Prosperous Sustainability:

Clean Technology

Forecasts to 2050

Picking Winners or Securing Options?

Australian CleanTech

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Prosperous Sustainability: Clean Technology Forecasts to 2050

Summary

To build long term economic sustainability, it is essential to have a view of the likely technologies that will adopted on large scale and the likely timing of these adoptions. Much contemporary literature provides advice on current and forecast cost curves for future energy technologies, but this is usually only extended to 2030 at the furthest. These analyses also rarely seem to extend through to other clean technologies. There is of course a good reason for the constraints placed on these reports: the longer the forecast period and the wider the technology scope, the less accurate the output forecasts will be.

This short report attempts make these longer term technology forecasts. In doing this however, it is recognised that there have been significant assumptions made and that there are likely to be inaccuracies in the forecasts. However, to be able to make long term policies, it seems essential to have a feel for the probable development paths of the major known technologies.

The forecast charts in this report present a profile of clean technology progress through to 2050. It has made assumptions on the timing of mass roll-outs of technologies and when some of them will become superseded by alternatives. The charts are presented using an undefined 'Activity Measure'. This could represent employment numbers, revenues or market capitalisations depending on the viewpoint.

In the attachments are various comparable charts produced by other organisations. There is one major difference between the charts presented in this report and those from other organisations and that is that the measure of activity is more general in this report and is not tied to, for instance, megawatts of installed generating capacity. When looking at wind turbines, the installed assets will continue to generate power but, as the installation rate decreases, the level of 'activity' will decline. The logic behind this approach is that much of the economic activity associated with a particular sector is in the manufacture and installation of equipment rather than the ongoing operational costs.

Even taking account of the alternative measurement techniques, there are still differences of opinion on the take-up rate and subsequent decline of certain industries. For instance, in the charts presented in this report:

- the wind industry provides a smaller proportion of the long term generation portfolio and declines as a technology of choice earlier;
- the solar thermal industry provides a larger proportion and matures earlier;
- the geothermal industry matures earlier but does not end up being such a significant contributor; and
- dedicated electric vehicles are assumed to become more dominant more quickly.

There is no right answer to these issues, but there are some driving assumptions that are detailed below that have led this report to come to its conclusions. Some these are clearly different to assumptions used in other reports.

Picking Winners or Securing Options?

It could be argued that this is an exercise in picking winners, which is always a risky proposition. An alternate viewpoint however is that by understanding technology development pathways and likely maturation profiles, policy makers are able to ensure that they secure options for the future scenarios.

By understanding the likely timing of technology maturation, it is possible to ensure that policies are developed to ensure that maximum benefits for a specific region are secured. These benefits may include opportunities for economic development, the creation of so-called ‘green collar’ jobs and the potential to establish global or regional centres of excellence.

It is clear that some cities, states or countries will become leaders in various technologies. The greatest chance for securing a leadership position will be secured by recognising this potential early and then implementing proactive policies with respect to building the foundations necessary for success. These foundations may include policies focussed on investment attraction and the development of industry, infrastructure and skills.

Forecast Limitations

The forecasts made in this report have many limitations. Some of these are as follows:

- **Geographic Constraints** – some technologies will develop more in certain countries because of climatic, mineral or other natural resource differences. For instance, solar technologies will be more prevalent in sunny countries and countries with no oil may transition to electric vehicles more quickly.
- **Temporal Constraints** – the report assumptions have been developed on the basis that there is a gradual increase in regulatory drivers for the majority of the technologies considered. This would be consistent with what appears to be the incremental approach to global agreements on issues such as emissions caps. If the pace of regulatory drivers increases due to early onset catastrophic climate change or slows because of reduced environmental concerns then the assumed timeframes of this report will vary.
- **Data Integrity** – this analysis is not backed up by rigorous data and analysis, but rather has been developed from many years understanding the emerging improvements, possible applications and limitations of each of the technologies. The results can not therefore be verified although some of the key assumptions have been set out below. Other reports may provide more bottom up data in an attempt to demonstrate rigour in the presented results. The bottom up numbers are however based entirely on assumptions such as those provided below and therefore there is no reason for any improved forecast accuracy.
- **New Technologies** – the profiles have been compiled largely on known technologies although there is some allowance for 'Other' technologies in the outer years of the profile. It is quite possible that some very early stage technologies, that have not yet had sufficient coverage to warrant inclusion in this profile, make significant progress and enter this profile in reality.

These limitations mean that this report is not intended to be used in any form as an absolute forecast, but rather as a tool to interrogate the technology maturation profiles for specific regions. It will also be essential to revisit this forecast on a regular basis to capture technology developments as they occur.

Technology Assumptions

The assumptions made about each of the technologies included in, and some of those excluded from, this review have been set out below.

- **Wind** – the current wind technology is assumed to maintain a high level of activity through to about 2015, after which it starts to be replaced by second generation wind technologies. The current technology has no further installation after 2022.
- **Wind, Generation 2** – this is undefined as to the exact technology in question, but may consist to vertical axis or Darrieus turbines or other improvements on the current large scale horizontal axis turbines. This technology is forecast to take over from the existing wind technology progressively from 2015, increasing in activity through to about 2025 and reducing to low level of ongoing activity by 2035.
- **Solar Roof Top Panels** – whilst this is forecast to increase in activity through to 2012, it is forecast that the applications will reduce thereafter and finally becoming obsolete by 2020. This will initially be driven by feed-in tariffs but then decline due to other solar technologies becoming more economic.
- **Concentrating Solar** – is forecast to have a long gestation, with large scale roll out not apparent until 2018, but to form a major component of the industry by 2050, although maybe down from its peak in the late 2020s.
- **Building Integrated Solar** – this is also forecast to be one of the long term successes with its roll out and adoption continuing to grow through to the end of the forecast period as applications continue to be extended through from rooves and windows to a greater variety of surfaces
- **Geothermal** is another long term survivor. The forecast shows an initial adoption that starts to become significant from 2015 onwards. There is also a forecast increase in the roll out in the 2030s as unspecified technology improvements increase the efficiency.
- **Wave and Tidal** power follows the growth of Geothermal through to about 2030, after which it starts to decline as other technologies, with fewer mechanical parts, emerge as cheaper options. Whilst it is forecast to continue to have some niche applications by 2050, they are seen as only some geographic specific applications rather than more ubiquitous projects.

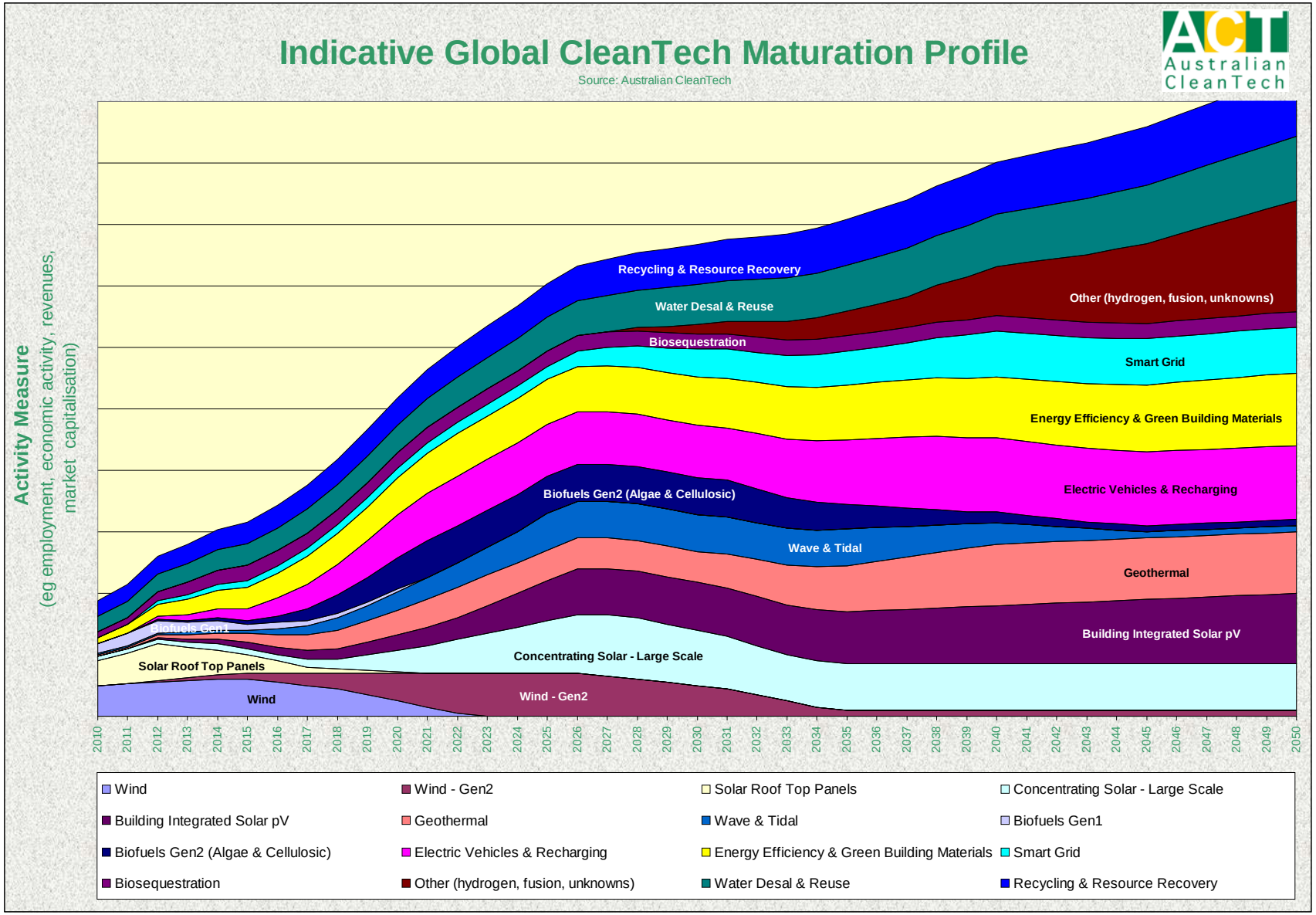
- **Biofuels – Generation 1** – it is assumed first generation biofuels has a steady activity on a global basis through to 2012, after which it goes into decline and is steadily replaced by Gen-2 Biofuels of algae and cellulosic technologies. Once these technologies have been proven, they are forecast to experience growth through to 2025 and then to remain steady for 10 years before going into decline. It is forecast that there will be continuing niche uses of biofuels in 2050.
- **Electric Vehicles and Recharging** – the forecast growth in battery electric vehicles and the associated recharging infrastructure has been brought forward by recent events in the global car industry. It is now forecast that the major roll out will commence in 2012 and continue to grow throughout the forecast period.
- **Energy Efficiency and Green Building Materials** – it forecast that this is a major part of the solution and continues to grow and innovate throughout the entire period. There are of course many components of the this sector but as a whole there is forecast to be continuing focus on reducing energy requirements and using more sustainable materials.
- **Smart Grid** – similarly this category is forecast to expand throughout the period, although it will not start a widespread roll-out until 2012 and will only significantly expand in the 2020s. There are likely to be many iterations of what is considered 'smart' in a grid and it is only towards the end of the forecast period that it might become fully interactive. Having said that there are likely to be large capital projects throughout the period as old grids are progressively upgraded.
- **Bio-sequestration** – is forecast to have modest activity throughout the period and will continue to be driven by the need for carbon offsetting projects. It is not forecast to grow as many of the other technologies will start to become cost competitive and there will consequently be a decreasing level of carbon to be offset.
- **Other Technologies** – including hydrogen, nuclear fusion and other as yet unknown technologies may become significant parts of the equation after 2030. To understand what these might be it is important review this analysis on a regular basis to identify emerging technologies and factor them into future policy decisions.

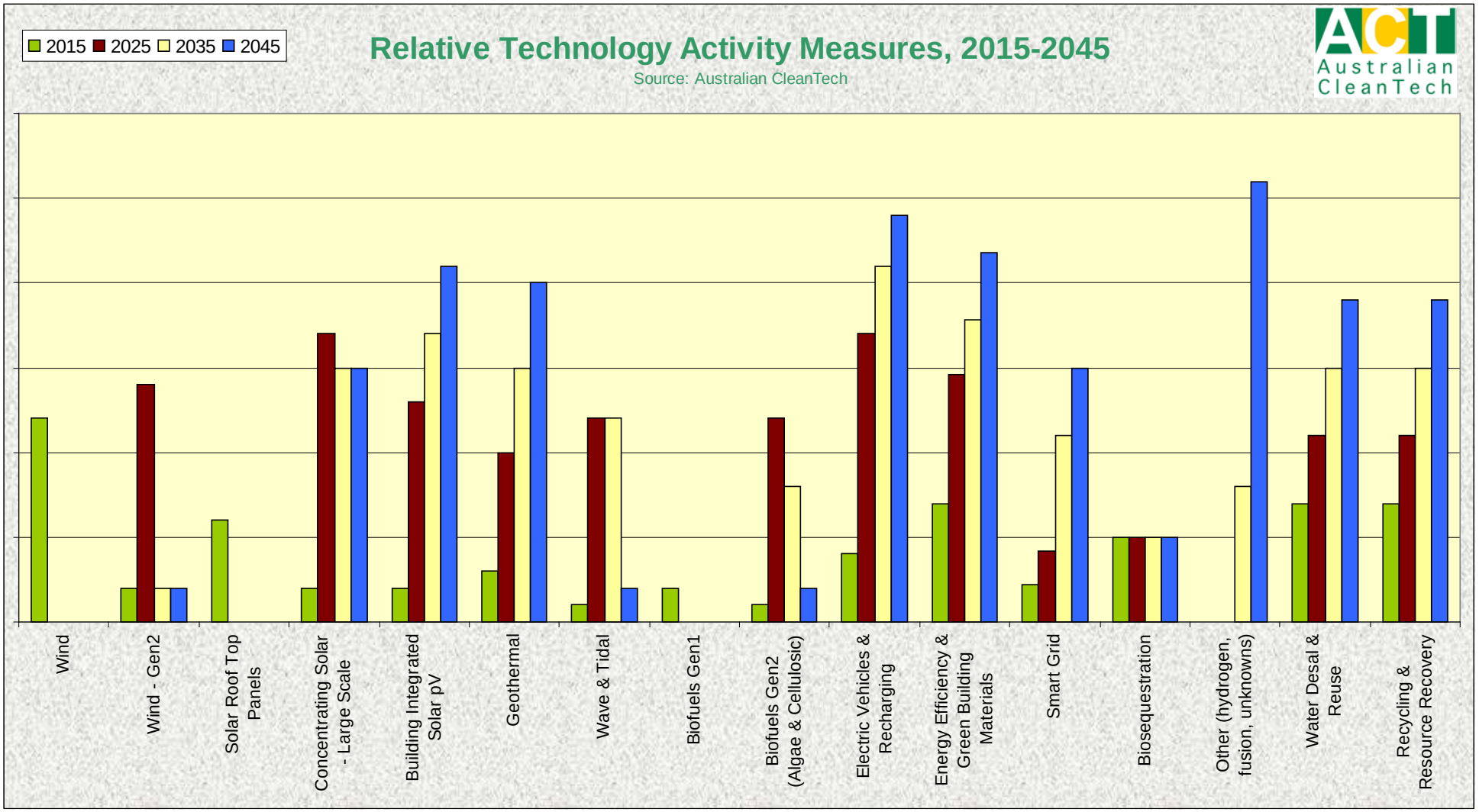
- **Water Desalination and Reuse** – it is forecast that this will continue to be a growing area of activity throughout the forecast period. There are many technology options within this broad category. Preserving, reusing and creating new sources of potable water is however sure to continue to grow to provide for growing populations and improved living standards.
- **Recycling and Resource Recovery** – similarly to water usage and for the same reasons, materials recycling and resource recovery is forecast to grow throughout the period. Again there are many individual technologies available in this sector and there will be varying trends in the uptake of individual technologies.

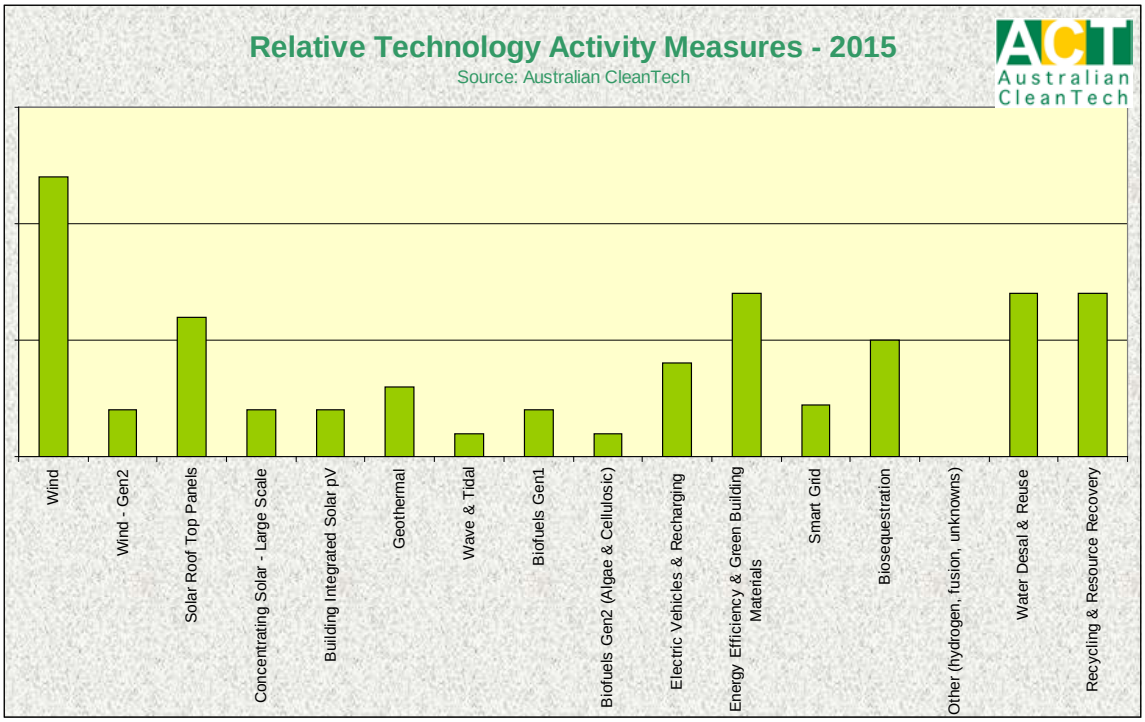
Forecast Presentations

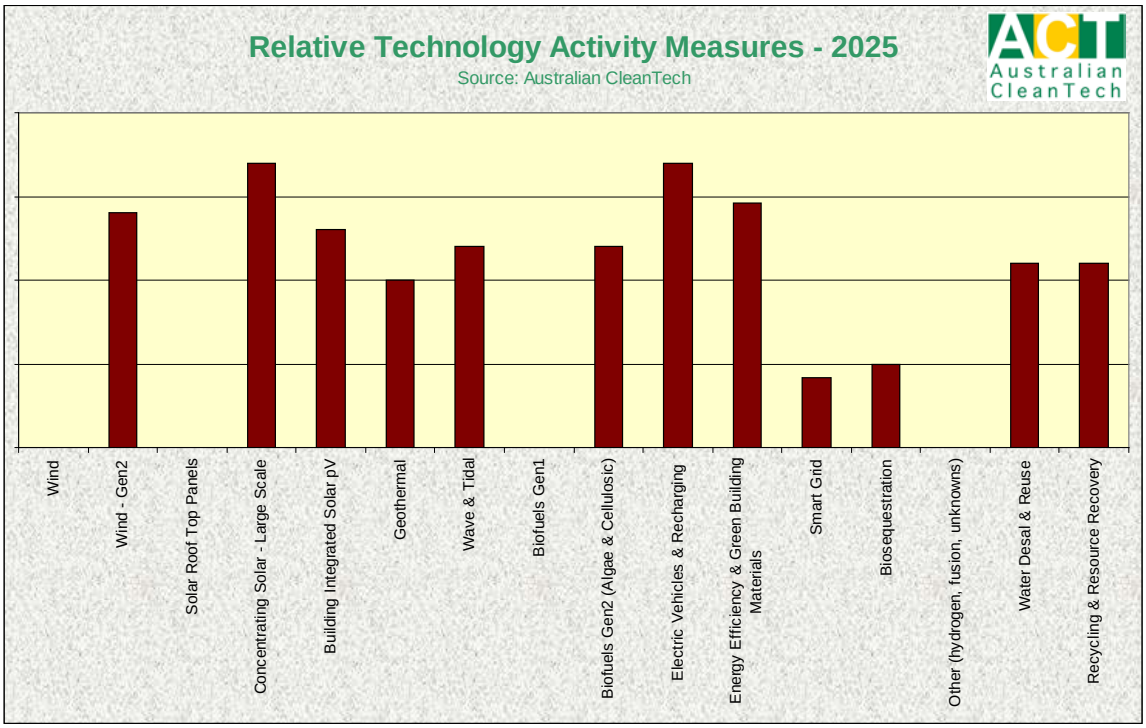
The charts below present the same data in three different formats:

- The first chart shows a year by year profile of the forecast activity in each of the cleantech sectors. This shows how technology activity levels will change with time and in comparison to other technologies. It also shows the overall cumulative activity profile of the cleantech sector as a whole.
- The second chart provides a compilation of four snapshots showing which technologies will be dominant at a particular time, comparisons between the technologies and how technology activity levels will change with time.
- The final four charts provide the component parts for the second chart, with snap shots of cleantech activity in the years 2015, 2025, 2035 and 2045. This shows which sectors are more dominant at these points in time and which sectors may present the greatest potential for economic development at that time.


Indicative Global CleanTech Maturation Profile
Source: Australian CleanTech
Activity Measure
(eg employment, economic activity, revenues, market capitalisation)
Recycling & Resource Recovery
Water Desal & Reuse
Biosequestration
Other (hydrogen, fusion, unknowns)
Smart Grid
Energy Efficiency & Green Building Materials
Electric Vehicles & Recharging
Biofuels Gen2 (Algae & Cellulosic)
Wave & Tidal
Geothermal
Building Integrated Solar pV
Biofuels Gen1
Concentrating Solar - Large Scale
Solar Roof Top Panels
Wind
Wind - Gen2
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
Smart Grid
Biosequestration
Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
Recycling & Resource Recovery


2015 2025 2035 2045
Relative Technology Activity Measures, 2015-2045
Source: Australian CleanTech
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
Smart Grid
Biosequestration
Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
Recycling & Resource Recovery


Relative Technology Activity Measures - 2015
Source: Australian CleanTech
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
Smart Grid
Biosequestration
Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
Recycling & Resource Recovery


Relative Technology Activity Measures - 2025
Source: Australian CleanTech
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
Smart Grid
Biosequestration
Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
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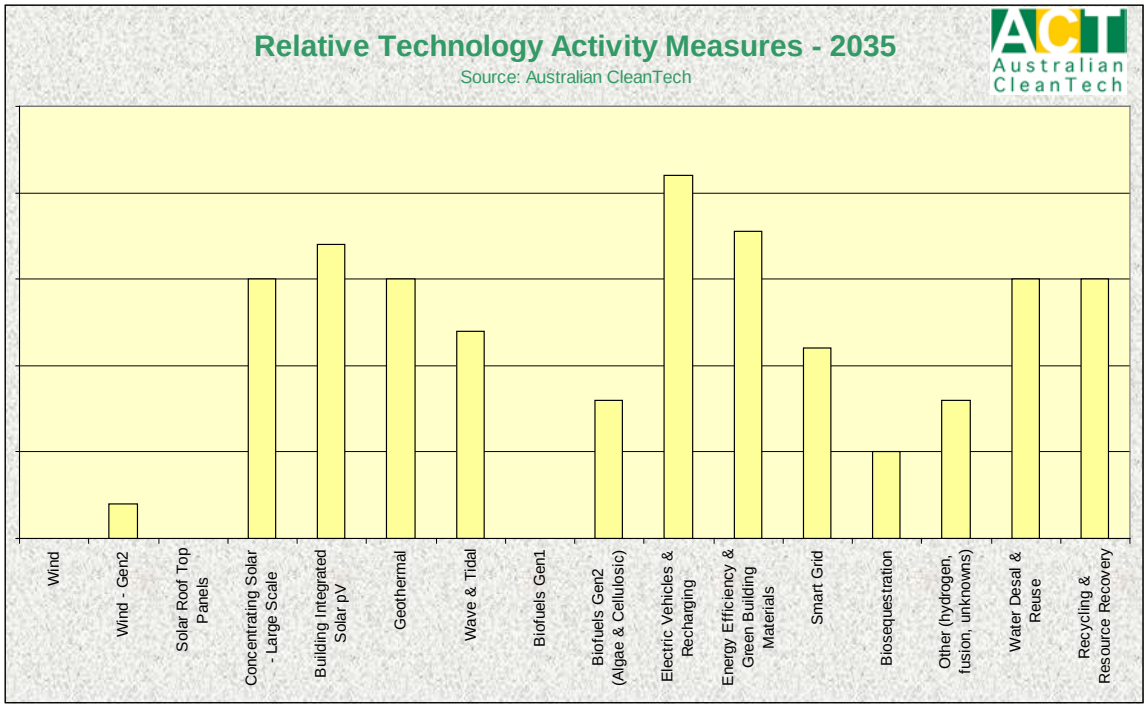
Relative Technology Activity Measures - 2035
Source: Australian CleanTech
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
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Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
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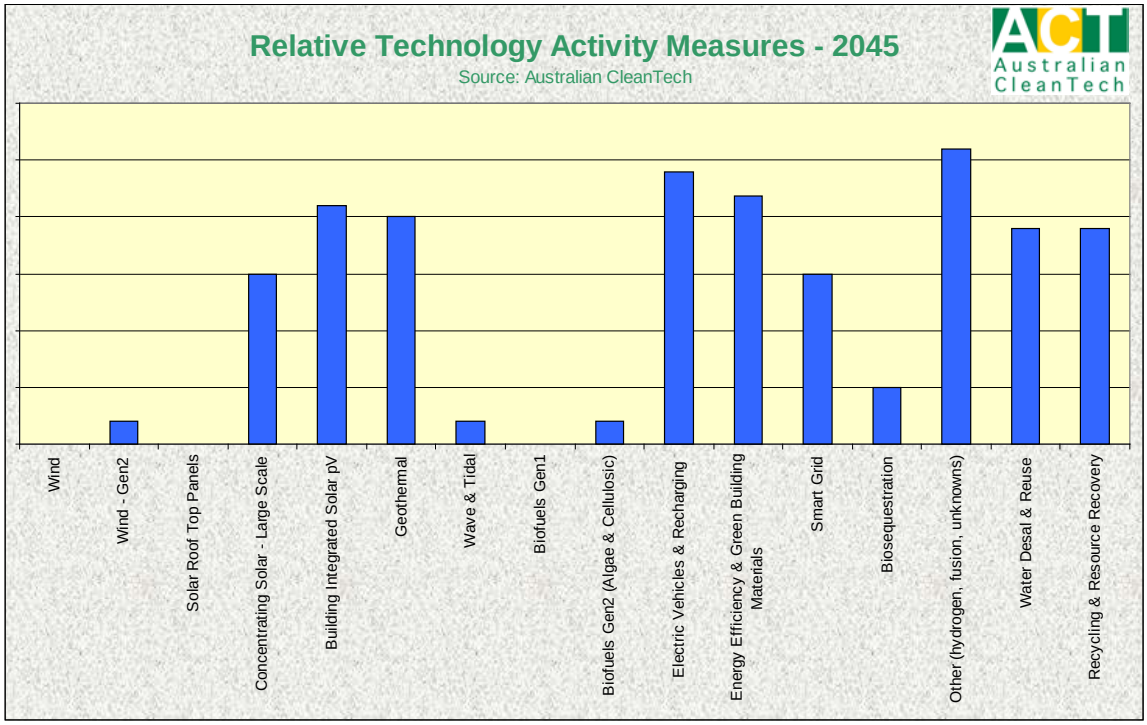

Relative Technology Activity Measures - 2045
Source: Australian CleanTech
Wind
Wind - Gen2
Solar Roof Top Panels
Concentrating Solar - Large Scale
Building Integrated Solar pV
Geothermal
Wave & Tidal
Biofuels Gen1
Biofuels Gen2 (Algae & Cellulosic)
Electric Vehicles & Recharging
Energy Efficiency & Green Building Materials
Smart Grid
Biosequestration
Other (hydrogen, fusion, unknowns)
Water Desal & Reuse
Recycling & Resource Recovery

Application of the Data

The data presented in this report can be used to build a profile of the pipeline of technologies that will be deployed. By careful application of the assumptions above to the circumstances of a specific region, it may therefore be possible to progressively target the industries that will shortly emerge. If done well, this could enable a region to be become significant players in many of the technologies that have a global presence. The benefits for local communities and economies from this success would be likely to be significant.

By understanding the technology flow, a government could develop a system to encourage and develop industries at different levels dependent on their likely time to maturity. Reviews would need to be undertaken on a regular basis to understand whether any of the technologies had moved into the next category of maturity and so would require a different policy focus.

Four stages that could be considered for the profiling of technologies into maturity categories are:

- **Mature** – those technologies that are currently, or about to, undergo widespread deployment.
- **Start-up** – those technologies that have achieved sales and commenced specialist and niche application roll-out.
- **Incubator** – those technologies that are working through the commercialisation stages but have not yet achieved revenues.
- **Research** – those technologies that are still going through a research stage.

The systems adopted by governments for each of these stages include many levers to assist these industries to locate and share the benefits of their success with local communities. Examples of measures that have been used in various jurisdictions include:

- **Mature** – measures might include loan guarantees or public purchase agreements to provide sufficient demand to enable the company to achieve a viable scale of operation.
- **Start-up** – a suitable suit of incentives for start-up phase companies might include commercialisation grants, business advice, funding of dedicated venture capital funds, international expansion facilitation, government backed demonstration parks or sites.

- **Incubator** – early stage commercialisation technologies need advice and assistance and this can often best be done through an incubator type operation. There are examples of very successful incubators around the world that provide a best practice benchmark.
- **Research** – research grants, linkages and networks with industry and investors to ensure research is being targeted at solutions that both industries will value and investors will back.

It could be possible to combine all four stages into a cleantech park initiative that hosted a pipeline of technologies that were expected to come to the market in a staged fashion over 20+ years. Not only would this provide continuity with respect to economic development, with an emerging technology taking over from a declining one, but also would enable the added benefits of co-location of technologies in related fields at different maturation stages. The mature industries could provide business support to the early stage technologies and may even be investors if their own technology starts to decline. The research and early stage companies can provide the drive to the more settled larger companies to ensure that they continue to innovate and improve.

With reference to the Global Cleantech Maturation Profile, maybe an ideal cleantech park established in 2010 would comprise of the following technologies:

- **Mature** – wind turbine manufacture, pV panels, energy efficiency technologies, desalination technologies, recycling technologies
- **Start-up** – building integrated photovoltaics, concentrating solar, geothermal, wave energy, water recycling.
- **Incubator** – Gen2 Biofuels, generation 2 wind turbines, electric vehicles and recharging infrastructure, smart grid.
- **Research** – biomaterials, nanotechnology.

The exact combination of technologies will of course depend on the specific issues of the location of the operations. A suggested process for finalising the preferred residents of a cleantech park at each of the four maturity levels is discussed below.

Steps Required to Extend this Analysis to Regional Profiles

The work covered in this report provides a useful first step to designing future industry. There are however a number of specific steps that need to be completed before a robust plan to secure prosperous sustainability for a specific region can be finalised. These further steps are set out below.

1. **Regional Competitive Advantages**

   Undertake an analysis of the competitive advantages of the economy and natural resources that the region has when considering sustainable technologies. This may be undertaken with reference to the Carbon Trust's work in the UK considering the competitive advantages of UK plc.

   Based on the contents of this report, provide a forecast of likely staged technology adoption within the region. This will be used to provide a profile of attractive industries currently at various different points in their lifecycles enabling the recommendation of an ideal spread of companies, each reaching their peak production at different points through the long term planning period.

2. **Current Cleantech Industry Profile**

   Complete an analysis of the existing regional cleantech industry in terms of company activity, estimated annual revenue and current potential growth. Look at what strengths currently exist within the industry and where areas of potential growth might exist.

3. **Cleantech Incubator**

   Consider global examples of cleantech incubators and assess an optimum design for a regional equivalent.

4. **The Ideal Future Cleantech Industry Profile**

   Using a consideration of all of the above analyses, provide recommendations on the ideal profile of companies attracted to the that present the maximum long term economic development opportunity.

5. **Identify Existing Target Companies**

   From the profile developed above, provide recommendations of specific existing companies that should be approached and encouraged to establish or expand operations in the region. This search should consider global companies and include everything form technology commercialisation start-up companies to conglomerates with leading edge technology.

6. Identify Future Technologies Requiring Research Expertise

Any gaps that remain in the full profile after target companies have been identified may be appropriate to be filled through the development of research expertise. In consultation with leading university researchers, it would be possible to develop program development profiles to meet these needs as they are required.

Attachment 1 – Reference Data

Figure 3-4: National generation mix, 2020

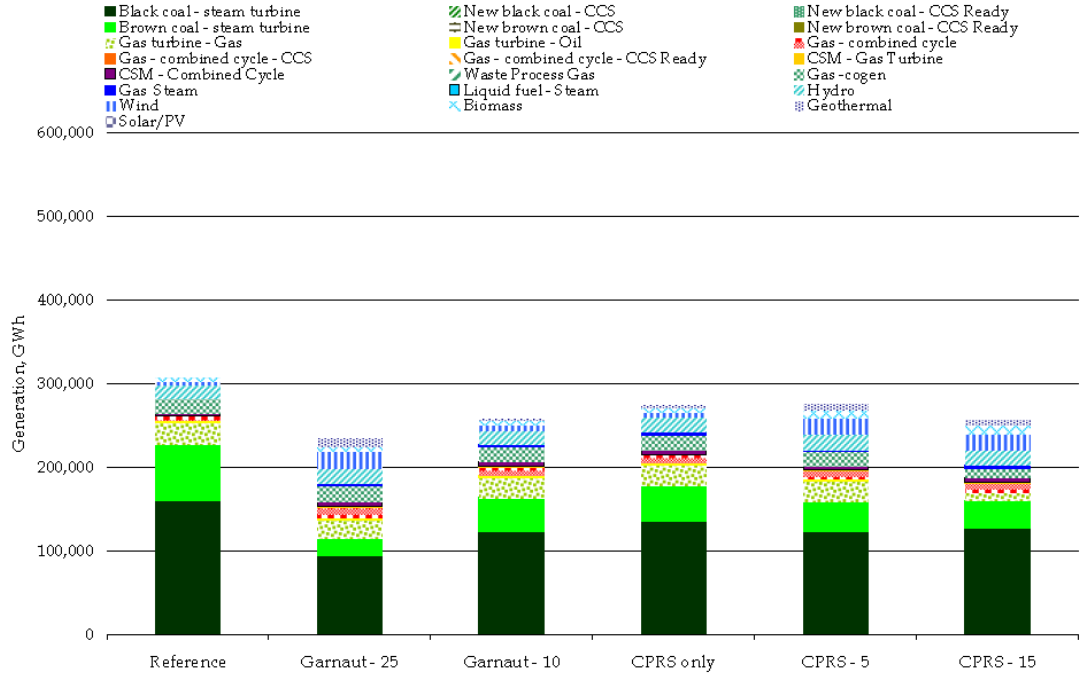
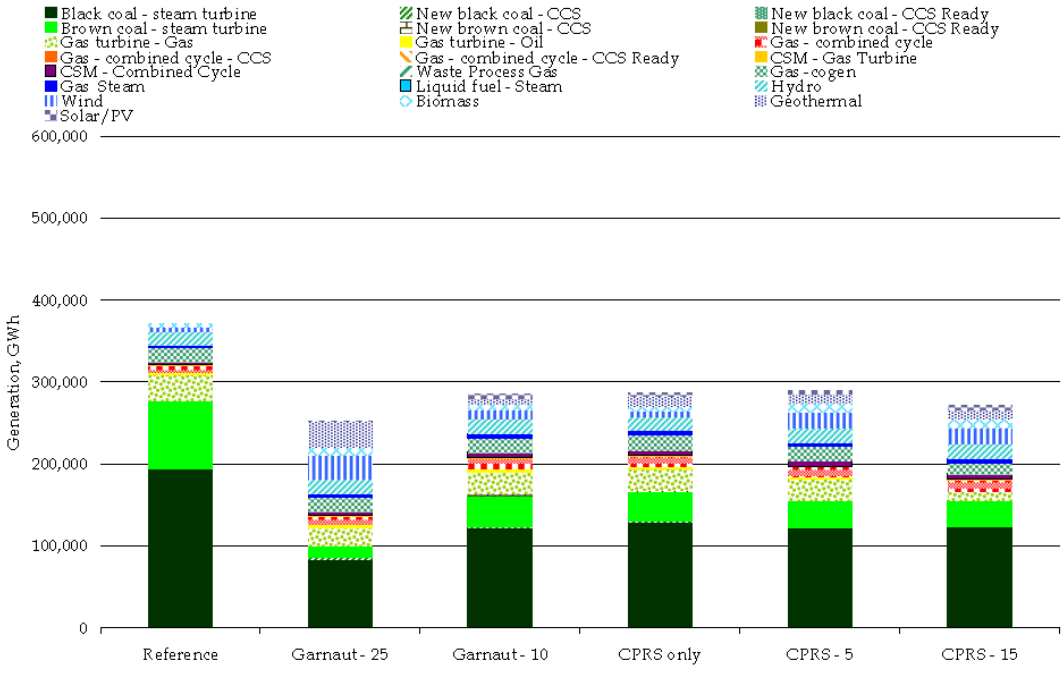
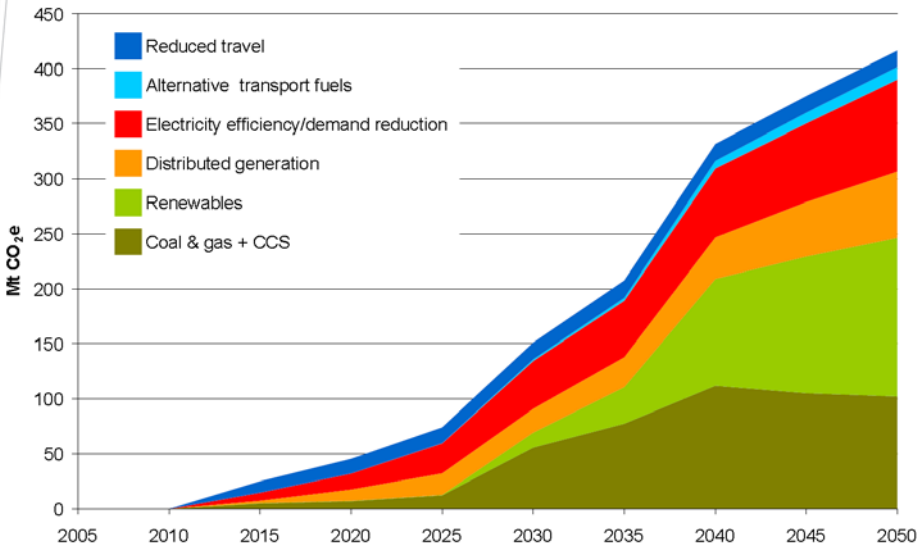


Figure 3-5: National generation mix, 2030

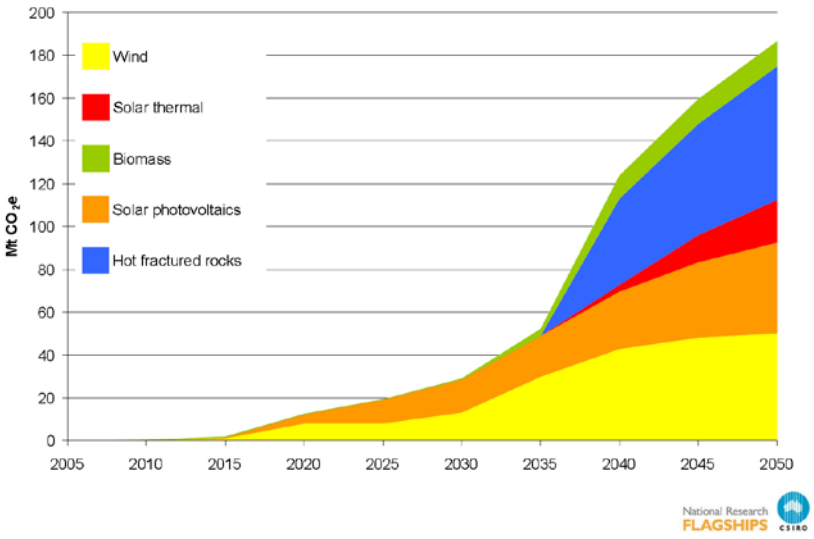


Source: Impacts of the Carbon Pollution Reduction Scheme on Australia's Electricity Markets, McLennan Magasanik Associates, 27 October 2008

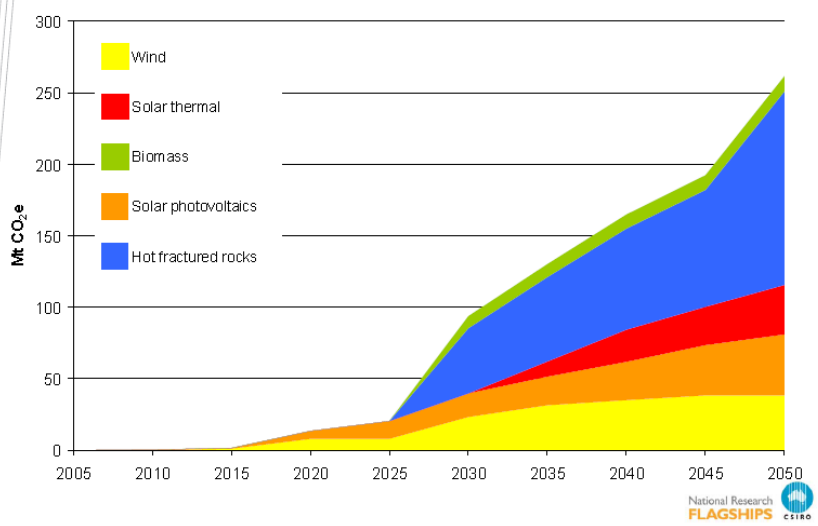
Technology category share of energy sector abatement : 550 ppm emission path



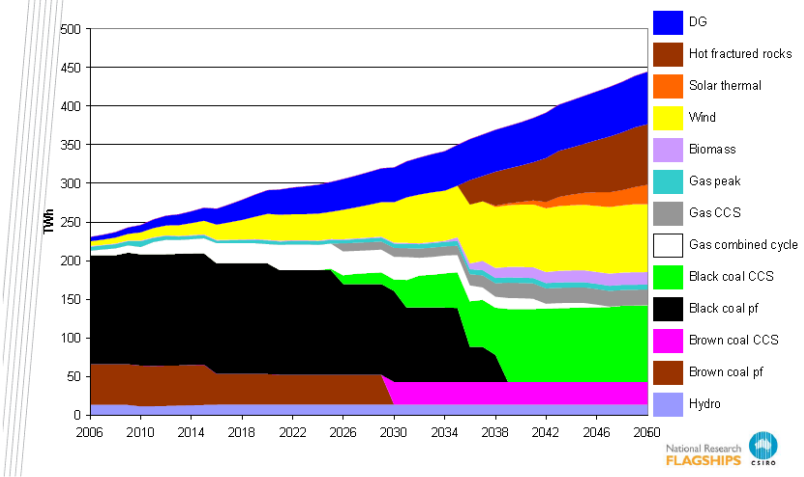
Technology share of renewable electricity abatement: 550 ppm emission path



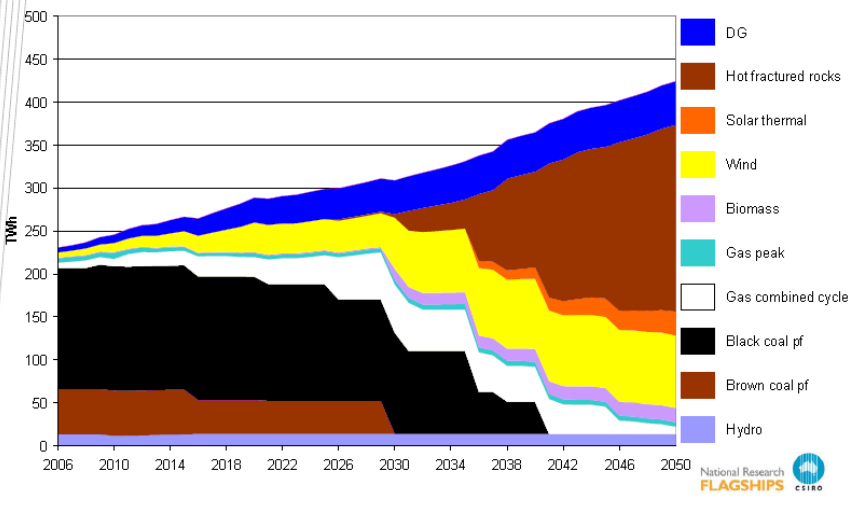
Technology share of renewable electricity abatement: 450 ppm emission path



Technology share of generation: 550 ppm emission path



Technology share of generation: 550 ppm emission path, CCS not available



Technology share of generation: 550 ppm emission path, CCS not available, nuclear allowed

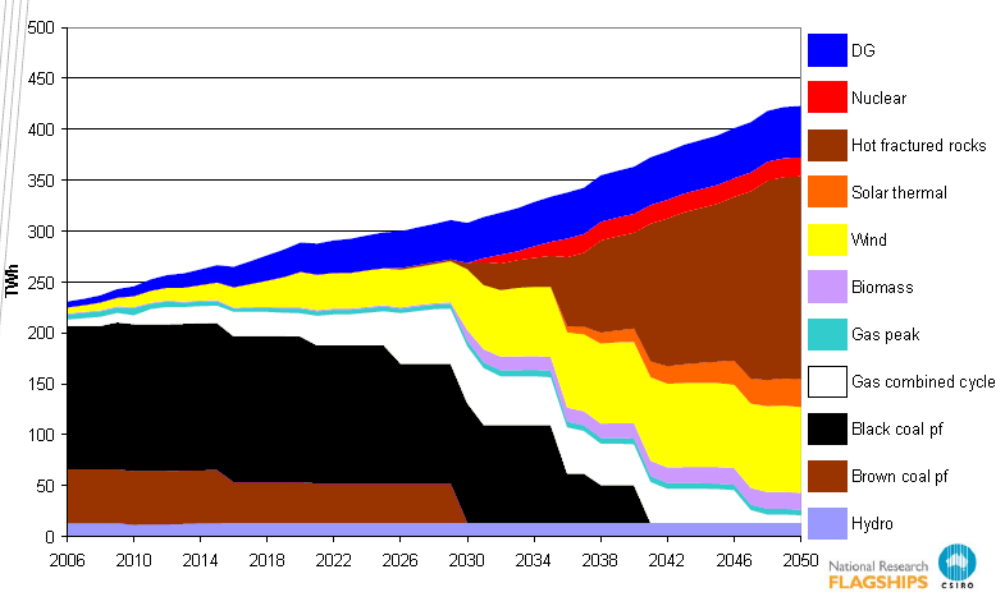


Figure 13: Projected increasing electrification of road transport vehicles: EIA high oil price and 60% below 2000 emission target scenario.

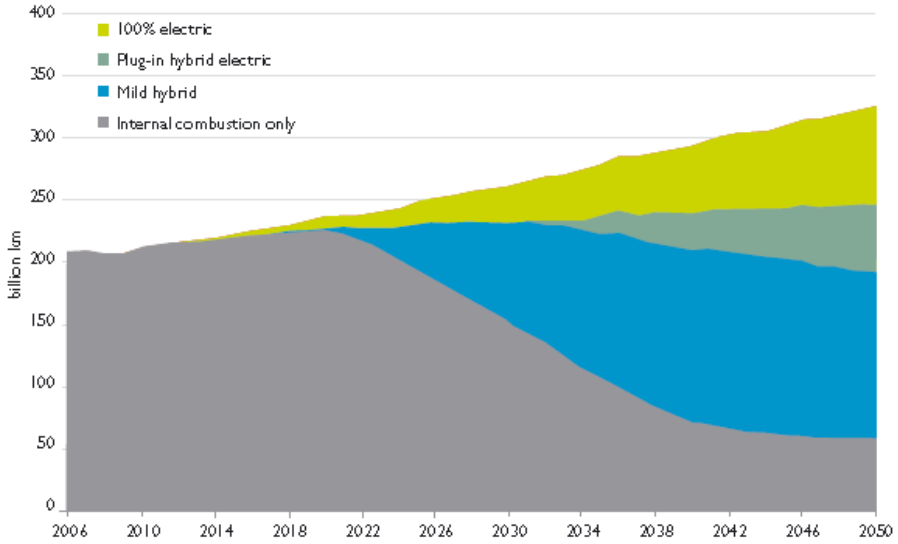


Figure 19: Consumption of transport fuels under slow decline in oil supply, fast technology response, fuel cell cars available and 60% below 2000 levels by 2050 emission target scenario.

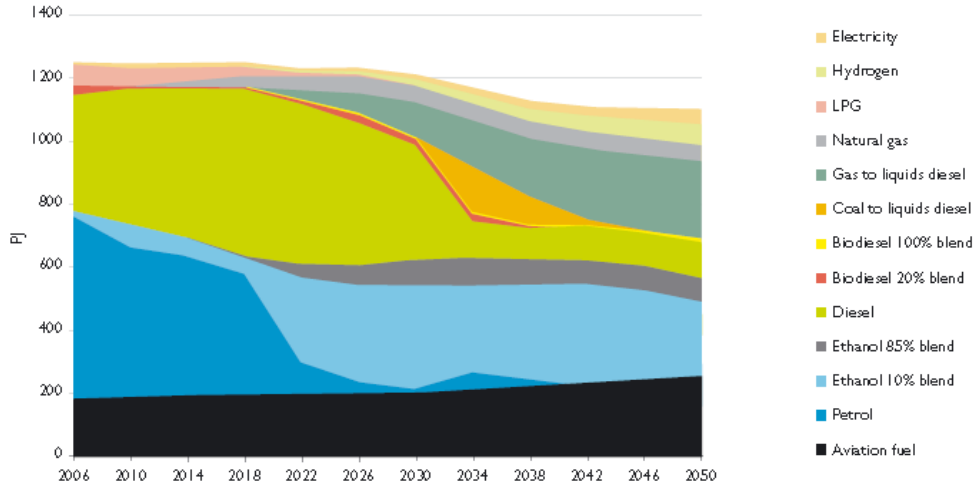
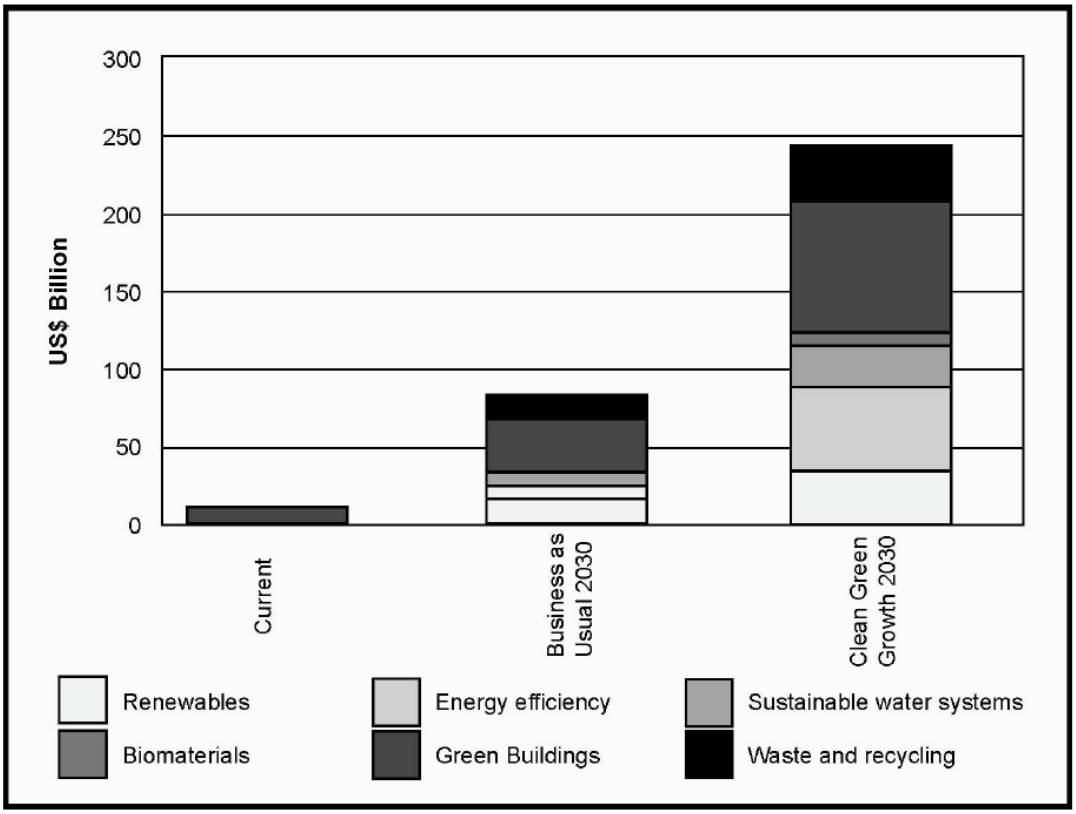
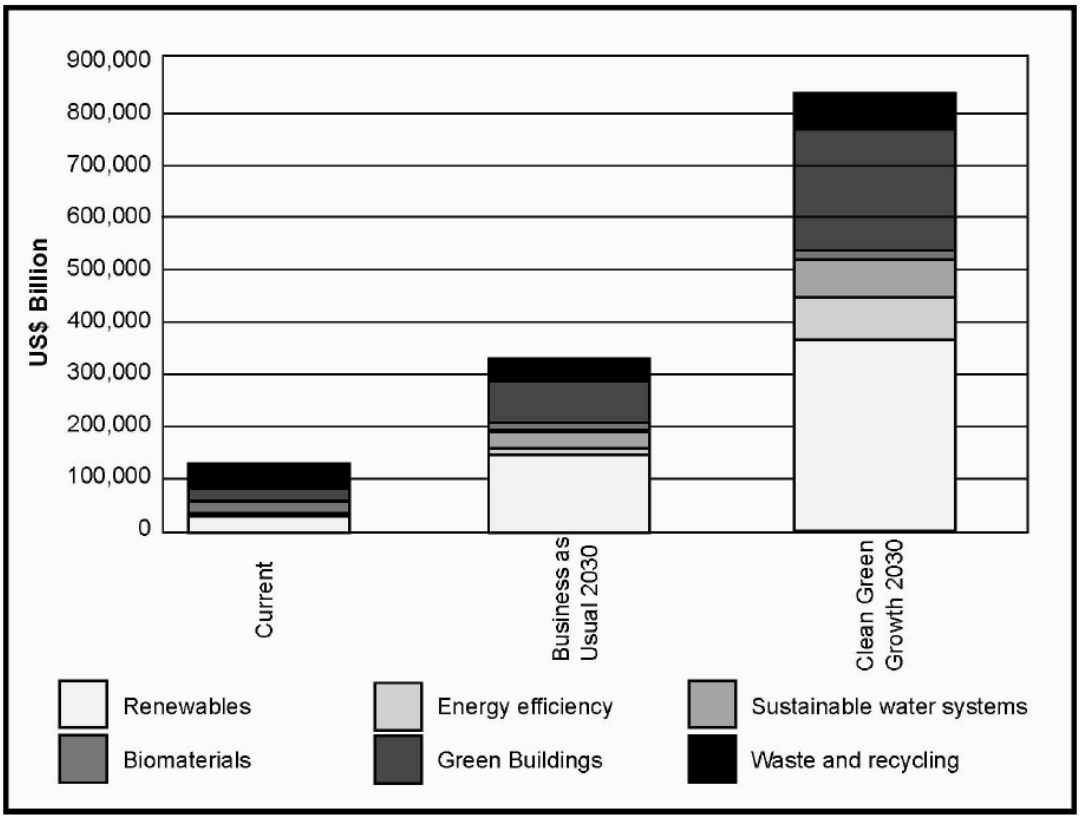


Figure 1: Projections of Australian market share for six green industries to 2030



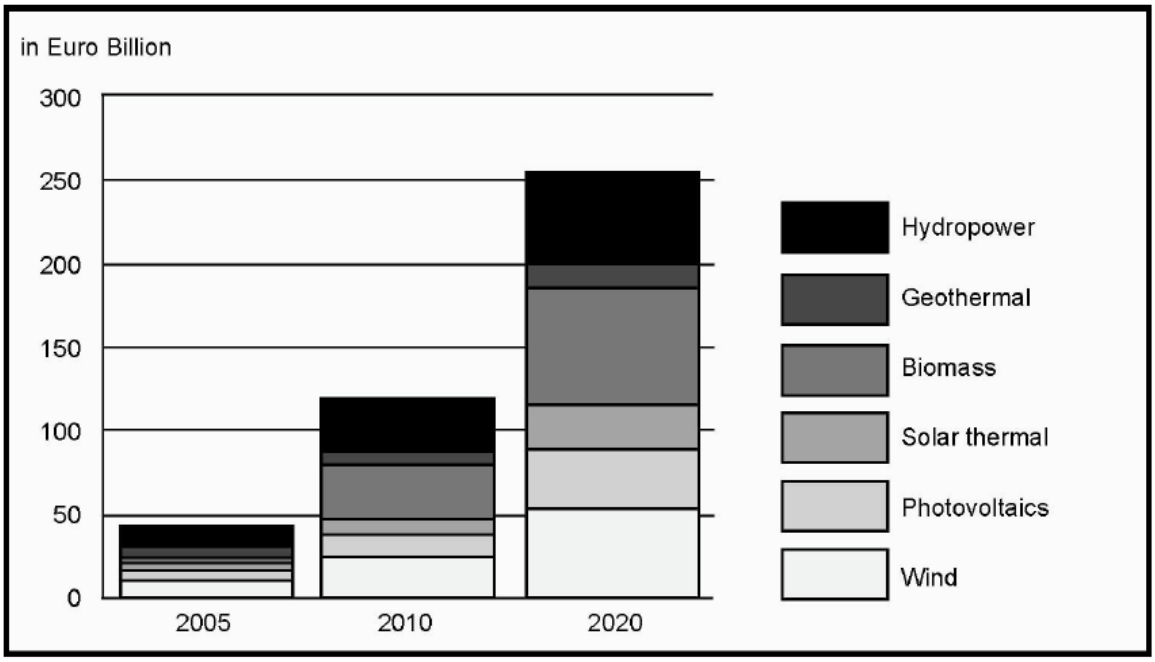
Source: Green Gold Rush, ACF & ACTU, 2009

Figure 2: Projections of Australian jobs for six green industries to 2030



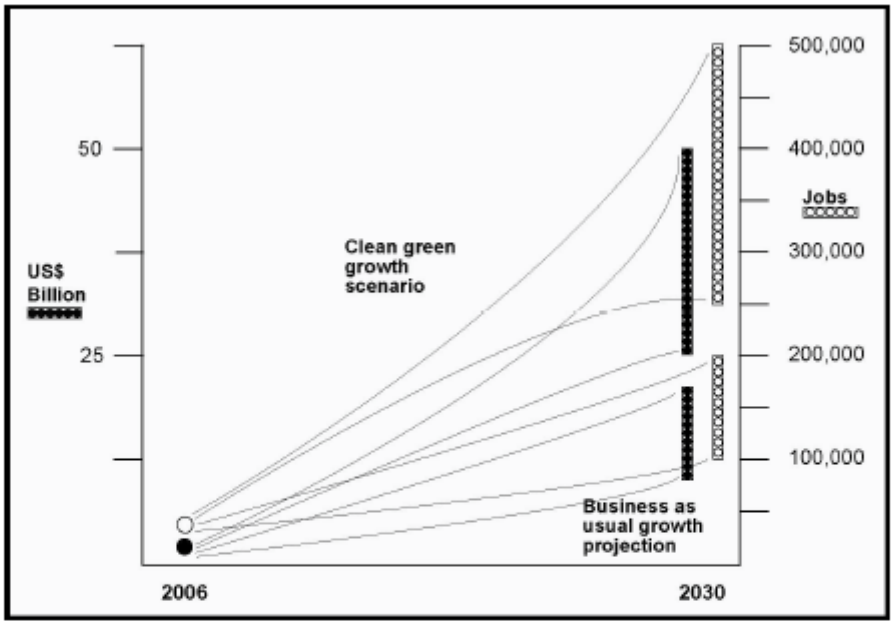
Source: Green Gold Rush, ACF & ACTU, 2009

Figure 3: Global market projections for renewable energy technologies[36]



Source: Green Gold Rush, ACF & ACTU, 2009

Figure 4: Projections for Australia's renewable energy sector



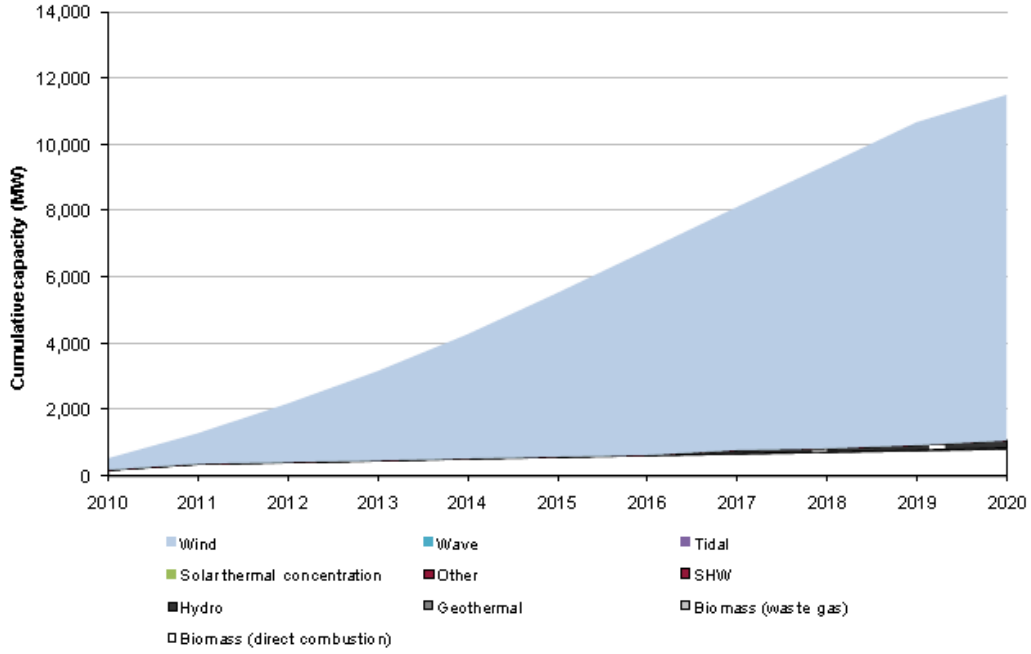
Business as Usual scenario assumes Australia maintains its place in the global market, as a result of the National Renewable Energy Target and other policy measures (representing about 2 per cent of the global market by 2030).

Clean, green growth scenario assumes Australia takes strong proactive steps now to secure a greater share of the global market, and reaches 5 per cent of the global market by 2030

Market figures refer to investment per year to install new capacity, and manage existing capacity

Source: Green Gold Rush, ACF & ACTU, 2009

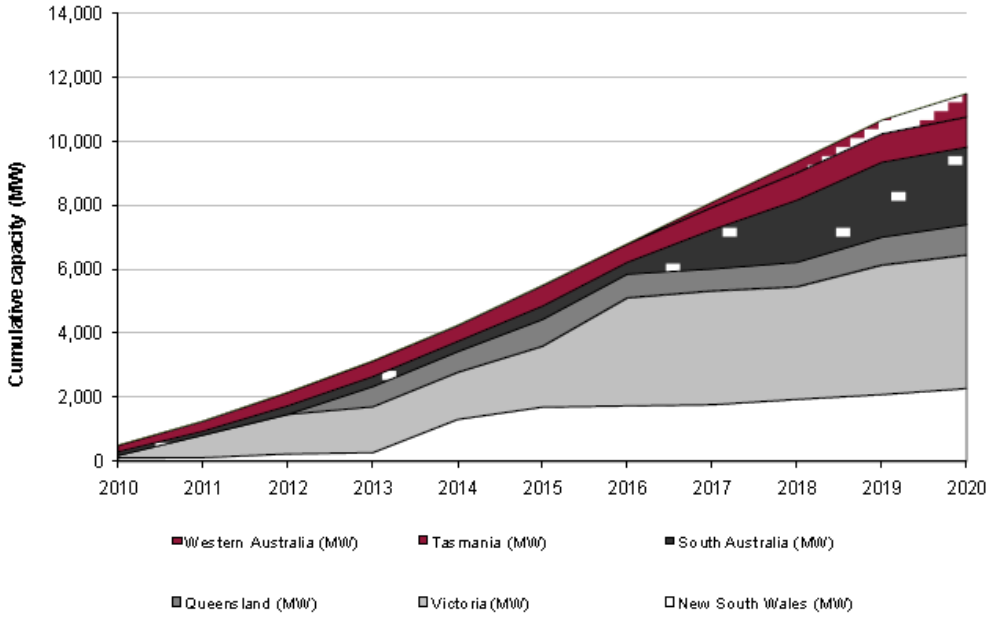
Chart 3.3 Renewable electricity capacity installed from the expanded RET – all regions



Source: Access Economics modelling

Source: Access Economics, *The net employment impacts of climate change policies*, June 2009

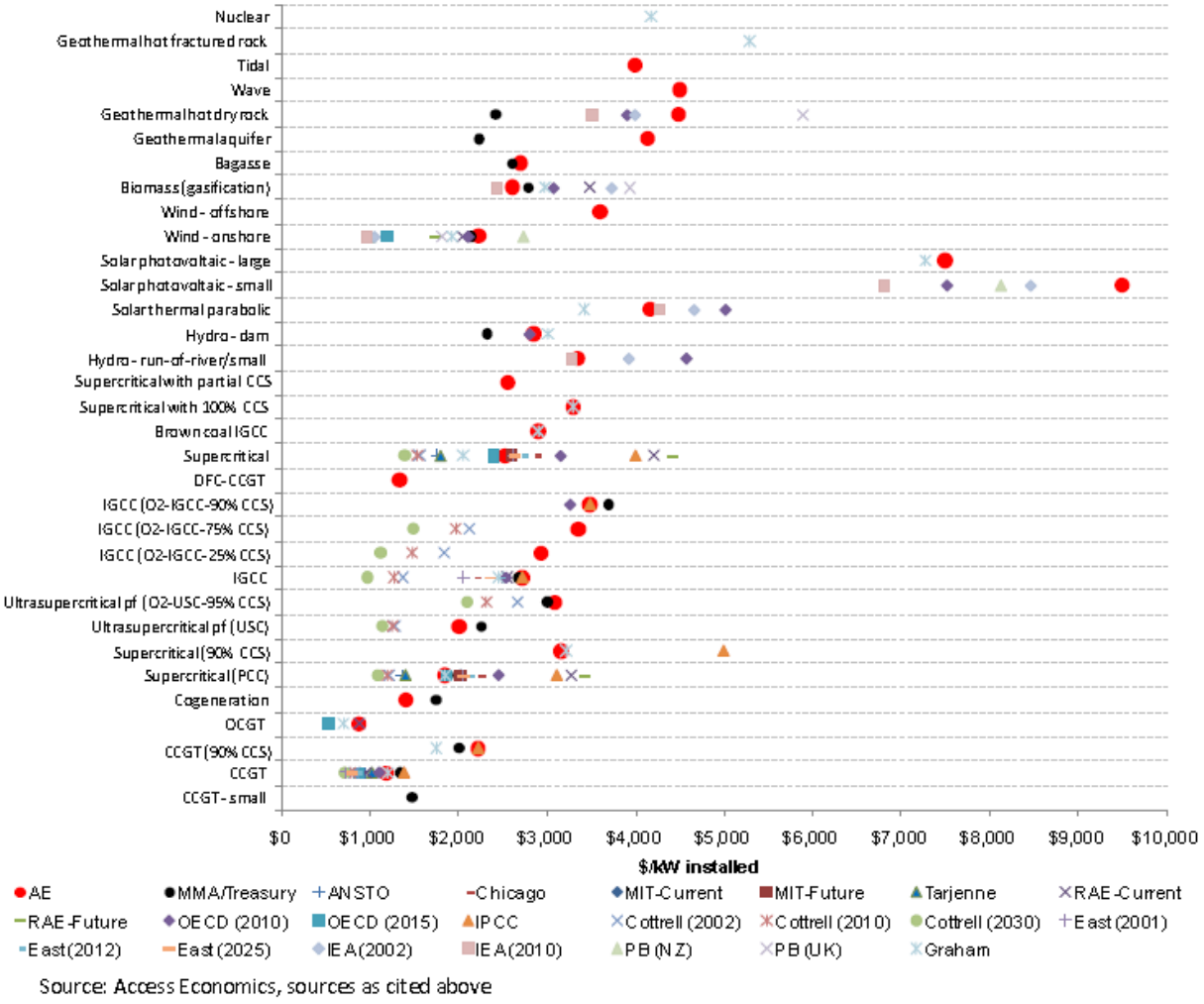
Chart 3.4 Renewable electricity capacity installed from the expanded RET – by region



Source: Access Economics modelling

Source: Access Economics, *The net employment impacts of climate change policies*, June 2009

Chart 3.8 Capital cost estimates of new plant at 2009 ($2009)



Source: Access Economics, sources as cited above

Source: Access Economics, *The net employment impacts of climate change policies*, June 2009

Attachment 2 - Australian CleanTech Profile

Australian CleanTech is a research and broking firm that provides advice to cleantech companies and financial institutions. Through its work it provides a bridge between investors and the investment requirements of cleantech projects. With extensive experience in both cleantech technology assessment and investment analysis, Australian CleanTech provides unique services that will facilitate and deliver successful Australian clean technology investments.

Research Database - Australian CleanTech has developed and maintains a database of global cleantech companies. The database contains company profiles of more than 1400 companies, over 350 of which are based in Australia. Each company is assessed on the basis of their technical, regulatory and commercial risk profiles.

ACT Australian Cleantech Index - Australian CleanTech publishes the *ACT Australian Cleantech Index* provides a measure of the performance of the Australian listed stocks in the cleantech sector. With over 75 companies following under the coverage of the index and with a combined market capitalisation of over $7Bn, the index presents for the first time a picture of the Australian cleantech industry's growth in a single measure.

Investor Services - Project sourcing, technical assessment, investment management, delivering exit strategies, lobbying.

Project Services – Development of growth strategies, sourcing funding, industry and technology research, strategic, project delivery, Intellectual Property protection strategies, securing and retaining the right people, securing Government grants and power, water and environmental credit purchase agreement negotiation, commercialising strategies, international expansion.

Government Services - policy development, policy impact analysis, economic development, facilitation of Industry Clusters, information dissemination

Principal Author

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John is the founder and Managing Director of Australian CleanTech and has advised numerous organizations on their options with respect to securing or making cleantech investments. He has also launched the *ACT Australian CleanTech Index* that tracks the performance of Australia's listed Cleantech companies, is facilitating the Adelaide Cleantech Network, is a member of the South Australian Premier's Climate Change Council and is publishing a book titled *Opportunities Beyond Carbon* in June 2009.

John previously worked for Origin Energy on growth, strategy and M&A projects in addition to being the founding secretary of the company's Operational Risk Committee. He specialized in reviewing and filtering clean energy and water industry opportunities. Through the combination and interaction of these sectors he became interested in the emerging cleantech sector and in 2004 started developing the plans for a cleantech business.

He has engineering degrees from the University of Oxford and Trinity College, Dublin and an MBA from the University of Adelaide. He has completed the AICD's Company Directors Course, is a chartered engineer with the Institute of Engineers Australia and is a member of the Australian Water Association and the Responsible Investment Association of Australasia.