Review of the Renewable Energy Target

WWF-Australia submission to the Climate Change Authority

1. Summary and Key Recommendations

To reduce greenhouse gas emissions and contribute to avoiding two degrees warming above pre-industrial levels, Australia should aim to be 100% reliant on renewable energy by 2050 at the latest.

WWF-Australia commissioned Climate Risk (the report, *Our Clean Energy Future:100% Renewables Powering our Energy Future*, is attached to this submissions) to assess the feasibility of achieving a transition to 100% renewable energy in Australia, and the impact that different policy settings will have on the transition to 100% renewable energy.

For the electricity sector, without including expansion of land based transport, Australia could achieve 100% renewable energy by 2037.

If we are to achieve 100% renewable energy in all energy sectors, then we must tackle transportation and electrify the transport system, this could be achieved by 2050. The report found this will require 169,000 GWh of renewable energy to be installed by 2030 (requiring average growth rates of 20%). One hundred precent renewable energy can still be achieved if 137,000 GWh's of renewable energy is installed by 2030, but this will require growth rates closer to 30% after 2030.

The Renewable Energy Target (RET) will play a critical role in achieving this goal, alongside the carbon price mechanism, and energy efficiency measures.

According to modelling in *Our Clean Energy Future*, in the medium term the carbon price is unlikely to be enough on its own. In the absence of a sufficiently high carbon price or some other investment signal there is a strong risk that investment in Australia's renewable energy industry will collapse when the existing RET is not increased after 2020.

Under current renewable energy policy settings, and for all tested carbon prices modelled in *Our Clean Energy Future*, all renewable energy technologies – except for solar hot water and hydro-electricity – will likely cease deployment in 2020. This is because renewable energy prices will not have reached price convergence with the electricity market before the current RET scheme is halted.

To prevent an industry collapse, not only do we need to maintain the current 2020 GWH target, but a post 2020 'safety' RET will be required to meet the cost shortfall between renewable energy costs and energy prices.

Both the carbon price and the RET will only support the cheapest renewable and low pollution technologies as they become cost competitive. A gap will still exist for emerging technologies such as solar thermal, geothermal and wave. Investing in these technologies and resources now will help provide experience that can reduce the cost or risk of future deployments at scale; drive competition; improve market reliability and security; achieve 100% renewables by 2050; and accelerate transition if we need to reduce emissions faster.

The Clean Energy Finance Corporation (CEFC) will help grow some emerging technologies by providing finance to overcome capital market barriers that hinder the financing, commercialisation and deployment of higher cost renewable energy, energy efficiency and low emissions technologies. However the CEFC won't be enough to grow all emerging renewable technologies concurrently, especially post 2020. A post-2020 'Safety' RET should be banded or weighted, with different targets for each renewable energy industry, and with a mechanism to phase out each industry as it achieves cost convergence with the energy and carbon market.

Prior to 2020, WWF remains concerned that the CEFC will be eligible for Renewable Energy Credits (RECs) under the RET scheme but there is no guarantee the projects will deliver renewable energy above and beyond the current 41,000 GWh RET target.

Failure to make CEFC investments additional to the current RET target could create price uncertainty in the RET and add additional barriers and uncertainty to planned investment. It is also an inefficient use of government funding and would constitute a missed opportunity to accelerate Australia's transition to 100% renewable energy.

To provide investor certainty and confidence the RET target should remain legislated as a GWh target and not as a percentage which will change as energy demand fluctuates, and, hopefully reduces form project BAU in line with strong energy efficiency measures.

Recommendations:

1. RET targets inscribed as GWh targets and not percentage targets

To provide investment certainty over the investment timelines for renewable energy projects, the targets legislated in the *Renewable Energy (Electricity) Act 2000* must be inscribed as firm GWh targets and not changed to a percentage target which is subject to fluctuation as energy demand changes.

2. Maintain current RET 2020 GWh target and extend and increase the RET to at least 137,000 GWh by 2030

The Climate Risk analysis finds that it will be critical to increase the RET target out to 2030 to avoid a stalling of the industry after 2020. Given the uncertainty about future carbon prices, increasing the RET will provide a safety net for Australia's renewables industry ensuring there is no investment shortfall if carbon price is low. WWF recommends a 2030 target of between 137,000 GWh to 169,000 GWh which is equivalent to 43% to 53% Business-as-Usual (BAU) electricity projection.

3. Make CEFC projects eligible for, but additional to, the current RET target

To avoid potential price uncertainty in the RET and maximise government funds WWF-Australia recommends making CEFC projects additional to the current RET target. This can be done in two ways:

<u>Option 1 (preferred): Extend and increase the RET target</u>: CEFC projects generate RECs and the RET target is expanded to reflect this investment. This option is consistent with WWF's call to increase the 2030 RET target to at least 137,000 GWh by 2030.

Option2: Replace RECs for CEFC funded projects: For each REC provided to a CEFC project, the government 'tops up' a REC back into the scheme to ensure the integrity of the 2020 target. This mechanism already exists for waste coal mine gas projects under the RET.

4. Band or weight the Safety RET after 2020 to support resources concurrently

The Climate Risk analysis finds that Australia's six main renewable energy sources need to grow concurrently to achieve 100% renewables by 2050, or risk some technologies having to grow at unsustainably high rates at later dates. Current policies such as the carbon price and the current RET design favour low cost technologies first. Banding or weighting the RET will give less developed/more costly technologies a leg up to develop and bring down their cost curves, alongside cheaper renewable technologies.

5. Remove waste coal mine gas from the RET

Waste coal mine gas was included under the RET as a bridge between the cessation of the NSW Greenhouse Gas Abatement Scheme and the introduction of a national carbon price scheme. Now a national carbon price has been introduced there is no longer a need to include waste mine gas technologies in the RET.

6. Maintain small scale Renewable Energy Scheme in its current form

With State Governments significantly reducing feed-in tariff schemes it is important to maintain the small scale Renewable scheme to support and grow the industry until price parity has been reached.

2. Introduction

WWF-Australia welcomes the opportunity to submit its views on the *Renewable Energy Target Review* being conducted by the Climate Authority.

WWF's goal is for a reduction of greenhouse gas emissions to keep the global temperature increase well below two degrees Celsius above pre-industrial levels and to achieve 100% global renewable energy by 2050.

Through the Cancun Agreements, Australia and the rest of the international community have agreed that the global aim should be to keep emissions below 2 degrees Celsius. According to the Australian Government, for this global goal to be met Australia will need to take on a national greenhouse gas (GHG) emissions targets of 80% below 2000 levels by 2050 (now legislated) and by between 5-25% below 2000 levels by 2020.To contribute its fair share and minimise risks of tipping points and overshoot, WWF believes Australia must aim for national emissions reductions of at least 25% below 1990[1] levels by 2020 and at least 90% by 2050. WWF also believes it is in Australia's best interest

[1] We acknowledge that a final decision on the 2020 target will be not be made until 2014 at the earliest as part of the cap setting process for the emissions trading scheme. In the meantime it is vital that we continue to build a policy and regulatory framework that is capable of delivering the full range of short- and long-term targets and lay the foundations for the transition to a low carbon economy faster if we need to.

economically to try and achieve these reductions domestically, and our modelling shows that this is achievable.

As new scientific evidence comes to the fore, even stronger targets may be necessary and must be anticipated. Indeed it is possible that the goal posts will shift and that the world and Australia will need to act faster and make deeper cuts. Ensuring our energy sector can transition faster if need be, is therefore essential.

The energy sector is the major contributor of Australia's greenhouse gas emissions and will also need to do more of the heavy lifting as some sectors like agriculture may struggle to meet required emissions reduction targets. This means the energy sector will need to undergo massive transformation over the coming decades, shifting to 100% renewable energy, if we are to meet our global and domestic targets. Given that energy projects have long lifespans of between 15 and 30 years, investments made now have repercussions for how the energy market will look in 20-30 years' time. Providing stable long-term policies is important for investors and industry.

Australia will need to add a wide number of clean energy technologies and resources into the energy market as early as possible to create a diverse, competitive, and reliable energy market that can decarbonise faster, if science and governments deem necessary. This requires governments to foster concurrent development of renewable industries now and not wait for each technology to become 'cost competitive' in its own time. Is it achievable?

Globally the clean energy revolution has already begun. Global investments in 2011 in renewable energy climbed to USD$257 billion, a six-fold increase since 2004.[2] More money is now invested in new renewable power than conventional high pollution energy generation.[3]

In 2011, WWF International and leading renewable energy consultants, Ecofys, released a report arguing that the world could achieve 100% renewable energy by 2050. The report showed that such a transition is not only possible but also affordable and cost effective. If 100% renewable energy can be achieved globally, where currently 1.4 billion people do not have access to reliable electricity, then surely the same can be achieved in Australia.

Indeed, Australia has no shortage of renewable energy. Australia receives an average of 58 million Peta Joules (PJ) of solar radiation per year, approximately 10,000 times larger than its total energy consumption[4]. Geothermal could provide 26,000 times our annual energy consumption[5]. Near-shore wave energy can provide approximately four times our current national power needs, including 35 per cent of our baseload power needs[6]. We also have world class skills, infrastructure and know how.

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[2] http://www.map.ren21.net/GSR/GSR2012.pdf
[3] http://www.bloomberg.com/news/2011-11-25/fossil-fuels-beaten-by-renewables-for-first-time-as-climate-talks-founder.html
[4] http://www.ga.gov.au/energy/other-renewable-energy-resources/solar-energy.html
[5] http://www.agea.org.au/media/docs/aboutgeoengfactsheetfinala4lowres.pdf
[6] https://www.cleanenergycouncil.org.au/technologies/marine.html

Not surprisingly, polling shows that renewable energy also has strong public support.[7] The average Australian can see the great potential in renewable energy.

Shifting to 100% renewable energy represents a significant increase from the current levels, but the momentum is there for this transition to happen within the coming decades. While renewable resources currently supply only 10% of Australia's electricity needs and approximately 4% of total primary energy consumption, there has been strong growth in recent years.[8] Renewable energy now dominates investment activity in Australia's power sector, with over $3 billion of renewable projects in the advanced stage of development, almost double that for coal and gas. Across Australia there are more than 120 renewable energy projects at various stages of development, with a combined capacity of over 23,000 MWh and worth more than $41 billion.[9]

Recent analysis by Worley Parsons for the Australian Government shows that Australian renewable energy is expected to become increasingly competitive over the coming decades.[10] In some circumstances renewable energy technologies are now competitive with fossil fuel sources. For example:

- In the US, Brazil, Sweden and Mexico wind power projects have displayed a levelised cost of energy of around US$68/MWh, compared to US$67/MWh for coal and US$56/MWh for gas.[11]
- Solar PV has reached retail grid parity for three out of four Australians – everywhere except Victoria, Tasmania and Canberra.[12]
- In South Australia where wind contributes to 21% of the state's electricity, wholesale prices have not increased over the past five years and in fact have dropped from $50/MWh to $49/MWh in that time period. Wind is now routinely displacing more expensive technology like open cycle gas.[13]

Given the global momentum towards renewable energy growth, WWF-Australia commissioned Climate Risk to assess:

- The feasibility of achieving a transition to 100% renewable energy in Australia, with a particular focus on the electricity sector;
- A plausible timeline for achieving this transition; and
- The impact that different policy settings will have on the transition to 100% renewable energy.

[7] TCI (2012) Climate of the Nation. http://www.climateinstitute.org.au/verve/_resources/TheClimateOfTheNation2012_Final.pdf
[8] Bureau of Resources and Energy Economics (2012) *2012 Australian Energy Update*, available online at: http://www.bree.gov.au/documents/publications/energy/BRE0133EnergyUpdate2012.pdf.
[9] Analysis of BREE data from: http://www.bree.gov.au/documents/publications/energy/elec-generation-projects-appendix.xls
[10] http://www.bree.gov.au/documents/publications/Australian_Energy_Technology_Assessment.pdf
[11] http://bnef.com/PressReleases/view/139
[12] Andrew Blakers is the Director of the Centre for Sustainable Energy Systems and the ARC Centre for Solar Energy Systems at the Australian National University http://theconversation.edu.au/solar-will-force-coal-and-nuclear-out-of-the-energy-business-2557
[13] Osmond and Osborne (2011) Peaking Capacity, Co2-e emissions and pricing in the South Australian Electricity Grid with high wind penetration. Windlab systems Pty Ltd.

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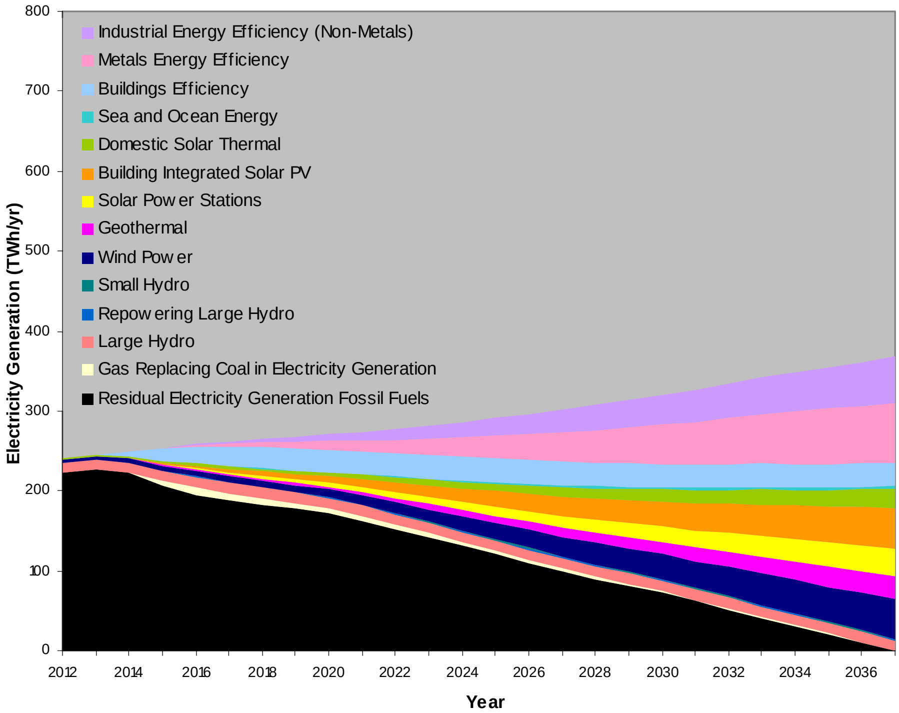
The report, *Our Clean Energy Future*, finds the transition to 100% renewable energy can be achieved in the Australian electricity sector as early as 2037 with stable industry growth rates of 20% per annum, not including electricity demand increase due to electrification in the transport sector (see figure 1 for growth wedges of renewable energy resources).

Figure 1: Energy wedge diagram for the 100% Constrained Renewable Scenario showing the deployment of renewable energy in the electricity generation sector assuming no additional baseline demand from the electrification of automotive transport.



To allow renewable energy to meet transport sector needs, electricity generation baseline demand can be expected to increase significantly. When this expanded demand is taken into consideration, the attainment of 100% renewable electricity in Australia is delayed to 2050 (at industry growth rates of 20% per annum). See figure 2 for growth wedges of renewable energy resources catering for electrification of land based transport.

Figure 2: Energy wedge diagram for the 100% Renewable scenario showing the deployment of renewable energy in the electricity generation sector with the additional baseline demand from the electrification of automotive transport (COA 2011a).

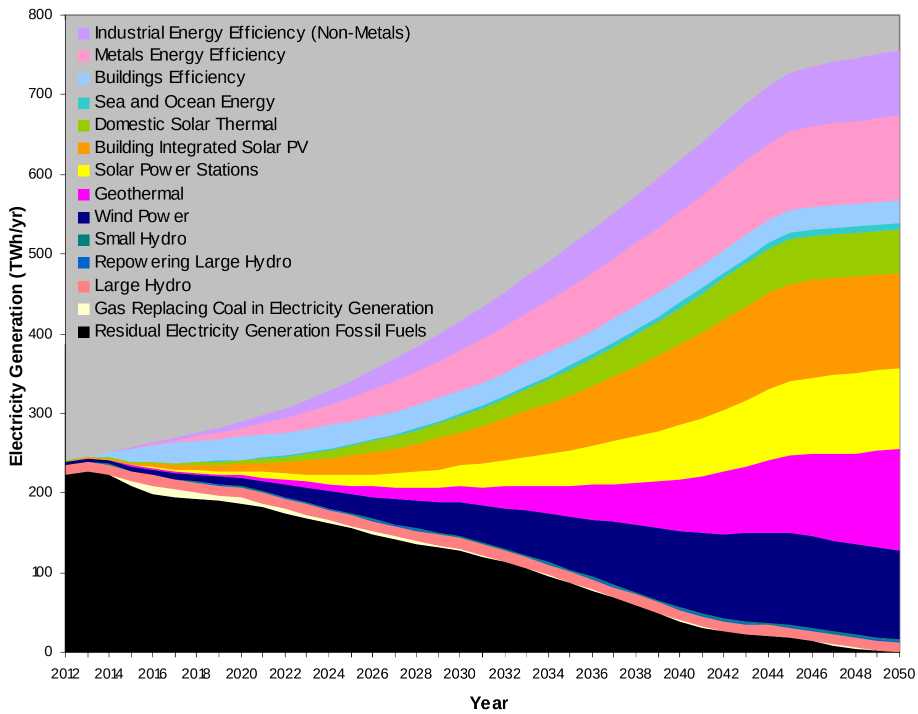


Table 1 below shows the amount in TWhs and fraction of renewable energy generation required between now and 2050 to achieve 100% renewable energy. It is important to note that the modelling importantly assumes higher energy efficiency take-up than BAU[14], which means that renewable energy percentages presented in the table are higher than those quoted for the current RET which are with respect to BAU.

Table 1: The fraction of renewable energy in electricity generation from 2020 to 2050

	Renewable Generation (TWh) and Fraction of Total Electricity Generation (%)			
Year	When Additional Electricity Demand from Transport Electrification is Excluded		When Additional Electricity Demand from Transport Electrification is Included	
2020	45	20%	48	20%
2025	87	41%	102	39%
2030	130	64% (41% BAU)	169	57% (53% BAU)
2035	184	90%	272	76%
2037	206	100%	321	83%
2040		100%	399	91%
2045		100%	508	97%
2050		100%	538	100%

(Note: Because the modelling assumes higher energy efficiency than current Bureau of Resources and Energy Economics (BREE) (2011) and Treasury (2011) BAU, the percentages in the table are higher than those currently quoted for the current RET, and for context equivalent BAU percentages have been included for the 2030 period.)

3. Transport missing in action

The report *Our Clean Energy Future* argues that if we are to achieve 100% renewable energy in all energy sectors, then we must tackle transportation. Transport accounts for approximately 15.3 per cent[15] of Australia's emissions profile and rising.

However there are very few policies currently aimed at reducing emissions in this sector, for example transport was effectively excluded from the carbon price.

There have been some trends to reduce GHG emissions from vehicles, including greater fuel efficiency standards, inclusion of biofuels in fuel mix, the production of hybrid cars that use a mix of petrol and electrification, and fully electrified vehicles.

Our Clean Energy Future suggests that to achieve 100% renewable energy by 2050, Australia will need to significantly transform our transport sector shifting from combustion engines and their reliance of liquid to an electric automotive transport system. At the same time, allocate of bio-hydrocarbons to aviation and shipping.

[14] Energy and emissions baselines are a combination of BREE (2011) and Treasury (2011)
[15] DCCEE (2011) Australian National Greenhouse Accounts: National Greenhouse Gas Inventory – December 2010, pg 10. http://www.climatechange.gov.au/~/media/publications/greenhouse-acctg/national-greenhouse-gas-inventory-accounting-december-quarter-2010.pdf

WWF-Internationals 2009 report "Plugged In: The End of an Oil Age", outlined how the electrification of automotive transport offers a promising way forward[16.] According the report, grid-connected vehicle technology is available based on existing infrastructure and current technology. Battery electric vehicles (BEVs) and as a transition, plug-in-hybrid electric vehicles (PHEVs) – which may be supported by sustainable biofuels for range extension – can dramatically reduce the crude oil dependency of automotive transport in a highly efficient and sustainable manner[17].

A report by McKinsey & Company "Roads Toward a Low Carbon future" finds that a shift towards an electric transport system achieves the greatest amount of emission reductions by 2030 and has greater longer term emission savings, than a 'mixed technology scenario' and a 'fuel efficient combustion engine scenario'.[18]

Electrifying Australia's transport system will require some level of planning, including infrastructure for charging facilities, incentives to switch to electric vehicles and strong signal to vehicle manufacturers. WWF believe the Government should prepare a White Paper on electrification of Australia's transport system to begin laying the foundations for transition.

In the meantime, the shift towards the electrification of the automobile is already underway at considerable speed. The Australian Energy Market Commission released Draft Recommendations in September 2012 for changes to regulations to support the efficient integration of electric cars into the National Electricity Market. Therefore we should be planning now for increasing demand in the electricity sector and ensure we have the growth in renewable energy to meet the increased electricity demand.

4. Safety RET

Emission trading and its carbon price will play a critical role in transitioning to renewable economy, by bringing forward the cost competitiveness of each renewable energy in the open electricity market, but the analysis in *Our Clean Energy Future* shows that under all price scenarios[19] a carbon price is not enough on its own to provide industry development continuity until cost convergence is achieved.

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[16] WWF (2009) Plugged In: The End of an Oil Age. http://awsassets.panda.org/downloads/plugged_in_full_report___final.pdf

[17] WWF (2009) Plugged In: The End of an Oil Age. http://awsassets.panda.org/downloads/plugged_in_full_report___final.pdf

[18] McKinsey (2009) Road Towards a Low-Carbon Future: reducing Co2 emissions from passenger vehicles in the global transportation system. http://www.mckinsey.com/clientservice/ccsi/pdf/roads_toward_low_carbon_future.pdf

[19] The High Carbon Price and Core Carbon Price trajectories used in this report are taken from Treasury figures published in the "Strong Growth, Low Pollution: Modelling a Carbon Price" report (COA 2011a, COA 2011b). The Low Carbon Price projection (which falls to AU$4/tCO2e in 2018 and rises linearly to AU$30/tCO2e in 2050) is made up from low international carbon market forecast data from Bloomberg New Energy Finance and the European Commission (BNEF 2012, BNEF 2011, BNEF 2010, EC 2006).

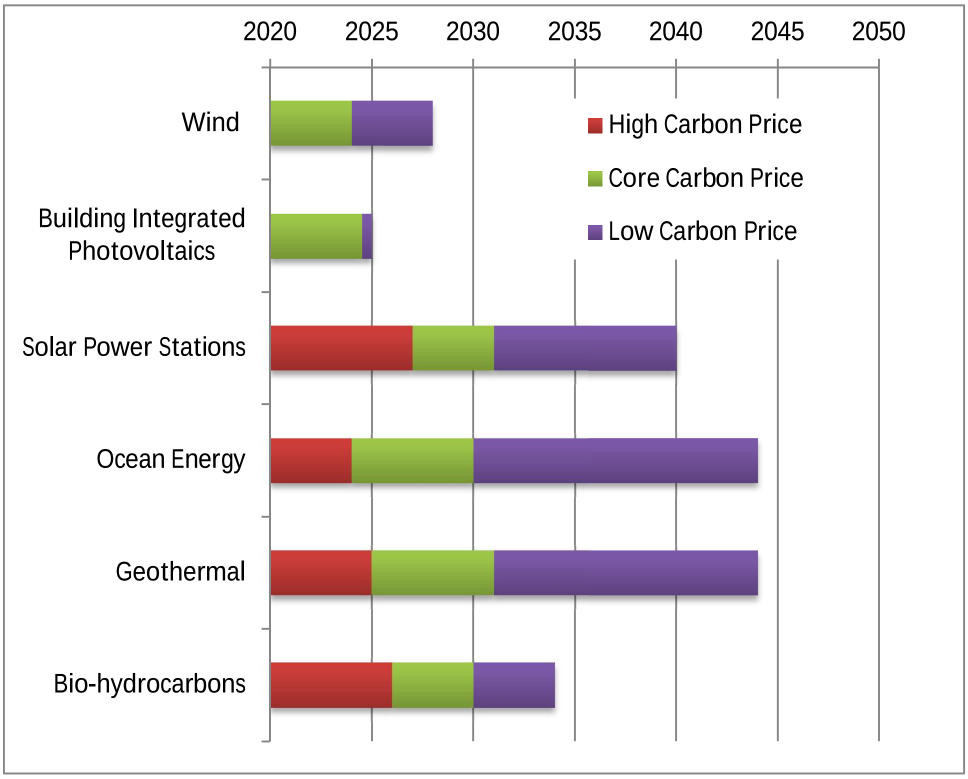
The report examined the additional cost of employing low-carbon energy technologies above the business-as-usual price of energy (including carbon price) that would otherwise have been incurred, i.e. the marginal cost of abatement. The analysis found that under:

- Only the highest Treasury carbon price forecast is sufficient to avoid the need for ongoing renewable energy investment post-2020.
- Other estimates of carbon price require at least a further AU$13 billion to be spent in the 2020-2030 period.
- Removing the carbon pricing scheme would leave an AU$67 billion deficit in low-carbon energy investment requirements that would need to be met using other policy measures.

The report then looked at the performance of the current Renewable Energy Target (RET) and the role of a RET beyond 2020.

The report found many of the renewable energy technologies deployed under the 2020 RET of 20% will not have reached grid parity by this time. Assuming the RET and current renewable energy finance mechanisms (such as the CEFC and ARENA) are not extended beyond 2020, there is insufficient market incentive to maintain growth in these industries unless there is either a sufficiently high and reliable carbon price, or an alternative mechanism to bridge the price shortfall. Under current emission trading and renewable energy policy settings (no increase of the RET after 2020), most renewable energy industries will collapse in 2020 and cease project development for between 4 and 32 years until cost convergence is achieved subject to carbon price, see Figure .

Figure 3: The duration of renewable energy industry collapse and stall for each of the carbon prices once the current RET finishes in 2020.



The only exceptions are large hydro and solar hot water (regardless of carbon price), and wind energy and building- integrated solar photovoltaics[20] (under the highest high carbon price scenario). To prevent an industry collapse, it is recommended that a post-2020 'Safety Net' Renewable Energy Target be implemented to meet the cost shortfall between renewable energy costs and energy prices.

Table 1 above shows that a 2030 RET target of 169,000 GWh (which is equivalent to a percentage target of 53% of BAU) would avoid a stalling of the renewable energy industry post-2020, maximise the industry development in line with achieving 100% renewable energy by 2050 and accommodate electrification of the transport sector.

A low 2030 RET of 137,000 GWh (which is equivalent to a percentage target of 43% of BAU) is possible but it would defer renewable industry growth until after 2030 (see table 2) which would require renewable industries to grow at close to their maximum plausible growth rate (30% per annum) after 2030 to deliver 100% renewable energy by 2050. This scenario carries very high risks of failure as there is no room for industry underperformance, and worse, could push companies onto financially vulnerable business development pathways.

Table 2. 2030 Renewable energy targets when de-carbonised transport needs are included

2030 Renewable electricity generation (TWh)	2030 RET using BAU electricity demand only	2030 RET with energy efficiency measures and transport electrification	Industry growth rate post-2030 required to meet 100% renewable electricity by 2050
169	53%	57%	20%
159	50%	53%	23%
137	43%	46%	>27%

5. CEFC eligible but additional to 2020 RET target

As outlined in WWF submission to the Senate Economics Committee Inquiry into the Clean Energy Finance Corporation Bill,[21] WWF supports CEFC projects being eligible for Renewable Energy Certificates (RECs) under the RET legislation. This is likely to be important to ensure the projects are commercially viable, especially while current projections are that the carbon price may be lower in the short-term than originally thought[22]. However, WWF believes the investments made through the

[20] Conservative assumptions were made with respect to Solar PV, including (1) the SRES would end by 2020, and (2) forecasts were based on long-term learning rate cost reduction trends rather than short-term cost reduction phenomenon. See *Our Clean Energy Future* Report for more details.

[21] http://www.aph.gov.au/Parliamentary_Business/Committees/Senate_Committees?url=economics_ctte/clean_energy_corporation_bill_2012/submissions.htm, Submission 5. WWF

[22] For example Bloomberg New Energy Finance modeled the carbon price to be at AUD $17.50 in 2020 http://bnef.com/PressReleases/view/162

CEFC should support projects that will deliver renewable energy above and beyond the current 20% Renewable Energy Target (RET). Currently there is no guarantee this will happen.

The current 20% RET will see up to an estimated $19 billion in private capital invested in the most cost effective commercial scale renewable energy technologies (primarily wind).[23] It makes sense to ensure the CEFC does not interfere with that investment pipeline. Rather it should be invested in technologies where private sector investment is not flowing, with emphasis on emerging technologies, which will help make market based mechanism such as the RET and the carbon price, as well as the energy market, more efficient and cost effective in the longer term.

Published analysis of the potential new renewable energy generating capacity from the CEFC range from 1.5GWh by ClimateWorks Australia through to 7GWh by Bloomberg New Energy Finance[24], while a US Department of Energy Loan Guarantees Program investing US$10 billion led to approximately 3GW of new solar energy generation and 2.5GW of annual PV production capacity[25]. So while there is uncertainty as to how much renewable capacity could be deployed through the CEFC, what is clear is there is potential for a substantial amount of new renewable capacity beyond what the 20% RET is already scheduled to deliver.

WWF is therefore concerned that by making CEFC projects eligible for but not additional to the current RET two things may happen:

1. The 20% RET target will act as a "cap" on renewable energy deployment, so CEFC projects will effectively just displace current planed renewable projects, meaning there would not be additional renewable in the grid beyond the 20%. This is likely to be the case if the carbon price remains low out to and beyond 2020; and
2. It could create price uncertainty in the RET and add additional barriers and uncertainty to planned investment.

However, if the CEFC is additional to the RET, Australia could reap the benefits of increased private investment, more jobs and a faster transition to a clean energy future.
What is also clear is that not making CEFC projects additional to the current RET target is an inefficient use of carbon price revenue (Government funds) and a wasted opportunity.
There are at least two clear options to ensure that CEFC projects are above and beyond the 20% target:

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[23] MMA (2010), *Impacts of Changes to the Design of the Expanded Renewable Energy Target*, Report to the Department of Climate Change and Energy Efficiency.
[24] ClimateWorks Australia (2011), *Low Carbon Growth Plan for Australia, 2011 Update*; Australian Solar Energy Society (2012), *Australian Solar Energy Society Welcomes New Solar Flagships Arrangements* accessed at http://www.aapmedianet.com.au/MNJ/Release.aspx?R=727361&K=8685907
[25] National Renewable Energy Laboratory (2011), *DOE helps 'guarantee' future for solar*, accessed at https://financere.nrel.gov/finance/content/doe-helps-guarantee-future-solar-0

- Option1: Replace RECs for CEFC funded projects: For each REC provided to a CEFC project, the government 'tops up' a REC back into the scheme to ensure the integrity of the 20% target. This mechanism already exists for waste coal mine gas projects under the RET.

- Option 2: Expand and extend the RET target: CEFC projects generate RECs and the RET target is expanded to reflect this investment.

6. Band or weight the RET after 2020 to support resources concurrently

The Climate Risk analysis finds that Australia's six main renewable energy sources need to grow concurrently to achieve 100% renewables by 2050, or risk some technologies having to grow at unsustainably high rates (greater than 30%) at later dates.

Current policies such as the carbon price and the current RET design favour low cost technologies first. Less commercially developed and currently more expensive renewable energy resources and technologies are less attractive to investors under the carbon price and the current RET scheme, however the present significant opportunity to provide low cost energy in the longer term.
WWF recommends the 'Safety ' RET be banded or weighted with specific regulated targets/weights for each renewable resource and and with a mechanism to phase-out each industry as it achieves cost convergence with the energy and carbon market.

Banding or weighting the RET will give less developed/more costly resources a leg up to develop and bring down their cost curves, alongside cheaper renewable resources and technologies.
Note that this is a 'technology neutral' approach as it does not specify the technology that is necessary to harness each resource.

This banding mechanisms is also useful for economic efficiency as a means of phasing industries out of the RET as they become competitive in the open electricity market.

There is already some precedence with the current RET having two bands - one to support small-scale renewable energy and one band for large-scale renewable technology.

Unless the suggested changes are made to the RET, additional deployment mechanisms such as large scale feed-in-tariffs will be needed.

7. Conclusion

Transitioning to 100% renewable energy is necessary, desirable, technically achievable, affordable, and popular amongst Australian's.

The report, *Our Clean Energy Future*, shows that even under a high carbon price scenario not only should the current 2020 RET target remain, but an increase in the RET out to 2030 will provide an important safety net to prevent a collapse in many renewable industries. It will also maintain renewable energy industry development until each achieves cost convergence with the energy and carbon markets.

Arguments that a RET is too costly per tonne of emissions, ignores its role beyond pure emissions reductions, such as developing a secure, competitive and reliable energy market that can decarbonise faster if science and governments deem necessary. Banding the RET post 2020 maximises its effectiveness.

Consideration must also be given to how we tackle emissions from transportation. Electrification of land based transport sector is feasible and we should be planning now for increasing demand in the electricity sector and to ensure we have the growth in renewable energy to meet the demand.

WWF urges the Climate Authority to recognise the benefits to Australia's economy, society and environment of a transition to 100% renewable energy and the critical role the RET can play in achieving this transition.

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WWF REPORT AUS 2012

THIS REPORT HAS BEEN PRODUCED IN COLLABORATION WITH:

Climate Risk

Our clean energy future

100% renewables powering Australia’s future

WWF

WWF-Australia is part of the WWF International Network, the world's largest and most experienced independent conservation organisation, with over 80,000 supporters in Australia, five million supporters worldwide and a global network active in more than 100 countries.

Our mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

CLIMATE RISK

Climate Risk Pty Ltd provides professional services to business and government on risk, opportunity and adaptation to climate change in Australia and Europe. Climate Risk also provides software and proprietary modelling for the quantification of risk, cost-benefit-analysis and for policy analysis.

Climate Risk and its staff are committed to non-government and not-for-profit organisations have access to the best people, analysis and modelling to ensure advocacy based on the best possible information. The company welcomes WWF's development of policy recommendations based on the findings presented in this report and takes full responsibility for the validity of the data and models used.

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Foreword

In 2012, we are witnessing the beginning of the clean energy revolution. Global investments in 2011 in renewable energy climbed to USD$257 billion, a six-fold increase since 2004. Last year more money was invested in new renewable power than conventional high-pollution energy generation.

So where is Australia?

Donald Horne once penned the term "Australia the lucky country", not as a positive term, but as an ironic indictment of Australia's lack of innovation and enterprise in the 1960s. He argued, as a nation, we were lucky to develop at a time when we weren't being particularly clever.

Now, as the world begins the clean energy revolution, Donald Horne's ironic use of Australia as the lucky country is invoked again, for similar reasons, but with a twist. In the case of access to abundant renewable energy resources, Australia truly is the lucky country – but are we being clever?

Australia has no shortage of renewable energy. We have some of the world's highest solar irradiance. We have average wind speeds that are much higher than those available for most countries. Our geothermal resource is capable of providing 26,000 times our annual energy consumption. Our near-shore wave energy has the potential to provide approximately four times our current national power needs. We also have world class skills, infrastructure and know how.

Not surprisingly polling shows that renewable energy also has strong public support. The average Australian can see the great potential in renewable energy. As too can some business who are already seizing on the opportunities and prosperity a clean energy revolution can bring to Australia – they should be congratulated.

So why in 2012 are only 4% of Australia's total energy needs coming from renewable energy? Why are some of Australia's largest business and industry associations calling for mechanisms that support renewable energy development in Australia, like the Renewable Energy Target (RET) and the carbon price, to be scrapped or pulled back? Why are these business and industries standing in the way of our transition to a clean renewable economy? And why aren't we being the clever country, taking advantage of our abundant natural renewable resources to transform our energy sector and establish a globally competitive low cost, low carbon economy?

In 2011, WWF-International and leading renewable energy consultants, Ecofys, released a report arguing that the world could achieve 100% renewable energy by 2050. The report showed that such a transition is not only possible but also affordable and cost effective. If 100% renewable energy can be achieved globally where currently 1.4 billion people do not have access to reliable electricity, then surely the same can be achieved in Australia.

WWF called on the expertise of respected energy and climate consultants Climate Risk – known for their work with industry, infrastructure and government – to answer to the question: Given our large fossil fuels energy sector and heavy reliance on oil for transport, how quickly can we achieve a transition to 100% renewable energy in Australia?

This report, containing the results of the Climate Risk computational analysis, shows that a transition to 100% renewable energy is achievable with the right policy settings. It will also show that this scale of shift is not only possible, but is necessary to reduce our carbon pollution in line with Government targets.

What we need now is for governments and business to move boldly to bring the renewable economy into reality. Then we can truly say we are the lucky country.

Dermot O'Gorman
CEO, WWF-Australia

Contents

EXECUTIVE SUMMARY

1. About this study

WWF-Australia commissioned Climate Risk to assess:

- The feasibility of achieving a transition to 100% renewable energy in Australia, with a particular focus on the electricity sector;
- A plausible timeline for achieving this transition; and
- The impact that different policy settings will have on the transition to 100% renewable energy.

Climate Risk used a probabilistic computational model designed to capture real world industrial growth patterns and constraints. To ensure the analysis is plausible the following constraints were applied:

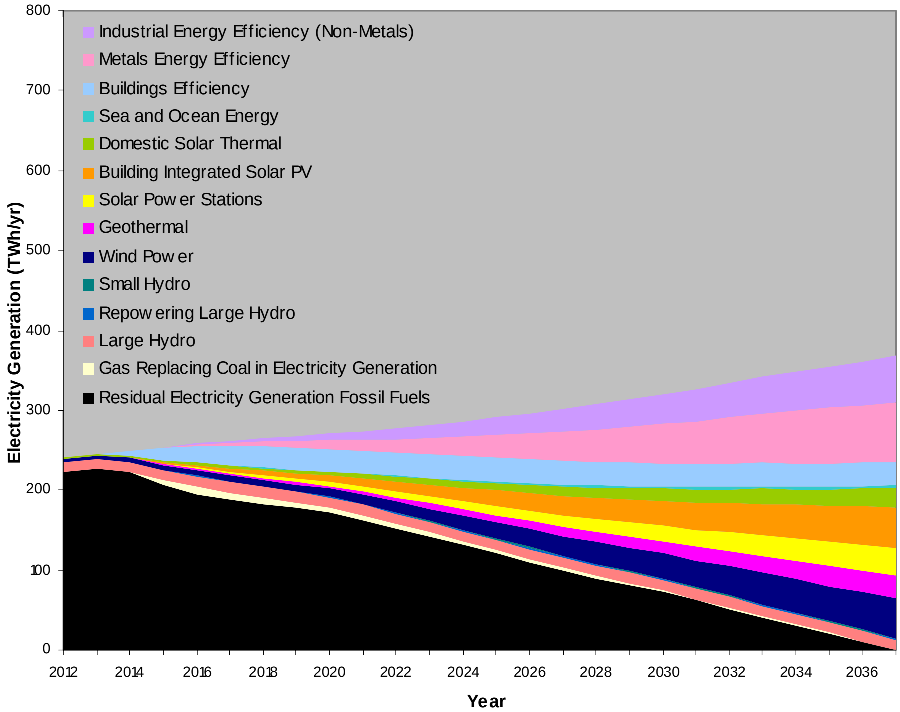
- Industrial growth – which underpins the deployment of renewable energy projects – is constrained to levels consistent with empirical growth rates in renewable and related industries.[1]
- The scenarios are consistent with current national emission goals of 80% emission cuts by 2050. Where relevant, the implications of possible increases in this 80% target – subject to international negotiations – are noted.
- The growth of energy efficiency uptake across both stationary energy and transport is accounted for, as is the growth in electricity demand required to supply (directly or indirectly) the electrification of land-based transport (e.g., from electric automobiles).
- Renewable energy is deemed to exclude carbon capture and storage (CCS) and coal seam methane.

2. Major results

1. The transition to a 100% renewable energy supply could be achieved in the Australian electricity sector as early as 2037, with stable industry growth rates peaking at 20% per annum. This result includes the effects of increased energy efficiency growth, but not those of increased electricity demand due to electrification in the transport sector (see Figure 1).

[1] (Mallon, Hughes and Kidney 2009).

Figure 1: Energy wedge diagram for the constrained renewable energy scenario showing the deployment of renewable energy in the electricity generation sector, assuming no additional baseline demand due to electrification of automotive transport.



2. For renewable energy to meet almost all land-based transport sector needs, an additional 305 terawatt hours (TWh) per year by 2050 would be required. Taking this expanded demand taken into consideration, 100% renewable electricity in Australia could be achieved by 2050 (based on industry growth rates that peak at 20% per annum). See Table 1.

Table 1: The fraction of renewable energy in electricity generation from 2020 to 2050. Note the model assumes higher energy efficiency uptake than business as usual (BAU)[2]. This results in higher projected renewable energy percentages than those quoted for the Renewable Energy Target (RET), which are with respect to BAU.

	Renewable Fraction of Total Electricity Generation (TWh and %)			
Year	When Additional Electricity Demand from Transport Electrification is Excluded		When Additional Electricity Demand from Transport Electrification is Included	
2020	45	20%	48	20%
2025	87	41%	102	39%
2030	130	64%	169	57%
2035	184	90%	272	76%
2037	206	100%	321	83%
2040			399	91%
2045			508	97%
2050			538	100%

3. Emissions trading and the associated carbon price will play a critical role in bringing forward the cost competitiveness of each renewable energy industry in the open electricity market. However, the analysis shows that under all price scenarios a carbon price is not, on its own, sufficient to provide renewable industry development continuity until cost convergence with conventional sources is achieved.

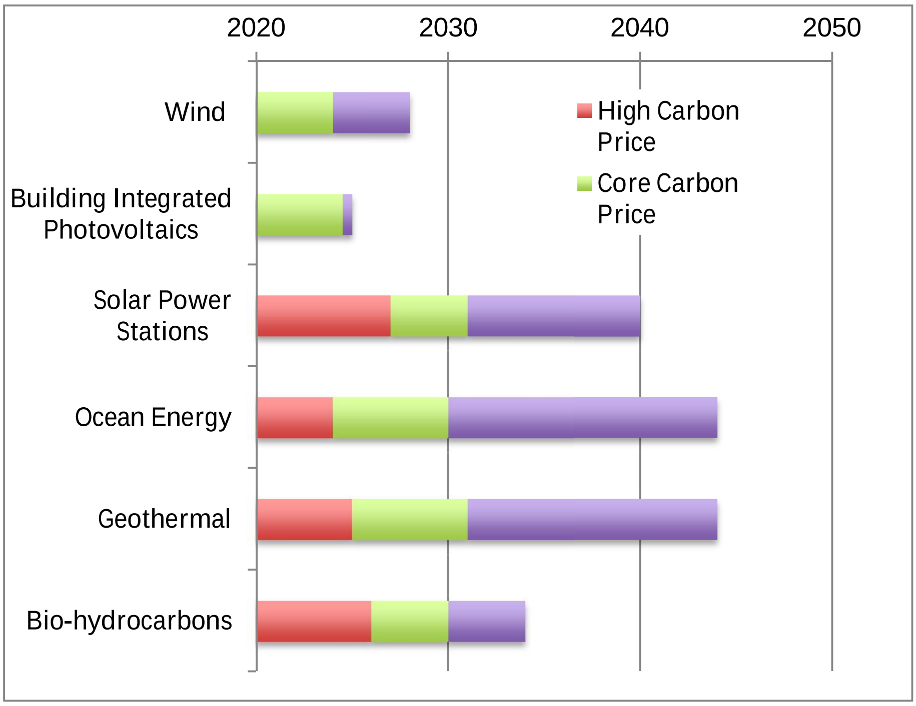
4. Under the "100% electricity by 2050" pathway, each of the renewable industries considered is projected to independently achieve cost competitiveness in the electricity market between 2018 and 2025 under the High

[2] Energy and emissions baselines are a combination of BREE (2011) and Treasury (2011).

Carbon Price Scenario; between 2022 and 2031 under the Core Carbon Price Scenario; and by 2026 to 2046 even with a Zero Carbon Price scenario.

5. Under current emission trading and renewable energy policy settings (no increase in the RET after 2020), the analysis finds that most renewable energy industries will collapse in 2020 and cease project development for between 4 and 32 years until cost convergence is achieved, subject to carbon price; see Figure 2. Exceptions are large hydro and solar hot water (regardless of carbon price), and wind energy and building-integrated solar photovoltaics (PV) (under the High Carbon Price Scenario).

Figure 2: The duration of renewable energy industry collapse and stall upon no increase in the RET post 2020, at different levels of carbon price.

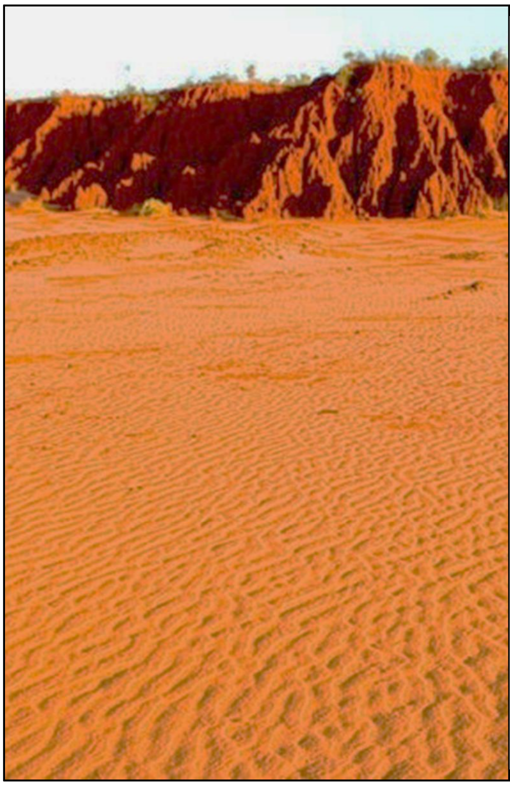


6. Removing the carbon-pricing scheme altogether would leave an AUD$67 billion deficit in low-carbon energy investment requirements; this shortfall would need to be addressed using other policy measures.

3. Policy implications

- To prevent a renewable energy industry collapse post-2020, a "Safety Net" Renewable Energy Target would be required to meet the cost shortfall between renewable energy costs and energy prices.
- A 2030 RET target of between 137,000 gigawatt hours (GWh) per year to 169,000 GWh per year (equivalent to 43-53% of BAU) is required, to avoid a post-2020 renewable energy industry stall, to maximise this industry's development in line with achieving 100% renewable energy by 2050, and to accommodate electrification of the transport sector, which may also seek to use renewable energy.
  - It is possible to deliver 100% renewable energy by 2050 with a low 2030 RET of 137,000 GWh (equivalent to a percentage target of 43% of BAU) but this would defer renewable industry growth until after 2030. This level of RET would require close to the maximum plausible renewable industry growth rates (30% per annum) after 2030. This scenario carries very high risks of failure as there is no room for industry underperformance; worse, this scenario could push companies toward business development pathways that expose them to financial vulnerability.
  - To prevent the monopolising of a Renewable Energy Target by the lowest-cost renewable energy industry, the post-2020 RET should be "banded". That is, each renewable energy resource should have a designated target appropriate to its scale of development. Additionally, a mechanism to phase out support for each industry once it achieves cost convergence with the energy and carbon market would prevent "free-riders".

- In addition to continuing the RET and other renewable investment mechanisms (like the Clean Energy Finance Corporation [CEFC] and Australian Renewable Energy Agency [ARENA]) post-2020, achieving a 100% renewable energy by 2050 will require other, complementary policy measures in Australia. These complementary policies will need to:
    - Foster electrification of the automotive transport sector, encouraging the adoption of electric vehicles and use of rail alternatives where possible;
    - Support the uptake of bio-hydrocarbon resources in aviation and shipping; and
    - Prioritise the use of CCS capacity for industrial processes that cannot currently be converted to renewable alternatives.



4. WWF Recommendations

1. Retain the carbon price
2. Extend and increase the RET to at least 137,000 GWh by 2030
3. Band or weight the RET after 2020 to support resources concurrently
4. Set a national energy efficiency target and scheme
5. Produce a White Paper for the electrification of the transport system
6. Set emissions performance standard for electricity generation
7. Reform National Electricity Market and invest in smart grids and smart meters, and overcome infrastructure barriers.

PART 1 – WWF PERSPECTIVE

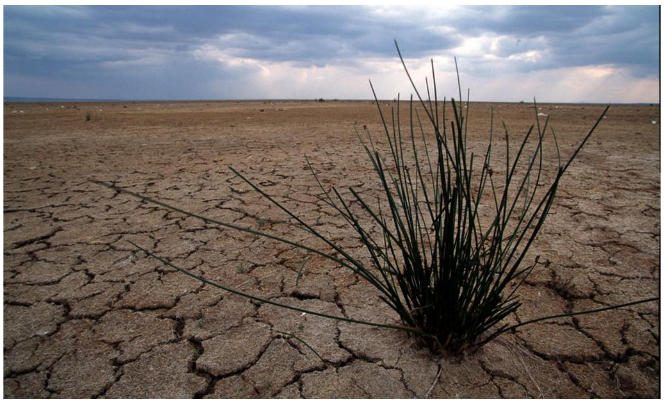
"WWF has a vision of a world powered by 100% renewable energy sources by the middle of this century and Australia leading the way"

1. A Renewable Energy Future - Why We Need It

WWF has a vision where our homes, businesses, industries and modes of transport are powered by cheap renewable energy, where we use energy smarter, our standard of living has improved, we live healthier lives and our unique environmental icons – like the Great Barrier Reef, marine turtles and polar bears – are thriving. WWF believes transitioning to 100% renewable energy is affordable and achievable and, as outlined below, in Australia's national interest.

Tackling climate change

It is widely accepted that, of developed countries, Australia has the most to lose from ongoing climate change.[3] Already, endangered species and ecosystems in Australia are suffering the impacts of climate change. Climate change is harming iconic Australian species such as marine turtles[4] and Carnaby's black cockatoos[5]; and precious ecosystems like the Great Barrier Reef[6]. Some scientists fear that unless we address climate change we could lose up to a quarter of all species.[7]



To avoid the worst impacts of climate change, we urgently need to slow then reverse the build-up of greenhouse gases in the atmosphere. Globally, energy use accounts for around two-thirds of annual greenhouse gas emissions, with coal, oil and gas the biggest contributors. In Australia the situation is even worse, with close to three quarters of emissions coming from the energy sector. Our electricity grid is ranked in the top ten most polluting in the world.[8]

Transitioning to 100% renewable energy along with improved energy efficiency is one of the best ways we in Australia, and the world, can achieve rapid emission reductions.

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[3] Garnaut (2011) Carbon Pricing and Reducing Australia's Emissions. Climate Change Review Update 2011:Update paper 6, pg.6. http://www.garnautreview.org.au/update-2011/update-papers/up6-carbon-pricing-and-reducing-australias-emissions.pdf
[4] WWF (2008) Australian Species and Climate Change. http://awsassets.wwf.org.au/downloads/sp029_australian_species_and_climate_change_25mar08.pdf
[5] Saunders, D.A., Mawson, P. and Dawson, R (2011) The impact of two extreme weather events and other causes of death on Carnaby's Black Cockatoo: a promise of things to come for a threatened species? Pacific Conservation Biology Vol.17: 141–148. Surrey Beatty & Sons, Sydney. 2011.
[6] http://www.gbrmpa.gov.au/our-partners/connecting-with-the-community
[7] http://www.nature.com/nature/journal/v427/n6970/abs/nature02121.html
[8] Climate Analysis Indicators Tool (CAIT) Version 8.0., Washington, DC: World Resources Institute, 2011.

Energy security and affordability

Australian energy consumers are increasingly at the mercy of fluctuations in global energy prices. Most people understand that the price of petrol will rise and fall with the global oil price, but what is less well understood is that the prices of coal and gas are also increasingly determined by international prices.

In the short to medium term, as the global population continues to rise, demand for fossil fuels will also grow. At the same time, the supply of some fossil fuels – particularly conventional oil – is also expected to slow. As more people compete for fewer resources, this will place upward pressure on global energy prices.

While some are considering filling the energy supply gap with unconventional sources such as shale gas and oil from deep water platforms, these come at unprecedented production and environmental costs. These unconventional sources often cost more to extract, use more energy, use more water and produce large quantities of greenhouse gasses.[9] They are often in some of the world's most pristine areas – such as tropical rainforests and the Arctic – that are vital for biodiversity and ecosystem services.

A shift to renewable energy will increase energy security in Australia and reduce exposure to increasing fossil fuel costs. Australia also has a key role to play in the renewable energy solutions and improving energy security in our region.

Nuclear is an expensive and dangerous option

Some see nuclear power as a solution because it can produce large-scale electricity with low carbon emissions. In reality, nuclear remains a dangerous and expensive option.

Nuclear power produces dangerous waste that remains toxic for thousands of years, and there is still nowhere in the world where it can be stored safely. According to the U.S Environmental protection agency it will be at least 10,000 years before the threat to human health of nuclear waste is reduced.[10]

It is common knowledge that nuclear power plants typically have high capital costs, long lead times for building the plant, but reportedly low direct fuel costs. However, proper consideration is rarely given to the challenges related to the fuel cost and safety aspects of nuclear power such as the extracting, processing, using, plant decommissioning, and storing the fuel over the long term. General Electric CEO Jeff Immelt told the UK Financial Times in June of this year that it was becoming increasingly difficult to justify the expense of nuclear power compared to other forms of energy.[11]

2. Global Clean Energy Revolution

Renewable energy sources have grown to supply an estimated 16.7% of global final energy consumption in 2010.[12] In July this year, the International Energy Agency (IEA) released a report saying that, despite economic uncertainties in many countries, from 2011 to 2017 renewable electricity generation should accelerate by 1,840

[9] (1) KPMG (2012) Shale Gas a Global perspective http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Pages/shale-gas-global-perspective.aspx. (2) Howarth, R., Santoro, R. and Ingraffea, A. (2011) "Methane and the greenhouse-gas footprint of natural gas from shale formations", *Climatic Change*, Volume 106 (4), available online at: http://www.springerlink.com/content/e384226wr4160653/. (3)Petron, G. et al (2012) "Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study",*J. Geophys. Res.* Volume 117.
[10] http://www.epa.gov/rpdweb00/yucca/about.html
[11] http://www.ft.com/intl/cms/s/0/60189878-d982-11e1-8529-00144feab49a.html#axzz263y3XrU5
[12] http://www.map.ren21.net/GSR/GSR2012.pdf

TWh, a growth rate almost 60% higher than that registered over the 2005-2011 period.[13] Wind power is expected to grow at 16.4% per year, solar PV generation at around 27.4%.[14]

Global investments in 2011 in renewable energy rose by 17% to a record USD$257 billion. This increase was double the figure for total investments in 2007.[15] The top five countries for total investment in renewable energy in 2011 were China, United States, Germany, Italy and India.[16]

3. Australia's Abundant Renewable Energy

Australia has significant potential to grow its renewable energy generation, thanks to our access to abundant renewable energy sources that could provide our current energy needs many times over.

Australia has access to six critical renewable energy resources: wind, solar, bio-energy, geothermal, hydro-electricity and ocean energy. Some sources can be harnessed in multiple ways – for example, solar energy can be harnessed on rooftops as electricity or heat, via large-scale solar photovoltaic projects, or through large, grid-connected solar thermal power stations.

Australia receives an average of 58 million petajoules (PJ) of solar radiation per year, approximately 10,000 times more than its total energy consumption[17]. Geothermal sources could provide 26,000 times our annual energy consumption.[18] Near-shore wave energy can provide approximately four times our current national power needs, including 35% of our baseload power needs.[19]

Shifting to 100% renewable energy represents a significant increase from the current levels of clean energy supply, but the momentum exists for this transition within the coming decades. Renewable resources currently supply only 8% of Australia's electricity needs and approximately 5% of total primary energy consumption, but growth has been strong in recent years.[20] For example, South Australia generates 21% of its electricity from wind power alone.[21] Each year since 2007 average growth for wind and solar was more than 20% and 80%, respectively.[22]

Renewable energy now dominates investment activity in Australia's power sector. More than $3 billion of renewable projects are in an advanced stage of development, almost double that for coal and gas. Across Australia more than 120 renewable energy projects are at various stages of development; these projects have a combined capacity of over 23,000 MW and are worth more than $41 billion.[23] But on an international scale, Australia lags significantly behind other countries including China, Brazil, Denmark, UK, USA and Germany.[24]

4. Renewable Energy is Affordable, Investing Early has Benefits

The additional cost of renewable energy technologies is often cited as the key barrier to their widespread deployment. However, prices fell sharply in response to the last decade's unprecedented level of investment in renewable energy globally. For example, the cost of solar PV cells fell by an estimated 76% between 2008 and 2011.[25] The cost of wind turbines fell by 19% between 2007 and 2010.[26] In some cases renewable energy technologies are now competitive with fossil fuel sources:

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[13] http://www.iea.org/textbase/nppdf/stud/12/MTrenew2012.pdf
[14] http://www.iea.org/textbase/nppdf/stud/12/MTrenew2012.pdf
[15] http://www.map.ren21.net/GSR/GSR2012.pdf
[16] http://www.map.ren21.net/GSR/GSR2012.pdf
[17] http://www.ga.gov.au/energy/other-renewable-energy-resources/solar-energy.html
[18] http://www.agea.org.au/media/docs/aboutgeoengfactsheetfinala4lowres.pdf
[19] https://www.cleanenergycouncil.org.au/technologies/marine.html
[20] Bureau of Resources and Energy Economics (2012) *2012 Australian Energy Update*, available online at: http://www.bree.gov.au/documents/publications/energy/BRE0133EnergyUpdate2012.pdf.
[21] Osmond and Osborne (xxx) Peaking Capacity, Co2-e emissions and pricing in the South Australian Electricity Grid with high wind penetration. Windlab systems Pty Ltd.
[22] Analysis of BREE data from: http://www.bree.gov.au/publications/aes-2012.html
[23] Analysis of BREE data from: http://www.bree.gov.au/documents/publications/energy/elec-generation-projects-appendix.xls
[24] Roland Berger (2012) Clean Economy, Living Planet - The Race to the Top of Global Clean Energy Technology Manufacturing http://www.rolandberger.com/media/pdf/Roland_Berger_WWF_Clean_Economy_20120606.pdf
[25] 25 Analysis of BREE data from: http://www.bree.gov.au/documents/publications/energy/elec-generation-projects-appendix.xls
[26] http://bnef.com/PressReleases/view/139

- In the USA, Brazil, Sweden and Mexico, wind power project energy costs have levelled at around USD$68 per megawatt hour (MWh), compared to USD$67/MWh for coal and USD$56/MWh for gas.[27]
- Solar PV has reached retail grid parity for three out of four Australians – that is, everywhere except Victoria, Tasmania and Canberra.[28]
- In South Australia, despite wind contributing to 21% of the state's electricity, wholesale electricity prices have not increased over the past five years; instead they dropped from $50 per MWh to $49 MWh during that time period. Wind now routinely displaces more expensive technology such as open-cycle gas.[29]

Recent analysis by Worley Parsons for the Australian Government shows that Australian renewable energy is expected to become increasingly competitive over the coming decades.[30]

Electricity prices in Australia have risen substantially over the last five years. By far the main reason for these price increases is the tens of billions of dollars being invested in new poles, wires and other grid infrastructure. Network charges now account for around 51% of the average household electricity bill; and account for most of the 40% price rise experienced over last three years[31]. In contrast, policies to support renewable energy account for only 3% of electricity bills.[32]

Shifting away from high-polluting energy sources to renewable energy will require a significant investment in Australia's energy sector. This will, of course, come at a cost in the short-term. But the longer governments delay this transition, the more costly it becomes. For example, the 2011 International Energy Agency report argues that every $1 worth of investment in a low-carbon transition between 2011 and 2020 will avoid an additional $4.30 in required expenditure between 2021 and 2035 to compensate for the increased emissions.[33]

5. Summary

Transitioning to 100% renewable energy is necessary, desirable and, as the following Climate Risk analysis shows (taking into account the electrification of transport), technically achievable by 2050 with the right policy settings.

The analysis leads to some important policy implications, which inform WWF's recommendations. Two key points to emphasise:

- If we are to achieve 100% renewable energy in all energy sectors, then we must tackle transportation emissions. Electrification of the land-based transport sector is feasible. We should plan now for increasing demand in the electricity sector to ensure that growth in renewable energy can meet the demand.
- Between 2020 and 2030 the carbon price is unlikely to drive the transition required to put Australia on the pathway to achieve 100% renewable in all energy sectors by 2050. Without an increase in the RET post-2020 most renewable industries will collapse. A 2030 'safety' RET could prevent collapse of the renewable energy sector post-2020, drive this sector's costs down more quickly, and put Australia on a 100% renewable pathway.

Our hope is this report will inspire governments and businesses to move boldly to maintain strong renewable energy growth in Australia.

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[27] http://bnef.com/PressReleases/view/139

[28] Andrew Blakers is the Director of the Centre for Sustainable Energy Systems and the ARC Centre for Solar Energy Systems at the Australian National University http://theconversation.edu.au/solar-will-force-coal-and-nuclear-out-of-the-energy-business-2557

[29] Osmond and Osborne (2011) Peaking Capacity, Co2-e emissions and pricing in the South Australian Electricity Grid with high wind penetration. Windlab Systems Pty Ltd.

[30] http://www.bree.gov.au/documents/publications/Australian_Energy_Technology_Assessment.pdf

[31] http://www.ret.gov.au/Department/Documents/clean-energy-future/ELECTRICITY-PRICES-FACTSHEET.pdf

[32]http://www.ret.gov.au/Department/Dcuments/clean-energy-future/ELECTRICITY-PRICES-FACTSHEET.pdf

[33] IEA World Energy Outlook, 2011 www.worldenergyoutlook.org

6. WWF Recommendations

1. Retain the carbon price

The Climate Risk analysis shows that a carbon price will be an important driver of renewable energy investment in Australia. It shows that removing the carbon pricing scheme would leave an AUD$67 billion deficit in renewable investment, a shortfall that would need to be bridged by other policy measures and the budget bottom line.

2. Extend and increase the RET to at least 137,000 GWh by 2030

The analysis finds that it will be critical to extend and increase the RET out to 2030 to prevent a stalling of the industry after 2020. Given uncertainty about future carbon prices, extending and increasing the RET will provide a safety net for Australia's renewables industry, ensuring there is no investment shortfall should the carbon price be low. WWF recommends a 2030 target of between 137,000 and 169,000 GWh, equivalent to 43-53% of BAU electricity projection. The lower range is the minimum required to achieve 100% renewable energy by 2050 (including transport), but will require high growth rates post 2030.

3. Band or weight the RET after 2020 to support resources concurrently

The Climate Risk analysis finds that Australia's six main renewable energy sources need to grow concurrently to achieve the 100% renewable energy goal by 2050. If they do not, some renewable energy technologies may need to grow at unsustainably high rates at later dates to allow the goal to be met. Current policies such as the carbon price and the RET design favour the development of low-cost technologies first. Banding or weighting the RET will give less developed/more costly technologies a "leg up" to develop and bring down their cost curves, to spur their growth alongside cheaper renewable technologies.

4. Set a national energy efficiency target and scheme

Energy efficiency has a crucial role to play in achieving 100% renewable energy by 2050, but remains the poor cousin of low-carbon policy. Numerous studies show that price is not the only barrier to energy efficiency. Therefore a carbon price on its own may be insufficient to drive energy efficiency. Efforts by the Department of Climate Change and Energy Efficiency to investigate an energy efficiency target and energy savings scheme must be accelerated and commitments made now to implement these policies.

5. Produce a White Paper for the electrification of the transport system

The Climate Risk analysis shows that if we are to achieve 100% renewable energy in all energy sectors, then we must tackle transportation emissions and electrify the transport system. This will require a significant level of planning: infrastructure for charging facilities; incentives to switch to electric vehicles, including off-peak pricing; and a strong signal to vehicle manufacturers. WWF believes the Government should prepare a White Paper on electrification of Australia's transport system to begin laying the foundations for this transition.

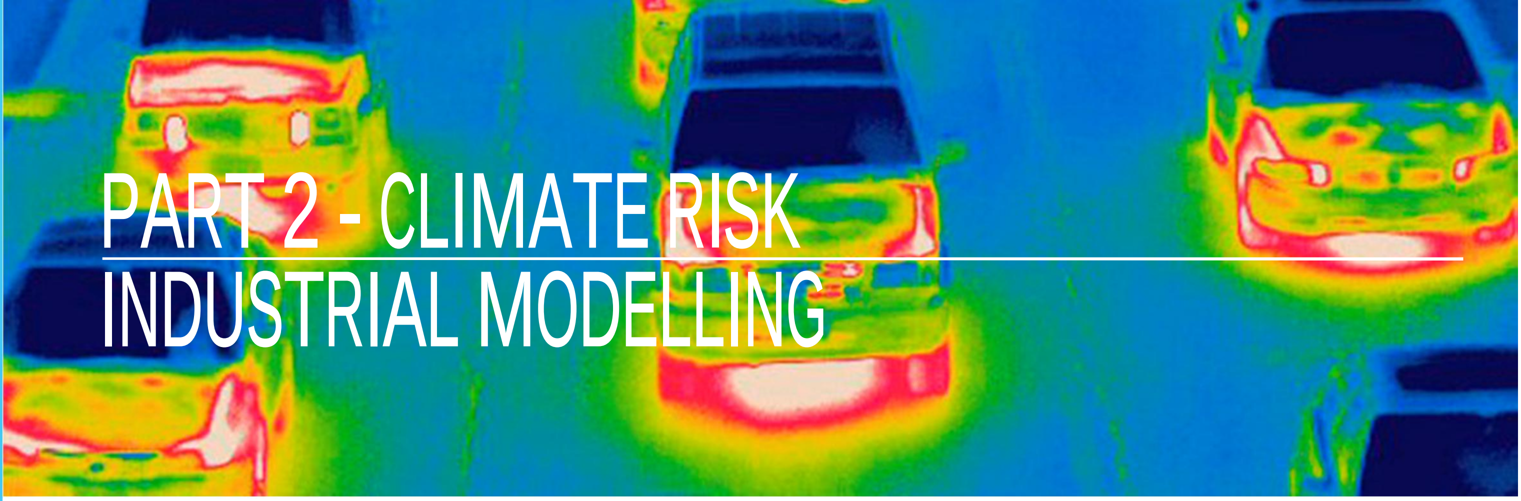
6. An emissions performance standard for electricity generation

To provide certainty to power sector investors and avoid the risk of locking in gas generation, the Government should introduce an emissions performance standard for electricity generators to achieve the following:

- An emissions standard of 400-450 kg CO_2-e/MWh for new generators between 2012 and 2019.
- An emissions standard of 150-200 kg CO_2-e/MWh for new generators after 2020.
- A retrofit of all non-peaking gas plants built between 2012 and 2019 to achieve a low emissions standard of 200 kg CO_2-e/MWh or less within 15 years of construction.

7. Reform National Electricity Market and invest in smart grids and smart meters

To drive energy efficiency, improve affordability of renewable energy, accommodate variability and create incentives for electric vehicles we need significant reform of the National Electricity Market, a more rapid roll out of smart grids and smart metres, and to overcome infrastructure barriers. WWF supports calls to establish a Government agency to manage electricity market reforms and coordinate the roll out of smart grids and metres. Serious consideration should be given to amending the National Electricity Objectives to better reflect broader policy objectives such as carbon pricing, renewable energy targets and consumer protection policies.



PART 2 - CLIMATE RISK INDUSTRIAL MODELLING

1. Objectives of this study

This report has been prepared to analyse:

(a) the feasibility of achieving a plausible and economically rational transition of the Australian electricity sector to 100% renewable energy, or close to this level, by 2050; and

(b) the contribution of current policy measures toward delivering such a target.

This analysis examines how quickly Australia's renewable energy industries could expand to achieve a 100% renewable energy footing in the electricity generation and transport sectors under stable industry growth conditions. Though 100% renewable energy represents a significant increase from the current level of 5% renewables in the 2012 energy supply (BREE, 2012), renewable energy growth already has strong momentum. In the national electricity market 608 MW of renewable energy capacity is committed for installation, compared to just 21 MW of gas (AEMO, 2012) (committed coal capacity is assumed to be obsolete in the light of emissions trading).

1.1 Policy Context

This report examines the impact of various carbon pricing scenarios on the delivery of such a target, as well as the role and duration of complementary policy mechanisms such as the Clean Energy Finance Corporation and the Australian Renewable Energy Agency.

The impact of the current Renewable Energy Target to 2020 and expansion of a similar scheme beyond 2020 is also explored in this report. This is analysed within the context of providing a "safety net" to avoid industry collapse should carbon prices or other measures fail to achieve the pricing and investment levels required to enable renewable energy costs competitiveness in the open electricity market.

1.2 Efficiency

The analysis includes opportunities for energy efficiency in residential, commercial and industrial sectors. Energy efficiency will play a major role in achieving 100% renewables, by reducing the energy demand that renewables would be required to meet.

1.3 Transport

The de-carbonisation of transport, industry and other energy consumption sectors would have a significant impact on the demand for renewable electricity generation. Therefore this report also examines the timing and limitations related to achieving the broader target of 100% renewable energy across all energy use within Australia. It is particularly important to consider the de-carbonisation of the land transport sector, where the current momentum is a shift away from petrol and diesel technology, and toward electric cars, buses, trains and trucks, combined with static (parked vehicle) or dynamic (in road induction) charging and storage. The scale and growth of transport demand will put a significant additional generation requirement on the electricity sector, a requirement that is therefore considered in this report.

1.4 Carbon Capture and Storage

This report also considers industrial processes that are not currently able to convert to renewable alternatives (e.g., cement and steel manufacturing, which employ chemical processes that requires the use of fossil fuels, as well as fuel for energy). In these cases, we assume that carbon capture and storage (CCS) is adopted to capture the associated greenhouse gas emissions. Therefore when considering Australia's entire energy demand, a goal of near 100% renewable energy is used, with the remaining – non-convertible – energy requirements achieved via fossil fuel energy used in conjunction with CCS.

1.5 Policy Implications

Finally, this report identifies policy elements that will be important to enable the 100% renewable energy goal to be achieved in a stable and cost-effective manner.

2. Overview of the CRISTAL Model

This project utilises a computational model called the Climate Risk Industry Sector Technology Allocation (CRISTAL) model. This model emulates real-world industrial growth. It uses current data for the resources, technologies and services available to meet energy demand and/or reduce greenhouse emissions, adopting the Princeton/Socolow abatement "wedges" emissions framework (Pacala & Socolow 2004).

The model then uses probabilistic modelling techniques – including Monte Carlo methods – to combine this information and calculate the industrial growth rates required to achieve the necessary renewable energy and/or greenhouse gas emissions reductions, while satisfying the projected demand for energy and other services. Monte Carlo methods are a class of algorithms that rely on repeated random sampling to compute their results. Often used when simulating physical systems, they allow multiple data sets and ranges of expert opinion to be used simultaneously.

The outputs of the scenarios from the CRISTAL model focus on industrial growth rates. This focus reflects the potential of these growth rates to critically constrain delivery of future renewable energy and emissions levels. That is, they could fundamentally restrict the industry response rates available to deliver economic and government policy measures. By assessing the capabilities and rate of change for each industry, the model provides a picture of its output and constraints, assembling these outputs across industries and resources.

What emerges is an overall picture of national future emissions levels, energy production and renewable energy investment requirements.

The CRISTAL model is primarily an "industrial model" rather than an "economic model". Price and cost are not used as an imput to drive the uptake of technologies but are instead an output of the model, indicating the investment required to achieve the scenario goals. In the model, emissions outcome and renewable energy target are fixed as inputs, and the consequences for industrial development are an output. By forcing industries to deliver the required emissions outcomes (i.e., the inputs) the plausibility of output growth rates, costs and impact of other real-world constraints can be considered. For simplicity, a single set of industrial growth rates has been applied across all renewable energy generation industries in this project.

Figure 3 shows the basic structure and interdependencies of the CRISTAL model.

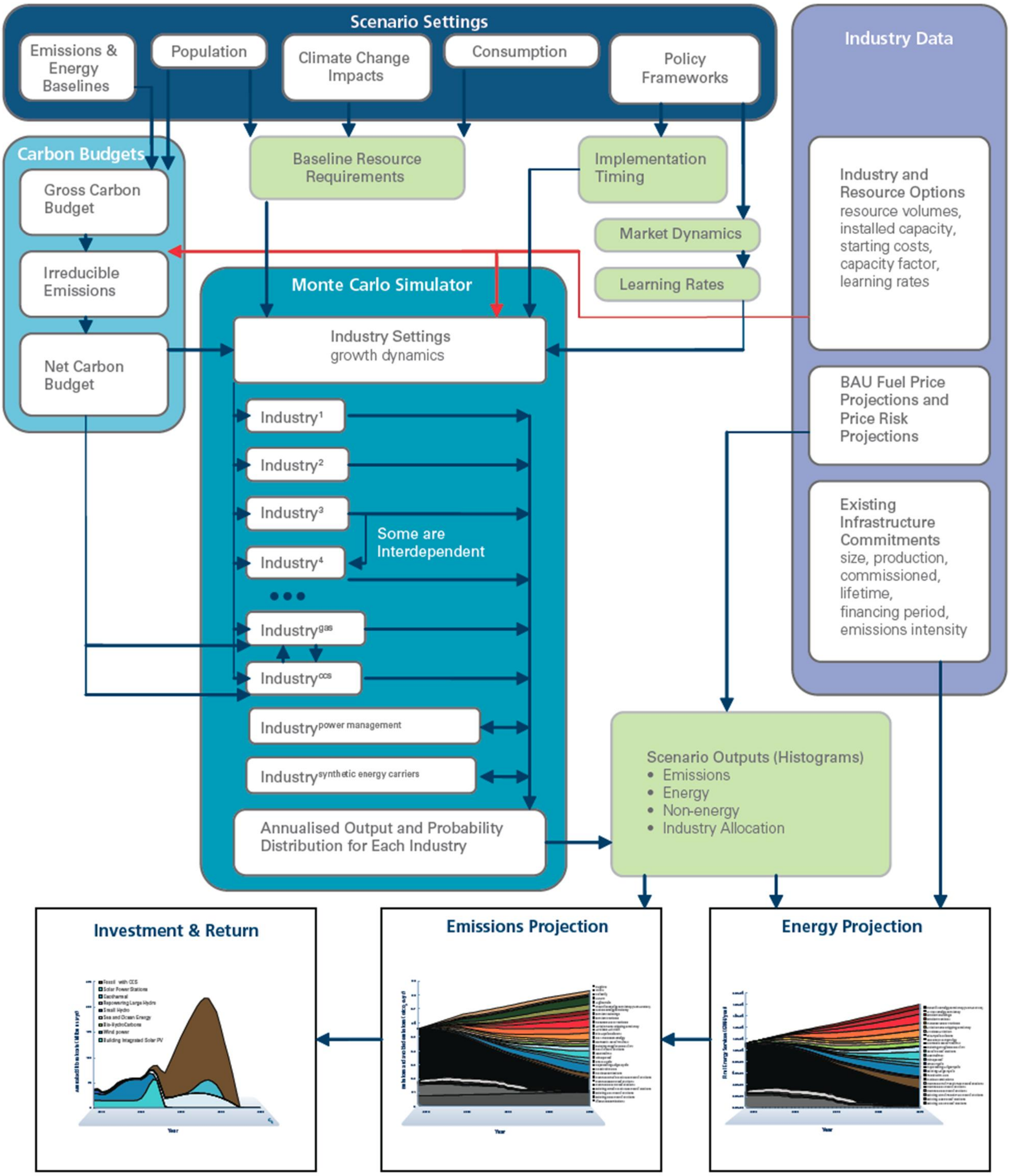


Figure 3: Schematic diagram showing the basic structure of the CRISTAL model.

2.1 All Major Emissions Sectors

The CRISTAL model includes all major emissions sectors: electricity generation, industrial processes, transport, land use and land use change, forestry, waste, fugitive emissions, agricultural emissions and bunker fuels. This allows a side-by-side analysis of different abatement options and low-carbon activities, although no preference or order of implementation is implied.

2.2 Resource and Technology Costs

Only emissions abatement technologies that are commercially available, or likely to be so in the near term, have been included.

The CRISTAL model is able to look at price shortfalls between energy costs of included technologies and business-as-usual, as well as the impact of carbon prices.

The costs and potential savings of renewable energy generation technologies are expressed relative to their fossil fuel competition. Since there is considerable uncertainty surrounding the future costs of fossil fuel energy, this report conservatively assumes that the cost of energy generated using fossil fuels increases at a linear rate of 2% each year out to 2050 in real dollars (2012$). The rate of cost decrease for each renewable energy generation technology is assumed to continue along its historic learning rate trajectory (see Appendix B: Learning Rates for further information on learning rate behaviour).

By using the current costs and rational learning rates of each abatement technology, the CRISTAL model indicates the commodity cost profile for each renewable energy industry. The cost profile is also able to take into account policy measures such as a carbon price. Using this information, it is possible to determine any relative cost shortfall that must be accounted for through additional investment in the form of price support. In this way, the CRISTAL model provides a forecast of the amount of investment (and its timing) that would be required to achieve the desired outputs associated with each renewable energy resource.

2.3 Extending the Pacala-Socolow "Wedges" Concept

Considerable modelling has been undertaken in the fields of both climate change and energy. Many models are constructed in ways that let scenarios evolve based on key costs, such as the price of oil or the cost of carbon. A "wedges" model, developed by Pacala and Socolow (2004), is widely regarded as an industry standard for considering and presenting the means of achieving future greenhouse gas emissions levels. Such a model provides an excellent starting point for this analysis. It divides the task of emissions stabilisation and energy transformation out to 2050 into a set of wedges (delivered by emissions-avoiding technologies).

The CRISTAL model presented here builds on the Pacala-Socolow wedges model. However, it has been adapted to provide insight into measures that go beyond the stabilisation of emissions in 2050. Rather, the model analyses measures that achieve specified energy or emissions targets. To do so, the CRISTAL model:

- Extends the penetration of abatement industry deployment to achieve abatements consistent with plausible future carbon budgets and required renewable energy targets.
- Simulates real-world industrial growth behaviour by assuming: that the growth of any technology will follow a typical sigmoid (S-shaped) trajectory; that constraints impose a maximum on the rate of sustainable growth (see Appendix C: Sustainable Industry Growth Rates); and that the ultimate scale depends on estimated resources and other specific constraints.
- Draws on diverse expert opinion and literature on the potential size and scale of emissions abatement resources and uses these as inputs.
- Employs a probabilistic approach, using the Monte Carlo computational methods. All scenarios are run with over 5,000 Monte Carlo iterations.
- Seeks to minimise the replacement of any stock or system – such as a fossil fuel power plant – before the end of its physical or economic life.

- Includes energy and emissions contingencies that allow for the possibility that some solutions may encounter significant barriers to development and therefore fail to meet the projections set out in the assumptions.

2.4 Top-Down and Bottom-Up

The CRISTAL model is structured to combine top-down and bottom-up aspects of emissions abatement analysis. Thus it approaches calculations of future industrial development from both the perspective of the national requirement for energy and abatement opportunities (top-down), and the perspective of developing options to meet these needs (bottom-up). This permits the model to capture the best of both approaches in its calculations.

The starting point for the top-down aspect of the model is the Bureau of Resources and Energy Economics (BREE) and Treasury baselines for energy and emissions through to 2050 (BREE 2011, Commonwealth of Australia 2011). However, top-down approaches can introduce perversities, such as inflated baselines, which create the illusion of greater emissions reductions than are possible.

The bottom-up aspect of the model builds a set of abatement industries to meet the projected energy services demand, sector by sector. This requires some assumptions about the level and type of consumption – for example, what proportion of energy is used for transport, homes and industry, and so forth. This information is used to ensure that the emissions abatement wedges are internally consistent and avoids the “double counting” of overlapping abatement opportunities. The model accomplishes this by considering, within each sector, the total energy services needed for that sector and then the role of abatement opportunities. Thus the model maintains the best possible internally-consistent evolution of energy and emissions.

2.5 Using Ranges of Data

Proponents of any one solution tend to be optimistic regarding the extent of its contribution and the time frame over which its benefits may be achieved; non-proponents may have lower expectations. Rather than make value judgements on the independence of opinion or publications, this project uses ranges of data that reflect the diversity of opinion. All such ranges of data are entered into the model as a “triangular” probability distribution defined by the lowest, highest and best estimate for any given variable (Figure 4). The project therefore seeks to include a broad range of independent sources for any given variable.

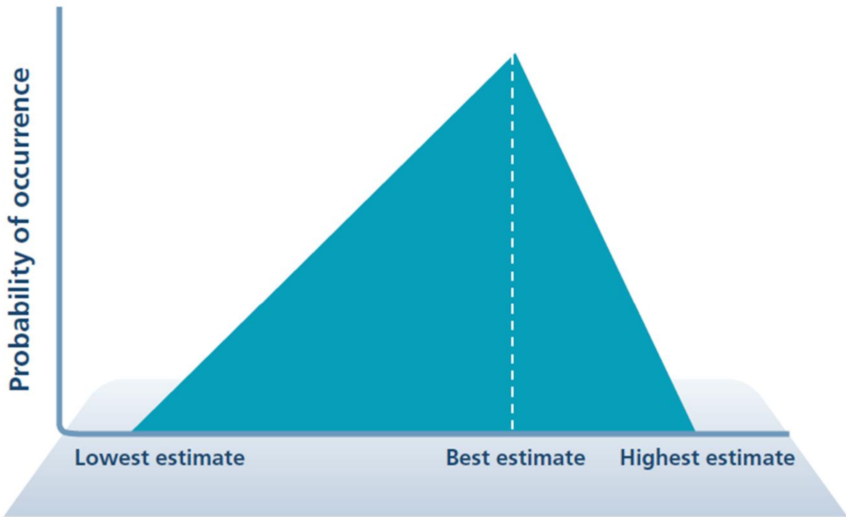


Figure 4: Instead of picking a single number for important parameters, input data are entered into the model as ranges of values. The probability distribution is triangular and defined completely by the lowest, best and highest estimates from published literature.

2.6 Modelling Industry Deployment Behaviour

Whereas Pacala and Socolow simplify the avoided emissions to a wedge shape with linear growth, in actuality any market innovation follows a standard sigmoid or S-curve, similar to that shown in Figure 5.

Such a profile is underpinned by an industry that starts from a small base, at which point it provides negligible abatement (though there may be considerable investment and growth occurring in this phase). Over time, the industry starts to make an increasingly significant contribution (the “ramp- up” phase). This growth will approach a plateau of steady development as the industry matures (the period of near-linear growth). As the unexploited resources diminish or other constraints impinge, the industry’s growth gradually diminishes (the “ramp-down”). In some cases, there may some level of industry contraction (e.g., the electricity production from large dams may be reduced by silting).

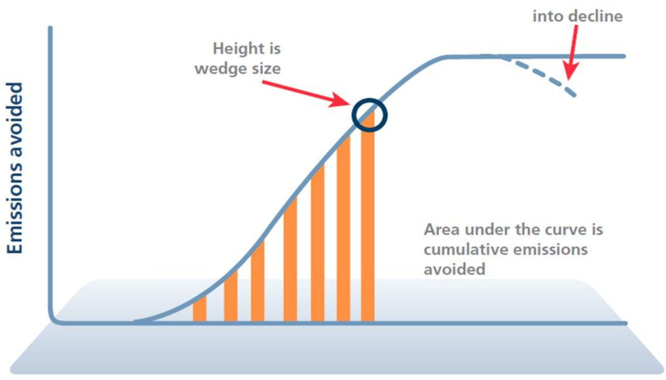


Figure 5: Emissions abated as a new industry grows.

2.7 A Trapezoid Approximation of Growth

The S-curve shown in Figure 5 indicates the cumulative effect of an installation or industry that grows quickly at the start, reaches a steady state, and ultimately contracts. The actual growth phases might best be described by a bell-shaped curve. However, in the CRISTAL model, growth is approximated as a trapezoid, as shown in Figure 6. Within the CRISTAL model, each emissions reduction solution is described in units most appropriate to the technology or resource; for example, the number of megawatts of turbines installed, or million of tonnes of oil-equivalent avoided through increased vehicle efficiency.

Any climate solution trapezoid can be fully defined by the set of variables that are designated as c, b, p, s and m in Figure 6. However, these variables are not put directly into the model because in many cases the relevant data are not known. For example, it is hard to estimate the year in which the growth of industrial energy-efficiency implementation will level-off (b in Figure 6). Instead, more easily estimated parameters are used, such as the turnover rate of industrial equipment, available resources, current installed capacity, standard or forced growth rates for each development phase, or the year in which commercial roll-out commences.

Combining these various “known quantities” in simultaneous equations (which will be different for different low-carbon industries) allows variables c, b, p, s, and m to be calculated, and the shape of the trapezoid and the S-curve of cumulative annual contribution from each abatement industry to be estimated.

In terms of the trapezoid approximation of industry growth (see Figure 6), the progression of industry development can be summarised into the following phases:

i. The growth phase (also referred to as the critical development period), when industry growth accelerates toward the maximum growth rate (i.e., in each successive year more units are produced per annum).

ii. The stable phase, when industry growth rate is constant and the maximum number of new units (m in Figure 6) are produced each year.

iii. The saturation phase, when the industry growth rate decreases and fewer new units are produced each year as the economically viable resource becomes fully exploited.

iv. A possible decline phase, when the total size of the industry starts to decrease (i.e., existing installed units are taken out of service and not replaced, or fewer units are produced).

Each industry may have a different industry growth profile depending on the relative size of these periods. For all emerging technologies examined in this report, periods are set at 0-20% for the growth phase (critical development period), 20-80% for the stable phase and 80-100% for the saturation phase.

These settings reflect the concept that a participating investor will want a sufficiently long period of production from an existing factory to recover the investment. That is, an industry will not keep growing indefinitely or right up to the point that a resource is saturated. For example, a new factory to build wind turbines would not be built when there is only need for one more wind farm; the necessary wind farm components would instead be supplied – perhaps more slowly – from existing factories.

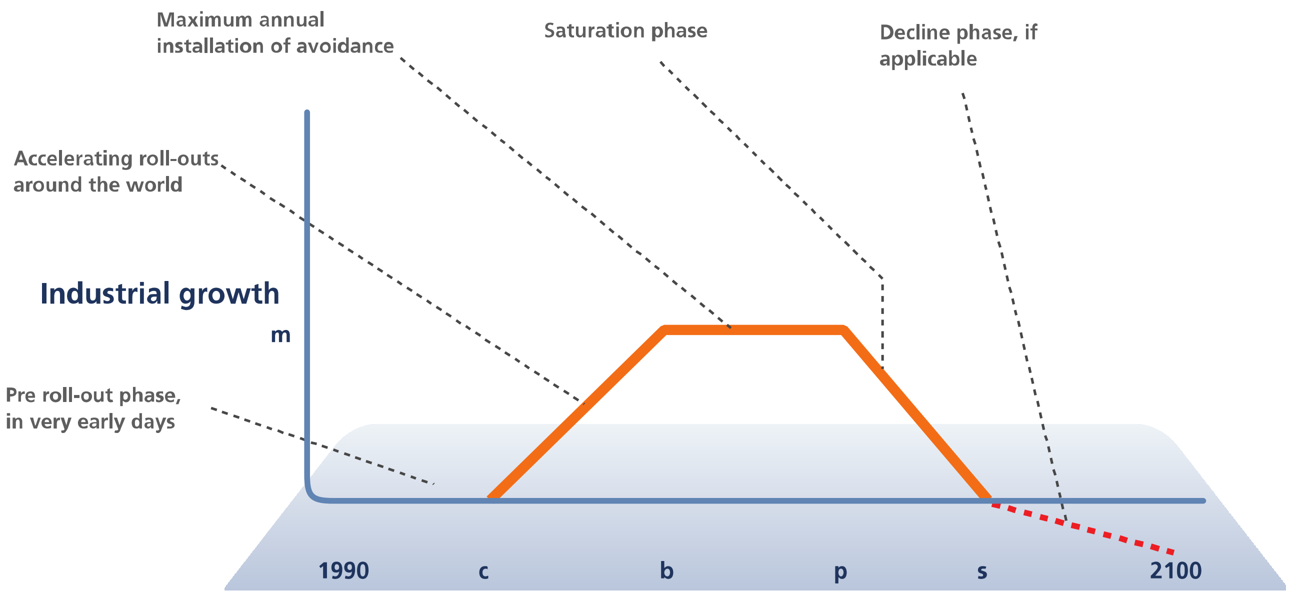


Figure 6: Trapezoid approximation of industrial growth. Any climate solution trapezoid can be defined by the set of variables, c, b, p, s and m.

3. Achieving 100% Renewable Energy in Australia

With an abundant supply of accessible renewable energy resources and a 20% renewable energy footing in the electricity sector by 2020, Australia may be well positioned to roll-out 100% renewable energy in the coming decades. This chapter explores the timescales over which this goal could be achieved with stable and sustainable growth within renewable energy industries.

This chapter also considers the implications of wide-scale electrification of the transport sector, along with renewable requirements in the stationary energy sector beyond electricity generation (such as in industry, mining and agriculture).

Any discussion of how quickly 100% renewable energy can be achieved in Australia must consider both required investment levels (where grid parity is not yet achieved) and real-world limitations on industry growth rates (see Appendix C: Sustainable Industry Growth Rates for further information). Both of these key issues are addressed here.

This report assumes a 30% per annum maximum rate for low-carbon industry growth under free-market conditions. For the central 100% Renewable Scenario shown in this chapter, a consistent growth rate of 20% per annum is assumed for all renewable energy industries until 2050. These rates are consistent with global renewable energy industry growth rate performance, which was 26% in 2010 and 24% in 2011 (REN21, 2012).

Note that this report does not seek to analyse grid supply requirements related to 100% low-carbon energy. Rather, it assumes such considerations could be adequately addressed via a diverse distribution of energy generation types, geographic locations and energy storage opportunities.

3.1 Electricity Generation

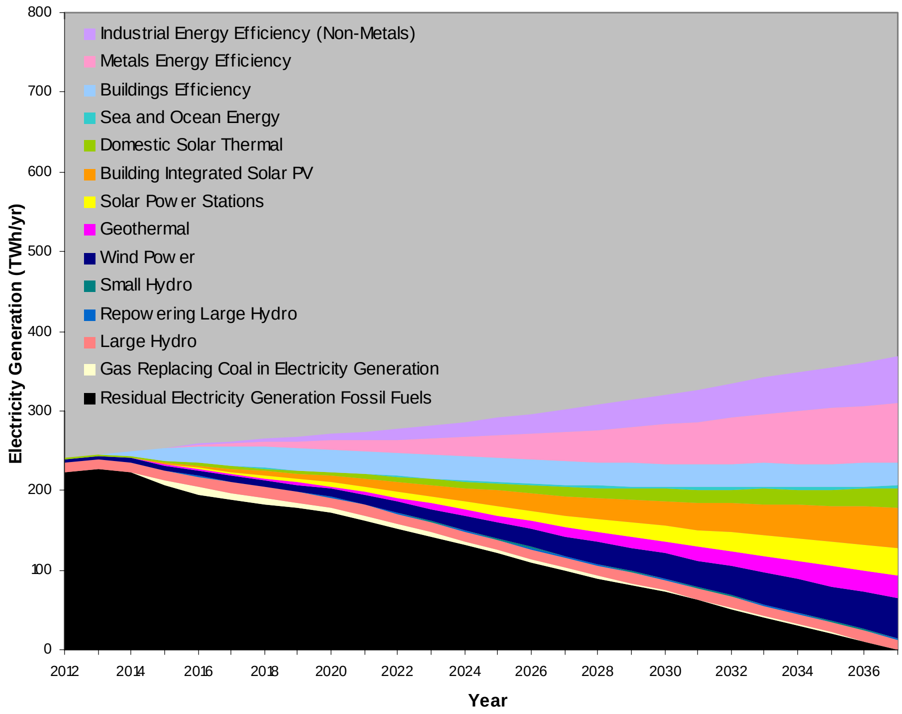
By 2020, when approximately 20% of Australian electricity generation will be sourced from renewable energy, the subsequent scaling up to 100% renewable electricity generation could proceed rapidly given the appropriate legislative support and investment landscape. However, other Australian energy consumption sectors such as industry, agriculture and transport will also need to be de-carbonised at the same time. This will create additional demand for renewable energy resources beyond those typically encompassed by electricity generation.

Consequently, it is unrealistic to assume that all renewable energy capacity will be focused entirely into electricity generation over the coming years. Nor would it be advisable to ignore the increased demand for electricity created by broader de-carbonisation in the Australian economy.

Therefore, when determining how quickly 100% renewable electricity generation can be achieved in Australia, this report assumes that new renewable capacity is distributed between electricity generation and other stationary energy consumption (primarily in the industry, mining and agricultural sectors). Renewable energy capacity is distributed proportionately within stationary energy to achieve an even level of de-carbonisation across this sector by 2030, with this proportionality being maintained out to 2050.

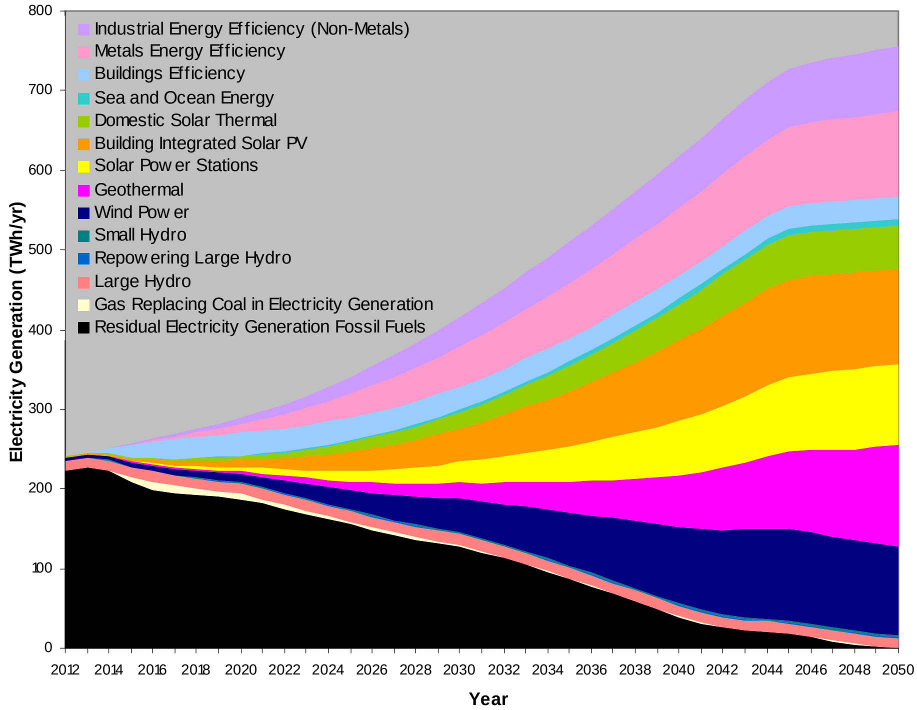
This study has used Treasury's Medium Global Action Scenario (COA 2011a) electricity demand baseline. There are, however, other studies which indicate lower trajectories for energy demand, which would make the renewable transformation examined in this analysis easier (AEMO 2012). Nevertheless, with the selected baseline, and assuming no additional electricity demand from electrification of the transport sector, 100% renewable electricity could be achieved as early as 2037 (see Figure 7). This result is based on an assumed annual industry growth rate of 20% sustained across all renewable energy industries, and ongoing efficiency improvements in electricity consumption sectors.

Figure 7. Energy wedge diagram for the constrained renewable energy scenario showing the deployment of renewable energy in the electricity generation sector, assuming no additional baseline demand from the electrification of automotive transport (COA 2011a).



By contrast, if the additional baseline demand associated with the electrification of automotive transport (rolling out at a growth rate of 26% per annum) is included, the goal of 100% renewable electricity generation would be realised in 2050 (see Figure 8).

Figure 8: Energy wedge diagram for the 100% Renewable Scenario showing the deployment of renewable energy in the electricity generation sector, with the additional baseline demand from the electrification of automotive transport (COA 2011a).



Note that the model assumes the development of a range of energy efficiency opportunities above and beyond business-as-usual estimates (Mallon, Hughes and Kidney 2009; Mallon and Hughes 2008) in both the stationary energy and transport sectors. Therefore the fraction of energy from renewables will be higher in the presented scenarios compared to BAU baselines from Treasury and BREE, which have less efficiency and therefore higher demand. Energy efficiency initiatives are crucial to the success of any energy sector de-carbonisation strategy because they act to halt the increase in energy demand that would continue in their absence.

Obviously, the attainment of 100% renewable electricity generation would occur earlier than reported here if renewable industries were to grow faster than 20% per annum, or if renewable capacity were focused primarily into electricity generation at the expense of renewable uptake in other Australian energy consumption sectors.

The associated renewable electricity generation volumes and renewable energy fraction of the electricity supply for the electricity generation scenarios shown in Figures 7 and 8 are given below in Tables 2 and 3, respectively.

Table 2: Renewable electricity deployment for the Constrained Renewable Scenario (the electrification of automotive vehicles is not included in the electricity demand baseline).

Renewables in Electricity Generation (without automotive electrification)		
Year	Annual Renewable Electricity Generation (TWh)	Fraction of Total Electricity Generation (%)
2020	45	20%
2025	87	41%
2030	130	64%
2035	184	90%
2037	206	100%

Table 3: Renewable electricity deployment from 2020 to 2050, with inclusion of automotive vehicle electrification in the electricity demand baseline.

	Renewables in Electricity Generation (with automotive electrification)	
Year	Annual Renewable Electricity Generation (TWh)	Fraction of Total Electricity Generation (%)
2020	48	20%
2025	102	39%
2030	169	57%
2035	272	76%
2040	399	91%
2045	508	97%
2050	538	100%

If baseline demand from the electrification of the automotive sector is not included, renewable generation could reach 64% of the electricity supply by 2030 and 100% by 2037. Even with the inclusion of the additional baseline demand associated with the electrification of automotive transport, 57% of electricity generation could be obtained from renewable sources by 2030 and 100% by 2050.

It should be noted that potential electricity generation capacity savings from off-peak charging strategies for electric and plug-in hybrid vehicles and/or demand side load management (by virtue of their battery system) were not included in the modelling in this report. Such strategies could potential speed the attainment of 100% renewable electricity generation because they would help reduce baseline electricity generation capacity requirements.

The extent of contribution and number of renewable energy power stations required in 2050 is set out in Appendix D. Renewable energy power stations tend to be distributed. Wind farms will tend to be placed on existing agricultural land allowing continued cropping and grazing, solar energy will be collected both on building roofs and in large thermal power stations, and geothermal plants will be located in the outback where the geothermal resources exist. Major hydroelectric resources have all largely by been exploited, but these plant may be re-fitted for greater efficiency and augmented by small run-off river facilities. The new breed of wave and tidal energy facilities will likely be located off-shore of major cities.

3.2 Stationary Energy

As noted above, the de-carbonisation of the broader stationary energy sector is assumed to progress apace with renewable adoption in electricity generation. To meet the 2020 RET, the allocation of renewable energy capacity is slightly biased towards electricity generation. However, by 2030, the percentage conversion of non-electricity stationary energy usage (i.e., in industry, mining, agriculture, etc.) to low-carbon energy alternatives is assumed to be evenly matched with that of electricity generation (i.e., 57% and 64%, respectively, with and without the inclusion of baseline demand from automotive electrification). Since the low-carbon energy fraction of stationary energy matches that of electricity generation from 2030 onwards, the year in which stationary energy can be converted to 100% low-carbon energy is also 2037 (without the additional baseline demand required to support the electrification of the automotive sector; Figure 9) or 2050 (with the inclusion of the additional demand from automotive transport electrification; Figure 10). In both cases renewable energy industries are assumed to grow at 20% per annum.

Note that some industrial processes consume energy that is not easily converted to renewable alternatives (e.g., industrial methods in which fossil fuels not only act as a heat source, but also as a chemical component, such as in blast furnace steel making). This analysis assumes these industries receive priority access to CCS technologies and capacity, since renewable alternatives are relatively more easy to implement in the area of electricity generation.

The necessity for some industrial CCS in the stationary energy mix means the real world scenario is a “near” 100% renewable energy outcome, with approximately 6% of stationary energy associated with industrial CCS (when including additional baseline demand from electric vehicles; if vehicle electrification demand is excluded, CCS makes up 7% of stationary energy). See the brown CCS wedge in figures 9 and 10

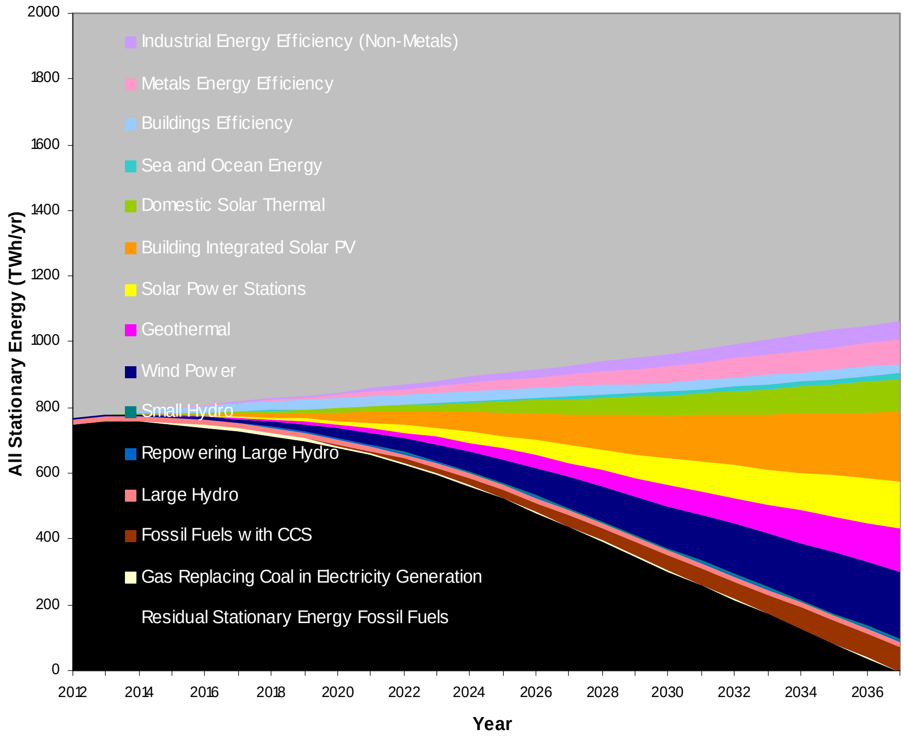


Figure 9: Energy wedge diagram for the Constrained Renewable Scenario showing all stationary energy, without the additional demand from the electrification of automotive vehicles in the baseline.

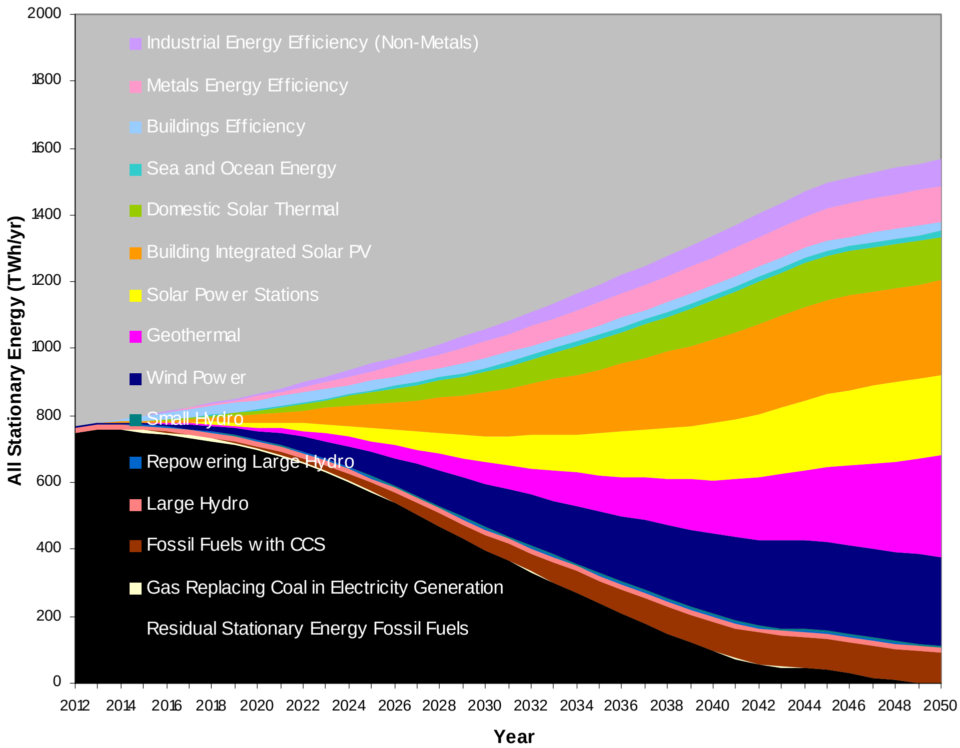


Figure 10: Energy wedge diagram for the 100% Renewable Scenario showing all stationary energy, with the additional demand from the electrification of automotive vehicles in the baseline.

3.3 Transport

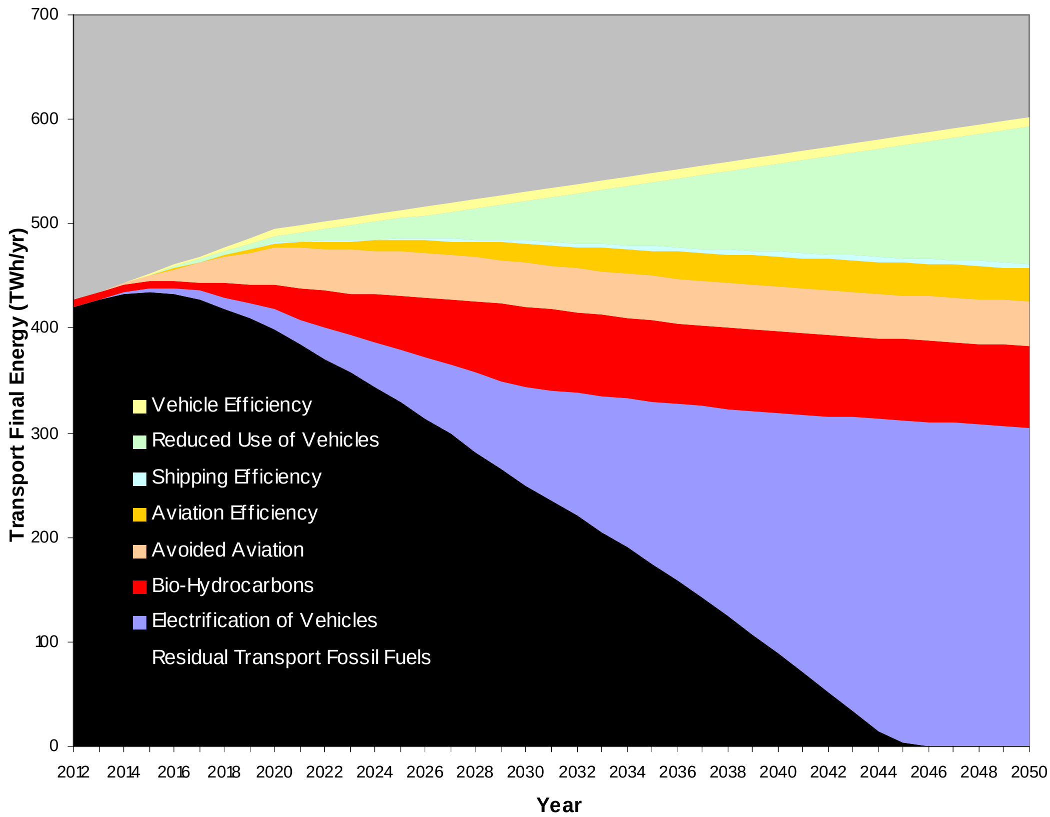
To approach 100% renewable energy supply across all final energy in Australia, considerable abatement efforts will be required within the transport sector. This primarily involves electrification of the automotive sector via the adoption of alternatives such as electric vehicles or switching to rail where available. In the case of electric vehicles, several energy storage media are available, including battery electric vehicles, hydrogen fuel cell electric vehicles (where the hydrogen is produced using renewable electricity), and plug-in hybrid vehicles (as an intermediate step).

This analysis assumes that as renewable electricity generation capacity is increased, these electric alternatives to traditional automotive modes will be powered by renewable sources. We assume that the electricity used in the transport sector is obtained from 100% renewable sources by 2050. We also assume that bio-hydrocarbons are preferentially allocated to aviation and shipping requirements since these transport modes are not easily converted to battery power due to their high energy density requirements (i.e., they have energy-to-weight and energy-to-volume constraints).

To complete the renewables transformation in transport by 2050, the adoption of electric alternatives in the automotive sector will need to grow by about 26% per annum from current levels. If significant advances in battery technologies and cost efficiencies are absent, policy support will be required to ensure consistent industry-wide growth in electric vehicle adoption at this level. Policy measures that encourage switching from road to electrified rail could also assist in the electrification of the automotive sector. Such measures would require expansion of rail capacity to accommodate the increased demand.

Note that energy storage and charging will require major changes to the use of roads – including street-side charging and dynamic charging (in-road induction charging for moving vehicles) for heavy and long-range vehicles. These changes will also present opportunities for enhanced demand-supply management of intermittent renewables due to the significant increase in electrical storage capacity introduced through an electrified transport system.

Figure 11: Transport final energy wedge diagram for the 100% Renewable Scenario, including the wedge for electrification of automotive vehicles.



3.4 Total Final Energy and Domestic Emissions Abatement

Combining the renewable transformation in the stationary energy and transport sectors discussed above, Figure 12 shows that nearly 100% renewable energy (that is, 95%) can be achieved across all final energy sectors in Australia by 2050. The outstanding 5% of non-renewable energy stems from the use of fossil fuels with CCS in industrial processes not currently adaptable to use with renewable alternatives (see Section 3.2 for further details).

Figure 12: Final energy wedge diagram for Australia under the 100% renewable scenario.

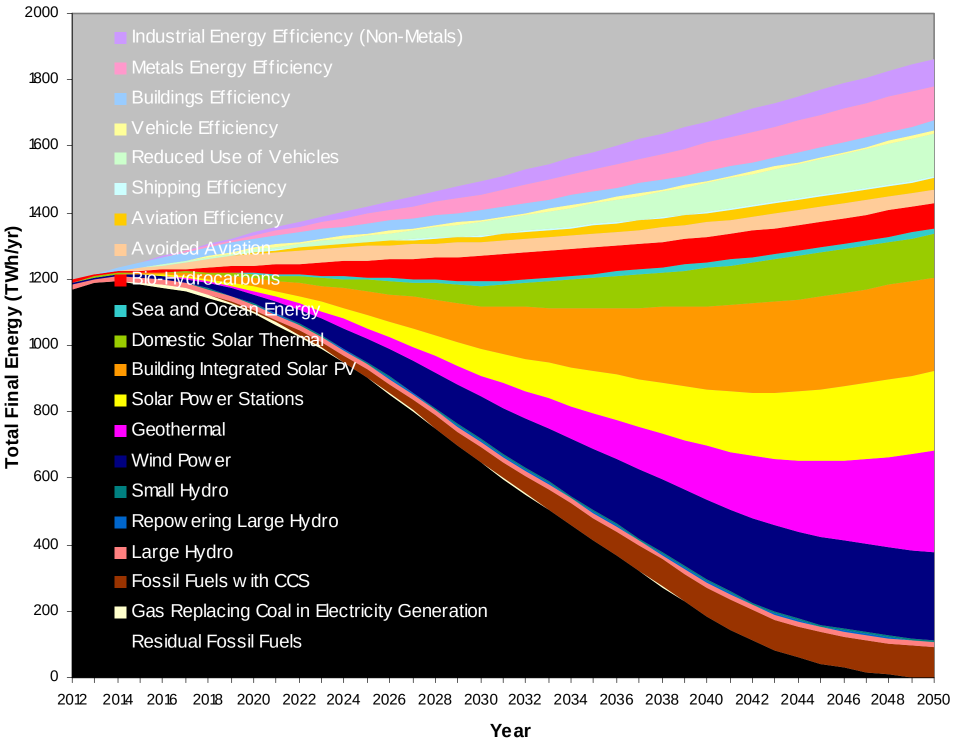
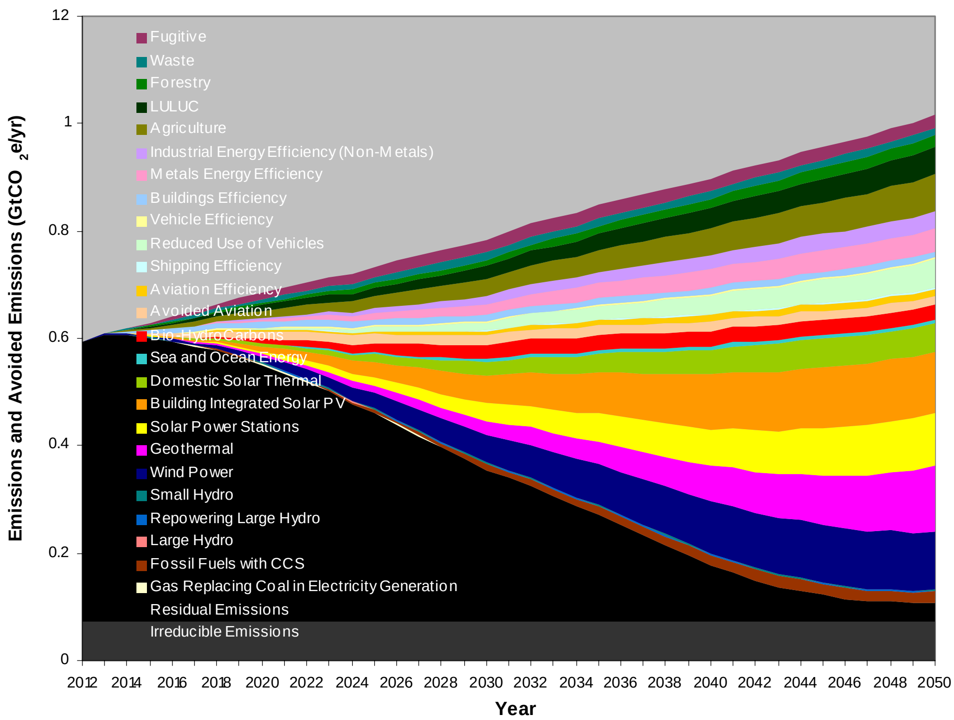


Figure 13 illustrates a collateral benefit of achieving nearly 100% renewable energy in total final energy by 2050: Australia could meet its 2050 target of an 80% emissions reduction relative to 2000 emission levels by using entirely domestic sources of emissions abatement. This outcome has considerable benefits for the Australian economy in terms of inward investment in renewable energy and jobs.

Note, however, that European Union (EU) and other overseas greenhouse gas offsets are important components of the carbon pricing strategy within Australia. These instruments provide an essential means of ensuring Australia achieves the Government's goal of meeting its interim emissions abatement commitments in the case where domestic offsets are not yet available or abatement targets are increased.

Also note that the attainment of such high levels of domestic abatement carries significant risk minimisation should international negotiations lead to an increase in Australia's 2050 emissions target. In this case, Australia would be well positioned to respond to such an increase, without excessive reliance on international offsets.

Figure 13: Emissions abatement wedge diagram for Australia under the 100% renewable scenario.



4. The Role of the Carbon Price

The following scenarios examine the impact of carbon pricing on the investment requirements for renewable energy over the 2050 timeframe for the 100% Renewable Scenario introduced in Chapter 3. The costs shown in Figures 14 through 21 represent the additional cost of employing low-carbon energy technologies above the business-as-usual price of energy (including carbon price) that would otherwise have been incurred. That is, they represent the marginal cost of abatement.

For each scenario, two figures are shown. The first shows the annual additional cost, which represents the annual expenditure above business-as-usual required for each low-carbon commodity; the second illustrates the cumulative additional cost, which shows how these annual expenditure levels sum up to provide a tally of total expenditure out to 2050.

How these additional investment requirements are met is considered later in the report, however, for the period to 2020 this investment is largely passed through to consumers through the RET scheme, feed-in tariffs and subsidised by carbon price revenues through schemes like the CEFC and ARENA. Note that the costs described in this report do not take into account any administrative costs associated with running the carbon price scheme.

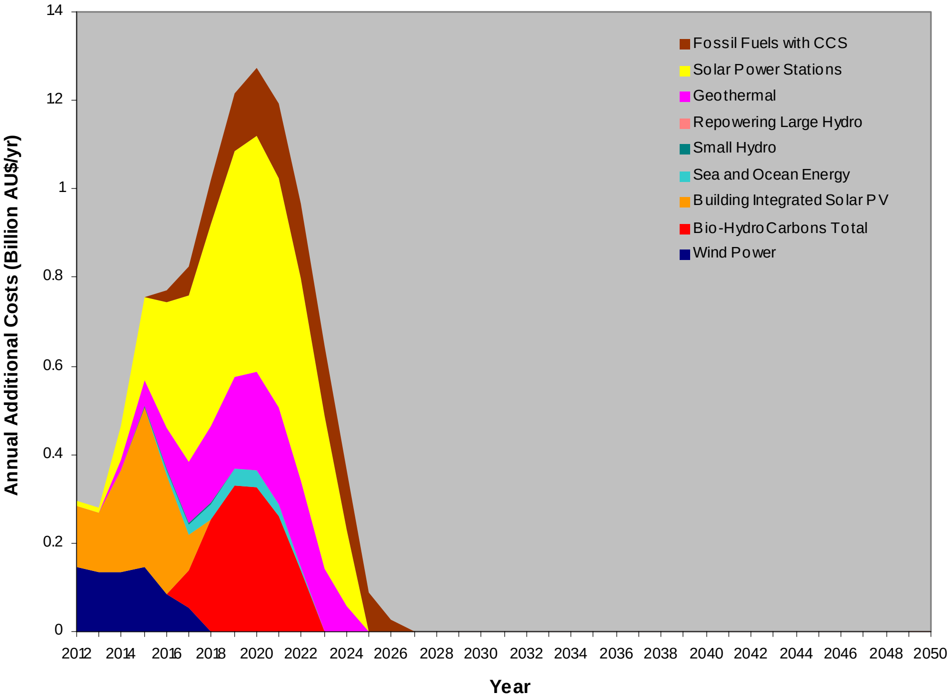
The High Carbon Price and Core Carbon Price trajectories used in this report are taken from Treasury figures published in the "Strong Growth, Low Pollution: Modelling a Carbon Price" report (COA 2011a, COA 2011b). The Low Carbon Price projection, which falls to AUD$4 per tonne of equivalent CO_2 (tCO_2e) in 2018 and rises linearly to AUD$30/$tCO_2e$ in 2050, is made up from low international carbon market forecast data from Bloomberg New Energy Finance and the European Commission (BNEF 2012, BNEF 2011, BNEF 2010, EC 2006). It should be noted that the Low Carbon Price projection assumes no U.S. participation in an emissions trading scheme and access to international forestry offsets.

The scenarios discussed below show the role of the carbon price in offsetting the amount of capital investment required to roll out 100% renewable energy. The CRISTAL model utilises the same energy uptake figures (from the 100% Renewable Scenario discussed in Chapter 3) for each of these carbon price scenarios and gives an industry-by industry breakdown of the annual and cumulative investment required beyond business-as-usual and in addition to the carbon price.

4.1 High Carbon Price 100% Renewable Scenario

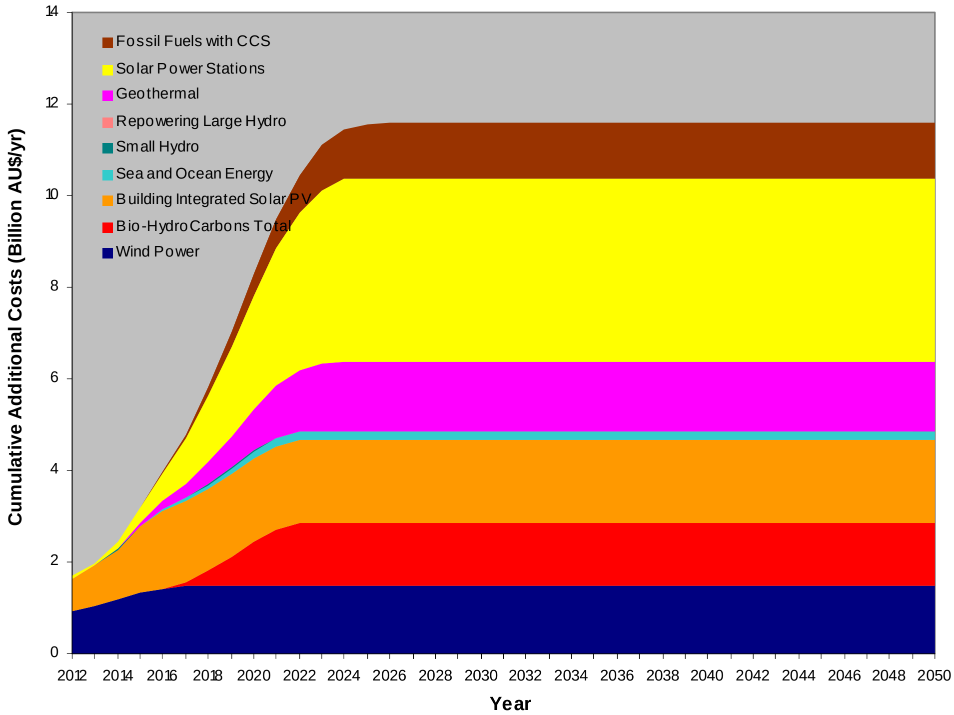
Under the Treasury's High Carbon Price trajectory (starting at $23 a tonne in 2012 and rising to $275 in 2050), close to 100% renewable energy can be achieved across all Australian final energy sectors by 2050 with no additional investment requirements beyond the AUD$13 billion allocated over the next decade through the CEFC and ARENA (Figure 15). The High Carbon Price trajectory is sufficient to support continued growth throughout Australian stationary energy sectors post-2020 (Figure 14).

Figure 14: Annual additional cost for the High Carbon Price 100% Renewable Scenario.



Note that the scale of transport industry transformation observed under this scenario would likely require additional policy support (such as an industry framework and/or financial incentives) to target electrification of the automotive sector and preferential allocation of bio-hydrocarbons to aviation and shipping. This requirement also applies to the other scenarios examined in this chapter.

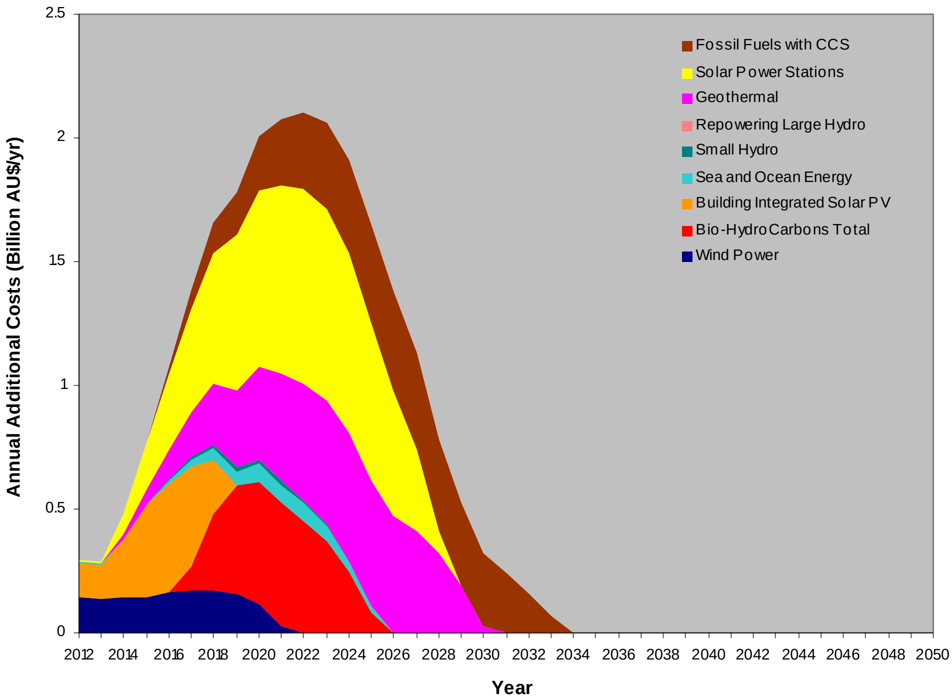
Figure 15: Cumulative additional cost for the High Carbon Price 100% Renewable Scenario. Note that the total cumulative amount required would be covered by the $13 billion currently allocated over the next decade through the Clean Energy Finance Corporation and Australian Renewable Energy Agency.



4.2 Core Carbon Price 100% Renewable Scenario

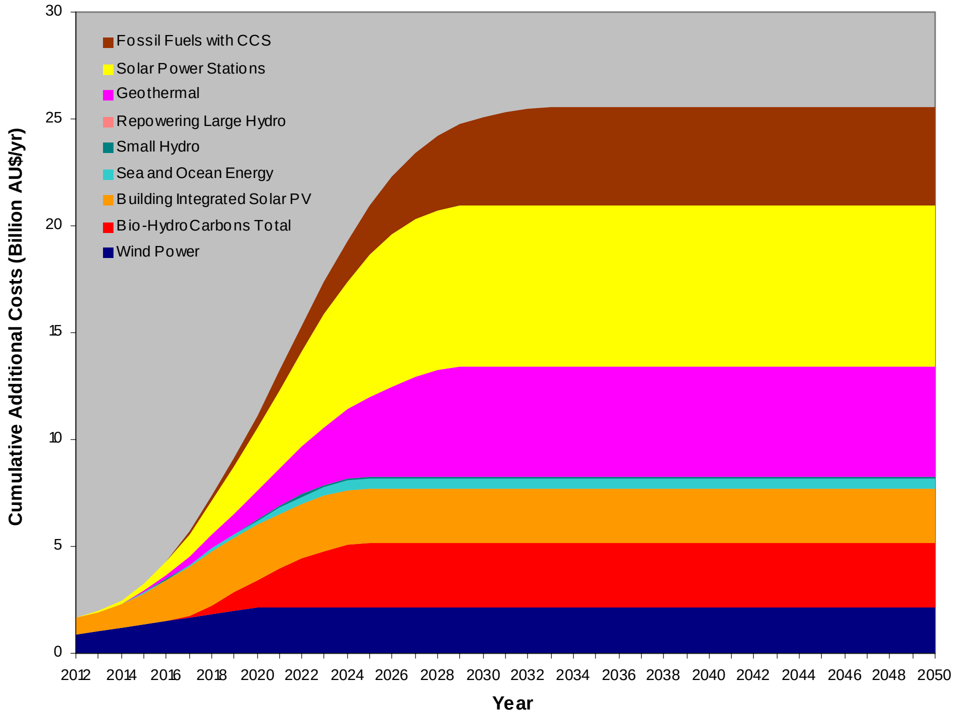
When applying the Treasury's Core Carbon Price projection (starting at $23 a tonne in 2012 and rising to $131 in 2050), Figure 17 indicates a close correlation with Treasury figures for low-carbon energy investment requirements out to 2020 (i.e., approximately equivalent to the AUD$13 billion allocated to the CEFC and ARENA over the next decade). In the decade following 2020, additional expenditure of approximately the same amount again (i.e., a total of approximately AUD$21 billion – excluding CCS) would be required under the Treasury's Core Carbon Price assumptions. This is also in good agreement with the Treasury's estimates over this

Figure 16: Annual additional cost for the Core Carbon Price 100% Renewable Scenario.



timeframe. Since all low-carbon technologies reach grid parity by 2033 for this carbon price trajectory, no further renewable energy investment support mechanisms would be required after this year (Figure 16), though the transport-specific policies mentioned in the previous scenario would also be required here.

Figure 17: Cumulative additional cost for the Core Carbon Price 100% Renewable Scenario.



4.3 Low Carbon Price 100% Renewable Scenario

It can be seen in Figure 20 that low-carbon industries (starting at $23 a tonne in 2012, declining to AUD$4/t$CO_2$e in 2018, and then rising to $30 a tonne in 2050) require approximately AUD$47 billion (excluding CCS) in investment support to 2050. In this analysis, all renewable energy technologies reach grid parity under this carbon price trajectory by 2040, however, CCS does not reached grid parity by 2050 (Figure 19) and would require ongoing investment support to be financially viable in the absence of further carbon price increases.

Figure 18: Annual additional cost for the Low Carbon Price 100% Renewable Scenario.

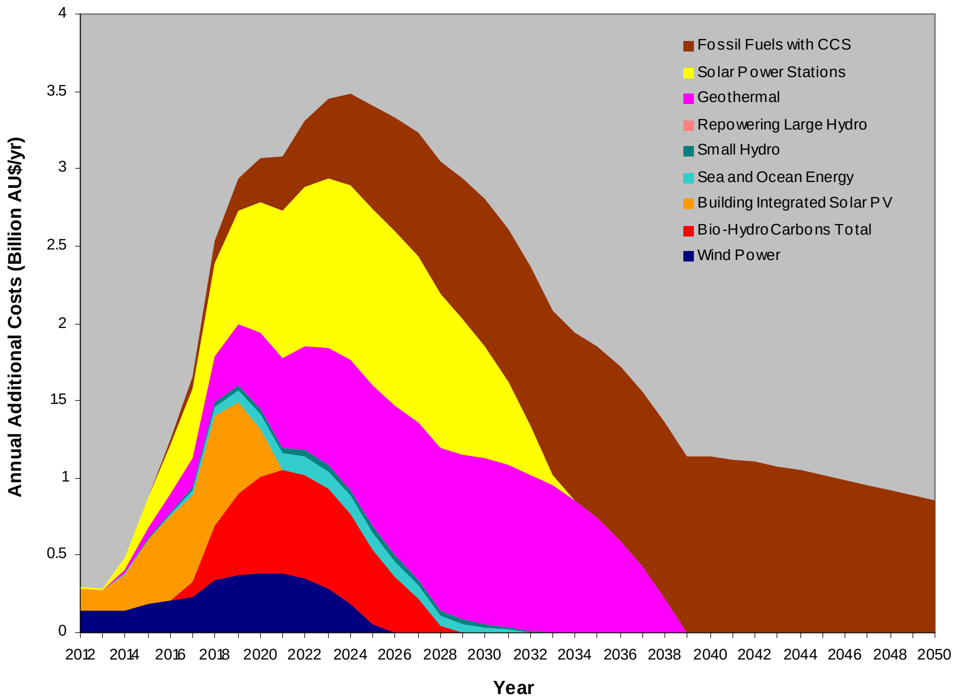
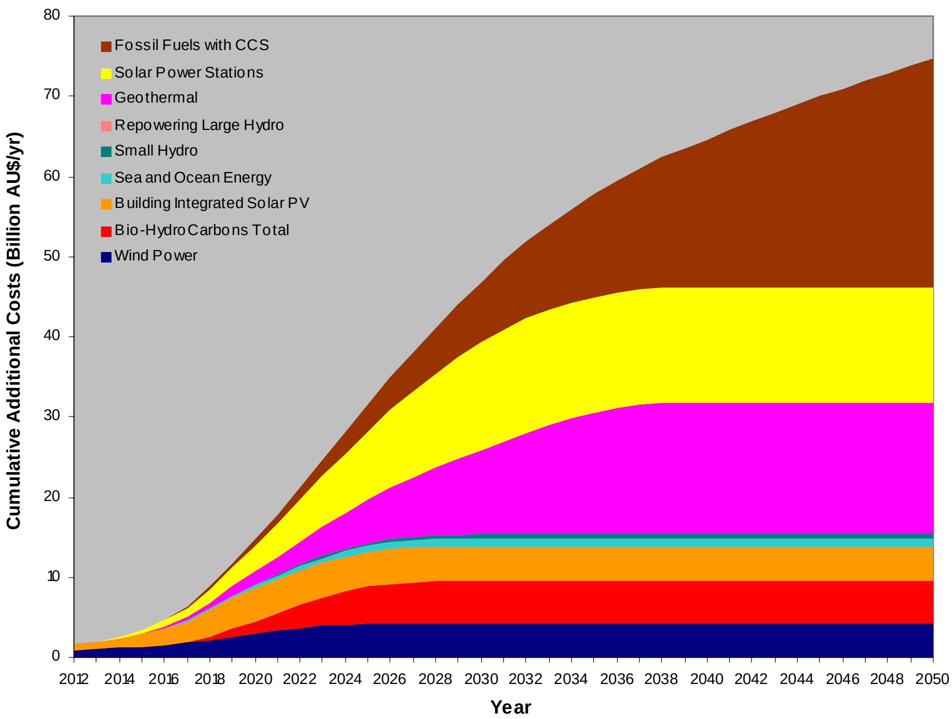


Figure 19: Cumulative additional cost for the Low Carbon Price 100% Renewable Scenario.



4.4 No Carbon Price 100% Renewable Scenario

In the absence of a carbon price, the total investment requirements in low-carbon technologies out to 2050 increase by about AUD$67 billion (excluding CCS) compared to the Treasury Core Policy Carbon Price Projection; see Figure 21.

Figure 20: Annual additional cost for the No Carbon Price 100% Renewable Scenario.

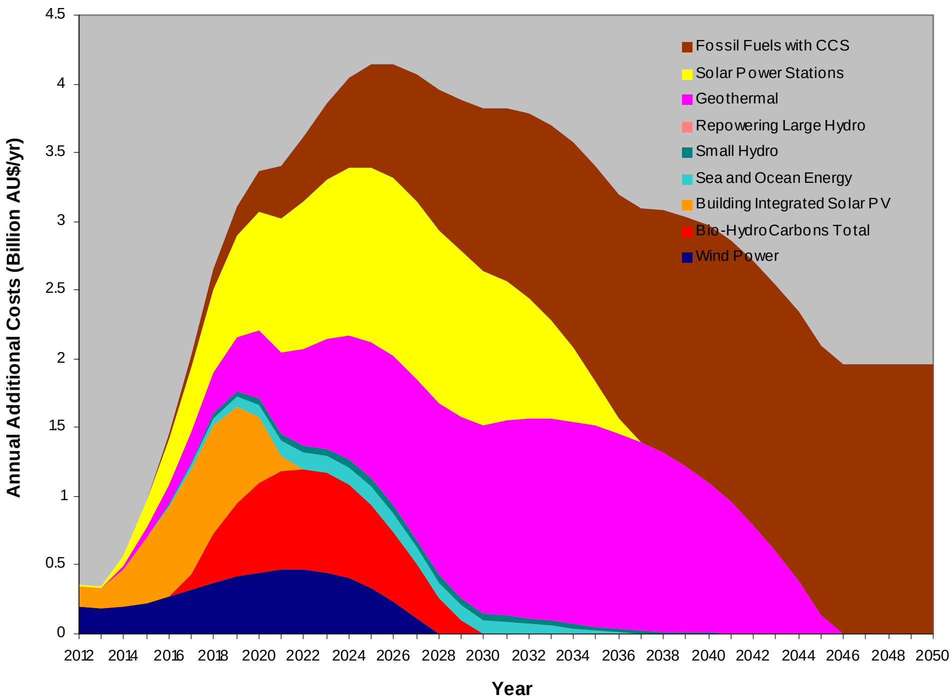
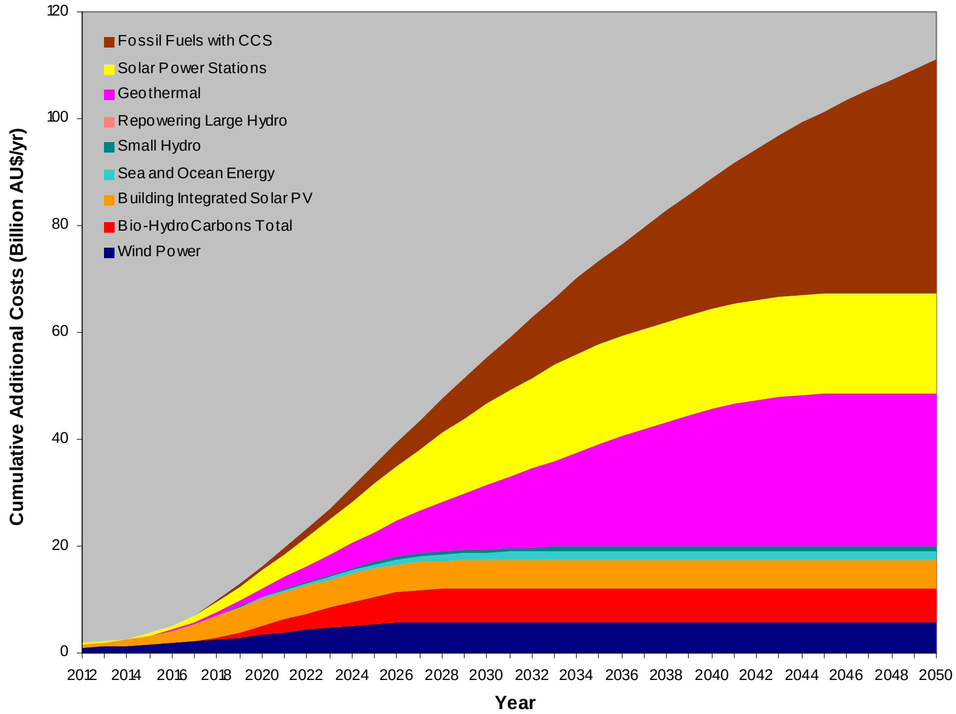


Figure 21: Cumulative additional cost for the No Carbon Price 100% Renewable Scenario.



5. Current and Expanded RET Analysis

The analysis shown in this chapter explores the performance of the current Renewable Energy Target (RET) and the role of a RET beyond 2020.

The impact of renewable energy industry development under the current RET is considered with respect to Australia's domestic emissions reductions and the delivery of 100% renewable energy by 2050. The modelling outputs in this chapter aim to illustrate the renewable energy outcomes under the current policy settings: no increase in the RET after 2020.

This chapter's analysis examines different carbon price scenarios. Each scenario maps out the energy and emissions trajectory forecasts for Australia in the absence of a RET increase beyond 2020. The scenarios all assume existing policies and programs (including the CEFC and ARENA) remain but are not extended beyond their current remit. In other words, these policies contribute substantially to the attainment of the 2020 RET but do little to address the levels of renewable energy investment required beyond 2020.

5.1 Current RET Findings

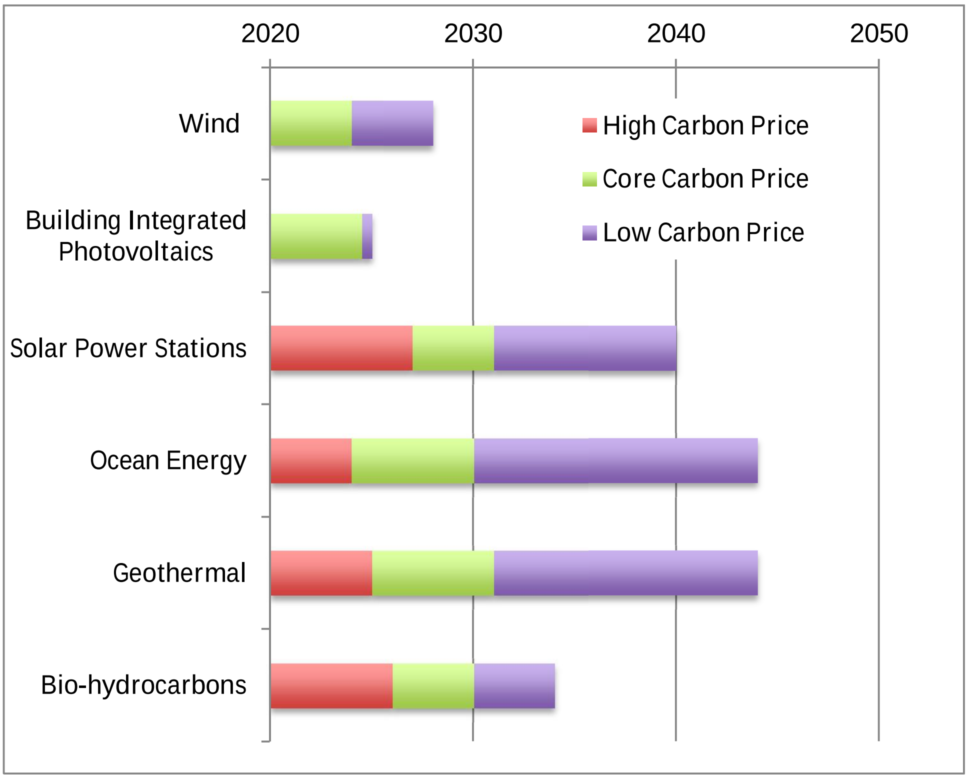
Many of the renewable energy technologies deployed under the 2020 RET of 20% will not have reached grid parity by this year. Assuming the RET and current renewable energy finance mechanisms (such as the CEFC and ARENA) are not extended beyond 2020, there is insufficient market incentive to maintain growth in these industries unless there is either a sufficiently high and reliable carbon price, or an alternative mechanism to bridge the price shortfall.

While a very high carbon price is capable of driving this investment, there is no guarantee that the international trade price of carbon offsets will be sufficient to achieve this, especially if carbon markets remain as low as current levels.

In the absence of a carbon price sufficiently large enough to drive growth – and therefore economies of scale – to bring renewable industries into grid parity with existing electricity prices, most of these industries will stall post-2020. Without a post-2020 RET or similar policy measure, their growth will not resume until ongoing international development and industry learning in these industries has brought their costs down to grid parity (see Appendix B: Learning Rates for more information on learning behaviour).

Figure 22 sets out the duration of collapse and stall for each renewable energy industry for the high, core and low carbon price scenarios, while the annual behaviour under each scenario is then presented in more detail below.

Figure 22: The duration of industry stall for each of the carbon prices once the current RET finishes in 2020.



The anticipated stall in industry growth post-2020 is shown below for the high, core and low carbon price scenarios introduced in Chapter 4 (see Appendix A: Matrix of Key Model Inputs for more details on the carbon price scenarios used in this report).

Figure 23: New renewable energy installed annually for the High Carbon Price No 2030 RET Scenario (based on the Treasury High Carbon Price projection; COA 2011a, COA 2011b).

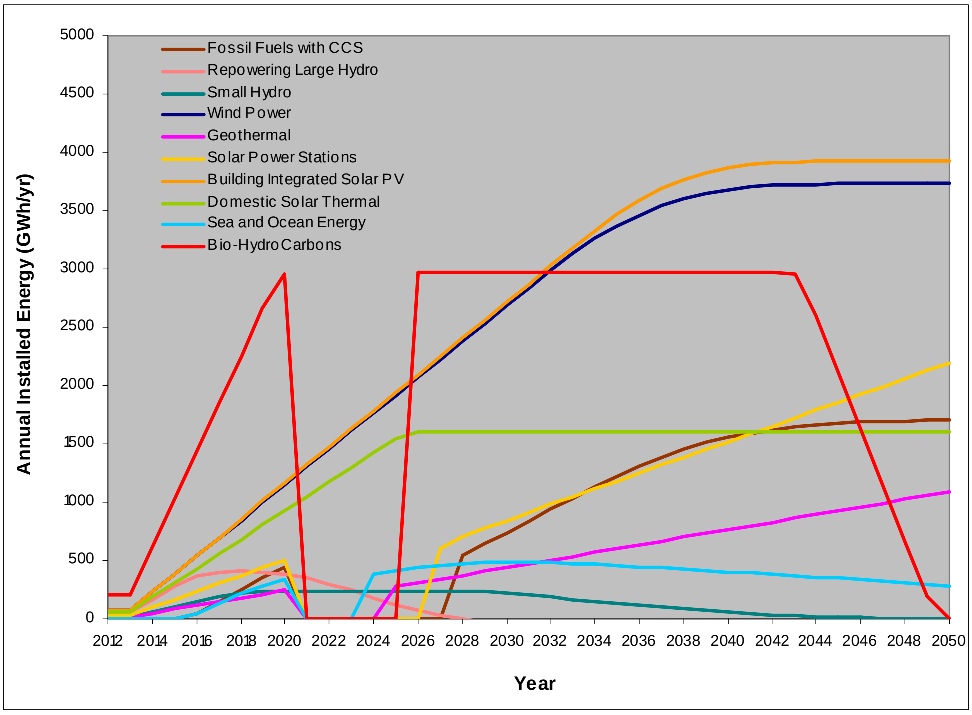


Figure 24: New renewable energy installed annually for the Core Carbon Price No 2030 RET Scenario (based on the Treasury Core Carbon Price projection; COA 2011a, COA 2011b).

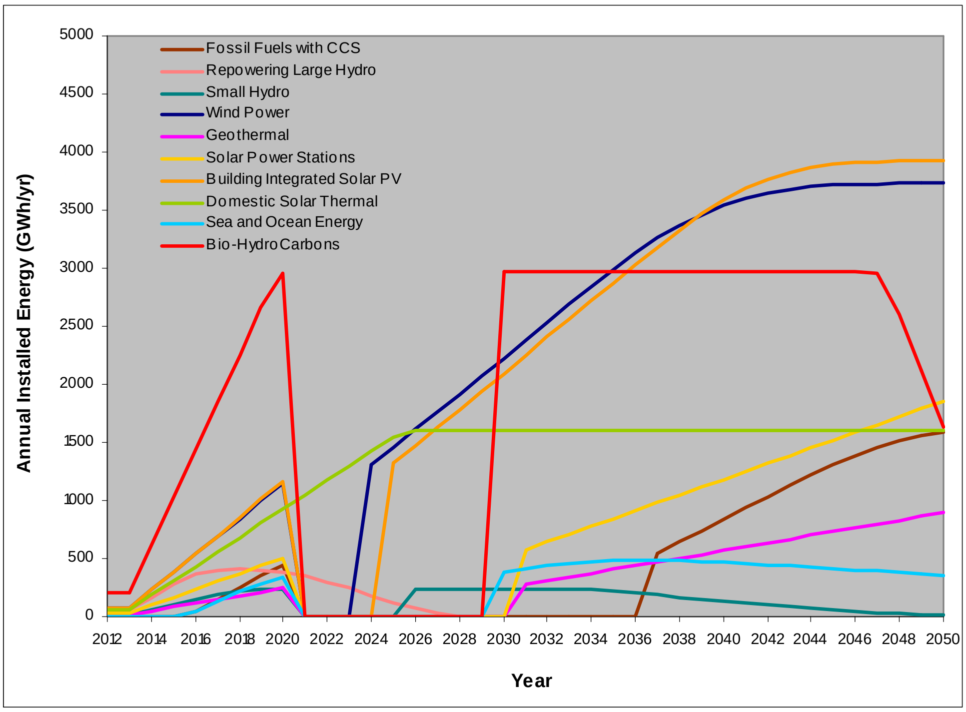
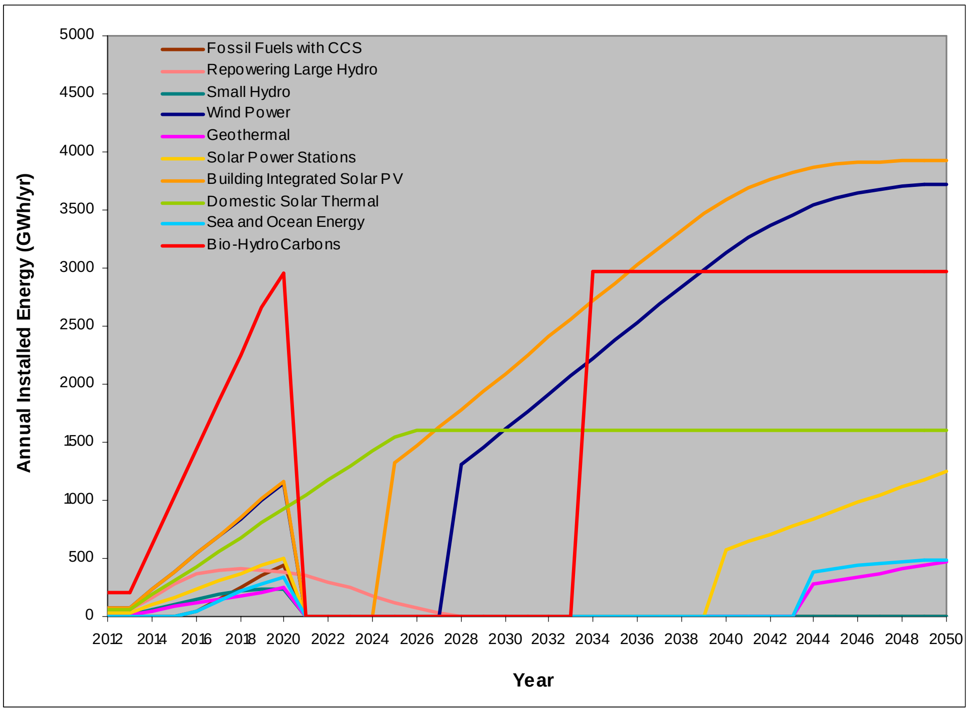


Figure 25: New renewable energy installed annually for the Low Carbon Price No 2030 RET scenario (based on carbon price forecast data from Bloomberg New Energy Finance and the European Commission; BNEF 2012, BNEF 2011, BNEF 2010, EC 2006)



As can be seen in Figures 22 through 25, there is a post-2020 stall in the growth of renewable industries for all three of these carbon price scenarios. The only exceptions are large hydro and domestic solar thermal (which have already achieved grid parity), as well as wind and building integrated solar photovoltaics under the High Carbon Price No 2030 RET Scenario.

Such a stall in domestic growth of renewable industries could hinder domestic learning and further delay the resumption of growth in these industries. However, effects like these have not been included in this analysis. Rather the most optimistic possible resumption has been assumed: that is, once they have reached grid parity, renewable energy industries would recommence growing at the rate at which they were expanding prior to the post-2020 stall.

It should be noted that in this report we have taken a conservative stance with regard to Building Integrated Solar PV grid price parity. This is because the supply/demand mismatch that has driven the recent large downward trends in PV module prices is expected to undergo some level of correction in coming years. This stance is based on learning rate trends in this industry over the past 30 years in which supply/demand mismatches of this kind have consistently been corrected by market forces. In this case, such market correction is already starting to take shape in the form of market rationalisation of PV module manufacturers along with increased demand from China as new domestic policy incentives are introduced. Therefore, the solar PV cost forecasts used in this report - along with all the other renewable technologies examined - are based on long-term learning rate cost reduction trends rather than short-term cost phenomenon.

Similarly, this report also takes a conservative approach with regard to the role of the Small Scale Renewable Energy Scheme (SRES) beyond 2020. Of the 45,000 GWh per year target for the RET, 4,000 GWh per year has been nominally assigned to the SRES, but is ‘uncapped’. Rather than projects receiving certificates for annual projection as is the case for the Large Scale Renewable Energy Target (LRET), projects under the SRES are awarded their certificates for 15 years production at the point of installation. The value of Small-Scale Technology Certificates (STCs) and required acquittal by liable entities is set and administered by the Clean Energy Regulator.

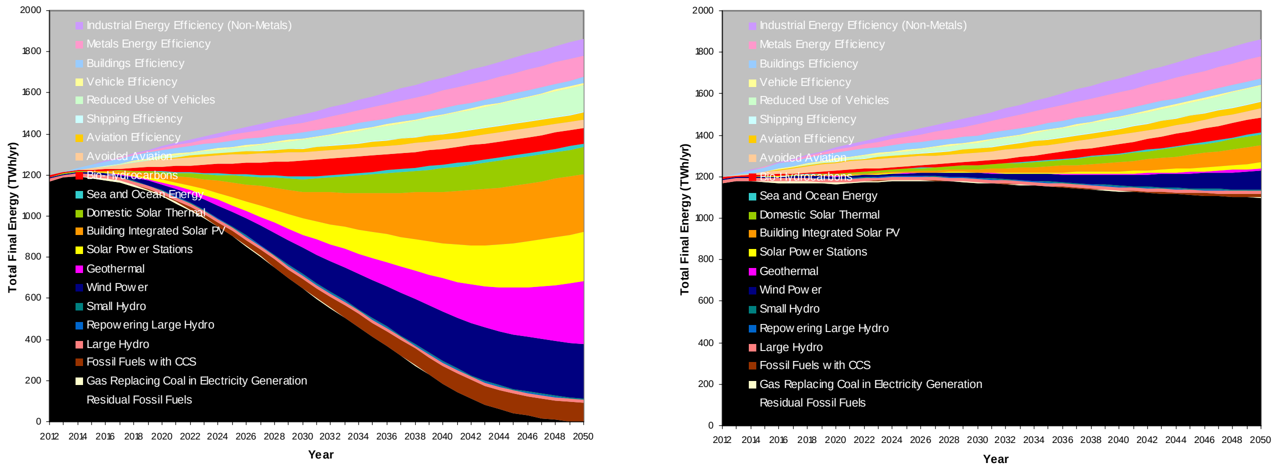
In this analysis it has been assumed that the actually volume of generation from both the LRET and the SRES will be met as originally legislated for a total of 45,000 GWh per year by 2020. It is further assumed that under such conditions the Government would then bring the SRES scheme to a close. What has not been assumed is that by 2020, less than 45,000 GWh per year is being produced and so the SRES continues for some time beyond, nor that the SRES will be allowed to continue post-2020 despite the 45,000 GWh per year target being met – which would represent an increase of the RET.

The results of the analysis serve to highlight the important role that the SRES has to play post-2020.

5.2 Emission and Energy Impact of Stall

Appendix E provides graphs showing the impact on domestic emissions reduction of no 2030 RET under the three carbon price scenarios. It is evident from the graphs that the collapse and then stall of the renewable energy industries at a critical time in their development would lead to a major reduction in the level of renewable energy production and emission cuts achieved. The modelling shows that (under the Core Carbon Price Scenario) fossil fuel use is not substantially reduced in the absence of a post 2020-RET scheme, or equivalent industry development mechanism which is in sharp contrast to the previous finding that, technically, the renewables are able to reduce fossil use from 1200TWh per year to approximately 100TWh per year (see Figure 26 below).

Figure 26: Comparison of the 100% Renewables Scenario with the Core Carbon Price No 2030 RET Scenario showing the stark difference in their impact on fossil fuel consumption.



6. A Safety RET

6.1 The Requirement for a Renewables Safety Net

As the analysis in this report sets out, under the current policy framework most renewable energy industries are set to stall in 2020. This stall would occur because the current RET will finish before all but two industries (solar hot water and large hydro) have achieved cost convergence with the projected energy prices. The number of industries that stall and the duration of their stall will depend on the carbon price. For example, a very high carbon price could see wind and building-integrated solar PV escape a stall, however, it is more likely that wind, building-integrated solar PV, geothermal, small hydro and ocean energy will stall for between 4 and 20 years. This outcome is at odds with the Government's commitment to renewable energy as one of the four pillars of its clean energy plan[34], which states, "The transformation of our energy sector will drive around $100 billion in investment in the renewables sector over the period to 2050."[35]

Therefore a Renewables Safety Net RET is required to maintain renewable energy industry development until each achieves cost convergence with the energy and carbon markets. The most obvious solution is a new but more sophisticated incarnation of the RET after 2020. In the case of a sufficiently high carbon price and adequate renewable energy finance mechanisms, the RET would act as a safety net only and would naturally be superseded by the carbon price market at no additional cost to the economy or consumers.

In the case of a low carbon price, under which investment in renewable industries would otherwise stall, a post-2020 RET would ensure price stability for these industries, and stable continued growth and development of the domestic low-carbon economy. A RET beyond 2020 would also provide a platform from which Australia could meet extended emissions targets under future international agreements.

Since the stall in renewables growth is most significant in the decade from 2020 to 2030, the establishment of a RET safety net, or "Safety RET", for 2030 appears to be a suitable step.

6.2 Establishing a 2030 RET Level

The set of post-2020 targets discussed in this section build on the findings of Chapter 3 and have been set out to be consistent with:

- Achieving 100% renewable electricity by 2050
- Maximising (>90%) domestic clean energy production across all Australian energy sectors by 2050
- A domestic emission level in 2050 that is 80% less than that 2000 emission levels
- Stable industry growth rates that are within plausible limits

As shown in Chapter 3, by 2030 renewable energy industries are capable of providing 169 TWh per year, assuming the inclusions of additional baseline electricity demand from the electrification of automotive vehicles. This renewable electricity level is based on the assumption of 20% growth per annum across renewable energy industries and is indicative of the renewable deployment levels that should be met if 100% renewable energy is to be achieved in Australia by 2050.

Achieving 169 TWh of renewable electricity generation by 2030 is equivalent to a 2030 RET levels of 53% compared to BAU.[36]

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[34] The plan has four pillars: a carbon price; renewable energy; energy efficiency; and action on land. http://www.cleanenergyfuture.gov.au/clean-energy-future/our-plan/

[35] http://www.cleanenergyfuture.gov.au/clean-energy-future/renewable-energy/

[36] To avoid confusion, any percentage renewable electricity generation figures quoted in the text of this section are created with respect to the Business As Usual scenario for electricity. It should be noted however the 100% Renewable Scenario (a) assumes much greater levels of energy efficiency than BAU, and (b) the electrification of transport which must then be provided for from renewables. Thus the actual electricity generation levels under the 100% Renewable Scenario will be quite different from the BAU. For comparison purposes, both sets of figures are shown in Table 4.

If sustained renewable industry growth rates in excess of 20% per annum are achieved, it is possible that these 2030 renewable electricity deployment levels may be exceeded. Or, as shown in Table 4, a lower 2030 RET level could be set if renewable industry growth is modelled to be much higher than 20% post-2030. Sensitivity analysis indicates that a 2030 RET as low as 137 TWh (i.e., 43% of BAU electricity generation) could still lead to 100% renewable electricity by 2050 if renewable industries are assumed to grow at between 27% and 30% post-2030. However, this is close to the plausible maximum rate for annual industry growth, and sustaining such levels over a 20-year timeframe would be a very challenging proposition. Such a scenario carries a high risk of failure as there is no room for industry underperformance, and worse, it could push companies onto business development pathways that expose them to financial vulnerability.

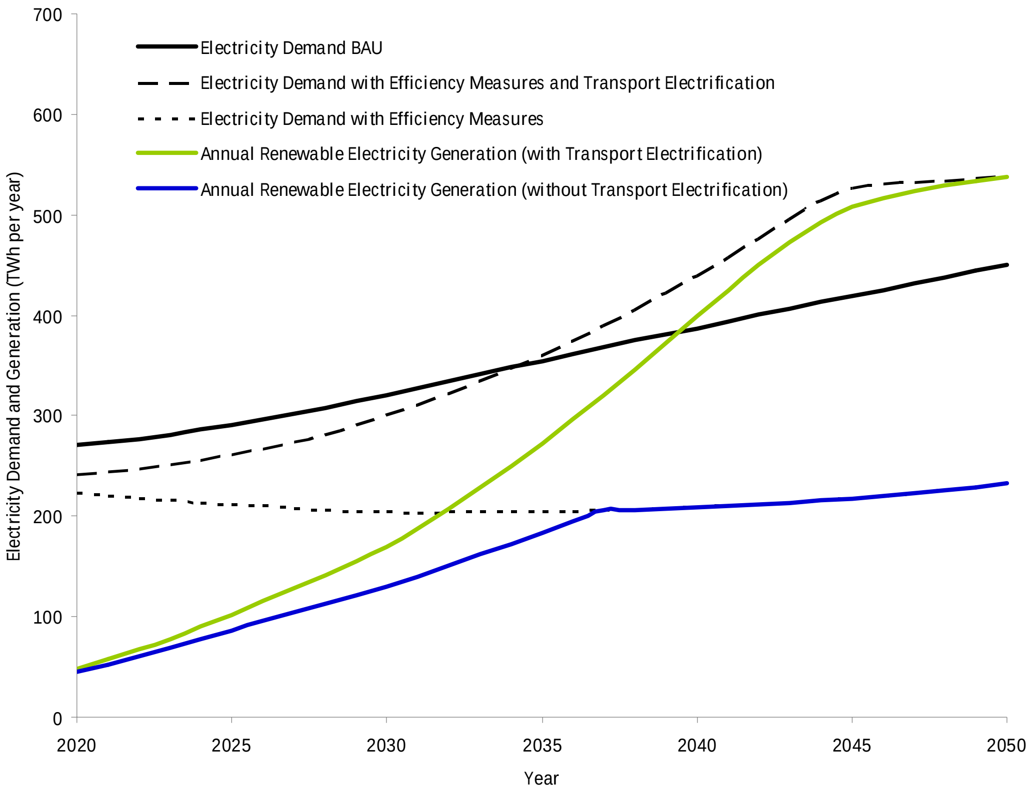
As a more moderate pathway, a 2030 RET level of 159 TWh (i.e., 50% of BAU electricity generation levels) would require renewable industries to grow at a more reasonable 23% per annum post-2030 to achieve 100% renewable electricity by 2050.

Table 4. Potential 2030 Renewable energy targets which consider the inclusion of de-carbonised transport needs.

2030 Renewable electricity generation (TWh)	2030 RET using BAU electricity demand only	2030 RET with energy efficiency measures and transport electrification	Industry growth rate post-2030 required to meet 100% renewable electricity by 2050
169	53%	57%	20%
159	50%	53%	23%
137	43%	46%	>27%

An illustration of the BAU electricity demand and the impact of energy efficiency measures and transport electrification is presented in Figure 27. This shows the BAU electricity projection as a solid black line. This line is reduced down to the dotted line when energy efficiency measures are included and raised up to the dashed line when the impact of transport electrification is also added. The renewable energy trajectory (green line) shows the scale of the task required to meet electricity generation (including transport electrification and energy efficiency measures) with 100% renewable sources by 2050. The trajectory shown in blue indicates the renewable energy trajectory required to meet electricity demand with energy efficiency measures only.

Figure 27: Electricity demand and generation trajectories with and without additional baseline demand from transport electrification and BAU demand reduction from energy efficiency and avoidance measures.



6.3 Banded Production Targets

To ensure that renewable resources are not left undeveloped due to the presence of other, lower cost renewable energy – as is the case under the current RET – the Safety RET should be banded with specific regulated targets for each renewable resource. Note that this is a "technology neutral" approach, that is, it does not specify the technology that is necessary to harness each resource.

This banding mechanisms is also useful for economic efficiency as a means of phasing industries out of the RET as they become competitive in the open electricity market.

7. Conclusions and Policy Implications

- The target of 100% renewable energy can be achieved in Australian electricity generation as early as 2037 with stable renewable energy industry growth rates of 20% per annum, and assuming strong development of energy efficiency.
- If electricity demand is increased to accommodate the electrification of land based transport, Australia can achieve 100% renewable electricity by 2050 at industry growth rates of 20% per annum. This requires an electrification transformation of the automotive sector (growing at 26% per annum) and preferential allocation of Australian bio-hydrocarbon resources to use in aviation and shipping (which are limited by stricter energy density requirements).
- In terms of Australia's total energy needs, it is possible that 95% of required supply could be sourced from renewable technologies by 2050, with the remaining 5% accounted for by the use of fossil fuels with CCS in industrial processes that are not readily adaptable to use with renewable alternatives.
- Achieving near-100% renewable sources for all Australian final energy by 2050 carries a collateral benefit for the Australian economy in that 100% of the 2050 low-carbon economy emission levels (80% below year 2000 levels) could be achieve without further overseas trading.
- The scenarios examined in this report indicate that a carbon price will not be sufficient to ensure continued development of renewable energy in Australia beyond 2020 because:
    - The carbon price may be too low or volatile to cover renewable energy costs in the short and medium term.
    - Uncertainty surrounding forward targets, and therefore carbon prices, makes for a weak investment incentive for new technologies.
    - A carbon price may be altered or replaced by future governments.
- To avoid the possible collapse or stalling of renewable energy deployment in Australia post-2020, a 2030 RET safety net (Safety RET) is essential.
- It was found that a 2030 RET target of between 137 TWh per year and 169 TWh per year is sufficient to avoid a stalling of renewable energy industries post-2020 and to achieve 100% renewable energy by 2050 (including additional electricity demand from the electrification of the transport sector).[37]
- The impact of a lower 2030 RET – 137 TWh per year – would have the effect of deferring substantial renewable industry growth until after 2030. It is found that this would require renewable industries to grow at close to their maximum plausible growth rate (30% per annum) after 2030 to deliver 100% renewable energy by 2050. As a result this scenario carries very high risks of failure as there is no room for industry

[37] This is equivalent to between 43% and 53% of business-as-usual electricity generation.

underperformance, and worse, could push companies onto financially vulnerable business development pathways.

- Different carbon price trajectories change the low-carbon energy investment required to achieve 100% renewable energy in Australia. Several carbon price scenarios have been considered and the results indicate that:
    - Only the highest Treasury carbon price forecast is sufficient to avoid the need for ongoing renewable energy investment post-2020.
    - Other estimates of carbon price require at least a further AUD$13 billion to be spent in the 2020-2030 period.
    - Removing the carbon pricing scheme would leave an AUD$67 billion deficit in low-carbon energy investment requirements that would need to be met using other policy measures.
- Therefore, a carbon price is an essential component of Australia's low-carbon strategy.
- Achieving 100% renewable energy in Australia by 2050 will require further complimentary policy support to address:
    - The electrification of the automotive transport sector, to encourage the adoption of electric vehicles and use of rail alternatives where possible.
    - The preferential allocation of bio-hydrocarbons to aviation and shipping.
    - The preferential allocation of CCS resource to industrial processes that cannot be converted to renewable alternatives.

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Appendix A: Matrix of Key Model Inputs

Table 5: Carbon price trajectories used in this report (COA 2011a, COA 2011b, BNEF 2012, BNEF 2011, BNEF 2010, EC 2006).

Year	High Carbon Price ($/t$CO_2$e)	Core Carbon Price ($/t$CO_2$e)	Low Carbon Price ($/t$CO_2$e)	No Carbon Price ($/t$CO_2$e)
2012	23	23	23	0
2013	27.5	24.15	24.15	0
2014	28.8	25.4	25.4	0
2015	30.3	29	15	0
2016	51.5	29	16	0
2017	53.6	29	17.05	0
2018	56.2	29	4	0
2019	58.8	29	4	0
2020	62	29.4	4.8	0
2021	65.6	31.1	5.7	0
2022	69.7	33	6.5	0
2023	74	35	7.3	0
2024	78.6	37.1	8.2	0
2025	83.5	39.4	9	0
2026	88.7	41.8	9.9	0
2027	94.1	44.3	10.7	0
2028	99.7	46.9	11.5	0
2029	106	49.9	12.4	0
2030	111.9	52.6	13.2	0
2031	117.5	55.4	14	0
2032	124.7	58.9	14.9	0
2033	132.2	62.4	15.7	0
2034	139.9	66.1	16.6	0
2035	147.8	69.9	17.4	0
2036	156	73.8	18.3	0
2037	164.3	77.8	19.1	0
2038	173.2	82	19.9	0
2039	179.8	85.2	20.8	0
2040	186.8	88.6	21.6	0
2041	194.2	92.1	22.5	0
2042	201.9	95.9	23.3	0
2043	210	99.8	24.1	0
2044	218.4	103.8	25	0
2045	227	108	25.8	0
2046	235.9	112.2	26.6	0
2047	245	116.7	27.5	0
2048	254.6	121.2	28.3	0
2049	264.5	126	29.2	0
2050	274.7	130.9	30	0

Table 6: Current capacity and capacity factor assumptions (ABARE 2011, BREE 2012, REN21 2011, Copeland 2010, Geoscience Australia and ABARE 2010, Mallon and Hughes 2008).

Sector	Current Capacity (GW)	Capacity Factor		
		Low	Best	High
Large Hydro	8.35	0.20	0.25	0.30
Small Hydro	0.15	0.50	0.60	0.70
Wind Power	2.18	0.25	0.30	0.35
Geothermal	0.0001	0.80	0.85	0.90
Solar Power Stations	0.003	0.25	0.56	0.73
Sea and Ocean Energy	0.001	0.20	0.35	0.45
Building Integrated PV	1.04	0.10	0.16	0.20
Domestic Solar Thermal	1.8	0.22	0.27	0.30
Bio-Hydrocarbons	0.77	1.00	1.00	1.00
Fossil Fuels with CCS	0	0.50	0.55	0.70

Table 7: Maximum resource potential by 2050 assumptions (ABARE 2011, ABARE 2010, BREE 2012, BREE 2011, EFF 2006, Saddler 2004, IEA GIA 2007, CIE 2006, NREL 2003).

Sector	Maximum Resource by 2050 (TWh)		
	Low	Best	High
New Large Hydro	14	17	20
Small Hydro	4	4	11
Wind Power	200	200	444
Geothermal	28	124	1429
Solar Power Stations	252	238	224
Sea and Ocean Energy	2	5	50
Building Integrated PV	179	282	479
Domestic Solar Thermal	80	94	275
Bio-Hydrocarbons	92	92	92
Fossil Fuels with CCS	136	136	136

Table 8: Learning rate and unit cost assumptions (Hearps and McConnell 2011, REN21 2011, ABARE 2011, Taylor 2006, IEA 2000).

Sector	Historical Learning Rate	Current Cost ($/MWh)		
		Low	Best	High
Large Hydro	0.01	30	45	50
Small Hydro	0.05	50	80	120
Wind Power	0.1	50	85	117
Geothermal	0.08	80	110	120
Solar Power Stations	0.18	140	180	206
Sea and Ocean Energy	0.15	70	110	300
Building Integrated PV	0.180	170	340	500
Domestic Solar Thermal	-0.043	20	50	90
Bio-Hydrocarbons	0.15	250	250	250
Fossil Fuels with CCS (addition cost)	0.2	30	90	150

Appendix B: Learning Rates

Learning rates are a measure of the cost reduction for a doubling of production (Taylor 2006). For emerging technologies, the unit cost decreases as the production volume increases due to economies of scale, technological improvement, production efficiencies, increased know-how, etc.

It can be argued that Australia as a small market can afford to take a back seat on technology development and be a late implementer. However, many parts of industry growth are inescapably local, including the development of expertise and private sector capacity including planning, legal contracting, component manufacture or assembly, and key trades such as electrical installation and site works.

This analysis takes a neutral view as to where in the world technology and industry are developed. It is therefore assumed that Australia, as well as participating in the process of per capita emissions convergence, is also sharing in the industrial development of the major solution technologies and their industries. It is of course possible that Australia may focus particular attention on specific technologies within this mix that may be less likely to receive support by the broader international community, including solar hot water, deep geothermal energy and metals processing efficiency.

Appendix C: Sustainable Industry Growth Rates

Limitations in manufacturing capacity, resource development, labour and skills generally restrict the stable expansion of new industries. While exceptions may exist in the short-term, consistent annual growth rates higher than a certain threshold start to result in supply dislocations that cause temporary price increases and learning rate retardation. In this report, this threshold is assumed to occur at sustained annual growth rates of 30% over the long-term based on empirical evidence for learning rate retardation activation (Mallon, Hughes, Kidney 2009).

It is important to note that growth rates higher than 30% are possible under a "command and control" scenario, as has been observed historically during times of war. However, any potential increase in annual growth rates achieved by forcing the reallocation of resources under such a scenario would still be limited by the finite nature of the underlying resources in the economy. Given the undesirable nature of such an outcome, this scenario has not been considered in this report.

Appendix D: Required renewable energy generation and installation by 2050

Table 9: Table of required power stations and installations for each renewable energy technology for electricity generation with transport by 2050

Resource	Number of Installations	Installation Size
Small Hydro	42	10 MW installations
Wind Power	86	500 MW power stations
Geothermal	34	500 MW power stations
Solar Power Stations	47	500 MW power stations
Buildings Integrated Solar PV	77%	of total available PV roof-space
Domestic Solar Thermal	100%	of total available solar thermal roof-space
Sea and Ocean Energy	10	250 MW power stations

Table 10: Table of electricity generation (including transport) for each renewable energy technology by decade (all units GWh)

Year	Large Hydro	Repowering Large Hydro	Small Hydro	Wind Power	Geothermal	Solar Power Stations	Building Integrated Solar PV	Domestic Solar Thermal	Sea and Ocean Energy
2020	12742	777	746	10386	3936	5118	9065	4760	898
2021	12742	900	881	12719	5037	6532	11540	5901	1208
2022	12742	1004	1010	15269	6244	8075	14241	7148	1529
2023	12742	1092	1136	18092	7580	9775	17219	8526	1854
2024	12742	1160	1261	21187	9049	11637	20480	10040	2176
2025	12742	1208	1380	24495	10652	13657	23995	11685	2489
2026	12742	1234	1482	27889	12375	15815	27642	13368	2786
2027	12742	1241	1559	31246	14200	18088	31264	14998	3064
2028	12742	1237	1617	34633	16184	20542	34914	16636	3334
2029	12742	1226	1656	38059	18338	23177	38599	18293	3595
2030	12742	1207	1673	41409	20609	25863	42200	19913	3835
2031	12742	1216	1720	45916	23542	29337	46987	22086	4166
2032	12742	1230	1769	50894	26895	33161	52266	24486	4517
2033	12742	1241	1811	55985	30494	37091	57668	26940	4851
2034	12742	1247	1848	61117	34310	41075	63121	29414	5158
2035	12742	1255	1888	66520	38476	45263	68859	32019	5452
2036	12742	1264	1931	72182	43001	49650	74871	34749	5725
2037	12742	1273	1973	78019	47849	54181	81072	37564	5969
2038	12742	1282	2017	84091	53076	58905	87534	40498	6187
2039	12742	1288	2058	90107	58574	63691	94028	43461	6368
2040	12742	1295	2101	96067	64478	68676	100615	46548	6533
2041	12742	1300	2140	101485	70637	73690	106756	49547	6672
2042	12742	1304	2179	106273	77167	78846	112287	52215	6802
2043	12742	1306	2215	110118	83957	84025	116805	54404	6918
2044	12742	1305	2248	113035	90977	89177	120220	56077	7022
2045	12742	1294	2263	114464	97580	93551	121900	56851	7068
2046	12742	1272	2257	114426	103505	96671	121921	56748	7049
2047	12742	1246	2244	113835	109250	98878	121319	56425	7009
2048	12742	1220	2232	113210	115132	100377	120663	56114	6970
2049	12742	1196	2221	112646	121199	101186	120065	55836	6936
2050	12742	1172	2208	111998	127285	101299	119375	55515	6896

Table 11: Table of electricity capacity (including transport) for each renewable energy technology by decade (all units GW)

Year	Large Hydro	Repowering Large Hydro	Small Hydro	Wind Power	Geothermal	Solar Power Stations	Building Integrated Solar PV	Domestic Solar Thermal	Sea and Ocean Energy
2020	5.9	0.2	0.1	4.0	0.5	1.2	6.9	5.4	0.3
2021	5.9	0.2	0.2	4.9	0.7	1.5	8.7	6.7	0.4
2022	5.9	0.3	0.2	5.8	0.8	1.9	10.8	8.2	0.5
2023	5.9	0.3	0.2	6.9	1.0	2.2	13.0	9.7	0.6
2024	5.9	0.3	0.2	8.1	1.2	2.7	15.5	11.5	0.8
2025	5.9	0.3	0.3	9.3	1.4	3.1	18.1	13.3	0.9
2026	5.9	0.3	0.3	10.6	1.7	3.6	20.9	15.3	1.0
2027	5.9	0.3	0.3	11.9	1.9	4.2	23.6	17.1	1.1
2028	5.9	0.3	0.3	13.2	2.2	4.7	26.4	19.0	1.2
2029	5.9	0.3	0.3	14.5	2.5	5.3	29.2	20.9	1.3
2030	5.9	0.3	0.3	15.8	2.8	5.9	31.9	22.7	1.3
2031	5.9	0.3	0.3	17.5	3.2	6.7	35.6	25.2	1.5
2032	5.9	0.3	0.3	19.4	3.6	7.6	39.6	28.0	1.6
2033	5.9	0.3	0.3	21.4	4.1	8.6	43.7	30.8	1.7
2034	5.9	0.3	0.4	23.3	4.6	9.5	47.8	33.6	1.8
2035	5.9	0.3	0.4	25.4	5.2	10.5	52.2	36.6	1.9
2036	5.9	0.3	0.4	27.5	5.8	11.5	56.8	39.7	2.0
2037	5.9	0.3	0.4	29.8	6.4	12.5	61.5	42.9	2.1
2038	5.9	0.3	0.4	32.1	7.1	13.6	66.4	46.2	2.2
2039	5.9	0.3	0.4	34.4	7.9	14.7	71.3	49.6	2.2
2040	5.9	0.3	0.4	36.7	8.7	15.9	76.4	53.1	2.3
2041	5.9	0.3	0.4	38.8	9.5	17.1	81.1	56.6	2.3
2042	5.9	0.3	0.4	40.6	10.4	18.3	85.4	59.6	2.4
2043	5.9	0.3	0.4	42.1	11.3	19.5	88.9	62.1	2.4
2044	5.9	0.3	0.4	43.2	12.2	20.7	91.6	64.0	2.5
2045	5.9	0.3	0.4	43.7	13.1	21.7	93.0	64.9	2.5
2046	5.9	0.3	0.4	43.7	13.9	22.4	93.1	64.8	2.5
2047	5.9	0.3	0.4	43.5	14.7	23.0	92.6	64.4	2.5
2048	5.9	0.3	0.4	43.3	15.5	23.4	92.1	64.1	2.5
2049	5.9	0.3	0.4	43.1	16.3	23.6	91.7	63.7	2.4
2050	5.9	0.3	0.4	42.8	17.1	23.7	91.1	63.4	2.4

Appendix E: Domestic Abatement with no RET

The energy and emissions wedge diagrams for three carbon price no RET scenarios are shown below in Figure x through Figure x:

- Figure 28 and Figure 29 – High Carbon Price No 2030 RET scenario.
- Figure 30 and Figure 31 – Core Carbon Price No 2030 RET scenario.
- Figure 32 and Figure 33 – Low Carbon Price No 2030 RET scenario.

For the scenarios below, domestic abatement measures accounted for 55% and 53% of emissions abatement in 2050 for the High Carbon Price No 2030 RET and Core Carbon Price No 2030 RET scenarios, respectively. This is in good agreement with the Treasury's modelling of domestic emissions abatement in Australia under their Core Policy Carbon Price scenario (Figure 34).

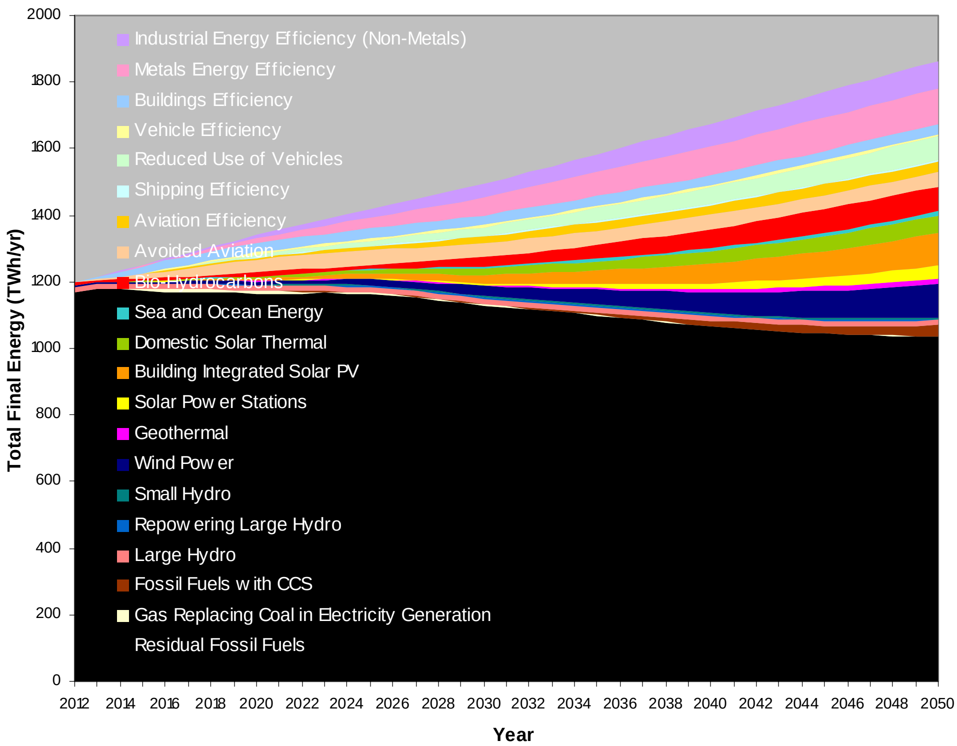


Figure 28: Final energy wedge diagram for the High Carbon Price No 2030 RET scenario (based on the Treasury High Carbon Price projection; COA 2011a, COA 2011b).

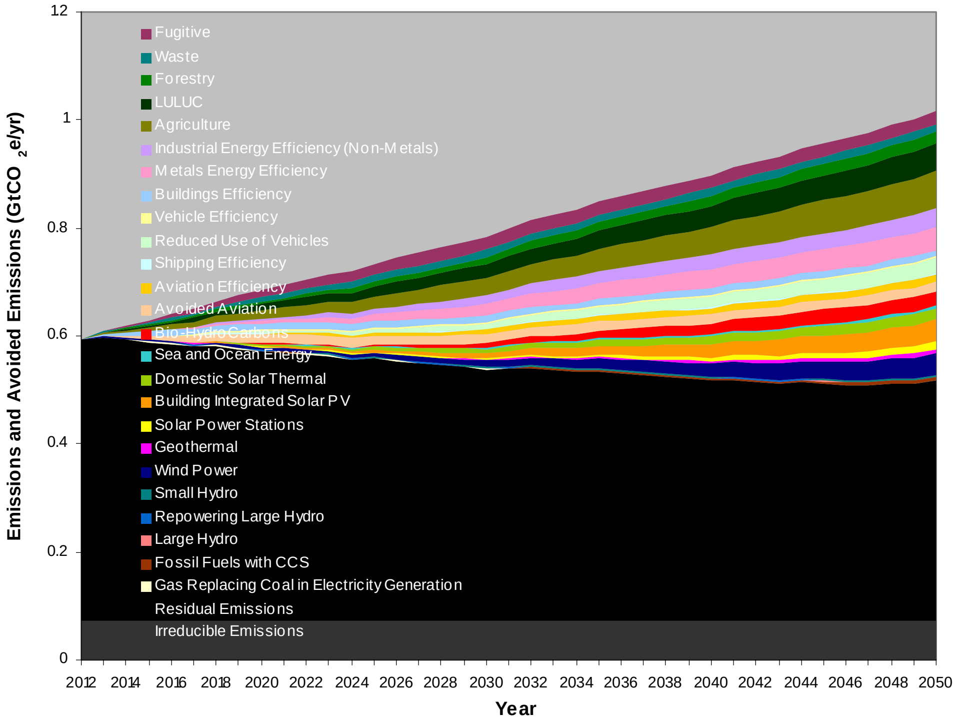


Figure 29: Emissions abatement wedge diagram for the High Carbon Price No 2030 RET scenario (based on the Treasury High Carbon Price projection; COA 2011a, COA 2011b).

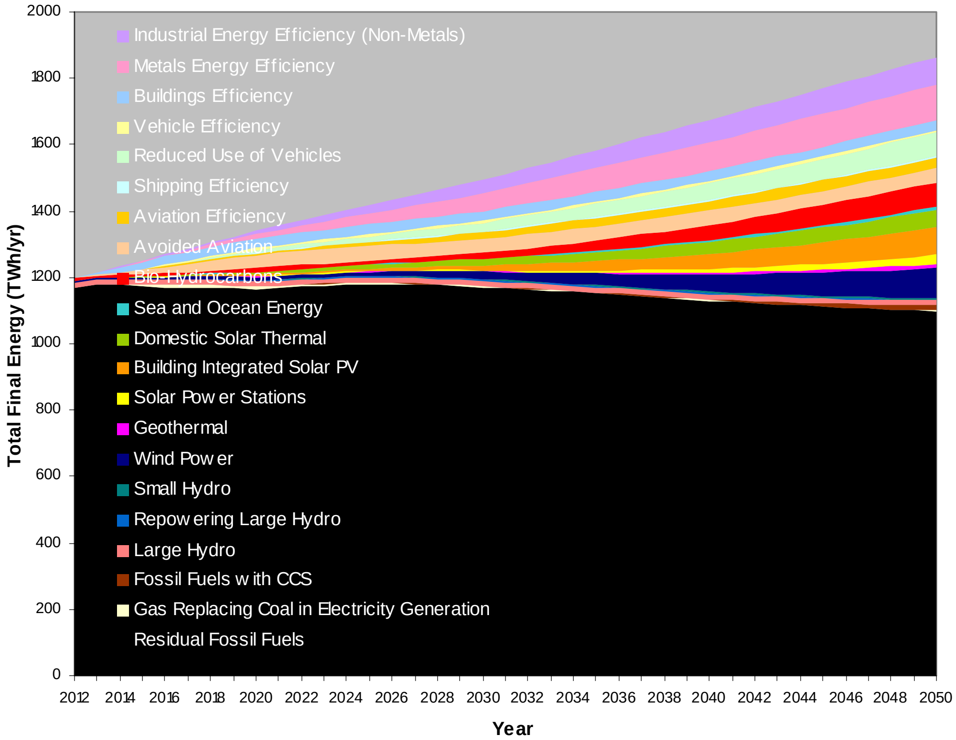


Figure 30: Final energy wedge diagram for the Core Carbon Price No 2030 RET scenario (based on the Treasury Core Carbon Price projection; COA 2011a, COA 2011b).

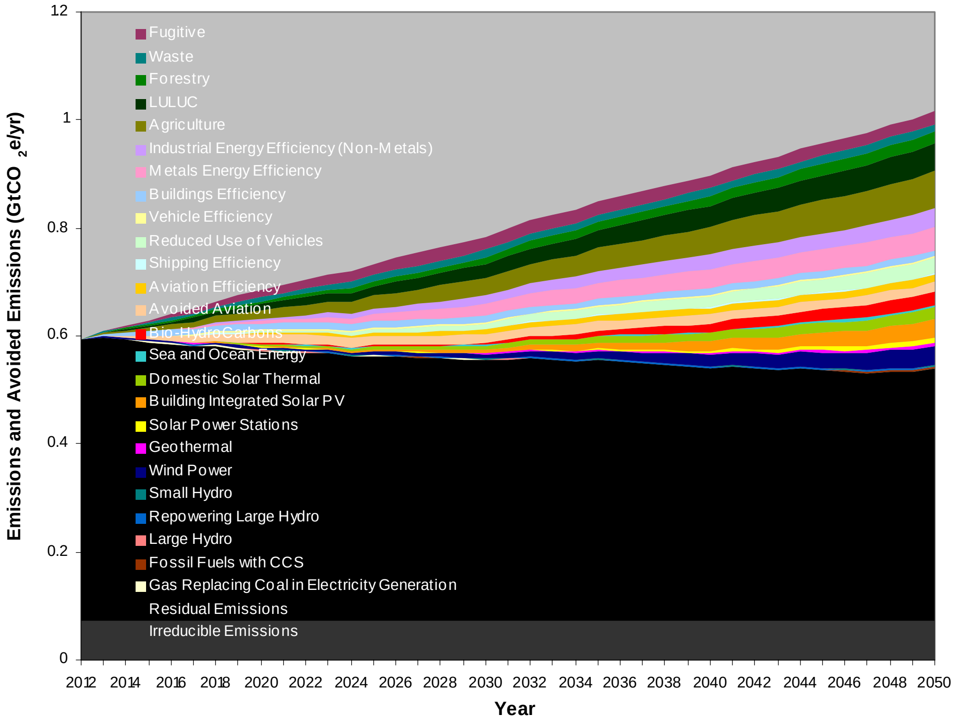


Figure 31: Emissions abatement wedge diagram for the Core Carbon Price No 2030 RET scenario (based on the Treasury Core Carbon Price projection; COA 2011a, COA 2011b).

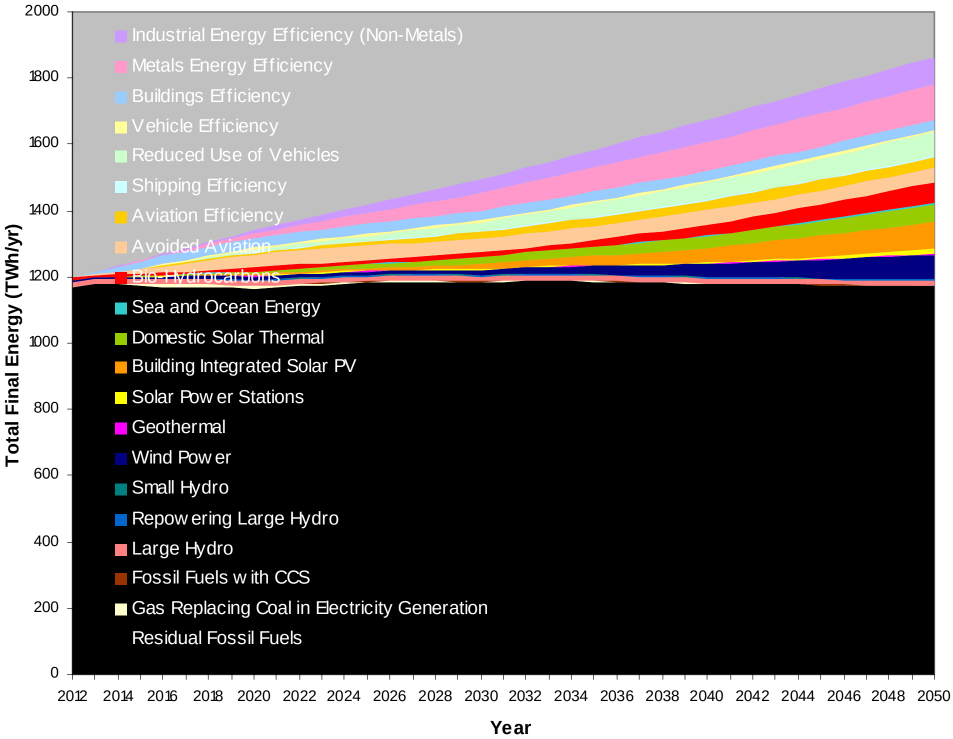


Figure 32: Final energy wedge diagram for the Low Carbon Price No 2030 RET scenario (based on carbon price forecast data from Bloomberg New Energy Finance and the European Commission; BNEF 2012, BNEF 2011, BNEF 2010, EC 2006).

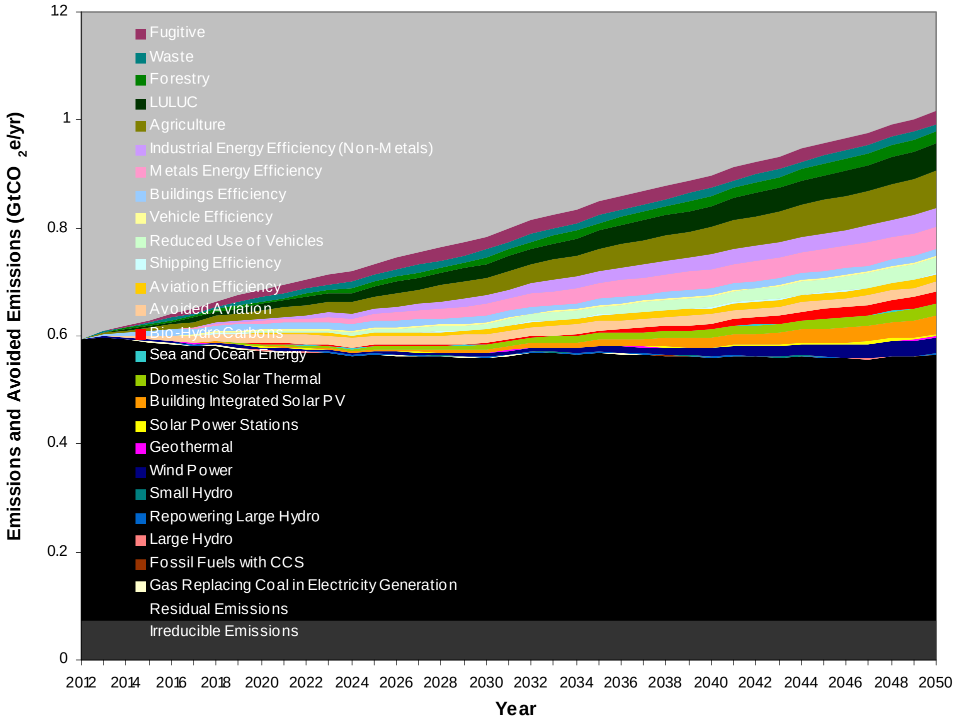
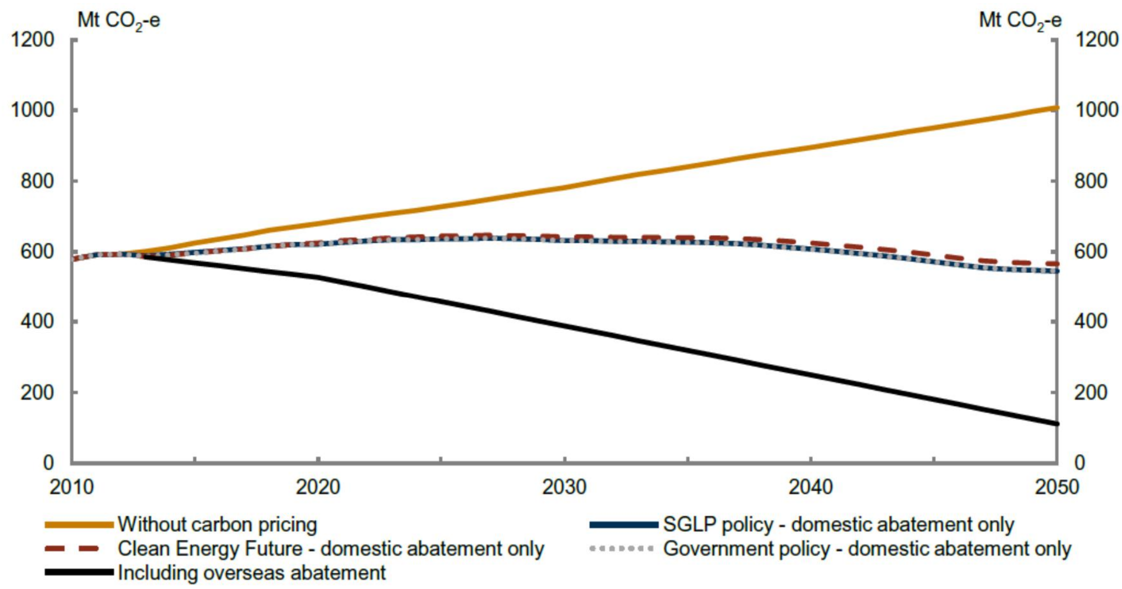


Figure 33: Emissions abatement wedge diagram for the Low Carbon Price No 2030 RET scenario (based on carbon price forecast data from Bloomberg New Energy Finance and the European Commission; BNEF 2012, BNEF 2011, BNEF 2010, EC 2006).

Figure 34: Treasury domestic and overseas emissions abatement projections (COA 2011b).



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