ClimateWorks
AUSTRALIA

Low Carbon Growth Plan for Australia

March 2010

Preface

ClimateWorks Australia (ClimateWorks) was founded in 2009 through a partnership between The Myer Foundation and Monash University, with a mission to substantially reduce Australia's greenhouse gas emissions over the next five years. ClimateWorks believes the practical steps required to achieve these reductions are more likely to be undertaken if presented in an easy to understand, overarching and cohesive climate change strategy for Australia.

This strategy has been built on the following principles:

1. Establish a comprehensive fact base
2. Examine greenhouse gas (GHG) emissions reduction opportunities from multiple perspectives (including societal and investor or business)
3. Identify the lowest cost means to reduce GHG emissions
4. Understand the range of barriers to GHG emissions reduction
5. Build momentum for collaborative action based on a solid understanding of the opportunities, the economics and the barriers

This report provides the basis of a living framework that reflects these principles and can incorporate new findings and improved analysis on how to reduce GHG emissions at lowest cost as new data becomes available. It is not a detailed plan for each emissions reduction opportunity or the final word on emissions reduction potential and costs. Similarly it is not intended as an assessment of climate science or of the impact of GHG emissions on global temperatures. However, it is the basis from which to launch well considered and balanced actions to achieve GHG emissions reduction at lowest cost.

While this report is focused on identifying and explaining the opportunities that business and the community have to reduce GHG emissions, it is not meant to discount the extra cost that reducing emissions will have on some businesses and individuals. However there are many ways to reduce emissions that save costs. The intent is to highlight the practical opportunities for business to enable more Australian winners.

The next step for ClimateWorks is to work with both business and experts to unlock the opportunities identified in this plan. ClimateWorks hopes to help business, government and consumers identify the lowest cost emissions reduction opportunities, the barriers to implementation and how to overcome them.

ClimateWorks hopes readers find this a useful contribution to meeting the climate change challenge Australia faces.

Acknowledgments

In developing the Low Carbon Growth Plan, ClimateWorks Australia has sought insights, analysis and data from numerous experts in academic, scientific, business and governmental organisations, and received dedicated practical and financial support.

ClimateWorks Australia would particularly like to thank the Commonwealth Department of Climate Change (DCC), the Victorian Department of Sustainability and Environment and Victorian Department of Transport for contributing staff resources to the project, and McKinsey & Company for providing analytical support and the methodology for the GHG emissions reduction cost curve.

In addition ClimateWorks Australia gratefully acknowledges the contribution of the Australian Government through the Australian Carbon Trust for its financial support particularly focused on the commercial buildings sector analysis, and the practical support from DCC through participation in the project steering committee and review of data and outputs across all key sectors.

The US-based ClimateWorks Foundation has also been integral to this project, and we extend our appreciation for the use of their ground-breaking low carbon growth plan methodology, and for their input to the project steering committee. In addition to developing highly targeted campaigns focused on effecting rapid and significant emissions reductions, the ClimateWorks Foundation has supported the development of low carbon growth plans for several countries to date, including Mexico and Indonesia. ClimateWorks Australia is proud of its association with this dedicated, action-focused network.

While this report and the ideas expressed in it belong solely to ClimateWorks Australia, we wish to extend our gratitude to the following individuals, companies and organisations for their valued input:

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Professor Tom Heller	Stanford Professor; Project Catalyst lead member; Executive Director, Climate Policy Initiative
Mick Keogh	CEO, Australian Farming Institute
Sam Mostyn	Director, Sydney University Institute for Sustainable Solutions
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Ann Sherry AO	CEO, Carnival Australia
Mike Waller	Director and Partner, Heuris Partners; former BHP Billiton Chief Economist; Chair of Sustainability Victoria
Jennifer Westacott	Partner in Charge, Sustainability, Climate Change & Water, KPMG
Bob Williams	Senior Research Scientist, The Energy Group, Princeton Environmental Institute, Princeton University
Dr Alex Wonhas	Director, CSIRO Energy Transformed Flagship

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Contents

Executive summary

Australia can significantly reduce greenhouse gas (GHG) emissions between now and 2020 at low cost. Reducing GHG emissions can protect Australia's economy into the future, provide immediate benefits for society and create profitable opportunities for businesses.

SUMMARY OF FINDINGS

1. Australia has the potential to achieve GHG emissions reductions of 249 $MtCO_2e$ at a low cost

- Australia has the potential to reduce GHG emissions by 249 $MtCO_2e$ by 2020—a 25% reduction from 2000 levels—at an average annual cost to society of A$185 per household without changing lifestyle or the mix of businesses that comprise Australia's economy.
- This Low Carbon Growth Plan identifies 54 separate opportunities—across all sectors—that can be implemented over the next ten years to reduce emissions in Australia to 25% below 2000 levels. Almost one third of these emissions reduction opportunities offer a net savings to society, and the remaining two thirds have a weighted average cost of A$41 per tonne of carbon dioxide equivalent (CO_2e).
- The power and forestry sectors offer the largest emissions reduction opportunity (59% or 147 $MtCO_2e$) but come at the highest cost (average of A$40 per tCO_2e). Industry, buildings, agriculture and transport each offer smaller reduction opportunities, but together still represent a 102 $MtCO_2e$ opportunity. They are also mostly economically attractive with average net savings to society of A$40 per tCO_2e.

2. Reducing GHG emissions can be profitable for businesses

- Almost a quarter of these opportunities (or 54 $MtCO_2e$) generate a positive return for businesses, even without a carbon price. By using resources more efficiently and thus reducing input costs, many businesses will be able to achieve returns above their cost of capital while at the same time reducing their GHG emissions. These profitable opportunities are concentrated in the buildings, transport and industry sectors.
- Reducing GHG emissions will also provide additional growth opportunities for businesses. As the world moves towards a low carbon economy, demand for carbon-efficient products and services will steadily increase, providing significant opportunities for businesses that supply these, such as engineering and construction companies and equipment and product manufacturers and installers.

3. A combination of a carbon price and targeted actions is required to achieve Australia's full potential of low cost emissions reductions

- A carbon price will increase the incentive for business to invest in emissions reduction. For example, a carbon price of A$43 per tonne in 2013 rising to A$69 per tonne in 2020 (the price estimated by Australian Treasury in its Garnaut -25 forecast[1]) is likely to more than

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[1] Australian Treasury. *Australia's Low Pollution Future: The Economics of Climate Change Mitigation.* 2008. This price was based on global price forecasts and expected use of Clean Development Mechanism (CDM) offsets; converted to 2010 dollars.

triple the emissions reduction opportunities with a positive return for business, increasing the total of profitable opportunities from 54 $MtCO_2e$ to 199 $MtCO_2e$ (80% of the total identified opportunity).

- Additional action will be required to overcome other barriers that do not respond to a carbon price. These include market structure and supply, information gaps, decision processes, capital constraints and investment priorities. Overcoming these barriers will most effectively be achieved through targeted action. The barriers to emissions reduction vary by specific opportunity and subsector and so a portfolio of tailored measures is needed for the different opportunities.
- Business-led solutions are critical to address the emissions reduction challenge. In some cases, the complexity or difficulty of a barrier will make business-led solutions less feasible or less efficient, and thereby necessitate further government action to create market conditions where full capture of emissions reduction is possible. But in many cases, businesses have the ability now to achieve more cost-effective emissions reductions.

4. A portfolio of prompt action is required

- Three broad types of action taken now will help Australia implement the 54 opportunities and achieve maximum emissions reduction at lowest net cost to the economy. The type of action depends on the risk of “lock-in” of emissions and the ease of emissions reductions:
  - Remove barriers for those opportunities for which a positive return is already available for business
  - Introduce a price for carbon and remove further non-price barriers to capture opportunities for which technology and economics are well understood, but not currently profitable to undertake
  - Undertake longer term actions to improve the economics and certainty of high potential emissions reduction opportunities that are currently difficult to implement
- Delaying action will mean some low cost opportunities are lost. Many emissions reduction opportunities, like avoiding the installation of inefficient equipment that has a 20–30 year life, exist only for a finite period. Without prompt action the reduction potential will disappear, and any remedial measure to later “make up” the deficit will cost more.

This report sets out Australia’s emissions reduction opportunities in cost order and by sector, the challenges faced in capturing them, and actions required to succeed. It also illustrates the significant opportunities available to business. ClimateWorks Australia hopes this report (and the substantive fact base that underpins it) will be useful to prompt and guide the actions required from government, business and consumers to achieve the emissions reduction potential for Australia at the lowest possible cost.

The opportunity

The opportunity

KEY POINTS

- Without additional actions, Australia's GHG emissions will increase to 20% above 2000 levels by 2020
- Australia can reduce GHG emissions to 25% below 2000 levels by 2020 at an average annual cost to society of A$185 per household using technologies that are available today
- 22% of emissions reduction opportunities appear already profitable from an investor's perspective
- New opportunities will be created for business to supply goods and services as the world moves toward a lower carbon economy

Chapter 1 outlines the opportunity for GHG emissions reductions in Australia. It aims to answer key questions such as: what are the lowest cost emissions reduction opportunities? What do the economics of emissions reduction look like from a business or investor perspective? What are the additional opportunities for business?

This chapter begins with an explanation of the "business-as-usual" case, which is an estimate of GHG emissions in 2020 without any of the actions identified in this report. The view here is consistent with the Department of Climate Change projections.[2] The report then explores the opportunity for society, which examines the overall emissions reduction opportunity and the costs to society as a whole. It then reviews the opportunity from the perspective of business including the economics of individual emissions reduction opportunities for companies.

Later chapters examine the actions required by businesses, households and governments to fully realise these opportunities to reduce emissions.

BUSINESS-AS-USUAL CASE

Without any additional actions beyond those already underway or legislated, Australia's annual GHG emissions are forecast to increase from 553 $MtCO_2e$ in 2000 to 664 $MtCO_2e$ by 2020, or a 20% increase, at a growth rate of 0.9% per year (see Exhibit 1). The majority of emissions growth will be from increased emissions from industry and mining, transport and stationary energy (power stations). This compares to a projected economic growth rate of 2.9%, meaning that the emissions intensity of the economy will continue to decline.

Existing actions by government, businesses and households in recent years have reduced the rate of increase in future emissions. Exhibit 2 shows how the forecast emissions have fallen by 5% over the last 3 years. This improvement in Australia's emissions intensity is driven by current

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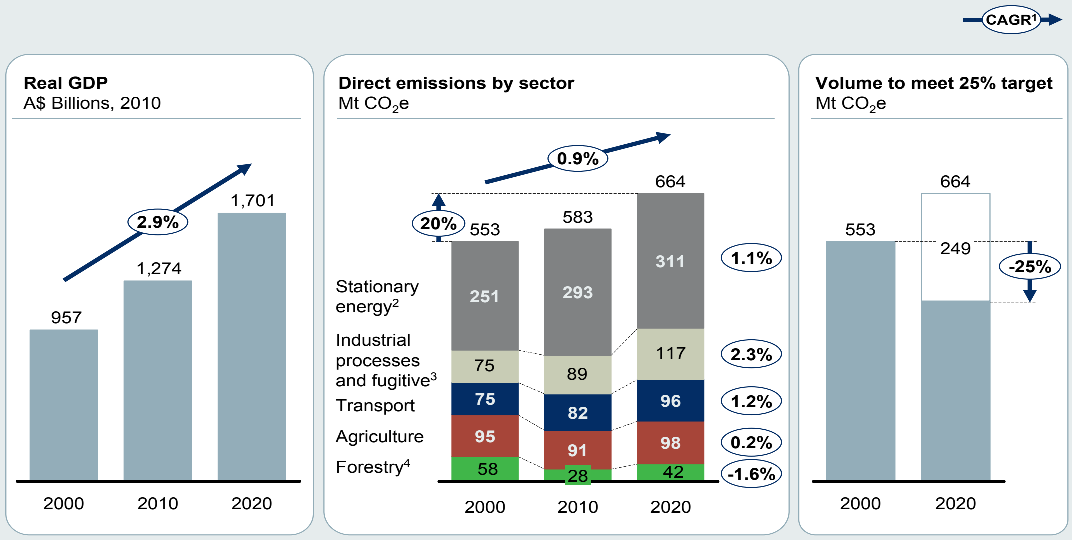
[2] Department of Climate Change. *Tracking to Kyoto and 2020 – Australia's Greenhouse Emissions Trends 1990 to 2008–2012 and 2020.* 2009.

Exhibit 1: Business-as-usual projected economic and emissions growth



1 Compound Annual Growth Rate per annum, 2000–20

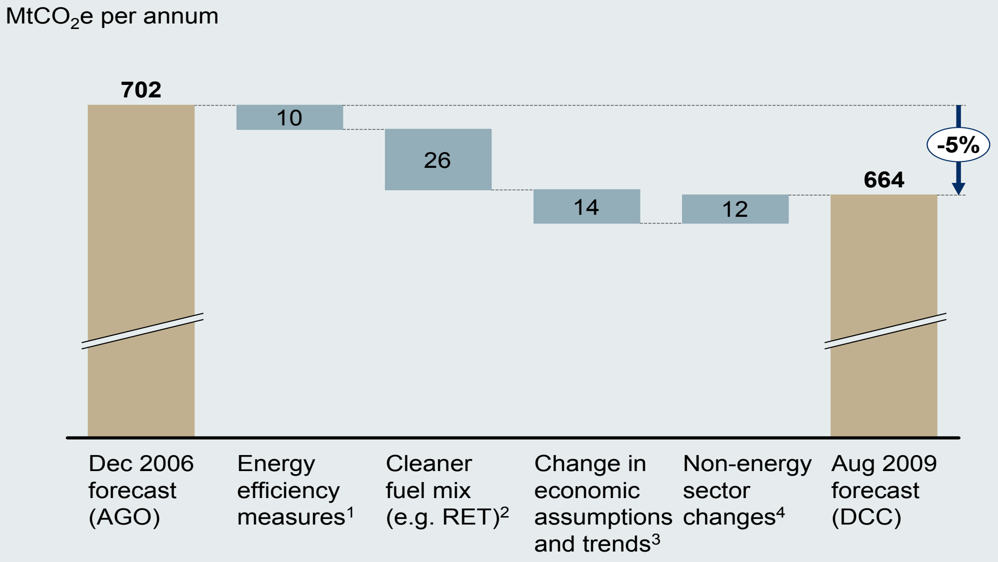
2 Direct emissions from the power sector can also be regarded as indirect emissions from downstream power-consuming activities (e.g. power use in the building and industry sectors)

3 Includes fugitive emissions, industrial process emissions and waste emissions

4 Net emissions after subtracting growth in carbon sinks (e.g. new plantations) from emissions due to land clearing; Kyoto accounting method used

SOURCE: Australian Department of Climate Change (2009); ClimateWorks team analysis

Exhibit 2: Improvement of 2020 BAU forecast from 2006 to 2009



1 Includes measures such as phase out of electric hot water heaters, sustainable housing and insulation rebate

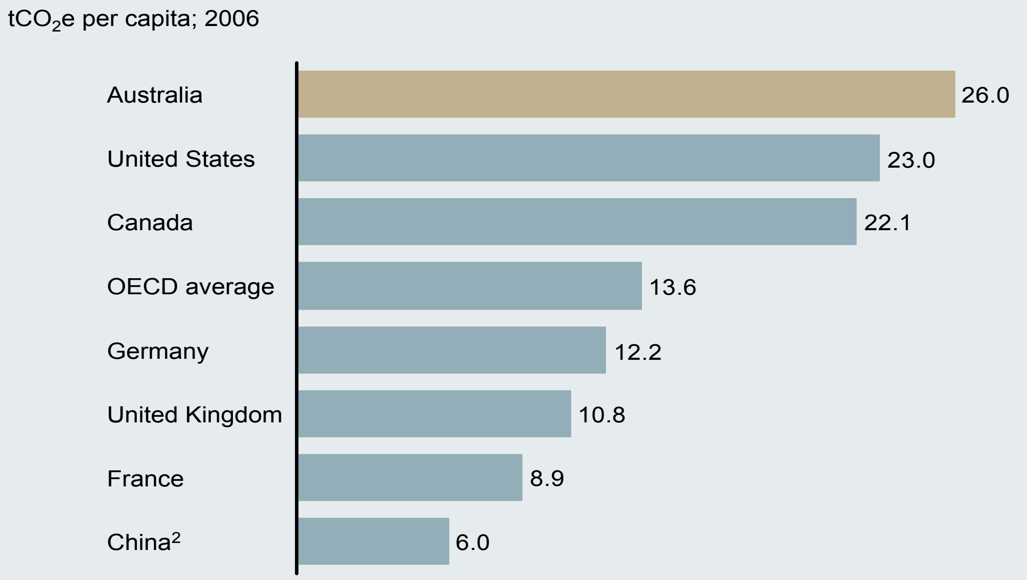
2 Includes impact of the Renewable Energy Target (RET) which increases the use of renewable sources of energy, and an increased use of gas

3 Includes impact of a decrease in power generation growth and power station emissions intensity

4 Includes mainly changes in land use and forestry

SOURCE: Department of Climate Change (2009); Australian Greenhouse Office (2006)

Exhibit 3: Greenhouse gas emissions per capita[1]



1 Includes all local emissions, regardless of where locally manufactured or created goods (e.g. cattle or aluminium) are consumed.
2 China data is 2005

SOURCE: UN Statistics Division (2009), US Congressional Research Service (2008)

policies such as the expanded Renewable Energy Targets and energy efficiencies measures including improved standards for buildings, insulation rebates and phase out of electric hot water heaters (see Exhibit 2).

This report focuses only on emissions generated domestically in Australia. Although this includes GHG emitted locally to produce products for export (e.g. beef cattle methane or aluminium refining), it does not include emissions in other countries that rely on Australian raw materials (e.g. power generated with imported coal, or cars manufactured from imported aluminium).

Australia has the largest emissions per capita in the developed world (see Exhibit 3).

THE OPPORTUNITY FOR SOCIETY

Our analysis suggests that a GHG emissions reduction of 25% below 2000 levels, equivalent to 249 $MtCO_2e$ below the 2020 business-as-usual forecast, can be achieved at an average annual cost to society of A$185 per household[3] without assuming major technological breakthroughs or changes to business mix or lifestyle. This is shown using a 'GHG emissions reduction cost curve' (Exhibit 4), which illustrates the volume of each emissions reduction opportunity and orders them by cost per tonne reduced.

This cost curve displays emissions reduction opportunities by sector, and has been constructed based on the following principles:

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[3] These costs will differ by household (e.g. products sold in regional areas may face higher costs due to energy used in transport), and may not always be borne directly depending on the amount of cost passed through by businesses in their pricing, or government support.

- Include only opportunities for which technology is commercially available, or on the path to commercialisation
- Exclude opportunities or actions which are expected to occur under current policies (as these are captured in the business-as-usual case) except for the introduction of a carbon price through emissions trading as it has not yet been legislated
- Exclude changes in business mix (e.g. shifting mix of economy from manufacturing to service industries)
- Exclude changes in lifestyle (e.g. driving less)
- Estimate cost from a societal perspective (see box below)

Societal perspective

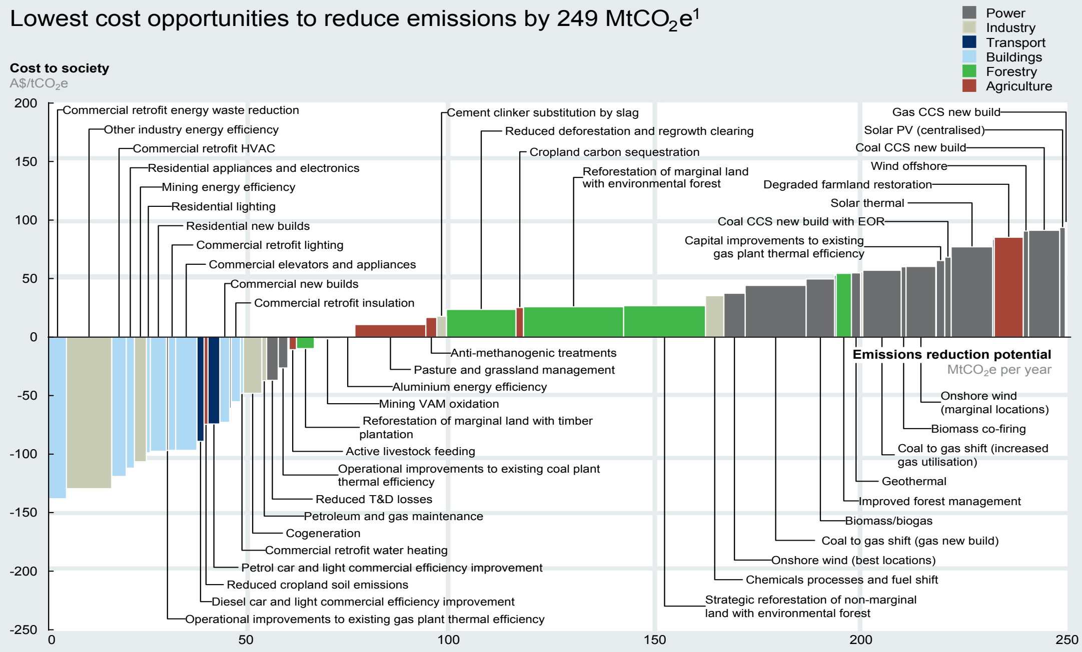
For the version of the cost curve shown in Exhibit 4, emissions reduction costs are calculated from a societal perspective (i.e. excluding taxes and subsidies and using a cost of capital close to the long term government borrowing rate). The methodology also does not take account of the transaction and program costs associated with implementing these emissions reductions—such as the administration costs of government programs or management time—as these vary with the precise approach chosen for each option. The methodology also does not take account of co-benefits, such as improved health or reduced congestion.

This methodology allows comparison of emissions reduction potential across sectors, countries and years, and means that broad conclusions can be drawn on which set of emissions reduction activities should be undertaken to provide the highest possible return to society.

However, these societal costs differ from the costs that a company or consumer would incur. This curve cannot be used to estimate a carbon price, which is one measure available to capture these opportunities, and excludes any further emissions reductions from lifestyle changes which may also be prompted by such measures.

This curve also includes some opportunities that are not included in Australia's Kyoto obligations (such as soil carbon sequestration, reduced cropland emissions, and improved forest management) which together represent 12% of the total opportunity shown. It is important to note that although these are real opportunities to reduce emissions, they will face added implementation challenges as long as they remain outside of Australia's international obligations. We have included these to ensure we comprehensively identify the lowest possible cost emission reduction opportunities for Australia.

Exhibit 4: 2020 GHG emissions reduction *societal* cost curve


Lowest cost opportunities to reduce emissions by 249 $MtCO_2e^1$

1 Includes only opportunities required to reach emission reduction target of 249 Mtpa (25% reduction on 2000 emissions); excludes opportunities involving a significant lifestyle element or consumption decision, changes in business/activity mix, and opportunities with a high degree of speculation or technological uncertainty

SOURCE: ClimateWorks team analysis (refer to bibliography)

A full page version of this chart is included in Appendix 1.

This curve reflects an assessment of the size and cost of emissions reduction opportunities in Australia, based both on international data generated by The ClimateWorks Foundation and McKinsey & Company, and local data drawn from a range of Australian sources (see bibliography). While a broad, cross-sector analysis will be somewhat cursory by nature, ClimateWorks Australia is confident that this represents a reasonable estimate of the emissions reduction opportunities available to Australia.

Further detail on the cost curve methodology and how to read this chart are provided in the box 'How to read the GHG emissions reduction cost curve' below. To foster an open and inclusive discussion, key assumptions underlying this analysis have also been included in Appendix 3: Key assumptions.

ClimateWorks Australia chose to focus this report on the 2020 cost curve, as a ten year timeframe is relevant for identifying the practical actions that can be taken now, and also corresponds to the government's current targets and commitments. A 2030 cost curve is provided in Appendix 1, but not discussed further in this report.

How to read the GHG emissions reduction cost curve

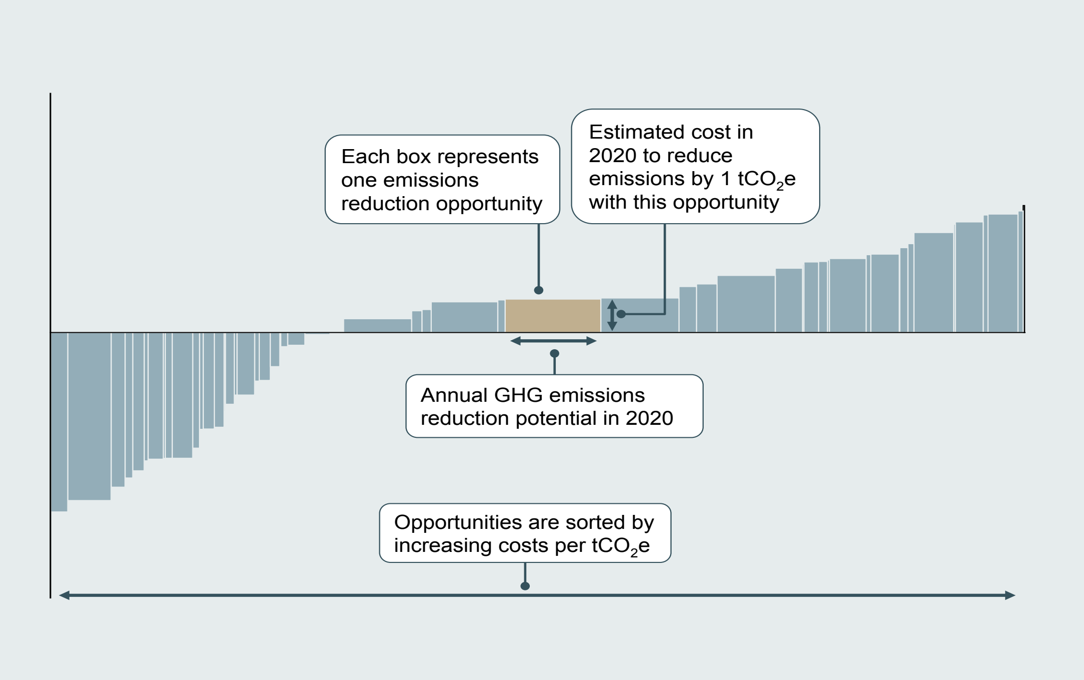
The GHG emissions reduction cost curve summarises our estimate of the realistic volume and costs of technical opportunities to reduce GHG emissions. The width of each column represents the GHG reduction potential of an opportunity in the specific year compared to the emissions forecast under the business-as-usual (BAU) case (discussed above). The height of each column represents the average cost for that activity of abating a tonne of CO_2e in the specified year. All costs are in 2010 real Australian dollars (A$), and the graph is ordered left to right from the lowest cost to the highest cost opportunities.

The curve includes only the lowest cost opportunities required to reduce GHG emissions by 249 $MtCO_2e$ (the reduction required beyond BAU to reach 25% below 2000 emissions) and excludes opportunities involving changes in what Australia produces (business mix) and in what Australians consume (lifestyle) as well as opportunities with a high degree of speculation or technological uncertainty.

BALANCED ASSESSMENT, UNCERTAINTY REMAINS

The volume shown represents our assessment of realistic reduction potential, rather than the full technical potential for each opportunity, reflecting constraints such as the availability of inputs (including technology, labour, capital stock), but assuming that businesses and government are able to fully overcome the barriers discussed in this report. In practice, a robust analysis of the nature and impact of these barriers—including transactions costs—is essential to the design and implementation of effective business strategies and

Exhibit 5: How to read an emissions reduction cost curve



SOURCE: ClimateWorks team analysis

government policies to unlock the emission reduction potential indicated in this report.

Given significant uncertainty about volume and costs for emerging technologies, a balanced approach has been adopted in formulating the underlying assumptions. ClimateWorks Australia has drawn from as wide array of technically verifiable sources as possible in developing this report. Despite these efforts, ClimateWorks acknowledges that there remains substantial room for debate and refinement of specific estimates, and as such has laid out the assumptions behind this analysis in Appendix 3: Key assumptions.

In aggregate, the total emissions reduction opportunity quantified through the bottom up analysis presented in this report is broadly consistent with the results of top down economic modelling for Australia. Our analysis suggests these domestic emissions reductions could be achieved at somewhat lower net societal cost with effective business and government policy action to complement a broad based carbon price.

INTEGRATED MODEL

Opportunities have also been integrated within and across sectors, meaning that the interplay of emissions reduction potential between opportunities has been taken into account. For example, increasing the penetration of hybrid vehicles will decrease the new cars available for electric; and reducing energy use in buildings will reduce emissions saved by shifting to cleaner electricity generation.

COMMERCIAL TECHNOLOGY

This report only reviews technologies that are commercially available today (e.g. solar PV) or are well established on the path to commercialisation (e.g. carbon capture and storage), and assumptions about likely learning curves for technologies currently undergoing commercialisation are consistent with historical data. Promising technologies with high current technical uncertainty (e.g. biochar and underground coal gasification) have been excluded from this report.

SOME COSTS AND BENEFITS EXCLUDED

While the costs included in the GHG emissions cost curve are likely to constitute the vast majority of costs to the Australian economy, they do not include difficult-to-quantify transaction costs, such as management time required to implement such changes (see page 25 for further discussion on transaction costs) or program costs that depend on how policy makers choose to implement each opportunity. Furthermore, they do not include the likely cost of climate change itself, such as the costs induced by a decline in agricultural production, the destruction of the Great Barrier Reef, or increased damage from extreme weather. Nor do they include the co-benefits of acting to reduce emissions, such as improved health benefits or value created in the economy through the pursuit of new business opportunities. Opportunities involving lifestyle or behavioural shifts are also excluded from the curve, because their costs or benefits are largely non-financial and thus more difficult to quantify (for more discussion on lifestyle shifts see page 19).

For more detail see Appendix 1: Methodology.

THE COST OF EMISSIONS REDUCTIONS

The total net cost to society in 2020 of a 249 $MtCO_2e$ reduction in emissions (25% below 2000 levels) is estimated to be A$1.8 billion p.a. This is equivalent to A$185 per household per annum. This is less than 1% of the predicted growth in GDP per household between 2010 and 2020 or 0.1% of the projected GDP per household in 2020. This net cost includes the benefits of economically attractive opportunities (i.e. those emissions reduction opportunities that will save money). Excluding these items, the total cost would be A$7.3 billion, or an average of A$749 per household.

The GHG emissions reduction opportunities identified in the cost curve can be split into three categories (see Exhibit 6): those that offer net savings to society (cost less than A$0 per tonne), those that are accessible at a relatively moderate societal cost (A$0 to A$30 per tonne) and those that incur a higher societal cost (above A$30 per tonne). Each of these is discussed further below.

Actions required by businesses, households and government to realise these opportunities are discussed in Chapters 2, 3 and 4.

Net savings opportunities

29% of the GHG emissions reduction opportunities identified already offer net savings to society. These opportunities are shown on the left-hand side of the curve and total 71 $MtCO_2e$ of GHG emissions reductions by 2020. The savings generated by this reduction can be used to offset the cost of further GHG emissions reduction opportunities.

These opportunities are primarily composed of energy efficiency improvements in buildings, industry and transport.

GHG emissions reductions in the buildings sector can be achieved through improving the efficiency of appliances, equipment and lighting, and by designing more temperature-efficient buildings to reduce the heating and cooling load. Pursuing such opportunities in buildings provides 28 $MtCO_2e$ of GHG emissions reductions in 2020, or 11% of the total opportunity, while providing energy cost savings to businesses and individuals.

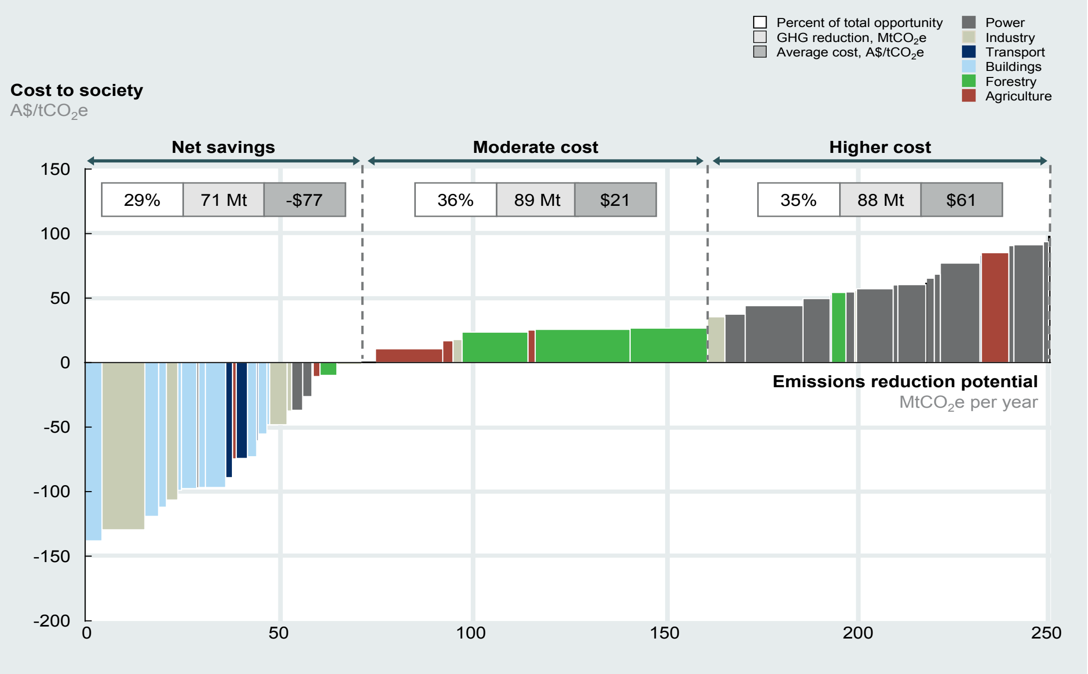
Reducing the consumption of fuel (coal, natural gas and electricity) in the industry sector through more efficient equipment and processes also provides significant opportunities, with 15 $MtCO_2e$ (6% of the total) of GHG emissions reductions from industry energy efficiency in 2020 and a further 11 $MtCO_2e$ (5% of the total) available through better utilisation of waste heat and fugitive gas, as well as reduction of leaks in the gas distribution system. These also come with energy cost savings for business.

Improvements in the efficiency of internal combustion engine (ICE) vehicles also offer net savings opportunities. ICE efficiency gains can reduce the fuel required per kilometre by 12–39% for passenger cars and light commercial vehicles and 3–10% for buses and rigid trucks, resulting in 5 $MtCO_2e$ of transport emissions reductions that save money in 2020.

Moderate cost opportunities (under A$30 per tonne)

In 2020, 89 $MtCO_2e$ of GHG emissions reductions identified (36% of the total) are estimated to cost society between A$0 and A$30 per tonne, with an average cost of A$21 per tonne. These opportunities are primarily in the forestry and agriculture sectors, as shown in the middle of the cost curve (see Exhibit 6).

Exhibit 6: Key *societal* cost curve metrics



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Forestry emissions reduction opportunities tend to be low cost because of the marginal value of much of the land on which these opportunities can be pursued. Reforesting less than 1.5% of agricultural land with environmental plantations (i.e. forests planted purely for their carbon sequestration benefits) has an estimated potential of 45 $MtCO_2e$ (18% of total) of emissions reduction opportunities in 2020 at an estimated societal cost of A$26 per tonne on average. Achieving this will require policy settings to provide long run confidence.

The moderate cost of GHG emissions reductions in the agriculture sector is largely due to the productivity improvements that accompany these opportunities. Cropland carbon sequestration, for example, has the potential to improve the productivity of the soil by increasing its carbon content while at the same time reducing emissions by 2 $MtCO_2e$ in 2020 (there are a number of differing estimates of the soil carbon sequestration emissions reduction opportunity—further details are provided in the agriculture sector summary in Chapter 3). Similarly, anti-methanogenic treatments (e.g. vaccines that reduce methane emissions) have the potential to make livestock more productive by reducing the proportion of calorie intake that is consumed by bacteria, while at the same time providing 3 $MtCO_2e$ of emissions reductions in 2020.

Higher cost opportunities (more than A$30 per tonne)

The third set of identified GHG emissions reduction opportunities in 2020, representing 88 $MtCO_2e$ or 35% of the total opportunity, involve estimated societal costs between A$30 and A$100 per tonne of CO_2e, with an average cost of A$61 per tonne. These opportunities are concentrated in the power sector, and generally require a shift in the mix of power generation towards lower emissions technologies (predominantly through substituting gas or renewable fuels for coal). As a result of the significant capital expenditures required to achieve such shifts, power sector emissions reduction opportunities tend to be relatively high cost, and will require policy settings to provide long run confidence.

The impact of lifestyle and behaviour changes

The cost curves discussed in this report consider only those emissions reduction opportunities that do not require changes in the lifestyle of individuals (e.g. changing from private car use to public transport). This was a conscious design choice, as it allows for an analysis of how much emissions can be reduced without Australians changing the way we live, travel and consume on a day-to-day basis. However, lifestyle changes can offer a large and often economically attractive method of reducing emissions. Therefore, while not incorporated directly in the Low Carbon Growth Plan, following is a brief explanation to illustrate their potential impact.

For most Australians, lifestyle emissions can be broken into three key broad categories:

- **Passenger transport.** The average individual emits 44% of his or her greenhouse gases as a result of travel. Passenger cars will make up 53% of Australian transport emissions in 2020 (or 8% of total emissions).
- **Household energy.** The next largest emissions source is in the home, where heating, cooling, lighting, refrigerating, washing, cooking and increasingly computing contribute another 36% of an average individual's GHG emissions, mainly via the electricity that these activities consume.
- **Consumables.** The remainder of an individual's impact is from the GHGs emitted during the manufacture and transport of products purchased and consumed, including food, clothing, cars and appliances as well as emissions created when these products are thrown away.

There are a variety of adjustments individuals and businesses can make to their lifestyle and work patterns in each of these categories

Exhibit 7: Example opportunities to reduce emissions through lifestyle and behaviour change

Categories	% of personal carbon footprint	Example opportunities	2020 emissions reduction potential Volume $MtCO_2e$	 Net savings $A\$/tCO_2e$
Passenger transport	44%	Avoid 25% of business flights on high traffic routes through increased videoconferencing	0.4	200
		Switch 15% of total urban car trips under 3 km to walking or cycling	1.1	6
		Reduce total urban car travel by 5% through increased use of public transport	1.6	6
		Shifting car occupancy rates from 1.4 to 1.6 persons per car	2.8	150
Building and household energy	36%	Reduce required home temperature by 2°C	1.1	56
		Reduce required commercial temperature change by 2°C	1.6	92
		Switch key home appliances from standby to off when not in use	0.2	56
Consumables	20%	Switch 50% of bottled water drunk in Australia to tap water	0.1	200

SOURCE: BITRE/CSIRO (2008); Australian Institute of Petroleum (2009); Ovum (2008); ABS (2009 and 2010); DEWHA (2008); Hackett et al (2009); Australasian Bottled Water Institute (2009); Econometrica (2009); ClimateWorks team analysis to reduce carbon emissions, many of which would save money or be financially profitable.[*] Exhibit 7 contains a number of specific examples, including their emissions reduction potential and cost savings.

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[*] In this report, profitable is defined as a positive return on incremental invested capital and operating expenses (excluding transaction or policy implementation costs).

CO-BENEFITS

In addition to GHG emissions savings, many of the emissions reduction opportunities outlined above offer significant co-benefits such as improved energy security, reduced energy infrastructure investment requirements, improved productivity and better health and welfare. For example, recent studies conducted in the United States show that green buildings can deliver up to 10% increase in productivity and 40% decrease in sick days compared to average buildings, numbers corroborated in Australia by observations following a major green refurbishment at 500 Collins Street, a 30 year old building in Melbourne.[4] Industrial operational improvements, in addition to reducing energy costs, often improve productivity by making better use of equipment (e.g. reducing idle time or optimising the loads for trucks). Similarly, by increasing the carbon content of the soil, the fertility of the land can be improved, leading to greater productivity. By using less energy, Australia will also be able to reduce some of its expected A$40 billion worth of proposed power generation projects over the medium term,[5] saving billions of dollars in capital investment. These benefits have not been reflected in the cost curve, but provide a significant additional motivation to move to a low carbon economy.

THE OPPORTUNITY FOR BUSINESS

The societal perspective offers a view of emissions reduction opportunities and their costs for society as a whole, but what about the view for individual businesses that make actual investment and operating decisions?

Re-building the emissions reduction cost curve to reflect the investor's view enables us to develop this perspective (see Exhibit 8).

The key differences to note between the societal and investor cost curves are as follows:

- 22% of opportunity (or 54 $MtCO_2e$) remains profitable from an investor's perspective
- The average cost for the moderate and higher cost opportunities increases by 27% from A$41 per tCO_2e in the societal view to A$52 per tCO_2e in the investor view, as the large capital expense of these opportunities is heavily impacted by the private sector's cost of capital

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[4] Colliers International. *Colliers International Office Tenant Survey.* 2008; McGraw Hill Construction. *Smart Market Report.* 2006; Turner Construction. *Market Barometer.* 2004; The Hon Peter Garrett AM MP, Minister for the Environment, Heritage and the Arts. *Keynote address,* Green Cities Conference, 2009.

[5] ABARE, *Electricity generation – Major development projects.* October 2009.

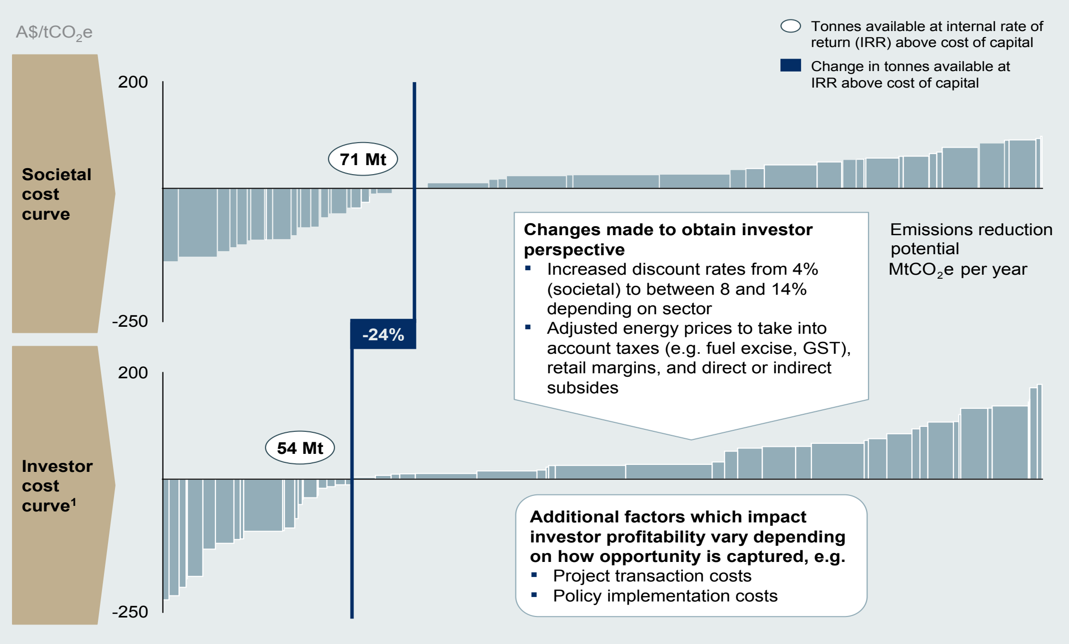
- The average cost saving of the profitable opportunities increases by 45% from A$77 to A$103 per tonne

- The cost order of some opportunities change (e.g. improvements in the efficiency of smaller ICE vehicles become more profitable than most building energy efficiency improvements)

Otherwise the societal and investor cost curves lead to similar conclusions:

- Economically attractive opportunities are concentrated in the buildings, industry and transport sectors, offering both net savings to society and profit for investors
- Moderate cost opportunities are still largely in forestry and agriculture
- Higher cost opportunities are in the power sector

Exhibit 8: Comparison of societal and investor cost curves



Changes made to obtain investor perspective
- Increased discount rates from 4% (societal) to between 8 and 14% depending on sector
- Adjusted energy prices to take into account taxes (e.g. fuel excise, GST), retail margins, and direct or indirect subsidies

Additional factors which impact investor profitability vary depending on how opportunity is captured, e.g.
- Project transaction costs
- Policy implementation costs

[1] Does not include the impact of a carbon price

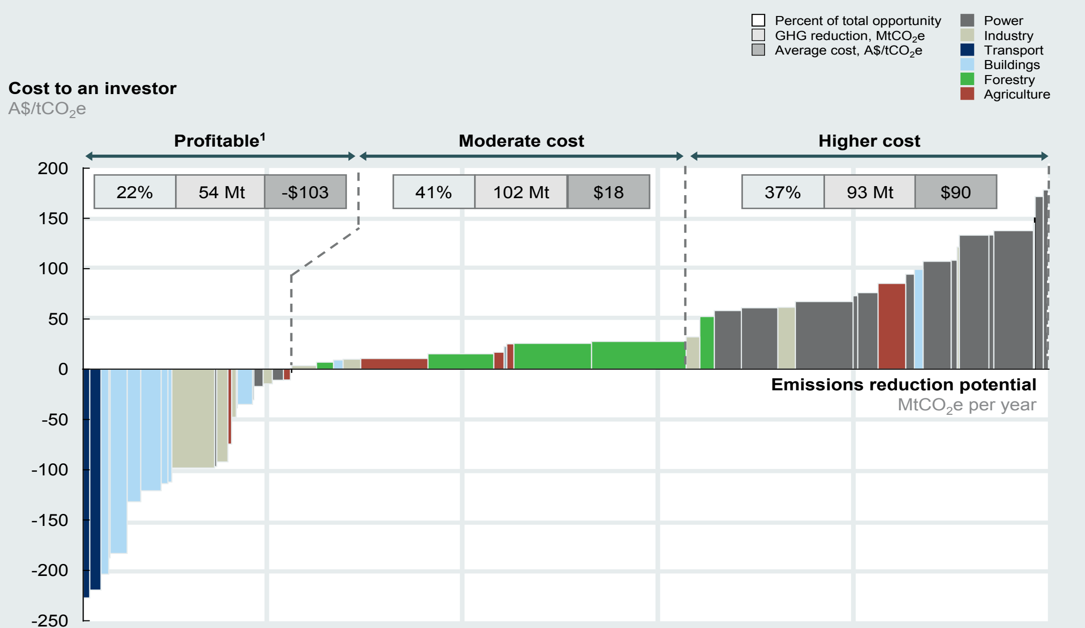
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Investor perspective

The Investor cost curve illustrates the net direct cost faced by a company or consumer to implement an emissions reduction opportunity. This requires adjusting costs calculated from a societal perspective, to include the typical private cost of capital for each sector (8 to 14%), and energy taxes, retail margins and subsidies.

This curve does not incorporate some factors which impact investor costs but vary depending on how the opportunity is captured, such as project transaction or policy implementation costs. A discussion of how to lower these costs is included in Chapter 2: The Challenge.

Exhibit 9: Key *investor* cost curve metrics



1 In this report, profitable is defined as positive return on incremental invested capital and operating expense (excluding transaction or policy implementation costs)

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Detailed versions of the investor curve with individual opportunities labelled are shown for each sector in Chapter 3.

Additional opportunities exist for business and investors as the world moves towards a low carbon economy. Growing demand for carbon-efficient products and services will provide significant opportunities for businesses that supply them. Outlined below are some examples of these opportunities for some important sub-sectors:

- Demand for better performing and more sustainable **basic materials** such as aluminium or new insulation materials for buildings, copper for wind turbines and electricity transmission, and light weight plastics and carbon composites for cars or airplanes could lead to major growth opportunities in the chemicals and metals sectors.

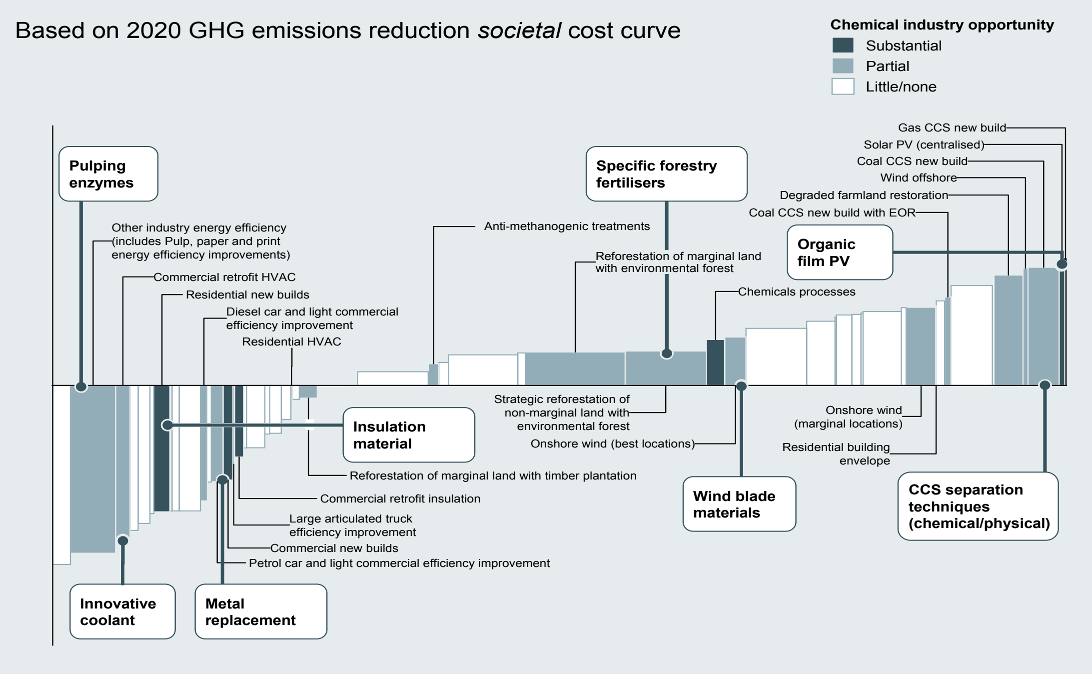
- Some elements of the **resources** sector can also benefit. For example, as Australia has more than 30% of the world's bauxite reserves, it could benefit from increased aluminium demand. It is also one of the few countries with significant deposits of rare earth elements which is critical for battery and magnet manufacture for electric vehicles and wind turbines. Increased demand for natural gas to replace more carbon-intensive fuels both domestically and internationally will also be an opportunity for the gas sector in the coming years. As energy prices increase, electricity generation from fugitive gases (such as methane from coal mines) may also provide additional revenue streams.

- Despite a probable lower growth in energy demand and increase in costs, **power generators** will also have opportunities to increase their revenues and profitability, including through the participation in emerging markets such as green power. Australia also has an opportunity to become a world leader in cleaner coal energy with research and pilot projects already in place (e.g. carbon capture and storage).

- The expansion of energy efficient retrofits represents an opportunity to trigger new growth for **engineering and construction** companies and energy services companies (ESCOs). It has been estimated that retrofits of private offices (about 11% of total commercial floor space) could create more than 10,000 jobs annually in the construction industry,[6] and energy service companies have been experiencing strong demand growth in the past few years as demand for end-to-end energy efficiency solutions has grown steadily.
- **Equipment and product manufacturers** can profit from increased penetration of clean technologies (e.g. solar panels and wind mills), high-efficiency equipment (e.g. appliances, electronics and vehicles) and more sustainable inputs (e.g. greener fertilisers).
- A low carbon economy will provide additional (potentially profitable) uses of **farmers'** land such as reforestation to create a carbon sink, or installation of wind farms for power generation.

Exhibit 10 shows a more detailed example of new opportunities that a low carbon economy can create for the chemical industry, especially in the basic materials and products manufacturing sub-sectors.

Exhibit 10: Opportunity scan for a chemicals company



Based on 2020 GHG emissions reduction *societal* cost curve

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

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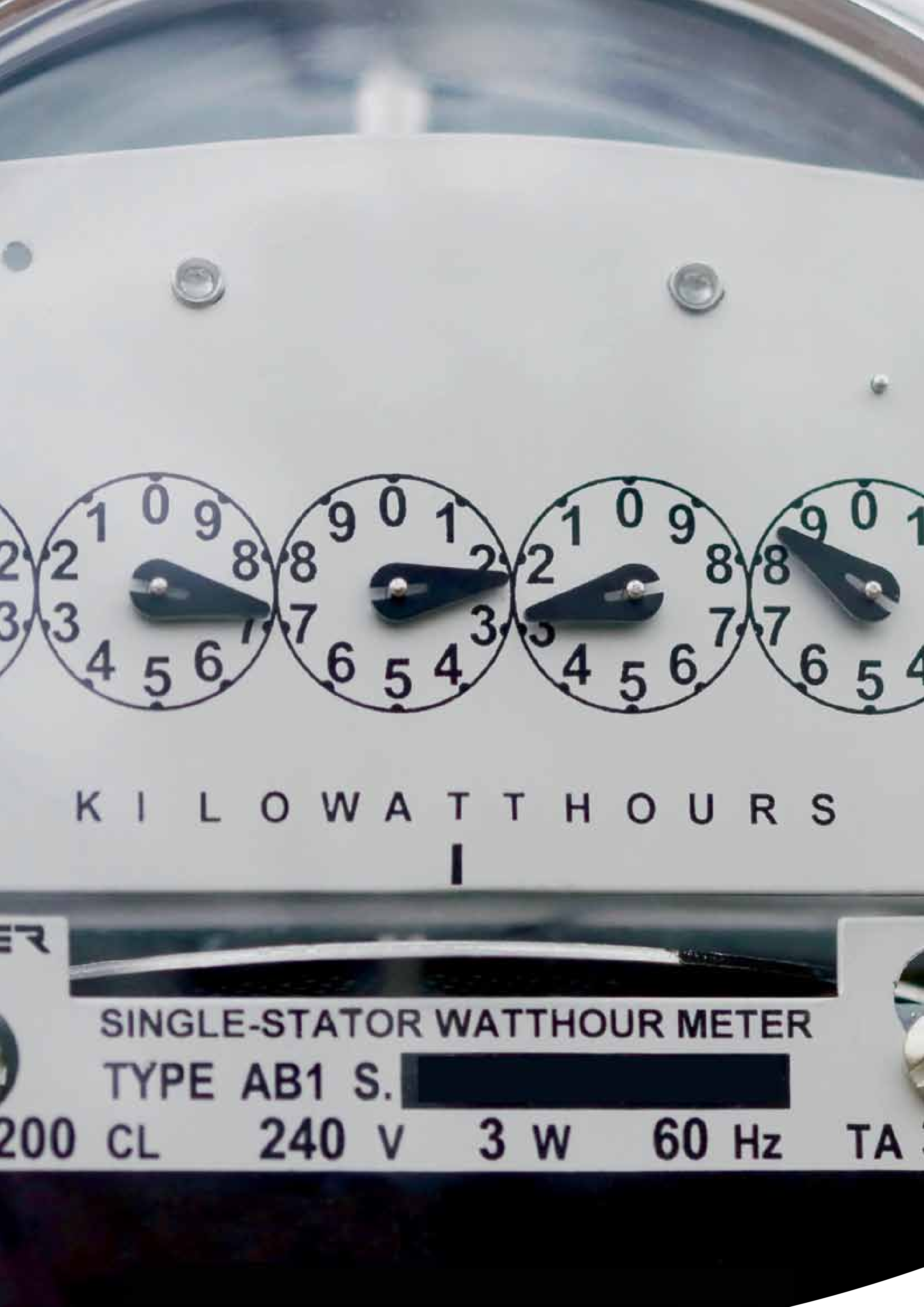
[6] Lend Lease Corporation, Lincolne Scott and Advanced Environmental. *Responses to additional questions by the Senate Select Committee Inquiry on Climate Policy.* May 2009.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The challenge

The challenge

KEY POINTS

- A carbon price would more than triple the volume of emissions reductions opportunities that are profitable for businesses (from 54 $MtCO_2e$ to 199$MtCO_2e$), under the 25% target price modelled here
- In addition, further non-price barriers also need to be addressed in a targeted fashion to ensure maximum realisation of the emissions reduction opportunity identified in this report as realistically achievable using known technologies between now and 2020. In particular these barriers are: market structure and supply, information gaps and decision making, and capital constraints and investment priorities
- There is a role for both business and government in creating the market conditions to ensure implementation of the emissions reduction opportunities

Chapter 1 identified the emissions reduction opportunity that we estimate is realistically achievable using known technologies between now and 2020, over and above what would already be achieved in the business-as-usual case. This assessment is built up from detailed analysis of the practical actions that make up this national opportunity.

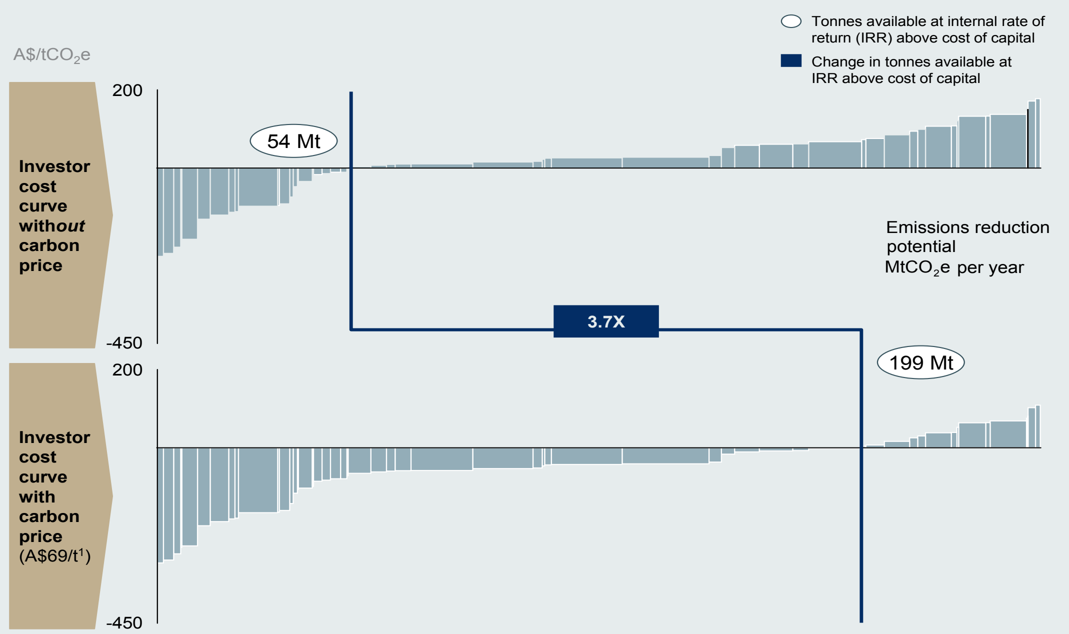
Chapter 2 is focused on building an understanding of the challenges to motivating these emissions reductions to happen, given that they are above what is forecast to happen under business-as-usual. It begins with an overall examination of the economics of emissions reduction and a review of the potential impact of a broad based carbon price on those economics. It then examines non-price barriers that are critical to address in a targeted fashion. Unlike a broad price-based mechanism, targeted measures depend on the specific opportunity or specific decision makers. This report therefore does not propose a solution to each barrier in this chapter, but instead addresses these on a sector-by-sector basis in Chapter 3: Sector Summaries. This chapter discusses the potential role of business and government in addressing some of these identified challenges.

PRICE OF GHG EMISSIONS

The pricing of GHG emissions can be an effective, market-based method to ensure the opportunities that are currently costly to an investor become profitable (as shown in Exhibit 11). The introduction of some form of carbon price, such as through an emissions trading scheme with a cap set at the level of emissions reductions to be achieved (25% below 2000 levels in this report), is thus central to overcoming the barrier that decision makers currently overlook the long run costs imposed by activities that produce emissions—or the benefits of reducing them.

By imposing a cost on emissions, a carbon price will amplify the operational savings available from emission reducing activities. For example, a carbon price of A$43 per tonne in 2013 rising to A$69 per tonne in 2020 (the carbon price estimated by Australian Treasury in its Garnaut -25

Exhibit 11: Impact of carbon price economics



1 Carbon price in 2020 of A\$69 per tonne based on Treasury Garnaut -25% estimate (*Australia's Low Pollution Future*) converted to 2010 dollars
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

forecast[7]) would push the return on investment above the cost of capital for an additional 145 $MtCO_2e$ of emissions reduction opportunities (see Exhibit 11). As a result, a total 199 $MtCO_2e$ of additional emissions reduction would become profitable for businesses (3.7 times the profitable pre-carbon price opportunity).

This has been calculated by assuming direct pass through of the price of carbon on all emitters and not accounting for any barriers to its effectiveness (see Exhibit 12 for estimated price traction per opportunity given non-price barriers).

For a carbon price mechanism to be effective, especially for longer term investment decisions, policy certainty is important. If investors are unsure of policy outcomes, the risk of acting or investing based on the price signal increases, thus reducing policy traction.

NON PRICE BARRIERS

Creating a further profit incentive for businesses to act on climate change can help achieve a substantial portion of the emissions reductions identified in Chapter 1: The opportunity. However, it is not enough to ensure that the full opportunity will be captured, as illustrated by the fact that there already exist profitable emissions reduction opportunities that are not pursued today (namely the opportunities on the left-hand side of Exhibit 4). Although a carbon price will encourage investors to invest in a greater range of emissions reduction opportunities,

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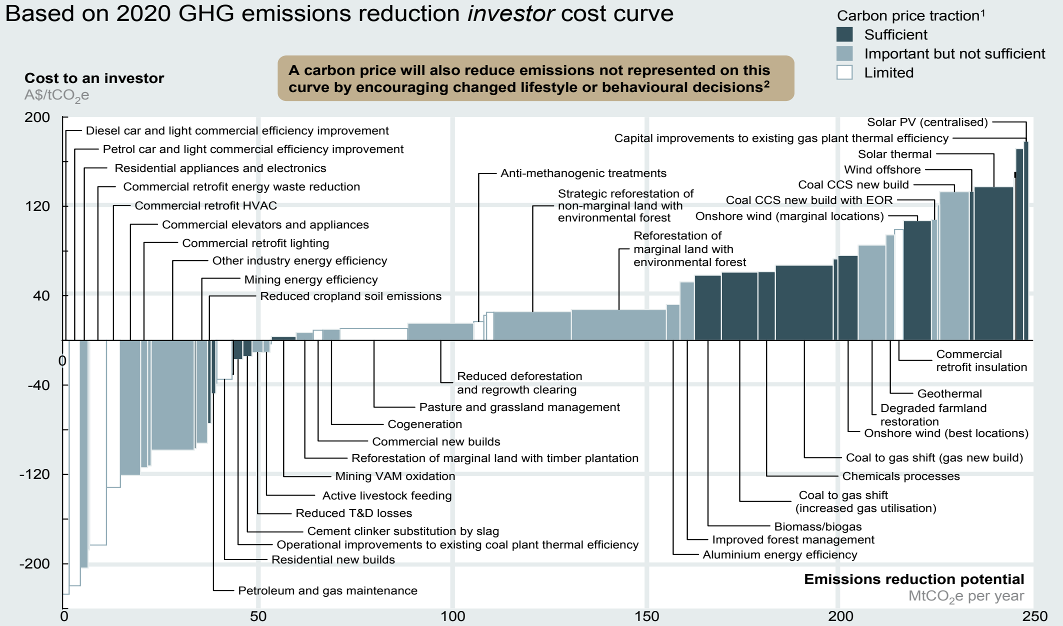
[7] Australian Treasury. *Australia's Low Pollution Future: The Economics of Climate Change Mitigation.* 2008. This price was based on global price forecasts and expected use of Clean Development Mechanism (CDM) offsets; converted to 2010 dollars.

Exhibit 12: Expected traction of carbon price

Based on 2020 GHG emissions reduction *investor* cost curve



A carbon price will also reduce emissions not represented on this curve by encouraging changed lifestyle or behavioural decisions[2]

1 Analysis assumes a carbon price large enough to make each opportunity profitable

2 Such as reduced consumption (e.g. turning lights off, driving fewer kms) and switching to less carbon-intensive forms of consumption (e.g. using public transport instead of driving)

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

including through the announcement effect drawing attention to already profitable energy efficiency options, non-price barriers to profitable emissions reductions also exist.

This results in differing levels of price "traction" for each opportunity, depending on the number and strength of the non-price barriers faced by investors or decision makers. The estimated price traction for each emissions reduction opportunity is summarised in Exhibit 12. The shading represents an assessment of how efficiently each emissions reduction opportunity will respond to the introduction of a carbon price signal. This assessment is based on the number of barriers that apply to each opportunity, the strength or importance of these barriers and the proportion of decision makers to which these barriers are applicable.

It is not surprising to see that the most profitable opportunities (pre-carbon price) on the curve face non-price barriers. These are opportunities that are expected to be profitable in the BAU case, yet are unlikely to be captured without further action.

Price and non-price barriers interact. Effective action to address non-price barriers will increase the amount of emissions reductions achieved for any particular carbon price, lowering the societal cost of achieving our national targets.

Effective action requires a set of approaches that are tailored to the specific opportunities and their barriers, and that work together with a broad based carbon price to overcome these challenges in the most cost-effective ways.

Three key categories of non-price barriers require additional action to achieve the lowest cost emissions reductions:

- Market structure and supply
- Information gaps and decision process
- Capital constraints and investment priorities

The discussion below examines these barriers in more detail, and includes some examples of companies and organisations that are addressing these barriers in innovative ways. The purpose of these examples is to inspire Australian businesses to consider the potentially profitable opportunities that may be available in addressing these non-price barriers (particularly those that impact emissions reduction opportunities that are already profitable).

MARKET STRUCTURE AND SUPPLY

Even when an emissions reduction project is profitable, the structure of a market or the behaviour of market participants can make it difficult to capture the opportunity. This report identifies three key market structure and supply constraints—high transaction costs, split incentives, and contract structures—that are outlined further below.

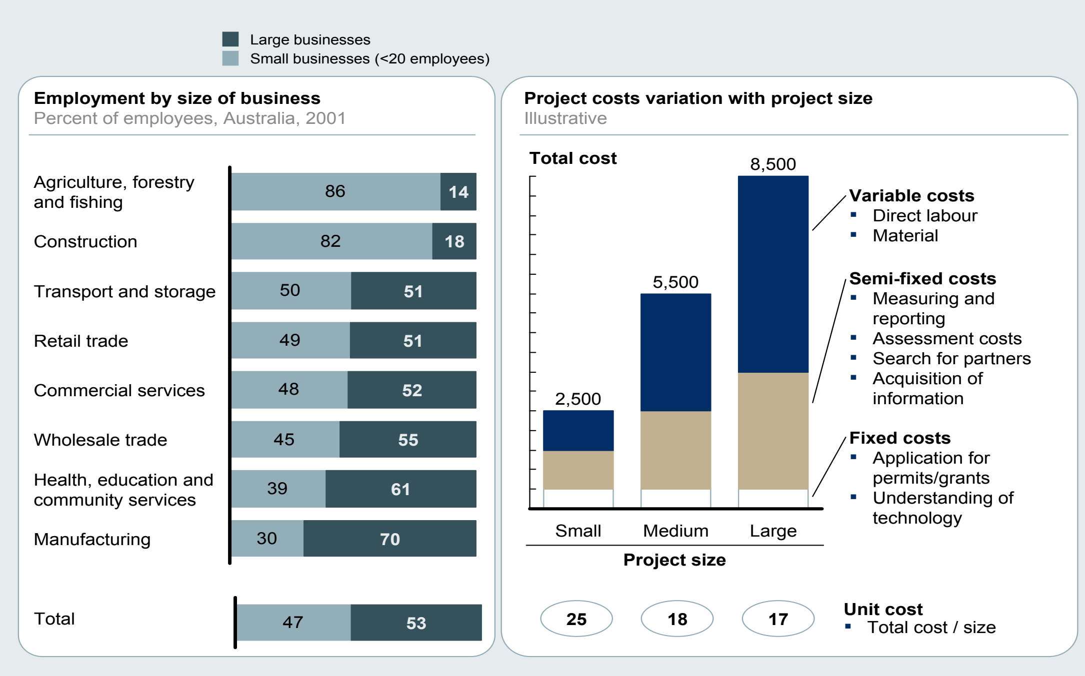
High transaction costs

Transaction costs are the indirect costs of projects that involve multiple participants, including the time involved in deciding and implementing actions. These costs include information gathering to choose a product, energy audits, price negotiations and monitoring of results. Transaction costs tend to be a higher share of total costs for smaller activities or organisations, as they must be incurred regardless of the project or entity size. Opportunities that require multiple “transactions” to achieve the same volume of emissions reduction will be more materially impacted by these fixed per-transaction costs (see Exhibit 13). Multiple transactions can be driven either by a fragmented investor base such as dairy farmers (about 8,000 in Australia compared with just 2 steel producers), or a small project size such as retrofitting a small office rather than a large commercial building. For example, the purchaser of an individual passenger car would find it more costly to do similar research as an individual who procures on behalf of a fleet of cars.

As lack of scale or fragmentation of decision makers is the greatest driver of transaction costs (per tonne of emissions reduced), opportunities to aggregate or standardise across large groups will have greatest impact.

Some energy service companies (ESCOs) have made a business of aggregating small scale projects on behalf of commercial building owners or city councils, therefore lowering the cost of assessment, planning and implementation of energy efficiency retrofits.

Exhibit 13: Small business in Australia and project costs



SOURCE: Australian Bureau of Statistics (2001); UN Environment Programme (2003); ClimateWorks team analysis

Transaction costs also depend on how or why an investor acts. For example, if energy efficient appliance standards are voluntary, many consumers will have to incur the cost of research and manufacturers will have to incur the cost of labelling or marketing to capture the opportunity. If these same standards are mandatory, these two additional costs will not be required for the same emissions reduction opportunity (but they may be partially replaced by government auditing or reporting requirements). Thus, a careful assessment of likely transaction costs is necessary in designing policy measures or other change programs.

Split incentives

Split incentives occur where the costs and benefits of emissions reduction accrue to different parties. Split incentives are a particular problem in capturing energy efficiency opportunities in residential buildings as they affect almost the entire residential housing stock. Tenants occupy around 30% of Australian homes; for these buildings, energy efficiency investments are unlikely to be made because the energy savings benefit the tenant while the owner is responsible for the necessary investment. Split incentives also occur in owner-occupied dwellings, where the average length of ownership is seven years—around the same length of time it takes to pay back some energy efficiency retrofits.

Some large commercial real estate companies have begun to subsidise energy efficiency upgrades of their tenants’ equipment, even though there is no immediate financial benefit, as they have recognised that demand for energy efficient buildings will increase in the future (particularly as energy prices rise and climate change awareness increases) and are positioning themselves as leaders in the market.

Contract structures

Some long term or less variable contract structures diminish the positive impact of short term action, or of changed price signals. The profitability of energy efficiency opportunities can be strongly impacted by the energy price that businesses negotiate or the rate at which their energy costs vary with usage. For example, some of the largest industrial energy users pay low wholesale rates for their variable electricity use and a relatively large fixed charge to access the network. This means the savings from energy efficiency improvements are only partially accessible by the user, while the large fixed network portion of their bill is not adjusted to reflect these savings. This can also bias decisions towards network expansion and increased generation, rather than considering profitable demand management options.

INFORMATION GAPS AND DECISION PROCESS

Access to adequate and accurate information is vital to achieving the full emissions reduction potential outlined in the GHG reduction cost curve. Even when an opportunity is profitable, it will not be captured if decision-makers are not aware of it, or are not convinced of its impact.

Information gaps

Information gaps arise in a number of circumstances. Decision-makers may have a concern about emissions but be unaware of the potential solutions, or may dismiss known emissions reduction activities because they do not have the knowledge to determine their effectiveness. In addition, energy use (price and volume) and related emissions are rarely transparent during consumption, making it difficult for decision-makers to make informed choices about how they use energy. An illustration of this can be seen in the consumption behaviour of households. On items for which energy efficiency information is readily available at point of sale, such as refrigerators, freezers and dryers, purchasing decisions favour energy efficient appliances. This can be contrasted with the strong trend towards the purchase of large televisions (average screen sizes increased from 46 cm in 2003 to 73 cm in 2006[8]), which are not required to display information about their energy use.

Broad educational campaigns are a relatively simple way to raise awareness, and have been successfully conducted by a number of players in the past:

- The public water conservation campaign launched by the Victorian government in 2000 resulted in a 22% per capita reduction of water use in the state before high level water restrictions were introduced
- Businesses often lead in educating their customers through marketing or labelling the energy or emissions performance of their products (e.g. energy star ratings for household appliances or eco-labelling of paper products). When large, influential businesses adopt this approach, they can have widespread results. For example, Walmart in the US adopted a focus on energy in its 100 Million Bulb Campaign in 2007.[*] This focus helped increase compact fluorescent light (CFL) penetration in that country from 5% to 10% over nine months.

[*] Walmart. *Wal-mart surpasses goal to sell 100 million compact fluorescent light bulbs three months early.* 2007.

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[8] Department of the Environment, Water, Heritage and the Arts. *Energy use in the Australian residential sector 1986–2020.* 2008.

- It can also be cost effective to target information or awareness campaigns at trusted intermediaries or suppliers, rather than directly at individual decision makers. For instance, the local solar hot water heater industry has recently targeted its marketing to electricians and plumbers, rather than directly at a broader set of homeowners.
- Industrial organisations can also play a role in leading sector-wide change, for example by creating guidebooks or educational materials for their members (which has the additional benefits of decreasing the transaction costs for smaller businesses). A successful example of such leadership is the voluntary target set by the International Aluminium Institute (IAI) to reduce global aluminium production related emissions of perfluorinated compounds from 4.9 tonne CO_2e per tonne of aluminium in 1990 to 0.7 tonnes in 2010. The global target was reached in 2006, and Australia smelters have gone further, using the lessons from the process to reduce emissions to 0.26 tonnes CO_2e per tonne of aluminium.

Decision process

Even where full information about emissions reduction opportunities is available, a company's or government's decision process may make it difficult or impossible for managers to act. This can occur in large companies or departments where capital investment and operating expense budgets are separate, sometimes resulting in the net effect of limiting upfront capital at the expense of higher total life-cycle costs.

Other criteria may also take priority over the profitable use of energy efficient equipment. For example, the car fleet policies of state governments often give preference to locally produced but fuel inefficient cars. Similarly, operational managers in the industrial sector may replace their equipment with a familiar or readily available part, to reduce the risk of production disruptions or quality control issues, ignoring more efficient options.

Even the decision processes of smaller businesses and households may reduce uptake of energy savings opportunities, as they delegate these decisions to their suppliers, who can be motivated by competing incentives. For example, plumbers or small contractors play a decisive role in the choice of home and small business water heaters, but rarely choose the most energy efficient option, prioritising instead the equipment with which they are most familiar or on which they achieve the highest return (which is usually the lowest upfront cost, but not most efficient option).

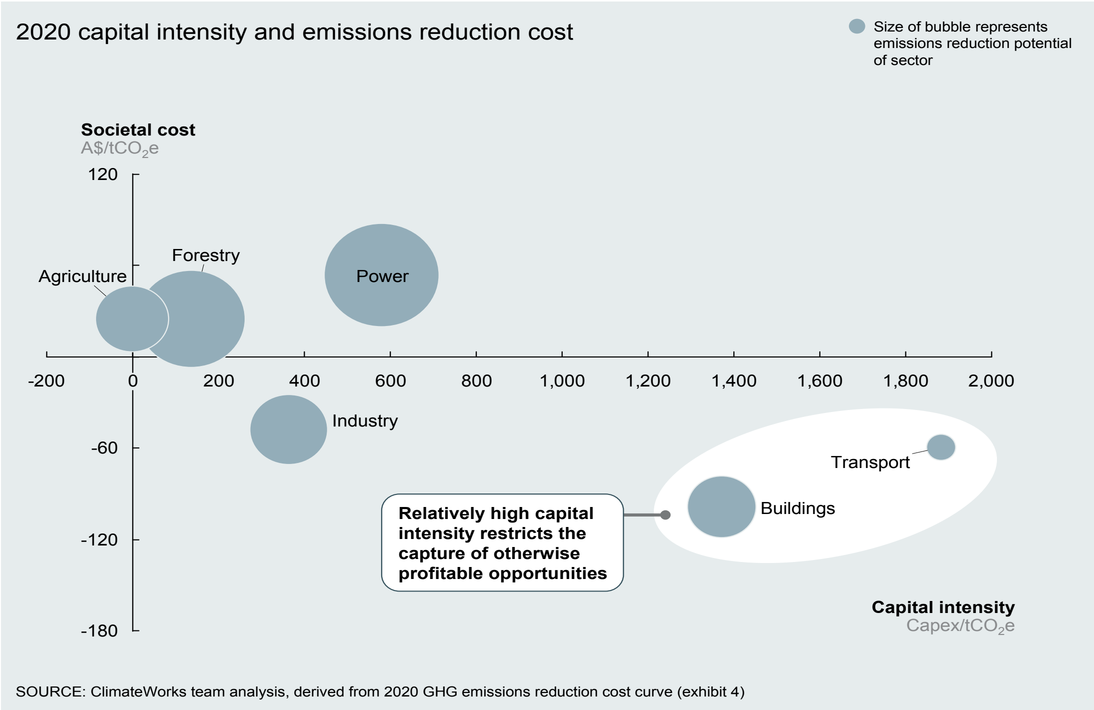
CAPITAL CONSTRAINTS AND INVESTMENT PRIORITIES

Many emissions reduction opportunities require an upfront capital investment, which is then paid off over time through savings on operational expenses. These profitable opportunities are often not captured as the businesses, organisations and families who would benefit from them cannot access, or do not want to part with, the required capital. Often, the sectors with lower cost emissions reduction opportunities (buildings and transport) also tend to require more capital (see Exhibit 14), which is a key reason they are not captured in the business-as-usual case.

Access to capital

The capital available to investors is often limited by their other investment obligations. For example, first-time home buyers often do not have the resources to invest in more expensive, energy efficient appliances, insulation or quality window coverings even though the investment

Exhibit 14: Capital intensity of opportunities by sector



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

will pay for itself in energy savings. Access to capital can also be restricted despite positive project fundamentals, when lenders are uncomfortable with the risk profile of the project manager. This counterparty risk assessment could be based on credit history or amount of funds already committed to the company or industry. As much of the capital spent on energy efficiency projects is not transferable once invested (e.g. the bank cannot easily remove and reuse windows, insulation or tailored machine parts), there is little collateral if a borrower defaults. This can make lending standards more stringent for emissions reduction projects, especially in the commercial property sector or among smaller businesses.

Considerable scope exists for lending institutions, both established and entrepreneurial, to develop innovative financing solutions to capture some of the margin currently lost due to limited access to capital. Here are a few examples:

- ESCOs have started to exploit this niche by offering financing solutions to their capital-constrained customers, setting up reimbursement through savings schemes or leasing arrangements. Project cash flows then become entirely positive and very attractive for investors.
- Manufacturers of expensive energy efficient equipment can use similar approaches by lowering the upfront costs of their product in return for a proportion of the future savings generated.
- Large companies that are sensitive to input prices but have fewer limits on their access to capital can also help their suppliers finance energy efficiency projects in return for lower prices in the future.

Long pay-back periods

Even where decision-makers can access sufficient capital to undertake profitable emissions reduction opportunities, investments may not be pursued because they have lengthy payback periods. Investors with a short term profit focus are unlikely to view such opportunities as attractive. This was demonstrated in a survey of 170 managers of commercial offices who cited payback periods as the main barrier to improving energy efficiency.[9] The average acceptable payback period given by those surveyed was four years.

Investment priorities

Profitable emissions reduction opportunities may also be missed where their rate of return is less than alternative investments, or where the emissions reduction activity is not considered core business. This can be seen in hospitals, where scarce capital is focused on improving patient care, or in high growth industries where increased market share may be prioritised over cost reduction opportunities.

Companies which have identified energy efficiency as a long term priority overcome this barrier by modifying the price of energy used to calculate the internal rate of return for projects. Some high profile Australian companies with aggressive emissions reduction targets now use an internal carbon price for the assessment of investment opportunities.

A similar trend has been observed among some property groups that have identified energy efficiency as a key driver of future market demand and are using increased prices of energy internally to make sure that energy efficiency projects are pursued over their whole building base.

THE ROLE OF BUSINESS AND GOVERNMENT IN ADDRESSING NON-PRICE BARRIERS

Where profit potential does not already exist, government leadership is required to ensure that public interest is properly reflected in business decisions. A common, market based mechanism to internalise the public's interest in reducing GHG emissions is through the implementation of a carbon price. Other options include mandating certain practices such as the replanting of forests after harvesting, or targeted financial incentives such as subsidies or tax rebates on energy efficient products.

However, no single action or policy can overcome all challenges at minimal cost and disruption to the economy, so any broad-based government action must be accompanied by solutions targeted to particular challenges and opportunities. As shown above, many of the non-price barriers are complex and specific to the individual opportunity. Resolving them will require well designed and targeted measures.

In general, where profit potential already exists, businesses should be encouraged to develop solutions in preference to top-down government action. The most effective business-led solutions occur where imperfect markets have constrained the capture of full value for participants, for instance where short-term focused investors miss profitable energy efficiency

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[9] The Warren Centre for Advanced Engineering. *Low Energy High Rise Building Research Study Final Research Survey Report.* March 2009.

opportunities because they have long payback periods. Barriers such as these will be overcome when profit-seekers identify the potential and mobilise to exploit it – achieving both a positive outcome for themselves, and reducing emissions.

In other cases, when timing is critical and when the barriers are too high for individual investors to overcome, government support may be required to create incentives for businesses and consumers to take action.

For example, for small and medium enterprises (SMEs) where there is a large energy efficiency potential but high transaction costs and limited (and expensive) access to capital, there could be a role for government to lower the cost of capital by creating a guarantee fund or by enabling lenders to get access to collateral in case of defaults. Such action could substantially reduce emissions at a very low cost to government and create economic benefit for the sector.

Where awareness of emissions reduction opportunities is limited, or where the market is slow to capture new opportunities, government can also help to build momentum by offering temporary financial incentives, by conducting information campaigns or by funding research and development or pilots to accelerate progress along the learning curve (e.g. existing financial incentives for solar hot water, residential insulation and ventilation air methane (VAM) oxidation pilots).

Although the challenges to achieving the full potential outlined in the GHG emission reduction cost curve are considerable, a combination of well-planned and targeted actions from business and government can overcome most, if not all barriers.

Chapter 3 reviews each sector in more detail, including the emissions reduction potential, emissions reduction cost and targeted actions that can be taken to overcome the non-price barriers that exist.

Sector summaries

Sector summaries

This chapter examines the business-as-usual case (BAU), emissions reduction opportunity, challenges and potential solutions in more detail by sector—power, forestry, industry, agriculture, buildings and transport.

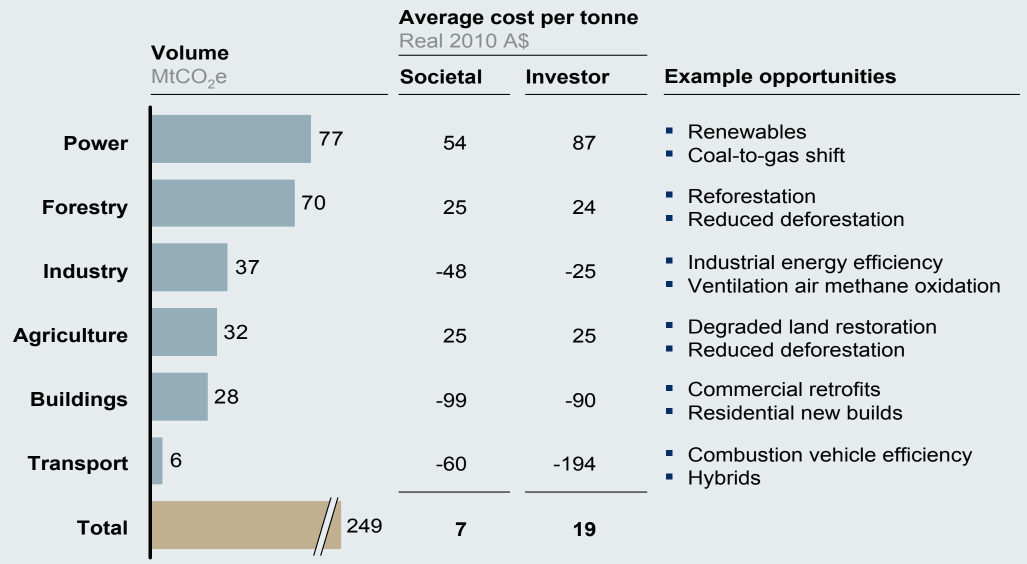
As shown in Exhibit 15, the power and forestry sectors offer the largest emissions reduction opportunity (59% or 147 $MtCO_2e$), but come at the highest cost (average of A$40 per tCO_2e). Industry, buildings, agriculture and transport each offer smaller reduction opportunities, but together still represent a 102 $MtCO_2e$ opportunity. They are also mostly economically attractive with average net savings to society of A$40 per tCO_2e.

Each sector covers the following:

- Emissions growth under business-as-usual
- Emissions reduction opportunities
- Challenges to capture these opportunities
- Tools to overcome these challenges

Most of the costs discussed within each of the sector summaries are societal costs. However, also shown in each sector is an investor cost curve to also illustrate the costs of emissions reduction from an investor perspective, including after the impact of a carbon price.

Exhibit 15: Australian 2020 abatement potential by sector[1]



	Volume $MtCO_2e$	**Average cost per tonne** Real 2010 A$ **Societal**	**Investor**	**Example opportunities**
Power	77	54	87	▪ Renewables ▪ Coal-to-gas shift
Forestry	70	25	24	▪ Reforestation ▪ Reduced deforestation
Industry	37	-48	-25	▪ Industrial energy efficiency ▪ Ventilation air methane oxidation
Agriculture	32	25	25	▪ Degraded land restoration ▪ Reduced deforestation
Buildings	28	-99	-90	▪ Commercial retrofits ▪ Residential new builds
Transport	6	-60	-194	▪ Combustion vehicle efficiency ▪ Hybrids
Total	249	**7**	**19**	

1 Includes all emission reduction opportunities required to achieve 249Mtpa

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Power

KEY POINTS

- The power sector has the potential to contribute 31% of the total 2020 lowest cost emissions reduction opportunity for Australia. Fully implementing these would result in emissions reduction of 77 $MtCO_2e$ in 2020, a 39% reduction on the BAU case.
- The largest opportunities in the power sector are in onshore wind, coal to gas shift, and solar thermal with storage. Opportunities that offer net savings in the power sector are improved coal and gas power plant thermal efficiencies and reduced transmission and distribution losses.
- However, emissions reduction in the power sector is generally higher cost at an average of A$54 per tonne and A$87 per tonne from the investor's perspective.
- As cost is the primary barrier, a carbon price can be particularly effective, increasing the volume of opportunities that are profitable to investors seven-fold (from just over 5 $MtCO_2e$ to over 35 $MtCO_2e$) under the 25% example price used in this report.

The power or electricity generation sector is Australia's single largest sector for direct GHG emissions, accounting for 35% of Australia's total in 2010, which is roughly in line with other developed countries (e.g. 33% for Germany, 36% for Japan, 30% for UK and 37% for US). Black and brown coal-fired generators make up ~92% of these emissions.[10] Natural gas-fired and distillate power plants, which are generally used for peaking capacity, contribute the remaining 8% of emissions.

An abundance of cheap domestic thermal coal and a moratorium on nuclear power are the main drivers behind the high carbon intensity of Australia's power sector (~0.86 tCO_2e per MWh in 2005). This ranks in the top five worldwide, just below South Africa (0.92 tCO_2e per MWh), on par with China (0.87 tCO_2e per MWh), and much higher than other developed nations such as Germany (0.6 tCO_2e per MWh), the USA (0.6 tCO_2e per MWh) and the UK (0.56 tCO_2e per MWh).[11]

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[10] Department of Climate Change. *National Greenhouse Gas Inventory.* 2009.

[11] Centre for Global Development. *CARMA (Carbon Monitoring for Action) database.* 2007.

EMISSIONS GROWTH UNDER BUSINESS-AS-USUAL

Emissions are projected to decrease from 210 $MtCO_2e$ in 2010, to 200 $MtCO_2e$ by 2020 (a 5% decrease). Over this period, the natural growth in electricity demand is offset by the following factors:

- Impact of the expanded Renewable Energy Target (RET) which establishes a target of 20% renewable electricity production by 2020. In the legislation and based on projections by Treasury, this has been translated into a fixed target of an additional 41,000 GWh of large-scale renewable electricity production (over and above the existing renewable electricity production in 1997) by 2020.
- Technological improvements which should see a reduction in the carbon emissions intensity of fossil fuel power plants
- A forecasted preference for new gas-fired power plants over coal, with production share of the former increasing from 15% to 22% between now and 2020 (in the BAU case)

EMISSIONS REDUCTION OPPORTUNITIES

Seventeen measures were identified to further reduce emissions from the power sector (illustrated in Exhibit 17, which is a societal cost curve for the power sector alone). Fully implementing all opportunities included in this plan would result in the emissions reduction of 77 $MtCO_2e$ in 2020, or a 39% reduction on the business-as-usual case. Higher cost opportunities account for 72 $MtCO_2e$ or 93% of the potential, with the remainder offering net savings.

Many of the emissions reduction measures in the power sector (such as renewable energy, carbon capture and storage (CCS), and coal-to-gas shift) involve replacing fossil fuel plants that would have been built in the future with a cleaner source of electricity. In addition, an amount of early-retirement of brown and black coal-fired plants has been assumed,[12] which will also be replaced by a cleaner source of electricity.

These volumes have been developed after factoring in the reduction in electricity demand due to energy efficiency measures implemented in other sectors such as Buildings and Industry.

However, these numbers do not include the impact that lifestyle or consumption pattern changes will have on demand for electricity e.g. using the air conditioner less in summer. The emissions reduction resulting from these actions is difficult to quantify, but has the potential to be large. The implication for the curve will be less volume for measures in the power sector, but a lower average cost of reaching the target of 25% below 2000 emissions. The largest opportunities using known technologies in the power sector are in:

- **Onshore wind.** Onshore wind power is currently the cheapest renewable technology. 5 $MtCO_2e$ pa of emissions reduction is possible in 2020 at an average cost of A$37 per tCO_2e by building 1.6GW of wind farms in favourable locations, in addition to what will occur due to the RET. A further potential of 7 $MtCO_2e$ is available (from building a further 3.3GW of

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[12] Assumed black and brown coal plants with remaining lifetime in 2020 of less than 5 and 10 years respectively are retired early and replaced with renewables.

wind farms, at higher cost of A$60 per tCO_2e) in more marginal locations with lower wind speeds or further away from existing electricity transmission.

- **Coal to gas shift.** 15 $MtCO_2e$ pa of emissions reduction is possible by replacing coal new builds with gas new builds at an average cost of A$44 per tCO_2e, and a further 9 $MtCO_2e$ pa of emissions reduction is possible at an average cost of A$57 per tCO_2e by increasing the uptime of gas power plants.

- **Solar thermal with storage.** Solar thermal technology involves turning water or other liquid into steam using the sun's direct heating power. Along with solar PV, solar thermal is well suited to Australia's hot, sunny climate and could provide 10 $MtCO_2e$ pa of emissions reduction by 2020 from building an additional 2.5GW of solar thermal plants, albeit at a higher average cost of $77 per tCO_2e.

There are also a number of opportunities in the power sector that are already offer net savings:

- **Improved coal and gas power plant thermal efficiencies.** The thermal efficiency of coal and gas power plants can be improved through better operational practices such as reducing coal moisture, reducing auxiliary power consumption at the plant, and reducing operator variability. These improvements represent cost savings for the generator, but are often not exploited because of poor operating protocols or lack of management priority. Implementing such practices could reduce emissions by 3 $MtCO_2e$ pa by 2020 at average net savings of A$39 per tCO_2e.

- **Reduced transmission and distribution losses.** Transmission and distribution losses along the electricity network can be reduced from the current nationwide average of 8% to 6.5% through implementation of a number of loss reduction measures (e.g. installing larger capacity conductors, installing more reactive power sources, upgrading to low loss transformers, raising distribution voltages, balancing loads). These sorts of investments have not been made in Australia's electricity network due to a lack of incentives within the regulated pricing structure, but doing so could reduce emissions by 3 $MtCO_2e$ pa by 2020 with average net savings of A$37 per tCO_2e.

Other key technologies which have the potential to define Australia's future energy mix include:

- **Carbon capture and storage.** CCS is a critical technology due to the dominance of coal-fired power plants in Australia and could reduce emissions by 8 $MtCO_2e$ pa by 2020. It is also promising in Australia due to the relative abundance of suitable storage locations near existing power plants (e.g. Gippsland basin, Gladstone/Rockhampton basin, Perth/Kwinana basin). This report assumes that by 2020, a number of demonstration plants (such as the Wandoan and ZeroGen projects in Queensland) will be running at full capacity, with commercialisation following thereafter. It is worth noting that Australia is taking a lead position globally on CCS, through the establishment of the Australian Global CCS Institute, and the commitment of more than A$1 billion for the construction of demonstration plants in the CCS Flagship Program. Australia will also soon have the largest operating carbon capture and sequestration project in the world at the Gorgon LNG project in Western Australia.

- **Geothermal.** Geothermal technology is a promising prospect in Australia as there is an abundance of geothermal energy, and it is a renewable technology that can run almost continuously (like traditional baseload plants). By 2020, up to 2 $MtCO_2e$ pa of emissions reduction opportunity is estimated to be available at an average cost of A$55 per tCO_2e.

Despite a number of technical hurdles specific to the "hot dry rock" nature of Australia's geothermal sources, this report assumes that commercial geothermal technology can be realised by 2020 and numerous public companies are already working towards an even more aggressive timeline.

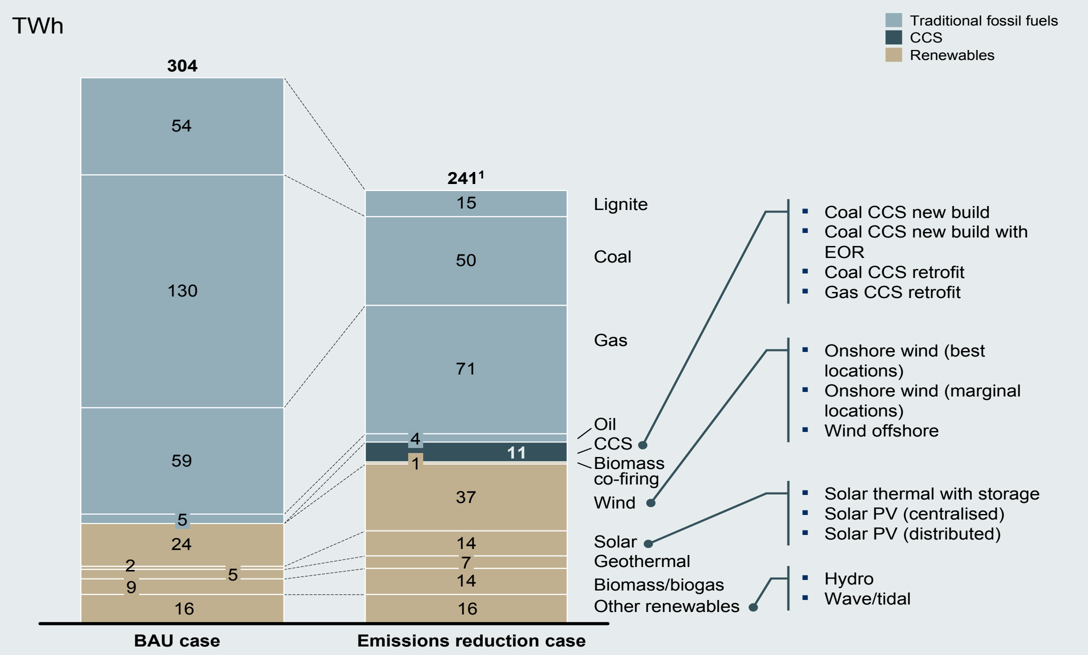
Exploiting all of these opportunities will significantly change Australia's power mix by 2020. Exhibit 16 illustrates the shift and also the potential demand reduction through the implementation of the efficiency improvements noted above.

CHALLENGES

Emissions reduction opportunities in the power sector face a number of barriers:

- **Price of GHG emissions.** More than 90% of the emissions reduction volume in the power sector is currently uneconomic for investors (see Exhibit 18). Without a price for carbon, or some other form of government intervention, the private sector has little incentive to achieve that potential. As shown in Exhibit 19, a carbon price will have particularly high traction in the power sector, as non-price barriers are less prevalent. In addition emissions reduction opportunities such as CCS and geothermal face a number of technical hurdles before they can be developed commercially at scale, which makes early investments too risky for individual investors.
- **Market structure and supply.** Coal-fired power plants in Australia have benefited from cheap, domestic coal prices due to long term contracts negotiated at favourable prices, often with state government involvement. Consequently, the relative production cost differential between coal-fired power plants and renewable sources is larger than it would otherwise be.

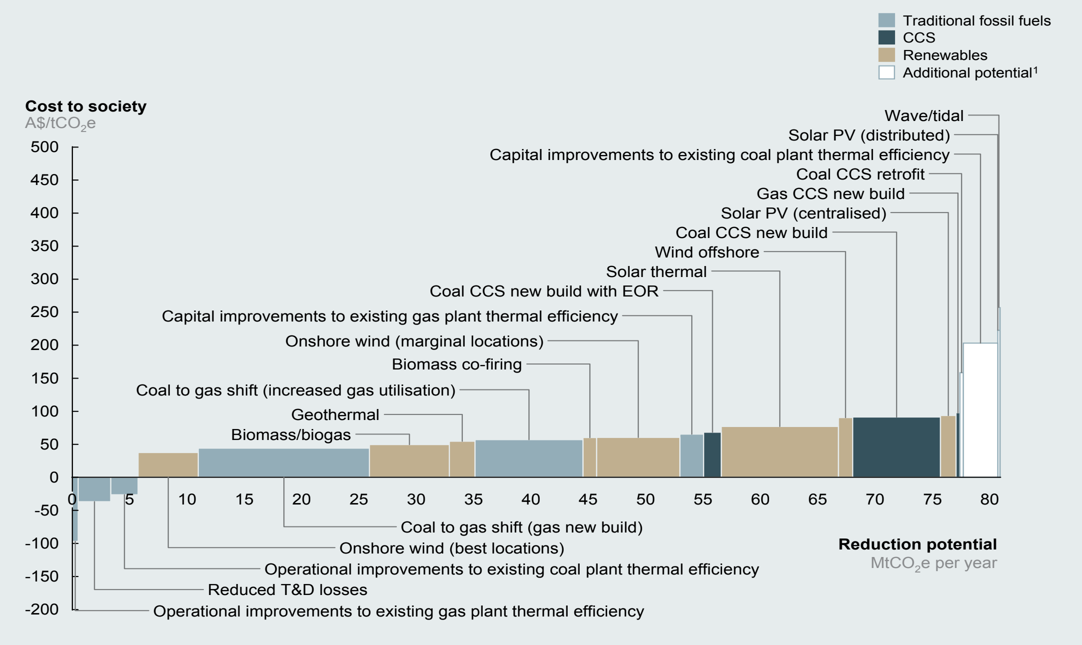
Exhibit 16: Total electricity production 2020



1 Total electricity production is lower in the emissions reduction case because of demand reduction

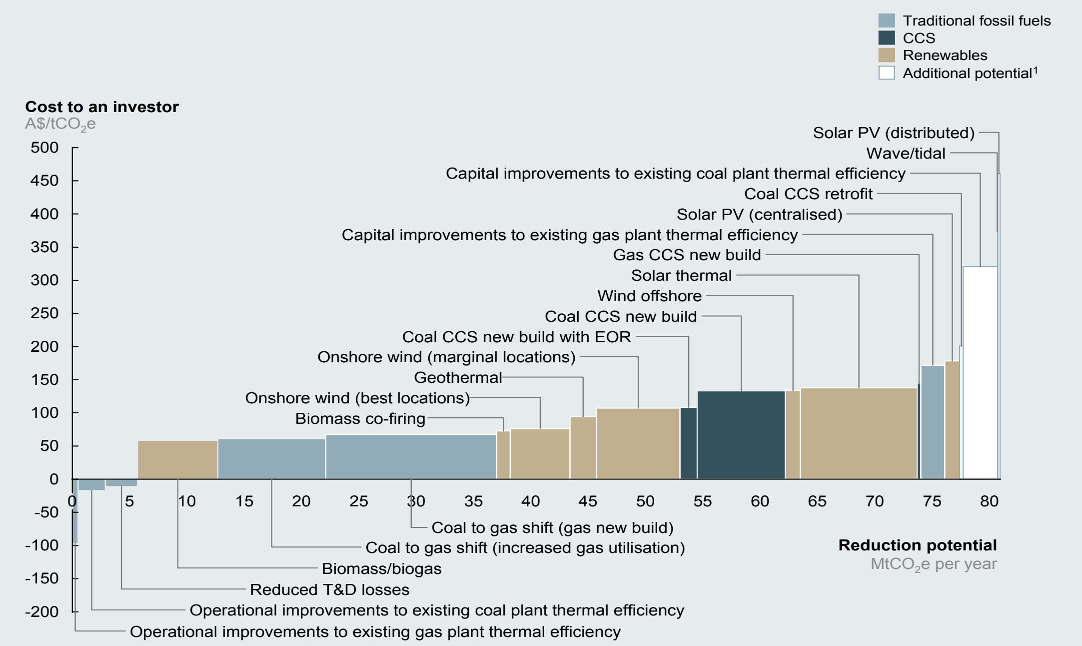
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 17: 2020 Power GHG emissions reduction *societal* cost curve



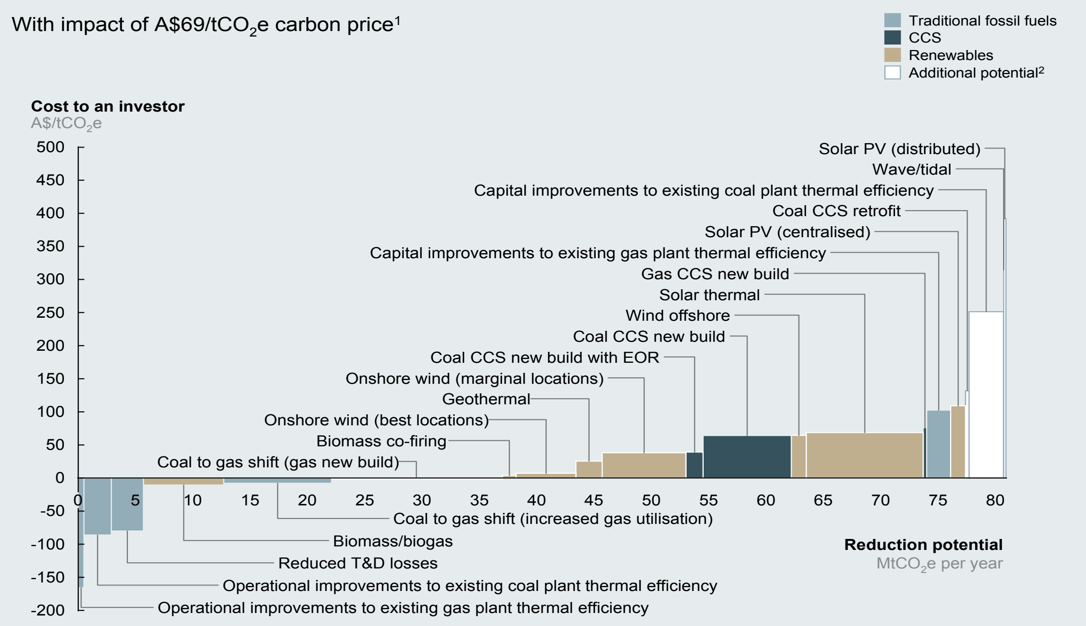
NB: Energy efficiency measures in other sectors such as buildings and industry also result in ~42Mtpa of emissions reduction
1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 18: 2020 Power GHG emissions reduction *investor* cost curve



NB: Energy efficiency measures in other sectors such as buildings and industry also result in ~42Mtpa of emissions reduction
1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 5)

Exhibit 19: 2020 Power GHG emissions reduction *investor* cost curve



NB: Energy efficiency measures in other sectors such as buildings and industry also result in ~42Mtpa of emissions reduction
1 Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars
2 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

- **Capital constraints and investment priorities.** Almost all emissions reduction opportunities in the power sector require a large degree of upfront capital investment to implement and so the cost of emissions reduction will be quite sensitive to the cost of capital. Depending on the degree of risk or uncertainty, pool of available capital, and other competing investments, such projects can face very high discount rates.

TOOLS TO OVERCOME THESE CHALLENGES

- **Improve economics of emissions reduction investments.** One of the biggest barriers within the power sector is economic unattractiveness of many emissions reduction opportunities. This barrier can be overcome using a number of financial incentives such as introducing a price for carbon, capex subsidies (e.g. CCS and Solar Flagships, solar PV rebate), increasing fuel taxes, and creating alternative revenue streams (e.g. renewable energy certificates, feed-in tariffs). For the power sector it is also particularly important that governments establish a stable policy framework that provides the confidence required for investment in long lived generation assets, as the returns on different investments are highly sensitive to different long term price outlooks.

- **Develop alternative sources of financing.** An opportunity exists for both the public and private sector to support accessible, low-cost financing. The public sector can provide government guarantees or interest free loans, for example. On the other hand the banking industry could develop new financial products or markets that pool 'green funds' together and syndicate risks.

- **Support R&D and pilot programs.** Providing financial and technical support to private research and development (R&D) efforts and pilot programs are effective ways to accelerate the maturation of new technologies and reduce first-mover disadvantages. Australia’s Global CCS Institute, Cooperative Research Centre for Greenhouse Gas Technologies, and CCS Flagships program are prime examples of this.

- **Provide training and industry support.** Government training programs or grants to develop new industries will ensure that market supply is able to satisfy the demand for renewable or CCS technologies. Tax concessions to “green power” industries are another way to encourage the private sector to fill niches or gaps in the supply chain.

- **Fuel efficiency targets and energy management practices.** In the short term, fossil fuel power plants can reduce their carbon emissions by improving their thermal efficiencies. Setting a mandatory target or agreeing to an industry-wide voluntary target for fuel efficiency can drive improvements. Alternatively, extending mandatory energy audits to power generators could increase awareness and reveal low-cost opportunities to reduce fuel consumption or auxiliary electricity consumption.

Forestry

KEY POINTS

- The forestry sector has the potential to contribute 28% of the total 2020 lowest cost emissions reduction opportunity for Australia, delivering emissions reductions of 70 $MtCO_2e$ in 2020. 70% of this opportunity is estimated to come from reforestation and most of the remainder from reduced deforestation.

- These emissions reduction opportunities have an average societal cost of A$25 per tonne, and a similar cost from the investor's perspective of A$24 per tonne.

- As cost is the primary barrier, a carbon price can be particularly effective, making nearly all the volume of opportunities profitable to investors (over 65 $MtCO_2e$) under the 25% example price used in this report. Information and long term policy certainty are other important barriers to overcome.

We have defined the forestry sector as including deforestation (primarily clearing of forests and regrowth for agricultural purposes) and reforestation. Currently the forestry sector has net emissions of 28 $MtCO_2e$ p.a., 5% of Australia's total GHG emissions. Deforestation actions currently emit approximately 49 $MtCO_2e$ p.a. of GHG, whilst 21 $MtCO_2e$ is sequestered by reforestation resulting in the net 28 $MtCO_2e$ noted above.

This section considers total emissions reduction potential whether or not the emissions reduction qualifies under international carbon accounting rules.

EMISSIONS GROWTH UNDER BUSINESS-AS-USUAL

Net emissions from the forestry sector are projected to reach 42 $MtCO_2e$ p.a. in 2020, a 28% reduction from 2000 levels (but 50% increase from 2010). Deforestation emissions are projected to remain relatively flat between now and 2020. Forest sequestration is, however, projected to decline. This is largely due to an expected fall in the rate of new forest establishment.

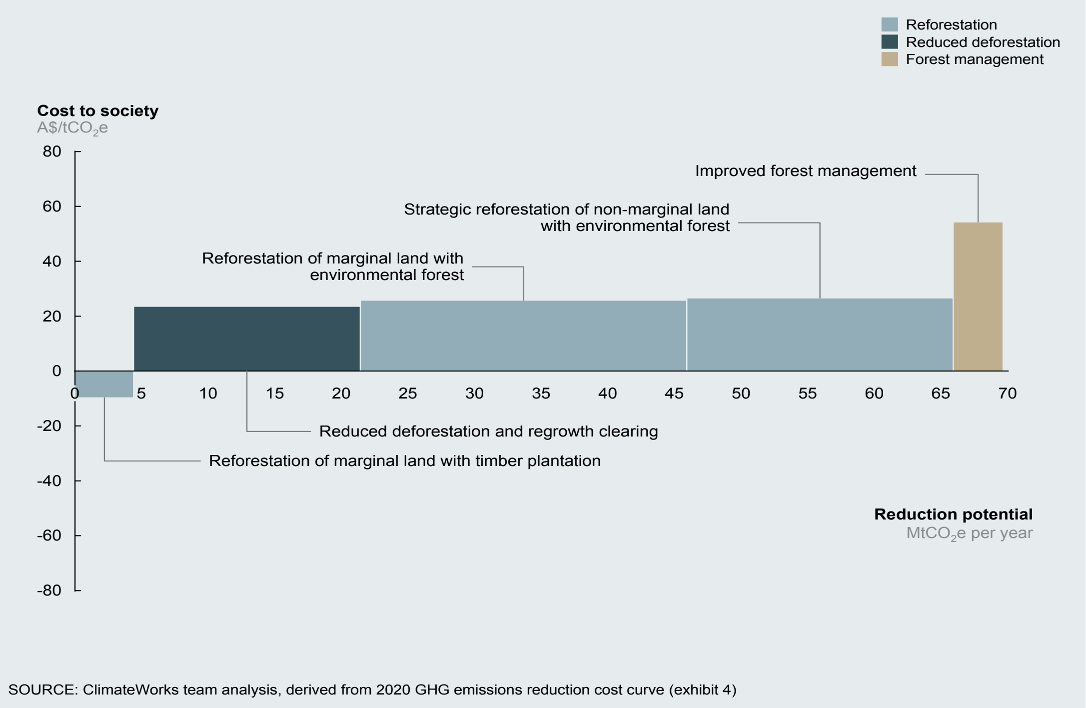
THE EMISSIONS REDUCTION OPPORTUNITY

Five key measures were identified to reduce emissions from the forestry sector that together could result in an emissions reduction of 70 $MtCO_2e$ in 2020, most of which is at a societal cost of under A$30 per tonne. Exhibit 20 illustrates the societal emissions reduction cost curve for the forestry sector. There are three major categories of opportunities in this sector:

- **Reforestation.** The largest emissions reduction opportunity is in reforestation (total of 49 $MtCO_2e$ or 70% of total Forestry emissions reduction), which is split across three specific opportunities:
  - Reforestation of marginal land with timber (4 $MtCO_2e$), which offers net savings to society of A$10 per tCO_2e. This essentially means planting trees for eventual harvest on land that is less suitable for other purposes (i.e. marginal land). A reduction in emissions occurs because carbon is sequestered as the trees grow, released as they are harvested and recaptured over time as new trees are planted and grow—therefore in the long term over these cycles these types of forests capture around half of the total carbon captured if a forest were not harvested. This opportunity offers net savings, as it is assumed there will be a return for the timber sold from the plantation.
  - Reforestation of marginal land with environmental forests (25 $MtCO_2e$) at an average cost of A$26 per tCO_2e. In this opportunity the marginal land is planted with native forest and not harvested and therefore has a higher cost.
  - Strategic reforestation of non-marginal land with environmental forest (20 $MtCO_2e$) at an average cost of A$27 per tCO_2e. See description below.

  In total, 6 Mha of land is required for reforestation across these three categories to produce the sequestration depicted in Exhibit 20. Of this, 65% is assumed to be less productive or marginal land, minimising the impact on productive farm land, though achieving slower growth rates and less sequestration. Within marginal land reforestation, 15% is assumed to be planted as commercial timber and 85% as environmental forests (native forests planted purely for sequestration, not harvest). This split reflects the greater area of land suitable for environmental forests and the increased ease of planting.

Exhibit 20: 2020 Forestry GHG emissions reduction *societal* cost curve



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

In reality the ratio of these two types of planting will be at the discretion of landowners who will need to make decisions based on what best suits their land and their long term business plans.

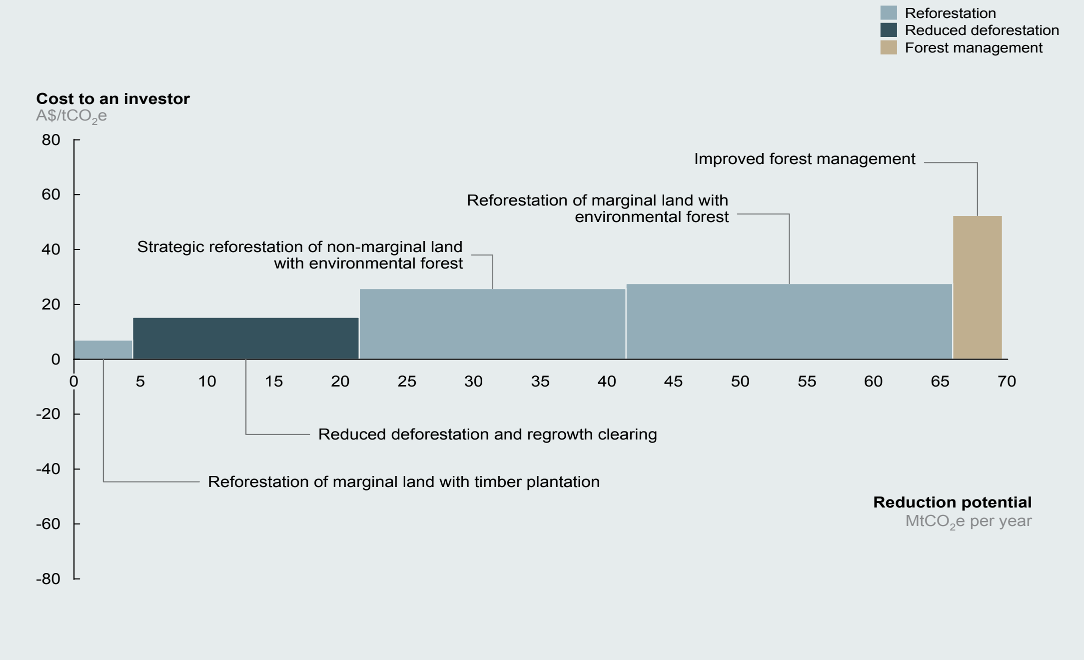
The remaining 35% or 2 Mha is allocated to non-marginal or more productive farmland. This equates to planting 1–2% of non-marginal farm land with trees in the form of windbreaks, plantings along waterways and as tree islands to shade livestock. This is consistent with best practice farm management and is likely to increase the long term productivity and sustainability of farming enterprises. It is therefore referred to as strategic reforestation as opposed to more broad scale reforestation.

- **Reduced deforestation and regrowth clearing.** Reduced deforestation has delivered almost 90 $MtCO_2e$ p.a. of emissions reductions from 1990 to 2009, and can further reduce emissions by 17 $MtCO_2e$ (24% of the total Forestry opportunity, and 35% of expected deforestation under BAU) at an average cost of A$24 per tCO_2e. Deforestation emissions are the net effect of the emissions from first time clearing of land and sequestration from regrowth on the land cleared post 1990 (regrowth on land cleared pre-1990 is categorised as reforestation). Reducing deforestation emissions therefore means reducing either first time clearing or regrowth clearing. This report assumes the reduction in emissions will require a combination of both.
- **Forest management.** Improvements in the management of existing forests is the highest cost opportunity in this sector, representing a potential emissions reduction of 4 $MtCO_2e$ at an average cost of A$54 per tCO_2e. Improved forest management includes practices such as removal of weeds like lantana and blackberries that limit woody growth, control of feral animals, insects and pests to promote tree growth and fire management. These practices are intended to increase forest growth and consequently increase the quantity of carbon stored in forests.

CHALLENGES

- **Price of GHG emissions.** Planting forests is an initially expensive and long term commitment that farmers are unlikely to pursue without economic incentives and certainty over how carbon crediting will operate. Despite the proliferation of forestry schemes and proposals to credit various forestry activities under an emissions trading scheme, a continuing lack of certainty and financial incentives for farmers is likely to constrain much of the Forestry opportunity. The potential decline in land values that farmers face from not clearing, particularly with re-growth, also presents a significant price barrier to reducing deforestation and is likely to cause resistance from landowners. Exhibit 21 illustrates the cost of emissions reduction from an investor perspective. As can be seen, none of the opportunities in the forestry sector are profitable for investors, without further financial support.
- **Information gaps and decision process.** Farmers and landowners remain uncertain as to how they will be able to earn income via various types of forestry. Without clarity on the options available, their different impacts, requirements and merits, farmers will lack the confidence to make long term decisions that potentially utilise their land for long periods of time.
- **Capital constraints and investment priorities.** Forestry projects typically require upfront investment for planting and land preparation. As discussed in more detail in the agriculture sector, many farmers are capital constrained and will be unable to pursue reforestation options without investments of private capital.

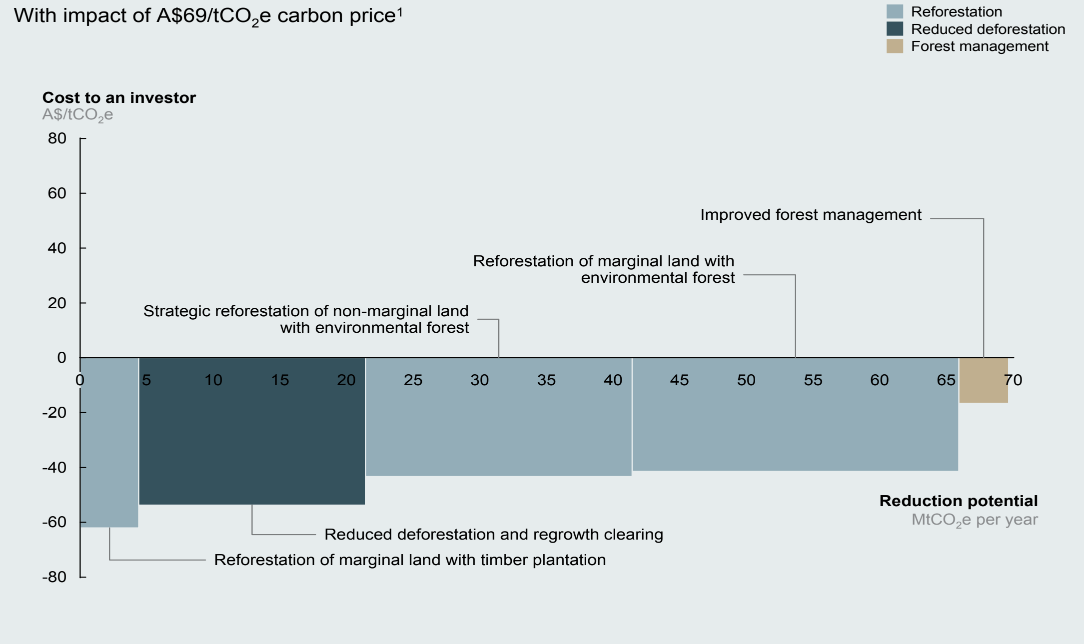
Exhibit 21: 2020 Forestry GHG emissions reduction *investor* cost curve



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 5)

Exhibit 22: 2020 Forestry GHG emissions reduction *investor* cost curve

With impact of A$69/tCO$_2$e carbon price[1]



[1] Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

TOOLS TO OVERCOME THESE CHALLENGES

Options to overcome these challenges include:

- **Improve profitability and create clear long term position on forestry.** The ability of the Forestry sector to access capital is satisfactory where policy settings are perceived to be stable, and results in commercial rates of return. A transparent and consistent system for accounting for and receiving income from forest sequestration, possibly by the integration of the various existing forestry programs and a carbon price, will assist farmers and other land managers to make long term reforestation decisions and pursue what would otherwise be unprofitable plantings. This will also improve their ability to seek a range of co-benefits through carbon forestry and plantings.
- **Inform land owners.** Farmers will need to be provided with good information on the various forestry options available for their type of land. Trusted local organisations can play a leading role in this process and should be assisted to provide appropriate information to their constituents.

Kyoto and Forestry

The forestry emissions reduction opportunities assessed in this report all comply with Kyoto rules with the exception of improved forest management, which comprises 4 $MtCO_2e$. There are some deforestation and reforestation opportunities beyond those that are listed here and that may not comply with Kyoto rules, but this analysis concludes these are of too high a cost to be included in this cost curve (i.e. they are ranked further out on the cost curve than the opportunities that sum to 249 $MtCO_2e$ which delivers the 25% reduction below 2000 levels, and hence are not identified as low cost opportunities in this plan).

Industry

KEY POINTS

- The industrial sector has the potential to contribute 15% of the total 2020 lowest cost emissions reduction opportunity for Australia, delivering emissions reductions of 37 $MtCO_2e$ in 2020. Without further action, emissions from the industrial sector are expected to grow by 40% between 2000 and 2020, driven largely by growth in mining and gas subsectors
- 73% of the emissions reduction potential offer net savings to society, The largest opportunities are from improved energy efficiency (17 $MtCO_2e$) and cogeneration (5 $MtCO_2e$)
- Non-price barriers are relatively more important to address in this sector given over half of the 2020 emissions reduction potential is profitable from the investor's perspective

Industry will account for 41% of Australia's GHG emissions in 2010, aligned with the world's average of 42%. Cheap energy prices and high availability of mineral commodities have shaped an industrial sector dominated by heavy, energy-intensive industry. Industry sector emissions in 2010 can be divided between 74 $MtCO_2e$ of industrial process or fugitive emissions, and 167 $MtCO_2e$ of energy use (roughly half from grid, half direct combustion). Mining[13] is the largest emitter of industrial emissions with 25%, followed by Petroleum and gas (14%), Aluminum (10%), Iron and steel (8%), Cement and lime (7%) and Chemicals (5%). The remainder is largely from the Pulp and paper and Food industries.

EMISSIONS GROWTH UNDER BUSINESS-AS-USUAL

Growth in the mining and gas sectors is the main driver for growth of industry emissions in the coming years. In the BAU case emissions are projected to grow from 204 $MtCO_2e$ in 2000 to 285 $MtCO_2e$ in 2020 (a 40% increase). This is despite the implementation of current policies such as Energy Efficiency Opportunities (EEO) and the Greenhouse Gas Abatement Program (GGAP) that are expected to increase the take up of energy efficiency improvements in BAU and to accelerate the maturation of new technologies to capture fugitive mining emissions.

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[13] Includes natural gas liquefaction

EMISSIONS REDUCTION OPPORTUNITY

Nine industrial emissions reduction opportunities have been identified, that together contain many sub-sector opportunities: energy efficiency, new technologies, fuel or ingredient substitution, cogeneration, industrial processes and reduced discharges of natural gas. Fully implementing all opportunities included in this plan would result in the emissions reduction of 37 $MtCO_2e$ in 2020, a 13% reduction on the business-as-usual emissions. Net savings opportunities account for 27 $MtCO_2e$ or 73% of the potential, with the remaining being split between moderate (17%) and higher (10%) cost. Exhibit 23, an emissions reduction cost curve for Industry, provides an overview of the emissions reduction opportunities in this sector, and their estimated costs (from a societal perspective).[14]

The key opportunities in the Industry sector are:

- **Energy efficiency.** Energy efficiency improvements represent an opportunity of 17 $MtCO_2e$ in 2020 (47% of total industry emissions reduction potential) at average net savings of A$100 per tCO_2e. Low energy prices have led to little focus on energy efficiency historically, leaving potential savings of about 10% overall.[15] Major improvements typically include: improved control systems and processes, reduction of duplicated or oversized equipment, upgrade of motor systems, decrease of energy losses in boilers and steam distribution systems, waste heat recovery for pre-heating or other uses, and building utilities. Emerging technologies in aluminum smelting (drained wetted cathode and inert anode) and mining (improved weighing system to optimise truck loads or more accurate autonomous drilling) should also contribute to energy efficiency by 2020.

- **New technologies.** Technologies which are currently under development represent an opportunity of 9 $MtCO_2e$ in 2020 (24% of Industry total) at an average cost of A$9 per tCO_2e. This category includes: new technologies in aluminum smelting (drained wetted cathode and inert anode) which could decrease energy and process emissions by 40%; Ventilation Air Methane (VAM) oxidation which can reduce fugitive methane emissions from gassy underground mines by 70%; CCS which could produce significant emissions reduction by 2030; emerging technologies such as improved weighing system to optimise truck loads or more accurate autonomous drilling which reduces total drilling requirements could also save 7% in mining energy use. Australia has a key role to play in the development of emerging technologies such as VAM oxidation and CCS which could produce significant industrial emissions reduction by 2030.

- **Cogeneration** (also called combined heat and power or CHP). This represents an opportunity of 5 $MtCO_2e$ in 2020 (12% of industry total) at average savings of A$63 per tCO_2e. This technique provides primary energy savings by creating heat and electricity from the same fuel source. The potential is particularly high in the Iron and Steel industrial sectors, where all electricity use could be generated internally through this process.

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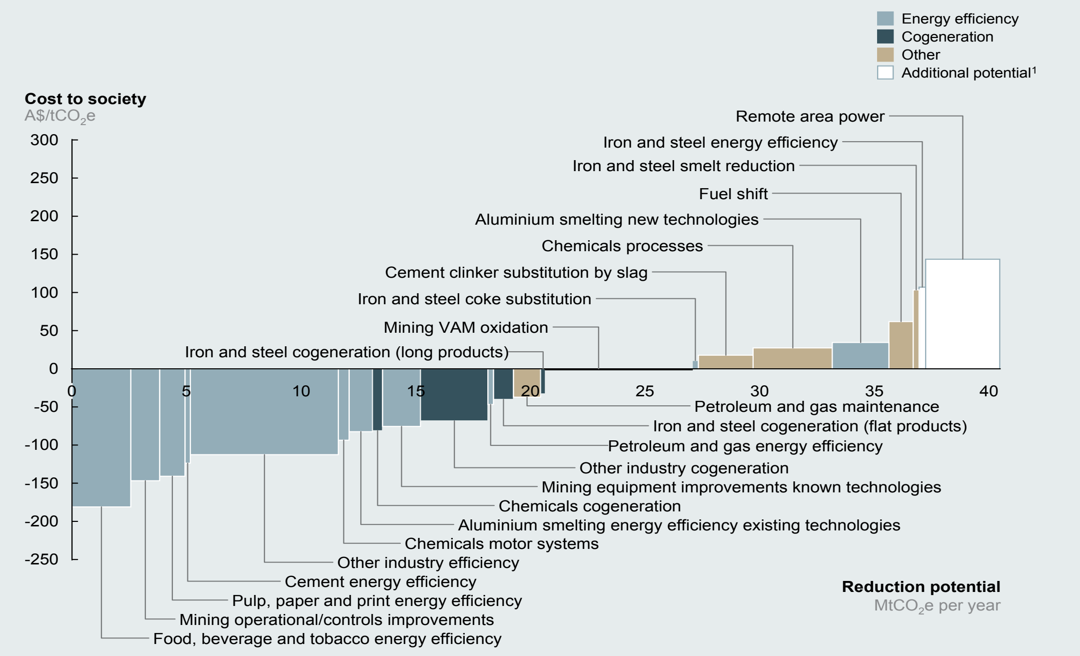
[14] Here we describe many of the industrial opportunities in more detail—splitting Aluminium, Mining and Other Energy Efficiency into nine separate opportunities (aluminium smelting efficiency through existing or new technologies, mining operations/controls or improved equipment, improved chemicals motor systems, and improved efficiency in cement, petroleum and gas, food and beverage, paper and print, and other industries); and Cogeneration into four (chemicals, iron and steel flat products and long products, and other industries); Iron and Steel Processes include coke substitution and smelt reduction; and Chemical Process and Fuel Shift are described separately.

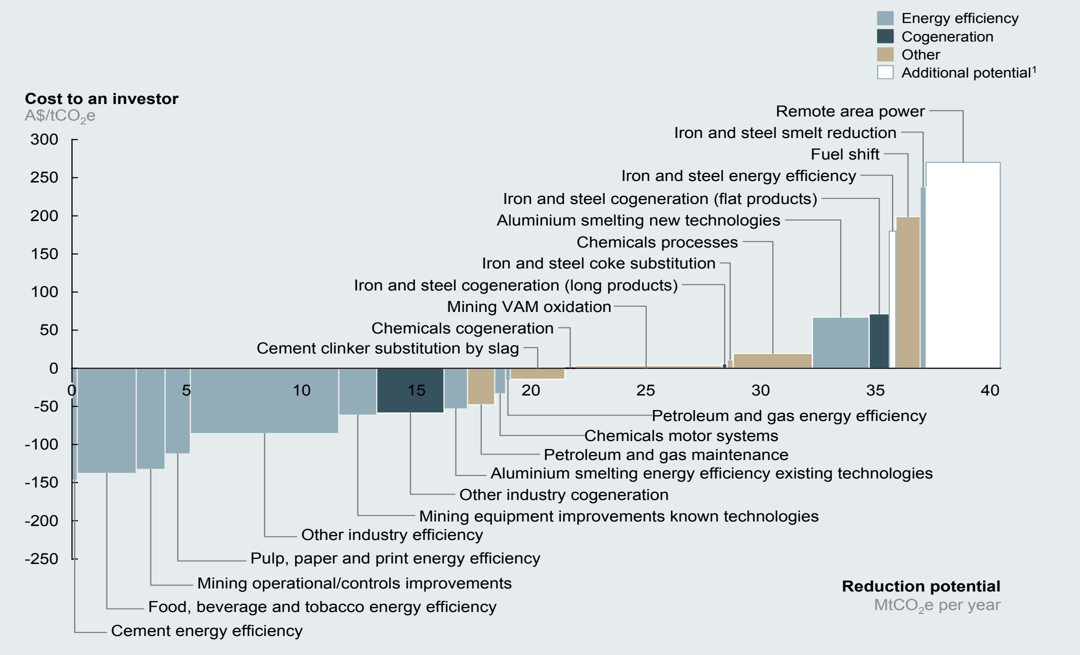
[15] This number represents an estimate of the technological potential, not including the impact of behavioural changes.

Exhibit 23: 2020 Industry GHG emissions reduction *societal* cost curve



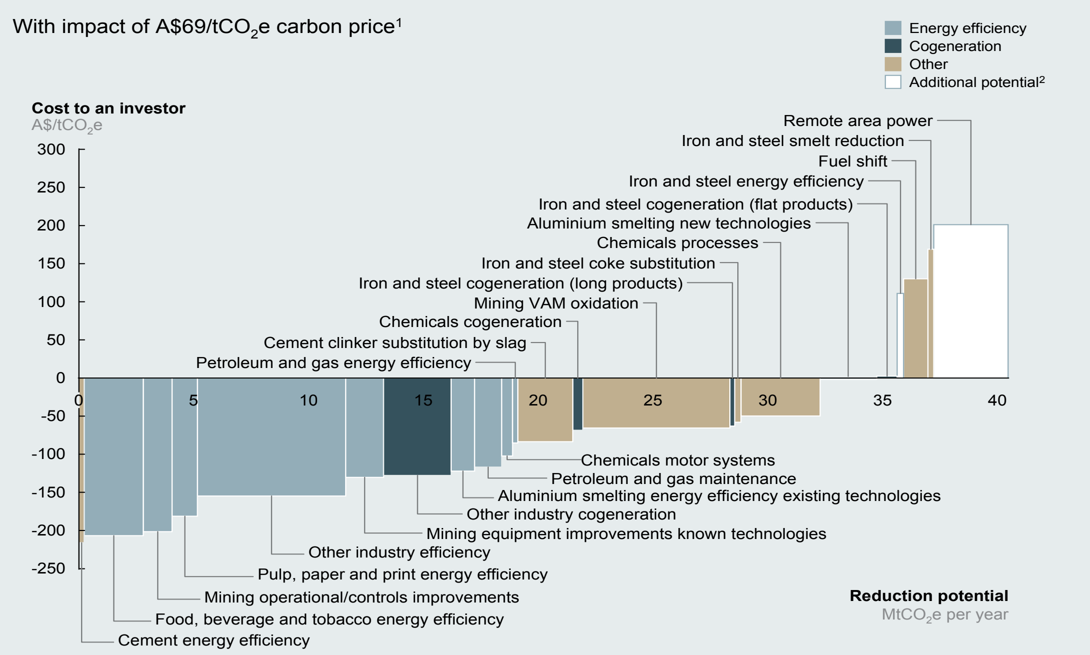
1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 24: 2020 Industry GHG emissions reduction *investor* cost curve



1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 5)

Exhibit 25: 2020 Industry GHG emissions reduction *investor* cost curve



1 Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars
2 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

- **Other opportunities.** Fuel or ingredient shift, industrial process improvement and reducing discharges of natural gas represent an opportunity to reduce emissions by 15 $MtCO_2e$ in 2020 (41% of total) at an average cost of A$12 per tCO_2e. Major opportunities include replacement of remote mines' inefficient gas or diesel generators by solar generators, fuel switches such as replacing coke by biomass for iron and steel production or clinker by slag in cement production, improvement of chemicals processes and catalysts and improved maintenance of the gas distribution system in remote locations.

CHALLENGES

- **Price of GHG emissions.** Currently, 42% of the emissions reduction opportunity is not profitable from an investor perspective (see Exhibit 24). This is particularly the case for most opportunities arising from new technologies.

- **Market structure and supply.** A number of factors in the market can restrict the take up of emissions reduction opportunities: some large industries benefit from extremely low energy prices, which decrease the profitability of energy efficiency measures; some businesses can also be reluctant to implement costly upgrades to aging plants when facing low cost competitors or an uncertain future. As for supply, low demand for energy efficient equipment has led to a gap or lack of variety in the equipment being offered in some sectors. Moreover, equipment replacement often follows a break-down and needs to be completed in a short timeframe to prevent operations disruptions. Replacements are therefore mostly taken from available inventory, made up of the most standard products. Access to alternative fuels or ingredients, such as biomass or industrial waste material is often limited and profitability decreases if they have to be imported or transported from a distant location (e.g. slag for cement processes).

- **Information gaps and decision process.** Limited understanding of energy consumption and the value of efficiency improvement –due to little sub-metering and benchmarks –continues to limit the emissions reduction action in this sector. Moreover, risks of operational disruptions and production quality or timelines degradation involved in setting up new equipment or suppressing some back-up systems are often overestimated compared to the energy savings potential.

- **Capital constraints and investment priorities.** Implementing emissions reduction opportunities can come at a high upfront cost, e.g. installation of sub-metering or cogeneration plants. Competition for capital is intense and energy efficiency improvements or GHG emissions reductions are often a low priority as they are not a core business activity and offer returns which are lower and perceived as riskier than other potential investments, in part because future policy settings are currently highly uncertain.

TOOLS TO OVERCOME THESE CHALLENGES

Options to overcome these challenges include:

- **Promote energy management practices.** Strong company-wide energy management practices supported by accountable energy managers, sufficient capital, comprehensive energy assessments, performance targets and tracking have proven effective in achieving greater energy efficiency—up to 20–30%.

- **Provide information.** Distributing training material (including benchmarks and guidebooks targeted at given sub-sectors or technologies) and increasing awareness has provided good results in the past (e.g. first results of the EEO program). Industry organisations can play a key role in sharing knowledge and increasing awareness in a given sector. Mandatory disclosure of performance can also help increase the priority of emissions reduction measures in businesses' agendas.

- **Set up targets and standards.** Voluntary agreements, under different formats and with various incentives (e.g. financial, regulatory, brand image, CEO commitment), have been seen to drive significant improvements. For example, long term agreements between The Netherlands Government and the chemical industry (LTA1 and LTA2) resulted in a 23% improvement in energy efficiency from 1998 to 2006. Efficiency standards can be effective for most standard support-system equipment such as air conditioners or standard boilers, but need to be developed by industry organisations or by companies themselves for more specialised equipment.

- **Develop third party financing.** Enabling “pay as you save” type of repayment reduces capital constraints and cost pressure on industries while increasing potential demand for energy-efficient equipment and creating a profitable activity for new market players. For example, manufacturers can decrease the upfront cost of equipment and set up shared savings arrangements, or large industries with low capital constraints and high supply costs can provide capital to their suppliers and get repaid through decreased costs of goods reflecting the energy savings. Energy service companies can also offer this type of arrangement for larger scale projects. A public entity may have to play that role for investments with high perceived risk.

- **Support pilots.** Providing financial and technical support to pilots will be an effective way to accelerate the maturation of new technologies identified above and lower the risk and cost for followers.

- **Improve economics of emissions reduction investments.** Energy price increases, for example by introducing a price for carbon, would significantly improve the economic attractiveness of a number of opportunities, such as energy efficiency measures, cogeneration, or capture of fugitive gases to generate electricity.

- **Coordination of waste streams.** A better circulation of waste streams between industrial and commercial sites—such as waste heat or waste products—could help reduce the supply constraint on alternative sources of energy. New market players could act as brokers between interested parties.

Agriculture

KEY POINTS

- The agriculture sector has the potential to contribute 13% of the total 2020 lowest cost emissions reduction opportunity for Australia, delivering emission reductions of 32 $MtCO_2e$.
- These emissions reduction opportunities have an average societal cost of A$25 per tonne, and the same cost from the investor's perspective.
- 78% of the estimated opportunity (25 $MtCO_2e$) is through soil carbon sequestration.
- As cost is the primary barrier, economic incentives such as a carbon price can be particularly effective, making most of the volume of opportunities profitable to investors (26 $MtCO_2e$) under the 25% example price used in this report. Information and long term policy certainty are other important barriers to overcome.

Agriculture will account for 16% of Australia's GHG emissions in 2010. Livestock are the principle contributors, accounting for over 60% of these emissions, primarily through enteric fermentation in cattle and sheep, a digestive process which involves the release of methane gas as plant material is broken down. Other emissions come from soils, fertilisers, manure and savannah burning.

Emissions reduction opportunities in the sector fall into two main groups: reducing direct livestock or crop emissions and increasing the amount of carbon stored in soils.

EMISSIONS GROWTH UNDER BAU

Growth in agricultural emissions will be primarily driven by increases in the size of beef and dairy cattle herds and sheep flocks. Livestock emissions are projected to increase by over 11% between 2010 and 2020, as Australian livestock numbers rise in response to an expected increase in demand for Australian meat and dairy products from a more affluent Asia. The land area devoted to cropping, the use of fertiliser and crop yields will also contribute to emissions growth, and the sector's expected recovery from drought drives small projected increases in cropping emissions. In total, emissions are projected to reach 98 $MtCO_2e$ in 2020, a 9% increase on 2010 levels.

EMISSIONS REDUCTION OPPORTUNITY

Agriculture can play a central role in transforming Australia to a healthier, less emissions intensive country. The desire to reduce the emission and build-up of atmospheric greenhouse gases from activities across Australia is an opportunity for farmers to further improve land management practices that drive long term sustainability, supported by the broader resources of society.

Identified emissions reduction opportunities do not, however, come at the expense of food production. As the population of Australia and the world grows, we will be increasingly reliant on highly productive crops. Reducing emissions and increasing stored carbon will therefore result from farmers doing things that increase or maintain productivity over the long run, giving farmers the tools and information necessary to pursue appropriate strategies and allowing farmers to make their own decisions. Broadly speaking, this is likely to result in a shift to more perennial crops and pastures, various forms of forestry on less productive land and more active efforts to increase the efficiency with which livestock convert feed to energy (thus minimising methane emissions).

Six agricultural opportunities have been identified that reduce $C0_2e$ in the atmosphere by 32 Mt in 2020, 7 Mt from a 7% reduction in emissions, and 25 Mt from storing extra carbon in the soil. Exhibit 27, an emissions reduction cost curve for agriculture, provides an overview of the emissions reduction opportunities in this sector and their estimated costs (from a societal perspective).[16]

The key opportunities in the agriculture sector are:

- **Reducing cropland soil emissions.** Reducing cropland soil emissions is the lowest cost opportunity in agriculture at an average net saving of A$75 per tCO_2e for a total reduction of 1 $MtCO_2e$. This primarily involves reducing tillage, which reduces CO_2 emissions through less disturbance of the soil, and improved nutrient management, which reduces nitrous oxide (N_20) emissions through more precise application of fertiliser. These practices save farmers money via reduced labour, tillage and fertiliser costs, but there is not a large volume of emissions reduction opportunity nationally as these practices are already widely adopted.

- **Reducing livestock emissions.** Active livestock feeding and anti-methanogenic treatments represent opportunities to reduce livestock emissions by 2 $MtCO_2e$ and 3 $MtCO_2e$ in 2020 at a saving of A$11 per tCO_2e and a cost of A$17 per tCO_2e respectively. Active feeding programs that allow animals to gain weight more quickly with higher quality feed both reduce emissions per day and also reduce the time it takes to bring an animal to slaughter weight, thus reducing lifetime emissions. The anti-methanogenic category represents a range of treatments that act to reduce the prevalence of methane producing methanogens in livestock. Many of these treatments, such as vaccines, are still being developed or trialled.

- **Pasture and grassland management.** Improved pasture management and natural grassland management represent opportunities to reduce emissions and increase soil carbon by 3 $MtCO_2e$ and 14 $MtCO_2e$ in 2020, at estimated costs of A$5 per tCO_2e and A$12 per tCO_2e respectively. These similar practices are applied over two different grazing systems—more intensively managed improved pastures and the far larger natural grasslands (or rangelands), the latter being areas that have not typically seen extensive fertilisation or introduction of grass species. Both practices involve optimising grazing intensity and timing to maximise

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[16] Here we describe two of the six agriculture opportunities in more detail based on the type of farmland practiced upon—improved pastures or natural grasslands for Pasture and Grassland Management—plus cropland for Degraded Farmland Restoration.

productivity and carbon sequestration, increasing the prevalence of deep rooted perennial grass species, managing fire and increasing fertiliser use. Overseas experience indicates that these practices can reduce the amount of emissions from livestock on the land via improved grass feed and better livestock management and increase the amount of carbon stored in stable long term forms in the soil, but there are some uncertainties about the potential to achieve similar results in Australia.

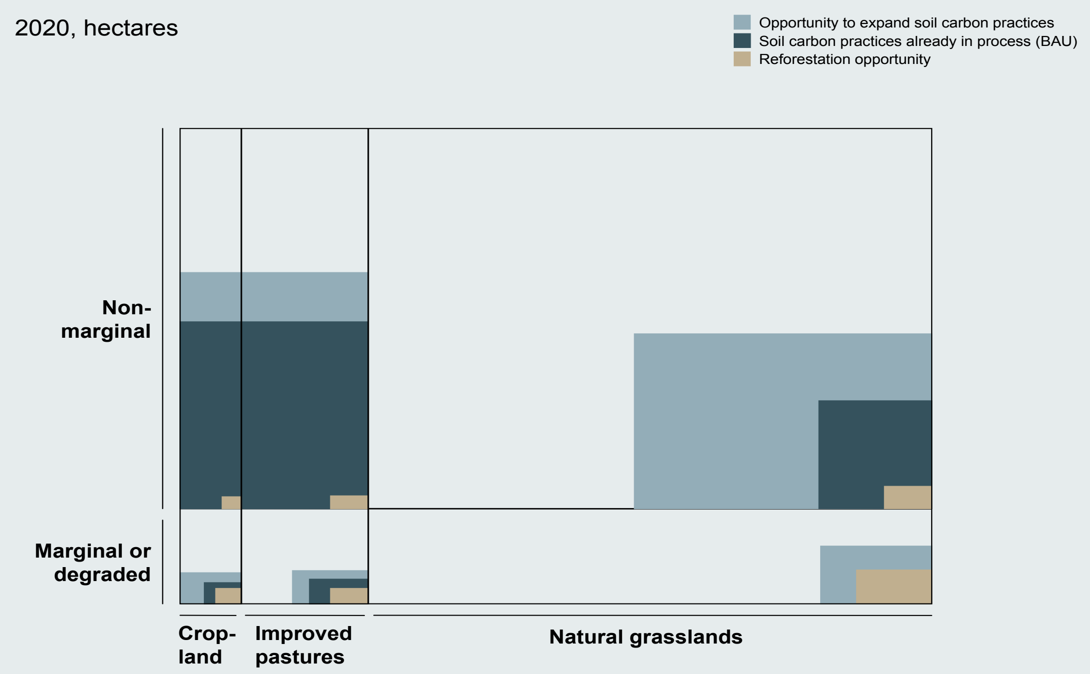
- **Cropland carbon sequestration.** Cropland carbon sequestration activities can reduce emissions by 2 $MtCO_2e$ at an average cost of A$25 per tCO_2e, by increasing the use of deeper rooted crop varieties that allocate more carbon to the soil, and reducing the use of bare fallow and planting cover crops.
- **Degraded farmland restoration.** The restoration of degraded cropland, pastureland and natural grassland represents an opportunity to increase soil carbon by 1 $MtCO_2e$, 1 $MtCO_2e$ and 5 $MtCO_2e$ respectively in 2020, at costs of A$63 per tCO_2e, A$78 per tCO_2e and A$94 per tCO_2e. Principally, restoration involves reducing salinity, acidification and erosion through revegetation, application of nutrients and other measures to restore the health of land and increase its ability to support vegetation and store soil carbon. Though the opportunity is large, active restoration of degraded land is expected to be the most expensive on less managed rangelands. Restoring degraded land may not always be this expensive, as farmers are already demonstrating that in some instances productivity gains may quickly offset the costs of restoration.

These opportunities are categorised based on the type of land on which they are undertaken. In total across all the agriculture opportunities, 78% of the emissions reduction opportunity in 2020 (25 $MtCO_2e$) comes from soil carbon sequestration—i.e. storing extra carbon in the soil.

There is a wide disparity of estimates internationally on the potential of soil carbon sequestration. Variations exist across all key aspects of soil carbon calculations, such as the sequestration rates, penetration rates and costs. The broad range is compounded locally by the specific challenges of Australian soil conditions and the considerable geographic differences in soil type within Australia and within regions. This report has reviewed leading studies and takes a balanced approach to the range of estimates that lead to the volume and cost of the opportunities identified above.

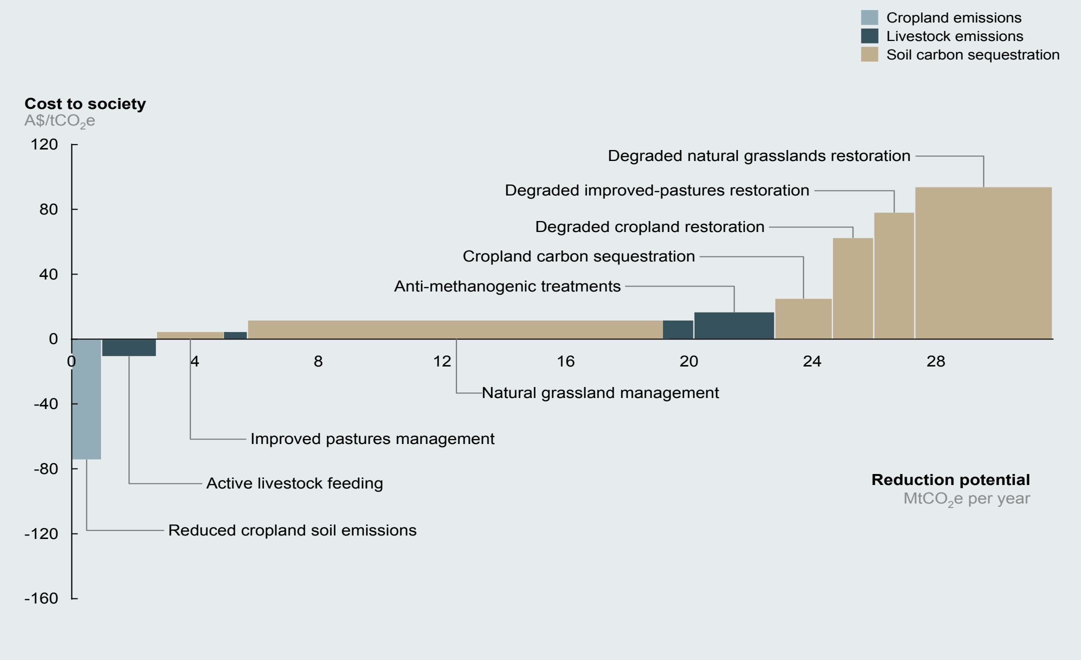
Given the size of Australia’s land used for agriculture, the size of the soil carbon opportunities described above (improved pasture management, natural grassland management, cropland carbon sequestration and degraded land restoration) are highly sensitive to the rate of adoption assumed (penetration rate). To show the relative scale of the rates assumed in this report, Exhibit 26 illustrates an estimate of potential penetration by 2020, with the entire rectangle (including all colours and white space) representing all Australian agricultural land (~400 Mha), divided into cropland, improved pastures and natural grasslands, and by marginal and non-marginal land, and the internal shaded sections representing the maximum penetration of this land by sequestration activities (BAU plus emissions reduction opportunity). As this illustrates, BAU practices are forecast to adopt some soil carbon sequestration in 15% of all agriculture land by 2020, To achieve further emissions reductions, a modest extension of these practices is assumed, with the larger land areas of natural grassland showing the largest increase.

Exhibit 26: Potential farmland penetration of carbon sequestration practices



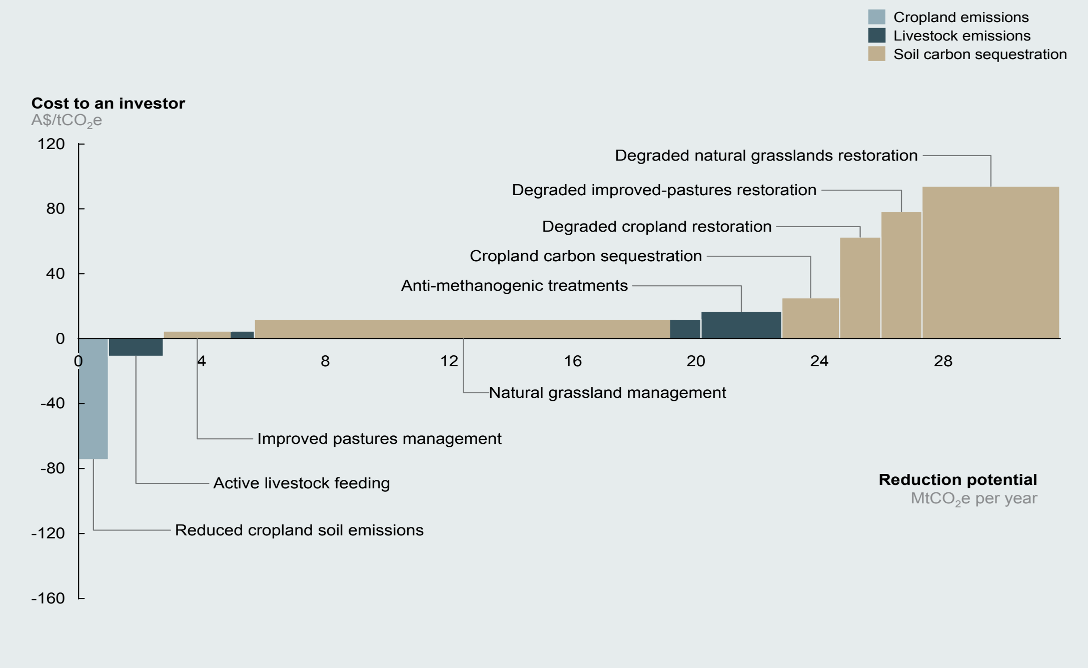
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 27: 2020 Agriculture GHG emissions reduction *societal* cost curve



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

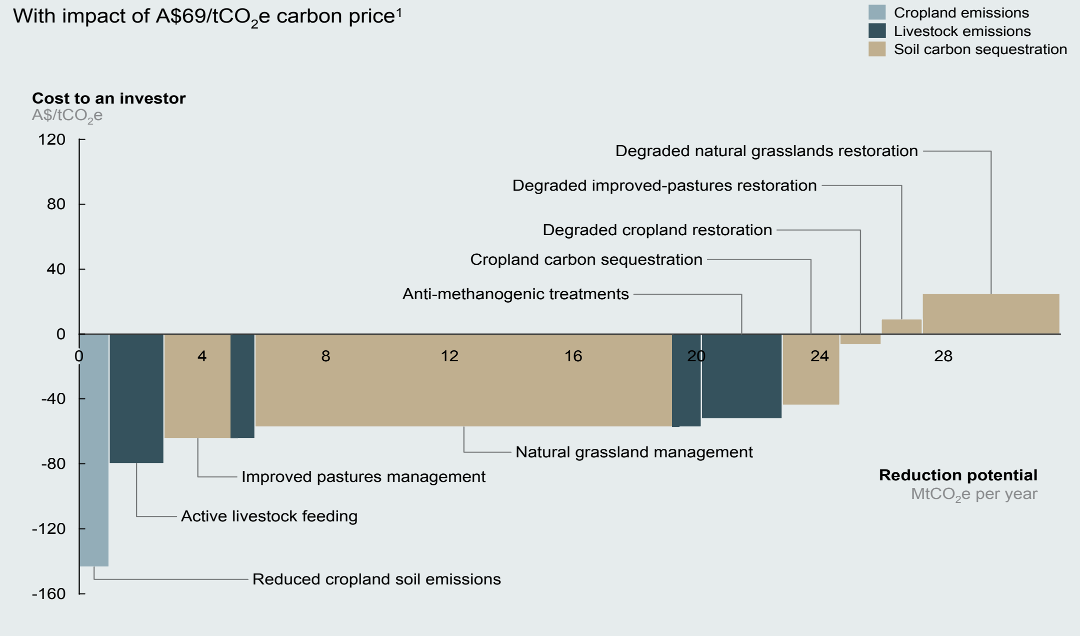
Exhibit 28: 2020 Agriculture GHG emissions reduction *investor* cost curve



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 29: 2020 Agriculture GHG emissions reduction *investor* cost curve

With impact of A$69/tCO$_2$e carbon price[1]



1 Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars

CHALLENGES

Emissions reduction opportunities in the agriculture sector face a number of challenges:

- **Price of GHG emissions.** The majority of identified opportunities to reduce emissions or increase carbon storage are expected to come at a cost to farmers (the costs from the investor perspective are the same as the costs in the societal view for agriculture, due to the absence of capital costs). Current uncertainty over how farmers will be able to engage in the carbon market, what activities will be credited and over what time period and at what price makes it difficult for farmers to invest with the level of certainty they require. Without certainty over the economics, farmers will be reluctant to lock themselves in to any changes in land use or land management, particularly where this involves them taking on liabilities if soil carbon later declines (such as due to prolonged drought).

- **Market structure and supply.** The fragmented nature of the agriculture sector may increase transaction costs involved in setting up and implementing many of these emissions reduction projects. For example, developing new varieties of perennial crops and grasses is not profitable for any one farmer, and will require coordination and commitment among a larger group of users before research and development funds are committed. There are also restrictions on the supply and use of some deep rooted plant varieties that would aid in carbon storage, as some species are non-native and others are considered weeds that may reduce crop yields.

- **Information gaps and decision process.** Farmers are a diverse and dispersed set of decision makers, who may not always have access to information regarding the methods by which emissions reduction can be achieved nor feel confident that they can pursue them. There is also a risk that farmers will not feel engaged or assisted by scientific advice around emissions reduction nor confident in the emissions accounting systems. Creating a reliable soil carbon accounting system is also a considerable challenge for policy makers, as soil carbon levels vary widely between geographies and fluctuate naturally over time.

- **Capital constraints and investment priorities.** Australian farming is characterised by high individual ownership and low return on capital (excluding land value appreciation). Many farmers are cash constrained, a position exacerbated by the prolonged drought. The land management changes and improvements necessary to reduce emissions or increase carbon storage will require new investment priorities, posing an additional implementation challenge.

TOOLS TO OVERCOME THESE CHALLENGES

Options to overcome these challenges include:

- **Create a clear system of agricultural carbon accounting and payment.** A clear, open and transparent system by which farmers can be credited for emissions reduction or carbon storage is needed. Once in place, even if not initially perfect, it will provide a basis for farmers to make investment and management decisions. A clear system will also allow private capital to follow emissions reduction opportunities. Research is necessary to support the creation of a reliable carbon accounting system capable of assessing farm soil carbon levels reliably and at low cost. Support to expand carbon accounting under international agreements will help ensure local governments and businesses are fairly rewarded for these efforts.

- **Give farmers a range of tools.** Extensive research and development should be undertaken to develop perennials that are both more productive and better at sequestering carbon. Additionally, a concerted research effort to establish the ability of Australian farming soils to sequester carbon under various land management techniques will provide greater certainty on the feasibility of soil carbon programs and how best to pursue them.

- **Provide information.** Emissions reduction science needs to be kept relevant to farmers. The specific opportunities, regulations and risks need to be explained to farmers by trusted local institutions and individuals. Farmers have demonstrated their ability to react quickly to changed circumstances and alter management practices rapidly (for instance under water trading regulations in the Murray Darling), but this will occur only once information is clearly conveyed and a transparent and well understood accounting and incentive system is in place.

Kyoto and Agriculture

Our current Kyoto reporting obligations do not cover soil carbon content or CO_2 emissions from soils. Consequently, only reductions in non-CO_2 emissions (livestock methane and N_20 from fertilisers) would count towards meeting Australia's present Kyoto obligations. Over time, it is possible that CO_2 emissions from soils will be included in Australia's obligations, which would bring all opportunities discussed here within Australia's Kyoto accounts.

Focus area—opportunity for the individual farmer

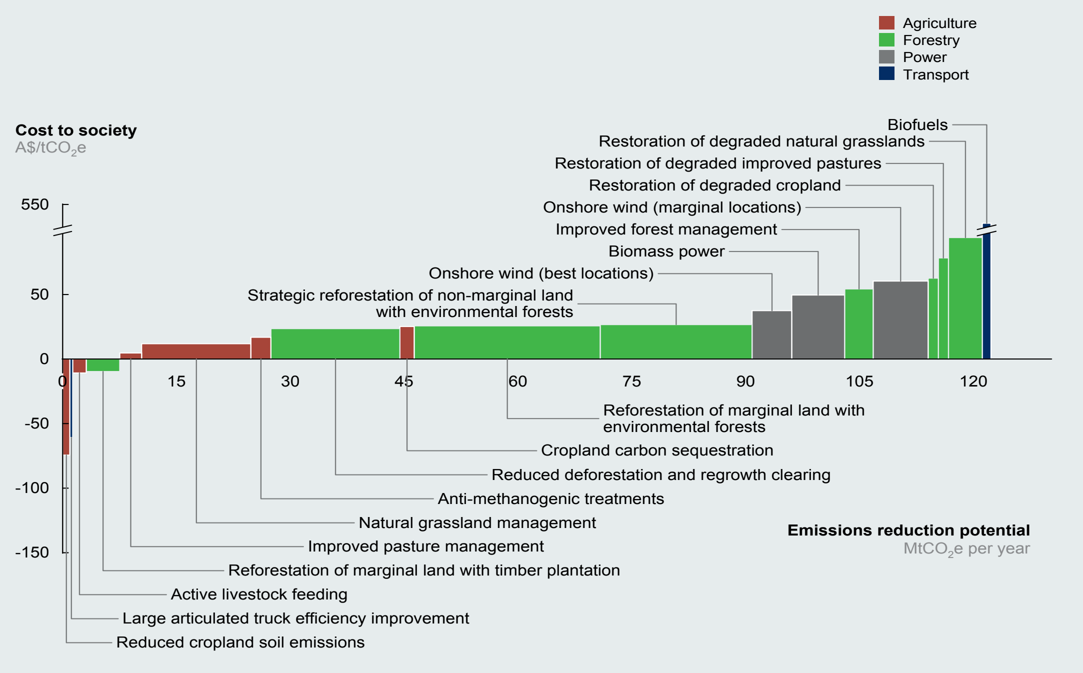
Efforts to reduce GHG emissions can open up new economic opportunities for farmers. Carbon may become another commodity for farmers to trade in, potentially supplementing or replacing existing incomes and reducing income variability and risk.

Exhibit 30 displays the broad range of emission reduction opportunities in which farmers are a key decision maker or investor.

Farmers are able to have an impact on emissions reductions outside the agriculture sector by participating in the following emissions reduction opportunities:

- **Reforestation.** Reforestation can occur on agricultural land, and farmers will have a range of tree planting options to choose from. Some options will allow both carbon sequestration credits and ongoing timber revenue, others will earn carbon credits only, though over a longer period. If farmers choose to reforest, they will also have the choice of where on their land to plant trees. The productivity of the land chosen will influence tree growth rates and related income, and will also dictate the opportunity cost of lost revenue from the previous use of that land.
- **Reducing deforestation and regrowth clearing.** Over 90% of current deforestation and regrowth clearing in Australia is agriculture related. Reductions in deforestation emissions will therefore be driven by farmers. Without support, reducing regrowth clearing and deforestation is likely to come at a cost to farmers. An appropriate combination of financial incentives and regulations will need to be deployed to engage farmers and allow emission reductions without adverse financial impacts on farmers.

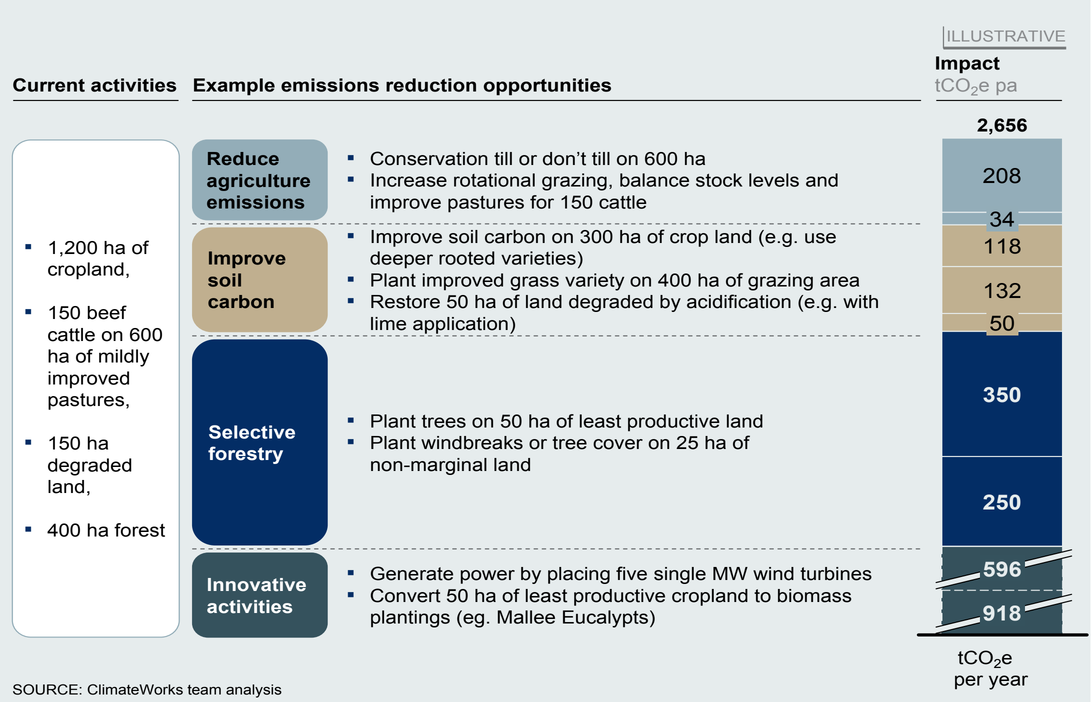
Exhibit 30: 2020 GHG abatement opportunities that farmers can impact



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

- **Biomass provision.** Biomass power generation involves generating electricity by using organic matter (biomass) as fuel. When this technology comes into use, farmers will have an opportunity to sell crop residues and other waste products, or grow particular plants or trees as biomass feedstock, providing an additional revenue stream. The suitability of these enterprises will depend on the price electricity generators are prepared to pay for biomass feedstock, the production and transportation costs faced by farmers and the impact on other farm enterprises. The opportunity for farmers to grow mallees (a species of eucalyptus) for biomass is currently being investigated in Western Australia. Early research suggests that this can be done in small stands across cropping land with minimal impact on existing cropping. If harvesting and transportation costs are able to be reduced by using better equipment, harvesting practices, or strategic positioning of biomass electricity generation sites, this may become an additional revenue stream for suitable farmers.
- **Biofuels production.** Increasing demand for biofuels would increase the income farmers can derive from particular crops or products. Increased demand for bioethanol, made primarily from sugar and starch crops such as wheat, corn and sugar cane, may push up the price of these crops. Similar income opportunities may occur with biodiesel inputs such as animal fats, vegetable oils, soy, rapeseed, and sunflower oil.
- **Wind turbine placement.** An assessment of wind resources in Australia demonstrates that a substantial proportion of the best on-shore land available for wind turbines is agricultural, offering farmers the opportunity to collect rent for the placement of turbines or produce distributed electricity themselves. In the latter case, the farmer's own electricity costs can be reduced, excess electricity can be sold back into the grid, and the farmer may even qualify for

Exhibit 31: Example impact of a single farm



Current activities

- 1,200 ha of cropland,
- 150 beef cattle on 600 ha of mildly improved pastures,
- 150 ha degraded land,
- 400 ha forest

Example emissions reduction opportunities

Reduce agriculture emissions

- Conservation till or don't till on 600 ha
- Increase rotational grazing, balance stock levels and improve pastures for 150 cattle

Improve soil carbon

- Improve soil carbon on 300 ha of crop land (e.g. use deeper rooted varieties)
- Plant improved grass variety on 400 ha of grazing area
- Restore 50 ha of land degraded by acidification (e.g. with lime application)

Selective forestry

- Plant trees on 50 ha of least productive land
- Plant windbreaks or tree cover on 25 ha of non-marginal land

Innovative activities

- Generate power by placing five single MW wind turbines
- Convert 50 ha of least productive cropland to biomass plantings (eg. Mallee Eucalypts)

SOURCE: ClimateWorks team analysis

renewable energy certificates under the expanded RET program. Furthermore, experience shows that wind turbines have relatively small footprints and can be installed with minimal disturbance to existing agricultural activities. Where infrastructure can be suitably extended to connect them to the electricity grid, wind turbines offer a potential additional income source for farmers.

Exhibit 31 depicts a potential range of opportunities an individual farmer could pursue, and the resulting impact on GHG emissions of these decisions—though the size and mix of the opportunities selected is purely illustrative.

Buildings

KEY POINTS

- The buildings sector has the potential to contribute 11% of the total 2020 lowest cost emissions reduction opportunity for Australia
- These emissions reduction opportunities offer an average net saving to society of A$99 per tonne, and offer investors an average profit of A$90 per tonne
- 77% of the opportunity is within the commercial sector (including 16 $MtCO_2e$ for existing buildings retrofits and 4 $MtCO_2e$ for new builds)
- Around three quarters of the emissions reduction opportunities identified are profitable to investors, even without a carbon price, therefore addressing non-price barriers is central to unlocking emissions reductions in this sector

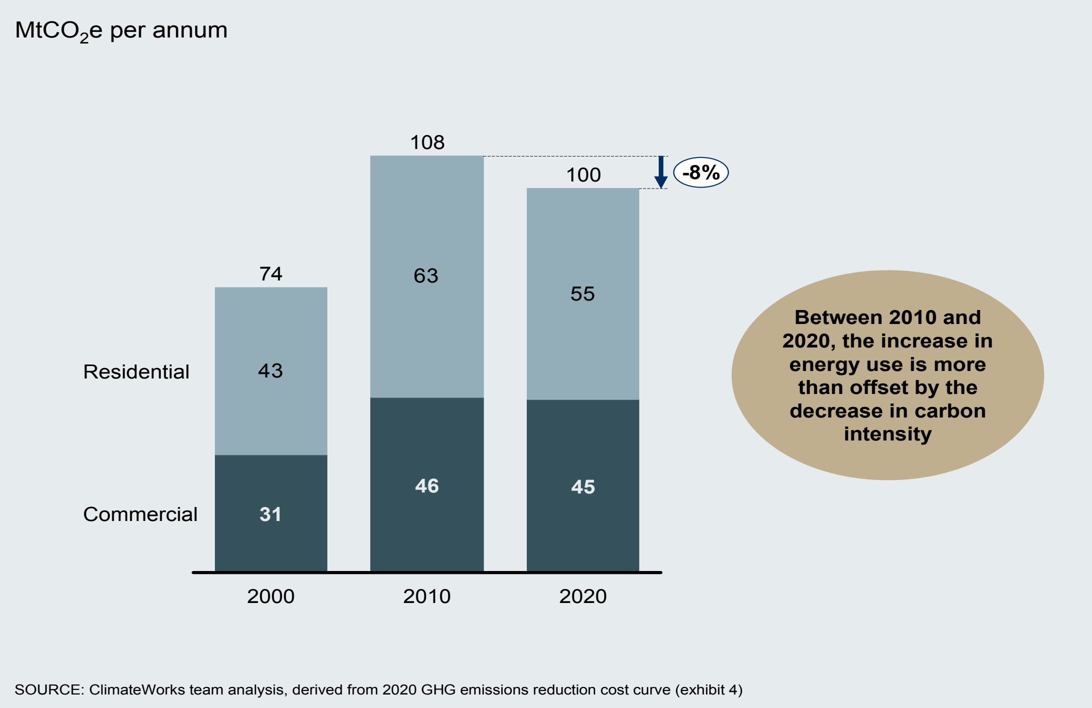
Buildings will account for 18% of Australia's greenhouse gas emissions in 2010, with residential buildings accounting for 58% of these and the commercial buildings responsible for the remaining 42%. The emissions from the buildings sector are by-products of the energy used for heating and cooling, lighting, and appliances, combining direct emissions (from gas, wood and oil combustion) and indirect emissions (from electricity use), and the emissions reduction opportunities in the sector are driven by energy efficiency improvements. Although Australia has a mild climate compared to other developed nations and so requires less energy for the heating and cooling of buildings, cheap energy prices have led to inefficient equipment and buildings shells.

EMISSIONS GROWTH UNDER BUSINESS-AS-USUAL

Emissions from buildings are projected to be 35% higher in 2020 than in 2000 (see Exhibit 32). A slight decline will occur in the next ten years from 108 $MtCO_2e$ in 2010 to 100 $MtCO_2e$ in 2020 due to the combined effect of decreased carbon-intensity of electricity and implementation of governmental measures to improve energy efficiency of existing and new buildings. This decrease is mainly concentrated in the residential sector, with emissions dropping 13% from 63 $MtCO_2e$ in 2010 to 55 $MtCO_2e$ in 2020.

Growth of energy use in the residential sector will occur due to increases in population, average floor space per person, ownership of electrical appliances (especially electronics and air-conditioning) and use of electricity in comparison to less carbon-intensive sources of energy. However this will be more than offset by the decrease in carbon intensity due to the implementation of RET (16% decrease compared to expected intensity without RET) and by the impact of measures promoting energy efficiency improvements. These measures include the

Exhibit 32: Buildings sector emissions evolution in the business-as-usual case



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

extension of Mandatory Energy Performance Standards (MEPS), the phase out of incandescent light bulbs and GHG intensive electric water heaters, the Solar Hot Water Rebate Program and the Insulation Rebate. Altogether, the measures implemented since the beginning of 2009 are estimated to cause a reduction of 9 $MtCO_2e$ on the BAU emissions. In the commercial sector, the increase in floor space is balanced by improvements in the energy efficiency of new equipment and building shells (impacts of MEPS and mandatory disclosure of commercial office building energy efficiency).

EMISSIONS REDUCTION OPPORTUNITY

Twelve measures have been identified to reduce buildings sector emissions (see Exhibit 33).[17,18] If fully implemented, the measures included in this plan would result in emissions reduction of 28 $MtCO_2e$ in 2020, a 28% reduction on BAU emissions. Almost all of these opportunities offer net savings from a societal perspective.

The key emissions reduction opportunities are:

- **Commercial sector** accounts for 77% of the potential (see Focus Area below). Opportunities in this sector can be split into three categories: new builds, improved efficiency through technology and energy waste reduction.

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17 Not including changes in lifestyle (e.g. turning off appliances at the power point, changing the thermostat).

18 Here we describe two of the twelve buildings opportunities in more detail—splitting Commercial Elevators and Appliances into those purchased with new buildings, and those during building retrofits (the latter split further into electronics, cooking and refrigeration, and elevators and other appliances); and Residential Lighting into LEDs and high efficiency halogen.

  - **New builds.** Increasing new builds' energy efficiency above current standards (by the equivalent of a one star improvement for office buildings in the NABERS rating system) could deliver 2 $MtCO_2e$ of emissions reduction by 2020 with net savings of A$73 per tCO_2e. These improvements could be achieved through improved building design and orientation, improved insulation and air tightness, usage of better materials and more efficient heating, ventilation and air conditioning (HVAC) and water heating systems.

  - **Improved efficiency through technology.** Technological improvements represent a 14 $MtCO_2e$ opportunity. These include actions such as replacing inefficient light bulbs, improving the energy efficiency of all appliances and equipment, but also decreasing energy losses experienced with open refrigeration, insufficiently insulated ovens or water mains. It also involves switching to less carbon-intensive fuels when possible, for example using more gas and solar-powered instead of electric water heaters. Implementing or upgrading control systems for lighting and HVAC systems can also reduce fixed energy use, especially in subsectors such as offices or hotels. Most technological improvements also deliver secondary benefits in terms of reduced need for HVAC. For example, putting doors on refrigeration systems reduces the heating load of supermarkets and improving the insulation of large ovens or installing more efficient light bulbs decreases the cooling load of restaurants or offices. These secondary benefits, which come at no or very low capital cost, have been estimated to represent 2 $MtCO_2e$ of emissions reduction in 2020.

  - **Energy waste reduction.** The cheapest opportunity in existing buildings is in reducing energy waste, which could deliver at least 10% energy savings with very little capital expenditure. This includes actions such as reducing oversized and unnecessary equipment and better management of existing controls systems.

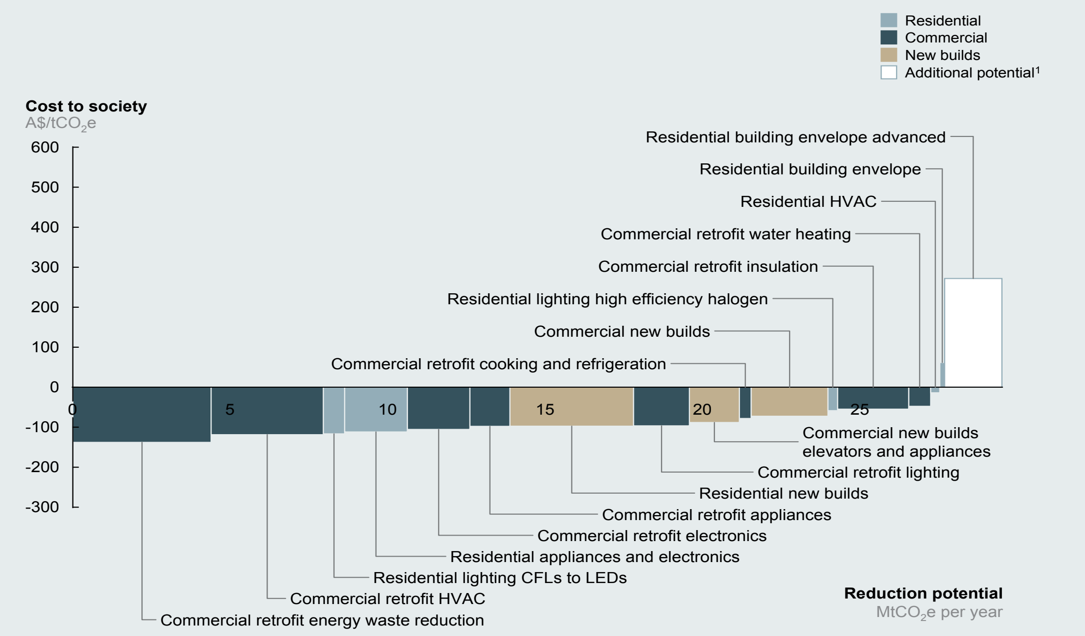
- **Residential sector** accounts for the remaining 23% of the potential identified with 6 $MtCO_2e$ reductions by 2020. As most of the potential from increased insulation of existing buildings and replacement of greenhouse intensive water heaters by heat pumps or solar and high-efficient gas water heaters is already captured in BAU, most of the further opportunity lies in the improvement of new house shells. Specifically, upgrading new homes to 7.2 stars in the HERS rating system (compared to 4 and 5 stars for NSW and other states in the current standards) could unlock 4 $MtCO_2e$ in 2020 with net savings of A$98 per tonne. Other major opportunities include the replacement of CFL light bulbs by LEDs and increased efficiency of appliances and equipment above current levels.

CHALLENGES

- **Price of GHG emissions.** Profitability is not a major barrier in the buildings sector as significant opportunities are already profitable for investors (see Exhibit 34). However, deeper structural retrofits, which could deliver additional emissions reduction, are not economically viable today but could become so if energy prices increase.

- **Market structure and supply.** Market barriers include non-market electricity pricing, split incentives and lack of scale. Some large businesses have little incentive to reduce their energy consumption as they pay low rates for their energy consumption, and instead pay some combination of a fixed fee or discounted unit price. Split incentives arise when buildings are occupied by tenants or short-term owners: any capital investment made by the owner to improve energy efficiency will be recouped in part by the tenant or the next

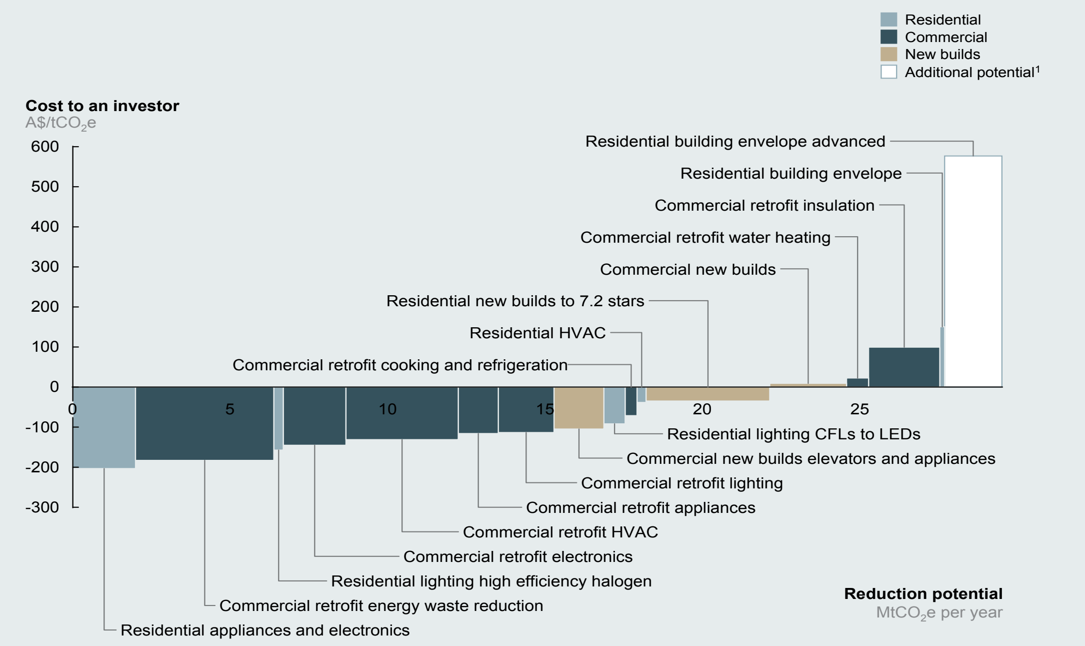
Exhibit 33: 2020 Buildings GHG emissions reduction *societal* cost curve



1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 34: 2020 Buildings GHG emissions reduction *investor* cost curve

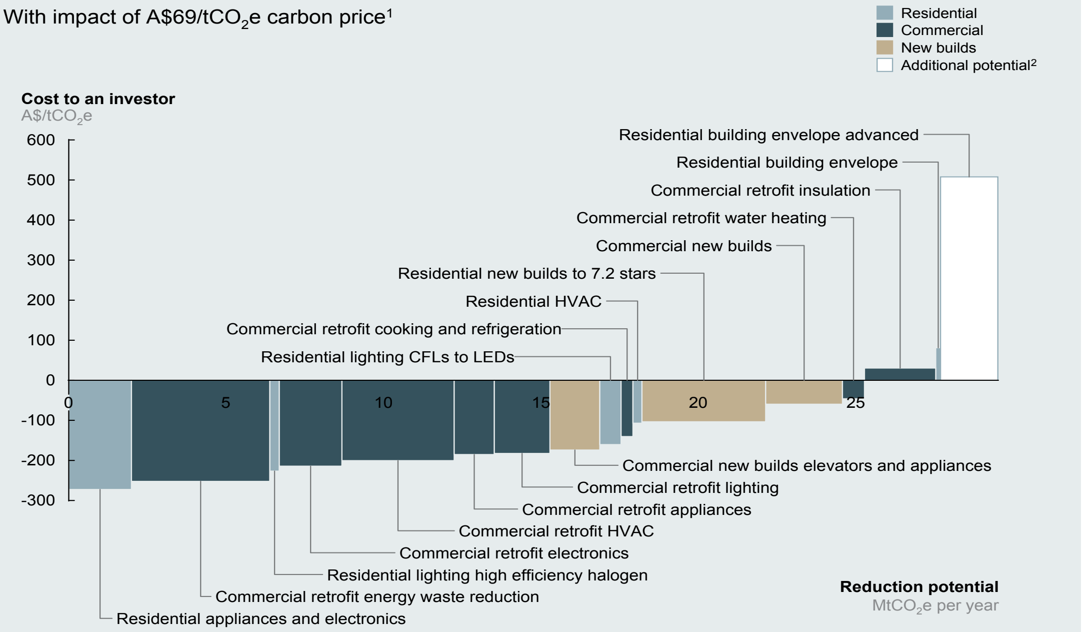


1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 35: 2020 Buildings GHG emissions reduction *investor* cost curve

With impact of A$69/tCO$_2$e carbon price[1]



1 Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars
2 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels
SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

owner. In addition, the fragmented nature of the sector means the transaction costs of pursuing energy efficiency can be very high—small businesses or homeowners in particular need to invest significant time to acquire the information, set up the financing and find the equipment or contractors to install it.

- **Information gaps and decision process.** In many cases, homeowners and businesses—in particular those with low energy bills as a proportion of outgoings—may not closely follow how much energy they use, and the savings which could be achieved through improved energy efficiency. Moreover, the equipment needed to estimate and verify energy savings is not readily available and comes with a cost, making it difficult to build traction on energy efficiency measures. Even when energy efficiency measures are pursued, savings are often undermined by a lack of understanding of the proper use of new equipment, or inadequate investment in the skills of auditors and contractors.

- **Capital constraints and investment priorities.** Some improvements such as lighting or high-efficiency appliances come at a low additional cost, but some other measures such as insulation, switch to solar-powered equipment or whole systems upgrade are capital intensive, offer long payback periods and are usually perceived as non-critical to the business. Moreover, banks are reluctant to offer loans for such projects at reasonable rates due to the lack of collateral and their already high level of property exposure. The situation is even worse for SMEs who generally already face higher borrowing rates.

TOOLS TO OVERCOME THESE CHALLENGES

Options to overcome these challenges include:

- **Information.** Awareness campaigns, expansion of labeling (e.g. NABERS, Energy Star), and disclosure of energy efficiency performance can all increase public awareness and stimulate demand for energy efficient equipment and spaces. Communicating the secondary benefits of improvements such as increased value of properties or improved productivity and health for office workers could also help trigger interest in energy efficiency.

- **Energy price structure.** Increasing the use of “smart meters” and removing energy pricing distortions (such as fixed costs or retail price caps) would provide better incentives for reducing energy use.

- **Third-party funding.** Innovative forms of financing which allow loan repayments to be collected through utility meters, energy performance contracts, leasing contracts or property levies can enable investors to maintain a positive cash flow on energy efficiency investments and in some instances overcome split incentives barriers.

- **Increased facilitation services.** Transaction costs can be reduced by facilitating a competitive market in energy service companies for smaller scale projects, and creating facilitation centres in large corporations or services (e.g. public administration) that have many small scale buildings.

- **Mandatory standards, rebates and tax incentives.** Well targeted energy efficiency regulation has a proven track record in unlocking emissions reductions and energy savings potential (e.g. MEPS or Solar Hot Water Rebate).

- **Market-based initiatives.** A cap and trade system dedicated to commercial building retrofits could release most of the emissions reduction potential at a low cost to investors, but it may involve higher costs to energy users in the short term.

- **Leading by example.** Role modeling has been shown to be a very effective means of raising awareness and commitment. In residential buildings this can be achieved through education campaigns and networking, and in commercial buildings experience has shown that the attitude of the CEO plays a major role in thought and behaviour leadership when it comes to energy efficiency.

Focus area – commercial building retrofits

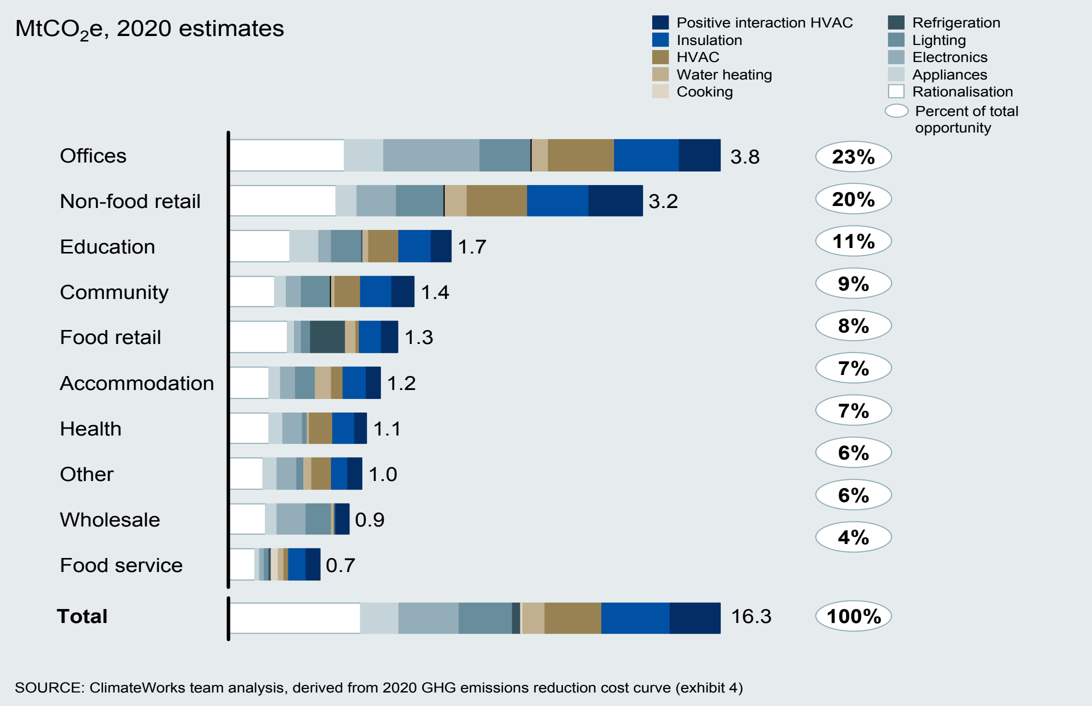
16 $MtCO_2e$ of emissions can be reduced from commercial buildings at a net savings to society. This opportunity is spread across a wide range of subsectors and technologies. Exhibit 36 below details this opportunity.

A few observations can be made from this data:

- There is more to commercial buildings than offices: with 3.8 $MtCO_2e$ of opportunity, offices represent just 23% of the total opportunity in commercial buildings
- Other sub-sectors such as retail (food and non-food) and education (schools and universities) represent respectively 28% and 11% of the total opportunity
- A large part of the opportunity comes at a low capital intensity: 37% of the opportunity comes from downsizing and getting rid of unnecessary equipment (energy waste reduction and positive interaction of improvements of other equipment's energy efficiency on the heating and cooling load) and about half of the remaining opportunity lies in small stand-alone equipment such as kitchen appliances, electronics and small space heaters or air conditioners

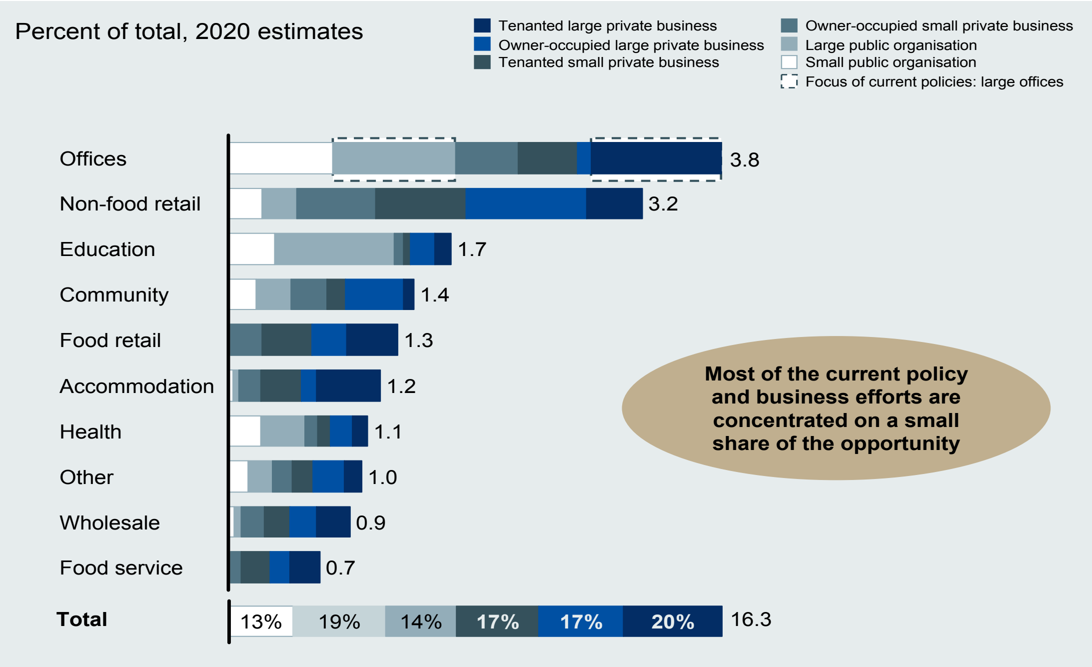
The barriers to emissions reduction for these economically attractive opportunities are varied in nature across the different opportunity areas. A detailed understanding of those barriers is required to effectively design actions or policies to meet these challenges (by business or government). The characteristics of the building owner and occupant is critical as it has a major impact on capital availability, transaction costs and investment priority, three of the major barriers to energy efficiency implementation. A detailed analysis along four occupancy

Exhibit 36: Emissions reduction opportunity in commercial building retrofits by technology



SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 37: Emissions reduction opportunity in commercial buildings retrofits by segment



SOURCE: Australian Bureau of Statistics (2001 and 2008); Tertiary Education Facilities Management Association (2004); Australian Institute of Health and Welfare (2008); ClimateWorks team analysis

criteria – public or private, activity type, owner-occupied or tenanted, size of business – shows that:

- Most efforts from policy makers and business players (such as real estate and energy service companies) concentrate on only 13% of the opportunity (large public and private offices)
- Of the remaining relatively untouched opportunity, 37% lies in segments with strong incentives for energy efficiency improvements (other public sector buildings and large businesses with high energy costs)
- The remaining 50% of the opportunity will need significant support or mandates (small private businesses and large businesses with low energy costs)

Transport

KEY POINTS

- The transport sector has the potential to contribute 2% of the total 2020 lowest cost emissions reduction opportunity for Australia.
- The largest opportunity in the sector (68% of total) is improving the fuel efficiency of conventional internal combustion engine (ICE) vehicles – an opportunity that already offers net savings to society in 2020 of A$60 per tonne, and offers greater savings to investors with an average profit of A$194 per tonne.
- As the emissions reduction opportunities identified are profitable to investors, even without a carbon price, addressing non-price barriers is central to unlocking the low cost emissions reductions.
- There are also significant opportunities to reduce transport emissions through changing the way we travel, such as carpooling or cycling—these are briefly discussed in the Focus Area, "Impact of Lifestyle and Behaviour Changes", but not included in the cost curve.

Transport accounts for 14% (82 $MtCO_2e$) of Australia's GHG emissions in 2010, with road transport accounting for the majority of this (87%) and the remaining being split between air (8%), sea (3%) and train (2%) transport. Large distances, relatively low fuel prices and heavy vehicles have shaped a road transport sector that is among the most emissions intensive per capita in the world (i.e. 4t of CO_2 per person, versus 3t OECD average, and 1t world average[19]).

EMISSIONS GROWTH UNDER BUSINESS-AS-USUAL

Total transport emissions are projected to rise from 75 $MtCO_2e$ in 2000 to 96 $MtCO_2e$ in 2020 (a 28% increase). Growth of population and rising per capita income are the main drivers for the increase in transport emissions in the coming years. Population is projected to be the more important as the correlation between income and car travel weakens as people reach a limit on the amount of time they choose to spend in transit. Road freight will also continue to increase with total economic activity.

Despite this increase, there is significant upside captured in BAU projections. There are BAU improvements in vehicle efficiency, minor penetration of hybrid and electric vehicles (2% of the new car fleet in 2020), a shift from petrol to diesel in new car sales and a small proportion

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[19] Garnaut. *The Garnaut Climate Change Review: Final Report.* 2008

of biofuels made from first generation feedstocks including waste starch and C-molasses (for ethanol) and tallow and used cooking oil (for biodiesel).

Further, BAU also includes operational improvements in, for example, freight performance. Growth in freight emissions is correlated with growth in economic activity and thus is likely to increase at a faster rate than passenger road transport, which is typically correlated to population. Freight efficiency improvements (through advances in truck productivity, scheduling and modal shift to rail) are one of the largest emissions reduction opportunities in the transport sector, with estimates of over 10 Mtpa in 2020.[20]

EMISSIONS REDUCTION OPPORTUNITY

Identified emissions reduction opportunities include a number of improvements to the traditional internal combustions engine (ICE) vehicle, expansion of electric or hybrid (cars using an ICE plus electric motor) fleet or increased use of renewable biofuels in petrol or diesel engines. Each opportunity was assessed for petrol and diesel passenger cars, light commercial vehicles, buses, rigid trucks and large articulated trucks. Implementing the opportunities included in this plan will reduce emissions by approximately 6 $MtCO_2e$, or a 6% reduction on the BAU transport emissions. The key opportunities are:

- **Internal Combustion Engine** (ICE) vehicle efficiency. In 2020, most of the emissions reduction opportunity in road transport (5 $MtCO_2e$) comes from efficiency improvements to traditional internal combustion engine (ICE) vehicles. These efficiency improvements are created through a range of technology improvements, for example decreasing the accelerating and rolling resistance and weight of the vehicles. The opportunities for petrol and diesel passenger cars, light commercial vehicles and large articulated trucks are economically attractive (average net savings of A$67 per tonne), as the fuel savings are expected to be larger than the incremental capital expenditure required to improve the vehicles.
- **Alternative power technology.** The introduction of hybrid and electric vehicles can reduce emissions by 1 $MtCO_2e$ at an average cost of A$124 per tonne. Hybrid passenger cars remain moderately expensive in 2020, resulting in expected penetration of less than 10% of new cars. Electric vehicles remain high cost in 2020, although this is heavily sensitive to assumptions on battery cost, range of electric vehicles and uptake by specific segment (e.g. higher distance drivers will find non-range limited electric vehicles more cost effective, potentially increasing their penetration). If battery charging or switching infrastructure can be established and electric vehicle manufacturers can successfully target the long-distance segment, drivers may shift more rapidly to electric vehicle technology.
- **Biofuels.** It is likely that biofuels derived from 'first generation' domestic feedstocks will remain only a small proportion of Australia's fuel needs. Over time, advanced or 'second generation' biofuels such as algal biodiesel and lignocellulosic ethanol are considered more likely to provide sustainable fuels with low overall emissions. However, the necessary technologies are not likely to be commercial scale until around 2020. Increased penetration of 'second-generation' biofuels offer an emissions reduction opportunity of 1 $MtCO_2e$ at an average cost of approximately A$500 per tonne, This estimate is subject to significant uncertainty, although costs are generally likely to remain high until the technology matures

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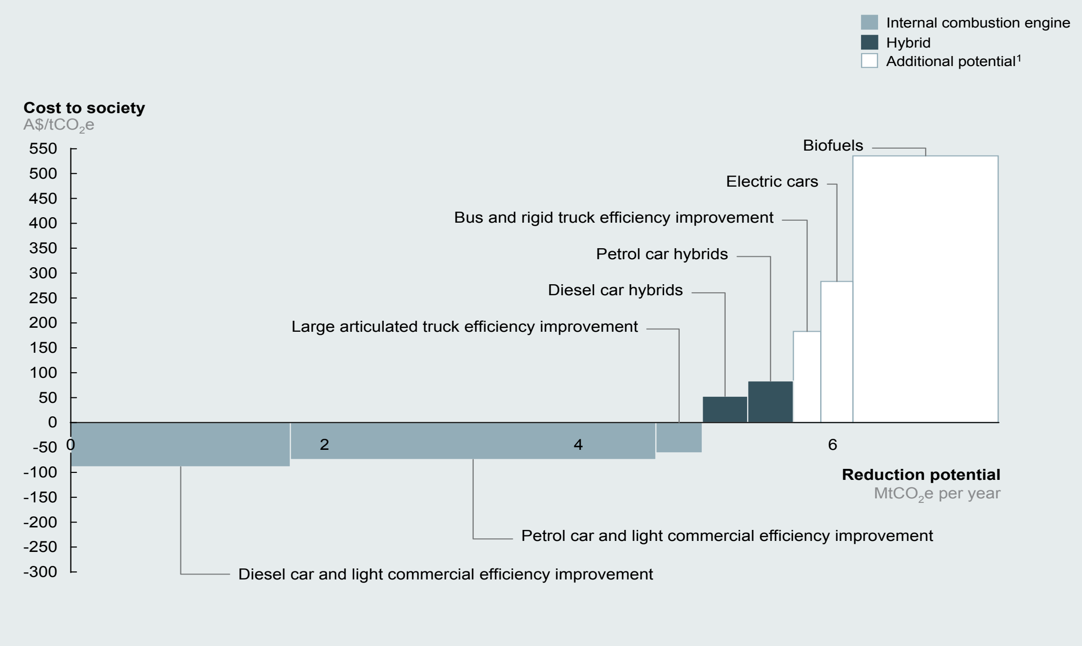
[20] Stanley et al. *Road Transport and Climate Change: Stepping off the greenhouse gas.* 2009.

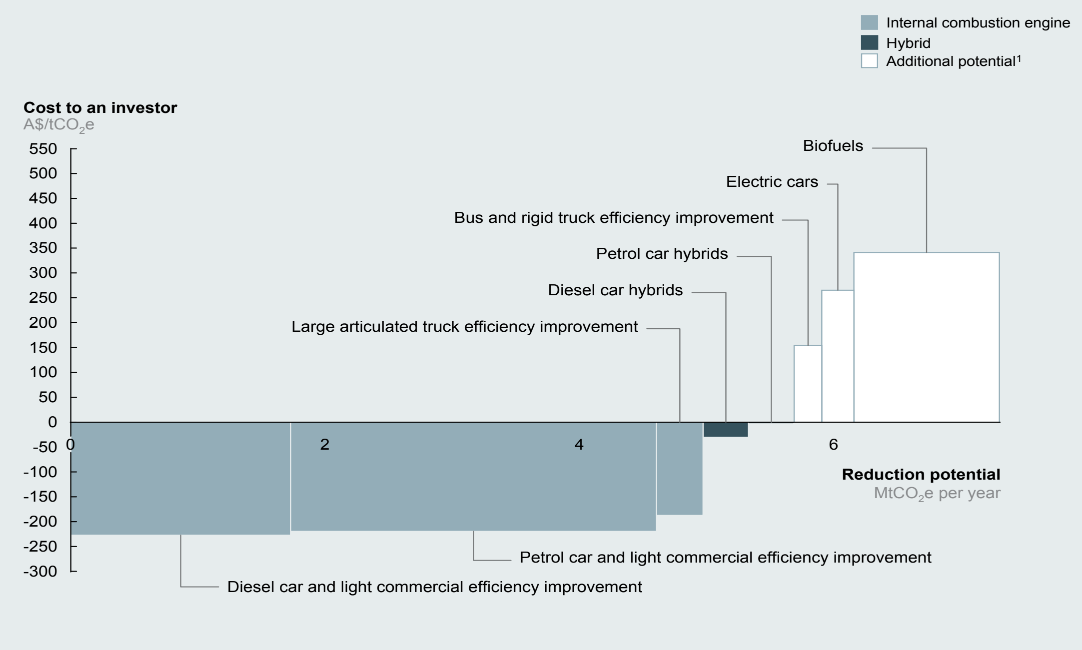
Exhibit 38: 2020 Transport GHG emissions reduction *societal* cost curve



1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

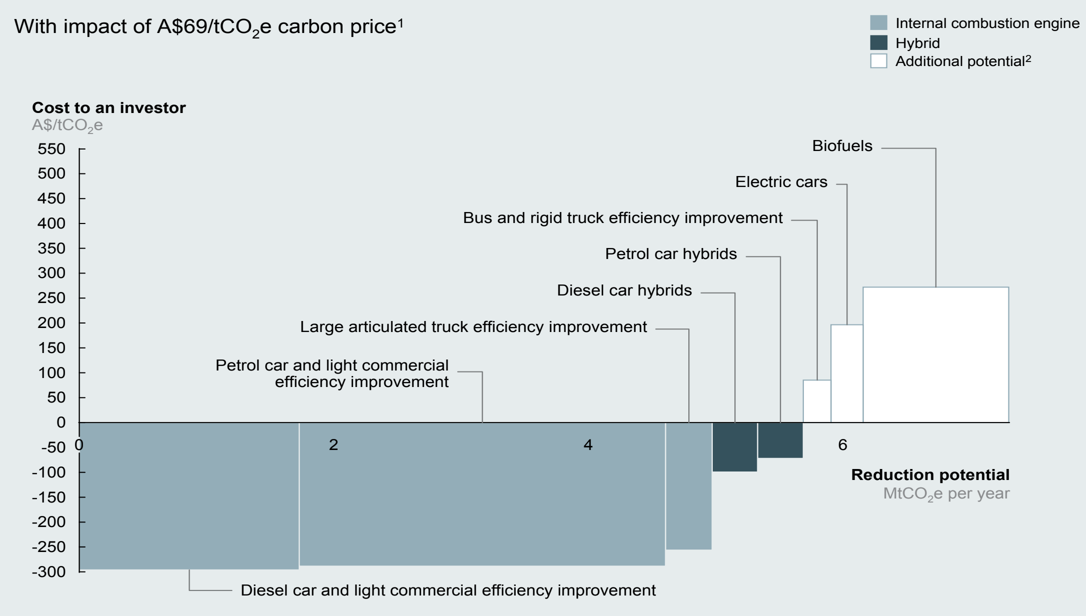
Exhibit 39: 2020 Transport GHG emissions reduction *investor* cost curve



1 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 40: 2020 Transport GHG emissions reduction *investor* cost curve



1 Carbon price in 2020 of A$69 per tonne based on Treasury Garnaut -25% estimate *(Australia's Low Pollution Future)* converted to 2010 dollars
2 Higher cost opportunities not required to meet target emissions of 25% below 2000 levels

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

CHALLENGES

Emissions reduction opportunities in the transport sector face a number of barriers:

- **Price of GHG emissions.** Exhibit 39 outlines the emissions reduction cost to investors. As can be seen, profitable emissions reduction opportunities are limited to ICE improvements, which can deliver up to 40% emissions reductions from cars, but only 11% to 13% emissions reduction on medium- to heavy-duty vehicles. Any improvement above this level necessitates the implementation of technologies such as hybrids or electric vehicles, which are unlikely to be profitable by 2020 without further financial incentive if fuel prices in Australia remain low compared to most other countries.
- **Market structure and supply.** Australian cars are typically operated for about five years longer than cars in Europe or Japan. This is in part due to policy related issues, such as the relatively high costs of new cars (reflecting tariffs and vehicle policies) and relatively low fuel excise (which reduces the benefits of purchasing new more efficient vehicles). Due to the age structure of the vehicle fleet, any action to reduce the emissions of new cars will have a more limited effect on total car emissions than it would have in other countries. Australia's vehicle manufacturing sector, which represents about 20% of total cars bought in Australia each year, is focused primarily on the production of larger, less fuel efficient vehicles. Some promising electric vehicles technologies (i.e. swappable batteries) will require costly new infrastructure, and depend on scale to become economically viable.
- **Information gaps and decision process.** Customers consider many criteria when choosing a car—safety, comfort, aesthetics, price—and fuel efficiency is only a small part of the decision process. Australia's relatively low fuel prices and high upfront costs for new cars, compared to other countries, also serve to reduce the importance of fuel efficiency. Fleet cars could be

expected to be more sensitive to factors such as total cost of ownership, but these are also chosen based on other factors, such as preference for local manufacture or size requirements.

- **Capital constraints and investment priorities.** Car purchases can only be financed through either savings or personal loans, which come at a high cost of capital and in limited amounts. This restricts the take-up of more efficient cars, which offer lower cost of ownership but higher upfront costs.

TOOLS TO OVERCOME THESE CHALLENGES

Given the challenges above, a suite of interdependent, coherent policy measures will be necessary to realise the identified emissions reduction opportunities and minimise the impact of the aforementioned challenges.[21] Options to overcome these challenges include:

- **Set mandatory vehicle emissions standards for manufacturers.** In the shorter term, a mandatory vehicle emissions standard offers a low-cost way of realising the large profitable emissions reduction opportunity in the road transport sector (see the Focus Area below on cars and light commercial vehicles). Voluntary fuel efficiency standards may also be implemented but there is an implied risk that they will not be met in practice. The existing voluntary national average fuel consumption (NAFC) target, while in place, has led to no agreement between government and car manufacturers on new emissions levels which changes with the scope of vehicles covered by the new procedures. Finally, there has been debate regarding the compatibility of mandatory fuel efficiency standards and proposed emissions trading legislation. The Federal Government has recognised the need for additional, 'complementary' measures to operate in tandem with emissions trading. These measures should address a market failure that is not expected to be adequately addressed by a carbon price alone.[22]
- **Set mandatory or voluntary standards for fleets.** As 46% of passenger cars are private or government fleet vehicles,[23] which have less capital sensitivity and more rapid turnover, key barriers should be more surmountable for fleets. Requiring a minimum fuel efficiency or promoting the set up of voluntary standards for fleets could both unlock a significant amount of emissions reduction and help overcome some of the supply constraints (this policy has already been implemented by the NSW government).
- **Financial incentives for low-emissions vehicles.** Setting pre-existing state and territory registration charges or stamp duties to reflect the emissions performance of the vehicle. This policy alters the economics of car ownership over the long term but most EU jurisdictions have only implemented it on new vehicles, and not enacted it retrospectively due to technical difficulties in calculating emissions of older vehicles. The impact of this measure in Sweden has been estimated to be approximately 5% per annum after 20 years.[24]

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[21] While the focus of the policy measures listed centres on changes to the composition of Australia's car fleets, more lateral solutions can be pursued in tandem. For example, in urban areas, changes are necessary to land use and planning decisions if Australia is to avoid locking cities into emissions-intensive transport patterns. Increasing the density of cities will help citizens remain mobile while reducing the environmental impact of urban travel.

[22] Australian Transport Council. *Vehicle Fuel Efficiency: Potential Measures to Encourage the Uptake of More Fuel Efficient Low Carbon Emission Vehicles.* 2009.

[23] National Transport Commission. *Carbon Emissions from New Australian Vehicles.* 2009.

[24] European Conference of Ministers of Transport. *Review of CO_2 Abatement Policies for the Transport Sector.* 2007.

- **Reduce 'network externalities' for low emission vehicles.** In addition to differential registration charges, there may be roles for government in encouraging the supply of and demand for low emissions vehicles, given that these can suffer from a network externalities or 'chicken and egg' problem: even when the technology matures people may be reluctant to buy an electric vehicle if the network requirements (charging points and battery changing stations) are not readily available. Also manufacturers may be unwilling to supply a sufficient network if demand for the vehicles is perceived to be low. Establishing standards for some items (such as vehicle plugs) will be important and government can play a role in coordinating actors to develop these standards.

- **Include the cost of carbon in fuel prices.** A broad-based emissions price or tax that adds to the price of fuels according to carbon content, or a general increase in vehicle fuel prices, would help ensure that road users consider the environmental impact of their transport choices. This would increase the attractiveness of more fuel efficient cars, lowering the emissions of road transport over the medium term.

- **Collaborate to transform local manufacturing.** It will be difficult for local manufacturers to adapt to higher fuel efficiency constraints on their own. As scale is an important element in making new technologies economically viable, building alignment between the government and major stakeholders to agree on priorities for future development would help transform the local manufacturing sector into a leader in greener car technologies.

- **Improve traffic flow and public transport use.** Congestion in major cities is expected to rise significantly over coming decades. Congestion disrupts traffic flow and increases fuel consumption at peak hours, causing increased emissions. Implementation of policies and programs to improve traffic flow can be very cost effective for society, including various forms of incentives such as time based road use charges. This is also valid for air transport, where congestion at major airports is responsible for significant wasted fuel that could be avoided by better air traffic control systems. Improving the public transport network or increasing the extent of high-quality, separated bicycle lanes can also reduce emissions.

- **Promote efficiency measures.** Reducing unnecessary travel can lead to significant fuel savings and emissions reduction. Examples include better utilisation of trucks—limiting the kilometres travelled by empty trucks—and increasing the use of tow trucks to move planes on the ground.

- **Educate consumers.** Better information through improving vehicle labelling (although this is typically not effective unless matched to differentiated registration), raising consumer awareness of the risk of lock-in caused by purchase of new inefficient vehicles.

- **Direct financial incentives to scrap older vehicles** that produce a disproportionate level of emissions assists in stimulating the renewal of the Australian fleet towards more fuel efficient vehicles.

- **Promote behavioural changes in drivers.** Whilst behavioural changes are not included in the cost curve emissions reduction, travel provides a unique opportunity for individuals to have a sizeable impact on the level of emissions produced. For example, there are opportunities to promote greater public transport use and increased car pooling.

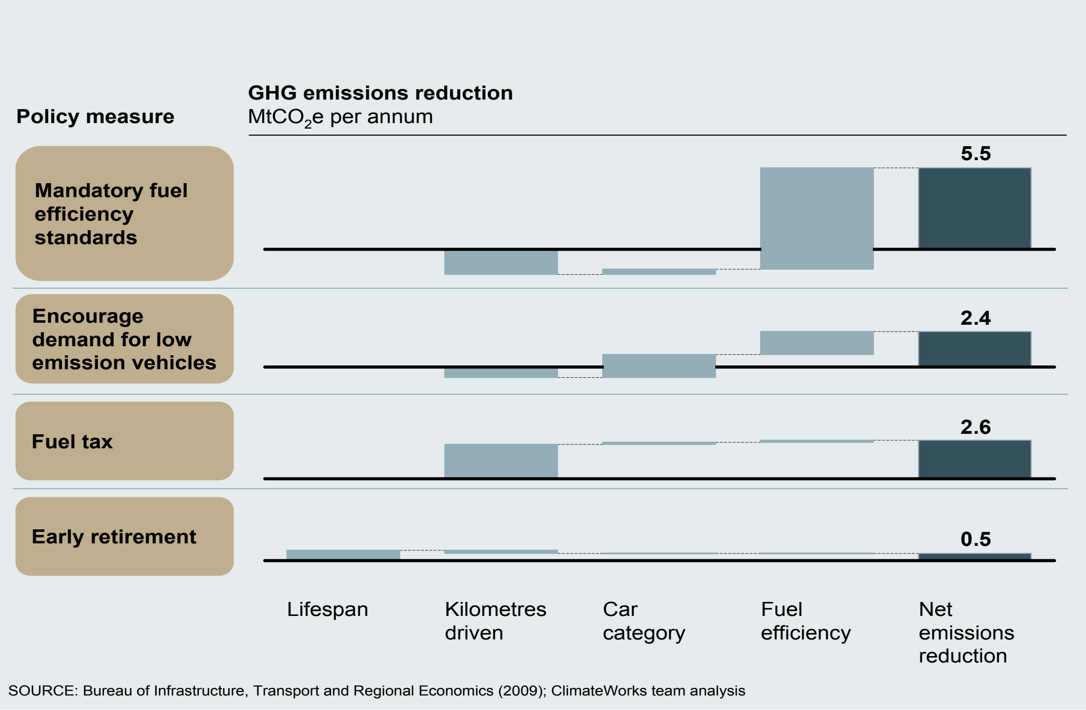
Focus area – cars and light commercial vehicles

Petrol and diesel cars and light commercial vehicles will account for over 75% of expected road transport emissions in 2020, with over half of these cars owned privately. 95% of the projected emissions reduction potential in the road transport sector depends on these drivers purchasing more fuel efficient vehicles. This Focus Area reviews the cost effectiveness of different policy options in encouraging and supporting drivers to overcome significant challenges and focuses on mandatory fuel efficiency standards as the most effective and efficient policy measure to curb carbon emissions.

The methodology has been to review the impact of four distinct policies to limit road transport emissions (mandatory fuel efficiency standards, encouraging demand for low emissions vehicles, fuel tax, early retirement) on the fundamental drivers of emissions in the sector (category of vehicle driven, fuel efficiency of cars within categories, average lifespan of vehicle, kilometres driven). Exhibit 41 indicates that to 2020 mandatory fuel efficiency standards are likely to have the largest impact of any single policy measure operating in isolation, achieving a 5.5 Mtpa reduction across all cars and light commercial petrol and diesel vehicles.

Mandatory fuel efficiency standards will directly impact the fuel efficiency of new buys, but also indirectly increase the number of kilometres driven (by making fuel on a per kilometre basis relatively less expensive) and lift the capex requirements for new cars, which will encourage a small number of drivers to switch to smaller (cheaper) vehicle categories. Reaching the 2008 EU fuel efficiency of approximately 140g per km in 2020 results in emissions reductions of

Exhibit 41: Comparison of policy measures to encourage fuel efficient passenger vehicles



SOURCE: Bureau of Infrastructure, Transport and Regional Economics (2009); ClimateWorks team analysis

5.5 Mtpa in petrol and diesel cars and light commercial vehicles (slightly larger than the ICE opportunity reflected in the cost curve, as here we are not allocating part of new car fleet to hybrids or electric vehicles, for consistency across the comparison of policy options considered in this Focus Area).

From a societal perspective, the imposition of mandatory fuel efficiency standards is an economically attractive policy initiative with fuel savings from reduced fuel usage outweighing the increased upfront capex requirements. Further, GHG emissions reductions can be significantly larger if more aggressive mandatory fuel efficiency standards are set for 2020, as Exhibit 42 indicates.

In addition, it should be noted the emissions reductions available under emissions sensitive **fuel taxation** are heavily dependent on, firstly, the level of taxation and, secondly, the underlying elasticity assumptions. With reference to the former, under the CPRS, increasing the price of fuel to reflect its carbon content would be part of the full inclusion of the transport sector in the CPRS, however Australian households and businesses will be reimbursed on a cent for cent basis. Over the long term, a CPRS can lock in decision making certainty for driver on elevated fuel prices as they impinge on driving behaviour. Equally, the relatively low current levels of fuel prices in Australia means that applying historical price elasticities estimated in this low price regime to large changes makes predicting actual driver behavioural responses over ten years problematic. In short, if alternative assumptions are made concerning driver decision making as affected by long term fuel prices (and the implied fuel price elasticities) then carbon sensitive fuel taxation will have significantly greater impact.*

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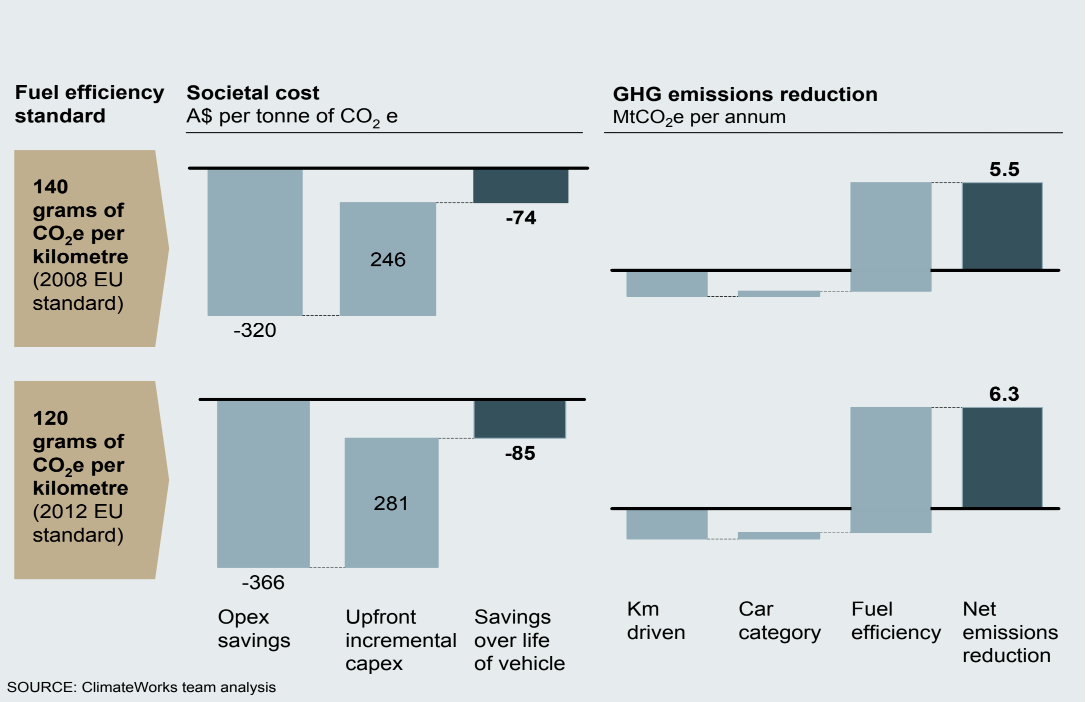
* For example, the European Conference of Ministers of Transport (2006) modelling, describes carbon sensitive fuel tax measurements as the most effective carbon emissions reduction policy tool based on alternative long term price elasticity assumptions

Exhibit 42: Impact of alternative mandetory fuel efficiency standards



SOURCE: ClimateWorks team analysis

The barriers to implementing mandatory fuel efficiency standards largely centre on upfront capital requirements of more fuel efficient vehicles, relatively low petrol prices in Australia (which makes fuel economy a lesser priority), and costs to local manufacturers of transitioning to more efficient vehicles (or market share loss if they fail to respond adequately). However, this emissions reduction opportunity is technically straightforward, as other jurisdictions already achieve these fuel efficiency levels and the vehicles exist, as illustrated by Exhibit 43.

While mandatory fuel efficiency standards are pivotal to securing large fuel efficiency gains in the Australian vehicle fleet, complementary policies can be pursued in conjunction to achieve the largest possible GHG emissions reductions rapidly and at low cost. In addition to reviewing the expected impact of policies in isolation, two combined polices have also been examined—mandatory fuel efficiency standards and early retirement programs; and mandatory fuel efficiency standards and fuel taxes. The combined effect of these policies is not necessarily additive but does exceed the emissions reduction potential of individual policies, as illustrated by Exhibit 44.

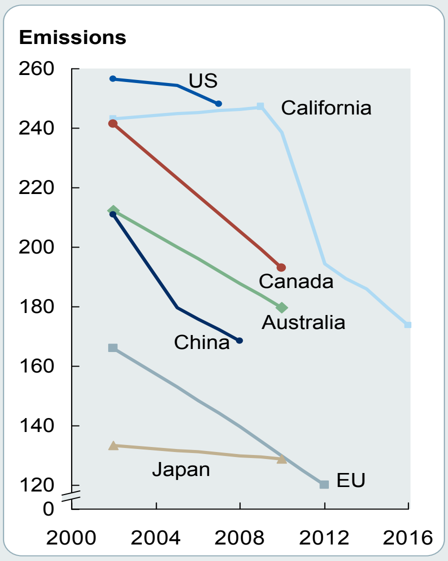
Early retirement of older cars combined with mandatory fuel efficiency standards. The efficiency gains created by imposing higher fuel efficiency standards are augmented by an increase in the rate of vehicles retired. By offering a A$2,000 incentive to early retire vehicles over 10 years old and introducing mandatory fuel efficiency standards of 140g per km by 2020, all sectors of Australia's vehicle fleet are targeted by a cohesive dual policy. Carbon emissions reduction of approximately 6 Mtpa is possible under conservative assumptions. This should also be achievable while ensuring net profitability for drivers. However, studies conducted on early retirement have suggested that additional complicating factors (e.g. those cars that were

Exhibit 43: Emissions reduction bundles and comparable international standards

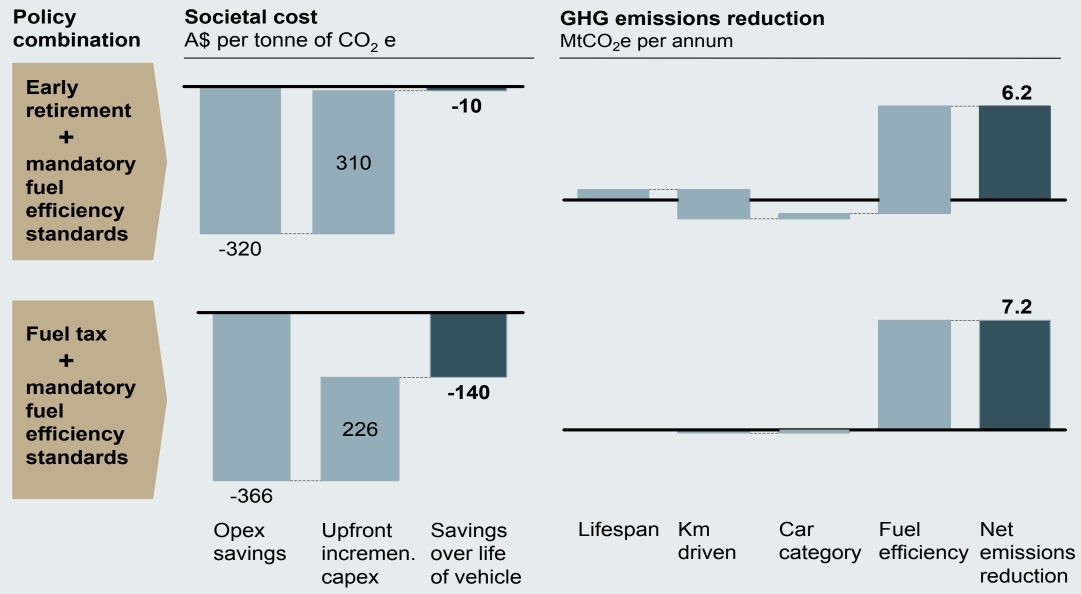
Emissions reduction technologies

	Powertrain	Non-powertrain
Petrol	• Direct injection • Variable compression ratio • Cylinder deactivation • Downsizing (strong) • Variable valve timing • Variable valve control • Electrical valve control • Engine friction reduction • Optimized transmission	• Low rolling resistance tires • Tire pressure control system • Strong weight reduction • Improved aerodynamic efficiency • Electrification of auxiliaries • Air conditioning modification • Start-stop (with or without regenerative breaking) • Advanced after treatment/ particulate trap
Diesel	• Torque-oriented boost • Piezo injectors • Increase injection pressure • Downsizing (strong) • Cylinder deactivation • Engine friction reduction • Optimized transmission	

Emissions standards comparison
Grams of CO_2 per kilometre



SOURCE: Pew Center on Global Climate Change (2005); ClimateWorks team analysis



SOURCE: Bureau of Infrastructure, Transport and Regional Economics (2009); ClimateWorks team analysis

scrapped were underutilised) mitigates the effectiveness of the early retirement policy.[#]

Fuel tax combined with mandatory fuel efficiency standards. Fuel tax and efficiency standards primarily focus on different emissions reduction levers and so have an increased combined effect. A 15% increase in the price of fuel above BAU and the imposition of mandatory fuel efficiency standards of 140g per km by 2020, combine to change the lifecycle cost of ownership and incentivise the purchasing of more fuel efficient vehicles. Consequently, approximately 7 Mtpa of emissions reduction can be achieved at a societal savings of A$140 per tCO_2e, although the expense of additional fuel costs will imply higher driving operating costs for individual drivers.

Each of these policy scenarios can encourage drivers to reduce their transport emissions, but early retirement combined with mandatory standards will have greatest impact, while mandatory standards alone are more cost effective per tonne of emissions saved.

[#] International Energy Agency. *Implementing Energy Efficiency Policies.* 2009.

The roadmap

The roadmap

KEY POINTS

A combination of a carbon price and targeted actions are required to maximise the emissions reductions from the 54 opportunities identified in this report. Together, these opportunities can achieve a 25% reduction in Australian emissions from 2000 levels

- A carbon price will capture opportunities for which technology and economics are well understood, but not profitable to undertake
- Targeted actions will be required to overcome barriers that do not respond to a carbon price
- Implementing each of the 54 opportunities requires different types of effort, based on the risk of emissions lock-in if actions are delayed and the ease of implementation of each opportunity. The roadmap in this report groups the opportunities into three categories of effort:
- Implement now (41% of the total (101 $MtCO_2e$) is in this category)
- Act now to remove barriers and motivate action (12% of the total (29 $MtCO_2e$) is in this category)
- Invest now in information and innovation to reduce long-run cost(48% of the total (119 $MtCO_2e$) is in this category)

The previous chapters of this report identify emissions reduction opportunities in Australia that are available at low cost, the main challenges to achieving that reduction and options to overcome those challenges. This chapter proposes a way to approach the various opportunities and integrate them into an overarching emissions reduction roadmap—one that can be agreed and understood by business, government and the community.

This is done by first exploring the risk of lock-in and the ease of implementation for each emissions reduction opportunity as a means to guide action. Following is a proposed implementation plan by emissions reduction opportunity.

RISK OF LOCK-IN

To achieve the emissions reduction opportunity identified in this report, Australia must act promptly. Many emissions reduction opportunities rely on improving technology, products and infrastructure at lowest cost–which is often when existing stock is already planned to be retired, replaced or overhauled. For example, improved vehicle efficiency opportunities come into effect as people replace their cars. Similarly, constructing energy efficient buildings is a perishable opportunity—it is much easier and cheaper to make a building energy efficient in the planning and construction phase than it is once the structure is complete. And of course the construction of power stations effectively locks in a particular fuel and technology for their

30+ year operational lives. The implication of this is that action in some specific areas should be taken as soon as possible to avoid locking in future emissions. Once an opportunity is lost, any remedial measure to make up the deficit, if at all possible, will incur a higher cost than would have been the case for the initial opportunity.

Four factors drive the risk of lock-in:

- **Lifespan of lost emissions reduction opportunity.** The duration of the impact on future emissions of a decision made today is critical. For example, locking-in the emissions of a new coal plant or of a deforested patch of land has a stronger impact on future carbon footprint than locking-in the emissions of an inefficient air conditioner or than deferring by a year an improved maintenance program for the gas distribution network or the implementation of better agronomy practices.
- **Size of emissions reduction opportunity.** The emissions reduction lost on a per annum basis will drive the criticality of the decision made. For example, even if a manufacturing site and passenger car have similar 20 year lifespans, the former is more critical due to the amount of emissions reduction potential tied up in a single decision.
- **Cost of remedial measures.** The more costly and difficult it is to regain the lost emissions reduction, the more critical avoiding lock-in is. For example, the opportunity cost makes it very costly to replace coal-fired power by greener technologies, and it is very difficult to reduce the energy inefficiency of an inefficient building structure, while retrofitting an inefficient lighting system comes at a relatively low cost.
- **Lead time.** Lead time is critical when it unnecessarily delays large reductions in emissions. For example, for technologies that require significant R&D and testing before they can be implemented on a large scale, it is critical to start investing now.

EASE OF IMPLEMENTATION

Consideration should also be given to how any climate strategy can build momentum as soon as it commences in order to secure future success and commitment. In the early years of a coordinated push to reduce emissions, it will be important to demonstrate that the task is possible and to share success stories so that momentum can be built towards a 2020 target. An effective way to do this is to prioritise the emissions reduction opportunities with the fewest implementation challenges in order to realise quick gains and learn lessons that can then be applied to more complex emissions reduction opportunities.

Two criteria can be used to identify emissions reduction opportunities with the fewest challenges:

- **Cost of emissions reduction opportunity.** Unlocking a profitable opportunity will be easier as businesses can help or drive the process to gain access to the new profit pool. Moreover, targeting lower cost opportunities first allows time for the economics of higher cost opportunities to improve, for example by ascending the learning curve, or through increased energy prices.

- **Difficulty of overcoming the barriers.** The number, complexity and strength of barriers determines the level of effort needed to overcome them. The barrier analysis outlined in Chapter 2 will help assess this criterion.

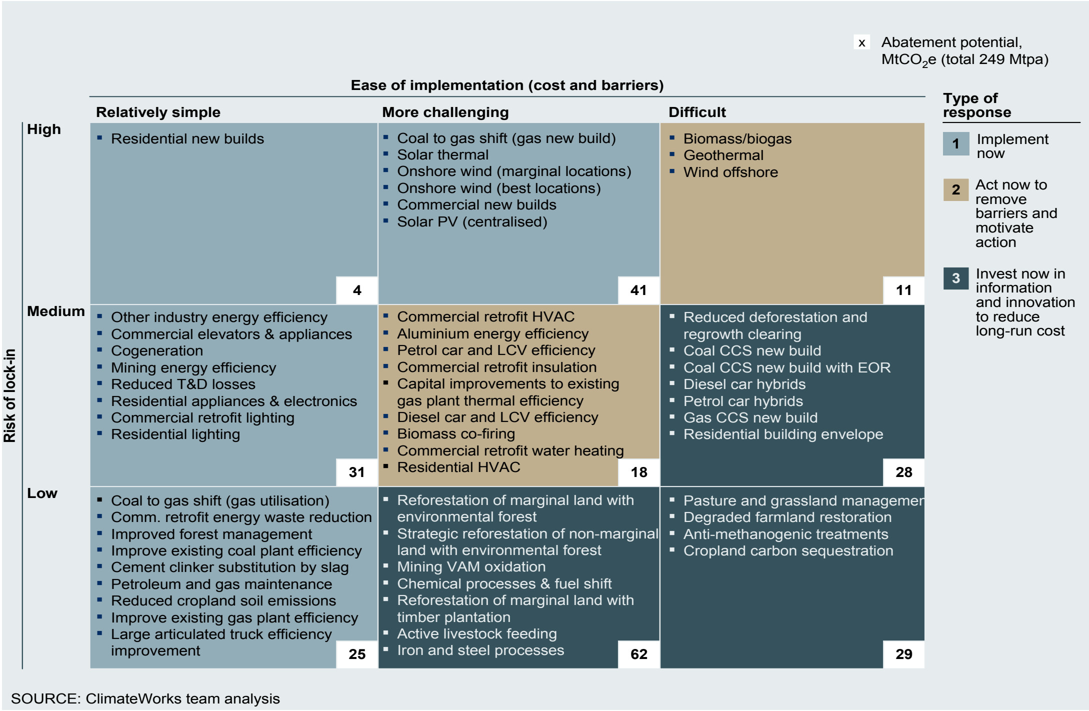
SUGGESTED RESPONSE

Australia must act now if it wants to reduce its emissions by 25% below 2000 levels (249 $MtCO_2e$) at low cost. There are 54 opportunities—across all sectors—that can be implemented in the next ten years to achieve the identified emissions reduction potential. The length of this list illustrates the complexity of the task ahead, and that there is no “silver bullet” to achieve significant emissions reduction at low cost. Yet the fact that there are many separate opportunities allows each sector of the economy to take part and benefit from the lowest cost opportunities identified.

An emissions reduction roadmap must also address the sequencing of each emissions reduction opportunity over time. The opportunities available to reduce Australia’s GHG emissions require different levels of preparation and planning.

By considering the relative risk of lock-in (low, medium, high) and ease of implementation (simple, more challenging, difficult) for each emissions reduction opportunity it is possible to develop a strategy for near term action as shown in the matrix in Exhibit 45.

Exhibit 45: Roadmap of action



x Abatement potential, $MtCO_2e$ (total 249 Mtpa)

Ease of implementation (cost and barriers)

Risk of lock-in

	Relatively simple	More challenging	Difficult
High	▪ Residential new builds 4	▪ Coal to gas shift (gas new build) ▪ Solar thermal ▪ Onshore wind (marginal locations) ▪ Onshore wind (best locations) ▪ Commercial new builds ▪ Solar PV (centralised) 41	▪ Biomass/biogas ▪ Geothermal ▪ Wind offshore 11
Medium	▪ Other industry energy efficiency ▪ Commercial elevators & appliances ▪ Cogeneration ▪ Mining energy efficiency ▪ Reduced T&D losses ▪ Residential appliances & electronics ▪ Commercial retrofit lighting ▪ Residential lighting 31	▪ Commercial retrofit HVAC ▪ Aluminium energy efficiency ▪ Petrol car and LCV efficiency ▪ Commercial retrofit insulation ▪ Capital improvements to existing gas plant thermal efficiency ▪ Diesel car and LCV efficiency ▪ Biomass co-firing ▪ Commercial retrofit water heating ▪ Residential HVAC 18	▪ Reduced deforestation and regrowth clearing ▪ Coal CCS new build ▪ Coal CCS new build with EOR ▪ Diesel car hybrids ▪ Petrol car hybrids ▪ Gas CCS new build ▪ Residential building envelope 28
Low	▪ Coal to gas shift (gas utilisation) ▪ Comm. retrofit energy waste reduction ▪ Improved forest management ▪ Improve existing coal plant efficiency ▪ Cement clinker substitution by slag ▪ Petroleum and gas maintenance ▪ Reduced cropland soil emissions ▪ Improve existing gas plant efficiency ▪ Large articulated truck efficiency improvement 25	▪ Reforestation of marginal land with environmental forest ▪ Strategic reforestation of non-marginal land with environmental forest ▪ Mining VAM oxidation ▪ Chemical processes & fuel shift ▪ Reforestation of marginal land with timber plantation ▪ Active livestock feeding ▪ Iron and steel processes 62	▪ Pasture and grassland managemen ▪ Degraded farmland restoration ▪ Anti-methanogenic treatments ▪ Cropland carbon sequestration 29

Type of response

1 Implement now

2 Act now to remove barriers and motivate action

3 Invest now in information and innovation to reduce long-run cost

SOURCE: ClimateWorks team analysis

The different types of near term action can be summarised as follows:

- **Implement now.** Actions that can prevent significant future liabilities and are feasible today should not be delayed. In this category fall the structures and central services of new builds in the commercial sector or fuel efficiency of new motor vehicles.
- **Remove barriers and motivate action.** Action should be taken today on opportunities that represent a high risk of lock-in but are hard to implement in the current decision environment. This action should address barriers, such as high implementation costs, and motivate action, for example by changing the economics to make them profitable (such as through introducing a carbon price). Attention should also be given to reducing the difficulty associated with emissions reductions, such as by developing 'template agreements for sharing the costs and benefits of achieving energy savings, or by investing in R&D to lower costs and technology risks. At the same time, momentum created by the implementation and success of the first priority actions should be used to start unlocking opportunities that are reasonably simple but not critical from a lock-in perspective.
- **Invest in information and innovation to reduce long term costs.** Action is required today to develop future solutions to challenging opportunities that don't represent a high risk of lock-in, allowing time for technological progress, changes in market dynamics and increased momentum—all of which will decrease the effort needed to unlock them.

The location of opportunities on the matrix will change over time as challenges are overcome, and technology or information improves.

ACTION PLAN

Moving forward to capture our national emissions reduction opportunities requires action to address the range of barriers that currently block effective action. This includes the introduction of a broad based carbon price to ensure decision makers increasingly take account of the long run costs imposed by GHG emissions, and seek out innovative ways to reduce carbon pollution. Targeted action is also required to address the non-price barriers discussed in this report.

Based on this strategy for near term action, and a clear understanding of the action required to achieve each opportunity, ClimateWorks has developed a roadmap to focus attention on the individual tangible actions Australia can undertake to meet its GHG emissions reduction targets (Exhibits 46–Exhibit 48).

This report sets out Australia's emissions reduction opportunities in cost order and by sector, the challenges it faces in capturing them, and actions required to succeed. It also illustrates the significant opportunities available to business. ClimateWorks hopes this report (and the substantive fact base that underpins it) will be useful to prompt and guide the actions required from government, business and consumers to achieve the emissions reduction potential for Australia at the lowest possible cost.

Exhibit 46: Implement now

💡 Power
🌲 Forestry
🚜 Agriculture
🏢 Buildings
⚙ Industry
🚗 Transport

● High
◍ Medium
○ Low

Sector	Opportunity	Action required to achieve	Societal cost A$/tCO$_2$e	Size of opportunity Mtpa	Responsive-ness to carbon price	Impact of non price barriers: Market structure and supply	Information and decision process	Capital constraints
💡	Coal to gas shift (gas new build)	Build an additional 4.5GW above BAU by 2020 to replace the equivalent of two large coal plants	44	14.9	●	◍		○
⚙	Other industry energy efficiency	Improve by ~5% in energy-intensive industries and ~13% in other industries; excluding aluminium and mining	-129	11.1	◍	◍	○	○
💡	Solar thermal	Construct an additional 2.5GW above BAU by 2020 to replace the equivalent of two large coal plants	77	10.2	●	◍		○
💡	Coal to gas shift (increased gas utilisation)	Increase uptime of all existing and new gas plants to 60%	57	9.4	●			
💡	Onshore wind (marginal locations)	Construct 3.3GW above BAU by 2020 to replace the equivalent of one large coal plant	60	7.3	●	◍		○
🏢	Commercial elevators and appliances	Reduce energy consumption by 21% and 29% on average in existing and new buildings by 2020	-97	5.2	◍	◍	○	○
💡	Onshore wind (best locations)	Build an additional 1.6GW above BAU by 2020 to replace the equivalent of one medium-sized coal plant	37	5.2	●	◍		○
⚙	Cogeneration	Implement 100% in two steel plants; 9% of thermal energy replaced in refineries; 7.5% energy savings in chemicals; 3% energy savings for other industries	-48	4.5	◍	○	○	◍
🏢	Commercial retrofit energy waste reduction	Reduce energy consumption by a 10% average in existing buildings by 2020	-138	4.4	○	◍	○	◍
🏢	Residential new builds	Build 100% of new builds to a 7.2 star rating between 2013 and 2020	-98	3.9	○	◍	○	
🌲	Improved forest management	Improve management of 375,000 ha forest annually to increase woody growth	54	3.8	◍	◍	○	
⚙	Mining energy efficiency	Save 5.2% energy through operational improvements and equipment upgrades	-106	2.9	◍		○	◍
💡	Reduced T&D losses	Reduce T&D losses from 8% to 6.5% across the national network	-37	2.8	◍	◍	◍	
🏢	Commercial new builds	From 2012, 100% of new commercial buildings have 6 stars in the NABERS rating	-73	2.4	○	●	○	
💡	Coal plant operational efficiency	Improve thermal efficiency of existing coal plants by 3% by implementing better operational practices	-26	2.4	●		◍	
⚙	Cement clinker substitution by slag	Increase share of slag in ingredients to 40%	18	2.4	●		○	◍

Exhibit 46: Implement now (cont.)

💡 Power
🌲 Forestry
🚜 Agriculture
🏢 Buildings
⚙ Industry
🚗 Transport

● High
◍ Medium
○ Low

Sector	Opportunity	Action required to achieve	Societal cost A$/tCO$_2$e	Size of opportunity Mtpa	Responsive-ness to carbon price	Impact of non price barriers		
						Market structure and supply	Information and decision process	Capital constraints
🏢	Residential appliances and electronics	100% of new buys are high-efficient (35% to 37% savings compared to standard) by 2020	-112	2.0	◍	◍	○	
🏢	Commercial retrofit lighting	Reduce energy consumption by a 10% average in existing buildings by 2020	-97	1.8	◍	●	○	
💡	Solar PV (centralised)	Construct an additional 0.7 GW above BAU by 2020 to replace the equivalent of one small gas plant	94	1.3	●	◍		○
⚙	Petroleum and gas maintenance	Reduce transmission leakage by 7% and compressor leakage by 15%; save 1.2% energy in refineries	-37	1.2	●		○	
🏢	Residential lighting	Replace 50% of living-area CFLs and 30% of non-living area CFLs with LEDs. Replace 30% (more than BAU) standard quartz halogen bulbs with energy efficient halogen bulbs	-99	1.0	◍	◍	○	
🚜	Reduced cropland soil emissions	Extend conservation tillage or nutrient management techniques on a further 13% of crop-land between 2010 and 2020	-74	1.0	●		○	
💡	Gas plant operational efficiency	Improve thermal efficiency of existing gas plants by 3.5% by implementing better operational practices	-97	0.5	●		◍	
🚗	Large articulated truck efficiency improvement	Improve energy efficiency of 56% of new large articulated trucks by 2020	-61	0.4	◍	◍	○	○

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 47: Remove barriers and motivate action

💡 Power 🚜 Agriculture ⚙ Industry
🌲 Forestry 🏢 Buildings 🚗 Transport

● High
◍ Medium
○ Low

Sector	Opportunity	Action required to achieve	Societal cost A$/tCO$_2$e	Size of opportunity Mtpa	Responsiveness to carbon price	Impact of non price barriers		
						Market structure and supply	Information and decision process	Capital constraints
💡	Biomass/biogas	Construct an additional 0.7GW of biomass and 0.1GW of biogas above BAU by 2020 to replace the equivalent of one medium-sized coal plant	50	7.0	●	●	○	○
🏢	Commercial retrofit HVAC	Reduce average energy consumption in existing buildings by 29% by 2020 through equipment upgrade and downsizing (positive interaction with other upgrades such as lighting and appliances)	-119	3.6	○	●	◍	◍
⚙	Aluminum energy efficiency	Reduce emissions by 3.5% through existing technologies and 50% by implementation of drained wetted cathode technology	0.3	3.5	◍	◍	◍	○
🚗	Petrol car and light commercial efficiency improvement	Improve energy efficiency of 34% of petrol car and LCVs by 2020	-74	2.9	○	◍	◍	◍
🏢	Commercial retrofit insulation	Reduce HVAC energy consumption by 18% average in existing buildings by 2020	-55	2.3	○	●	○	◍
💡	Geothermal	Construct an additional 0.3GW above BAU by 2020 to replace the equivalent of one small coal plant	55	2.3	◍	●		○
💡	Capital improvements to existing gas plant thermal efficiency	Improve thermal efficiency by 6.5% for 50% of all existing gas plants by upgrading equipment or components	65	2.1	●			◍
🚗	Diesel car and light commercial efficiency improvement	Improve energy efficiency of 34% of new diesel cars and LCVs by 2020	-89	1.7	○	◍	◍	◍
💡	Wind offshore	Construct an additional 0.3GW above BAU by 2020 to replace the equivalent of one small gas plant	91	1.3	●	◍		○
💡	Biomass co-firing	Obtain 10% of fuel through biomass co-firing at 20% of existing coal plants by 2020	60	1.2	●	●		
🏢	Commercial retrofit water heating	Reduce water heating energy consumption by 26% on average in existing buildings by 2020	-48	0.7	○	●	◍	◍
🏢	Residential HVAC	100% of new air conditioner, gas and electric heaters are high-efficient (respectively 20%, 20% and 48% improvements compared to standard); 15% more households maintain their HVAC systems properly compared to BAU	-14	0.3	○	◍	●	◍

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 48: Invest in information and innovation to reduce long-run costs

Power, Forestry 🌲, Agriculture 🚜, Buildings, Industry ⚙, Transport

● High
◐ Medium
○ Low

Sector	Opportunity	Action required to achieve	Societal cost A$/tCO$_2$e	Size of opportunity Mtpa	Impact of non price barriers			
					Responsive-ness to carbon price	Market structure and supply	Information and decision process	Capital constraints
🌲	Reforestation of marginal land with environmental forest	Plant 3.5Mha of marginal land with environmental forests, plant more rapidly in first 10 years, at 350,000 ha/yr, and then at 150,000 ha/yr for 2020-2030	26	24.5	◐	◐		○
🌲	Strategic refor-estation of non-marginal land with environmental	Plant small tree stands/forests on 2Mha of productive land, at a rate of 200,000ha/yr	27	20.0	◐	◐	◐	○
🚜	Pasture and grassland management	Plant deeper rooted perennials and optimise intensity and timing of grazing on a further 15% of grazing land	11	17.4	○	◐	●	
🌲	Reduced deforestation and regrowth clearing	Decrease first time clearing and clearing of regrowth to reduce emissions by 35%	24	17.0	◐	●	◐	
💡	Coal CCS new build	Demonstration plants totaling 1.1GW (Wandoan project, Zero Gen, Galilee Basin) are completed and operational by 2020	91	7.7	◐	●		○
🚜	Degraded farmland restoration	Restore 20% of degraded cropland between 2010 & 2020; restore 10% of degraded pastures between 2010 and 2020; extend conservation tillage or nutrient management techniques on a further 13% of cropland between 2010 & 2020	85	7.1	◐	◐	◐	○
⚙	Mining VAM oxidation	50% of gassy mines have oxidising plants	-1	6.4	●	◐	○	◐
⚙	Chemical processes & fuel shift	Implement 50% of ethylene cracking and nitric acid decomposition; 3% process intensification; 80% new builds and 50% retrofits switch from coal to biomass and from oil to gas	35	4.5	●		○	◐
🌲	Reforestation of marginal land with timber plantation	Plant 0.5Mha of marginal land with timber plantation, 50,000 ha/yr	-10	4.4	◐	◐		○
🚜	Anti-methanogenic treatments	Use anti-methanogenic vaccines or medications on 50% of all livestock to reduce emissions per animal by 10%	17	2.6	○	●		○
🚜	Cropland carbon sequestration	Improve crop varieties and use of perennials, extend crop rotations and avoid or reduce bare fallow on a further 13% of cropland between 2010 and 2020	25	1.9	○	◐	●	
🚜	Active livestock feeding	Increase proportion of beef cattle on active feeding regimes from 4% to 15% to reduce emissions per animal by 25%	-11	1.8	◐	●	◐	

Exhibit 48: Invest in information and innovation to reduce long-run costs (cont.)

Coal CCS new build with EOR	Construct the 0.2GW Flynn project in Victoria (close to oil reserves in Bass Straight) by 2020	68	1.5	◍	●		○
Iron and steel processes	Substitute 20% coke with biomass; implement smelt-reduction in 100% of mills	56	0.5	◍	◍	○	
Diesel car hybrids	Purchase 7.5% of new diesel cars as full hybrids	53	0.4	○	●	◍	◍
Petrol car hybrids	Purchase 7.5% of new gasoline cars as full hybrids	83	0.4	○	●	◍	◍
Gas CCS new build	Construct the 0.1GW Fairview 2 project in Queensland	98	0.3	◍	●		○
Residential building envelope	Install basic insulation in 50% of semi-detached or detached houses	61	0.2	○	◍	◍	◍

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

CONCLUSION

Australians want to reduce emissions but also look forward to continued prosperity.

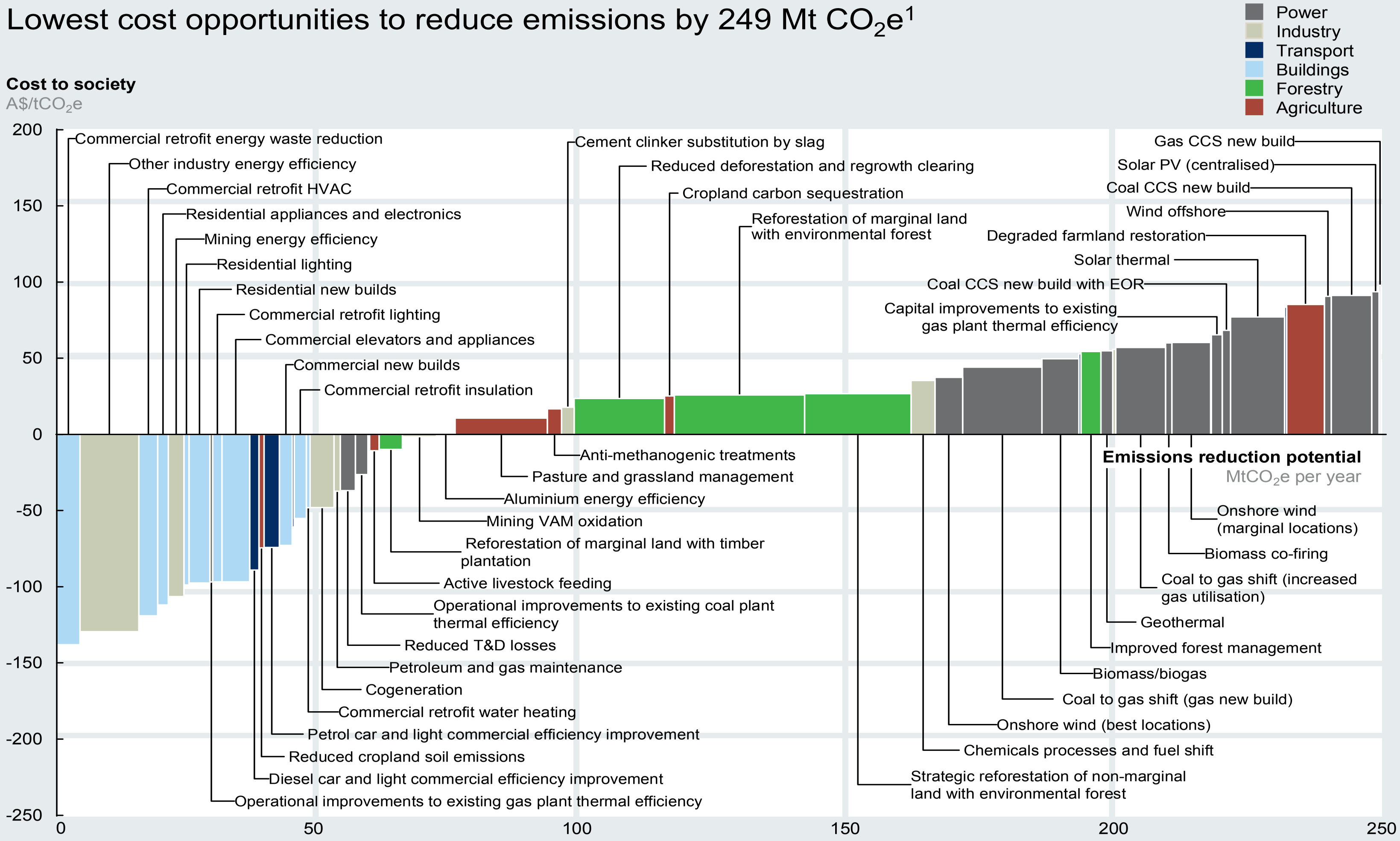
This report provides practical details of the lowest cost emissions reduction opportunities that can be undertaken across Australia's economy in the next ten years to achieve total reductions of 249 $MtCO_2e$ or 25% below 2000. It finds that these actions can be delivered at a cost of 0.1% of the projected GDP per household in 2020. While reducing Australia's GHG emissions is indeed a challenge, it is clear that practical opportunities exist for Australia to reduce emissions substantially while both continuing to grow the economy and offering profitable opportunities for business.

ClimateWorks will work with policymakers, business leaders and the community to support this program of practical action.

Appendix 1:
GHG emissions reduction cost curves

Exhibit 49: 2020 GHG emissions reduction *societal* cost curve

Lowest cost opportunities to reduce emissions by 249 Mt CO_2e[1]

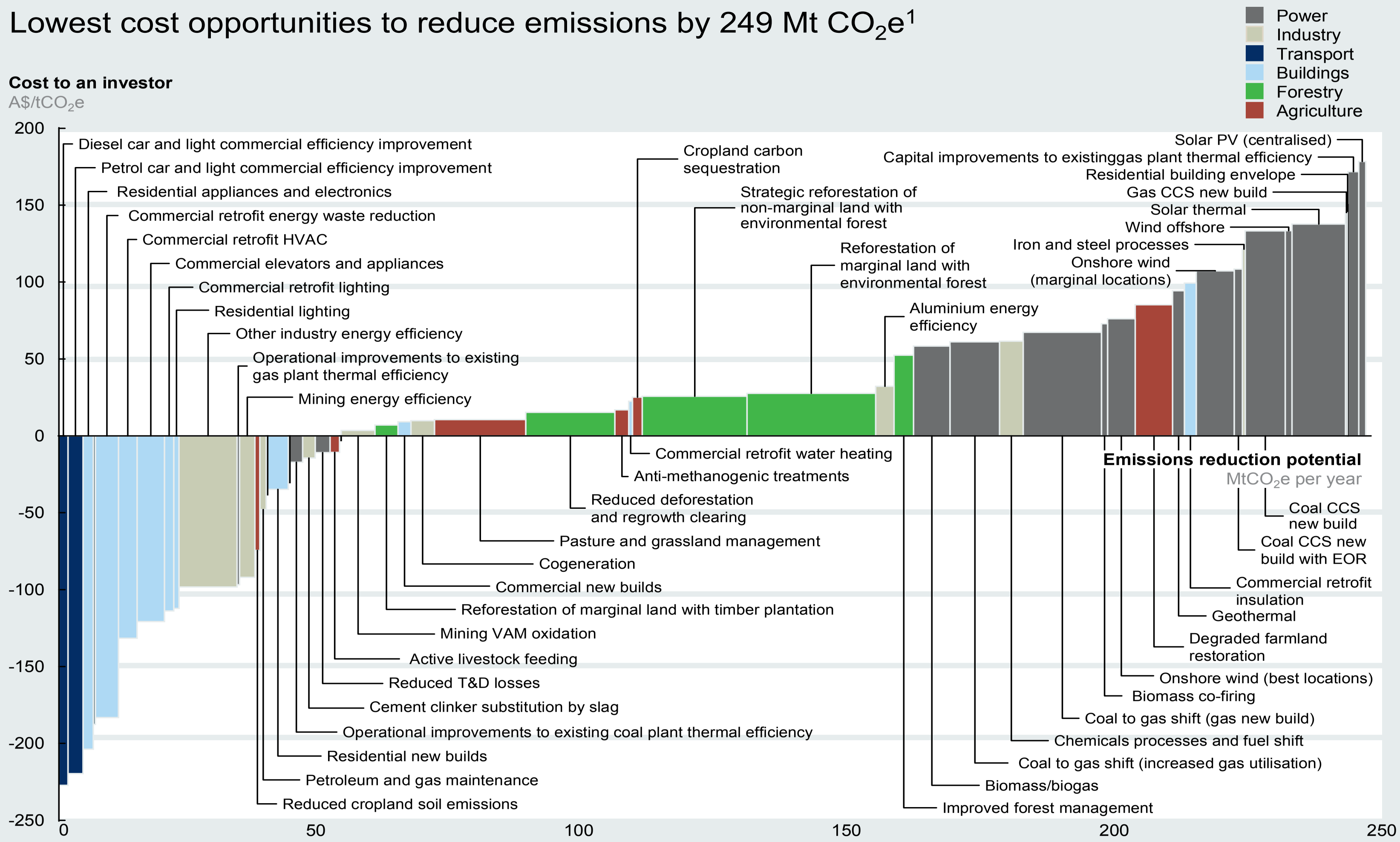


[1] Includes only opportunities required to reach emission reduction target of 249 Mtpa (25% reduction on 2000 emissions); excludes opportunities involving a significant lifestyle element or consumption decision, changes in business/activity mix, and opportunities with a high degree of speculation or technological uncertainty

SOURCE: ClimateWorks team analysis (refer to bibliography)

Exhibti 50: 2020 GHG emissions reduction *investor* cost curve

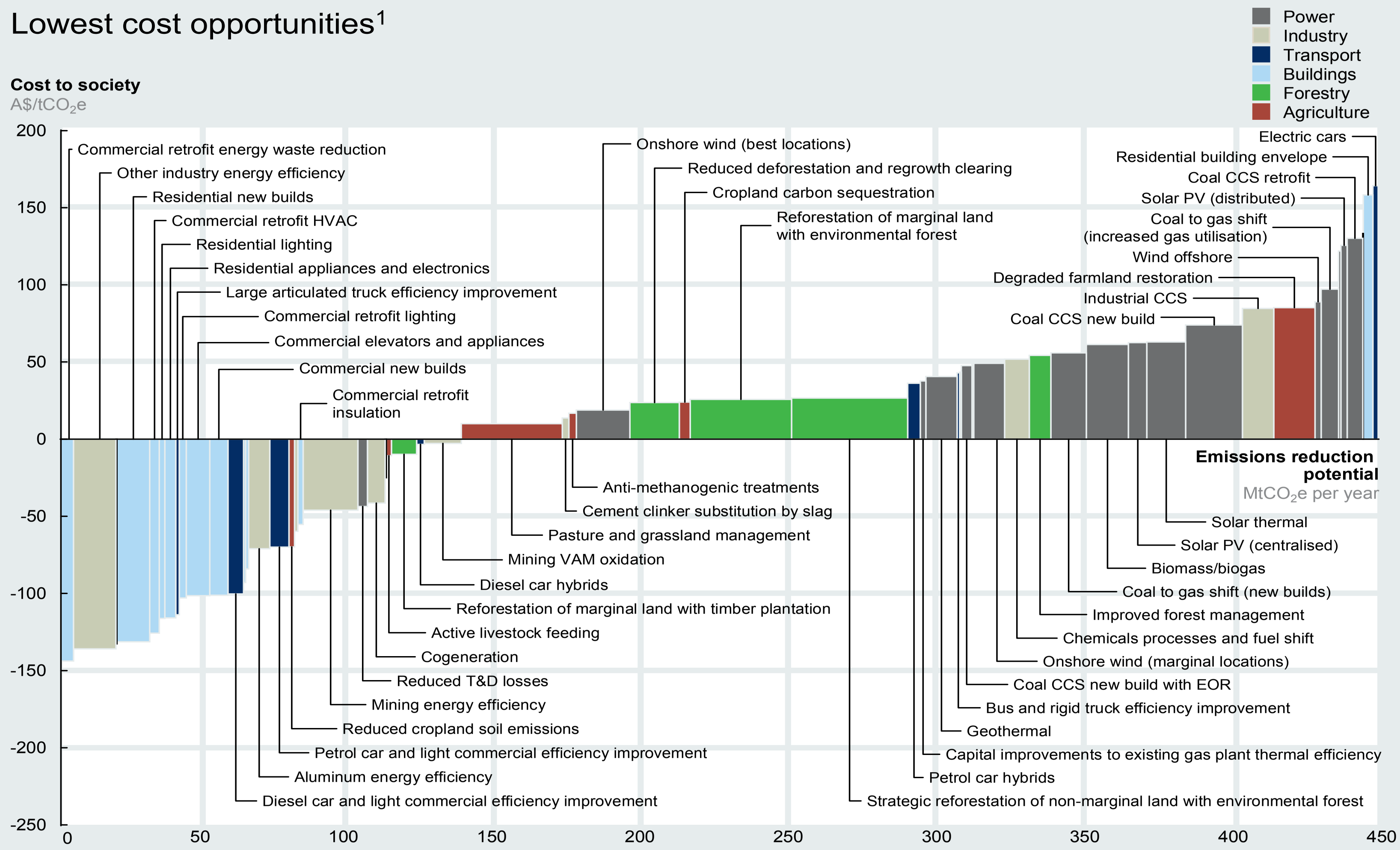
Lowest cost opportunities to reduce emissions by 249 Mt CO_2e^1



1 Includes only opportunities required to reach emission reduction target of 249 Mtpa (25% reduction on 2000 emissions); excludes opportunities involving a significant lifestyle element or consumption decision, changes in business/activity mix, and opportunities with a high degree of speculation or technological uncertainty

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Exhibit 51: 2030 GHG emissions reduction *societal* cost curve



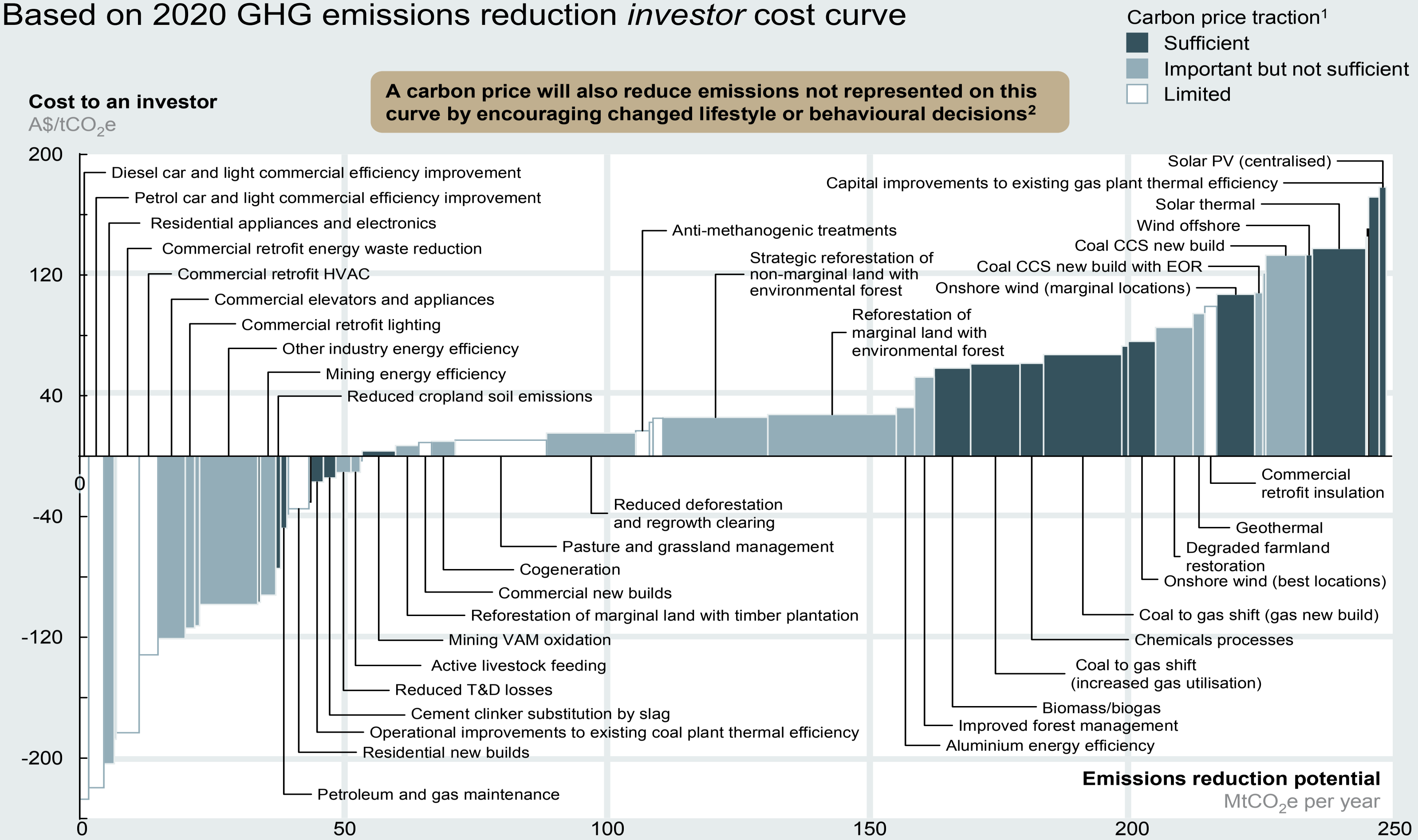
Lowest cost opportunities[1]

1 Excludes opportunities involving a significant lifestyle element or consumption decision, changes in business/activity mix, and opportunities with a high degree of speculation or technological uncertainty

SOURCE: ClimateWorks team analysis

Exhibit 52: Expected traction of carbon price

Based on 2020 GHG emissions reduction *investor* cost curve



1 Analysis assumes a carbon price large enough to make each opportunity profitable

2 Such as reduced consumption (e.g. turning lights off, driving fewer kms) and switching to less carbon-intensive forms of consumption (e.g. using public transport instead of driving)

SOURCE: ClimateWorks team analysis, derived from 2020 GHG emissions reduction cost curve (exhibit 4)

Appendix 2: Methodology

This appendix describes the approach used to identify opportunities to reduce GHG emissions in Australia and determine the amount of reduction possible and the cost per tonne of carbon dioxide equivalent (CO_2e) for each measure.

It starts with an overview of the methodology, explains the cost curve diagram used throughout the report and lists some of the key assumptions made.

DEFINITION OF BASELINE (BUSINESS-AS-USUAL)

The baseline or business-as-usual (BAU) forecast for 2020 is based on emissions projections by the Federal Government contained in the 2009 report *Tracking to Kyoto and 2020*. The BAU case represents how emissions and energy consumption would likely develop without any significant changes in existing consumption patterns or legislative initiatives. As a BAU case it does, however, include required replacement of infrastructure such as power plants and other technical equipment. For these replacements the BAU case assumes that old technology will be replaced by current technology, meeting existing norms for new investments.

The BAU case also assumes that legislation passed prior to the publication of this report will be implemented (such as the expanded Renewable Energy Target, which currently establishes a target of 20% renewable electricity production by 2020). However, the Carbon Pollution Reduction Scheme currently under consideration by Federal Parliament is not considered to be part of the BAU case.

IDENTIFICATION OF ENERGY SAVING AND EMISSIONS REDUCTION OPPORTUNITIES

To identify potential emissions reduction opportunities, a ClimateWorks team, with the assistance of Australian and global experts, looked at a wide range of options for reducing Australia's GHG emissions, including renewable energy sources, new technologies, alternative production processes, afforestation, waste management and energy efficiency measures. More than 150 opportunities were considered, and 54 measures were selected for the final cost curve after some were ruled out as inapplicable to Australia or already accounted for in the BAU case for 2020 (based on existing regulation).

Measures requiring new innovative technologies are included only if they meet four criteria:

- The technology is at least in the pilot stage
- The measure's technical and commercial viability in the medium term, starting by 2025 at the latest, is widely accepted
- Technological and economic challenges are well understood
- The technology is supported either by policy or industry, or is expected to lead to attractive economics

Measures that would require significant lifestyle changes are not addressed here. For example, using more energy efficient lighting is in the scope of the research, but reducing the average time that lights are on is not. Similarly, increasing the efficiency of residential heating is considered, but reducing average home temperatures in winter is not.

CALCULATION OF EMISSIONS REDUCTION VOLUMES

Energy saving or emissions reduction volumes represent the potential reduction of GHG emissions that can be achieved by a certain measure compared to the BAU case. Since some measures can overlap in terms of their effects, the volumes are sensitive to the order of implementation. For example, since energy demand reduction initiatives in the steel industry also reduce the total amount of electricity required, they reduce the additional energy consumption and emissions reduction potential of the power sector as well. To avoid double counting, GHG emissions associated with certain measures are attributed to the sector where this measure is implemented. For example, reductions of power and heat consumed in buildings are attributed as "indirect emissions" to the buildings sector, despite the fact that the greenhouse gases are physically emitted by power plants.

Where measures within one sector overlap, the measure with lowest emissions reduction cost is assumed to be realised for its total potential, thus reducing the potential of all more expensive measures.

CALCULATION OF EMISSION REDUCTION COSTS

For each measure the reduction cost is calculated as the incremental cost of implementing the particular measure, compared to the cost of the activity that would otherwise be incurred. For the construction of new wind farms, for example, the costs considered are the difference in total costs (investments and operational) between a new wind farm and the mix of fossil fuel and renewable power plants (the reference mix) that would otherwise have provided that power under BAU. Costs for a certain year (e.g. 2030) are calculated based on the operational costs or savings in the particular year, resulting from the implementation of the measure, and

Exhibit 53: Fuel price assumptions

Real A$, 2010

		Societal perspective		Investor perspective			
	Units	**2020**	**2030**	**2020**	**2030**	**Source**	**Comments/rationale**
Black coal	A$/t	67.40	67.40	42.68	42.68	ACIL Tasman, "Fuel resource, new entry and generation costs in the NEM", Feb 2009, section 3.4; Consensus Economics; team analysis	Societal perspective includes factor representing opportunity cost of not exporting coal globally; investor perspective reflects cheap domestic coal prices
	A$/MWh	8.66	8.66	5.49	5.49		
Brown coal	A$/GJ	0.67	0.67	0.67	0.67	ACIL Tasman, "Fuel resource, new entry and generation costs in the NEM", Feb 2009, section 3.4; team analysis	Brown coal is currently not exportable so societal and investor perspectives are the same
	A$/MWh	2.41	2.41	2.41	2.41		
Natural gas	A$/GJ	6.63	9.43	6.63	9.43	ACIL Tasman, "Projected energy prices in selected world regions", May 2008, Table 1; team analysis	Anticipation that domestic natural gas prices will eventually reach export price parity
	A$/MWh	23.88	33.96	23.88	33.96		
Crude oil	A$/bbl	96.75	101.97	96.75	101.97	McKinsey Global GHG Abatement model v2.0	Investor perspective for transport sector includes fuel excise of 38 cents per litre
	A$/MWh	56.92	59.99	56.92	59.99		
Biomass	A$/MWh	18.20	18.20	18.20	18.20	Yun Y et al., "Mallee biomass as a key bioenergy source in WA", p3296; CSIRO, An analysis of GHG Mitigation and Carbon biosequestration opportunities from rural land use	50/50 use of biomass plantation (expensive) and biomass waste/residue feedstock (cheap/free)
Biogas	A$/GJ	0.67	0.67	0.67	0.67	ACIL Tasman, "Fuel resource, new entry and generation costs in the NEM", Feb 2009, section 3.4; team analysis	Assumed same as natural gas
	A$/MWh	2.41	2.41	2.41	2.41		

SOURCE: ACIL Tasman (2009), Yun Y et al., ClimateWorks team analysis “annualised capital investments”—spreading the investment costs over the full lifetime of the investments, considering the weighted cost of capital. All costs are averaged across sub-opportunities (e.g. different types of buildings), across Australian regions (which differ in fuel mix and duration of heating periods) and time of implementation.

Throughout the report, all costs are in 2010 Australian prices, and the fuel prices in Exhibit 52 have been used.

Costs for individual measures are calculated based on a series of assumptions. These assumptions are tailored to Australia and are based on the insights from McKinsey & Company’s global studies and more than 20 other national studies on GHG emission reductions. Australian specific assumptions have been made based on Australian sources or have been tested with Australian experts from institutes, non-government organisations, companies and government departments.

Appendix 3:
Key assumptions

Power

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
Reduced transmission & distribution (T&D) losses	- Reducing the amount of electricity lost through transmission and distribution lines means less electricity needs to be generated to satisfy a given amount of electricity demanded - Actions include upgrading to large capacity conductors, installing reactive power sources, upgrading to low loss transformers, balancing loads and rearranging distribution feeders **Assumptions:** - Current T&D losses of 8% nationwide can be reduced to 6.5% by 2020 - Capital cost of A$1.2 billion and annual operating cost of A$120 million for each percentage improvement - Demand reduction reduces the amount of electricity produced by both fossil-fuel plants as well as renewables	-37	2.8
Onshore wind (best locations)	- Build an additional 1.6 GW of wind farms in locations with high average wind speeds over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal **Assumptions:** - Uptime: 35% - Lifespan: 25 years - Capital cost in 2020: A$1,600/kW - Fixed maintenance cost in 2020: A$32/kW per annum - Variable maintenance cost in 2020: A$2/MWh - Intermittency cost in 2020: A$5/MWh - Grid maintenance/upgrade cost in 2020: A$40/MWh - Total installed capacity in emissions reduction case: 9.5 GW	37	5.2
Onshore wind (marginal locations)	- Build an additional 3.3 GW of onshore wind farms in locations with less favourable wind speeds over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal	60	7.3

Measure	Description	Societal cost A\$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: ▸ Uptime: 25% ▸ Lifespan: 25 years ▸ Capital cost in 2020: A\$1,600/kW ▸ Fixed maintenance cost in 2020: A\$32/kW per annum ▸ Variable maintenance cost in 2020: A\$2/MWh ▸ Intermittency cost in 2020: A\$5/MWh ▸ Grid extension cost in 2020: A\$3/MWh ▸ Grid maintenance/upgrade cost in 2020: A\$40/MWh ▸ Total installed capacity in emissions reduction case: 3.3 GW		
Wind offshore	▸ Build an additional 0.3 GW of wind farms in offshore locations over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal **Assumptions:** ▸ Uptime: 45% ▸ Lifespan: 25 years ▸ Capital cost in 2020: A\$3,229/kW ▸ Fixed maintenance cost in 2020: A\$161/kW per annum ▸ Variable maintenance cost in 2020: A\$3/MWh ▸ Intermittency cost in 2020: A\$5/MWh ▸ Grid extension cost in 2020: A\$10/MWh ▸ Grid maintenance/upgrade cost in 2020: A\$40/MWh ▸ Total installed capacity in emissions reduction case: 0.3 GW	91	1.3
Solar thermal with storage	▸ Build an additional 2.5 GW of solar thermal plants over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal ▸ Assumes solar thermal storage is available (e.g. molten salts) to increase uptime to near base-load levels	77	10.2

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: - Uptime: 60% - Lifespan: 25 years - Capital cost in 2020: A$4,121/kW - Fixed maintenance cost in 2020: A$62/kW per annum - Variable maintenance cost in 2020: A$2/MWh - Intermittency cost in 2020: A$5/MWh - Grid extension cost in 2020: A$3/MWh - Grid maintenance/upgrade cost in 2020: A$40/MWh - Total installed capacity in emissions reduction case: 2.9 GW		
Solar PV (centralised)	- Build an additional 0.7 GW of centralised solar PV plants over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal **Assumptions:** - Uptime: 25% - Lifespan: 30 years - Capital cost in 2020: A$2,516/kW - Fixed maintenance cost in 2020: A$25/kW per annum - Variable maintenance cost in 2020: A$2/MWh - Intermittency cost in 2020: A$5/MWh - Grid extension cost in 2020: A$3/MWh - Grid maintenance/upgrade cost in 2020: A$40/MWh - Total installed capacity in emissions reduction case: 0.7 GW	94	1.3
Solar PV (distributed) [not included in plan due to high cost]	- Build an additional 0.07 GW of distributed solar PV panels (e.g. rooftop PV) over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal	223	0.2

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: ▸ Uptime: 20% ▸ Lifespan: 30 years ▸ Capital cost in 2020: A$5,394/kW ▸ Fixed maintenance cost in 2020: A$27/kW per annum ▸ Variable maintenance cost in 2020: A$3/MWh ▸ Intermittency cost in 2020: A$0/MWh ▸ Grid maintenance/upgrade cost in 2020: A$0/MWh ▸ Total installed capacity in emissions reduction case: 0.11 GW		
Biomass/biogas	▸ Build an additional 0.7 GW of plants that generate electricity from burning biomass (e.g. waste wood, crop residues such as bagasse, plantation material) and an additional 0.1 GW of plants that generate electricity from burning biogas (methane captured from landfill or sewage) over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal ▸ Burning biogas also has the additional benefit of reducing the harmfulness of methane which would otherwise have been released into the atmosphere **Assumptions:** ▸ Uptime: 80% ▸ Lifespan: 30 years ▸ Capital cost in 2020: A$2,316/kW for biomass, A$2,200/kW for biogas ▸ Fixed maintenance cost in 2020: A$45/kW per annum ▸ Variable maintenance cost in 2020: A$4/MWh ▸ Intermittency cost in 2020: A$0/MWh ▸ Grid maintenance/upgrade cost in 2020: A$40/MWh ▸ Total installed capacity in emissions reduction case: 1.6 GW (biomass) and 0.6 GW (biogas)	50	7.0
Geothermal	▸ Build an additional 0.3 GW of geothermal (hot-dry rock type) plants over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal	55	2.3

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
	Assumptions: - Uptime: 80% - Lifespan: 25 years - Capital cost in 2020: A$4,140/kW - Fixed maintenance cost in 2020: A$83/kW per annum - Variable maintenance cost in 2020: A$3/MWh - Intermittency cost in 2020: A$0/MWh - Grid maintenance/upgrade cost in 2020: A$40/MWh - Grid extension cost in 2020: A$15/MWh - Total installed capacity in emissions reduction case: 1 GW		
Wave/tidal [not included in plan due to high cost]	- Build an additional 0.01 GW wave/tidal power over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal **Assumptions:** - Uptime: 25% - Lifespan: 25 years - Capital cost in 2020: A$4,563/kW - Fixed maintenance cost in 2020: A$228/kW per annum - Variable maintenance cost in 2020: A$2/MWh - Intermittency cost in 2020: A$5/MWh - Grid extension cost in 2020: A$3/MWh - Grid maintenance/upgrade cost in 2020: A$40/MWh - Total installed capacity in emissions reduction case: 0.01 GW	257	0.01
Coal CCS new build	- Build an additional 1.1 GW of coal new builds with carbon capture and storage over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal - Can be met by constructing Wandoan, Zero Gen and Galilee Basin projects	91	7.7

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: - Uptime: 85% - Lifespan: 40 years - Capital cost in 2020: A$4,450/kW - Fixed maintenance cost in 2020: A$90/kW per annum - Variable maintenance cost in 2020: A$4/MWh - Carbon transport and storage costs in 2020: A$20/MWh - Total installed capacity in emissions reduction case: 1.1 GW		
Coal CCS new build with EOR	- Build an additional 0.2 GW of coal new builds with carbon capture and storage over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal - In EOR or enhanced oil recovery, the carbon dioxide is sold to an oil company to pump into an oil reserve and boost recovery or output of oil - Can be met by constructing the Flynn project in Victoria (close to oil reserves in Bass Strait) **Assumptions:** - Uptime: 85% - Lifespan: 40 years - Capital cost in 2020: A$4,450/kW - Fixed maintenance cost in 2020: A$90/kW per annum - Variable maintenance cost in 2020: A$4/MWh - Carbon transport and storage costs in 2020: A$0/MWh - Total installed capacity in emissions reduction case: 0.2 GW	68	1.5
Gas CCS new build	- Build an additional 0.1 GW of gas new builds with carbon capture and storage over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal	98	0.3

Measure	Description	Societal cost $\text{A\$/tCO}_2\text{e}$ pa in 2020	Volume MtCO_2e pa in 2020
	Assumptions: ▸ Uptime: 39% ▸ Lifespan: 40 years ▸ Capital cost in 2020: A$2,079/kW ▸ Fixed maintenance cost in 2020: A$42/kW per annum ▸ Variable maintenance cost in 2020: A$4/MWh ▸ Carbon transport and storage costs in 2020: A$20/MWh ▸ Total installed capacity in emissions reduction case: 0.1 GW		
Coal to gas shift (increased gas utilisation)	▸ Increase the maximum uptime of new and existing gas plants to 60% (leaving enough room for peaking capacity).	57	9.4
Coal to gas shift (new builds)	▸ Build an additional 4.5 GW of gas new builds over and above BAU to replace reference energy mix new builds (coal, gas and oil) and early-retired coal **Assumptions:** ▸ Uptime: 39% ▸ Lifespan: 40 years ▸ Capital cost in 2020: A$1,027/kW ▸ Fixed maintenance cost in 2020: A$21/kW per annum ▸ Variable maintenance cost in 2020: A$4/MWh ▸ Total installed capacity in emissions reduction case: 4.5 GW	44	14.9
Operational improvements to existing coal plant thermal efficiency	▸ Improve thermal or fuel efficiency of existing coal plants so less fossil fuels need to be burnt to generate a given amount of electricity ▸ Actions include better operational practices such as reducing auxiliary consumption, reducing coal moisture, and reducing operator variability **Assumptions:** ▸ Improvement potential for black coal: ~3% ▸ Improvement potential for brown coal: ~3% ▸ Costs required: negligible	-26	2.4
Capital improvements to existing coal plant thermal efficiency [not included in plan due to high cost]	▸ Improve thermal or fuel efficiency of existing coal plants so less fossil fuels need to be burnt to generate a given amount of electricity ▸ Actions include upgrading equipment such as steam turbines, boilers and seals	203	3.0

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
	Assumptions: ▸ Improvement potential for black coal: ~3.5% ▸ Costs required for black coal: A$67/kW per percentage improvement ▸ Improvement potential for brown coal: ~6% ▸ Costs required for brown coal: A$112/kW per percentage improvement		
Operational improvements to existing gas plant thermal efficiency	▸ Improve thermal or fuel efficiency of existing gas plants so less fossil fuels need to be burnt to generate a given amount of electricity ▸ Actions include better operational practices such as reducing auxiliary consumption, reducing coal moisture, and reducing operator variability **Assumptions:** ▸ Improvement potential: ~3.5% ▸ Costs required: negligible	-97	0.5
Capital improvements to existing gas plant thermal efficiency	▸ Improve thermal or fuel efficiency of existing gas plants so less fossil fuels need to be burnt to generate a given amount of electricity ▸ Actions include upgrading equipment such as steam turbines, boilers and seals **Assumptions:** ▸ Improvement potential: 6.5% ▸ Costs required: A$62/kW per percentage improvement	65	2.1
Biomass cofiring	▸ Use biomass to offset a proportion of coal used in coal-fired power plants **Assumptions:** ▸ Cofire up to 10% of total fuel using biomass ▸ ~20% of existing coal plants are located close enough to biomass sources for this to be economic ▸ $40/kW to retrofit cofiring capability onto existing plants	60	1.2
Coal CCS retrofit [not included in plan due to high cost]	▸ Retrofit existing coal plants with CCS capability **Assumptions:** ▸ Additional capital cost required: ~3,500/kW	158	0.3

Forestry

Measure	Description	Societal cost A$/$tCO_2$e pa in 2020	Volume $MtCO_2$e pa in 2020
Reforestation of marginal land with timber plantation	- Plant timber for harvest on less productive land **Assumptions:** - Planting undertaken on 0.5 Mha of land (1 Mha by 2030) - Constant planting rate of 50,000 ha/yr - Technical emissions reduction potential 8.8 tCO_2e/ha/yr - Long rotation plantation: 35 years	-10	4.4
Reduce deforestation and regrowth clearing	- Reduce deforestation emissions by reductions in both first time land clearing and regrowth clearing **Assumptions:** - 35% reduction in projected annual emissions by 2020 - Combination of legislative and incentive measures reduce both regrowth and first time clearing	24	17.0
Reforestation of marginal land with environmental forest	- Plant forests that are not for harvest on less productive land **Assumptions:** - Planting undertaken on 3.5 Mha of land (5 Mha by 2030) - Planting occurs more rapidly between 2010–2020, at 350,000 ha/yr, and then at 150,000 ha/yr from 2020 to 2030 - Technical emissions reduction potential 7.0 tCO_2e/ha/yr	26	24.5
Strategic reforestation of non-marginal land with environmental forests	- Plant small tree stands/forests selectively on productive land to create wind breaks, shade and erosion protection on waterways **Assumptions:** - Planting undertaken on 2 Mha of land (4 Mha by 2030) - Planting occurs at a constant rate of 200,000 ha/yr - Technical emissions reduction potential 10.0 tCO_2e/ha/yr	27	20.0

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Improved forest management	Increase amount of woody growth in forests by: – Removal of weeds such as lantana and blackberry that limit native woody vegetation growth – Removal of feral animal species – Insect/plant pest control to promote tree growth – Fire control **Assumptions:** 375,000 ha of forest brought under improved management annually Technical emissions reduction potential 1.0 tCO_2e/ha/yr	54	3.8

Industry

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Aluminium energy efficiency	Combination of existing and new Aluminium smelting technologies (see below); all Alumina potential is assumed to be captured in BAU	0	3.5
Aluminium smelting energy efficiency existing technologies	Energy efficiency improvements which are known today but no taken up in BAU due to long payback periods **Assumptions:** 5% savings in indirect energy and 4% in direct energy can be achieved Penetration rate of 70% by 2020 and 100% after 2020 Incremental cost of A$33/GJ with an average lifespan of 10 years	-82	1.0
Aluminium smelting new technologies - drained wetted cathode	Reducing the distance between the anode and the cathode decreases the energy consumed in aluminium production	34	2.5

Measure	Description	Societal cost A\$/t$\mathrm{CO_2}$e pa in 2020	Volume Mt$\mathrm{CO_2}$e pa in 2020
	Assumptions: ▸ 20% savings can be achieved ▸ Penetration rate of 50% in 2020 ▸ Price neutrality is achieved for a cell-life of 1000 days for investors in 2010; cell-life is 500 days in 2020 and 1000 days in 2030		
Aluminium smelting new technologies - inert anode (combined with drained wetted cathode) *[not included in plan as forecast implementation after 2020]*	▸ Carbon anodes are consumed in the Hall-Héroult process, making the continuous manufacture of new anodes and constant changing of the consumed anodes necessary. Inert anodes enable a reduction in this consumption and, when combined with a wetted cathode and compared to the traditional Hall-Héroult cells, are expected to provide significant reductions in operating costs and greenhouse gases. **Assumptions:** ▸ Total emissions (energy consumption and process) are reduced by 41% ▸ Penetration rate of 10% in 2025 and 25% in 2030 ▸ Same capital costs as drained wetted cathode technology and operating costs are reduced by 10%	N/A	0
Mining energy efficiency	▸ More efficient operations and controls, and known and existing equipment improvements (see below)	-106	2.9
Mining operational/ controls improvement	▸ Includes operational improvements (reduce idle time of shovels/trucks, improved fuel monitoring and maintenance, etc) and improved control and planning (control of transport equipment, truck dispatch optimisation, etc) **Assumptions:** ▸ ~5% savings in energy ▸ 50% implementation in reference case, 100% in emissions reduction case by 2015 ▸ Cost of about A$1.8 per GJ saved	-147	1.3
Mining equipment improvements known technologies	▸ Equipment improvement includes truck light weight dump bodies, improved weighing system, shovel light weight dippers, autonomous drilling, replacement of light vehicles with hybrid cars	-76	1.7

Measure	Description	Societal cost A\$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: ~5% savings in energy 0% implementation in reference case, 66% in emissions reduction case by 2020 and 100% by 2025 Cost of about A\$9 per GJ saved		
Mining equipment improvements emerging technologies *[not included in plan as forecast implementation after 2020]*	Equipment improvement includes: continuous hard rock mining of waste and ore, real-time geological analysis and early ore and waste separation, flat-ground conveying to plant and waste dump, effective crushing and High Pressure Grinding Rolls (HPGR) replacing ball/SAG mills, micro cracking, electrical discharge with heat recovery, coarse flotation, high-angle conveying out of pit, also for waste **Assumptions:** ~7% savings in energy 0% implementation in reference case, 50% in emissions reduction case in 2025 and 100% in 2030 Cost of about A\$11 per GJ saved	N/A	0
Remote Area Power [not included in plan due to high cost]	Replace traditional remote power generation by solar panels **Assumptions:** ~100% emissions abated Penetration rate of 50% in 2020 and 100% in 2030 Solar capital costs decrease from A\$7,733/kWh in 2010 to A\$3,336/kWh in 2030 and operating costs decrease from A\$53/kWh in 2010 to A\$24/kWh in 2030 Capital costs for reference technology (small CCGT) of A\$2,000/kWh in 2005 and decreases by 0.5% per annum; fixed operating costs of A\$31/kWh; gas efficiency of 7.6 GJ/MWh in 2005 which improves by 0.6% per annum	144	3.2
Other industry energy efficiency	Combination of energy efficiency opportunities in cement, chemicals, iron and steel, and petroleum and gas (see below)	-129	11.1
Cement energy efficiency	Improvement of equipment (eg conversion to modern grate cooler, or to high-efficiency roller mill) and processes (eg reduction of idle time, implementation of monitoring and controls of kiln and crusher)	-124	0.2

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
	Assumptions: - 7% savings in coal consumption, 15% in gas consumption and 10% in electricity consumption - Penetration rate increases from 25% in 2015 to 100% in 2030 - Cost of A$5/GJ on average		
Chemicals motor systems	- Introduction of energy saving measures in motor systems, such as adjustable speed drive, more energy efficient motors, and mechanical system optimisation **Assumptions:** - ~25% savings in indirect energy compared to standard systems - 100% implementation in reference by 2020 compared to 30% in BAU - Costs of ~A$94 per MWh installed base	-94	0.5
Petroleum and gas energy efficiency	- Maintenance and monitoring of steam traps/steam distribution or monitoring and reduction of fouling (deposit build up in the pipes) - Improved process control that reduces suboptimal performance i.e., due to undesired pressure drops across gas turbine air filters, an undesired turbine washout frequency, suboptimal well and separator pressures - Waste heat recovery via heat integration and replacement of boilers/heaters/turbines/motors **Assumptions:** - 8.4% savings - Penetration rate increases regularly from 25% in 2015 to 100% in 2030 - Costs: Capital cost investment of A$76 million required for a reference refinery with a capacity of 180 MBBL/day, scaled by volume. Operating cost estimated at ~5% of total required capital cost	-47	0.2
Other industry (includes Food, beverage and tobacco and Pulp, paper and print)	- Major opportunities include improved control systems (automated or manual); reduction of duplicated or oversized equipment; boilers and steam distribution systems; waste heat recovery (eg used for pre-heating or other sites); building utilities	-133	10.1

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
	Assumptions: - Savings of 18% are achievable by 2020, 5% being included in BAU - Costs of A$40 per GJ saved, with an average measure lifespan of 10 years		
Cogeneration	- Cogeneration opportunities in chemicals, steel, petroleum and gas and other industry	-48	4.5
Chemicals cogeneration	- Cogeneration or CHP (combined heat and power) is a technique to involve the energy losses in power production to generate heat for processes, in order to increase system efficiency and decrease the amount of fuel needed for power generation	-81	0.4
	Assumptions: - 15% savings in direct power - 40% implementation in 2030 above BAU - Cost of ~A$100 per MWh existing direct power in a given plant		
Iron and steel cogeneration (flat products)	- Blast Furnace/Basic Oxygen Furnace (BF/BOF) steel-manufacturing process generates gas as a by-product. This gas can be recovered, cleaned and used for power generation, which reduces the total energy demand **Assumptions:** - 100% implementation by 2020 compared to 0% in BAU - Costs of ~A$1 billion for an emissions reduction of 880,000 tCO_2e	-40	0.9
Iron and steel cogeneration (long products)	- Same as Iron and steel cogeneration (flat products) above **Assumptions:** - Penetration rate: 28% implementation co-generation in BAU (existing plant), 100% implementation in emissions reduction scenario by 2030 - Costs of A$114/$tCO_2e$	-33	0.2
Other industry cogeneration	- Generation of electricity and thermal energy in a single, integrated system **Assumptions:** - 3% energy savings by 2020 and 2030 above BAU - Annualised Capital cost is estimated to be around A$12/GJ	-68	2.9

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
Iron and Steel processes	- Combination of fuel substitution and process improvement in the iron and steel production	56	0.5
Iron and Steel coke substitution	- Coke substitution with fuel based on biomass **Assumptions:** - 20% coke can be substituted - No substitution in BAU, 100% implementation by 2030 - No capital cost required	11	0.3
Iron and Steel smelt reduction	- Technique that integrates the preparation of coke with iron-ore reduction to reduce energy use at the iron production stage. The emission savings are achieved as less direct fuel is used when integrating preparation of coke with iron-ore reduction. **Assumptions:** - ~8% reduction in after treatment energy intensity - 10% implementation in BAU and 100% implementation in emissions reduction scenario by 2030 - Capital cost of ~A$188/t steel annual capacity	103	0.3
Chemicals processes and fuel shift	- Improvement of chemical techniques and replacement of traditional fuels by less intensive ones	35	4.5
Chemicals processes	- Nitric acid: applying filtering measures in order to decompose N_2O from the tailgas of nitric acid production, where N_2O is produced as a process emission - Ethylene cracking: improvement includes furnace upgrades, better cracking tube materials and improved separation and compression techniques that lowers the direct energy used in the cracking process - Process intensification includes continuous processes, improved process control, preventative maintenance, more efficient burners and heaters and logistical improvements - Catalyst optimisation (process and direct energy emissions decrease) includes improved chemical structure of catalysts, design to lower reaction temperatures, and chain reaction improvements	27	3.4

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
	Assumptions: ▸ Nitric acid: reduction by ~6 t of N2O per Mt acid; 100% implementation by 2020 compared to 0% in BAU; Costs of ~A$9 per MWh installed ▸ Ethylene cracking: ~1.1 MWh savings per tonne of Ethylene, 100% in implementation by 2020 compared to 0% in BAU;, Capital cost of ~A$94/t Ethylene production and overhead cost of ~A$47/t Ethylene ▸ Process intensification and catalyst optimisation: modelled in 3 steps with increasing costs. For each step: 0.1% p.a. process intensification and catalyst optimisation above BAU; capital cost respectively A$0, ~A$375, and ~A$750/ tCO_2e; operating cost delta respectively at A$0, A$19, and A$38/$tCO_2e$		
Fuel shift	▸ Shifting direct energy use from coal powered systems to biomass, and oil powered systems to gas, thereby lowering the carbon intensity per MWh of energy produced given the lower carbon intensity of gas and biomass **Assumptions:** ▸ 80% biomass in new builds, 50% in retrofits compared to 0% in BAU in 2020; 80% gas in new builds, 50% in retrofits compared to BAU ▸ Costs of ~A$9 per MWh installed	62	1.1

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
Petroleum and gas maintenance	- Replace compressor seals: replacing traditional wet seals, which use high-pressure oil as a barrier against natural gas escaping from the compressor casing, with dry seals reduces methane leakage from compressors - Improved maintenance on compressors: a directed inspection and maintenance (DI&M) program is a means to detect, measure, prioritise and repair equipment leaks to reduce methane emissions from compressors, valves, etc. - Improved maintenance in distribution network: same as above, focusing on surface and metering stations - Improved planning: reduces emissions due to transmission combustion by reducing unnecessary (de-)pressurisation by actively matching compression needs with natural gas demand **Assumptions:** - Replace compressor seals : 6% savings on transmission leakage; 100% implementation by 2020; capital cost of A$300,000 and A$75,000 and operating cost of A$13,000 and A$92,000 per compressor for dry and wet seals - Improved maintenance on compressors: 14% savings on transmission leakage; 100% implementation by 2020; no capital cost and operating cost of A$250 per compressor - Improved maintenance in distribution network: 80% of the gap between current practice and technical best practice can be reduced; 100% implementation by 2020; no capital cost and operating cost of A$985,000/bcm - Improved planning: 7% reduction in fuel consumption; implementation increases regularly from 25% in 2015 to 100% in 2030; capital cost of A$188,000/bcm and operating cost amounting to 15% of capital cost	-37	1.2

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
Cement clinker substitution by slag	- Reducing the clinker content in cements, by substituting clinker with slag, fly ash, and other mineral industrial components, reduces process and fuel combustion emissions as well as electric power from clinker production, which together accounts for over 90% of total emissions from the cement industry **Assumptions:** - There is no potential to increase share of waste/bio-mass as kiln fuel above BAU - Slag replaces 40% of clinker (no increase in fly ash and other Mineral Industrial Components (MIC) as slag is assumed to take all substitution potential) - Capital costs of A$132/t for slag granulation capacity and A$141/t for slag grinding capacity. Material cost of A$34/t (imports)	18	2.4
Mining VAM oxidation	- Reduce fugitive emissions from gassy underground mines by oxidising Ventilation Air Methane (VAM) to transform it into CO_2 **Assumptions:** - 70% of VAM emissions from gassy mines can be saved - Implemented in 50% of mines by 2020 and 100% by 2030 - Cost of A$17/t$CO_2$e minus electricity revenue (0.16 MWh of electricity produced for every tonne of CO_2e abated)	-1	6.4
Petroleum and gas reduced flaring [not included in plan as forecast implementation after 2020]	- Measures to reduce continuous flaring by capturing the otherwise flared gas and bringing it to market **Assumptions:** - 31% of BAU flaring can be abated with a 25% penetration rate in 2025 and 100% in 2030 - Cost of A$600 million/bcm for the gathering system and A$40 for the pipes per flare; operating cost estimated at 15% of total required Capital cost	N/A	0
Iron and Steel energy efficiency [not included in plan due to high cost]	- Measures such as preventative maintenance, improved process flow, motor systems, new efficient burners, oxygen injection in EAF, scrap preheating, laser analysis of scrap, insulation of furnaces	107	0.3

Measure	Description	Societal cost A\$/tCO_2e pa in 2020	Volume $MtCO_2e$ pa in 2020
	Assumptions: - 0.4 p.a. general energy efficiency increase above BAU - Costs of A\$132/tCO_2e		
Industrial Carbon Capture and Storage (CCS) [not included in plan as forecast implementation after 2020]	- CCS opportunities in Cement, Chemicals, Petroleum and Gas	N/A	0
Cement CCS	- Sequestration of CO2 after it has been emitted due to fuel combustion and the clinker calcination process. CCS can be build-out with new Cement production capacity coming online as well as retrofitted to existing capacity **Assumptions:** - 2 plants only are large enough and situated in favorable locations; a capture rate of 90% is assumed, with implementation to start in 2025 for retrofits. - Capital cost of ~A\$1,128/tCO_2e annual emissions reduction capacity decreasing to ~A\$376 in 2030; transport cost ~ A\$13/tCO_2e; storage cost A\$21/tCO_2e ; separation cost A\$6/tCO_2e; overhead cost A\$28/tCO_2e	N/A	0
Chemicals CCS	- Blast Furnace/Basic Oxygen Furnace (BF/BOF) steel-manufacturing process generates gas as a by-product. This gas can be recovered, cleaned and used for power generation, which reduces the total energy demand **Assumptions:** - 100% implementation by 2020 compared to 0% in BAU - Costs of ~A\$1 billion for an emissions reduction of 880,000 tCO_2e	N/A	0
Petroleum and gas CCS	- Fugitive emissions from venting can only be reduced by CCS technology	N/A	0

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: - CCS is assumed to be able to capture 90% of venting emissions after 2025 for 50% of gas fields open after 2015; BAU implementation only includes Gorgon project - Capital cost of ~A$1,128/tCO$_2$e annual emissions reduction capacity decreasing to ~A$376 in 2030; transport cost ~ A$26/tCO$_2$e decreasing to 10 by 2030; storage cost A$21/t CO$_2$e; separation cost A$6/tCO$_2$e; overhead cost A$11/tCO$_2$e		

Agriculture

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
Reduced cropland soil emissions	- Reduce tillage to zero or restrict to 1-2 cultivations - Avoid burning of residue - Use fertilisers more efficiently: adjust application rates based on precise estimation of crop needs, place Nitrogen more precisely in soil, avoid application in times when susceptible to loss, use coated, slow release fertilisers **Assumptions:** - Reduced tillage: significant BAU penetration, however, full tillage still occurring on 1.4 Mha of land and reduced tillage on 8.1 Mha. Reducing tillage practices in these areas can reduce emissions at a weighted average rate of 0.26 tCO$_2$e/ha/yr. Penetration rate in these areas increases from 0% in 2010 to 35% in 2020 and 70% in 2030, bringing penetration of zero-tillage across all normal cropland to 90% - Fertilisers usage: apply to 27 Mha of normal cropping land, reduce Nitrogen fertiliser use by ~20% to reduce emissions by 0.03 tCO$_2$e/ha/yr, penetration rate increases progressively from 60% in 2010, rising to 75% in 2020, and reaching 90% from 2030, compared to BAU of 65% in 2030	-74	1.0

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
Cropland carbon sequestration	▸ Reduce use of bare fallow ▸ Use improved crop varieties that allocate more soil carbon ▸ Utilise cover crops **Assumptions:** ▸ Apply to 27 Mha of normal cropping land, split into two climate types; moist warm 7.5 Mha and dry warm 19 Mha ▸ Technical emissions reduction potential; moist warm: 1.0 tCO$_2$e/ha/yr, dry warm: 0.4 tCO$_2$e/ha/yr ▸ Penetration rate increases progressively from 50% in 2010, rising to 63% in 2020, and reaching 75% from 2030, compared to BAU of 50% in 2030	25	1.9
Pasture and grassland management	▸ Improve improved-pasture and grassland management to increase soil carbon sequestration and decrease livestock emissions	11	17.4
Improved-pastures management	▸ Optimise grazing intensity and timing for carbon sequestration & productivity ▸ Promote land productivity ▸ Fire management ▸ Species introduction – perennial grasses with higher productivity or greater sequestration through deep roots **Assumptions:** ▸ Apply to 53 Mha of normal improved-pastures land ▸ Technical emissions reduction potential 0.3 tCO$_2$e/ha/yr sequestered in soil ▸ Penetration rate increases progressively from 50% in 2010, rising to 63% in 2020, and reaching 75% from 2030, compared to BAU of 50% in 2030 ▸ Improved pasture management also drives 15% reduction in beef cattle enteric emissions ▸ O.5 head of beef cattle per hectare of improved-pastures brought under improved management	5	2.9

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
Natural grassland management	- Optimise grazing intensity and timing for sustainable carbon sequestration - Promote land productivity via nutrients - Fire management - Species introduction – perennial grasses with higher productivity or greater sequestration through deep roots **Assumptions:** - Apply to 238 Mha of normal natural grasslands - Technical emissions reduction potential 0.3 tCO$_2$e/ha/yr sequestered in soil - Penetration rate increases progressively from 5% in 2010, rising to 22% in 2020, and reaching 40% from 2030, compared to BAU of 5% in 2030 - Improved grassland management drives 15% reduction in beef cattle enteric emissions - O.1 head of beef cattle per hectare of grassland brought under improved management	12	14.5
Active livestock feeding	- Actively feed beef cattle higher quality feed to increase growth rate and shorten time to reach slaughter rate, most likely via feedlotting **Assumptions:** - Technical emissions reduction potential – reduce beef cattle enteric emissions by 25% per head - Penetration rate increases progressively from 4% of beef cattle heard in 2010, rising to 15% in 2020, and remaining at 15% in 2030, compared to BAU of 4% in 2030 - Assumes sufficient demand for actively fed beef for 1 cent additional net profit per kilo of meat	-11	1.8
Anti-methanogenic treatments	- Dietary additives - Injections - Water medication - Vaccines	17	2.6

Measure	Description	Societal cost A$/$tCO_2$e pa in 2020	Volume $MtCO_2$e pa in 2020
	Assumptions: - Technical emissions reduction potential: reduce livestock enteric emissions by 10% per head - Penetration rate increases progressively from 0% of livestock heard in 2010, rising to 50% in 2020, and remaining at 50% in 2030, compared to BAU of 0% in 2030		
Degraded farmland restoration	- Restore degraded land to improve soil carbon sequestration	85	7.1
Degraded cropland restoration	- Reduce salinity, acidification, erosion by: - Re-vegetation - Applying lime - Improving fertility via nutrient application - Applying organic substrates **Assumptions:** - 20% of Australian cropland is degraded (6.6 Mha) - Technical emissions reduction potential 1.0 tCO_2e/ha/yr - Penetration rate increases progressively from 5% in 2010, rising to 25% in 2020, and reaching 45% in 2030, compared to BAU of 5% in 2030	63	1.3
Degraded improved-pastures restoration	- Reduce salinity, acidification, erosion by: - Re-vegetation - Applying lime - Improving fertility via nutrient application - Apply organic substrates **Assumptions:** - 20% of improved-pasture land is degraded (13.3 Mha) - Technical emissions reduction potential 1.0 tCO_2e/ha/yr - Penetration rate increases progressively from 5% in 2010, rising to 15% in 2020, and reaching 25% in 2030, compared to BAU of 5% in 2030	78	1.3

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Degraded natural grassland restoration	‣ Reduce salinity, acidification, erosion by: ‣ Re-vegetation ‣ Applying lime ‣ Improving fertility via nutrient application ‣ Apply organic substrates **Assumptions:** ‣ 20% of natural grassland is degraded (59.4 Mha) ‣ Technical emissions reduction potential 1.0 tCO_2e/ha/yr ‣ Penetration rate increases progressively from 0% in 2010, rising to 8% in 2020, and reaching 15% in 2030, compared to BAU of 0% in 2030	94	4.5

Buildings

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Residential new builds	▸ New houses are built to 7.2 star according to the HERS rating system **Assumptions:** ▸ Heating, ventilation and air conditioning (HVAC) energy consumption of households decreases from 38 KWh/m^2 to 20.4 kWh/m^2 in states following the BCA (all but NSW), and from 36 KWh/m^2 to 15 KWh/m^2 in NSW ▸ Incremental cost is A$24/$m^2$ in BCA states and A$30/$m^2$ in NSW ▸ 100% of new homes are built to a 7.2 star standard from 2013	-98	3.9
Residential building envelope	▸ Basic retrofit including sealing areas of air leakage, weather stripping doors and windows, insulating attic and wall cavities **Assumptions:** ▸ 30% savings on heating and 20% on cooling ▸ Incremental cost of A$9/$m^2$ ▸ BAU penetration rate increases progressively from 26% in 2010 to 78% in 2020 and 86% in 2030 ▸ Penetration rate reaches 90% in 2020 and 100% in 2030 in the emissions reduction scenario	61	0.2
Residential building envelope advanced [not included in plan due to high cost]	▸ Retrofit to 'passive' standard, in conjunction with regular building renovations. Includes installing high efficiency windows and doors; increasing outer wall, roof, and basement ceiling insulation; mechanical ventilation with heat recovery, basic passive solar principles **Assumptions:** ▸ 60% savings on heating and cooling ▸ Incremental cost of A$120/$m^2$ in 2010 and A$85/$m^2$ in 2030 ▸ Penetration rate increases progressively from 2% in 2010 to reach 40% of households in 2030 (only among top 50% HVAC-energy consumers), compared to 6% in 2030 in BAU	272	1.8
Residential appliances and electronics	▸ New appliances and electronics purchased are in the top performers of their category (named high-efficiency)	-112	2.0

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
	Assumptions: - 35% savings for high-efficiency appliances compared to average new buys, 37% for electronics - Penetration rate of high efficiency appliances increases from 6% in 2010 to 67% in 2020 and 100% in 2030 compared to 40% in 2030 in BAU - Penetration rate of high efficiency electronics increases from 9% in 2010 to 57% in 2020 and 100% in 2030 compared to 40% in 2030 in BAU - Price premium is about 1% for electronics and 12% for appliances		
Residential lighting	- Replacement of traditional light bulbs by high-efficiency light bulbs	-99	1.0
CFLs to LEDs	- Replace compact fluorescent lamp (CFL) by light emitting diode (LED) **Assumptions:** - In 2030, 50% of non-living areas and 100% of living area CFLs are replaced by LEDs. Replacement is made progressively from 0% in 2010 to 100% in 2030 - Incremental cost for LEDs of A$62 in 2010 decreasing to A$32 in 2030	-117	0.7
High efficiency halogen	- Replacement of standard quartz halogen bulbs by high-efficiency halogen bulbs **Assumptions:** - 30% energy savings - Penetration rate increases progressively to 60% above BAU in 2030 - Incremental cost of A$7 per bulb	-59	0.3
Residential HVAC	- New air conditioners and space heaters purchased are in the top performers of their category (named high-efficiency) - Improved maintenance: improved duct insulation, correct level of refrigerant and new air filters	-14	0.3

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
	Assumptions: 20% savings for air conditioners, 20% for gas heaters, 48% for electric heaters and 10% for maintenance Penetration rate increases progressively from 0% in 2010 to 100% in 2030 compared to 40% in 2030 in BAU for air conditioners; the rate increases from 25% in 2005 to 100% in 2030, compared to 40% in BAU for space heaters; it increases from 15% in 2010 to 75% in 2030, compared to 25% in BAU in 2030 for maintenance Incremental cost is A$575 for air conditioners, A$800 for gas heaters, A$3,760 for electric heaters and around A$1,150 to cover a 150 m^2 house over lifespan of equipment for maintenance		
Commercial energy waste reduction	Experience shows that significant savings can be achieved with minimal capital investment by getting rid of or downsizing unnecessary equipment **Assumptions:** 10% savings across all end uses Incremental cost of A$4/$m^2$	-138	4.4
Commercial retrofit lighting	Replace CFLs with LEDs, replace inefficient T12s or T8s with new super T8s and T5s, install lighting control systems (dimmable ballasts, photo-sensors to optimise light for occupants in room) **Assumptions:** 26% savings in 2020 Incremental cost of A$55/t$CO_2$e on average	-97	1.8
Commercial elevators and appliances	Replacement of traditional elevators/ escalators, appliances, electronics and kitchen equipment (cooking and refrigeration) by high-efficiency equipment	-97	5.2
Commercial retrofit elevators and appliances	New purchases are in the top performers of their category (named high-efficiency), early retirements are conducted when economic **Assumptions:** 15% savings in 2020 Incremental cost of A$240 per unit on average	-98	1.3
Commercial retrofit electronics	New purchases are in the top performers of their category (named high-efficiency)	-106	2.0

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: - 37% savings in 2020 - Incremental cost of A$1,000 per unit on average		
Commercial retrofit cooking and refrigeration	- Replace open refrigeration spaces by closed ones, new purchases are highly efficient - Better insulation of commercial ovens, new purchases are highly efficient **Assumptions:** - Refrigeration: 13% savings in 2020, incremental cost of A$95/tCO$_2$e on average - Cooking: 11% savings in 2020, incremental cost of A$188/tCO$_2$e on average	-79	0.4
Commercial new builds elevators and appliances	- New purchases are in the top performers of their category (named high-efficiency), early retirements are conducted when economic **Assumptions:** - 15% savings in 2020 for elevators and appliances, 35% for electronics, 59% for refrigeration and 8% for cooking - Same incremental cost as for commercial retrofits	-89	1.6
Commercial retrofit water heating	- Replace standard gas water heaters with tankless gas, condensing gas, or solar water heater; replace electric water heater with heat pump or solar water heater **Assumptions:** - 26% savings in 2020 - Incremental cost of A$103/tCO$_2$e for gas heaters and A$368/tCO$_2$e for electric heaters	-48	0.7
Commercial retrofit insulation	- Improve building airtightness by sealing areas of potential air leakage, weather strip doors and windows **Assumptions:** - 18% savings in 2020 - Incremental cost of A$23/m^2	-55	2.3

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Commercial retrofit HVAC	▸ HVAC equipment: install highest efficiency system when current expires, improve HVAC control systems to adjust for building occupancy and minimise re-cooling of air ▸ Positive interaction with other energy efficiency improvements: experience shows that significant downsizing of HVAC system can be done once other equipment improvements have been implemented (e.g. lighting, cooking, refrigeration) **Assumptions:** ▸ HVAC equipment: 15% savings in 2020, incremental cost A$17,000 and A$8,650 per unit for equipment and controls ▸ Positive interaction: 20% savings in 2020, no incremental cost	-119	3.6
Commercial new builds	▸ All new builds to a 6 star equivalent in the NABERS rating system on average (for subsectors where no rating exists, equivalent reductions above current BAU were taken) **Assumptions:** ▸ Office buildings are taken as a reference as they correspond to the average energy consumption per m^2 in the building fleet ▸ New average energy consumption for central services is 68 KWh/m^2 ▸ Incremental cost is A$181/$m^2$	-73	2.4

Transport

Measure	Description	Societal cost A$/$tCO_2e$ pa in 2020	Volume $MtCO_2e$ pa in 2020
Petrol car and light commercial efficiency improvements	▸ Efficiency improvements to traditional gasoline internal combustion engine (ICE) passenger and commercial vehicles, grouped into 4 bundles: ▸ Bundle 1 – Variable valve control, mild engine friction reduction, low rolling resistance tyres, tyre pressure control system, mild weight reduction (1.5%) ▸ Bundle 2 (additional to bundle 1) – medium down-sizing, medium weight reduction, electrification (steering, pumps), optimised gearbox ratio, improved aerodynamic efficiency, stop-start system with regenerative braking ▸ Bundle 3 (additional to bundle 2) – strong additional displacement, air conditioning modification, improved aerodynamic efficiency, start-stop system with regenerative braking ▸ Bundle 4 (additional to bundle 3) – direct pressure injection strong weight reduction, optimised transmission **Assumptions:** ▸ Opportunity only allocated to vehicles in production year; no retrofits or early retirement ▸ 20 year average life of vehicles ▸ 2020 fleet of 9.7 million vehicles, of which 6.1 million are purchased between 2010 and 2020 ▸ Fuel economy of 9.6 litres per 100 km in 2020 before efficiency improvements. Fuel economy of bundle 1 is 8.3 litres per 100 km, bundle 2 is 7.2 litres per 100 km, bundle 3 is 6.6 litres per 100 km, bundle 4 is 5.9 litres per 100 km ▸ In 2020, new vehicles sold with bundle technology applied are: 16% bundle 1; 34% bundle 2, 28% bundle 3, 6% bundle 4, 0% no ICE improvement ▸ Incremental capital cost in 2020: A$448 for bundle 1, A$1,629 for bundle 2, A$2,618 for bundle 3, A$3,784 for bundle 4	-74	2.9

Measure	Description	Societal cost A$/t$CO_2$e pa in 2020	Volume MtCO_2e pa in 2020
Diesel car and light commercial efficiency improvements	- Efficiency improvements to traditional diesel ICE passenger and commercial vehicles, grouped into 4 bundles: - Bundle 1 – Variable valve control, mild engine friction reduction, low rolling resistance tyres, tyre pressure control system, mild weight reduction (1.5%) - Bundle 2 (additional to bundle 1) – Piezo injectors, medium down-sizing, medium weight reduction, electrification (steering, pumps), optimised gearbox ratio, improved aerodynamic efficiency - Bundle 3 (additional to bundle 2) – torque oriented boost, air conditioning modification, improved aerodynamic efficiency, start-stop system with regenerative breaking - Bundle 4 (additional to bundle 3) – increase injection pressure, strong downsizing, strong weight reduction **Assumptions:** - Opportunity only allocated to vehicles in production year; no retrofits or early retirement - 20 year average life of vehicles - 2020 fleet of 7.3 million vehicles, of which 4.6 million are purchased between 2010 and 2020 - Fuel economy of 9.2 litres per 100 km in 2020 before efficiency improvements. Fuel economy of bundle 1 is 8.1 litres per 100 km, bundle 2 is 7.4 litres per 100 km, bundle 3 is 6.4 litres per 100 km, bundle 4 is 6.0 litres per 100 km. - In 2020, new vehicles sold with bundle technology applied are: 16% bundle 1; 34% bundle 2, 28% bundle 3, 6% bundle 4, 0% no ICE improvement - Incremental capital cost in 2020: A$2,176 for bundle 1, A$2,631 for bundle 2, A$3,489 for bundle 3, A$4,021 for bundle 4	-89	1.7

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
Bus and rigid truck efficiency improvements [not included in plan due to high cost]	‣ Efficiency improvements to traditional diesel ICE bus and rigid trucks, grouped into 4 bundles: ‣ Bundle 1 – rolling resistance reduction ‣ Bundle 2 – rolling resistance reduction, aerodynamic improvement ‣ Bundle 3 – rolling resistance reduction, conventional ICE improvement ‣ Bundle 4 – rolling resistance reduction, aerodynamics improvement, conventional ICE improvements **Assumptions:** ‣ Opportunity only allocated to vehicles in production year; no retrofits or early retirement ‣ 20 year average life of vehicles ‣ 2020 fleet of 0.6 million vehicles, of which 0.3 million are purchased between 2010 and 2020 ‣ Fuel economy of 28 litres per 100 km in 2020 before efficiency improvements. Fuel economy of bundle 1 is 27 litres per 100 km, bundle 2 is 27 litres per 100 km, bundle 3 is 26 litres per 100 km, bundle 4 is 25 litres per 100 km. ‣ In 2020, new vehicles sold with bundle technology applied are: 10% bundle 1; 10% bundle 2, 40% bundle 3, 40% bundle 4, 0% no ICE improvement ‣ Incremental capital cost in 2020: A$1,197 for bundle 1, A$1,995 for bundle 2, A$7,182 for bundle 3, A$7,980 for bundle 4	182	0.2
Large articulated truck efficiency improvements	‣ Efficiency improvements to traditional diesel ICE large articulated trucks, grouped into 4 bundles: ‣ Bundle 1 – rolling resistance reduction ‣ Bundle 2 – rolling resistance reduction, aerodynamic improvement ‣ Bundle 3 – rolling resistance reduction, conventional ICE improvement ‣ Bundle 4 – rolling resistance reduction, aerodynamics improvement, conventional ICE improvements	-61	0.4

Measure	Description	Societal cost A$/$tCO_2$e pa in 2020	Volume $MtCO_2$e pa in 2020
	Assumptions: ▸ Opportunity only allocated to vehicles in production year; no retrofits or early retirement ▸ 20 year average life of vehicles ▸ 2020 fleet of 0.1 million vehicles, of which 0.06 million are purchased between 2010 and 2020 ▸ Fuel economy of 35 litres per 100 km in 2020 before efficiency improvements. Fuel economy of bundle 1 is 51 litres per 100 km, bundle 2 is 50 litres per 100 km, bundle 3 is 49 litres per 100 km, bundle 4 is 47 litres per 100 km. ▸ In 2020, new vehicles sold with bundle technology applied are: 10% bundle 1; 10% bundle 2, 40% bundle 3, 40% bundle 4, 0% no ICE improvement ▸ Incremental capital cost in 2020: A$2,122 for bundle 1, A$3,396 for bundle 2, A$9,551 for bundle 3, A$10,824 for bundle 4		
Diesel car hybrids	▸ More fuel efficient diesel hybrid cars supplant less fuel efficient cars over the medium to long term **Assumptions:** ▸ Electricity economy in car and light commercial vehicles hybrid in 2020 is 0.25 KWh/km ▸ Electricity share in car and light commercial vehicles plug-in hybrid in 2020 is 66% ▸ In 2020, the penetration rates of car and light commercial vehicles diesel full hybrid is 7.5% (0.6 million vehicles) and car and light commercial vehicles diesel plug-in hybrid is 2.5% (0.2 million vehicles) ▸ The incremental cost from existing technology by bundles in 2020, for car and light commercial diesel plug-in hybrid is A$8,985, and for car and light commercial diesel full hybrid is A$6,618	53	0.4
Petrol car hybrids	▸ More fuel efficient petrol hybrid vehicles supplant less fuel efficient cars over the medium to long term	83	0.4

Measure	Description	Societal cost A$/tCO$_2$e pa in 2020	Volume MtCO$_2$e pa in 2020
	Assumptions: ▸ Electricity economy in car and light commercial vehicles hybrid in 2020 is 0.25 KWh/km ▸ Electricity share in car and light commercial vehicles plug-in hybrid in 2020 is 66% ▸ In 2020, the penetration rates of car and light commercial vehicles gasoline full hybrid is 7.5% (0.7 million vehicles) and car and light commercial vehicles gasoline plug-in hybrid is 2.5% (0.3 million vehicles) ▸ The incremental cost from existing technology by bundles in 2020, for car and light commercial vehicles gasoline plug-in hybrid is A$8,985, and for car and light commercial vehicles diesel full hybrid is A$4,766		
Electric vehicles (EVs) [not included in plan due to high cost]	▸ More fuel efficient electric vehicles supplant less fuel efficient cars over the medium to long term **Assumptions:** ▸ EVs have assumed electricity efficiency of 0.20 kwh/km ▸ The assumed penetration rate for EVs in 2020 is 5% (0.8 million vehicles), as opposed to 0% under the business-as-usual scenario ▸ Incremental costs from existing technologies in 2020 for EVs is A$15,902	283	0.25
Biofuels [not included in plan due to high cost]	▸ Replacing existing fuel types with biofuels. **Assumptions:** ▸ Reference case feedstock are limited to current first generation Australian feedstocks ▸ Penetration rates for biofuels as a percentage of petrol energy move to 1.9% in 2020	535	1.1

List of acronyms

ABARE, Australian Bureau of Agricultural and Resource Economics

BAU, business-as-usual

capex, capital expenditure

CCS, Carbon Capture and Storage

CFL, compact fluorescent light

CO_2, carbon dioxide

CO_2e, carbon dioxide equivalent (used for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO2) as the reference)

CPRS, Carbon Pollution Reduction Scheme

CSIRO, Commonwealth Scientific and Industrial Research Organisation

DCC, Department of Climate Change

EEO, Energy Efficiency Opportunities

ESCO, energy service company

GGAP, Greenhouse Gas Abatement Program

GHG, greenhouse gas (defined in the Kyoto Protocol to include four greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons)

GW, giga watt (one billion watts)

Ha, hectare

HVAC, heating, ventilation and air conditioning

IAI, International Aluminium Institute

ICE, internal combustion engine

kW, kilo watt (one thousand watts)

LED, light emitting diode

MEPS, Mandatory Energy Performance Standards

MRI, magnetic resonance image

Mt, mega tonne (one million tonnes)

$MtCO_2e$, million tonnes of carbon dioxide equivalent

Mtpa, million tonnes per annum

MW, mega watt (one million watts)

MWh, mega watt per hour

N_20, nitrous oxide

NABERS, National Australian Built Environment Rating System

p.a., per annum

PV solar, photo voltaic solar

REC, renewable energy certificates

RET, Renewable Energy Target

SME, small and medium enterprises

SUV, sports utility vehicle

VAM, Ventilation Air Methane

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