3

A GLOBAL EMISSIONS BUDGET FOR 2 DEGREES OR LESS

As established in Chapter 2, limiting the global temperature rise to below 2 degrees provides clear benefits to Australia.

Achieving this goal is challenging, but it remains technologically and economically feasible. All countries—in particular, major emitters—will have to take strong action to reduce their emissions to a level consistent with the 2 degree goal. A global emissions budget can be used to define the limit on emissions that is consistent with this goal. Australia's emissions reduction goals should therefore be considered in the context of a global budget.

Global emissions budgets specify the total amount of emissions that the world could release over a period of time that is consistent with a given rise in global temperature. The budgets are expressed in terms of probabilities to reflect uncertainties about the exact temperature effect of a given amount of greenhouse gases. A tighter global budget reduces the amount of emissions that can be released and provides a higher probability of keeping global warming to 2 degrees or less.

The Authority uses a global emissions budget that provides a likely chance (67 per cent probability) of limiting warming to 2 degrees or less as a reference point for this Review. This limits the amount of greenhouse gas emissions that can be released (as covered by the Kyoto Protocol) to a budget of approximately 1,700 gigatonnes of carbon dioxide equivalent (Gt CO_2-e) between 2000 and 2050. About 36 per cent of this budget had been used up between 2000 and 2012.

The Authority is required, under section 289 of the Clean Energy Act, to consider estimates of the global greenhouse gas emissions budget. A global emissions budget sets out the total amount of global emissions consistent with the aim of limiting warming to a specific temperature target. It does not dictate a particular emissions pathway, so long as the budget is not exceeded. This chapter examines global emissions budgets, including:

- whether limiting global warming to less than 2 degrees above pre-industrial levels remains feasible, and the scope and timing of action required to maintain a global emissions pathway consistent with that limit
- what budgets are consistent with a given probability of limiting temperature increases to below 2 degrees, including their characteristics and the greenhouse gases they cover
- the global emissions budget used in the Targets and Progress Review to inform the national budget, targets and trajectories (chapters 8 and 9).

3.1 FEASIBILITY OF LIMITING GLOBAL WARMING TO 2 DEGREES OR LESS

Avoiding the worst impacts of climate change will require strong international action to reduce emissions. For the Targets and Progress Review, the Authority has accepted Australia's interest in limiting global warming to below 2 degrees. This is consistent with the global goal agreed by the international community. It has also been adopted by other organisations, including the United Kingdom Committee on Climate Change and the German Advisory Council on Global Change, as a starting point in their consideration of national emissions reduction goals.

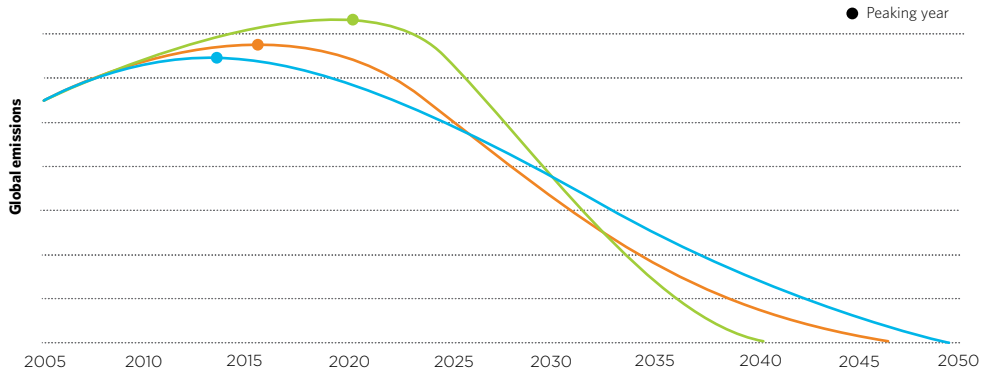
Two critical questions for policy-makers are whether a 2 degree temperature limit remains feasible, and the scope and timing of action required to maintain an emissions pathway consistent with that limit. Global emissions are currently tracking towards the upper bound of projections, on a pathway consistent with a 4 degree increase in global average temperature by 2100 (World Bank 2012, p. xiii). Analysis by the United Nations Environment Programme (UNEP) finds that it is still technically feasible to limit temperature rises to below 2 degrees (UNEP 2012, pp. 1–7). UNEP's analysis, as well as the level of global action, is discussed in more detail in Chapter 4.

The longer emissions reductions are delayed, the faster the available global emissions budget will be used up, requiring greater efforts to reduce emissions in future and eventually ruling out the possibility of limiting warming to 2 degrees or less. The literature on feasible 2 degree pathways finds that they have several important characteristics in common (Rogelj et al. 2011; UNEP 2012):

- **Early emissions reductions**—a near-universal finding is that early action is critical to limit future costs and maintain the feasibility of limiting temperature increases. Many studies point to the importance of global emissions peaking by 2020 (for example, see Rogelj et al. 2012). Delaying emissions reductions:
  - increases the rate of emissions reductions ('decarbonisation rates') that will be necessary in the future
  - increases costs of meeting emissions targets
  - reduces flexibility in choosing how to reduce emissions
  - increases reliance on the development and commercialisation of currently speculative technologies to achieve net negative emissions (see, for example, Rogelj et al. 2013).

Figure 3.1 shows illustrative emissions trajectories that result in the same amount of cumulative emissions, but with different peaking years and maximum rates of emissions reductions.

FIGURE 3.1: ILLUSTRATIVE ALTERNATIVE GLOBAL EMISSIONS TRAJECTORIES FOR A GIVEN GLOBAL EMISSIONS BUDGET



Source: Climate Change Authority

- **Steep decarbonisation rates**—even with early peaking of global emissions, scenarios to remain within 2 degrees generally require high, sustained rates of emission reductions for much of the rest of this century. The maximum rate of global emission reductions that can be maintained is a key constraint for feasible pathways. One recent study (den Elzen et al. 2010) estimated a maximum global rate of 3–4 per cent per year without using bioenergy with carbon capture and storage, or 4–5 per cent if this technology becomes viable.
- **Demand-side reductions in energy use**—under the IEA's low-emissions scenario ('450 Scenario'), over half of the required emissions savings from energy are achieved by energy efficiency improvements (IEA 2012b, p. 241). Another study found that strong action on energy efficiency can allow some flexibility in the choice and timing of other emissions reduction measures (Rogelj et al. 2013).
- **Negative emissions**—many 2 degree scenarios assume the use of negative emissions technology in the second half of this century (for example, bioenergy with carbon capture and storage). In its survey of 2 degree scenarios, UNEP found that 40 per cent of those considered to provide a likely chance of limiting warming to 2 degree or less require net negative emissions before 2100 (UNEP 2012, p. 26). If net negative emissions prove to be infeasible, a radical shift in mitigation options may come too late to stay below 2 degrees.
- **Technology investment and diversification**—a number of studies highlight the importance of investing in technology. The more ambitious the scenario, the earlier large investments in technology development are required. Pursuing multiple technology options simultaneously reduces the risk of particular technologies proving unviable, and is a more robust approach in the event that some technologies fail.

In submissions to the Review, the Business Council of Australia suggests that the Authority explores less ambitious temperature goals (higher levels of warming) because the world is not currently on track for 2 degrees (*Draft Report submission*, p. 2). Other stakeholders request that the Authority uses a lower, 1.5 degree temperature limit as the basis for its recommendations.

On balance, the Authority considers that a global budget based on 2 degrees is appropriate. As discussed in Chapter 2, it is clearly in Australia's national interest to support a global response to climate change that limits warming to below 2 degrees. While greater international action is necessary to achieve this goal, it remains technically and economically feasible. If the level of global action required to limit warming to below 2 degrees (discussed in Chapter 4) does not eventuate, Australia could reconsider its longer term goals in line with a less ambitious global budget.

While limiting global warming to 1.5 degrees is clearly desirable from a climate change impacts perspective, scenarios consistent with 1.5 degrees rely even more strongly on large-scale implementation of negative emissions technology in the second half of this century. This reliance creates larger risks that the 1.5 degree target would not be met if such technologies prove infeasible. Again, this could be reviewed in light of changing circumstances when Australia considers its longer term goals.

As emissions budgets express temperature outcomes in terms of probabilities, they inevitably include the chance that other temperature levels (besides 2 degrees) will be reached. Selecting an emissions budget with a lower probability of limiting warming to 2 degrees or less will increase the likelihood that higher global temperatures will be attained. By comparison, pathways that provide a 50 per cent or greater chance of limiting warming to 1.5 degrees share many of the same characteristics of 2 degree pathways in the first half of this century (Rogelj 2013). This raises the possibility that a 2 degree pathway could provide scope, with increased effort in future, to shift to a more ambitious 1.5 degree pathway.

CONCLUSION

C.2 Limiting global emissions to keep warming to below 2 degrees is still feasible, but only with immediate and strong international action—especially by the major emitting economies.

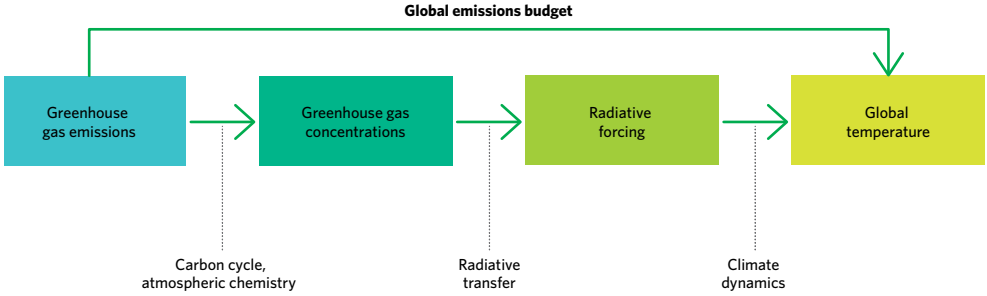
3.2 GLOBAL EMISSIONS BUDGETS

The magnitude of global temperature increases is not determined by emissions in any one year, but by the concentration of greenhouse gases in the atmosphere. This is the net outcome of total emissions and removals of greenhouse gases from the atmosphere over an extended period.

Global emissions budgets estimate the total amount of greenhouse gas emissions that will result in a given temperature increase, within a probability range. The emissions budget approach links cumulative emissions of greenhouse gases directly to temperature, without focusing on the intermediate steps shown in Figure 3.2 and discussed in Box 3.1. The relationship between cumulative emissions and temperature is expressed as a probability, to reflect uncertainty of the climate response to a given amount of greenhouse gas emissions.

While global emissions budgets identify the overall limit on global emissions, they do not prescribe the timing of peak emissions or the rate at which emissions must be reduced, so long as the overall budget is not breached. There will be a number of trajectories that could lead to the budgeted level of cumulative emissions and the related expected temperature increase over time, as illustrated by Figure 3.1. Because the emissions budget is ultimately fixed, however, delays in reducing emissions must be compensated with more rapid emissions reductions in future years.

FIGURE 3.2: RELATIONSHIP BETWEEN GREENHOUSE GAS EMISSIONS AND GLOBAL TEMPERATURE



Source: Adapted from Raupach, Harman & Canadell 2011

The concept of a global emissions budget provides important guidance for setting Australia's national targets. It links to Australia's ultimate aim of limiting warming to less than 2 degrees and provides clear guidance on the scale of the global challenge. Australia's national emissions budget, discussed in Chapter 8, can be thought of as our fair share of the global budget.

Two issues relevant to selecting a global emissions budget as a reference point for this Review are:

- the probability of limiting warming to 2 degrees or less
- whether to specify the budget in terms of CO_2 only or of multiple greenhouse gases.

BOX 3.1: GLOBAL EMISSIONS BUDGETS, ATMOSPHERIC CONCENTRATION AND RADIATIVE FORCING

Global emissions budgets, also referred to as carbon budgets, have gained prominence as a way to analyse and communicate the scale of emissions reductions required to remain within a global temperature limit. Emissions budgets help to link emissions targets and trajectories to the underlying science of climate change.

Emissions limits that keep global temperature increases to 2 degrees or less can be expressed in a number of ways. Two other measures are the concentration of greenhouse gases in the atmosphere, and the radiative forcing of greenhouse gases and other substances. As set out in Figure 3.2, these measures reflect different intermediate steps in the chain between emissions and global temperature. Atmospheric concentration has been a common way to communicate the limit consistent with a certain level of temperature rise. For example, an atmospheric concentration of 450 parts per million (ppm) is consistent with about a 50 per cent chance of limiting warming to 2 degrees or less.

An approximate 67 per cent probability of limiting warming to 2 degrees or lower could be expressed using the following measures:

- an equilibrium concentration of 415 ppm of CO_2-e
- an equilibrium radiative forcing of about 2.1 watts per square metre
- a global emissions budget of 1,700 Gt CO_2-e from 2000 to 2050.

3.3 PROBABILITY LEVEL FOR BUDGETS

Budgets are expressed in terms of their probability of remaining within a given temperature limit. A higher probability of limiting warming to 2 degrees or less corresponds to a smaller budget. For example, a 50 per cent probability of limiting warming to 2 degrees or less gives an allowable budget of Kyoto gases of approximately 2,020 Gt CO_2-e over the period 2000–2050. A 67 per cent probability reduces the allowable budget to approximately 1,700 Gt CO_2-e (adapted from Meinshausen et al. 2009, p. 1,161).

Choosing a budget with a higher probability better manages risks from:

- the long-term warming influence of long-lived greenhouse gases
- uncertainties over the precise temperature increase and the possibility of greater warming
- the severity of impacts of a temperature increase above 2 degrees, including the risk of triggering tipping points in the climate system that result in an abrupt change.

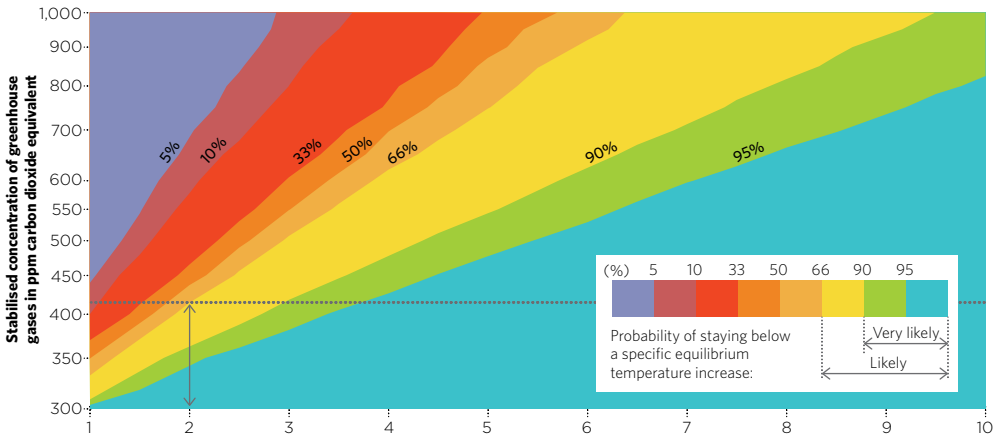
Tighter budgets will, however, require more action to reduce emissions.

In light of the severe global and national risks projected at temperatures of 2 degrees and above, the Authority considers that the global emissions budget used as a reference point for setting Australia's national budget should have at least a 67 cent probability of limiting warming to 2 degrees or less (defined as 'likely'). This is consistent with the probability used by the IPCC in its Fifth Assessment Report, discussed in Box 3.2.

Several submissions to the Issues Paper and Draft Report recommended the Authority use emissions budgets with higher, rather than lower, levels of probability of limiting warming to 2 degrees or less. Other expressed preference for budgets with a relatively high probability such as 80 per cent, but agreed a lower probability budget (such as 67 per cent) was more appropriate on the basis that higher probability budgets are no longer practicably attainable.

Figure 3.3 sets out probabilities (the coloured bands) of remaining below a specified temperature increase for different concentrations of greenhouse gases in the atmosphere. An atmospheric greenhouse gas concentration that provides an approximate 67 per cent probability of limiting warming below 2 degrees, shown by the horizontal dotted line, is also projected to give about a 90 per cent probability of staying below 3 degrees, and more than 95 per cent probability of staying below 4 degrees; however, it gives only a 10 per cent probability of staying below a 1 degree temperature increase.

FIGURE 3.3: PROBABILITY OF STAYING BELOW SPECIFIC TEMPERATURE INCREASES AT DIFFERENT CO_2-e STABILISATION LEVELS



Note: The left scale indicates a CO_2-e concentration level at equilibrium from all greenhouse-forcing agents. The arrow illustrates that to limit global temperature increase to below 2 degrees with a likely (greater than 66 per cent) probability, CO_2-e concentrations should be should be lower than 415 ppm.
Source: Adapted from Rogelj, Meinshausen & Knutti 2012

3.3.1 REVIEWING THE GLOBAL EMISSIONS BUDGET OVER TIME

The appropriateness of the chosen global reference budget can be reviewed and adjusted, if necessary, over the longer term. This can occur as part of periodic reviews of Australia's national emissions budget, which the Authority recommends be conducted at least every five years (see Chapter 7). This flexibility would better position Australia to respond should the international community choose a more stringent temperature goal, or if increased scientific understanding of climate uncertainties changes estimates of the allowable global emissions budget. Conversely, if the scale and pace of international action in future is such that a 67 per cent probability of limiting warming to 2 degrees becomes infeasible, the Authority could review whether to move to a reference budget with a lower probability.

3.4 CARBON DIOXIDE-ONLY OR MULTI-GAS BUDGETS

The Authority considered whether to adopt a CO_2-only or multi-gas budget that includes all the Kyoto gases. CO_2 is long-lived in the atmosphere and is the dominant contributor to human-induced climate change. CO_2-only budgets are simple, can give a good indication of the likely long-term temperature rise and target the most significant greenhouse gas. A multi-gas budget is most closely aligned with Australia's international obligations under the Kyoto Protocol, but has some scientific limitations. In part, this is because different gases behave differently in the atmosphere and remain there for varying lengths of time.

The Authority received a small number of submissions on the use of multi-gas budgets, with one submitter highlighting their potential limitations. Another supported a focus on CO_2 as the longest lived greenhouse gas, suggesting that additional separate budgets should be provided for the other gases.

While acknowledging the limitations, the Authority considers that a multi-gas approach is preferable for the purposes of setting Australia's national emissions budget. Multi-gas approaches recognise the range of activities and gases contributing to global warming. They are also consistent with Australia's international commitments and the approach adopted by other nations. Non-CO_2 greenhouse gases are also a significant component of Australia's emissions—about 28 per cent in 2011 (adapted from DIICCSRTE 2013, vol. 1, p. 29). A multi-gas approach acknowledges the importance of reducing these emissions.

3.5 GLOBAL BUDGET ESTIMATES

The Authority has used the global emissions budget estimates developed in a 2009 study by Meinshausen et al., *Greenhouse-gas emission targets for limiting global warming to 2°C* (Table 3.1). These estimates have been widely cited by other scientific studies and used by national and international bodies as a reference for global emissions budgets.

TABLE 3.1: ESTIMATES OF GLOBAL EMISSIONS BUDGETS 2000–2050

CARBON DIOXIDE (Gt CO_2)	KYOTO GASES (Gt CO_2-e)	PROBABILITY OF REMAINING WITHIN 2 DEGREE LIMIT
900	1,370	80 per cent
1,010	1,520	75 per cent (74 for Kyoto gases)
1,170	1,700	67 per cent
1,450	2,020	50 per cent

Notes: The budget figures in Meinshausen et al. are specified for 2000–2049; an extra year of estimated emissions has been added to give a budget to 2050. Figures rounded to the nearest 10 Gt. The Meinshausen et al. emissions budget estimates account for the temperature effects of aerosol pollution such as sulphates created by the burning of coal and oil. In 2009, the greenhouse gases covered by the Kyoto Protocol were CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluouride. A seventh gas, nitrogen trifluoride, has been added for the second commitment period of the protocol; overall emissions of this gas are expected to be relatively small.
Source: Adapted from Meinshausen et al. 2009, p. 1,161

The global emissions budget used by the Authority as a reference is 1,700 Gt CO_2-e for the period 2000–2050, which gives a 67 per cent probability of limiting temperature increases to 2 degrees or less. Approximately 36 per cent of this budget has already been used between 2000 and 2012, with about 1,090 Gt CO_2-e remaining for the period 2013–2050 (based on IEA 2012a; see Appendix F.6).

BOX 3.2: THE IPCC GLOBAL EMISSIONS BUDGET

For the first time, the IPCC quantified a cumulative emissions budget in its Fifth Assessment Report on the physical science basis of climate change, released in September 2013 (IPCC 2013). The IPCC refers to a global emissions budget of 1,000 Gt of carbon to provide a likely (greater than 66 per cent) chance of limiting global warming to less than 2 degrees, and notes that about half that budget has already been emitted.

The IPCC's estimated emissions budget is consistent with the budgets described in the Meinshausen et al. study discussed above and used in this Review. The two studies, however, use some different assumptions and report in different units, resulting in different budget figures. These differences include:

- The IPCC budget is specified in carbon (C) and the Meinshausen budget in carbon dioxide equivalent (CO_2-e). A tonne of carbon is equivalent to approximately 3.7 tonnes of carbon dioxide, with a 1,000 Gt C budget equating to a 3,700 Gt CO_2 budget.
- The IPCC budget considers the period of 1861–1880 to 2100; the Meinshausen budget only covers the period from 2000 to 2050. Both budgets, however, provide a robust indication of the cumulative emissions to give a likely probability of global warming remaining below 2 degrees.
- The IPCC budget covers the effect of CO_2 only and does not include the warming or cooling effects of other substances such as non-CO_2 greenhouse gases and aerosol pollution. The IPCC notes that the budget would be lower if these other effects were included.

As discussed above, the Authority has chosen to use a multi-gas budget for a specified time period to 2050 as the most appropriate reference budget for this Review.

The global budget proposed in this chapter as a reference point for the Review is consistent with Australia's national interest and the global goal to limit warming to below 2 degrees. It provides clear guidance on emissions that can be produced by the world to 2050 to give a likely chance of limiting warming to below 2 degrees. It is important to note, however, that continued global efforts to reduce emissions will be required after 2050 to avoid further warming.

CONCLUSION

C.3 A global emissions budget that provides at least a likely (67 per cent probability) chance of limiting warming to less than 2 degrees above pre-industrial levels is used as a reference for the Review. This equates to a global budget of no more than 1,700 Gt CO_2-e emissions of Kyoto gases from 2000 to 2050.