Origin energy

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INQUIRY INTO DEVELOPING AUSTRALIA'S NON-FOSSIL FUEL ENERGY INDUSTRY

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Introduction

Origin has a heritage of over 140 years of operating in Australia and is one of Australia's leading providers of energy and energy related products and services, with significant positions in exploration and production, power generation, retail and trading, as well as investments in and management of distribution networks. Origin has over 3000 employees, supplying natural gas, LPG and electricity to over 3 million customers throughout Australia, New Zealand and the near Pacific.

Origin believes major energy producers and consumers must acknowledge that we are now operating in an environment increasingly constrained in its ability to absorb greenhouse gases without unacceptable environmental impacts. Origin's greenhouse gas emissions, from electricity and gas production, transportation and customer use, represent about 12% of Australia's total energy emissions. Therefore, Origin has adopted a portfolio strategy to deliver energy services to our customers whilst meeting two objectives:

- To reduce the greenhouse gas intensity of our energy production and distribution
- To reduce the greenhouse gas intensity of customers' energy consumption

In order to meet demand and reduce the greenhouse intensity of energy, we believe that a diverse range of technologies must be deployed.

Background

The theme across the global renewable energy sector is consistent: 10 year annual growth rates closer to the realm of the computing and telecommunications industry and consistent cost reductions for each technology at each step in the supply chain. In fact, a factor limiting the more rapid uptake of renewable technologies, particularly wind and solar photovoltaic, are supply side constraints resulting from these unprecedented levels of 30-40% year on year growth respectively. However, it should be noted that much of this growth has occurred in countries/regions where favourable supportive policy has been in place.

Renewable technologies such as wind and solar are often criticised for their inability to meet 'baseload' demand and as such, are dismissed as being unable to satisfy increasing demand growth going forward. The reality, however, is that the electricity demand growth being experienced across most of the developed world is not for 'baseload' power supply, but for intermediate and peak power supply. These can be adequately supplied by wind, solar PV, and other renewable technologies, with variability smoothed with other renewables such as hydro, geothermal and concentrating solar thermal or alternatively, low emission gas fired generation technology. Recent experience with these technologies in countries such as Denmark, Germany and Spain in Europe, and to a lesser extent the United States, have demonstrated that large scale penetration of renewables is achievable.

The large scale penetration of renewables is largely constrained by power network issues. These constraints are technical/engineering in nature only, and relate to the effective network management at higher penetration rates. They do not, however, represent fundamental barriers to the industry since they are largely a function of the nature and age of existing infrastructure that was built for the purpose of accommodating few large stationary power generation sources. A new paradigm is needed for the transmission network of the future, with an ability to accommodate large numbers of small power sources.

In Australia, there is currently a mismatch between sources and markets, particularly for high quality wind, geothermal, wave and tidal, and large scale solar resources (for concentrating

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solar power in particular). Bearing in mind, however, that this mismatch once existed for the oil and gas (for example the Cooper Basin and North West Shelf, to a lesser extent QLD coal seam methane) and coal (for example Leigh Creek Coal in SA, along with QLD coal in the Walloons) resources, before their markets matured and government support enabled their exploitation, the maturation of the renewable energy market, through a combination of government policy support and demand from consumers, will see this issue become incidental. In the near term, the billions of dollars in transmission and distribution network upgrades that are required for Australia, and indeed most parts of the world, present an enormous opportunity to prepare for high volumes of renewable sources of electricity.

In terms of the storage of energy from renewable resources, it cannot be considered as an enabling factor that must be in place prior to their deployment: renewable technologies are already making significant contributions to emissions reductions. On the contrary, efficient storage of electrical or thermal energy represents a challenge and an opportunity for both renewable and conventional power generation facilities. At this stage, pumped storage of water presents the only commercially available and attractive opportunity to address this issue at the scale required for competitive electricity markets. The prospect of a 'hydrogen economy', to in some way ameliorate this issue of storage, is considered both technically and economically questionable, given the enormous cost and efficiency hurdles that must be overcome. Without high efficiency electrolysis or thermolysis the production of hydrogen must be via fossil fuels, which will only increase net emissions given the energy penalty associated with these processes. In addition, the storage and transport of hydrogen is notoriously difficult (high losses and short storage times) and it too carries a large energy penalty.

The following sections outline in detail the relative state of development for the solar, wave, tidal, geothermal and wind sectors, along with examining the role of hydrogen as an energy carrier. The prospects for economically viable electricity generation, storage and transmission are discussed.

Solar

Photovoltaic (PV)
PV technology has a long established history of research and development, commencing primarily with the need for cost effective power generation solutions for extra-terrestrial and remote locations in the 1960's. From its earliest developments, PV as a simple, large-scale and cost-effective stationary generation technology has been the industry's vision. Today, the development of MW scale PV arrays in Europe (Germany, Spain and Portugal), driven by favourable government incentives, has seen this eventuate. In addition, the widespread deployment of PV technology as a distributed power generation source has seen year on year growth of installed capacity reach levels of over 40% the last 5 years, with a compounded annual growth rate of greater than 20% over the last 15 years. Few industries can match these figures.

Historically, the installed price of PV per watt has diminished at approximately 20% for every doubling of cumulative installed capacity. Presently, however, enormous demand for PV driven by favourable government policies such as feed-in tariffs (particularly in Germany) has resulted in rapid increases in PV production facilities and as a consequence, the supply of hyper-pure silicon is currently constrained.

Origin is currently developing a novel silicon based PV technology known as SLIVER® which will ultimately result in cells requiring significantly less silicon compared to conventional PV cells.

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Currently, this technology is at the demonstration stage and we envisage commercial module production within 5 years.

In terms of economics, PV currently produces electricity at approximately 3 to 4 times the retail residential rate in Australia, and given the rapid rate of technical improvements, it is anticipated that in the next 5-10 years flat plate PV may be competitive with grid power. This is greatly assisted by the Government's Photo Voltaic Rebate Programme (PVRP), which now offers up-front subsidy of $8 per watt. There are some locations around the globe however, where high retail electricity rates, combined with low interest loans and a competitive installation market currently render flat plate PV competitive with grid power.

In terms of the necessary enabling factors to achieve grid parity, PV technology is improving at a rapid rate, with more efficient silicon processing, thinner wafers and increasing cell efficiencies continuing to drive down production costs. Production costs (not prices) are expected to fall by over 40% by 2010[1,2]. Key to these reductions are a global effort, on behalf of policy makers, in continuing to support technology development, along with creating market incentives for consumers, and indeed, generation companies, to view PV as a viable alternative.

PV's inherent operational simplicity (there are no moving parts for non-tracking systems), coupled with its peak output ability to match intermediate and peak demand, along with excellent prospects for further cost (and price) reductions, are likely to see PV compete against grid-connected power in Australia between 2015-2030, depending on the amount of solar insolation, the price of electricity and continued government support.

Concentrating PV
In the present environment of tight silicon supply and high prices for PV, the potential for technologies that minimise the use of silicon is an opportunity for Concentrating PV (CPV). CPV involves concentrating solar radiation, using mirrors, onto a small area of high efficiency PV cells. The cells have much higher efficiency than flat plate cells (>40% in laboratory conditions) and are cooled to operate effectively and efficiently.

The advantages of CPV over conventional flat plate PV include higher output per m^2, insensitivity to silicon supply constraints and lower capital cost on a $/W basis. However, there are several disadvantages. CPV must compare/compete with the wholesale price of electricity, not retail rates *cf* PV; it is very sensitive to steel and concrete pricing, with cost reductions only expected under large scale manufacturing regime; there is a need for complex cell cooling (and therefore water requirements); CPV does not operate efficiently under diffuse sunlight.

Australian-based Solar Systems[3] is currently the world leader in commercial CPV installations, having over 1MW installed of off-grid dish concentrator systems in central Australia, while their successful application for Low Emission Technology Development Fund monies will utilise as yet commercially un-proven central tower receiver technology, hoping to achieve manufacturing economies of scale to drive the installed capex to below $3/W by 2012.

As an indication of the industry view of viability, the European Union PV technology platform predicts that by 2020, the installed capex for CPV systems should be approximately €1.5/W,

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[1] Prometheus Institute, PV Technology Performance and Cost, 2006
[2] Photon Consulting, The True Cost of Solar Power: 10Cents/kWh by 2010
[3] www.solarsystems.com.au

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and under €1/W by 2030[4]. This must be balanced, however, with an average capacity factor of between 20% and 30% depending on the insolation levels at the plant's location, resulting in generation costs comparable to today's fossil fuel power stations.

Widespread uptake of CPV by generation companies is dependent on several factors, not least of which is the need to significantly reduce capital costs. While individual components of CPV plants (steel structure, concrete foundations, PV cells) do not have potential to decrease in cost measurably as stand alone components, economies of scale in production (in the MWs) are expected to yield cost reductions. The present lack of operating experience in a competitive electricity market is also a barrier to uptake, and until successfully demonstration in the several MW scale, CPV is unlikely to gain widespread market penetration without capital subsidies or market incentives.

Concentrating Solar thermal Power (CSP)
CSP is a commercially proven technology for the large scale production of power from solar energy. Solar radiation is concentrated by mirrors onto a working fluid (primarily oil, but also molten salt, water and air) which is used to raise steam and generate power via a steam turbine. There are currently over 400MW operational, with the bulk of this installed capacity located in the Mojave Desert of California. After a construction hiatus of over 15 years, principally due to the sustained period of low oil and gas pricing in the 1990's and early 2000's, the first large scale unit was recently commissioned in Arizona while another plant came on-line in Nevada the week beginning 4th of June[5].

Spain is currently the location of the majority of activity in the CSP industry, with a favourable feed-in-tariff (FIT) for CSP of over €180/MWh. There are over 1GW of announced projects, and over 100MW currently under construction. Of the proposed plants, the majority use the parabolic mirror or 'trough' type solar collector common to the US plants, while several of the smaller plants use commercially unproven 'power tower' or central tower receiver arrangement.

While there are several developments in Australia that have gained recent attention, including Solar Heat and Power's Compact Linear Fresnel Reflector (CLFR), Wizard Power's Big Dish and CSIRO's Solar Gas central tower receiver, each of these are unproven at the commercial scale for stand alone power generation, and as such, have market risks in addition to technological risks.

The ability to boost output using natural gas (to meet morning and evening peak demand periods) along with the potential to store the thermal energy for extending operation into the night, render CSP suitable for meeting base and intermediate load demand. In addition, the ability for the thermal energy output from a solar array to complement existing coal and gas fired generation facilities (CCGT or boiler, for example Macquarie Generation's Liddell Power Station) make it a technology that could be used now to increase efficiency at existing fossil fuel fired facilities.

The recently completed 64MW facility in Nevada is predicted to have a long run average generation cost between US$90-130/MWh (excluding thermal storage), while the plants being constructed in Spain, incorporating thermal storage (for 7 hours after the sun has set) are expected to approach US$300/MWh. A paper by the US DOE's National Research Energy

[4] www.eupvplatform.org/
[5] Acciona Solar Power, www.acciona.es

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Laboratory (NREL) in late 2003, predicted that CSP would approach a long run average generation cost of US$50-80/MWh by 2020[6], including thermal storage.

Thermal (Hot Water Heaters)
Origin currently retails solar hot water systems through a multitude of channels, including the Origin Energy Shop. Industry estimates suggest that between 80,000 and 100,000 units will be installed across Australia in the next financial year. The rate of uptake of solar hot water systems is largely being driven by government policy including the ability to create RECs under MRET, and in South Australia and Victoria where either a rain water tank or solar hot water system with is mandated with the construction of new homes. Next financial year's growth, on this basis, is predicted to top 15%.

In terms of technology status, there are a number of well proven technologies competing in the solar thermal space and the ability to retrofit solar thermal into existing gas and electric hot water systems is advantageous in terms of reducing household emission intensity.

Wave

With several proposed commercial projects in the UK and Portugal, wave power is fast approaching a commercial reality in areas with a favourable wave resource, policy support and high wholesale power price. However, there are significant differences in the both the means of harnessing the wave energy and the means of generating electricity, and a good source of literature on these is available from the US Electric Power Research Institute (EPRI)[7]. Of the projects underway in the UK and Portugal, all use the Pelamis Wave Energy Converter, developed by Scottish company Ocean Power Delivery Ltd[8].

A large body of researchers are currently based in Scotland, and the Scottish government have recently announced a Marine Energy Fund, demonstrating over 12 different technologies (including some tidal power technologies). Despite this knowledge base, and natural competitive advantage in the UK, commercial projects have been slow to materialise there. Instead, a favourable feed-in tariff (at €225/MWh) has meant that the bulk of activity is based off the coast of Portugal. By mid 2007, a 2.25MW commercial plant will be operating, with an option to expand to 30MW.

Australian company Oceanlinx (formerly Energetech Australia)[9] has developed a device for harnessing wave energy. Although the company has announced a significant pipeline of projects, demonstration to date has been limited to a pilot scale 0.3MW device at Port Kembla, NSW. The size and super-surface positioning of the Oceanlinx device, however, is likely to make the approvals process for large scale coastal installations difficult and prolonged, given the issues regarding the siting of land-based wind turbines.

The cost of generation from wave energy is contentious at this point. It is expected to be greater than A$300/MWh, although site specific issues such as resource (and capacity factor), along with distance to market (and sub-sea transmission requirements) may see this estimate vary. With the wind sector as a good case study - having reduced power generation costs by 80% since early 1980's - wave power may be competitive with other forms of generation in the next 10-15 years internationally, possibly later in Australia.

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6 NREL www.nrel.gov/csp/pdfs/34440.pdf
7 www.epri.com/oceanenergy/waveenergy.html#briefings
8 www.oceanpd.com/LatestNews/default.html
9 www.oceanlinx.com/

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Yet to be adequately addressed by developers are issues surrounding the environmental and social impact of wave energy devices. How developments in the UK and Portugal proceed will be a good indication of the likely impacts of this technology under Australian conditions.

Tidal

Tidal power remains a relatively un-tapped power generation technology. While the ebb and flow of tides is intermittent, the advantage of utilising tidal flow for power generation is that tide times can be precisely known and output from tidal power stations accurately forecast for specific sites.

There are two distinct sub-sets of tidal power technology: barrage or sub-sea. A substantial body of literature is also available from the EPRI[10]. Globally, there is established experience with commercial scale tidal barrage systems, with the Rance estuary in France home to the largest tidal power station in the world, at 240MW (24 x 10MW turbines - constructed in 1967). While small scale installations have been established in a number of countries, primarily for research purposes, environmental issues associated with the effective damming of a tidal estuary (the effect on estuary turbidity and salinity, along with impact on sediment flow and local fish schools) make it an unfavourable option.

Sub-surface tidal power, however, is not as established as barrage technology and currently there are a number of novel technologies for harnessing tidal power that are in the pre-development stage. A recently announced 1.2MW sub-sea facility planned for the coast of Ireland is predicted to have an installed capacity capital of $8.2M, equating to US$7M/MW. While these systems have significant potential to decrease their capital costs there is no clear technology of choice in terms of predicted lowest cost generation. The economics are likely to compare with wave power systems, although the 'dispatchability' of tidal power, that is, the ability to accurately schedule its output into the electricity market, is likely to be superior. Unfortunately, Australia's premier tidal resource is located in the north west and is far from sizeable electricity markets.

Geothermal

Hydrothermal (conventional)
The hydrothermal-geothermal industry has a current worldwide installed capacity of approximately 9GW, principally in the US, the Philippines and Mexico. New Zealand also has a significant installed base of geothermal generation, contributing over 5% to the total NZ installed capacity. Origin, through its 51% ownership of New Zealand company Contact Energy, is participating in the expansion of the geothermal industry through two proposed power stations of up to 260MW.

For Australia, there is limited opportunity for large scale deployment of conventional geothermal power systems, with the Otway and Great Artesian Basin the only prospective resources with accessible groundwater temperatures in the 90-130°C range respectively. At these temperatures, plant efficiencies are low and result in the requirement of a large numbers of wells to achieve the required thermal flow-rates. These wells are typically as shallow as 500m and extend to as deep as 2km.

[10] www.epri.com/oceanenergy/streamenergy.html

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Being well established, conventional geothermal power systems have little prospect for decreasing costs in the absence of break-throughs with deep drilling technologies. In addition, environmental issues such as the emission of trace sulphur gases, ground subsidence and reduced geyser activity (affecting the tourism industry), along with resource depletion through over-exploitation, are issues that need to be addressed before the full potential of conventional geothermal technology can be realised.

Enhanced Geothermal Systems - EGS
There is currently an Australia wide push to successfully develop large scale Enhanced Geothermal Systems, also referred to as Hot Fractured Rock (HFR) and Hot Dry Rock (HDR) systems. The technological premise behind these systems is simple: drill deep enough into the earth's crust to reach super-heated granite rocks (at around 250°C) and establish a hot reservoir through which a fluid (for example water) is circulated to recover the thermal energy and drive a turbine to generate power.

Research into EGS has occurred since the 1970's, largely concentrated in the United States, but also the United Kingdom, France, Germany and Switzerland. There are currently close to 20 companies developing EGS in Australia, and 4 have already commenced drilling[11]. Only Geodynamics Ltd has confirmed the scale of their resource by drilling deep production wells, while the remaining 3 companies have only shallow drills to date, from which they have extrapolated resource temperature at depth.

Another distinguishing feature of these EGS companies is their reservoir model: Geodynamics aims to use proven granitic fracture stimulation to develop their enhanced reservoirs, while several other industry participants aim to fracture stimulate the sediment that overlies the heat producing granite. While all the demonstration projects to date have use granitic reservoirs, none have successfully demonstrated the 'sediment' fracture stimulation to enhance a reservoir and produce sustained brine circulation. As such, this model is considered higher risk when compared to Geodynamics' approach.

Origin is a cornerstone investor in Geodynamics, whose resource, located in the oil and gas province in the Cooper Basin, is arguably the most favourable in Australia, and possibly the world. Important features that distinguish this resource include the highest temperature gradient measured to date (and heat flux), favourable fracture orientation (for water circulation) and low seismic activity. The hostile drilling environment at over 4km deep, however, has delayed successful completion of a pilot scale power generation plant. Geodynamics hope to have the second of a two-well circulation system established by mid 2007, with first power to grid in 2010 and over 500MW of grid connected plant by 2015, requiring a transmission connection to market of over 500km. Generation costs are estimated at $40-50/MWh for a large scale plant, excluding transmission[12].

Much has been made about the distance of the resource from the grid, but in Origin's view this should not be seen as an intractable problem. Although the distance is significant, building high voltage high capacity transmission connection is far from technically or economically problematic. Geodynamics commissioned Queensland's high voltage grid company, Powerlink, to estimate the cost of connection to the grid, and Powerlink's study estimated that large scale power could be transmitted to the grid for a cost around $5-10/MWh. After including this cost, baseload geothermal energy is very competitive when compared with other low emission technologies.

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[11] Geothermal Energy Group, Annual Report 2006
[12] GDY submission to ERIG (Energy Reform Implementation Group), 1st August, 2006

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Wind

Wind power has emerged as the lowest cost technology of choice for large capacity, grid integrated renewable generation. Since the early 1980's, cumulative installed capacity of wind turbines globally has experienced compounded annual growth rates of close to 30%, to reach an end of 2006 global installed capacity of over 74GW[13]. Again, this is largely as a result of supportive policies. There is broad operational experience and a significant technological base in the wind sector.

The cost of electricity generated from wind turbines has been decreasing at approximately 4% year-on-year Significant reductions have come mainly from decreasing capital costs, but also increasing capacity factors, stemming from an increase in turbine hub height above ground level, giving access to higher velocity and more constant wind streams.

A wide body of literature supports the view that the cost of electricity from wind turbines still has the potential to decrease significantly, as technology improvements, increasing scale, economies of scale with increasing size of manufacturing facilities and the move to off-shore wind sites, all work to increase the annual output for a given turbine[14]. The latter point, the move to off-shore, is unlikely to occur in Australia in the near term, given the availability of a significant wind resource on shore (particularly the Eyre Peninsula in SA, western Victoria and western Tasmania), and the anticipated prolonged development process arising from the concerns of coastal communities.

Renewable Energy Generators Australia (REGA) predict that wind will approach $50-55/MWh long run average cost in 2020[15], while the Australian Wind Energy Association believes that a figure of $35-50/MWh[16] is more likely, making it cost competitive with existing coal fired generation. However, the industry is currently experiencing supply chain constraints driven by surging demand in the US, meaning that prices in the near term are likely to remain relatively constant or even increase. As large scale manufacturing facilities come online around the globe in the next 5 years, particularly in China, this supply constraint will ease and it is believed that the historical relationship between cost and price will re-couple. However, another constraining factor is the availability of good wind sites close to the transmission grid. As the development of the wind energy industry in Australia proceeds, from optimum sites to higher cost sites, the cost of wind energy supplied to the grid will increase. Lower capacity factors and higher connection costs due to distance both have a significant impact on the economics of wind farms.

The ultimate cost of wind in Australia will therefore be a combination of two key factors: lower technology costs from global economies of scale in the equipment, and the higher costs associated with project development costs and lower wind speeds as optimum sites are exhausted.

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[13] Global Wind Energy Council, www.gwec.net

[14] Australian Wind Energy Association, www.auswea.com.au
IEA, Renewables for Power Generation, Status and Prospects, 2003.

[15] Renewable Energy Generators Australia (REGA), Renewable Energy – A contribution to Australia's environmental and economic sustainability, June 2006

[16] Australian Wind Energy Association, www.auswea.com.au Tradewinds, 2004-2005

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Energy Transmission and Storage

This section aims to discuss important advances in both the transmission of energy, as hydrogen and as electrical energy, along with the status and economic outlook for energy storage technologies.

Hydrogen

Hydrogen (as H_2) is not a source of energy - it is not found in appreciable quantities anywhere on earth. It is an energy carrier only, that is, it must be generated to be transmitted. As an energy carrier of the future, the "hydrogen economy" has for some time been predicted to supplant electrical transmission and petroleum products. The most common and cost effective method of generating hydrogen remains natural gas (or other fossil fuel) reformation, although this requires large energy inputs and, with the current price of natural gas in Europe and the US, results in the price of hydrogen being significantly more expensive when compared to natural gas on a dollar per unit of energy basis. This process is also very carbon intensive, and more so when the fossil fuel feedstock is coal.

The concept of the "hydrogen economy" was introduced in the early 1970s by the Institute for Nuclear Energy in Vienna[17], at a time when the future cost of electricity from nuclear power stations was predicted to diminish to the point of being "too cheap to meter". Two routes were proposed to achieve the transition to hydrogen as an energy carrier: electrolysis and thermolysis of water.

Electrolysis is perhaps the most commonly cited method of generating hydrogen, and has been suggested as a means to store electrical energy from 'intermittent' sources of power such as wind turbines or solar energy. This involves the cracking of water, H_2O, into molecular hydrogen and oxygen, to be stored separately for recombination at a later stage via combustion (for example, in a combined cycle gas turbine (CCGT) system) or via fuel cells. Unfortunately, the round trip efficiency (electrical energy in to electrical energy out) of this process in presently very low (~35-50% at the kWe scale) and the theoretical maximum efficiency is predicted to approach 75% depending on the irreversible heat generation[18].

The central idea of thermolysis, or thermo-chemical production of hydrogen, is to generate hydrogen using high temperature nuclear reactors and use the hydrogen to replace fossil fuels for all stationary uses. Thermolysis was the subject of over $40 billion (2003 USD) in research funding (primarily in the US, Europe and Japan) throughout the 1970's and 1980's, with the developers unable to demonstrate that the processes proposed were economically, let alone thermodynamically viable[17].

In addition to the thermodynamic and economic limitations to hydrogen production processes, the inherent difficulty and expense in its transportation (one cannot use existing natural gas pipelines and hydrogen attack of steel is a significant materials problem) and storing (cryogenic storage requires large energy inputs) remain major barriers to widespread up-take of hydrogen as an energy carrier.

Recent proposals to generate hydrogen by reforming natural gas using solar energy (for example, at the CSIRO National Solar Energy Centre (NSEC)), may overcome in part the

[17] Shinnar, Ruel; The hydrogen economy, fuel cells and electric cars. Technology in Society 25 (2003) 455-476

[18] NASA: Round Trip Efficiency of NASA Glenn Regenerative Fuel Cell System, January 2006

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difficulty of producing hydrogen efficiently, but the storage and transport of hydrogen, such that it would replace electrons as the energy carrier of the future, requires an infrastructure development of a scale comparative to the development of the electrical transmission infrastructure in use today.

Electrical transmission

The electrical transmission (and distribution) networks that deliver power to the world's economies are based on a model of development formulated in the 1950's: large centralised power stations, with oversupplied capacity, owned and operated by the state, feeding power into state owned and operated networks providing a subsidised electricity supply service for industry and citizens. Given the age of these assets, all OECD countries are presently facing enormous capital expenditure to modernise, update and expand their electricity networks. In addition, reliability requirements mean that network providers are faced with a heightened need to protect large and critical infrastructure from risks ranging from human error to terrorist attack.

Meeting Demand Growth
Australia's demand for baseload generation is growing slowly, while peak demand has increased rapidly in the past 5 years. This increase in peak demand is predicted to lead to over $24B of investment in transmission and distribution networks over the next 5 years, as some 1300MW of generation facilities are brought on line[19].

This need for expansion and augmentation presents an enormous opportunity to invest in transmission and distribution infrastructure in preparation for greater use of renewables, primarily wind, but also biomass (particularly in Northern QLD) and widespread distribution of PV installations in the near term.

'Intermittent' generation
With the advent of increasing climate change awareness, and legislation in many countries for expanded use of renewables, a primary concern of network providers is the ability of existing infrastructure to cope with high rates of penetration for 'intermittent' sources such as wind power. Given the experiences of Denmark, Germany and Spain, it is believed that wind power can contribute up to 20% of electricity supply on a large network 'without posing serious technical or practical problems'[20]. While the European grid is significantly 'meshed' with a number of inter-connecters throughout the continent, Australia's network is more 'radial' with large load centres transmitting power to end-of-line sites in regional areas. Therefore it remains to be seen the exact quantity of wind generation that Australia's national electricity market (NEM) could technically absorb, although according to AUSWEA it is expected to be in the vicinity of 8GW.

In terms of the predictability of wind generation, European experience indicates that 36 hours ahead is considered sufficient to achieve an accuracy of forecast of 80-90%, and that when forecasting on shorter timeframes, this increases significantly[21]. Given that conventional generation is scheduled into the NEM 24 hours prior to service (with the opportunity to rebid on volume up to 5 minutes before) and the ability to meet peak demand with Open Cycle Gas Turbines (OCGT) that can rapidly come on line, it is not envisaged that 20% supply penetration of wind generation will cause serious issues in Australia.

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[19] Centre for Energy and Environmental Markets (CEEM), UNSW, October 2006
[20] European Wind Energy Association, www.ewea.org Grid Integration Report, Dec 2005
[21] Renewable Energy World, March-April 2007

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Storage

In many respects, the search for storage technology is a solution looking for a problem. Firstly, the NEM does not distinguish between the technologies that supply energy to it; each unit of energy, regardless of its source, is accepted into the grid and priced equally. The NEM therefore does not 'require' wind or other intermittent sources to be baseloaded, although operational issues around grid integrity (as discussed earlier) must be taken into account. Secondly, the NEM already has significant storage capacity. At low demand periods where the price tends to be low, water can be pumped back up hill (in the case of Snowy) or retained up hill (in the case of the Tasmanian system) for generation later. This has driven the relatively low differential between peak and off-peak prices, which dampens the economic viability of any proposed storage system.

Nevertheless, for off grid systems there may be a role for storage systems. These can be classified as storing either electricity, after its generation, or thermal energy prior to conversion to electricity. The former relates to wind, PV and CPV technology, while the later relates primarily to CSP and to a lesser extent geothermal.

The Australian Greenhouse Office (AGO), through its Advanced Electricity Storage Technologies Programme, has published a review of energy storage technologies[22]. It should be stressed that the storage of electricity is not an issue peculiar to renewables - it has also been the focus of research by fossil fuel generators given that storage on a large scale would negate the requirement for capacity overbuild (for spinning reserve). In terms of outlining the state of current research and viable technologies available today, the AGO review should suffice as a source of literature on the subject.

The storage of thermal energy is inherently more efficient than the storage of electricity, as it avoids the conversion of a commodity high in exergy (or energy 'value') at the time of generation to a lower one (heat or chemical) for storage and then back at the time of use. Thermal energy storage is most applicable to CSP and is now entering commercial scale deployment in Spain (see CSP Section). The successful commercial operation of these plants is likely to render CSP with thermal storage a viable and favoured option for meeting intermediate and peak load demand in countries with high direct beam insolation in the next 5 to 10 years.

As previously discussed, the formation of hydrogen via electrolysis, as a means of storing energy from renewable energy sources such as wind, is not thermodynamically favourable, practical, or economically viable. This is due to the poor round trip conversion efficiency, both actual and theoretical maximum, the current inability to efficiently store hydrogen without significant losses, and the high energy and cost penalty associated with the storage and transport of hydrogen for re-combination and generation of electricity at a later stage.

While cost effective energy storage will aid the penetration of renewables into the electricity supply market, the lack thereof does not limit the ability to develop renewable power in the near term. Significant deployment of renewables can be achieved in the absence of cost effective energy storage by a combination of additional fast-start gas (or diesel if off-grid) or hydro, in combination with a well designed and efficient electricity transmission and distribution network. Energy storage is no more an enabling technology for renewable

[22] AGO Website, www.greenhouse.gov.au/renewable/aest/pubs/aest-review.pdf

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technologies than it is for 'conventional' fossil fuel generators and the transmission and distribution networks that transmit their power.

Implications for Policy Makers

There is clearly a wide range of non-fossil fuel technologies, at various stages of their development, which could form part of a low emission-intensive energy mix. The table below summarises the technologies reviewed in this paper, including the enabling factors that will encourage them towards full-scale commercial application.

Table 1: Summary of technology status and economics

Sector	Technology Sub-set	Development Status	Economics (2007)	Economics (2020)	Enabling Factors
Solar	PV	Early-commercial	$10-13/W ~$600/MWh	$3-5/W ~$200/MWh	Production scale, industry consolidation (vertical integration)
	CPV	Early-commercial	$10/W ~$400/MWh	$3/W ~$150/MWh	High efficiency cells, production scale
	Thermal	Early-commercial	NA	NA	Proving commercial scale
	CSP	Early commercial	$3-5/W $150-250/MWh	$1-2/W $70-150/MWh	Production scale, thermal energy storage
Wave		Demonstration	$4-8/W >$400/MWh	$1-2/W ~$100-200/MWh	Production scale, industry consolidation, environmental and community issue management
Tidal		Demonstration	$4-8/W >$400/MWh	$1-2/W ~$100-200/MWh	Production scale, industry consolidation, environmental and community issue management
Geothermal	Hydrothermal	Fully commercial	$3/W $60-90/MWh	NA	Deep drilling capabilities will expand total recoverable reserves
	EGS	Demonstration	$5/W $80/MWh	$3/W $60/MWh	Deep drilling capability, Kalina cycle scale up, economies of scale with drilling, transmission
Wind		Proven commercial	$2/W $70-80/MWh	$1-1.5/W $35-55/MWh	Increasing hub height, industry consolidation, economies of scale, more diverse transmission grid

Source: Origin estimates

The policy question centres on how these technologies should be assisted in their development and their deployment. But it is critical to first establish the policy objective. The interest in non-fossil fuel technologies is based on their ability to provide energy without associated greenhouse gas emissions. Origin would contend that the objective is reducing greenhouse emissions, rather than the development of any specific technology or set of technologies. Origin would also contend, in the line with economic principles, that any given greenhouse reduction amount should be achieved at least cost, for it is the national interest to ensure that the costs of such reduction are kept to a minimum.

Origin is therefore supportive of a carbon price signal, which would be driven by a cap-and-trade emissions trading scheme, as the *primary* deployment mechanism for all technologies

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that can contribute towards this objective. This mechanism unleashes the competitive and innovative forces of the market to find the least cost abatement. Clearly, the strength of this price signal will depend on the level of greenhouse reduction specified for the scheme, and this is the critical question for community (represented by the government) to decide. The more stringent the cap, the fewer greenhouse emissions, but this comes at higher cost.

It is sometimes said that an emissions trading scheme will not drive the deployment of renewable technologies. This contention is somewhat misconceived and based on an assumption that the carbon signal will be weak. At a given carbon price, each of the technologies identified in Table 1 above could be competitive with fossil fuel technologies, which will become more expensive when fossil fuel generators begin to factor the cost of greenhouse emissions into their cost structures. The extent to which a carbon price signal pulls through renewable technologies is therefore a function of the cap or target that is set for the scheme and its impact on electricity prices and the merit order. Once government has decided how much abatement society should be willing to pay for abatement, it would be inconsistent to then say that "more is needed" beyond this level, thus justifying additional intervention in the market. This is supported by the conclusions of the Prime Ministerial Task Group on Emissions Trading. The critical policy mistake to avoid is to duplicate the primary role of an emissions trading scheme with other deployment mechanisms.

It is also sometimes said that other measures, such as a clean energy targets, are required to drive the costs of technologies down over time and ensure that promising technologies proceed smoothly from research to development to deployment. Whilst the policy objective is commendable, clean energy targets, such as MRET, have been shown not to be very good at achieving this policy objective. MRET has been very successful at deploying existing technologies, such as solar hot water and wind, but has not assisted in the development of new technologies such as geothermal and wave.

If, on the other hand, the policy objective is to drive a larger share of renewables in the supply mix and thereby drive Australian renewable industry development, then a clean energy target is appropriate policy. It must be recognised, however, that this policy objective entails a move away from the least cost greenhouse reductions objective. In addition, the current mix of state and federal renewable energy target schemes is clearly a highly inefficient approach. A single, national MRET scheme that encompasses and replaces all of the state-based schemes would create a far more liquid market, provide the renewable industry with far greater certainty and reduce costs for liable parties (retailers) and ultimately consumers. However, the appropriateness of such a scheme over the longer term (in conjunction with emissions trading) is questionable, and would have to be carefully considered in light of the issues discussed above.

Origin believes that there is a role for government in assisting technologies in moving from early stage R&D through to early commercialisation. This view is also supported by the Task Group's report which suggested that revenues from permit auction could be utilised for this purpose.

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