ENERGY TRANSFORMED: SUSTAINABLE ENERGY SOLUTIONS FOR CLIMATE CHANGE MITIGATION

MODULE C
INTEGRATED APPROACHES TO ENERGY EFFICIENCY AND LOW EMISSIONS ELECTRICITY, TRANSPORT AND DISTRIBUTED ENERGY

This online textbook provides free access to a comprehensive education and training package that brings together the knowledge of how countries, specifically Australia, can achieve at least 60 percent cuts to greenhouse gas emissions by 2050. This resource has been developed in line with the activities of the CSIRO Energy Transformed Flagship research program, which is focused on research that will assist Australia to achieve this target. This training package provides industry, governments, business and households with the knowledge they need to realise at least 30 percent energy efficiency savings in the short term while providing a strong basis for further improvement. It also provides an updated overview of advances in low carbon technologies, renewable energy and sustainable transport to help achieve a sustainable energy future. While this education and training package has an Australian focus, it outlines sustainable energy strategies and provides links to numerous online reports which will assist climate change mitigation efforts globally.

CHAPTER 7: INTEGRATED APPROACHES TO ENERGY EFFICIENCY AND LOW EMISSIONS ELECTRICITY

LECTURE 7.3: CAN RENEWABLE ENERGY SUPPLY PEAK LOAD ELECTRICITY?
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The Natural Edge Project (TNEP) is an independent non-profit Sustainability Think-Tank based in Australia. TNEP operates as a partnership for education, research and policy development on innovation for sustainable development. TNEP's mission is to contribute to, and succinctly communicate, leading research, case studies, tools, policies and strategies for achieving sustainable development across government, business and civil society. Driven by a team of early career Australians, the Project receives mentoring and support from a range of experts and leading organisations in Australia and internationally, through a generational exchange model.
The International Energy Agency forecasts that if policies remain unchanged, world energy demand is set to increase by over 50 percent between now and 2030.\(^1\) In Australia, CSIRO has projected that demand for electricity will double by 2020.\(^2\) At the same time, The Intergovernmental Panel on Climate Change (IPCC) has warned since 1988 that nations need to stabilise their concentrations of CO\(_2\) equivalent emissions, requiring significant reductions in the order of 60 percent or more by 2050\(^3\). This portfolio has been developed in line with the activities of the CSIRO Energy Transformed Flagship research program; ‘the goal of Energy Transformed is to facilitate the development and implementation of stationary and transport technologies so as to halve greenhouse gas emissions, double the efficiency of the nation’s new energy generation, supply and end use, and to position Australia for a future hydrogen economy’.\(^4\) There is now unprecedented global interest in energy efficiency and low carbon technology approaches to achieve rapid reductions to greenhouse gas emissions while providing better energy services to meet industry and society’s needs. More and more companies and governments around the world are seeing the need to play their part in reducing greenhouse gas emissions and are now committing to progressive targets to reduce greenhouse gas emissions. This portfolio, *The Sustainable Energy Solutions Portfolio*, provides a base-capacity-building training program that is supported by various findings from a number of leading publications and reports to prepare engineers/designers/technicians/facilities managers/architects etc. to assist industry and society rapidly mitigate climate change.

The Portfolio is developed in three modules;

**Module A: Understanding, Identifying and Implementing Energy Efficiency Opportunities for Industrial/Commercial Users – By Technology**

**Chapter 1: Climate Change Mitigation in Australia’s Energy Sector**

Lecture 1.1: Achieving a 60 percent Reduction in Greenhouse Gas Emissions by 2050

Lecture 1.2: Carbon Down, Profits Up – Multiple Benefits for Australia of Energy Efficiency

Lecture 1.3: Integrated Approaches to Energy Efficiency and Low Carbon Technologies

Lecture 1.4: A Whole Systems Approach to Energy Efficiency in New and Existing Systems

**Chapter 2: Energy Efficiency Opportunities for Commercial Users**

Lecture 2.1: The Importance and Benefits of a Front-Loaded Design Process

Lecture 2.2: Opportunities for Energy Efficiency in Commercial Buildings

Lecture 2.3: Opportunities for Improving the Efficiency of HVAC Systems

**Chapter 3: Energy Efficiency Opportunities for Industrial Users**

Lecture 3.1: Opportunities for Improving the Efficiency of Motor Systems

Lecture 3.2: Opportunities for Improving the Efficiency of Boiler and Steam Distribution Systems

Lecture 3.3: Energy Efficiency Improvements available through Co-Generation

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Module B: Understanding, Identifying and Implementing Energy Efficiency Opportunities for Industrial/Commercial Users – By Sector

Chapter 4: Responding to Increasing Demand for Electricity
Lecture 4.1: What Factors are Causing Rising Peak and Base Load Electricity Demand in Australia?
Lecture 4.2: Demand Management Approaches to Reduce Rising ‘Peak Load’ Electricity Demand
Lecture 4.3: Demand Management Approaches to Reduce Rising ‘Base Load’ Electricity Demand
Lecture 4.4: Making Energy Efficiency Opportunities a Win-Win for Customers and the Utility: Decoupling Energy Utility Profits from Electricity Sales

Chapter 5: Energy Efficiency Opportunities in Large Energy Using Industry Sectors
Lecture 5.1: Opportunities for Energy Efficiency in the Aluminium, Steel and Cement Sectors
Lecture 5.2: Opportunities for Energy Efficiency in Manufacturing Industries
Lecture 5.3: Opportunities for Energy Efficiency in the IT Industry and Services Sector

Chapter 6: Energy Efficiency Opportunities in Light Industry/Commercial Sectors
Lecture 6.1: Opportunities for Energy Efficiency in the Tourism and Hospitality Sectors
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Lecture 6.3: Opportunities for Energy Efficiency in the Fast Food Industry

Module C: Integrated Approaches to Energy Efficiency and Low Emissions Electricity, Transport and Distributed Energy

Chapter 7: Integrated Approaches to Energy Efficiency and Low Emissions Electricity
Lecture 7.1: Opportunities and Technologies to Produce Low Emission Electricity from Fossil Fuels
Lecture 7.2: Can Renewable Energy Supply Peak Electricity Demand?
Lecture 7.3: Can Renewable Energy Supply Base Electricity Demand?
Lecture 7.4: Hidden Benefits of Distributed Generation to Supply Base Electricity Demand

Chapter 8: Integrated Approaches to Energy Efficiency and Transport
Lecture 8.1: Designing a Sustainable Transport Future
Lecture 8.2: Integrated Approaches to Energy Efficiency and Alternative Transport Fuels – Passenger Vehicles
Lecture 8.3: Integrated Approaches to Energy Efficiency and Alternative Transport Fuels - Trucking

Chapter 9: Integrated Approaches to Energy Efficiency and Distributed Energy
Lecture 9.3: Beyond Energy Efficiency and Distributed Energy: Options to Offset Emissions
Integrated Approaches to Energy Efficiency and Low Emissions Electricity

Lecture 7.3: Can Renewable Energy Supply Base Electricity Demand?

Educational Aim

The aim of this lecture is to provide an overview of the many ways that different forms of renewable energy can, individually and in combination, help to meet rising base load electricity demand and reduce greenhouse gas emissions. This lecture also aims to provide an awareness of the diversity of ways renewables can contribute to meeting base load electricity demand, as well as giving an overview and context outlining the potential ways that renewable energy can contribute to help Australia achieve at least 60 percent reduction in 1990 levels of greenhouse gas emissions by 2050.

Essential Reading

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5 Peer review by Dr Mike Dennis - ANU.
Learning Points

1. While it is widely acknowledged that distributed renewable energy can assist in meeting peak load demand, there is still much debate in Australia on whether distributed renewable energy can meet forecast base load electricity demand without some form of fossil fuel contribution. Significant efforts have been made globally to shift from using renewables simply to top up the existing system during peak load periods to actually providing reliable base load power.

2. Renewable distributed energy now accounts for a quarter of the installed capacity of California, a third of Sweden’s energy, half of Norway’s and three-quarters of Iceland’s, and since 2003 Denmark has generated 20 percent of its electricity from wind power. Many forms of renewable energy are not dependent on day-to-day weather variations and hence can provide electricity just as reliably as coal or nuclear, such as hydro, biomass, geothermal.

   - Hydro–power is based on converting potential energy of stored water into electricity as it flows downstream. Hydro already meets 7 percent of Australia’s electricity needs, and the International Hydropower Association estimates that for Australia only 49 percent of technically feasible hydropower has been developed.

   - Bioenergy is based on the combustion of crops and crop residues, or their gasification followed by combustion of the gas. In 2000 biomass provided 11 percent of the world’s total primary energy supply. At present Finland derives over 20 percent, Sweden 17 percent, Austria 11 percent and Australia about 3.3 percent of total primary energy supplies from biomass. The Australian Paper and Pulp industry already sources approximately 30 percent of its energy from biomass, substituting for base load electricity from external sources.

   - Geothermal power is based on converting heat stored in the earth into electricity and as this is a relatively stable source it is being used by more and more countries. In 2001 the electric energy produced from geothermal resources represented over 60 percent of the total electricity generated in Iceland, 27 percent in the Philippines, 12.4 percent in Kenya, 11.4 percent in Costa Rica, and 4.3 percent in El Salvador.

3. Co-Generation, as mentioned in Lecture 7.2, enables the simultaneous production of electricity and useful heat from the one energy source. Co-generation helps not only to meet industry’s peak load but also its base load electricity demand by generating electricity onsite through a combustion process that also harnesses the heat from the process for use on site in both industrial and commercial building processes. In Australia, aluminium giant Alcoa with its partner Alinta is investing significantly in co-generation to help meet its base load electricity needs.

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8 For further reading on biomass, a wealth of general information may be obtained from the Bioenergy Australia website at www.bioenergyaustralia.org. Accessed 2 June 2007. The international bioenergy collaboration within the International Energy Agency may be accessed via www.iea.bioenergy.com. A valuable international journal is Biomass and Bioenergy.


10 ABARE gives 202 PJ of biomass energy, but firewood experts suggest that the residential firewood component of this amount should be about 48 PJ instead of ABARE’s 80 PJ.

4. Furthermore, renewable energy flows from wind and solar are much less intermittent than many assume. Advances in energy storage technologies are allowing solar PV and concentrated solar thermal systems to provide base load electricity. Hence a range of significant studies suggests strongly that there is no technological impediment to shifting to a higher percentage of renewable energy, using gas fired turbines as back-up. Graham Sinden from the Environmental Change Institute at Oxford University has investigated the potential contribution from several different, variable, renewable electricity sources in the UK. Using real data spanning many years, on winds, sunshine, waves and tides at multiple sites, Sinden concludes that the major proportion of UK electricity could be generated from renewable energy sources, with wind from dispersed sites being the biggest source. As Sinden says, ‘...if you plan the right mix, renewable and intermittent technologies can even be made to match real-time electricity demand patterns. This reduces the need for backup, and makes renewables a serious alternative to conventional power sources.’ Many other studies have come to the same conclusion (see Brief Background Information).

5. The recent national scenario study, A Clean Energy Future for Australia, by the Clean Energy Future Group, came to a similar conclusion. This study was very conservative in its assumptions only assuming small improvements to existing technologies, and yet it still found that by 2040 renewable energy can contribute to 60 percent of electricity supply, while also reducing demand for electricity (by means of efficient energy use and solar hot water). The study finds that CO₂ emissions from electricity generation could be reduced by 78 percent compared with the 2001 level by 2040. It is an important study showing that Australia’s sustainable energy future - based on efficient energy use, renewable energies and natural gas (while it lasts) - is now technologically and economically feasible.

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15 Ibid.
Brief Background Information

Can Renewable Energy Significantly Contribute to Australia’s Base Load Electricity Demand?

It is widely acknowledged that renewable energy is very effective at contributing electricity to the grid to meet peak load demand, as renewable energy sources like co-generation, wind and solar produce the most amount of energy during peak load times of the day. Where there is still much debate in the media and among the engineering community is on whether distributed renewable energy can meet forecast base load electricity demand in Australia. Base load is commonly understood to mean technologies which provide electricity seven days a week 24 hours a day. In mainland Australia, base load power stations are mostly coal-fired (a few are gas-fired).

Many forms of renewable energy are not dependant on day-to-day weather variations and hence can provide electricity just as reliably as coal or nuclear - such as co-generation, geothermal, concentrated solar thermal with storage, and biomass. Furthermore, renewable energy flows from wind and solar are much more intermittent than many assume. Many are now coming to understand that there is in fact no unsurpassable technological impediment to shifting to a significantly higher percentage of renewable energy, using gas fired turbines as back-up. This has been confirmed by the following studies and models:

- Graham Sinden from the Environmental Change Institute at Oxford University has investigated the potential contribution from several different, variable, renewable electricity sources in the UK. He has found that adding up different renewable energy sources with different statistical properties can substantially reduce the total variability and hence the need for back-up. Using real data spanning many years, on winds, sunshine, waves and tides at multiple sites, Sinden concludes that the major proportion of UK electricity could be generated from renewable energy sources, with wind from dispersed sites being the biggest source (see Lecture 7.2).

- Sigurd Weinreich’s team at The Centre for European Economic Research, has developed a model that shows it is technologically and economically affordable for the EU to make a transition over the coming decades to meeting 100 percent of their electricity needs from renewable and distributed energy sources.

- An impressive European team of experts have found that Japan can make a transition to source 100 percent of its energy from renewable, distributed sources over the next half century.

- Studies by Allen consulting also show that if nations invest in energy efficiency, the economic gains will offset the additional costs of electricity from renewable energy over the next decade or two while renewable energy costs come down.

- Modelling by the Clean Energy Futures Group in Australia, published in their Clean Energy Reports for Australia, suggests that a combination of demand management, investment in energy efficiency and renewable energy, and using gas as a transition fuel, can supply a

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significant percentage of base load electricity demand by 2040. This study found that renewable energy could contribute 60 percent of electricity by 2040 and that CO₂ emissions from Australia’s electricity generation could be reduced by 78 percent compared with the 2001 level. It is important to note that this study was very conservative, assuming only small improvements to existing technologies. The modellers were required to assume there would not be any significant advances on currently available renewable technologies, which meant that in the model, solar will only contribute about 2-4 percent by 2040. But there are currently three significant developments in solar energy (not considered in the study) which will dramatically bring down the costs:

- ANU Solar Sliver Cells.21
- Developments in Concentrated Solar Thermal Energy and Storage.22
- The building of at least ten new silicon foundries globally to increase silicon production.23

A recent World Watch Institute report24 suggests that the combination of all these factors will reduce the costs of solar energy rapidly by at least 40 percent. Also the Clean Energy Futures Group did not factor in a significant contribution from geothermal power to Australia’s future energy supply mix because the industry is still in its infancy. This suggests that by 2060 it is technologically possible for combinations of all renewables, including solar and geothermal, to be responsible for the majority of Australia’s electricity.

Nations Utilising Significant Renewable Resources

There are already significant examples to suggest that such future scenario’s are plausible. For instance, renewable energy now already accounts for a quarter of the installed capacity of California, a third of Sweden’s energy, half of Norway’s and three-quarters of Iceland’s. Geothermal power, which supplies base load power with the same load profiles as coal and nuclear, is being used by more and more countries. In 2001 the electric energy produced from geothermal resources represented over 60 percent of the total electricity generated in Iceland, 27 percent in the Philippines, 12.4 percent in Kenya, 11.4 percent in Costa Rica, and 4.3 percent in El Salvador.25

Since 2003 Denmark has generated 20 percent of its electricity from wind power. There have been no major problems resulting from wind variability, although there is a temporary problem resulting from the connection of a large block of wind power from off-shore wind farms to a single point on a weak section of the transmission network. Because Denmark is connected by transmission line to other European countries, it does not need to install additional peak load plant to balance its wind power. Instead, it purchases additional power from its neighbours when necessary.

As highlighted in Lecture 4.4, one of the now classic cases of using renewable energy to meet base load demand comes from Sacramento, California. In 1989 Sacramento Municipal Utility District (SMUD) were forced by community action to close their unpopular nuclear plant, and had to replace half of its capacity virtually overnight - as much as 950 MW. Instead of building a conventional plant (e.g. coal-fired) to meet supply demand, SMUD first invested in providing energy efficiency services

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through the implementation of load management and energy efficiency measures. They then invested in a range of small scale, distributed forms of energy generation – wind, solar, co-generation fuel cells – to meet the remaining gap between energy supply and demand, experimenting to find the most effective combinations of renewable energy.

The following overviews the relevant types of base load renewable energy - hydro, biomass, co-generation, hot dry rock geothermal power, solar PV and solar thermal with storage, and large scale, geographically dispersed, wind farms.

**Hydro Power**

Hydro–power already meets 7 percent of Australia’s electricity needs.\(^{26}\) Much of this is used currently for peak load electricity, however, if strategies were implemented to significantly reduce peak load, then more electricity generated by hydro power could be used to provide low emission base load electricity. As discussed in Lecture 7.2, the International Hydropower Association estimates that for Australia only 49 percent of technically feasible hydropower has been developed.\(^{27}\)

**Bioenergy**

Bioenergy is based on the combustion of crops and crop residues, or their gasification followed by combustion of the gas.\(^{28}\) In 2000 biomass provided 11 percent of the world’s total primary energy supply.\(^{29}\) At present Finland derives over 20 percent, Sweden 17 percent, Austria 11 percent and Australia about 3.3 percent (about 170 PJ) of total primary energy supplies from biomass.\(^{30}\) Paper and pulp manufacturing plants in Australia already generate significant quantities of their energy from utilising biomass. As the *Australian Plantation, Timber Products and Paper Council’s Sustainability Action Plan* states,\(^{31}\)

*The plantation products and paper industry is both a producer and user of renewable energy. A large proportion of the renewable energy produced by the paper sector is obtained from the black liquor (lignin) that is extracted from wood when it is separated into its constituent fibres through chemical pulping processes. Some recent studies have suggested that the potential for power production from black liquor may be even higher if gasification and combined cycles are used.*\(^{32}\)

The Clean Energy Future Group’s study of future energy scenario’s for Australia found that,\(^{33}\)

*It appears that biomass could make a substantial contribution to electricity, heat and transport in Australia and at most only a minor fraction would have to come from dedicated energy crops, however, this does not have to be all forest. Oil seed crops and high lipid content algae*

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28 For further reading on biomass, a wealth of general information may be obtained from the Bioenergy Australia website at [www.bioenergyaustralia.org/](http://www.bioenergyaustralia.org/). Accessed 2 June 2007. The international bioenergy collaboration within the International Energy Agency may be accessed via [www.ieaiboenergy.com](http://www.ieaiboenergy.com). A valuable international journal is *Biomass and Bioenergy*.


30 ABARE gives 202 PJ of biomass energy, but firewood experts suggest that the residential firewood component of this amount should be about 48 PJ instead of ABARE’s 80 PJ.


could also play a role. Specifically for electricity generation it appears that all biomass crops and residues could together supply considerably more than 92 TWh (330 PJ) of Australia’s electricity in 2040, (roughly 10% of total electricity production in 2040) without competing with food production.

Co-Generation

Co-Generation enables the simultaneous production of electricity and useful heat from the one energy source. Co-generation helps not only to meet industry’s peak load but also its base load electricity demand by generating electricity onsite through a combustion process that also harnesses the heat from the process for use on site in both industrial and commercial building processes.34 In Australia, Alcoa with its partner Alinta is investing significantly in co-generation to help meet its base load electricity needs.35 Alcoa is continuing to introduce gas-fired co-generation with energy partner Alinta at their Western Australian alumina refineries. The Alcoa Pinjarra alumina refinery, with both an efficiency upgrade and a co-generation development, shows the potential opportunities that can be available:

- The Pinjarra efficiency upgrade project will improve the refinery’s energy efficiency (and greenhouse performance) by about 5 percent.
- Two new Alinta co-generation units at Alcoa’s Pinjarra Refinery will utilise gas-fired turbines to generate electricity for third party customers, with the (exhaust) heat producing steam for use by the refinery.
- Combining the efficiency upgrade project with the new Alinta co-generation project will reduce the greenhouse intensity of the Pinjarra Refinery by about 14 percent, giving an annual net CO₂ saving of around 380,000 tons.

Geothermal Energy

Geothermal energy is not strictly speaking renewable, as the rate of extraction exceeds the rate of formation of geothermal reserves underground. However it is often included in discussions of renewable energy because it is a low carbon supply technology with resources that will last hundreds, if not thousands, of years. Geothermal power supplies base load power with the same load profiles as coal and nuclear, and is being used by more and more countries. In 2001 the electric energy produced from geothermal resources represented 75 percent of Iceland’s total electricity generated, 27 percent in the Philippines, 12.4 percent in Kenya, 11.4 percent in Costa Rica, and 4.3 percent in El Salvador.36 As the Australian Uranium Information Centre states,37

Where hot underground steam can be tapped and brought to the surface it may be used to generate electricity. Such geothermal sources have potential in certain parts of the world such as New Zealand, USA, Philippines and Italy. Some 8000 MWe of capacity is operating, including 3000 MWe in the USA and 2000 MWe in Philippines, and in 2002 geothermal produced more electricity than did wind worldwide. In Japan 500 MWe of capacity produces 0.3% of the country's electricity. In New Zealand 420 MWe produces over 7% of the electricity, and Iceland gets most of its electricity from 200 MWe of geothermal plant. Lihir Gold mine in

34 Ibid.
Papua New Guinea has 56 MWe installed, the last 20 MWe costing US$ 40 million - about the same as annual savings from the expanded plant. Geothermal electric output is expected to triple by 2030. There are also prospects in certain other areas for hot fractured rock geothermal - pumping water underground to regions of the earth’s crust which are very hot or using hot brine from these regions. The heat - around 250°C - is due to high levels of radioactivity in the granites and because they are insulated at 4-5 km depth. They typically have 15-40 ppm uranium and/or thorium, but may be ten times this. The heat from radiogenic decay is used to make steam for electricity generation. South Australia has some very prospective areas. Ground source heat systems also come into this category, thought the temperatures are much lower. The new Geoscience Australia building in Canberra is heated and cooled thus, using a ground loop system of 350 pipes to use the earth as a heat sink or heat source at different times of the year.

Research by Dr P.N. Chopra while previously at ANU (and other respected research bodies) shows that Australia has one of the largest Hot Dry Rock (HDR) geothermal reserves in the world, which could provide electricity to meet all of Australia’s needs for thousands of years. Figure 7.3.1 shows the estimated temperature at a depth of 5km across Australia. Blue hues indicate relatively low temperatures at this depth while reds represent areas where the temperature is estimated to be particularly high. Parts of Central Australia are predicted to be >300°C at 5km depth. Australian of the Year, Tim Flannery, has raised awareness of the potential of HDR geothermal power, writing that,38 This one rock body in South Australia is estimated to contain enough heat to supply all Australia’s power needs for 75 years, at a cost equivalent to that of brown coal, without the carbon dioxide emissions. So vast is the resource that distance to market is no object, for power can be pumped down the power line in such volume as to overcome any transmission losses. With trial plants scheduled for construction this year, the enormous potential of HDR geothermal power is about to be tested. Hot dry rock geothermal energy relies on existing technologies and engineering processes such as drilling and hydraulic fracturing - techniques established by the oil and gas industry.

Figure 7.3.1. Australia’s geothermal resources

Source: Dr P.N. Chopra, Dept of Earth and Marine Sciences, Australian National University.

Solar PV

When advanced batteries become less expensive, PV electricity can become a very cost effective option for meeting base electricity load. One of the fastest growing markets in the world today is hybrid cars. This is stimulating significant R&D efforts to improve the effectiveness of batteries and fuel cells which can store electricity. The rapidly expanding hybrid car market is also creating a significant global market for advanced batteries and helping to bring their costs down through increasing economies of scale. Meanwhile, even without storage, a large amount of solar PV can substitute for coal and/or gas combusted in intermediate-load power stations because, if it is orientated to the north-west, its supply matches the summer peak load demand. Thus, statistically speaking, even solar electricity without storage has a degree of reliability during the daytime.

Concentrated Solar Thermal

Solar energy can also be stored at low cost as heat in water, rocks or thermo-chemical systems such as ammonia. Converting solar energy into heat can then be used to store energy during the day, which can then be released for use overnight as shown in Figure 7.3.2. Therefore, solar thermal electricity with thermal storage can supply base load and can be just as reliable as base load coal. Solar thermal energy is a technology for harnessing solar power for practical applications, from solar heating to electrical power generation. Solar thermal collectors, such as solar hot water panels, are commonly used to generate solar hot water for domestic and light industrial applications.

![Concentrated solar thermal energy transfers on a typical summers day](image)

**Figure 7.3.2.** Concentrated solar thermal energy transfers on a typical summers day


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Solar thermal energy is used in architecture and building design to control heating and ventilation in both active solar and passive solar designs. Solar thermal electric power plants are solar power plants that generate electricity by converting solar energy to heat in order to drive a thermal power plant. Solar thermal base load electric systems have been operating for up to 20 years. These plants include a number of Solar Energy Generating Systems,\(^{42}\) such as Nevada Solar One covering 350 acres of the desert near Boulder City, Nevada south of Las Vegas,\(^{43}\) and Solar Two covering 82,750 m\(^2\) with the ability to produce 10 megawatts.\(^{44}\)

![Solar thermal energy system](image)

**Figure 7.3.3.** Artist impression of Nevada Solar One, a 64 MW renewable solar power plant that will be constructed in Boulder City, Nevada

*Source: Solargenix Energy Inc\(^{45}\)*

![Solar Two power tower](image)

**Figure 7.3.4.** Solar Two, power tower

*Source: NREL's Photographic Information Exchange*

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There are several types of solar thermal systems\textsuperscript{46} which can contribute to base load electricity with storage. Australian scientists have made world class contributions to this important field of renewable energy over the last fifty years.\textsuperscript{47} CSIRO scientists, who published an extensive review of the field in October 2006, found that,\textsuperscript{48} 

It has been predicted that...If the higher rate of commercial application is achieved, the technology will play a significant role in base-load generation for Australia and other countries... These predictions show that Concentrated Solar Thermal technologies could be capable of meeting the requirements of two major electric power markets: large-scale dispatchable markets comprised of grid-connected peaking and base-load power, and rapidly expanding distributed markets, including both on-grid and remote/off grid applications... There is also an opportunity to use solar thermal energy for natural gas reforming, which results in 26% of embodied solar energy in the product gas.

In Australia, the large quantities of natural gas and coal seam gas, and the well developed gas and electricity grids, coupled with large areas with high solar insolation, provide an opportunity for using this approach to make a significant reduction in greenhouse emissions per unit of electricity, and in the amount of fossil energy consumption. The attractive environmental attributes of Concentrated Solar Thermal, combined with the inherent capability of the technology to meet dispatchable and distributed market needs, form a forceful argument for continued development of the technology.

Thermal storage technology is available and readily connected to concentrated solar thermal plants... The current plants in operation are achieving costs of about US $0.12 kWh which are the lowest of any solar technology. The technology can also be combined in hybrid form (solar thermal plants couple with fossil fuel-fired boilers) achieving cost of about US$0.08/kWh...

There is a concerted international effort to develop the technology through installations, to benefit from scale and the learning rate. It is predicted that the cost of concentrated solar thermal will become equal to coal fired generation when the concentrated solar thermal installed capacity is 5000 MW worldwide... targeted to achieve this by 2013.

Some of the most promising current work in Australia is being undertaken by the ANU Solar Thermal Group\textsuperscript{49} and at Sydney University.\textsuperscript{50} And both have been featured in front page news stories recently.\textsuperscript{51} The ABC’s 7.30 Report on October 1\textsuperscript{st} 2007, reported that

Two of America’s biggest power utilities have unveiled plans for a multi-billion dollar expansion of solar power supply. The company at the heart of their strategy is the one started by Australian solar expert David Mills - the former Sydney University professor - who left this country for California earlier this year to pursue the further development of his ground-breaking work. What makes the announcement more significant is that the utilities are confidently predicting that their solar power will soon be providing base-load electricity - that is, day and night - at prices competitive with coal.\textsuperscript{52}

\textsuperscript{48} Ibid
\textsuperscript{52} Ibid.
Global Renewable Energy Resources

Calculations by the World Energy Council\textsuperscript{53} of global renewable energy resources suggest that many countries will be able to technologically have the option to shift most of their electricity supply to renewable forms of energy. Calculations by the World Energy Council show that renewable energy resources significantly exceed that of non-renewable energy resources, stating that, ‘In one hour, the amount of sunlight falling upon the earth is close to the total energy used by the world’s population in one year’ [see Figure 7.3.1].


Figure 7.3.5. Comparison of global energy resources

Source: World Energy Council (2004)\textsuperscript{54}

The Australian Government’s Energy White Paper\textsuperscript{55} has outlined that there are significant renewable resources available and demonstrating this with resource maps\textsuperscript{56} for solar, geothermal, wind and bioenergy) in Australia. The Wind resource map is featured as an example (Figure 7.3.6). Studies show that wind power could provide as much as 20 percent of Australia’s electricity needs.\textsuperscript{57} Opponents of wind power grossly overestimate the amount of landmass this would need. Professor Diesendorf has provided an analysis of the land required for wind power:

To replace the electricity generated by a 1000 megawatt (MW) coal fired power station, with annual average power output of about 850 MW, a group of wind farms with capacity (rated power) of about 2600 MW, located in windy sites, is required. The higher wind capacity allows for the variations in wind power and is taken into account in the economics of wind power. Although this substitution involves a large number of wind turbines (300 turbines, each rated at 2MW), the area of land actually occupied by the wind turbines and access roads is only 5-19 square km depending on wind speeds. Farming continues between the wind turbines. For comparison, the coal fired power station and its open cut coal min occupies typically 50-100 square km.\textsuperscript{58}


\textsuperscript{54} Ibid.


\textsuperscript{56} Ibid, chp 2.


Figure 7.3.6. Map of Australia's wind resources (dark designating areas of strong wind resource.)

Source: The Energy Taskforce (2004)\(^{59}\)

Associate Professor Keith Lovegrove\(^{60}\) has shown that Australia has enough solar resources alone to meet Australia’s electricity needs easily if 138 km by 138 km of land in Australia was covered with 20 percent efficient solar thermal power stations (assuming 20 percent coverage of the 138 km by 138 km land).

Figure 7.3.7. Size of solar thermal power stations to meet Australia’s electricity needs

Source: Lovegrove, K. (2007)\(^{61}\)

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\(^{59}\) Ibid.
\(^{61}\) Ibid.
Australia has significant solar energy resources by any comparison with any country globally.

![Global map of solar resources (KWh/m²)](image)

**Figure 7.3.8.** Global map of solar resources (KWh/m²)

*Source: Lovegrove, K. (2007)*

It is beyond the scope of this project to now be able to provide detailed technical training in the full array of low carbon renewable energy technologies. Students of this package are directed to significant online technical resources for engineers and packages developed by RetScreen International Clean Energy Decision Support Centre and the US Department of Energy’s Energy Efficiency and Renewable Energy website. RetScreen is currently the major global online provider of open source training materials in low carbon renewable energy options. For those wishing to undertake courses to get formally accredited in installing renewable energy systems the Australian Business Council of Sustainable Energy is able to direct you to courses and training on Renewable Energy wherever you are based in Australia. They publish an annual list of such courses available in Australia.

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62 Ibid.
Optional Reading


2. For further reading on biomass, a wealth of general information may be obtained from Bioenergy Australia, website at [www.bioenergyaustralia.org/](http://www.bioenergyaustralia.org/). The international bioenergy collaboration within the International Energy Agency may be accessed via [www.ieabioenergy.com](http://www.ieabioenergy.com). A valuable international journal is *Biomass and Bioenergy*.


Key Words for Searching Online