SUSTAINABLE ENERGY

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Summary

Climate change is a major issue. Energy efficiency, renewable energy, carbon capture & storage ("clean coal"), afforestation and other measures all need to be harnessed to solve the problem. None of these options will prosper without a price on carbon pollution.

Renewable energy comprises many energy forms, including photovoltaics, solar thermal electricity, solar heat, wind, geothermal, bio energy, hydro, ocean energy, solar buildings and clean transport systems. Taken together, renewable energy and energy efficiency can provide most of Australia's energy needs by 2050. Renewable energy and energy efficiency are more job-intensive than coal fired power stations.

Direct solar energy such as photovoltaics and solar thermal, with a resource 1,000 larger than current energy consumption, is the most important of the renewable energy technologies in the long-term.

Baseload power can be met by wide geographical dispersion of collectors, technical diversity (using many different forms of renewable energy), storage (e.g. pumped hydro - pumping water uphill during the day and releasing it through turbines at night) and shifting loads from night time to daytime.

The worldwide solar energy industry is doubling in size every 20 months, and will reach $100 billion per year by about 2011. Wind energy is enjoying similar growth. Australia has real innovative strength in some sectors, notably photovoltaics. Australia can play an important environmental, employment and economic role in this industry.

It is important for Australia to have a balanced portfolio. Increased support is needed for renewable energy and energy efficiency R&D, demonstration, commercialisation and market incentives. The latter could include an extension to the Government's mandatory renewable energy target, carbon pricing and individual technology incentives.

Energy supply options

There are five available energy sources. These are energy from the sun (in its various forms), nuclear energy, fossil energy, tidal energy and geothermal energy.

Solar energy is available on a massive scale. The collection and conversion methods usually (but not always) entail few environmental or social problems. Solar energy includes both direct radiation and indirect forms such as biomass, wind, hydro, ocean thermal, ocean currents and waves. Most of these energy forms will be part of the energy mix when solar energy becomes the dominant traded-energy form.

Tidal energy can be collected using what amounts to a coastal hydroelectric system. It is sustainable in the sense that it will not run out. However, the coastline is a scarce resource and the collection of large amounts of tidal energy will have a major environmental impact.

Geothermal energy has its origins in the decay of radioactive elements within the Earth. Heat associated with volcanic regions can be used to generate steam for district heating or to drive a steam turbine to produce electricity. Another form is "hot dry rocks", which refers to hot masses of slightly radioactive rock buried several kilometres below the surface of the Earth. Cold water can be forced down to this rock, which is then fractured. Steam can be extracted from another borehole nearby. Geothermal energy is restricted to particular geographical locations. It is sustainable in the sense that it can be harvested with limited environmental damage, although the heat stored in a particular place can certainly be depleted.

Nuclear energy from fission has severe problems relating to nuclear weapons proliferation and nuclear terrorism. A country that possesses a nuclear energy industry has the raw materials, the technology and the trained people required for the production of nuclear weapons. Several countries have acquired nuclear weapons technology via the route of civilian nuclear energy. Other problems include waste disposal and reactor accidents. Nuclear fusion is still several decades away from commercial utilisation, but may make a major contribution to sustainable energy supply in the future.

Fossil fuels are the principal cause of the enhanced greenhouse effect and are subject to resource depletion. Other problems include oil spills, oil-related warfare (for example, the Gulf wars) and pollution from acid rain, particulates and photochemical smog.

The enhanced greenhouse effect

There is a consensus among climate scientists that the burning of fossil fuels is causing an enhanced greenhouse effect [IPCC; Climate models]. Consequences over the next 50 years could include:

- significant temperature rises (particularly at high latitudes)
- rising sea temperatures & levels (causing flooding, coastal erosion, damage to coral reefs)
- more frequent extreme weather events (such as floods, storms and drought)
- the need to move agricultural activities and infrastructure to different locations
- an expanded range for tropical diseases and disease vectors
- substantial reduction in biodiversity, and
- more severe bushfire seasons.

It is possible that there will be catastrophes over the next few decades such as positive feedbacks in climate change from large scale release of methane, loss of the Gulf Stream, due to changes in the circulation of the Atlantic Ocean, and destruction of the Amazon rainforest.

Solar Energy Options

Solar energy can eliminate the need for fossil and nuclear fuels over the next 50 years. Some solar energy technologies are more advanced than others. The key to successful mass-utilisation of solar energy is diversity. The solar energy mix will vary from region to region. Unlike fossil fuels, the resource is ubiquitous, which removes questions of monopolisation of energy supply.

Photovoltaics, solar heat and wind energy are the renewable energy technologies that can provide very large quantities of sustainable energy with high (more than 10 per cent) overall efficiency in order to limit land use requirements [Blakers 2000]. These conversion technologies have small environmental impacts and insignificant military or terrorist applications. In some countries biomass may also make a substantial contribution to energy supply, despite low conversion efficiency.

Indirect solar energy: Solar energy in the form of waves, ocean thermal gradients, ocean currents and hydro sources are geographically limited. Hydro energy is usually associated with large environmental impacts arising from the drowning of river valleys and the alteration of river hydrology. These energy forms could contribute substantially in particular regions to an environmentally responsible energy supply.

Biomass energy: Biomass can be derived from waste materials such as sugar cane bagasse, garbage, sawdust and sewerage. Firewood is another common form of biomass energy. When biomass production for energy is combined with other useful purposes the economic viability can be substantially improved. For example, the growth of Eucalyptus Mallee trees in the corridors between fields allows the harvesting of wood by coppicing. The Mallee also serves other purposes including as a windbreak, shade and an ecological corridor. In a country such as Australia, where the population density is low, multiple-purpose energy crops may be viable. In developing countries, where energy use per capita is low, biomass can be a substantial fraction of total energy use.

Unfortunately, the conversion of solar energy into chemical biomass energy has a very low overall efficiency. The conversion of solar energy to chemical energy has an efficiency of less than one per cent, and conversion to electricity has efficiency below 0.5 per cent (which is two orders of magnitude smaller than from photovoltaics, solar heat or wind energy). When used on a very large scale, biomass competes with food and timber production or with ecosystem preservation for the supply of arable land, water, pesticides and fertiliser. The notion that biomass can be grown at low cost on waste land with small environmental impact is incorrect. The use of low quality agricultural land results in low yields and high costs, whether the crop is for food, timber or for energy. Suggestions that genetic engineering can be used to greatly increase the energy conversion efficiency of biomass are far from current reality.

Low temperature solar heat: Good building design, which allows the use of natural solar heat and light, together with good insulation, minimises the requirement for space heating. Solar water heaters are directly competitive with electricity or gas in most parts of the world. Solar concentrator water heaters have been combined with photovoltaic collectors to produce 60–70 per cent efficient hot water & electricity systems.

Wind energy: Modern wind generators have capacities in the multi-megawatt range. They have 40–70 metre high tubular steel towers on a concrete foundation and have three blades, each 20–40 m long. They are computer-controlled and centrally monitored, with many safety features. They have availabilities above 98 per cent and will last more than 20 years. Wind generators alienate less land per unit of energy produced than any other energy source. Most windfarms are located on cleared farming land. Farming activities are scarcely affected, and the wind generators amount to a second cash crop for the farmer. A large fraction of future wind farms will be located offshore to take advantage of higher wind speeds and to avoid land use conflicts. Provided that a windfarm is not located in an ecologically sensitive area, the only significant environmental impact of wind energy is visual.

Wind energy is likely to generate 10-20 per cent of the world's electricity by 2030, and is now regarded as a conventional energy source [DWTA; EWEA]. The industry is growing at a rate of 20-30 per cent per year and has an annual turnover of around A$30 billion per year.

Photovoltaics: Photovoltaics (PV) is an elegant but expensive technology. It has found widespread use in niche markets such as consumer electronics, remote area power supplies and satellites. Large numbers of PV systems are being installed on house roofs in cities. The cost of PV systems is not a strong function of scale, which means that PV systems are often the most economical energy source for small applications. Over 90 per cent of the world photovoltaic market is serviced by crystalline silicon solar cells. This dominance is likely to continue for many years.

The worldwide photovoltaics (PV) industry has been doubling every 20 months for the past 7 years, which is far in excess of the growth rate in energy consumption. In 2006 the value of PV system sales was about $25 billion. Rapid growth in production is causing steady reductions in cost ("learning curve" reductions), which will eventually lead to a true mass-market developing.

The maximum theoretical efficiency of PV is 86%, compared with the current world record efficiency of 43%. Many decades will be required before PV technology approaches theoretical limits, and so the cost of PV systems can be confidently expected to continue to decline for decades – as has happened with the related integrated circuit industry.

Solar thermal electricity: Most solar thermal electricity technologies use mirrors to concentrate sunlight onto a receiver. The resulting heat is ultimately used to generate steam, which passes through a turbine to produce electricity. Two non-concentrating exceptions are solar chimneys and solar ponds. Concentrator methods are equally applicable to concentrating PV systems. The usual ways of concentrating sunlight are point focus concentrators (dishes), line focus concentrators (troughs, both reflective and refractive) and central receivers (heliostats and power towers).

Solar thermal electricity is not yet a commercial proposition. The reason for this is that, unlike PV, there are strong economies of scale. This means that small systems that might be suitable for an individual household are far too expensive. This lack of a niche market, in contrast to PV, inhibits the development of solar thermal electricity in the short to medium term.

The future of high temperature solar thermal might lie in the generation of thermochemicals and in the storage of heat at high temperature to allow for 24 hour power production.

High temperature solar heat: Concentrated solar energy can achieve the same temperatures as fossil and nuclear fuels, either directly (using mirrors) or through the use of chemicals (thermochemicals or bio fuels) created using solar energy. One problem for high temperature solar heat is that heavy industry (e.g. the steel industry) is often located near coalfields, in regions that are relatively poorly endowed with solar energy. Perhaps the next steel mill could be built in the Pilbara region of Western Australia, close to iron ore deposits, rather than on the east coast, close to coal deposits. North west Australia is one of the sunniest places on earth.

Solar heat can be used to extend fossil fuels. For example, if natural gas (CH_4) is heated using a dish concentrator in the presence of steam (H_2O) then hydrogen and carbon monoxide ($3H_2 + CO$) are produced. The energy content of the hydrogen and carbon monoxide is about 30 per cent larger than that of the methane, and so solar energy has been added to the original methane.

Energy efficiency: Hand in hand with the utilisation of solar energy goes energy efficiency. 'Solar energy' and 'energy efficiency' are often the same thing. For example, an energy-efficient building is a building that utilises natural solar light and heat sensibly. Walking rather than driving uses a small amount of solar energy (food) rather than a larger amount of oil energy. A clothesline, solar salt production and putting on extra clothing displaces an electric clothes dryer, fossil-fuel fired kiln drying of salt and gas or electric heating respectively.

Energy issues

Energy "payback" time: The time required to recover the energy investment in solar energy equipment is typically one tenth of the lifetime of the equipment. The energy intensity and cost of solar systems are closely linked. Both are falling. Concentrator and thin-film PV systems, which are the technologies that will dominate after 2010, are likely to have energy payback times of about 1-2 years compared with a system lifetime of 30 years.

Energy Storage and intermittancy: Energy storage issues are not likely to prove to be major obstacles to mass utilisation of solar energy. However, considerable work will be required on storage over the next four decades. Solar energy is generally less dispatchable than energy supply from fossil fuels. However, fossil fuel generation is not completely reliable. The question to be considered is how to ensure that the probability of failure of energy supply in a solar-dominated energy mix is similarly small to that in a fossil fuel dominated energy mix.

Biomass is dispatchable, in the sense that operators of a national grid can choose when to burn the biomass. Hot dry rocks and hydro have similar dispatachability to fossil fuel generators.

There are many options for the storage of low temperature solar heat (for water & space heating) that are simple and cheap. Examples include in building materials, water, crushed rock and phase-change materials. The latter are materials that melt and freeze at a particular temperature (e.g. 31C°). The large amount of heat energy liberated when a material freezes effectively pins the temperature of a house with phase change energy storage near the freezing point of the phase change material.

Another method of solar energy storage is via thermochemistry. One example that is being worked on at the Australian National University is ammonia [CSES]. Ammonia can be disassociated into hydrogen and nitrogen at the focus of a dish solar concentrator system. These gases can be pumped long distances in natural gas pipelines and recombined when convenient to form ammonia and to yield high temperature steam that is suitable for industrial use or electricity generation.

Storage of renewable energy electricity is not a serious issue until penetration of the grid reaches 10-20 per cent. This will not happen (except in a few places) for many years, giving time for improved storage technologies to be developed. A number of storage options are available, including thermochemical energy storage, fly wheels, compressed air and pumped hydro. The latter is a fully commercial technology that involves pumping water uphill to a reservoir during times of low power demand. The water is released through a turbine during periods of high demand. A river is not actually needed, since water can go around the cycle from upper to lower reservoir and return an indefinite number of times. For example, seawater and a some local hills is sufficient.

Wide geographical dispersal minimises storage requirements. If the wind or sun is not available in one region then it might well be available in another region. The use of satellites and other means allows for a high degree of predictability for unavailability of solar or wind energy, which allows alternative generators to be brought on-line.

Technology diversity (the use of a variety of energy conversion technologies) minimises storage requirements. For example, the probability that neither wind energy nor photovoltaic energy will be available at a particular time is lower than the probability that either is not available. The probability is low that a combination of solar, wind, hydro, biomass, geothermal, ocean, tidal and judicious use of fossil fuels cannot meet a particular load.

If one particular renewable energy technology, such as photovoltaics, is a large component of annual energy supply, then the fact that the sun does not shine at night can be accommodated for by shifting loads to daytime where possible (for example by time-of-day energy pricing).

Climate scientists believe that on-going use of fossil fuels at a rate of about 20% of current use is compatible with stabilisation of CO_2 emissions. Reservation of this tranche of energy supply for night time use (when solar is not available) and for peaking (eg from fast-response natural gas) allows considerable flexibility in managing a national grid.

In summary, geographical dispersal, technical diversity, the use of dispatchable technologies such as biomass, hot dry rocks and hydro, energy storage and the judicious use of relatively small quantities of natural gas will allow renewable energy to dominate electricity production while at the same time reducing fossil fuel use by 80%.

Hydrogen: A great deal has been written about the hydrogen economy. Hydrogen is a gas with a very low boiling point (-253° C). There are several technical problems associated with hydrogen, including the difficulty of storage. Hydrogen storage could be by way of compression or liquefaction, or by reversible sorption processes or chemical reactions. Storage for use in cars using methods that could compete economically with petrol or compressed natural gas is a challenging proposition, but is receiving considerable attention.

By far the largest problem is the question of the source of the hydrogen. Hydrogen is currently derived by reacting water with fossil fuels at high temperatures. This produces carbon dioxide and is no more sustainable than any other fossil fuel burning technology. Electricity can be used to split water into hydrogen and oxygen (electrolysis). In principle, the electricity can be from a sustainable solar energy source. Unfortunately, solar electricity is expensive. Electrolysis of water to produce hydrogen entails substantial conversion losses, and conversion of the energy in hydrogen to any form of energy other than heat entails further substantial losses. For example, the round trip efficiency of renewable electricity followed by electrolysis to form hydrogen followed by conversion of hydrogen back to electricity using a fuel cell is less than 50 per cent, which is much lower than other storage techniques. In most cases it is cheaper and more efficient to use the renewable electricity directly. The direct splitting of water under sunlight (e.g. by using titanium dioxide) has formidable technical obstacles, relating to corrosion and very low conversion efficiency, which are far from resolution.

Fuel cells: Fuel cells convert gaseous fuels to electricity without combustion. They have the potential to be considerably more efficient than conventional combustion, particularly in small systems. Substantial technical obstacles still remain. Fuel cells are sometimes claimed to be a renewable energy enabling technology because they could convert hydrogen energy (produced using solar energy) to electricity at relatively high efficiencies. However, there are too many conversion losses in this sequence, which amounts to a storage technology. Other storage technologies are usually cheaper, more efficient and more practical.

Fuel cells may have important applications in saving energy. For example, the use of fuel cells in houses to produce electricity from natural gas, with space & water heating as a by-product, could considerably reduce total greenhouse gas emissions from houses, particularly in cold climates.

Solar energy for transport: Liquid fuels from biomass (eg ethanol) can power vehicles, but only at substantial environmental cost if used on a large scale. The private car in cities can be largely replaced by public transport, which is much more energy efficient than a car and can be powered by renewable electricity. Freight can be shifted to electrically powered trains. Lightweight electric cars are more efficient than current automobiles for city use. It is an open question as to whether significant private motor vehicle ownership can be afforded in an environmentally-constrained world. Imagine India and China having similar car ownership levels to Australia.

Carbon sequestration: The fossil fuel industry is devoting considerable resources to the development of methods of storing carbon dioxide from power stations underground or in the ocean. One method is to separate the carbon dioxide from products of combustion, compress it and pump it into saline aquifers. Current estimates for the cost that 'zero emission coal' electricity might reach over the next decade or two are comparable with estimates for various forms of solar electricity. Carbon sequestration may assist the transition to a greenhouse-neutral energy economy in the period to 2050.

Large scale utilisation of solar energy for electricity production

Photovoltaics, solar heat and wind energy, together with modest contributions from other sources, can reduce consumption of fossil and nuclear fuels by 80% or more. The limited wind energy resources of the world means that wind will probably only contribute about 25% of the world's electricity in the long term.

The efficiency of solar thermal electric and solar photovoltaic energy systems will converge over the next decade to 15-25%. That is, at noon on a sunny day the electricity production will be about 200 Watts per square metre of solar collecting area. Allowance must be made for the fact that the collectors are spaced apart to avoid self-shading and that solar power systems only operate during sunlight hours. Taking these factors and all other losses into account, average power densities (24 hours per day) will be about 10-12 W/m^2 or 100 Gigawatt hours (GWh) per year per square km of land.

The proportion of the Earth's land surface that must be set to provide all of the world's current electricity consumption is about 0.1%, much of it in arid sunny regions. If solar energy also provides solar heat and solar chemicals to replace all fossil fuel use then two to three times as much land would be required. It is clear that land availability is not a constraint on a 100% solar energy future.

Approximately 2,600 km^2 of land (0.035% of Australia's land surface area) would be needed for PV panels to replace all of Australia's electricity from fossil fuels. This assumes that only one third of the land is covered by PV panels (to avoid self-shading). This is a tiny fraction of the area occupied by Australian cities. To put this in perspective, each person in Australia would need to have access to $40m^2$ of PV panel to eliminate the need to burn fossil fuels. An average suburban house block is $500\text{-}1{,}000m^2$. The area of house roof in Australia is sufficient to replace all of Australia's electricity from fossil fuels. Thus the area of land alienated by mass utilisation of solar energy is relatively very small.

In order to achieve carbon neutrality, a panel area of about $30m^2$ would be needed for a 4-5 star (energy rating) house with gas space heating, solar water heating and efficient electrical appliances. With such a panel the house would export as much electricity to the grid during the day as it imports at night. An additional $10m^2$ pf PV panel would be required to offset the greenhouse gas emissions from a modern car travelling 10,000-12,000 km/year. An additional $5m^2$ of PV panel would be required to offset the greenhouse gas emissions from a gas space heating system. A solar water heater of $5m^2$ would complete the solar collector system. The $50m^2$ of roof area required to make a house greenhouse neutral is much smaller than the typical roof area of $150\text{-}200m^2$.

PV and solar thermal energy collection alienates 3-10 times less land than does hydroelectricity per unit of annual energy production (and nil in the case of solar collectors on building roofs). It is comparable to the area of land alienated by fossil and nuclear power stations over their lifetimes, including the power stations themselves and their security perimeters, mines, transport corridors, waste dumps, cooling lakes and other infrastructure. Wind energy alienates very little land per megawatt, with farming operations continuing all around the turbine towers.

Material usage for solar energy conversion is small. The principle elements used in a PV system are extremely abundant on earth: silicon, oxygen, hydrogen, carbon, iron and calcium, with small amounts of other elements also being used. PV technology entails far lower need for mining (a factor of between 100 and 1,000 in the amount of material that is mined per unit of energy produced) than does nuclear or coal energy. Interestingly, for an advanced thin film silicon PV technology such as Sliver, the energy production per kg of silicon over the lifetime of the PV system is the same as the energy production per kg of refined nuclear fuel in a reactor.

Environmental impacts

The area alienated by the towers of a wind farm is less than 1% of the area spanned by the wind farm. Wind farms amount to a second cash crop for the farmer, with farming operations continuing largely unaffected around the towers. Increasingly, windfarms will be offshore and will therefore not alienate any land at all.

Solar water heaters, solar air heaters and photovoltaic solar electric systems located on building roofs alienate no land at all. There is enough roof space on Australian homes to supply all of Australia's electricity from solar energy.

Gram for gram, advanced thin film silicon solar cells produce the same amount of electricity over their lifetime as nuclear fuel rods. Per tonne of mined material, solar and wind energy systems have vastly better lifetime energy yield than either nuclear or fossil energy systems.

The principal elements required for solar and wind energy systems (silicon, oxygen, hydrogen, carbon, sodium, potassium, calcium, aluminium and iron) are among the most abundant on earth. Carbon dioxide emissions per unit of useful energy produced are among the lowest of all energy systems, and continue to decline. Only 0.1% of the world's land surface area would be required to supply all of the world's electricity from solar and wind energy - mostly in arid regions and on building roofs. Solar and wind energy can supply most of the world's energy needs with small environmental cost.

Cost of solar energy

The fact that there is currently no penalty for greenhouse gas emissions means that clean energy technologies have difficulty competing with fossil fuels. When the cost of geosequestration of carbon dioxide is added in to the cost of electricity from fossil fuels, the generation cost will rise to around A$0.07-0.10/kWh, which will cause the retail price of electricity in a low cost country like the USA or Australia to rise by about a quarter.

Wind energy can already compete with the generation cost of "zero emission coal". On current trends, solar thermal electricity and photovoltaics will also compete successfully within 20 years, and perhaps sooner. Low temperature solar thermal energy for water and space heating is already economic in most places. The provision of transport fuel and of high temperature heat for industry are more difficult challenges than the provision of solar electricity and low temperature solar heat. The challenge can be met by a combination of energy conservation and shifting loads to electricity (eg electric cars and trains).

Renewable Energy In Australia

Australia has excellent and diverse solar energy resources by world standards. Australia has a low population density, is one of the sunniest countries in the world and has vast wind resources, particularly along the southern coastline. Since it is a large country with a small population, biomass can make a major contribution. Australia also has large uranium, coal, oil and gas deposits.

The Australian Government has committed large resources to strategic fossil fuel R&D through a variety of mechanisms, including several Cooperative Research Centres, several CSIRO Divisions, the Rio Tinto Foundation, Geoscience Australia and others. Carbon sequestration is a particular focus. Such support is scarcely available to renewable energy. It is highly desirable for the Government to broaden its climate change portfolio to include support on a similar scale for renewable energy.

Photovoltaics and wind energy are likely to be A$100 billion per year industries by 2011. Australian Government policy over the past decade has been less supportive of the renewable energy industry than in comparable countries such as Germany and Japan. Nevertheless, Australia retains a foothold in the renewable energy industry, and silicon photovoltaic cells in particular. BP Solar and Rheem/Solahart have major manufacturing facilities in Australia for photovoltaics and solar water heaters respectively. Several wind energy companies are active in Australia. Two Australian companies (Origin Energy and Solar Systems) are taking new PV technologies to market.

Universities have been powerhouses for renewable energy innovation in Australia. Australian university renewable energy technology is highly valued in international technology markets. In particular, photovoltaics is an area of real Australian research and commercialisation strength. Two universities retain critical mass (more than 10 people engaged in R&D) in the area of solar energy: the Australian National University [CSES] and the University of NSW [KCPVE]. It is important to nurture University-based R&D, both directly for the development of new technologies and to service the research & training needs of a rapidly growing local industry. The new $150 million renewable energy innovation fund is a good start, but will need to greatly expanded over the next few years to be commensurate with the opportunities and the scale of the climate change problem.

The Mandatory Renewable Energy Target of the new Government requires that Australian electricity companies produce an additional 45000-60000 GWh of renewable electricity by 2020. The MRET program is an excellent market support mechanism. In effect, a very small tax per kWh on the vast electricity industry is used to support the nascent renewable energy industry. In order to achieve its potential it is desirable that ambitious MRET targets be set for each year out to 2050. MRET could be expanded to include other low emission technologies, including, importantly, energy efficiency.

Unfortunately other support mechanisms for renewable energy are weak compared with our foreign competitors. In particular, support mechanisms that favour manufacturers based in Australia need to be strengthened. The new $500 million renewable energy innovation fund could provide a significant boost to local manufacturing if the rules are drafted appropriately.

Support for renewable energy in Australia should preferably be focused on IP generation and the export of IP-rich high-value products and services. Australia is not a low cost manufacturing nation. Fortunately, Australia has substantial expertise in several renewable energy technologies, notably photovoltaics, that lend themselves well to such a strategy. This strategy would comprise substantial support for R&D, company-University interaction and professional education in Universities and CSIRO, coupled with strong incentives for companies to manufacture high value products in Australia for export and to license IP overseas.

Future retail cost of electricity in Australia

A typical domestic retail cost of electricity in Australia is 14 c/kWh. Regardless of future carbon pollution pricing, this is likely to increase over time because the cost of carbon fuel is increasing in line with the cost of oil.

Carbon pollution pricing is likely to add 2 c/kWh in the short term and 5 c/kWh in the longer term to the retail price of electricity. The introduction of time-of-day pricing will favour technologies that produce electricity at times of peak demand, which is typically on summer afternoons driven by air conditioning. This is likely to confer a price advantage of 5 c/kWh or more for technologies such as photovoltaics and solar thermal power. Mandatory low emission technology targets for 2020, arising from promises made in the 2007 Federal election, will confer a price advantage of about 5 c/kWh on renewable energy technologies.

Based on the above analysis, photovoltaic systems on house roofs, competing at the retail level, will be a fully competitive option if they can produce electricity for less than 30 c/kWh. This condition is met if the fully installed net cost (after all subsidies) of the photovoltaic system is $5,000 per nominal kW. This calculation assumes an interest/discount rate of 8% (approximating the mortgage rate), a system life of 30 years, replacement of the inverter after 10 years, solar insolation typical of SE Australia, and a system capacity factor of 15% (realistically taking account of losses such as dirty glass, shading from nearby trees and buildings, elevated cell temperature loss, inversion losses and a 1% per year decline in system output as the system ages). Such an installed system cost can be reached with a quite modest subsidy in large scale installation of PV systems; for example installing PV on every house in a new suburb. In the not too distant future no subsidy will be required.

Conclusion

Wind energy, solar thermal and photovoltaics are the only truly large-scale renewable energy generation technologies available. They are each likely to be $100 billion/year industries within 5-8 years. These technologies are relatively free of adverse environmental impacts, and have the potential to dominate the traded energy market over the next 50 years.

It is likely that international concern over the enhanced greenhouse effect will continue to increase. The consequence of this concern will be ever increasing support for solar energy around the world. It is to be hoped that Australian government policies will be such as to place Australian companies in the forefront of this rapidly growing industry.

Dedicated and strategically directed funding of solar energy R&D and research & professional training, together with reliable long-term commercialisation support for Australian-based manufacturing, is required if Australia is to become a major player in this vast new industry.

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