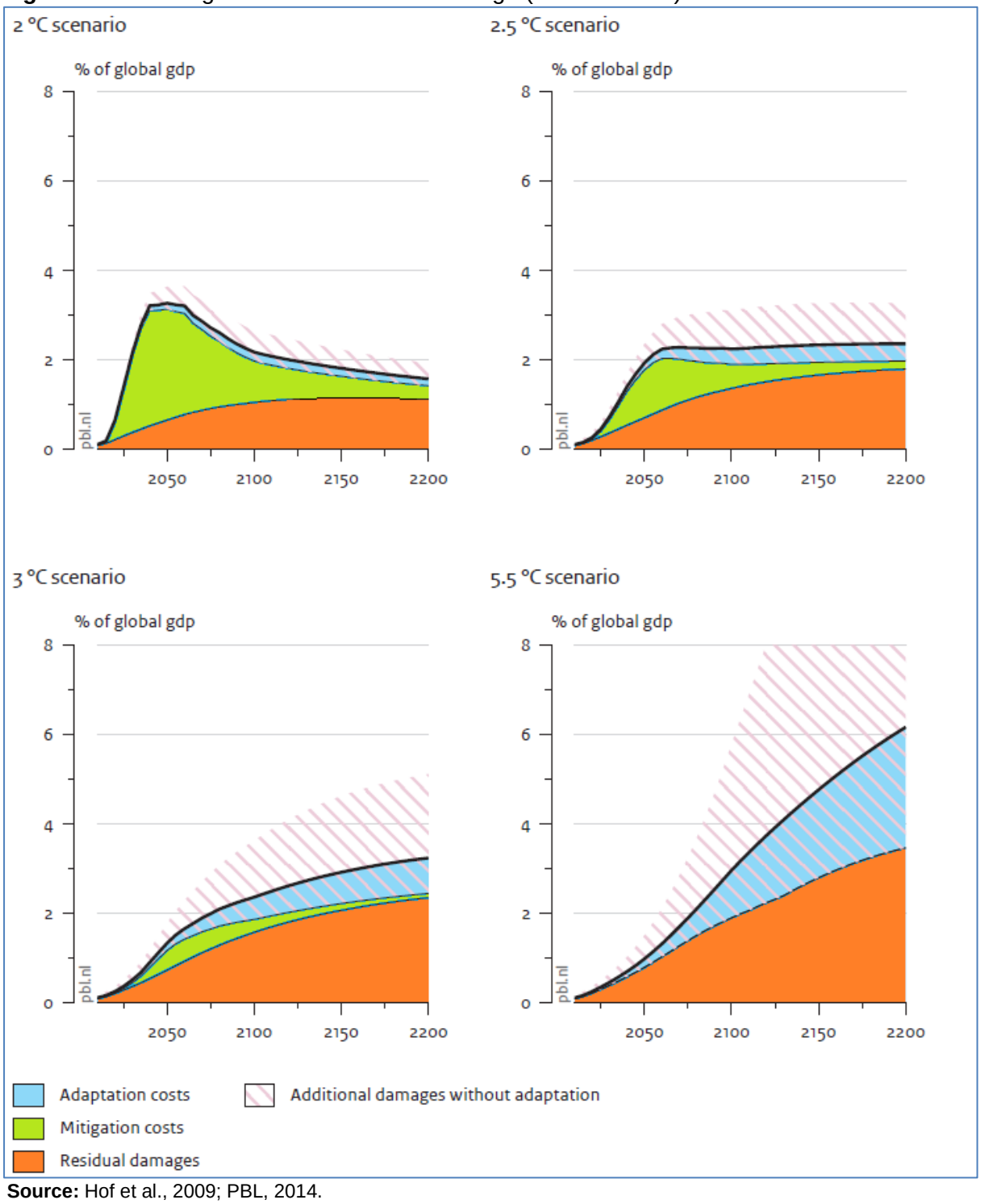
Source: Kriegler et al., 2013; Nordhaus & Sztorc, 2013; Weitzman, 2012; PBL, 2014.

Though mitigation costs are significant relative to global GDP over this century, scenarios consistent with 2°C still see global consumption and GDP grow significantly over the century, with the underlying growth trend remaining strong (IPCC, 2014, p. 449).

Global annual costs from mitigation, impacts and adaptation combined, are **lowest by the end of the century in scenarios consistent with 2°C, and incrementally higher in scenarios heading towards 2.5°C, 3°C, and 5.5°C respectively at 2100** (Figure 17).

[18] The large range in potential benefits of avoided damages comes from uncertainties in the actual economic costs of climate change impacts, and the temperature outcome of a given greenhouse gas emissions pathway.

Figure 19: Annual global costs of climate change (undiscounted)[19]



Source: Hof et al., 2009; PBL, 2014.

Who bears the cost of limiting temperature rise to 2°C

The costs of reducing greenhouse gas emissions (mitigation costs) will not be identical across countries. Costs will vary substantially between regions if there are no financial transfers between countries through climate finance or international carbon markets. For

[19] Residual damage is damage from climate change impacts after factoring in that some impacts are negated by adaptation.

example, in scenarios consistent with limiting temperature rise to 2°C, mitigation costs are half the global average for OECD countries, twice the global average for economies in transition, and over twice the global average for Middle East and African countries (IPCC, 2014). As there are likely to be outliers within each region, relative costs between countries will differ to an even greater degree.

Countries will be impacted both by what they do in terms of their own policies to reduce greenhouse gas emissions, and the level of action other countries take to reduce greenhouse gas emissions. For example, the economic growth of fossil-fuel exporting countries, such as Australia and Saudi Arabia, stands to be heavily impacted by the actions of other countries on climate change due to a decreased demand for fossil fuels and fossil-fuel intensive goods. In a scenario of global action on climate change resulting in a unified global carbon price of just over $50, modelling by Landcare Research (2015) suggests Australia's decrease in GDP may be around three to four times the global average drop in GDP at 2030, prior to international trading of carbon units.

New Zealand is expected to see a fairly sizable drop in GDP (and gross national disposable income) from other countries implementing measures to reduce greenhouse gas emissions.[20]

However, New Zealand is not as significantly impacted as countries like Australia and Saudi Arabia.[21] Modelling by Landcare Research (2015) confirms that in scenarios consistent with limiting temperature rise to 2°C and in which there is no financial transfers, New Zealand's GDP will not be impacted by as much as the global average. In scenarios consistent with 2°C, the global average drop in GDP at 2030 ranges from 1.8 to 2.3 per cent of GDP, compared with 0.8 to 0.9 per cent of GDP for New Zealand. However these scenarios would still see New Zealand with *domestic* greenhouse gas emissions in the order of 10 per cent above 1990 levels at 2030 (assuming a modest contribution of between 1 to 5 million tonnes of forestry abatement per year).

Many other high income countries are likely to see even less impact to GDP from global climate change policy *where they do not use financial transfers*. For example, the European Union's current 2030 target is estimated to have an impact of between 0.1 to 0.5 per cent of GDP (PBL, 2014). At present, the European Union, United States, and Japan have not stated an intention to use international carbon markets to meet their post-2020 targets.

[20] While New Zealand could mitigate the impact to GDP in the short term by opting to purchase international carbon offsets and not pricing its domestic greenhouse gas emissions, such a policy would increase the cost of achieving future targets and increase the cost of pricing greenhouse gas emissions in future (undiscounted).

[21] In general, as a rule of thumb, larger costs to GDP of global climate change policy are borne by (IPCC, 2014, p. 456-457):

- countries with higher levels of abatement (relative to baseline),
- countries with higher emissions intensities at present,
- fossil fuel energy exporting countries, who will be unfavourably impacted by terms of trade effects from mitigation policy,
- countries with larger and rising "business-as-usual" emissions.

Appendix 3: Estimating the effort of China's post-2020 target

China has a target of peaking carbon dioxide emissions by 2030. This has been estimated by the Ministry for the Environment (the Ministry) to equate to 273 per cent above 1990 levels, or 7 per cent above 2010 levels by 2030.

The baseline emissions pathway for China's CO_2 and abatement cost curve has been sourced from Landcare Research (2015). Baseline emissions have been calibrated to match Zhang et al., (2014), using the China-in-Global Energy Model (C-GEM). Zhang et al., see CO_2 emissions reach 16.5 billion tonnes of $CO_{2\text{-}e}$ by 2030 in a "business-as-usual" baseline.

In scenarios consistent with peaking CO_2 emissions by 2030, Zhang et al., (2014), project CO_2 emissions of 10.2 billion tonnes of $CO_{2\text{-}e}$ by 2030. This implies a policy effort of ~6.3 billion tonnes from the "business-as-usual" baseline, or a percentage reduction from baseline of 38.2 per cent.

CO_2 emissions from Landcare Research (2015) for China in 2030 are 14.1 billion tonnes of $CO_{2\text{-}e}$. The percentage reduction from Zhang et al., (2014), 38.2 per cent, is applied to CO_2 emissions from Landcare Research to calculate the implied emissions limitation target.

China's CO_2 emissions are subject to large degrees of uncertainty as China GHG inventory processes are less developed than for developed countries such as New Zealand and Australia. As such there is inherently a greater degree of uncertainty around China's target when using effort-sharing indicators.

Appendix 4: Assessment of countries INDCs versus progression

An important concept to various stakeholders in assessing countries' INDCs has been that of "progression." The broad concept of progression is that countries take targets that do not move backwards on previous commitments taken by that country in terms of target form, level and coverage of greenhouse gas emissions.

A simple assessment of the progression of tabled INDCs to date is provided based on the following criteria:

- **Target level** - *lower* than previous targets expressed against the same base year.
- **Target form** - moves in stringency from policies and measures, to intensity targets, to absolute single-year targets, to carbon budget targets.
- **Coverage of emissions** - increased coverage of emissions. If forestry classes (eg, grassland) are previously included within target, then they remain included.

An assessment by the Ministry is provided in Table 3 overleaf. Progression for each country is shown in **green**, unclear indicators are shown in **orange** and backsliding is shown in **red**.

Based on the Ministry's assessment, **all INDCs tabled or announced to date represent progression on previous undertakings**. The only possible exception to date is Japan's target, in which it is currently unclear whether the target is underpinned by a carbon budget or is a single-year target. Canada's target form is not categorised given its shift in forestry and land use rules from gross-net accounting to net-net accounting – which is difficult to assess according to the progression concept. Despite the shift in forestry and land use rules – Canada's target still represents progression in target level after adjusting for forestry and land use rules.

The lowest coverage of greenhouse gas emissions assessed in this paper is China's currently announced carbon dioxide target. This represents at least 80 per cent of China's present day GHG emissions. This could increase in China's tabled INDC if it takes targets covering other greenhouse gases. Other non-Annex I countries have taken targets covering approximately 98 to 100 per cent of their emissions profiles. In general, sectors or gases excluded from their targets have been minute sources that are likely to have high inventory measurement and reporting costs relative to the value and amount of greenhouse gas emissions that are not covered.

Russia and Mexico, who have previously only outlined conditional targets, have scaled back on conditions or taken an unconditional target. Russia has set a target predicated on recognising full forestry abatement from its forestry and land use sector, as was done with its 2020 target. Russia also set its 2020 target based on *legally binding* emission reduction targets being undertaken by *all* major emitting countries, but now drops this as an explicit condition and now states in the preamble of its INDC:

> *"However, the final decision of the Russian Federation on the INDC in the framework of the new climate agreement will be taken pursuant to the outcome of the negotiating process underway throughout the year of 2015 and the INDCs announced by major emitters of greenhouse gases."* (UNFCCC, 2015).

Table 3: Indicators of progression

Country	Target	Emissions coverage	Target level on same base year	Form	% reduction per year from 2020 to target
European Union	40% below 1990 levels by 2030	**100%**	**Lower**	**Same**	**2.8%**
Switzerland	50% below 1990 levels by 2030	**100%**	**Lower**	**Same**	**4.5%**
Norway	40% below 1990 levels by 2030	**100%**	**Lower**	**Same**	**2.5%**[22]
United States	26-28% below 2005 levels by 2025	**100%**	**Lower**	**Same**	**2.3 to 2.8%**
Canada	30% below 2005 levels by 2030	**100%**	**Lower**	**From gross-net to net-net**	**1.7%**
Japan	26% below 2013 levels by 2030	**100%**	**Lower**	**Unclear**	**2.3 to 2.5%**
China	CO_2 emissions peak by 2030	**>80%**	**n/a**	**Intensity to absolute**	**n/a**
Morocco	13% below BAU in 2030	**99.7%**	**n/a**	**First GHG target**	**n/a**
Andorra	37% below BAU in 2030	**98.5%**	**n/a**	**First GHG target**	**n/a**
Gabon	50% below BAU in 2025	**~99%**	**n/a**	**First GHG target**	**n/a**
Mexico	22% below BAU in 2030	**100%**	**n/a**	**Conditional to unconditional**	**n/a**
Liechtenstein	40% below 1990 levels by 2030	**100%**	**Lower**	**Same**	**n/a**
Russia	25-30% below 1990 levels	**100%**	**Lower**	**Softening of conditions**	**Unclear**

Source: Ministry for the Environment; modelling by Landcare Research; Climate Action tracker, 2015; World Resources Institute, 2015; United Nations Framework Convention on Climate Change, 2015.

[22] Based on 2013-2020 quantified emission limitation or reduction objective (QELRO).

Appendix 5: Brief description of each fair share indicator

Four indicators are used to assess fair share. A brief explanation of each indicator and its key assumptions are described below.

Equal cost between countries

The equal cost indicator has been generated using the Ministry for the Environment's "*Comparing Emission Reduction Target Tool."* Data used in the tool to calculate the cost of each country's targets is provided by Landcare Research.

The equal cost indicator is based on the area under the marginal abatement cost curve for each country. Hence, the cost is based on an estimate of the direct cost of mitigation, excluding any flow-on economic impacts, co-benefits and adverse side-effects.

Equal per-capita emissions in 2050

The equal per-capita emissions indicator is based on the contraction and convergence method conceived by the Global Commons Institute. The start date for the indicator is defined as 2013, and the year of convergence for per-capita GHG emissions is defined as 2050.

Global GHG emissions in 2030 and 2050 in scenarios consistent with 2°C are based on the LIMITS study scenarios within the IPCC fifth assessment report scenario database (IPCC, 2014).

GHG emissions allowances for the period 2021 to 2050 are adjusted based on countries' targets covering the period 2013 to 2020. A country that has taken a 2020 target that is more stringent than its emissions allocation from the contraction and convergence metric receives carryover 'credit' to the period 2021 to 2050.[23] The reverse is also true for countries who take targets less stringent than they would take according to the contraction and convergence metric. This adjustment helps to credit countries who have taken strong action out to 2020, and debits countries who have taken weak or no action out to 2020.

Historical and projected GHG emissions for each country are based on their chosen forestry rule-set, with countries either being judged on a gross-gross basis (eg, the European Union and New Zealand), or a net-net basis (eg, the United States and Australia).

Equal effort based on historical responsibility

The historical responsibility indicator is based on the Brazilian proposal, whereby countries future effort is based on their historical share of GHG emissions. This has been applied whereby a countries' share of the global mitigation effort at 2030 (from business as usual levels) is based on its share of global GHG emissions over the period 1990 to 2012. For example, if New Zealand was responsible for 0.15 per cent of global GHG emissions over

[23] This carryover 'credit' is distributed evenly across the period 2021 to 2050. For example, a country that took a 2020 target that was 30 million tonnes of carbon dioxide equivalent less than its allocation according to contraction and convergence would receive an additional allocation of 1 million tonnes of carbon dioxide equivalent per year from 2021 to 2050.

the period from 1990 to 2012, it would be responsible for taking on 0.15 per cent of the cumulative global GHG emissions reductions at 2030.

Global GHG emissions in 2030 in scenarios consistent with 2°C are based on the LIMITS study scenarios within the IPCC fifth assessment report scenario database (IPCC, 2014).

Countries historical GHG emissions are based on their chosen forestry rule-set, with countries either being judged on a gross-gross basis (eg, the European Union and Japan), or a net-net basis (eg, the United States and Australia).

Equal reduction from business as usual (BAU)

The equal reduction from BAU indicator suggests that each country should take on an equivalent percentage reduction from its business as usual (without climate change policies and measures) GHG emissions level in 2030.

Global GHG emissions in 2030 in scenarios consistent with 2°C are based on the LIMITS study scenarios within the IPCC fifth assessment report scenario database (IPCC, 2014).

Historical and projected GHG emissions for each country are based on their chosen forestry rule-set, with countries either being judged on a gross-gross basis (eg, the European Union and Japan), or a net-net basis (eg, the United States and Australia).