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The economics of net zero

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Key points

- Economic analysis provides a useful guide to think about the costs and benefits of policy actions designed to achieve net zero emissions.
- Because climate change is created by global emissions, it requires a global solution in which countries each agree to reduce emissions without unintentionally increasing the emissions of other countries.
- Similarly, within Australia actions by individual states need to ensure that emission reductions within that state result in genuine net emission reductions for all of Australia.
- Emissions abatement represents a national and global coordination challenge. Actions to reduce emissions are generally costly, and if global emissions are not genuinely reduced, then there is no benefit from these actions.
- Achieving net zero has both benefits and costs. Benefits arise in the long term through the prevention of increased global temperatures and in the short term through a range of co-benefits. Costs arise through the need for a change to production and consumption patterns that lead to net zero.

Contents

1. Introduction

Economic analysis is an essential tool for understanding both the nature of the climate challenge and potential policy approaches to dealing with it. While climate issues extend well beyond economics, the increasing concentration of greenhouse gases in the atmosphere is ultimately due to a wide range of economic activities, from energy generation to farming and forestry. It follows that economic approaches are required when deciding how to deal with the resulting climate change issues.

In addition, many contentious climate policy questions and debates are essentially economic in nature. For instance, how much will mitigation cost and how will we pay for it? And conversely, what will be the cost of climate change if we do nothing to mitigate it?

This paper sets out key economic concepts associated with the broad climate policy target of net zero emissions that has been adopted by many nations and all Australian jurisdictions. It introduces the conceptual frameworks economists use to understand the causes of and solutions to climate change.

In setting out these concepts, the paper aims to provide readers with a better understanding of the language used in climate policy debates as well as the tools and techniques that are used to analyse policy proposals.

While economics is a long way from having all the answers to the climate challenge, it does prompt some important questions to consider when examining legislative changes or policy positions.

The paper is structured as follows:

1. **An economic overview** provides a high-level summary of the key economic terms and ideas that appear in discussions of climate change
2. **The origins and definition of net zero** sets out the definition and emergence of net zero as a policy target adopted around the world
3. **The cost of net zero** summarises current understanding of the cost of reducing emissions and of directly removing carbon from the atmosphere
4. **The benefits of net zero** discusses how benefits emerge through the avoidance of future climate change. It introduces the idea of the social cost of carbon as a framework to assess the elements of the benefits of net zero. It also introduces the idea of co-benefits and the selective opportunities that emerge through the adoption of net zero technologies
5. **Considering policy** sets out some ideas of the types of questions that economic analysis asks of any new legislation or policy proposal.

2. An economic overview

2.1 A global externality

The economics of climate policy starts with the observation that human induced climate change is the result of a global externality.

Here externality refers to the fact that greenhouse gas emissions are an indirect consequence of economic activities and that the harm generated by those emissions is not accounted for in the economic decisions that led to the emissions — they are 'external' to the underlying decisions. This in turn means that correcting the externality requires finding some way of creating incentives for all actors who generate emissions to account for the effects of those emissions.

The global aspect is concerned with the fact that it does not matter where greenhouse emissions are produced; emissions from anywhere in the world have the same effect on the climate. Further, no single country is responsible for all climate change; it is the combination of many small amounts of emissions that accumulate to generate climate change.

This global aspect means that dealing with the externality also requires international coordination; countries need to agree on actions and then put measures in place to ensure that the actions lead to reduced emissions.

2.2 Providing incentives

While it is nations that sign international agreements, it is ultimately individuals (as consumers or producers) that make the choices to reduce emissions. The challenge for national governments is to create incentives for individuals to behave in ways that align with the international agreement. The challenge for state governments is to contribute to incentives at the state level in a way that is consistent with both the national and international objectives.

A large part of climate policy development has involved formulating and implementing various means of providing incentives to reduce emissions — this is essentially internalising the externality of climate change.

A wide variety of policies have been implemented, including:

- Various forms of carbon pricing which directly or indirectly charge producers and consumers for each tonne of carbon they emit. In some cases, carbon pricing also pays producers or consumers for each tonne of carbon they either remove from the atmosphere or prevent from being emitted. Carbon pricing may involve direct pricing or be implemented through an emissions trading scheme.[1]

- Direct subsidies to activities that abate emissions (for example, subsidies for installing solar panels or subsidised payment for solar electricity generation). Emissions abatement involves either reduction in emissions or direct carbon dioxide removal from the atmosphere.
- Direct regulation of emissions, with penalties for emissions beyond a particular threshold. The new vehicle emissions standard is an example of direct regulation with penalties.[2]
- Direct support for new low-emissions technologies, for example through subsidised loans.
- Funding of research and development for new products and technologies.

2.3 Emissions accounting

All climate policy is underpinned by systems of emissions accounting that track the ways in which emissions emerge from economic activities. Australia's national greenhouse gas accounts provide comprehensive reporting on emissions.[3]

When thinking about emissions, it is important to note that they can be measured from a production or a consumption perspective.

2.3.1 Production emissions

The production perspective is what is commonly used in international accounting and international agreements.[4] A production perspective measures emissions that arise from emission producing activities such as energy generation, transport and industrial processes. These emissions may be associated with goods that are consumed at home, or they may be associated with goods that are exported. Thus, for example, fugitive greenhouse gas emissions[5] from a coal mine producing for coal export are included in Australia's greenhouse gas accounts, even though the coal itself is not consumed here.

Emissions associated with products that are imported to Australia are not counted as part of Australia's production emissions inventory.

[1] See World Bank Group, *State and Trends of Carbon Pricing Dashboard*, 2024, accessed 12 June 2024.
[2] See Department of Infrastructure, Transport, Regional Development, Communication and the Arts, *New Vehicle Efficiency Standard*, n.d., accessed 13 June 2024.
[3] Department of Climate Change, Energy, the Environment and Water, *Tracking and reporting greenhouse gas emissions*, 31 May 2024, accessed 13 June 2024.
[4] H Ritchie, *How do CO_2 emissions compare when we adjust for trade?* Our World In Data, 7 October 2019, accessed 12 June 2024.
[5] Fugitive emissions are losses, leaks and other releases of greenhouse gases from coal and gas mining activities.

2.3.2 Consumption emissions

By contrast, consumption emissions are those associated with the use (consumption) of goods and services whose original production involved emissions.[6] This different perspective would include, for example, emissions embodied in imported goods and services.

Take cement production as an example. Under a production approach, emissions from the local production of cement count in Australia's inventory. If all local production of cement ceased, and all use was satisfied by imports, from the production perspective it would appear that Australia had reduced emissions. Globally, however emissions would not have fallen, because Australian production has merely switched to imports.

The distinction between production and consumption perspectives is crucial when considering the global implications of net zero because otherwise a country could get to measured net zero without any actual reduction in global emissions. Australia adopts a production perspective in its greenhouse accounts. It is important, however, when designing policy to also keep a consumption perspective in mind.

2.4 Balancing costs and benefits

An important focus of the economics of climate change has been understanding the balance of the costs and benefits of different actions to address climate change. Economics often focuses on achieving benefits at minimum cost, or in the most cost-effective way. Economising on the abatement of greenhouse gas emissions leaves resources available to do more if necessary. At the same time, some actions may be too expensive to justify the benefits, so it is important to understand when this situation may arise.

The analysis of costs and benefits is complicated by 2 features of climate change: the long timeframes involved and the degree of uncertainty surrounding all aspects of climate change.

2.5 Long timeframes

Greenhouse gas emissions stay in the atmosphere for many years, and any policies to reduce emissions may take centuries to have their full effect.[7] This means that the cost of abatement incurred today may not generate benefits for the current generation.

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[6] H Ritchie, *How do CO_2 emissions compare when we adjust for trade?* Our World In Data, 7 October 2019, accessed 12 June 2024.

[7] See United States Environmental Protection Agency (EPA), *Climate Change Indicators: Greenhouse Gases*, 14 May 2024, accessed 12 June 2024.

These long timeframes create a challenge for putting costs and benefits on a common basis in today's dollars. This inevitably involves the use of a discount rate – the rate at which future benefits are adjusted into today's dollars – when comparing costs and benefits. There is a very active debate about the appropriate value of the discount rate to be used.[8]

2.6 Uncertainty

A second difficulty for comparing costs and benefits is the large amount of uncertainty associated with all aspects of climate change. There are many components of this, including uncertainty about:

- Future emissions arising from future economic activity
- The response of the climate to increasing emissions (for example, in terms of increased temperature)
- The cost to the economy of future climate change and the cost and effectiveness of adaptation to future climate change
- The cost of low-emissions technologies — in particular the way in which this cost may change over time
- The prospects for new technologies to be developed to address climate change.

This uncertainty is typically dealt with through the use of scenario analysis, where different assumptions are used to construct different scenarios for each of the uncertain variables.

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[8] See for example: W Nordhaus, *Climate Change: The Ultimate Challenge for Economics*, Nobel Prize Lecture, 8 December 2018, p 455. For a more technical discussion, see M Weitzman, A Review of the *Stern Review on the Economics of Climate Change*, *Journal of Economic Literature*, 2007, Vol. XLV (September 2007), pp 703–724.

3. The origin and definition of net zero

3.1 Definition

'Net zero emissions' is achieved when there is a balance between the amount of greenhouse gases emitted by human activities and the amount removed from the atmosphere. If net zero were achieved, then the atmospheric concentration of those gases would no longer be increasing.

Reaching net zero involves both reducing emissions — where such reductions are cost effective and technically feasible — and removing carbon dioxide from the atmosphere (for example by planting trees) or capturing emissions (for example from fossil-fuel power stations or from industrial processes such as cement manufacture).

3.2 Origins

3.2.1 The Paris Agreement

The idea of net zero — and the specific target of net zero by 2050 which forms policy targets for all Australian jurisdictions and many countries around the world — emerged directly from the Paris Agreement. The Paris Agreement is an international agreement on climate change which was adopted in 2015 and came into force in 2016.[9] Australia is a party to the Paris Agreement. Under the Paris Agreement, the parties agreed to undertake measures needed to hold 'the increase in the global average temperature to well below 2°C above pre-industrial levels' and to pursue efforts 'to limit the temperature increase to 1.5°C above pre-industrial levels'.[10]

In essence, the Paris Agreement requires parties to work together to achieve a global temperature target. Converting this temperature target to an emissions target requires considerable scientific analysis of the relationship between emissions and global temperature.

3.2.2 The Special Report on 1.5 degrees

The Intergovernmental Panel on Climate Change (IPCC)[11] was asked to undertake a special analysis of the 1.5°C target. The IPCC *Special Report on Global Warming of 1.5 Degrees*

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[9] United Nations Climate Change, *The Paris Agreement: What is the Paris Agreement*, n.d., accessed 12 June 2024.

[10] United Nations, *Paris Agreement*, 2015, Article 2, 1 (a), p 3.

[11] The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. It was established in 1988 and seeks to provide governments with scientific information to assist in the formulation of climate policies.

drew on detailed scientific analysis and developed a sequence of scenarios of emissions pathways to assess which pathways were consistent with achieving the 1.5°C target.[12]

On average, and across many scenarios, the IPCC found that to keep global temperature increases below 1.5°C, global emissions would need to reach net zero by around 2050.[13]

Net zero has become a shorthand way to refer to an overall objective for emissions reductions. Underlying the IPCC scientific work is the notion of a 'carbon budget' which refers to the maximum quantity of emissions that can go into the atmosphere while still being consistent with achieving the temperature targets. This idea of an overall budget helps set the specific emissions pathway (that is, emissions targets in each year) on the way to achieving net zero emissions by 2050.

3.3 Leakage

Net zero is an international concept. It refers to *global* net zero. The temperature outcomes associated with net zero can only be achieved if global net zero (and the associated global emissions budget) is achieved. Put another way, no individual country or region can achieve the temperature targets through their action alone; it requires global coordination.

Implicit in the target of global net zero is a pragmatic coordination challenge to ensure that the actions of countries do not offset each other. That is, it is crucial that emissions reductions in one country do not result in emissions increases in another country. This is sometimes referred to as the problem of 'leakage'.[14] Trade and investment links between countries (and regions within countries) mean that abatement efforts are all interconnected.

The same is true for states within Australia. Every state and territory has a net zero target for 2050.[15] But to achieve national net zero emissions, the actions of individual states must be coordinated to ensure that emissions reductions are not offset within Australia.

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[12] IPCC (Intergovernmental Panel on Climate Change), Special Report on Global Warming of 1.5ºC, 2018, accessed 12 June 2024.

[13] IPCC (Intergovernmental Panel on Climate Change), Summary for Policymakers, in V Masson-Delmotte et al. (eds) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Cambridge University Press, 2018.

[14] See for example: Department of Climate Change, Energy, the Environment and Water, Australia's carbon leakage review, 21 March 2024, accessed 18 June 2024.

[15] See for example the NSW Net Zero Plan Stage 1: 2020-2030 (March 2020) and Climate Change (Net Zero Future) Act 2023.

To be consistent with the Paris Agreement, it is important that every tonne of abatement in NSW corresponds to a tonne of abatement for Australia as a whole. Similarly, it is important that a tonne of abatement for Australia corresponds to a tonne of abatement globally.

Where emissions reductions are not coordinated, or there is some form of leakage, then the cost of that abatement is not offset by the benefit of reduced climate change in the future.

4. The cost of net zero

4.1 What are costs of abatement?

Emissions abatement requires significant changes to the ways in which goods and services — particularly energy, but also including industrial processes and agriculture — are produced and consumed.

Emission reductions require developing, investing in, and adopting low-emissions technologies. At least initially, low-emissions technologies are more expensive than current approaches, which is why specific policies are typically needed to ensure their uptake.

Removing carbon dioxide from the atmosphere is also costly, either due to the cost of developing and operating the technology or the loss of alternative uses for any land that is used for capturing and storing carbon dioxide (carbon sequestration). Carbon can be sequestered in vegetation, soils, oceans and underground geologic formations.

The idea of the cost of abatement captures the opportunity cost of the resources devoted to the transition to net zero.

Understanding the cost of abatement is an important component of policy development as it provides a benchmark when comparing different policy and technical options. It is important to find minimum cost ways of achieving abatement. Incorporating abatement costs into cost-benefit analysis of projects, for example, helps ensure this.

4.2 Ways of thinking about the cost of abatement

There are a number of different ways of thinking about and measuring the cost of abatement, each capturing a different aspect of the overall idea:

- Estimates of the capital resources required to fund the new investments needed for the transition to net zero
- Estimates of foregone gross domestic product or national income
- Estimates of the ‘marginal cost of abatement’ per tonne abated
- Examining how the costs of abatement are distributed across industries and regions.

4.2.1 The capital resources needed

A number of studies have estimated the magnitude of capital investment required to fund net zero commitments.

For example, the Net Zero Australia project estimates that the cumulative capital cost to achieve net zero will be $9 trillion.[16] This is between 5 and 7 times more capital than required under a 'business as usual' (BAU) scenario where no abatement occurs. How this cost is shared between the government, private investors and consumers will depend on the policy settings, but ultimately these costs will be borne by the consumers of the relevant products (such as electricity).[17]

4.2.2 Foregone gross domestic product or national income

Another approach to understanding the cost of abatement is estimating foregone gross domestic product (GDP) or gross national income (GNI) — or the state counterpart, gross state product (GSP).

Foregone income is typically modelled using economywide simulation models to compare 2 alternative future states of the world: BAU and a scenario in which abatement measures for particular targets are put in place. Studies of this kind find that foregone income compared with BAU is of the order of 1 to 5 percent, depending on the exact configuration of the model simulations.[18] It is important to note that income does not decline in absolute terms in these studies. Rather, income continues to grow year on year under both the BAU and abatement scenarios, but growth is lower under the abatement scenario.

4.2.3 The marginal cost of abatement

An important concept on the cost side of net zero is the idea of the marginal cost of abatement (MCA, also called the marginal abatement cost or MAC). The MCA is the cost to eliminate or prevent the emission of one additional tonne of carbon dioxide equivalent ($\$/tCO_2$-e) into the atmosphere, while holding all other factors constant.[19]

The general term MCA can be used in a number of different ways. Sometimes it refers to the cost of abatement for an individual activity, and sometimes it can be used to refer to the cost of abatement for the whole economy.

The economywide marginal cost of abatement is a particularly useful concept as it provides a benchmark for comparison for any specific policy or abatement investment.

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[16] Net Zero Australia, *About Net Zero Australia*, n.d., accessed 13 June 2024.

[17] Another study that has looked at the magnitude of financing is Climateworks Centre, *Pathways to industrial decarbonisation: Positioning Australian industry to prosper in a net zero global economy*, 2023, accessed 13 June 2024.

[18] For a meta-analysis of Australian studies, see CIE (Centre for International Economics), *What existing economic studies say about Australia's cost of abatement*, Report prepared for Department of Environment and Energy, July 2019.

[19] As there are several different greenhouse gases, each with different effects on global warming, a tonne of carbon dioxide equivalent is a way of aggregating these different gases based on the contribution that each makes to global warming.

Different activities in the economy have different costs of abatement, and the idea of the economywide MCA assumes that the easier and cheaper activities to abate will occur before more expensive measures. As a result, the economywide MCA increases as the amount of economywide abatement required increases.

4.2.3.1 Estimating the marginal cost of abatement

There are 2 broad approaches taken in the literature to estimate the marginal cost of abatement.

A marginal abatement cost schedule

The first is the estimation of MAC schedules in the sense made popular by McKinsey and also used by the IPCC and other organisations.[20]

MAC curves depict different abatement measures according to their costs and their total abatement potential. For example, Figure 1 shows a hypothetical MAC curve where each bar represents a specific technology; the bar's height shows that technology's average abatement cost and the bar's width shows how much abatement the technology can achieve in total. When these average abatement segments are combined and arranged in increasing order, they generate an increasing cost schedule, or a stepped function that relates cost to abatement.[21]

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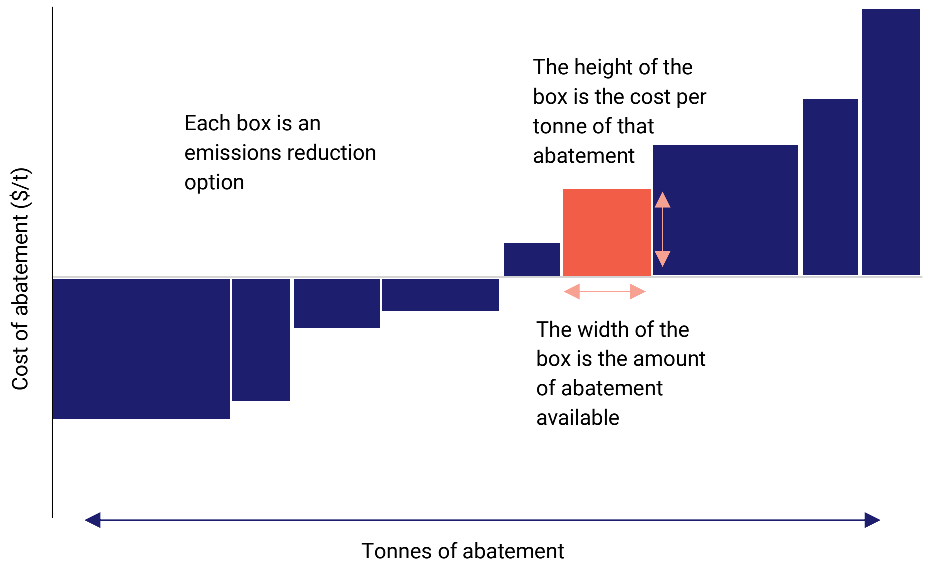
[20] See for example: McKinsey & Company, *An Australian Cost Curve for Greenhouse Gas Reduction*, 2008; Energetics, *Modelling and analysis of Australia's abatement opportunities, Report to the Department of the Environment*, May 2016.

[21] See for example: Climateworks Centre, *How to read a marginal abatement cost curve*, 2022, accessed 12 June 2024.

Figure 1: Illustrative marginal abatement cost curve



Source: Author provided

Use of simulation and optimisation models
While providing a useful insight into the cost of abatement, MAC schedules do not capture interactions between sectors of the economy, do not allow for demand side responses, and do not account for the simultaneous adoption of different technologies. Importantly, they do not capture the structural change in the whole economy required to achieve abatement targets.

The second approach to estimating the MCA for the whole economy (particularly the MCA associated with a particular target) is to simulate the cost of abatement using a detailed simulation model designed to capture different sectors of the economy and their interactions, along with the different technologies that can be used for abatement.

In these models, the economywide marginal cost of a particular target or level of abatement (net zero by 2050, for example) is found by imposing that target on the simulation model, and then solving for the implicit carbon price that achieves the target. In the simulation, the implicit carbon price works its way through the economy, changing the behaviour of producers and consumers (who adopt new production techniques or consumption patterns) until the target is met. The implicit carbon price estimated this way provides an estimate of the economywide MCA; the higher the carbon price required to achieve the target, the higher the MCA.

Rather than a strict sequence of technologies, this approach simulates different combinations of technologies at each point in time.

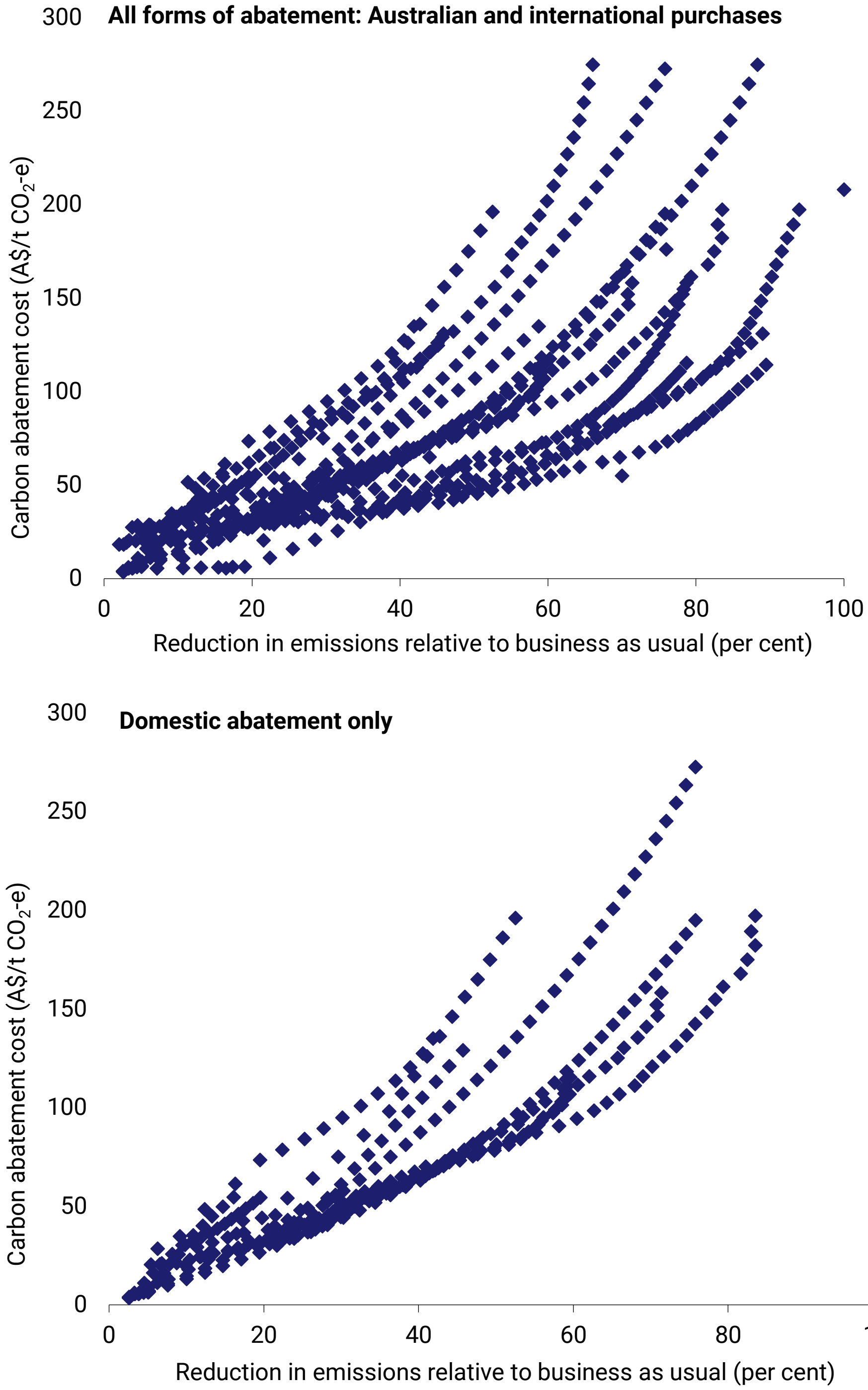
4.2.3.2 Australian economywide estimates of the cost of abatement

Within Australia, there is a very long history of using economic models — particularly economywide models — to estimate the implications of emissions abatement. Different modelling studies use different assumptions, parameters and structures to understand the economics of abatement. This diversity of approaches is appropriate, since having a wide range of scenarios is one way of dealing with uncertainty.

Figure 2 provides a summary of the economywide marginal cost of abatement estimates at different levels of abatement derived from a series of Australian studies. The original results of the studies have been put on a common basis to allow for comparison. On the horizonal axis, the figure shows the amount of abatement expressed as a percentage reduction in BAU emissions. Net zero emissions is equivalent to 100%. The vertical axis shows the cost (in dollars per tonne) of achieving that level of abatement.

The figure is divided into 2 panels because the original studies considered scenarios where Australian targets were met partially with the purchase of international abatement (such as carbon credits from overseas abatement projects), or with domestic abatement alone.

Figure 2: Marginal cost of abatement estimates from Australian studies



Source: CIE (Centre for International Economics), *What existing economic studies say about Australia's cost of abatement*, Report prepared for Department of Environment and Energy, July 2019.

The pattern of results from these studies illustrates some important points about estimates of the cost of abatement.

First, there is a wide spread of results from the different studies, indicating both the importance of their assumptions as well as how using different model configurations can provide an understanding of the uncertainties involved. The position of the abatement cost curve implied by each study depends very much on the model mechanisms and the particular scenario considered.

Second, the marginal cost of abatement increases as the amount of abatement increases, in some cases quite sharply.

Third, a comparison of the top and bottom panels of the chart indicates that the use of international abatement seems to lower the marginal cost of abatement to Australia.

Finally, for many of the studies the maximum abatement modelled was around 70 or 80 per cent of BAU. This partly reflects the overall set up of the studies, but it also illustrates that higher levels of abatement are harder to model.

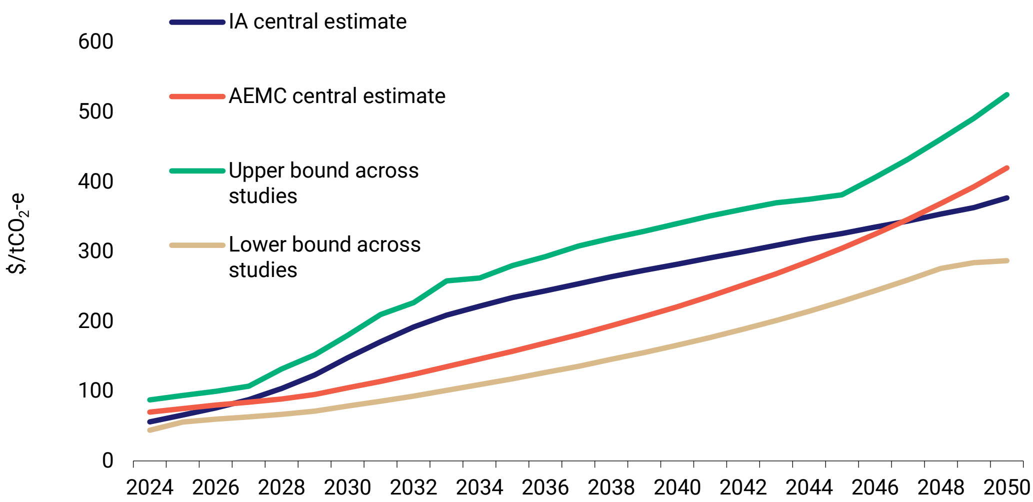
4.2.3.3 Recent abatement cost estimates for use in cost-benefit analysis

Recently, 2 Australian government agencies (Infrastructure Australia (IA) and the Australian Energy Market Commission (AEMC)) each provided recommendations about the cost of abatement consistent with Australia's emissions targets for use in cost-benefit analysis.[22] These recommendations were derived from a detailed analysis of Australian and international models using a comparison similar to that shown in Figure 1. IA provided a specific suggested range and AEMC suggested a 25% variation around their central estimate. These ranges are needed for performing sensitivity analysis, which is a component of cost-benefit analysis that estimates how much the results would change with different costs of abatement.

Figure 3 shows the average abatement cost estimates derived from each publication along with the maximum upper or minimum lower estimates from the 2 publications.

[22] Infrastructure Australia (IA), *Valuing Emissions for Economic Analysis*, May 2024; and Australian Energy Market Commission (AEMC), *How the national energy objectives shape our decisions*, Final guidelines, 28 March 2024.

Figure 3: Cost of abatement from 2 Australian reports



Source: Author estimates based on IA and AEMC

4.2.4 The sectoral and regional distribution of costs

The cost of abatement is a summary measure that hides the fact that the costs of abatement will be distributed throughout the economy in various ways.

There are 2 aspects of this. First, the cost of abatement to an individual state depends not only on the actions and targets of that state, but also on those of other states who are pursuing the same objectives. With the large amount of trade between Australian states (particularly on the eastern seaboard), abatement actions are distributed through trade and investment linkages. A good example of this is the integrated National Electricity Market. Electricity produced in one state is traded in the whole market, so it is easy for a reduction in generation and therefore emissions in one state to be offset by increased generation (and emissions) in another.

Second, it is possible to identify individual regions that are likely to be most affected by the transition costs of abatement. For example, a modelling study of abatement specifically identified regional impacts of net zero.[23] While it is important to note that this study is at the lower end of estimates of aggregate impacts (with an MCA of $150 per tonne in 2050), it provides valuable insights given the care taken to identify regional and sector impacts of abatement. Key findings include that:

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[23] P Adams, *Zero Greenhouse Gas Emissions by 2050: What it means for the Australian Economy, Industries and Regions*, CoPS Working Paper No. G-324, November 2021.

- The impact on total regional income in the Hunter region is 20 times larger than the NSW state average
- The impact on Newcastle and Lake Macquarie is around 3 times larger than the NSW state average.

4.2.5 Abatement costs and the actions of other countries

When considering the overall cost of abatement, it is important to keep in mind that costs will be incurred in NSW not only as a result of NSW's abatement actions, but also as a result of the actions of other states and other countries. For example, a paper commissioned as part of the 2021-22 NSW Intergenerational Report examined the impact on NSW of changes in coal demand resulting from international abatement action.[24] The paper found that, compared with the reference scenario, lower global coal demand resulted in gross state product being 0.9% lower than otherwise.

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[24] N Wood et al., *The sensitivity of the NSW economic and fiscal outlook to global coal demand and the broader energy transition for the 2021 NSW Intergenerational Report*, NSW Government, May 2021.

5. The benefits of net zero

There are 3 broad types of benefits from net zero:

- The benefits of net zero are implied by the terms of the Paris Agreement: to avoid global warming greater than 1.5 degrees, and therefore to avoid the economic costs associated with such warming
- Reduced greenhouse gas emissions are associated with co-benefits that are unrelated to climate change, such as improved air quality
- The global trade changes induced by net zero policies may involve export opportunities for commodities which may be of benefit to specific countries or regions.

5.1 Avoided cost of climate change

Calculating the economic costs of warming is a complicated and imperfect exercise. As far back as the Garnaut Review in 2008 it has been understood that while some aspects of the costs can at least be partially quantified, other aspects are extremely difficult or impossible to quantify.

The key effects of warming include:

- The potential adverse effect on agricultural productivity both through effects on rainfall and drought patterns, as well as through changes in the suitability of particular crops in particular regions and the patterns of pests and diseases
- Increases in sea level with associated costs of damage to infrastructure and property
- Direct effects on human health (and productivity) through heat stress
- Indirect effects on human health through changing disease patterns
- Increases in the frequency and severity of natural disasters, including bushfires and floods.

Detailed climate change projections covering each of these aspects for NSW are available from AdaptNSW.[25] Discussion of the impact of climate change on natural disasters in NSW is available in the NSW State Disaster Mitigation Plan.[26] Research undertaken as part of the 2021-2022 NSW Intergenerational Report quantified 4 areas of climate risk to the NSW economy, including selected cost of natural disasters, damage from sea level rise, the

[25] AdaptNSW, *Welcome to AdaptNSW*, 2024, accessed 12 June 2024.
[26] NSW Reconstruction Authority, *State Disaster Mitigation Plan 2024 - 2026*, NSW Government, February 2024.

effect of heat on workplace productivity and effects on agricultural production.[27] Each of these sources indicate potentially significant future costs of climate change.

5.1.1 Estimating the effects of climate change

Estimating the magnitude of the effects of climate change is a complicated exercise involving both scientific and economic analysis. The 'physical' effects of climate change (temperature increase, rainfall changes and so on) are usually estimated using complex meteorological models, often called general circulation models (GCMs).[28]

Converting these physical effects to economic effects involves a variety of economic techniques, including statistical analysis of past climate changes as well as statistical comparisons across regions with different climates. These techniques are used to generate a 'damage function' for climate changes. This function relates temperature change to changes in economic outcomes, such as income. These damage functions are often used in a type of model known as an integrated assessment model (IAM).[29] IAMs provide a simplified representation of the linkages between the climate and the economy.

5.1.2 The social cost of carbon

One way of thinking about the diverse costs of climate change (and therefore the benefits of mitigation) is through a concept known as the social cost of carbon (SCC). The SCC is defined as the economic cost caused by an additional tonne of carbon dioxide emissions or its equivalent. Specifically, it is the change in the value of future economic welfare (in today's dollars) from an additional tonne of carbon dioxide equivalent emissions.[30]

Calculating and understanding the SCC requires 4 steps:

- Modelling the link between emissions and greenhouse gas concentrations
- Establishing the link between greenhouse gas concentrations and 'physical' climate outcomes such as temperature, sea level rise and frequency of storms
- Establishing the link between these climate outcomes and future economic variables, via a damage function. Damages are usually measured in terms of GDP or national income
- Calculating future damages for each year, and then using an appropriate discount rate to express them in today's dollars.

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[27] N Wood et al., *An indicative assessment of four key areas of climate risk for the 2021 NSW Intergenerational Report*, NSW Government, April 2021.
[28] National Oceans and Atmospheric Administration, Climate.gov, *Climate Models*, Last updated 1 May 2024, accessed 12 June 2024.
[29] IAMC (Integrated Assessment Model Consortium), *What are IAMs?*, 2020, accessed 12 June 2024.
[30] W Nordhaus, Revisiting the social cost of carbon, *Proceedings of the National Academy of Sciences*, 14 February 2017, 114 (7): 1518-1523, doi.org/10.1073/pnas.1609244114.

This sequence traces one extra tonne of emissions through its effect on atmospheric concentration, temperature and economic activity in the future and then back to a total value expressed in today's dollars. Every step of this sequence is uncertain, and every element in the calculation is subject to debate. However, the structure of the SCC provides a very useful framework with which to consider the effects of climate change.[31]

It is interesting to note that the link between emissions, concentrations and temperature (in the first 2 steps set out above) is the same set of linkages that was required to establish net zero as a policy target required to keep temperature increases to 1.5 degrees in the first place. The new element incorporated in the SCC is establishing a link between the climate outcomes and economic outcomes. This damage function is notoriously hard to estimate.

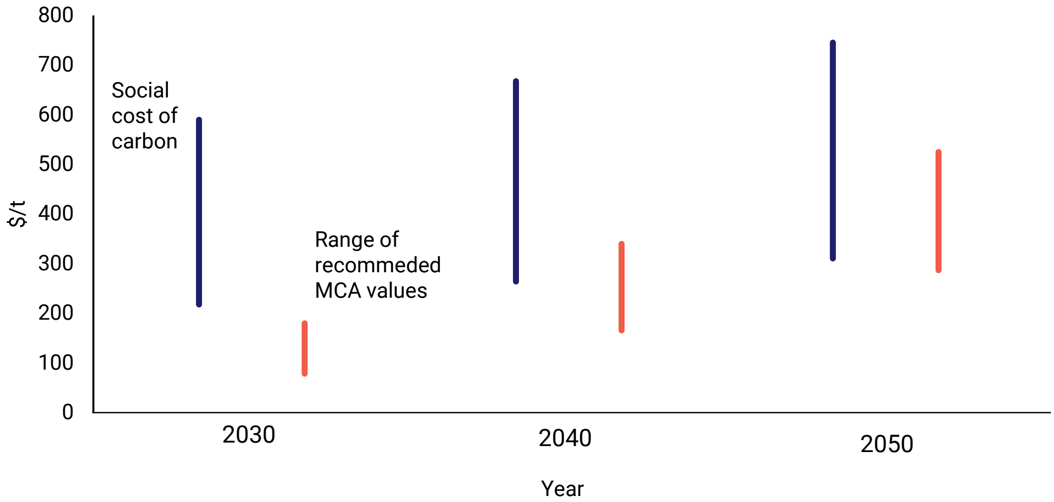
As a measure of the benefits of reducing a tonne of emissions, the SCC can also be used in cost-benefits analysis, either instead of or alongside estimates of the MCA associated with a particular target.

Figure 4 compares values for the SCC with the range of MCA estimates set out in Figure 2.[32] It shows that in the 2030s and 2040s, the recommended MCA values are generally lower than estimates of the social cost of carbon (implying that, at the margin, it costs less to achieve the national target per tonne of abatement than the benefits of reducing that tonne). By 2050, there is considerable overlap between the 2 sets of estimates. For the purposes of cost-benefit analysis, by 2050 both the MCA and the SCC will have similar values, noting that for the estimates summarised here, the SCC has a much wider range than the MCA.

[31] There are a variety of estimates of the SCC available. A good example is RFF (Resources for the Future), *Social Cost of Carbon Explorer*, 2024, accessed 12 June 2024. Recent estimates using the modelling work of Nobel Prize winner William Nordhaus are available from Barrage and Nordhaus, Policies, projections, and the social cost of carbon: Results from the DICE-2023 model, *Proceedings of the National Academy of Sciences*, 19 March 2024, 121(13): 1-8, doi.org/10.1073/pnas.2312030121.

[32] The values for the SCC presented here are taken from: U.S. Environmental Protection Agency (EPA), *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*, U.S. Government, September 2022. The author has converted the EPA figures to 2024 Australian dollars.

Figure 4: Comparing the social cost of carbon and the marginal cost of abatement



Source: Author estimates based on Figure 3, and footnote 32

5.2 Co-benefits

The general idea behind the emergence of co-benefits is that specific actions to reduce greenhouse gas emissions will themselves have spillover or externality benefits.[33] While in some cases (such as improved energy efficiency) these benefits could be achieved even without emission reductions, these co-benefits are considered important in understanding the full implications of policies such as net zero.

One of the most important co-benefits identified in the literature is reduced local air pollution from less burning of fossil fuels, as well as potential environmental improvements through associated changed land use practices. For example, the global health co-benefits have been estimated at between US$50 and US$380 per tonne of carbon dioxide.[34] The health effects of power generation and transport related pollution in Victoria were estimated at between AUD$30 and AUD$80 per tonne of carbon dioxide.[35]

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[33] See K Hamilton et al., *Multiple benefits from climate change mitigation: assessing the evidence*, Policy report, Grantham Research Institute on Climate Change and the Environment, November 2017. See also UNECE (United Nations Economic Commission for Europe), *The Co-benefits of climate change mitigation*, Sustainable Development Brief No. 2, January 2016.

[34] A Haines, Health co-benefits of climate action, *The Lancet Planetary Health*, 2017, 1(1): e4-e5, doi.org/10.1016/S2542-5196(17)30003-7.

[35] Department of Environment, Land, Water and Planning, *Estimating the health costs of air pollution in Victoria*, Victorian Government, 2018. See also Bureau of Transport and Regional Economics (BTRE), *Health Impacts of Transport Emissions in Australia: Economic costs*, Australian Government, 2005.

Co-benefits are generally specific to a location and a particular mitigation action, and it is generally recognised that they are hard to precisely estimate.[36]

5.3 Potential benefits through new trade opportunities

The transition to net zero emissions will inevitably involve changed trade patterns around the world as traditional areas of comparative advantage shift. For example, global net zero will result in reduced demand for coal, which is part of the cost of net zero through a loss of trade opportunities (particularly for NSW). On the other hand, it will require increased production and trade of critical minerals.[37] Production and export of these minerals provides a new trade opportunity for Australia and NSW. Australia may also be able to take advantage of broader possibilities in renewable energy trade, for example through the production and export of hydrogen.[38] The support of these potential new industries has emerged recently as a policy priority for the Australian and NSW governments.[39]

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[36] Ministry for the Environment, *The co-benefits of emissions reduction: An analysis*, New Zealand Government, 2018.

[37] United Nations, *The UN Secretary-General's Panel on Critical Energy Transition Minerals*, n.d., accessed 12 June 2024.

[38] Australian Trade and Investment Commission, *Hydrogen: Australia's next big export industry*, 2024, accessed 12 June 2024.

[39] Department of Industry, Science and Resources, *Critical Minerals*, n.d., accessed 12 June 2024; NSW Government, *Critical Minerals and High Tech Metals Strategy*, 2021.

6. Considering policy

The economic analysis of climate issues and policies provides a framework for thinking through the potential effects of specific legislative or policy proposals. Some useful questions that can be asked of any proposal include:

1. Does the proposal align with international agreements (or with the national approach to those agreements) or does it move towards such alignment, recognising that international coordination and cooperation is far from perfect?
2. Will the proposal lead to net global reduction in emissions, or is there still scope for leakage—where production emissions decline while consumption emissions increase?
3. What measures are in place to ensure that abatement takes place at minimum cost? For example, are potential costs lower than benchmark costs (such as in recent recommendations for cost-benefit analysis), or lower than the social cost of carbon?
4. Is there a clear identification and quantification of any co-benefits arising from the policy or legislative proposition?
5. What government involvement is required to gain from the trade opportunities implied by global mitigation?

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The Parliament of New South Wales acknowledges and respects the traditional lands of all Aboriginal people and pays respects to all Elders past and present. We acknowledge the Gadigal people as the traditional custodians of the land on which the Parliament of New South Wales stands.

This image comes from 'Our Colours of Country', which was created for the Parliament of NSW by Wallula Bethell (Munro) a Gumbaynggirr/Gamilaroi artist born and raised in Tamworth who has spent time living on Dunghutti Country and is currently living in Western Sydney on Darug Country with her husband and son.