KEY MESSAGES

1. Australia has enormous potential for renewable energy. This potential is currently under-utilised.

- Australia has world-class solar and wind energy resources in many parts of the country.
- Renewable energy offers many benefits for Australia including jobs in the sector, new business opportunities, fresh investments, reduced air pollution, and connecting communities to sustainable electricity generation.
- Renewable energy is becoming more and more affordable. Rooftop solar photovoltaic (PV) may already be the cheapest source of power for retail users in areas with high electricity prices. Solar PV and wind could be the cheapest forms of power in Australia for retail users by 2030, if not earlier, as carbon prices rise.
- With our extensive renewable energy resources and a strong track record of expertise in developing new renewable energy technologies, Australia is well-placed to build on recent growth in renewable electricity generation capacity.

2. Global use of renewable energy is growing strongly.

- Renewable energy is a critical source of electricity for the 21st century.
- Global investment in renewable power is increasing rapidly, and reached almost $250 billion in 2011. In fact, global investment in new renewable energy generating capacity exceeded spending on new fossil fuel power plants in 2011.
- China leads the world in renewable energy with the most installed renewable power and the largest investment in 2011.
- In 2011, 118 countries – more than double the number in 2005 – had targets to drive investment in renewable technologies and generation.

3. Momentum in Australia for renewable energy is building.

- Solar PV electricity generation has been growing rapidly in Australia. As of July 2012, almost 754,000 Australian households and businesses had installed solar panels. Queensland is leading in solar PV system installation and has doubled its use of solar energy in less than two years.
- The rate of growth of wind energy is well above any other large-scale generation source, growing at an average of 40% each year over five years to 2009–10.
- South Australia's wind energy per capita is higher than any major country in the world and wind is now contributing approximately 26% of the state's total electricity production.
- Many of Australia's renewable energy resources are located in regional areas, providing potential for new economic opportunities in those places.

4. In coming decades, the Australian economy could be powered almost entirely by renewable energy.

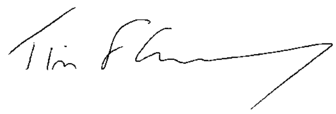
- If Australia's economy is to be powered by renewable energy, the expansion will need to be large and sustained. Investment growth will be encouraged by policy certainty.
- There are challenges ahead in making sure that Australia can utilise renewable energy. Shifting from a network designed around a few large generators to one where power sources are distributed around Australia will require changes. Technological innovation is required to further develop battery storage and to keep driving down the cost of renewable energy. The potential for growth is subject to community acceptance and planning requirements.

5. We have less than four decades to transform energy systems around the world to energy sources that do not contribute to climate change.

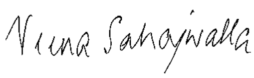
- To avoid the most damaging consequences of climate change we must virtually eliminate greenhouse gas emissions from fossil fuels within decades.
- To do this, we need to use energy more efficiently and harness low-emissions energy technologies including renewable energy.
- The challenge is to turn Australia's enormous potential of renewable energy into implementation at scale as rapidly as we can at the lowest cost possible.

With thanks to Dr Ben McNeil, Dr Muriel Watt and Mr Tony Wood for their comments on the report. The Climate Commission retains responsibility for the content of the report.

This report draws on the Climate Commission's reports *The Critical Decade: Climate science, risks and responses* and *The Critical Decade: International action on climate change*. This is the Climate Commission's 15th report.



Professor Tim Flannery
Chief Climate Commissioner



Professor Veena Sahajwalla
Climate Commissioner

INTRODUCTION

Energy is fundamental to the way we live, our economy, and our future. For many years, we have used cheap and abundant fossil fuels such as coal, oil and gas to produce most of our energy. Burning these fossil fuels is the main source of the greenhouse gases that are triggering the changes we are seeing in the global climate.

Governments and scientific bodies around the world accept that climate change is an immediate threat to global wellbeing and prosperity. If we are to avoid the most damaging effects of climate change, we need to virtually eliminate greenhouse gas emissions from fossil fuels within decades. To do this, we need to use energy more efficiently and harness energy technologies, including renewable energy, that produce either no greenhouse gas emissions or very low emissions.

Renewable energy is energy that is naturally replenished, day-to-day and year-to-year. Renewable energy comes from natural resources such as sunlight, wind, rain, waves, tides and geothermal heat.

The world currently relies heavily on fossil fuels for energy, particularly for electricity and transport fuels. Around two thirds of the world's electricity comes from fossil fuels (IEA, 2012a). Global demand for energy has doubled since 1980, driving increases in greenhouse gas emissions. Energy demand continues to grow and on current trends could increase by a further 85% by 2050 (IEA, 2012a).

Energy production is the main source of greenhouse emissions gases in Australia, and electricity generation is the largest single source, producing around 35% of total emissions (DCCEE, 2012a). It is critical that Australia and the world move to producing energy from sources that produce zero, or very low, greenhouse gas emissions.

Renewable sources of energy have been used to generate power for a long time. For centuries, people have used the wind to power boats, the sun to heat water and houses, and water to grind grain. Modern renewable energy can provide reliable, flexible and safe sources of power.

Renewable energy is a critical source of energy for the 21st century, and global renewable energy production capacity is growing strongly. This growth is driven by a number of factors including global imperatives to stabilise the climate and reduce air pollution; a desire by some countries for greater energy independence; economic measures aimed at stimulating 'green growth'; and the increasing affordability of some renewable energy technologies. Renewable energy is now a major power source in countries such as Brazil, Sweden, Switzerland and Canada, and some renewable technologies are getting cheaper at extraordinary rates.

Australia is the sunniest country and has world-class wind resources. With some necessary changes to the ways in which electricity is produced and distributed, Australia will be well-placed to further increase the use of renewable energy.

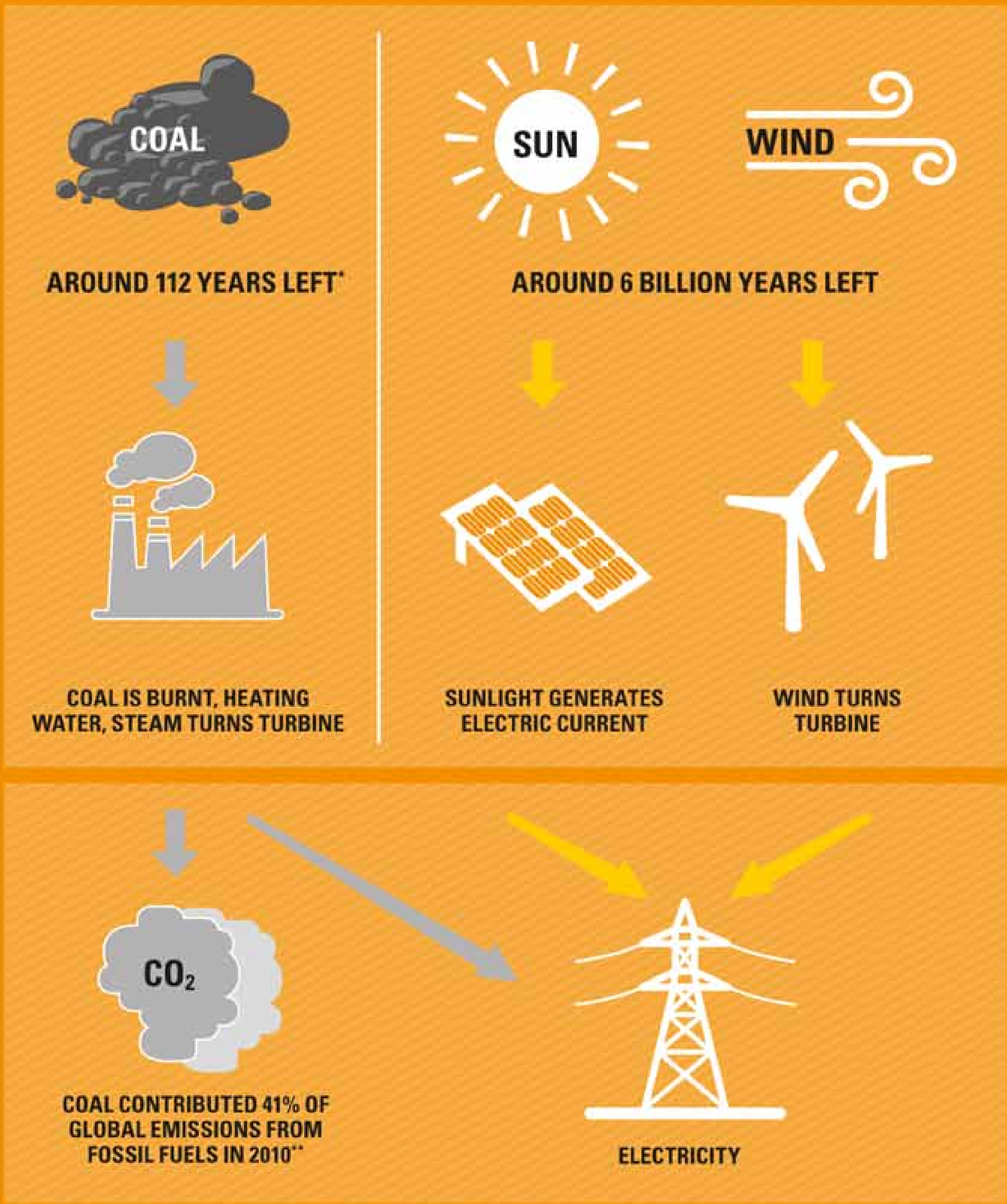
The Climate Commission has prepared this report after experiencing keen interest in renewable energy among communities across Australia. The report provides an overview of Australia's current and potential uptake of renewable energy, global developments in renewable energy and the challenges and opportunities for Australia in increasing use of renewable energy.

Electricity, liquid fuels (like diesel) and direct heating (like solar hot water) can all be produced with renewable energy sources. This report focuses on electricity.

The Climate Commission intends to publish more detailed reports on clean energy in the future.

DIFFERENT TYPES OF POWER

Renewable energy uses naturally replenishing resources that will last for a long, long time.



* Taken from the BP Statistical Review of World Energy, published June 2012 bp.com/statisticalreview

** Global carbon project 2011. http://www.globalcarbonproject.org/carbonbudget/10/presentation.htm

1. RENEWABLE ENERGY IN AUSTRALIA

Australia has large wind, solar, hydro and biomass resources that can be used to produce renewable energy (see figures 2 and 4 for wind and solar).

Renewable energy production in Australia is growing but makes up a small proportion – around 10% – of the energy mix (Figure 1). Apart from hydroelectricity (energy generated from the power of running water), Australia's renewable energy resources are largely undeveloped (BREE, 2012a).

Electricity generation from renewables other than hydroelectricity grew from 0.4% of the generation mix in 2000–01 to 3% in 2009–10 (ABARES, 2011) and are now at nearly 3.5% (BREE, 2012b). Australia's hydroelectricity capacity is larger and older and actual generation is influenced by Australia's variable rainfall. Hydro made up about 8% of Australia's total electricity supply in 2000–01 but dropped, when water supplies were low due to drought (ABARES, 2011), to around 5% during 2009 and is now nearly 7% (BREE, 2012b).

AROUND $18.5 BILLION HAS BEEN INVESTED IN RENEWABLE ENERGY GENERATION CAPACITY IN THE PAST 10 YEARS (SKM, 2012A).

Investment is supported by the national Renewable Energy Target scheme in particular, as well as state and territory feed-in tariffs, subsidies and other schemes (see Chapter 2).

At present, about three quarters of Australia's electricity comes from coal, reflecting the low cost and availability of coal-fired electricity generation and the well-established technology to produce electricity from coal. Natural gas is also a significant energy source, although costs are expected to rise significantly in the next few years (DRET, 2012). Use of coal and other fossil fuels is likely to decline during the transition to an electricity generation system that uses more renewable energy and produces less greenhouse gases (SKM, 2012a). With its extensive renewable energy resources and a strong track record of expertise in developing new renewable energy technologies, Australia is well-placed to build on recent growth in renewable electricity generation capacity.

Electricity generation capacity is a measure of how much electricity a power source can produce under certain conditions. Most electricity generators will not operate at their full capacity all the time. Reasons for this could include technical constraints, changes in demand and variability in the resource (e.g. solar resources are only available in the daytime). The amount of actual electricity generation from a power station is often less than the installed capacity.

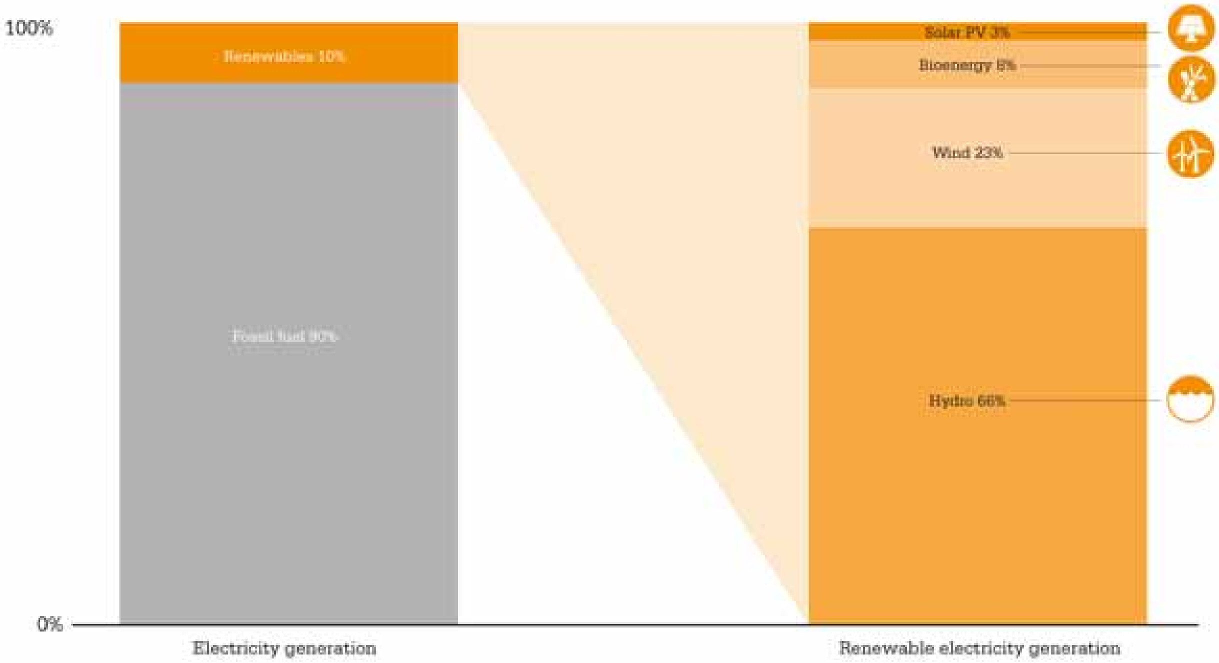
For example, a wind farm with capacity of 10 megawatts (MW) can generate 10 megawatt-hours (MWh) of electricity in one hour when operating at full capacity. However, variation in the wind resource may mean that on average the wind farm will operate at maximum capacity for one third of the time. Averaged over a year, the wind farm would produce about 3.3 MW of electricity per hour.

As Australia moves to reduce greenhouse gas emissions, some operations will close down and some industries will diminish, while other firms and industries grow. The types and locations of jobs may change. The switch to renewables can generate economic as well as social and environmental benefits, including new jobs, investment and businesses, and connecting remote communities to sustainable electricity generation. For example, as a general rule, an investment in a 50 megawatt (MW) wind farm, which may have around 20 turbines, could generate 48 direct construction jobs and a further five to six jobs for ongoing maintenance and operations (SKM, 2012b). With construction staff spending locally, a wind farm can also contribute up to about 3% each year to the regional economy (SKM, 2012b). Landholders allowing placement of turbines on their land can receive payments in return.

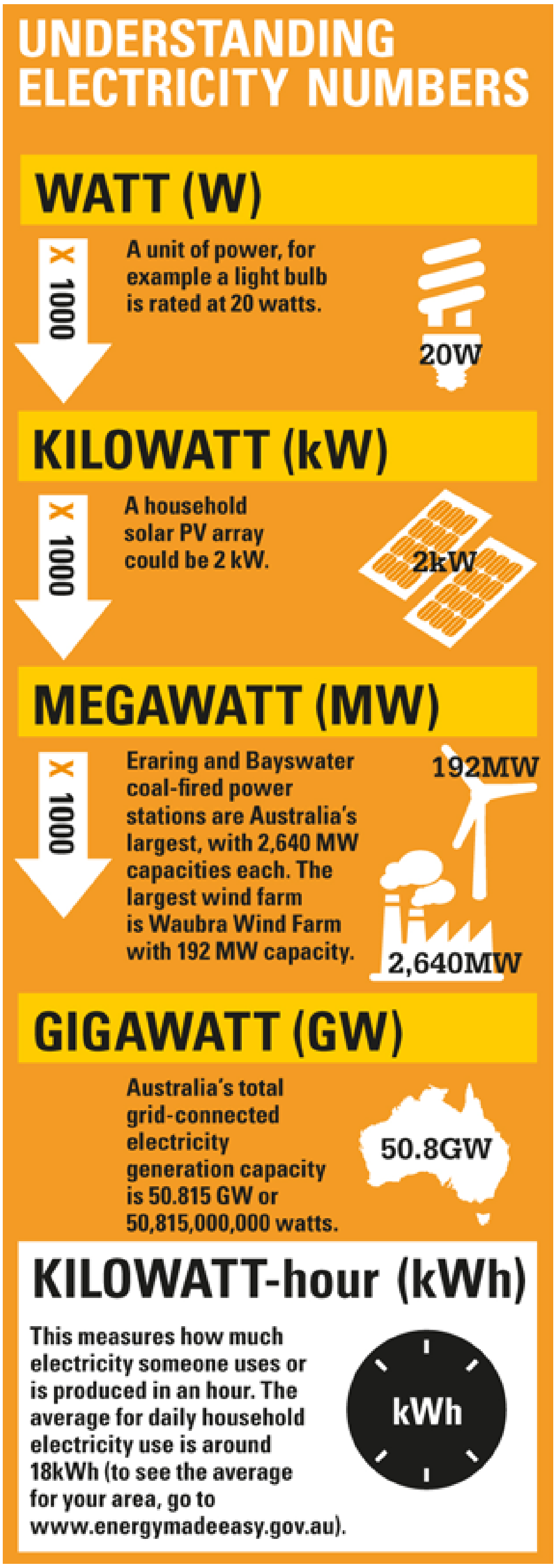
There are also opportunities for Australia through developing and exporting new renewable energy technology know-how.

AUSTRALIA'S RESEARCH AND DEVELOPMENT ACHIEVEMENTS IN SOLAR ENERGY TECHNOLOGIES ARE RECOGNISED AROUND THE WORLD.

Figure 1. Estimated percentage contribution of each technology to renewable generation.



Source: BREE 2012b



Wind

Wind powered electricity generation is one of Australia's growth sectors. It is one of the most cost-competitive renewable electricity sources and is able to power small and large communities, businesses and industry. Australia has a large potential to grow the generating capacity of wind power (Figure 2), subject to community acceptance and planning requirements.

The use of wind energy to produce electricity makes up the second largest share of Australia's renewable electricity, after hydro, generating around 23% of electricity (BREE, 2012b). The amount of electricity generated from wind has grown by an average of 40% each year over five years to 2009–10 (ABARES, 2011). This rate of growth is well above that of any other energy source. The dominance of wind generation in capacity growth reflects its lower cost compared to other renewable technologies (SKM, 2012a). While the rate of growth is substantial, the amount of wind-generated electricity remains a small fraction of that generated by fossil fuels.

The most common type of wind turbine is tower mounted with three blades (an upwind turbine). The blades turn a turbine that generates an electric current. Wind energy technologies continue to be refined. For example, use of stronger and lighter materials and larger turbines allows more efficient electricity generation (BREE, 2012a). Hybrid systems combine wind generation with diesel power or even solar power to address the intermittent nature of power from wind.

Wind energy isn't only used for large scale electricity generation. Wind farms in Europe originally started as community owned developments. The Hepburn community wind farm near Daylesford, Victoria, is a good example of a small scale wind farm.
Source: Hepburn Wind

Figure 2. Wind potential around Australia and current installed wind power.

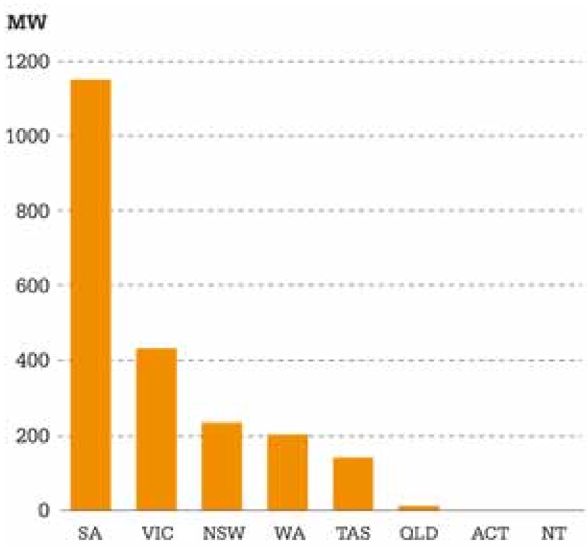
Source: Modified from Coppin et al., (2003) and BREE (2012a)
Note: this map is a rough guide only, actual wind speed will vary according to local conditions.

Currently, Australia has about 1,345 wind turbines in 59 operating wind farms including one small farm in the Australian Antarctic Territory (CEC, 2012a).

South Australia has the highest wind-powered generation capacity of any Australian state or territory, producing around half of the nation's wind energy (Figure 3) (CEC, 2011). The capacity of wind generation in South Australia continues to grow with wind energy contributing around 26% of the state's total electricity production in 2011–12 (AEMO, 2012). South Australia's wind-powered electricity generation both as a proportion of total generation and per person are now similar to those of Denmark, the world's leading wind power country (AEMO, 2011).

Wind energy isn't only used for large-scale electricity generation. Wind farms in Europe originally started as community-owned developments. The Hepburn community wind farm near Daylesford, Victoria, is made up of two turbines with a total output of 4.1 MW (Sustainability Victoria, 2012) producing enough electricity each year for 2,300 homes (Hepburn Wind, 2012).

Figure 3. Wind power installed by state (MW).



Source:: CEC, 2011

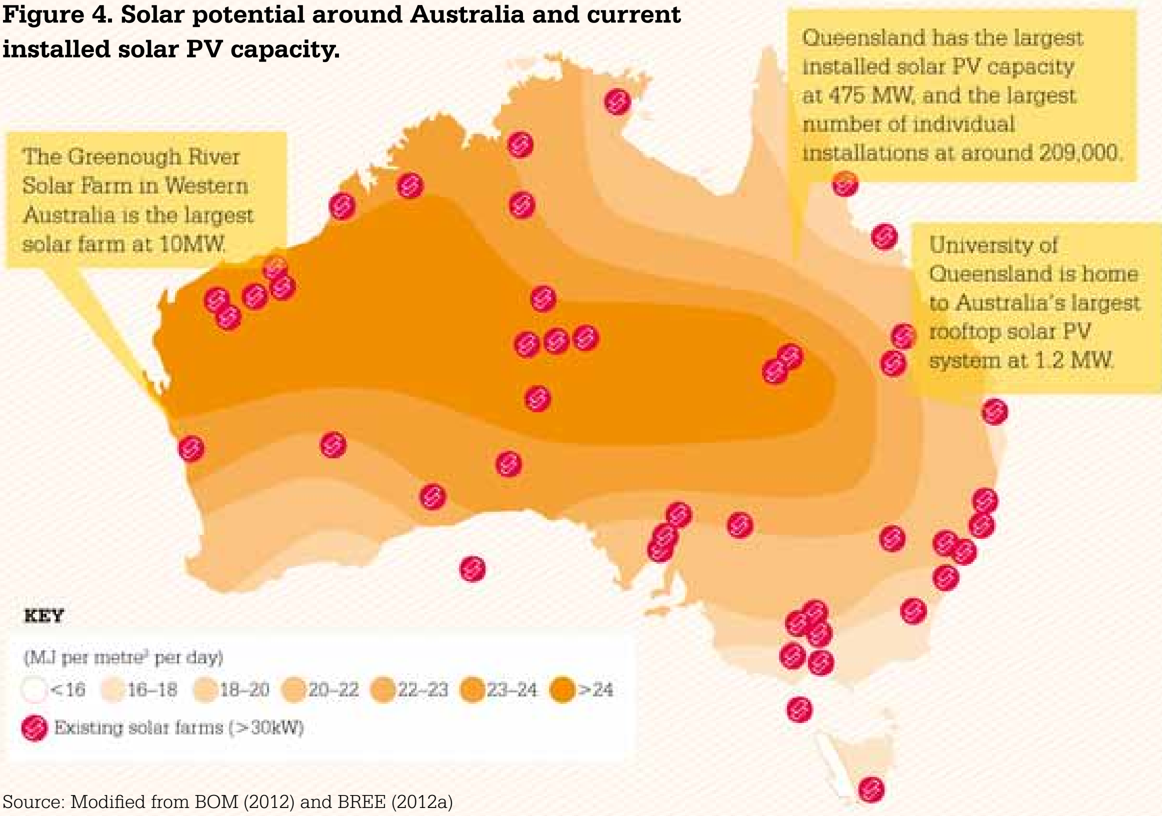
Solar

Australia has the highest average solar radiation per square metre of any country in the world (Geoscience Australia, 2012). The amount of sun received at any point varies based on local climate and the seasons, with higher solar radiation on average in the north-west of the country (Figure 4). Areas that receive low solar radiation levels by Australian standards, such as Victoria, receive more than leading solar power countries like Germany.

The main types of technologies used to capture solar energy are solar thermal and solar photovoltaic (PV) (see Box).

Solar PV electricity generation is increasingly popular among households and businesses in Australia. The annual capacity of solar PV has increased sharply in the last few years (Figure 5) due to innovation in the sector that has reduced technology costs, the strong Australian dollar and the financial incentives provided by the Renewable Energy Target Scheme and feed-in tariffs. The total new solar PV capacity added in Australia in 2011 was 837 MW (Watt, et al., 2012). Australia now has a total installed capacity of 2,000 MW (Sunwiz, 2012), which is comparable to the capacity of a large coal-fired power station. As of July 2012, almost 754,000 Australian households and businesses had installed solar panels (Wills, 2012). Queensland currently has the largest installed solar PV capacity in Australia, at more than 475 MW, and the most individual installations – more than 209,000 as at 30 June 2012 (Wills, 2012).

Figure 4. Solar potential around Australia and current installed solar PV capacity.



Source: Modified from BOM (2012) and BREE (2012a)
Note: this map is a rough guide only, actual solar exposure will vary according to local conditions.

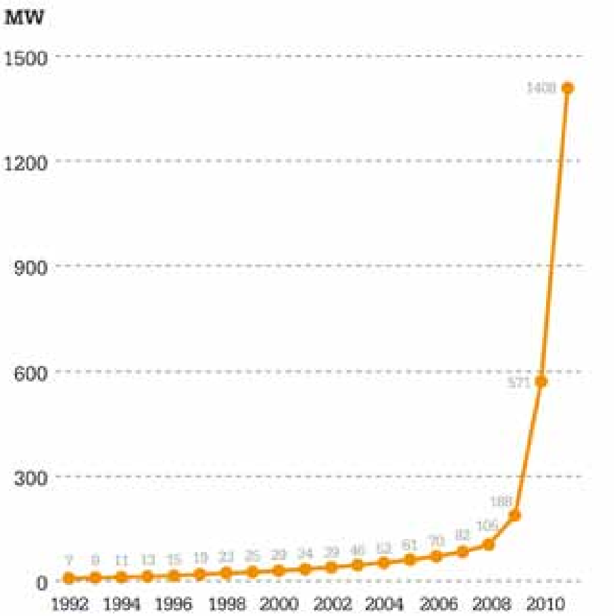
Box. Solar energy technology

Solar photovoltaic (PV): Some materials produce an electric current when exposed to sunlight, known as the photovoltaic effect. Solar PV is based on this effect and was first developed commercially in the 1960s to support space flight. The variable size of PV systems allows them to be installed in a variety of places: popularly installed on rooftops, integrated into building designs and fitted to vehicles. Solar PV can also be used to generate electricity on a large scale.

Concentrated solar PV: Lenses or curved mirrors are used to concentrate a large amount of sunlight onto solar photovoltaic cells. These systems can be more efficient than regular solar PV, since less photovoltaic material is required to produce the same amount of power. Tracking systems are also used with concentrated and regular solar PV, to follow the path of the sun through the day and maximise the amount of power produced.

Concentrated solar thermal: Concentrated solar thermal is used to produce electricity on a large scale. Concentrated solar thermal uses mirrors to reflect sunlight into a small area to heat fluids or salts. These heated fluids then drive a steam turbine to create electricity. An advantage of concentrated solar thermal is that it can incorporate energy storage, meaning a power station can produce energy even when the sun is not shining.

Figure 5. Cumulative installed solar PV power in Australia to 2011.



Source: APVA, 2012

While the majority of solar installations are at the scale of a house or business, there has recently been investment in larger scale installations in Australia. In October 2012, Australia's first utility-scale solar PV facility, the 10 MW Greenough River solar farm near Geraldton, Western Australia, was opened (Verve Energy, 2012). And other projects are in development, for example, at Nyngan (NSW), Broken Hill (NSW) and in the ACT. The 100 MW facility near Nyngan will be connected to a nearby transmission line and will produce enough power for 33,000 homes. Up to 300 jobs will be generated during construction (AGL, 2012).

Use of solar thermal power in Australia is still in its infancy with Australia's largest solar thermal plant a 3 MW facility at the Liddell power station in NSW (CEC, 2011).

Solar power is an attractive option in remote areas of Australia where there is no access to electricity distribution networks (or where connection would be very expensive) and diesel fuel is the main source of energy for electricity (Entura, 2010). Given the expected increases in diesel costs in the coming years (DRET, 2012), solar is increasingly cost competitive in off-grid areas. For example, three remote Aboriginal communities near Alice Springs use solar parabolic dish technology to help power their communities, reducing their use of diesel fuel (CEC, 2012b).

With Australia's world class solar resources, we have a unique opportunity. However, at present solar makes up less than 1% of Australia's total electricity generation (BREE, 2012b). As the technology is further developed and costs continue to decrease, there is potential and need for solar generation in Australia to grow rapidly.

Other renewable energy sources in Australia

HYDRO

Hydropower is the largest single contributor to Australia's renewable energy generation capacity providing 66% of total generation (BREE, 2012b). Most of Australia's suitable hydroelectric resources have already been developed (CEC, 2011; BREE, 2012a). The major facilities are in the Snowy Mountains and Tasmania. Australia currently has 124 operating hydro power stations with a combined generation capacity of around 8,500 MW of electricity (CEC, 2011).

Hydropower is the largest single contributor to Australia's renewable energy generation capacity.
Source: Flickr/SplaTT

BIOENERGY

Bioenergy generation technology is advancing and now makes up about 8% of Australia's renewable electricity generation capacity (BREE, 2012b). Bioenergy involves converting biological material into energy and includes the use of bagasse (sugar cane waste), landfill waste and other waste sources for generation. Sugar cane waste can be used to produce steam and to drive turbines to produce electricity. Many Australian sugar mills now use this process to generate their own electricity on site, reducing the amount of electricity they purchase from the grid (CEC, 2011).

Waste from sugar mills can be used to produce electricity.

GEOTHERMAL

Geothermal energy is extracted from the Earth's stored heat found in hot rocks and hot aquifers (water stored underground). Australia has large hot rock geothermal resources and exploiting even a small fraction of the resources could meet Australia's electricity demand for many years. However, this resource is difficult to access and, as a consequence, the Australian geothermal energy industry is in the early stages of development. Technical constraints and high exploration and development costs will need to be overcome before geothermal energy can support commercial electricity production (Huddlestone-Holmes and Russell, 2012).

MARINE

Marine energy, like geothermal energy, is at an early stage of development in Australia. Australia has considerable wave energy resources reasonably close to population centres and potential industry users (CSIRO, 2012). Construction of a 2 MW demonstration project at Garden Island, Western Australia is expected to start early next year. The project will be the first commercial scale grid-connected wave energy project in Australia (Carnegie, 2012).

Wave power is at an early stage of development, with the first commercial scale project scheduled for construction in 2013.
Source: Carnegie Wave Energy

2. GLOBAL MOMENTUM

2.1 Renewable energy investment and capacity

Global production of electricity from renewable sources has been growing steadily, at around 5% each year since 2005, and by 2011 renewables provided almost 20% of the total electricity supply (IEA, 2012b). Much of this electricity is produced from large-scale hydro.

The expansion of renewable energy is shown by shifts in new investment in electricity generation capacity. New investment reached almost $250 billion in 2011 – an increase of 19% on the previous year (IEA, 2012b). Investment in new renewable power generating capacity exceeded spending on new fossil fuel power plants in 2011 (Frankfurt School – UNEP, 2012).

118
countries with a renewable energy target

61
countries with a feed-in tariff for renewables

33
countries with a carbon price by 2013

1360
GW of renewable power capacity worldwide in 2011

Note: All figures taken from REN21, 2012 or report text.

2.2 Approaches to promoting renewable energy

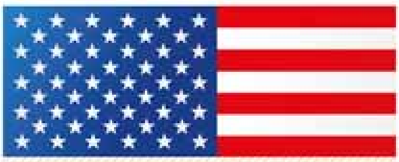
Many economies are taking up new policies that are helping to drive the boom in renewable energy. Until the 1990s, only a few countries had policies supporting renewable energy. In 2011, 118 countries – more than double the number in 2005 – had targets to drive investment in renewable technologies and generation (REN21, 2012). More than 85 countries have legislated or planned targets for expanding renewable energy production (CCA, 2012). Types of policies to help meet the targets include those outlined below.

- Carbon pricing approaches, including emissions trading schemes and carbon taxes, create a financial incentive to reduce greenhouse gas emissions and to invest in renewable energy. As fossil fuels become more expensive, renewable energy sources become relatively cheaper, so energy investment shifts toward renewables. Funds raised by a carbon price can be recycled for other purposes including support for renewable energy technologies. From 2013, emissions trading schemes are expected to be operating in 33 countries covering 30% of the global economy.
- Tradeable certificate schemes allow producers of renewable energy to generate certificates that represent an amount of renewable energy and requiring large electricity purchasers to buy a certain number of certificates. The payments support increased renewable energy production. Australia's Renewable Energy Target scheme is an example of this. The scheme is designed to support the achievement of the Australian Government's target of ensuring the equivalent of at least 20% of Australia's electricity comes from renewable sources by 2020. This is a target to which all of Australia's major political parties are committed.
- Feed-in tariffs are another commonly used incentive. A feed-in tariff is a rate paid for electricity fed back into the electricity grid from a renewable electricity source like a rooftop solar panel system or wind turbine. In 2011, at least 61 countries and 26 states/provinces had feed-in tariffs (REN21, 2012). Feed-in tariffs typically start at a premium but reduce to being equal to or even below prevailing retail electricity tariffs over time.

International action

CHINA

- **1:** global position for size of renewable power capacity (282 GW)
- **1:** global position for size of wind power capacity
- **9:** % of energy consumption from non-fossil resources in 2011 (China Daily, 2012)
- **1:** global position for size of new renewable energy investment in 2011 ($51 billion)



UNITED STATES

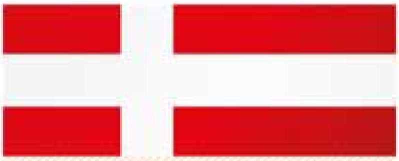
- **2:** global position for size of renewable power capacity (147 GW)
- **1:** global position for installed geothermal power capacity (3.1 GW) in 2011
- **13:** % electricity from renewable sources in 2011 (EIA, 2012a)
- **31:** number of states and DC with mandatory renewable energy targets (EIA, 2012b)

EUROPEAN UNION

- **12.4:** % of overall energy supply from renewable sources in 2010
- **20:** % target of energy supply from renewable sources by 2020

GERMANY

- **1:** global position for size of solar PV capacity, a third of the world's PV capacity
- **3:** global position for size of wind power capacity in 2011
- **17:** % of electricity generation from renewable sources in 2010
- **35:** % target for electricity from renewable sources by 2020



DENMARK

- **32:** % renewable share of electricity production in 2010
- **50:** % target for electricity consumption supplied by wind power by 2020

INDIA

- **5:** global position for size of installed wind power capacity in 2011
- **10:** % target for electricity from renewable sources by 2012

Note: These figures may vary due to differences in calculations among countries and agencies. All figures taken from REN21, 2012, unless otherwise noted.

- Some type of direct funding to support the uptake of renewable energy is offered in at least 52 countries. This can take many forms such as investment tax credits, import duty reductions, and/or other tax incentives to provide financial support (REN21, 2012). Government funding for such support may be drawn from carbon price revenue.
- Governments also directly support industry development and research, for example, by providing funding through competitive grant programs.

All policies that encourage renewable energy have costs that can be weighed against benefits. Benefits could include reducing greenhouse gas emissions, supporting innovation, and encouraging new industry development. Economic studies show that a broad-based carbon price (such as an emissions trading scheme) can encourage emissions reductions at lower cost than non-market based approaches.

3. A RENEWABLE FUTURE

Transforming the ways in which electricity is produced is challenging. Although renewables are already becoming a larger part of the energy production mix, problems – such as distributing power and meeting peak demand – will need to be solved in order to achieve more substantial and rapid growth. Innovation will transform electricity supply as we know it in ways that are comparable to moving from landline phones to smart mobile phones. There are many promising new technologies in existence or in development and we are still learning about the mix that will deliver a major part of Australia's electricity supply in effective and affordable ways. The suitability of different options can depend on the location; for this reason Australia is encouraging the development of a diversity of renewable energy technologies. For example, we already know wind resources are often best along the southern coast of Australia.

Any growth industry requires resourcing and investment in major expansion of Australia's renewable energy capacity will need to be large and sustained. Investment growth will most likely occur where there is a sufficient level of certainty that future policies will encourage, rather than constrain, renewable energy use.

Finding cheaper forms of power

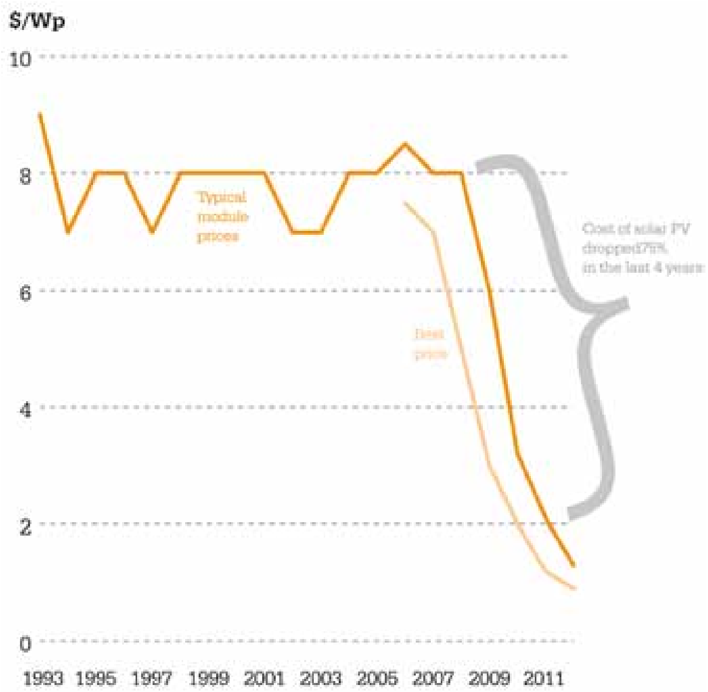
Renewable electricity is rapidly becoming more affordable and becoming economically competitive with electricity generated from fossil fuels. The costs of producing renewable electricity have often been higher than the traditional fossil fuel-based electricity generation because many types of renewable technologies have still been under development and generally installed on a smaller scale. Also, costs of generating electricity from fossil fuels have not traditionally incorporated the costs to society from the greenhouse gas emissions produced. Policies that put a price on these emissions or provide financial incentives for renewables have given drive to investment in renewable power, just as subsidies have previously (and in some cases still are) supported growth of fossil fuel industries. As the scale of renewable technologies increases and the technology evolves, the costs are falling, becoming more competitive with older generation industries.

Globally, renewable electricity is beginning to become less reliant on subsidy support.

Large and small hydropower, conventional geothermal and onshore wind compete well on cost with new coal and gas-fired plants in some areas around the world (IEA, 2012b). The cost of generating electricity with residential solar PV competes well with retail electricity prices in areas with good solar resources (IRENA, 2012). The cost of producing solar PV cells has dropped by 75% in the four years to 2011 and 45% in 2011 (Frankfurt School – UNEP, 2012) (Figure 6). The cost has come down as the technology continues to improve and increasing production leads to better manufacturing efficiency. Lower manufacturing costs have had an important effect on increasing their uptake, because the cost of the equipment is much greater than other costs, such as installation and operation (BREE, 2012c).

Renewable electricity generation, such as from wind and solar, can help lower electricity prices. South Australian wholesale electricity prices are

Figure 6. Typical solar PV unit (module) prices in Australia in 2011 in current dollars per watt peak* ($/Wp).



Source: APVA, 2012

*Watt peak is a measurement of the amount of power (or watts) that a solar PV module produces in ideal (or peak) conditions.

The rise of 'prosumers', Australians are becoming both producers and consumers of energy with the use of solar PV.

now lower than they have been since 2003. Increased wind generation has been found to be one of a number of factors that can lead to electricity price reductions (AEMO, 2011; Cutler et al., 2011).

Recent projections suggest that by 2030, if not earlier, on-shore wind power and solar PV could become the cheapest forms of electricity for retail users in Australia, as carbon prices rise (BREE, 2012a). In areas of Australia that have very high electricity prices, rooftop solar PV may already be the cheapest form of power for retail users (Bazilian et al., 2012).

Electricity grid integration: power where you want it

The electricity grid we have today was designed during the last century for a concentration of large power stations close to their energy source; a 'hub and spoke' model. We have coal-fired power stations located close to coal mines and the electricity grid has been built to link consumers to these stations.

Integrating renewables-based electricity into the grid is a challenge because it requires moving towards a substantially different system based on 'distributed energy'. Rather than just a few very large power plants, distributed electricity draws on sources of power all over the country and of all different sizes. Everything from small household solar PV to major hydro installations, large wind farms and commercial scale solar thermal is included in the system which needs to deliver these diverse and variable sources of power to the centres of demand.

Around the world countries are finding ways to integrate renewable electricity sources effectively into their grids (Cochran et al., 2012). Steps that assist effective integration include carefully planned additions to electricity grids, improving flexibility of electricity markets and establishing renewable electricity generation capacity across diverse geographic areas to help manage variability (Cochran et al., 2012).

The rise of 'prosumers'

As mentioned above, established electricity systems in Australia and many other countries consist of a few large producers and many consumers. As the use of solar PV, community-owned wind farms and small biomass plants increases, this changes. Owners of such assets are both producers and consumers of electricity. A parallel change is under way in the media, where the rise of the electronic media has allowed individuals to become 'prosumers' of information. Experience in other countries shows that this will necessitate changes in the way electricity is distributed and marketed and Australia will also need to consider changes.

Flexible power

The idea of 'baseload' power comes from fossil fuel electricity generation. Traditionally the cheapest source of power has been from coal-fired power plants designed to operate continuously. This constant source of cheap power is called baseload power. It is very important for some continuous refining and manufacturing processes. As important as having baseload power is having enough flexible power (generators we can turn on when we need them) so that electricity is provided when we most need it, to support what we call 'peak load' or 'peak demand' (see the following section). Traditionally peak load power has been provided by large-scale hydro and smaller gas fired power plants.

The advantage of the traditional system is reliability. The availability of fossil fuel inputs, coal, oil and gas, can, to a large extent, be controlled. The disadvantage is the production of high levels of greenhouse gas emissions.

Renewable energy sources such as geothermal, hydro and bioenergy can provide constant power.

When renewable energy from the sun and wind is stored it can also provide a constant stream of power. Wind and solar depend on the weather and the cycle of day and night.

THEREFORE, STORAGE OF ENERGY IS A KEY AREA OF DEVELOPMENT THAT WILL IMPROVE THE DISTRIBUTION AND SECURITY OF AN ENERGY GRID THAT RELIES ON RENEWABLES.

Stored energy is flexible, it can be provided when needed, and helps moderate variable power sources like wind and solar. Battery storage, for example, is commonly used to allow for a reliable electricity supply in off-grid small-scale systems.

Our transmission network is a key consideration for integrating renewable energy generation in Australia.
Source: Arthur Mostead

The most common and available storage technology is pumped hydro storage. Pumped hydro plants pump water into elevated reservoirs during periods of excess electricity production (or when prices are low) and release it to generate electricity during periods of high demand. Currently, pumped hydro makes up 99% of global energy storage capacity and more is being constructed to help integrate variable renewable sources (REN21, 2012). Pumped hydro can be driven from fossil fuel or renewable energy sources.

There are a number of additional energy storage options. Concentrated solar thermal plants heat molten salt, which stays hot overnight, allowing energy production even when the sun isn't shining. Biomass and biogas can also be stored to provide an energy source when needed (James and Hayward, 2012). Other ways of storing electricity include compressed air energy storage, flywheels, electrical batteries and vanadium redox flow cells, supercapacitors, superconducting magnetic storage and other types of thermal energy storage. Many of these storage technologies are still at the early stages of development and are relatively expensive (IRENA, 2012).

Peak demand: power when you most need it

We don't use energy at the same rate all the time; demand for electricity changes during the day. During hot summer afternoons demand for electricity can be extremely high but during the early hours of the morning it is quite low. Managing peaks of electricity demand is a key challenge for Australia's energy industry.

Feeding renewable energy into the grid rather than fossil fuel technologies has different consequences for grid management. Balancing the supply and demand of energy has always been a difficult task and our grids must be 'smarter' to manage more sources of energy with varying generation profiles.

Planning and forecasting can assist with overcoming such variability. Use of better weather forecasting and smart grids can help companies and consumers to understand their energy generation and consumption and can aid them to monitor and manage electricity supply to meet the demands. Smart grids incorporate sensors, information technology systems, smart meters and communications networks. They provide information that allows more efficient management of networks and help electricity users to better manage their consumption.

Pumped hydropower is an established energy storage technology that can be used with all energy sources for provision of on-demand power, here used at Wivenhoe Power Station in Queensland.
Source: CS Energy

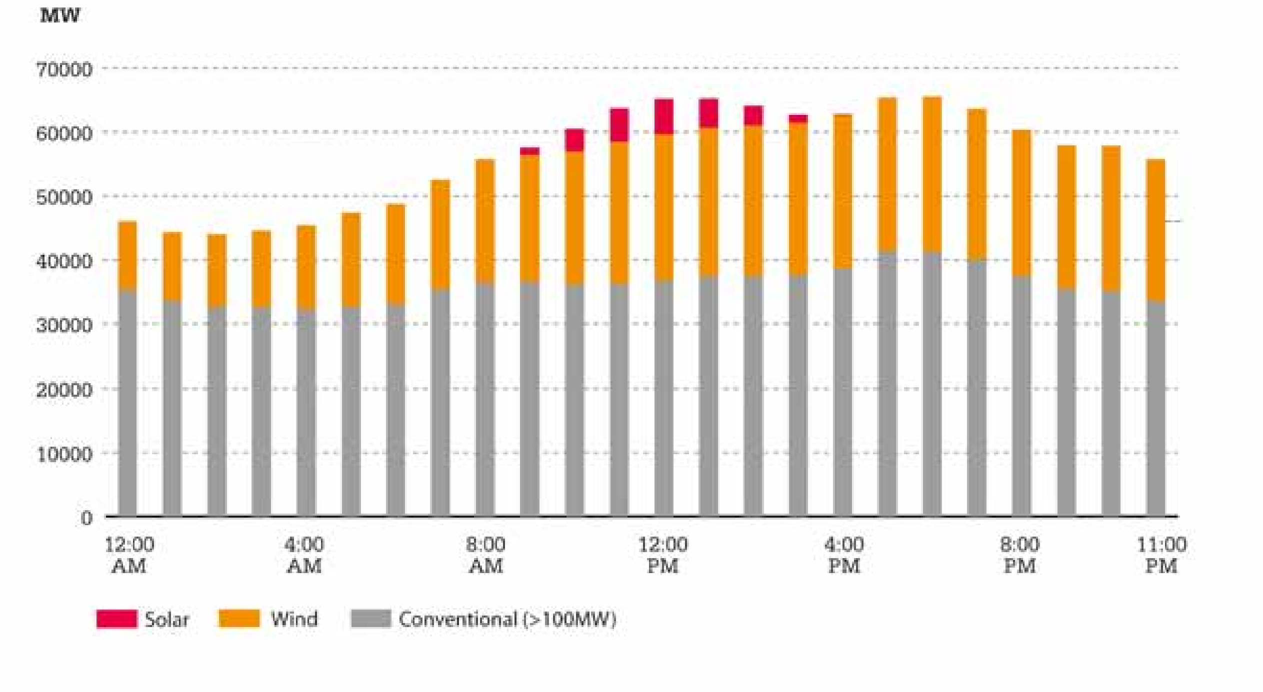
Smart grids can incorporate smart meters and in-home energy monitors, allowing users to better manage their electricity use.
Source: flickr/TomRaftery

Introducing time-of-use charging can also help reduce costs to the consumer and improve efficiency of electricity supply. Time-of-use charging works by having higher prices during peak electricity demand (for example, during summer afternoons) and lower prices when there isn't a lot of demand (for example, at midnight).

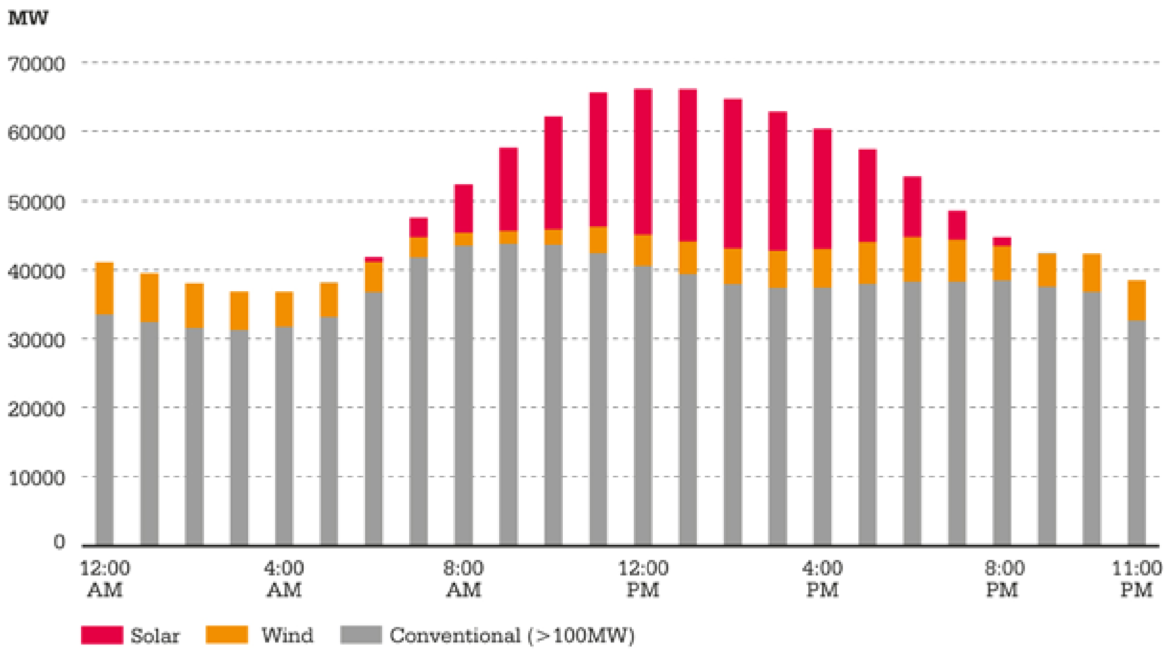
Some of the characteristics particular to renewable energy sources could be useful in meeting electricity demand. It is possible that complementary use of wind and solar could help support key peak load periods. For example, in Germany, wind has been found to support winter peak loads (Figure 7a) and solar to support summer peaks (Figure 7b). Using renewables to support peak loads requires a mix of renewable energy sources spread across the country to take advantage of different conditions. This might require higher levels of capital expenditure on both generation capacity and grids. Smarter grids may be required to support this diverse generation (see above) with associated costs. As a bridging strategy, it is likely that continued use of conventional power plants such as open cycle gas-fired power will be needed during peak load periods.

Figure 7. Peak winter and summer electricity demand in Germany.

a) 3 January 2012



b) 25 May 2012



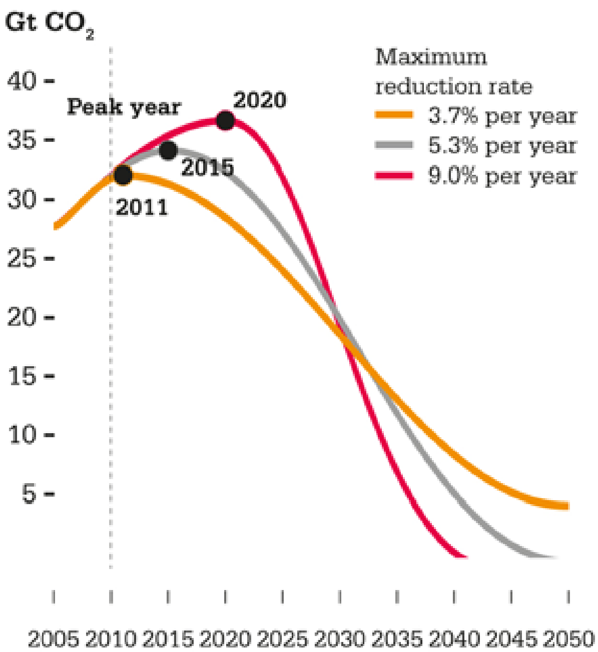
Source: EEX, 2012

4. A CRITICAL TRANSFORMATION

There is no doubt that renewable energy technologies have enormous potential to help transform our energy systems towards a low-emissions future. Development and implementation of renewable energy is gathering pace both here and around the world but the scale of the challenge that lies ahead should not be underestimated. To avoid dangerous climate change, we need to make substantial changes and transform our current energy systems.

Figure 8 shows three possible trajectories of global carbon dioxide emissions that would give us a two-thirds chance of stabilising global average temperature at 2°C or less above pre-industrial levels. This figure shows that we need to reduce emissions by a large amount and very rapidly. Global emissions will need to be very near zero by 2050, only 38 years away. That is, we have less than four decades to transform energy systems around the world. Most agree that the world's industrialised nations, including Australia, should play a strong leadership role in this transformation.

Figure 8. Three emissions trajectories giving a 67% probability of keeping global average temperature increases below 2°C (global emissions in Gt CO_2).



Source: WBGU, 2009

Today Australia produces only 10% of our electricity from renewable sources; the rest is produced by the combustion of fossil fuels. Achieving our 2020 target of producing 20% of our electricity from renewables is important but it is only a step along a longer and deeper transformation. Several analyses show a major role for growth in renewables, together with reducing fossil fuel use and adopting other low emissions technologies, in reducing Australia's greenhouse gas emissions (DRET, 2012). The potential for producing all electricity from renewables is also being investigated (DCCEE, 2012b).

At the global level, making deep cuts in emissions requires very large reductions in fossil fuel use. Renewables are likely to take the lion's share of the world's electricity production by the middle of this century (IEA, 2012a).

The rate at which the world achieves this transformation in energy production is critical. If global emissions could peak by 2015, just three years away, the maximum annual rate at which we will subsequently need to reduce emissions is about 5% – a big ask but possibly achievable. If we delay the peak year of emissions by only five more years to 2020, then the maximum subsequent rate of emission reduction becomes 9%, which is much more difficult and costly.

The need to reduce global greenhouse gas emissions to almost zero within decades is very clear, as is the need to supply energy across the world. New sources of energy are a major part of the solution, and the recent advances in development and uptake of renewable energy technologies show that these technologies can make a large contribution.

The challenge in front of us now is to turn the enormous potential of renewable energy into implementation at a large scale, as rapidly as we can. This is the critical decade to get on with the job.

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