Sustainable electricity generation

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1. Summary

Australia is the 15th largest electricity consumer in the world.

Demand for electricity in Australia continues to grow, and changes in the way we live are driving acceleration in the growth in demand. Traditionally, we have met this rising demand by adding more conventional fossil fuelled power stations to our existing generation base, as Australia is endowed with significant fossil fuel resources at very low cost by world standards.

Environmental issues are beginning to emerge as a key issue for the power consumption and production, with greenhouse gas emissions becoming an area of particular focus in recent years. In response, we can:

1. Reduce our demand for electricity;
2. Look for more efficient ways to use current resources by burning fossil fuels more efficiently; or
3. Look for alternative ways to create electricity.

Sustainable generation has become a particular focus within this last area. There a number of different ways to generate power sustainably that are relevant to Australia, but each faces challenges in the economic, technical and logistical senses (higher cost, less manageable output, limited fuel). Despite this, sustainable generation has a role to play in Australia's energy future.

The long term nature of the greenhouse gas emissions issue and long lives of capital intensive sustainable generation itself lends itself to the skill set of actuaries, who have made some contributions to the energy sector already.

2. Introduction

Much has been made in recent times of the issue of global warming, the effect of greenhouse gas emissions and the large contribution made by the power generation sector. Numerous reports have projected temperature increases this century, changes in rainfall, increases in extreme weather events and rises in sea level as an outcome.

Australia has abundant, low cost fossil fuel resources suitable for power generation, notably coal and lignite, and historically we have taken advantage of these to meet demand for electricity at low cost by international standards. In taking advantage of these resources, however, we have become the highest per capita emitter of greenhouse gases in the world.

We are also fortunate to have access to resource for generation using more sustainable fuels, in particular sunshine, wind, water and biomass. While we have begun to harness some of these resources, development of some others are in their infancy.

This paper examines these resources and the potential to generate electricity from them, including:

- Demand for electricity;
- A review of fossil fuel based generation;
- An introduction to key sustainable generation types;
- An examination of economics, technical and logistical aspects; and
- Potential for sustainable generation.

The paper also identifies areas where actuaries can apply their skill sets to add value to the industry.

3. Background

3.1. Demand for Electricity

3.1.1. Electricity Consumption: Australia in the International context

At 184 terawatt hours (TWh) in 2001, Australia ranks 15th in the world for aggregate electricity consumption, and 11th in consumption per capita. Despite this, we represent only 1.33% of the world total consumption of 13,870 TWh for the same year, well behind the very largest consumers. The top three are:

USA 3,602 TWh;
China 1,312 TWh; and
Japan 964 TWh.

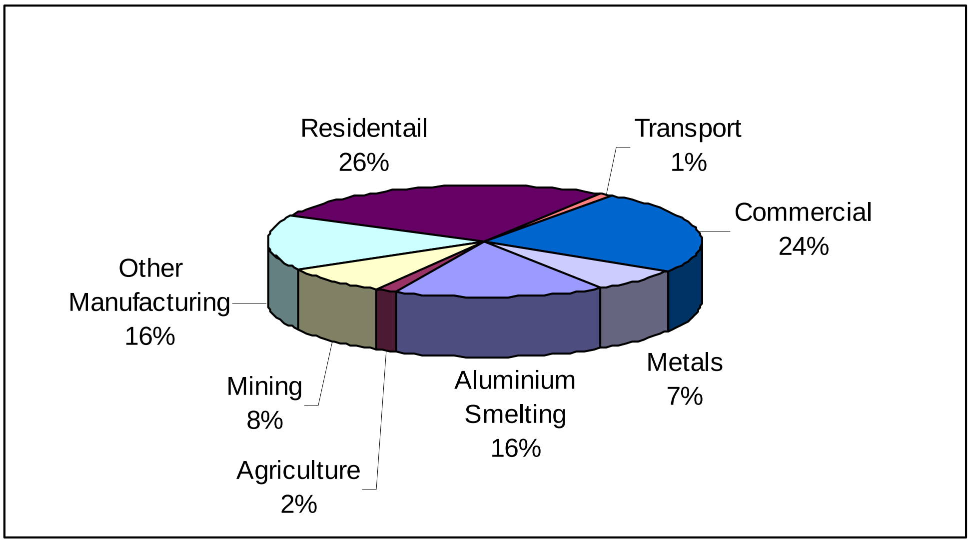
Making up more than 42% of the global total.

3.1.2. Key drivers

Electricity consumption in Australia can generally be regarded as driven by 4 main sectors with their own consumption patterns. These are:

Industry - which is a heavy driver of electricity demand, with energy intensive industries such as aluminium smelters using as much power as a town of half a million people. The Boyne Island smelter in Queensland consumes over 8 TWh pa on its own, more than some small nations. Other manufacturing industries also tend to use large amounts of power, and these drive "baseload' demand - demand that is 24 hour, 7 day - as well as some demands that operate on weekly cycles, with demands on 5, 6 or 7 days each week.
Commerce - drives demand in patterns that match the commercial world – again on weekly cycles, with demands on 5, 6or 7 days each week, typically during the day, and related to use of appliances, lighting heating and cooling.
Small Business - which typically follows the same type of cycles of the Commerce sector, but often without significant heating and cooling loads and often specific to industry (eg a bakery will use power very differently to a cinema complex); and
Domestic - relatively low demand during the day, with evening peaks during meal times and morning peaks as the day begins. For some purposes small business and domestic are grouped together as "mass market".

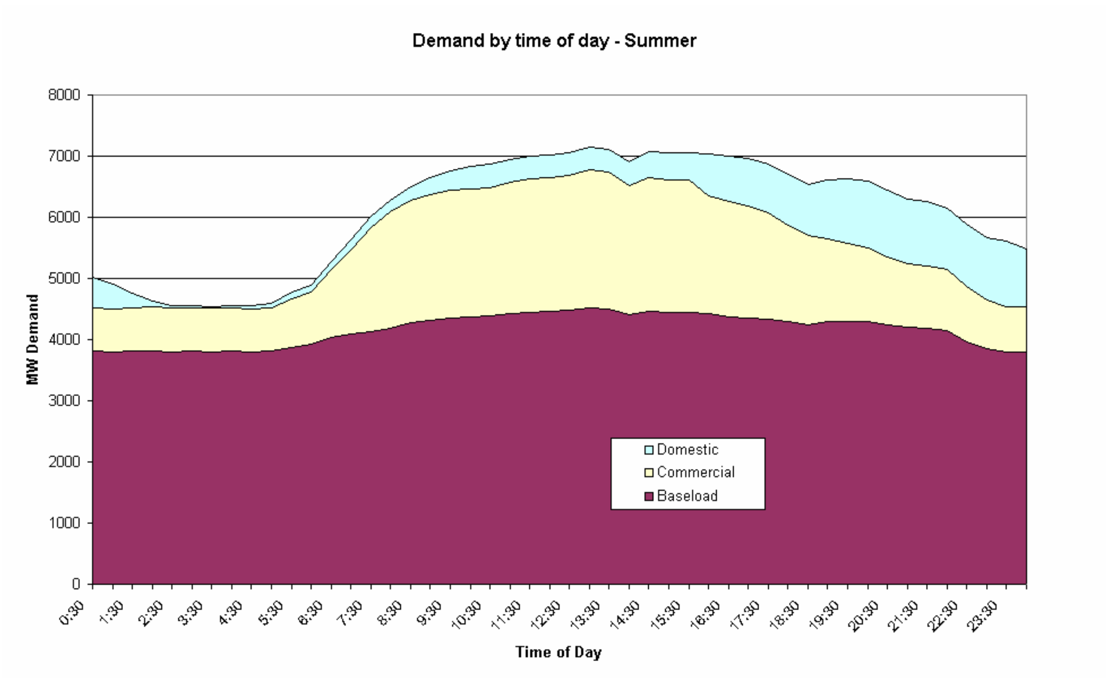
The chart below illustrates electricity use by sector. The industrial sectors (Aluminium Smelting, Metals, Mining, Other Manufacturing) consume 47% of Australia electricity, with commerce and residential using the remainder roughly evenly:



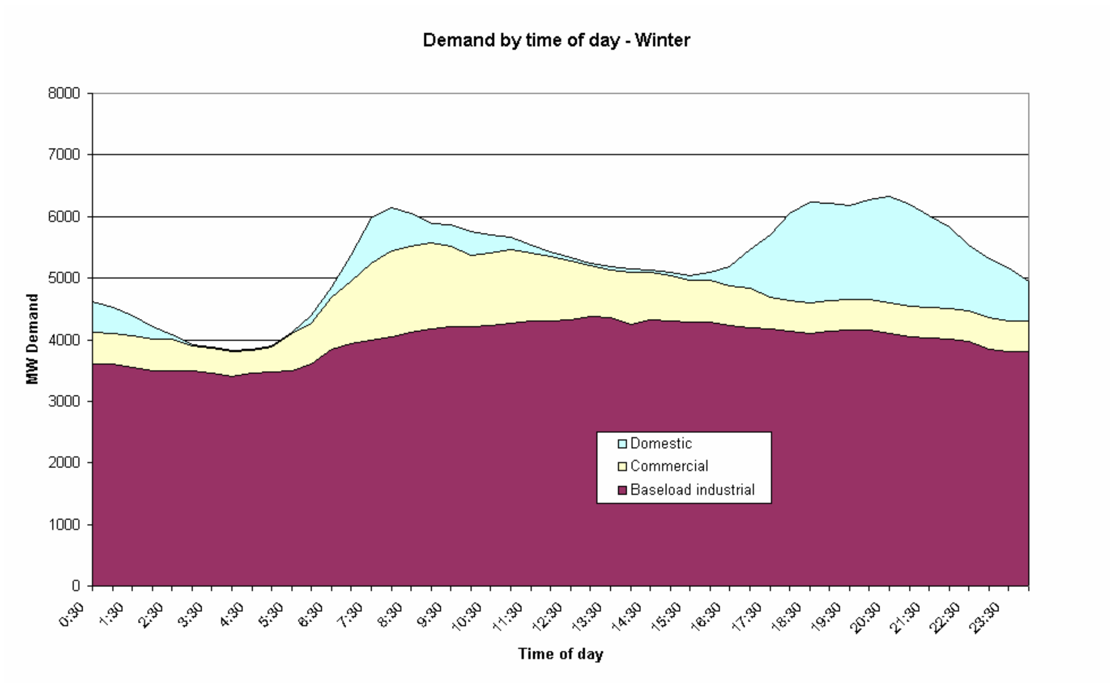
A key issue across most sectors at the present time is the increasing use of airconditioning, which is changing demand rapidly in the domestic sector and to some extent in small business.

3.1.3. Level, time of day, time of year

Demand follows some regular patterns over different time scales, notably daily, weekly and yearly cycles. The charts below show how typical days look in both summer and winter, and how demand cycles through a financial year.

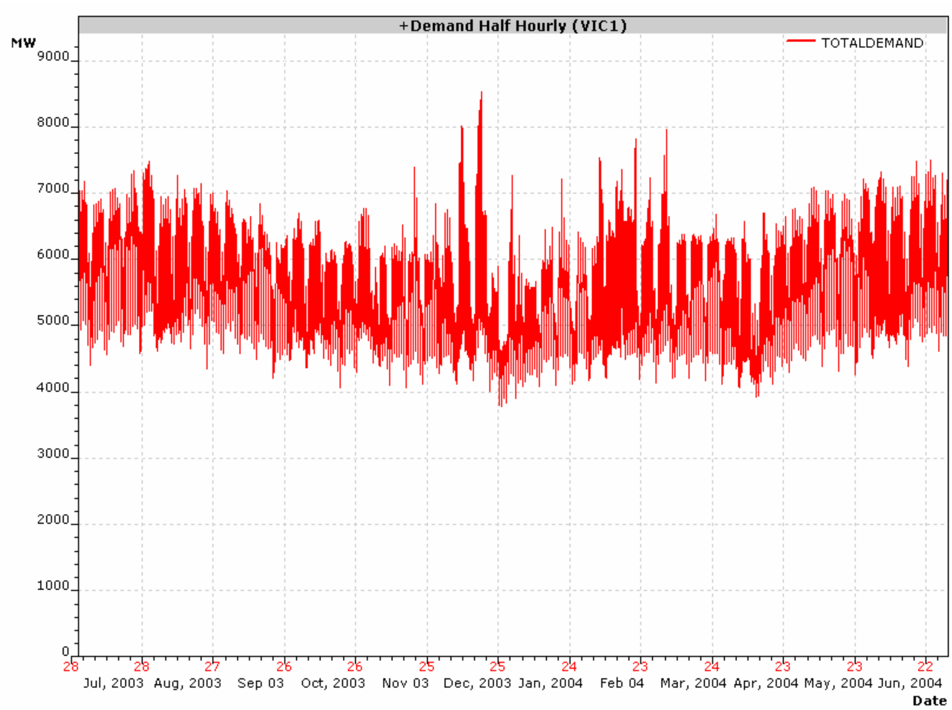


Summer days are characterised by a strong rise in demand during the middle of the day, driven by commercial airconditioning load. In recent times, this daytime peak has been extending well into the evening as domestic airconditioning load increases.



Winter days are characterised more by "twin peaks", where commercial and domestic heating combine to drive the morning peak, and evening peaks are defined by domestic heating and cooking loads.

While not shown, weekend demands lack some commercial and industrial component, and are usually at lower levels, and are relatively lower in the middle of the day due to the cooling element of commercial load being removed.



This annual demand chart for Victoria for the 0304 financial year shows some very high demand days during summer and also a seasonal increase in demand in winter. This type of annual cycle is representative of many electricity systems, although some exhibit their peak loads at different times (eg Tasmania is winter peaking)

3.1.4. In Summary

Demand varies considerably within a day and through the year, even though these variations are reasonably well patterned.

3.1.5. Growth

Demand for electricity has increased almost monotonically over the past two decades. Aggregate demand growth is often linked to changes in GDP at the aggregate level, and as economic activity grows, electricity consumption is expected to continue to increase. By 2020, demand is forecast to be 75% above 2000 levels, with sensitivities showing a growth range of 43 to 103% growth (UPDATE THIS WITH NEW FIGURES from 2003 report if available)

3.2. Meeting demand the traditional way

Demand varies considerably in daily, weekly and seasonal cycles. Supply must meet demand at all times, otherwise physical consequences occur (brownouts, electric motor burnouts). To achieve this match, generation must be flexible and able to be accurately controlled.

This section describes the different roles played by different types of generators.

3.2.1. Baseload

Baseload generators run all the time, often at full capacity. Such generators are typically high capital cost, low operating cost stations. In the Australian context this usually means black or brown coal fired boilers, creating steam which turns a turbine and a generator to create electricity. These units are usually low cost operated this way, but lack the flexibility to change output quickly. Gas fuelled baseload generators are not common at this stage. These units are typically designed with a life of 30 years, although some have run for much longer.

3.2.2. Intermediate

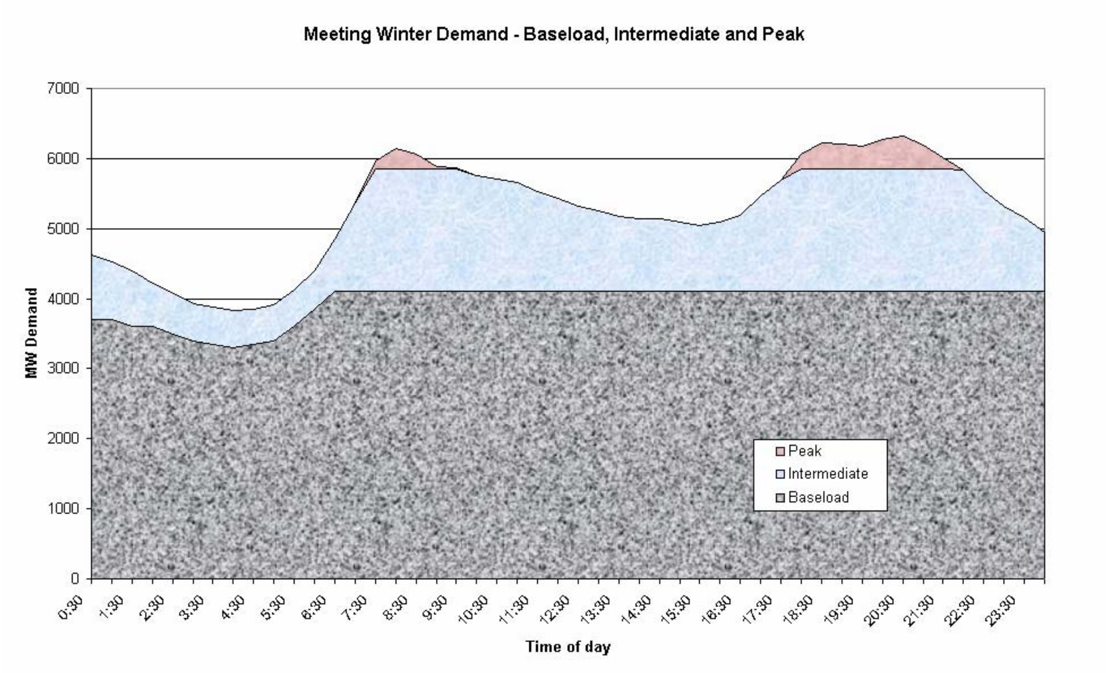
Intermediate class units are usually constantly running (or at least close to constant!), although their output is usually much more flexible and variable than a pure baseload generator. These are often gas fuelled, although some hydro generation in Australian context can be classed as intermediate. These units are often similar or slightly less capital intensive than baseload, but fuel is often more expensive and maintenance is also more costly due to cycling and thermal stressing of components. Asset life is also typically 20+ years for this type of generator.

3.2.3. Peak

Peaking generation cover peak loads at very high demand times and also operate in emergencies, eg when other units are offline. These generators are often run infrequently (less than 5% of the time), and must be able to warm up and start very quickly - typically within 10 minutes. To achieve this, such units are typically fuelled by gas or liquids. Design wise, they are very similar to the engines under the wing of a 747 (although they can be much larger!). While these units are low capital cost, asset life is often shorter than for baseload operations due to high wear and tear of multiple starts over their lifetime, which can be as low as 15 years.

3.2.4. A winter day

The chart below shows how baseload, intermediate and peaking generation might be used to meet demand on a cold winter day, using the same demand profile shown in 3.1.3 above:



3.3. The Australian context of fossil fuel based generation

Electricity Generation in Australia is dominated by fossil fuel generation, particularly black and brown coal. For the 0102 year, generation was made up this way:

Total Generation for the 2001/02 year, GWh

	NSW	Vic	Qld	SA	WA	Tas	NT	Snowy	Australia
Hydro	234	761	413			10,136		3,819	15,634
Black Coal	62,555		45,967		8,957				117,479
Brown Coal		47,944		4204					52,148
Natural Gas	1,023	733	2104	7,127	2,918		1,615		15,520
Liquids			159	1	330	78	65		633
	63,812	49,438	48,643	11,332	12,205	10,214	1,680	3,819	201,144

3.3.1. Coal, coal and more coal

The dominance of coal in generation (about 85% of the total above) is due to its abundance and low cost. At current usage levels, Australia's vast black coal reserves are expected to last more than 200 years, and there is enough brown coal for over 900 years generation. Both types are relatively cheap to mine by world standards, with black coal below $1.00/GJ and brown coal well below 50c/GJ.

Qld and NSW hold major black coal reserves (95% of the Australian total), and Brown coal is concentrated in Victoria with some reserves in SA.

3.3.2. Gas

Australia has 2P (Proven and Probable) natural gas reserves near 110,000 petajoules, about 90 years supply at current usage levels. New discoveries are being added regularly to this total.

While there are large gas reserves off the coast of WA, reserves for power generation primarily come from the Cooper Basin in SW Qld and NE SA, and from the Gippsland basin off eastern Victoria. The Otway basin off SW Vic is beginning to produce commercial quantities of gas which are being used to generate power in SA.

South Australia relies on gas fired electricity generation more than other states due to its limited endowment with commercial quality coal reserves.

Delivered to key gas fired power stations, natural gas generally costs over $3.50/GJ, which makes it hard to compete with coal in the baseload market, despite the lower capital cost of gas fired generators.

3.3.3. Hydroelectricity

Australia boasts two well developed large hydro systems, the Snowy Scheme and the combined Tasmanian system. The Snowy Scheme provides intermediate and peak power to NSW and Victoria (and to Qld and SA by onward connections). Tasmania is not yet connected to the mainland grid, so it currently relies substantially on its hydro system to provide all its power form baseload to peak.

3.4. The National Electricity Market

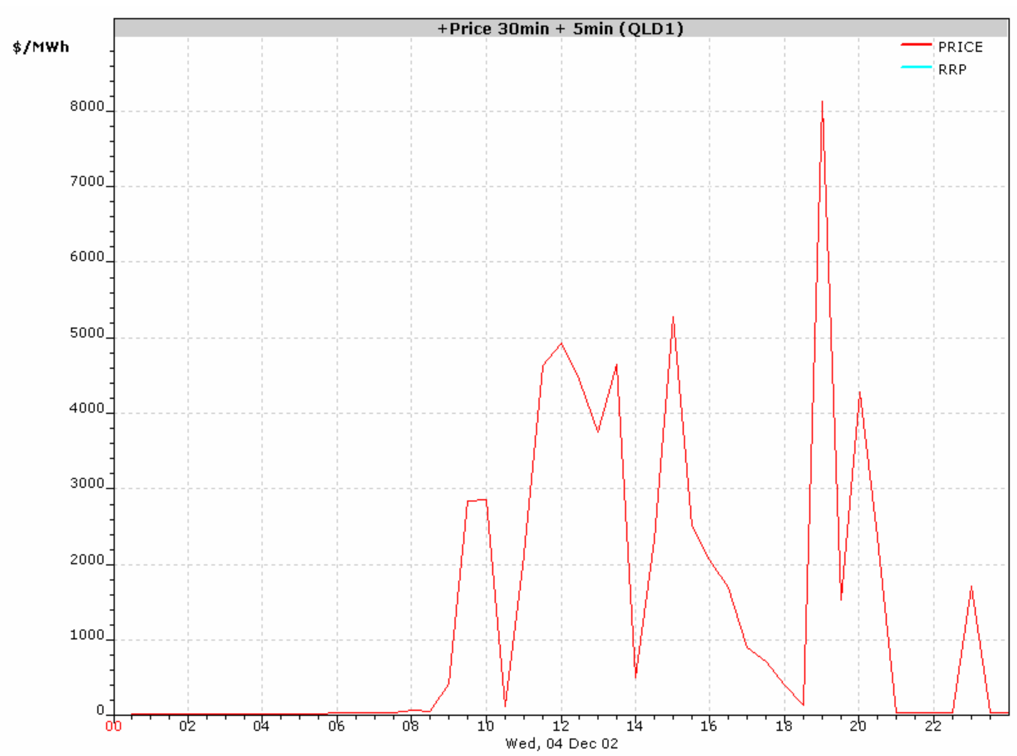
Deregulation of the industry in Australia started in Victoria in 1994, and NSW, SA and Qld followed (with Tasmania to join in 2005), leading to the current National Electricity Market. These regions are all now physically connected (with the Tasmanian link currently under construction). The Northern Territory and Western Australia are too physically distant to be connected to this system.

Physically, the NEM constitutes the longest power grid in the world, spanning from Cooktown in the north to Port Augusta in the south west.

Generators connected to this grid compete within a centrally managed dispatch system every 5 minutes to produce output and contribute to meeting demand. This usually results in generation patterns akin to those shown in 3.2.4 above.

Retailers buy power from this grid to supply customers. For the most part retailers can compete freely for these customers, although competition is not yet open in the mass market segment in Qld.

Because demand must be met instantaneously and electricity cannot be stored, prices can be hugely volatile. The chart below shows Queensland spot prices for December 4 2002:



Price varied between the mid $20's in the early hours of the morning to over $8,000/MWh for the half hour ending 7pm

3.4.1. Derivatives markets

Most market participants prefer more stable cashflow than provided by the spot market, and a reasonably active derivatives market has developed. Derivatives are mainly traded over the counter, but some exchange traded instruments are now transacted.

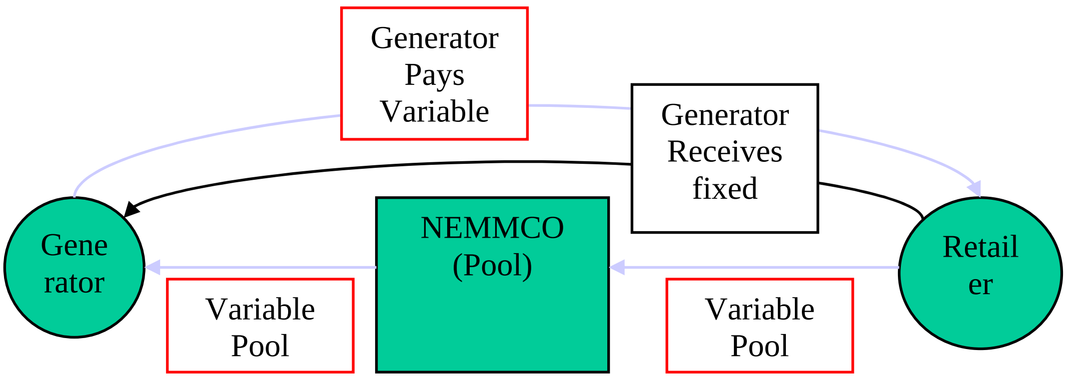
Typical trades would be for:

- All hours (flat)
- Peak (7am to 10pm, weekdays)
- Offpeak (all but peak)

Although a number of non standard transactions are traded directly between counter parties.

Contract durations are typically as short as a month or Quarter, with trades of up to 5 years duration sometimes made particularly to back a single customer load.

The diagram below demonstrates how a swap sold by a generator to a retailer would look, combined with pool payments:



3.4.2. Actuarial Issue 1: 30 year assets, 30 minute settlement

This brief overview of the nature of assets and the nature of the current market raises an issue of actuarial interest: Assets of a 30 year nature receive income based on transactions of durations as short as 30 minutes. This type of duration mismatch and volatility of income over time creates challenges for asset valuation and also for hedge portfolio construction to match a designated risk profile. The actuarial skill set is well established in the field of asset/liability mismatches, and can be applied to these areas.

3.5. Fossil Fuel Economics

3.5.1. Dirt cheap!

Coal fired electricity can be delivered well below $A40/MWh and in some cases below $A30/MWh, which is very low cost by world standards.
Baseload gas fired electricity can also be delivered below $50/MWh, which again is reasonable, but does not compete with coal.

Typical cost makeups and key statistics for new technology coal and gas fired generators are:

	Baseload Black Coal	Baseload Gas
Statistics		
Technology	Supercritical Thermal, Steam Turbine	Combined Cycle Gas Turbine
Capital Cost	$1.4m per MW installed capacity	$0.9m per MW installed capacity
Thermal efficiency	42%	52%
Operating regime	90% of capacity	80% of capacity
Delivered Fuel Price	90c/GJ	$3.50/GJ
Annual Costs, $/MWh		
Capital	18.85	14.10
Fuel	7.70	24.25
Operation and maintenance	3.50	7.00
TOTAL	**30.05**	**45.35**

With regard to Brown coal, this fuel has a higher water content than black coal and takes significantly more effort to burn. It is significantly cheaper to mine, but power station O & M is higher and capital costs are believed to be closer to $2m/MW compared to $1.4m/MW for black coal, giving an all up cost closer to $40/MWh.

3.6. The emerging questions

3.6.1. Finite resources?

Having shown that we have many, many years of fossil fuels available this may seem an unusual issue to address. Whether all the resources quoted above are economic remains unclear - it is certainly known that natural gas from the North west Shelf to Sydney is not close to economic right now. So while the resources are technically vast, they may be much more finite in practical terms. The further issue of usage acceleration may also arise, and reserves may be exhausted at much quicker rates than the "current usage" estimates.

Natural Gas is seen as a fuel of the future in many senses, but primarily because it burns much cleaner than coal giving off less than half the greenhouse gas emissions for the same power output. 110,000 Petajoules seems a large reserve, but to meet the 2001 annual demand for electricity entirely with cutting edge gas fired generation would exhaust these reserves on approximately 40 years rather than 90 years.
Many observers point out that new discoveries are constantly being made, and coal seam derived methane is an enormous untapped resource.
But the question remains: could we run out?

3.6.2. Emissions

Coal burning in particular produces a number of undesirable emissions, including nitrous oxides, sulphur dioxide and particulate emissions of various types. Concerns over these emissions are long standing overseas, and a traded market for Sulphur dioxide was introduced by the Clean Air Act amendments of 1990 in the USA. SO2 emissions have reduced drastically as a result.

Concern remains over particulate emissions, and emission standards for new plant are some 20% of the levels stipulated for plant constructed two decades ago.

3.6.3. What cost CO2?

Greenhouse Gases are now a mainstream issue not just in an environmental context but also in a much broader forum, due to increased acceptance that they are a driver of global warming and climate change. Electricity production is very Carbon Dioxide intensive, as well as producing small amounts of other greenhouse gases such as methane and sulphur dioxide.

While emissions are regarded with concern, they currently have no economic value placed upon them.

Valuing pollution (or clean air) has no natural mechanism. Its effects are believed to be both very long term, and potentially catastrophic, making valuation even more difficult. As most electricity generators are now commercial interests seeking to make an economic return for stakeholders, clean air has not traditionally been considered when making business decisions.

Should CO2 emitters have to pay for the right to do so, non CO2 emitters would gain an advantage. Changes in relative economics are discussed in section 4.7.3.

3.6.4. Actuarial Issue 2: valuing externalities

How is a concept like clean air given an economic value? Global warming is an issue spanning very long time periods, and the effects are unknown and potentially enormous with very uncertain financial impacts. Actuaries have been involved in areas where similar valuation techniques are required, eg catastrophe insurance. There may be a role for Actuaries in partnership with other professionals to add value in this field.

4. Sustainable Generation

4.1. Reducing emissions

Among the drives to generate sustainably, reducing emissions is most prominent. There are other ways to reduce emissions related to power production, which are outlined below.:

4.1.1. Generate with new fuels

Generation is now well proven with non fossil fuels many of which are sustainable. There are four key fuels of this type in Australia:

- Wind;
- Solar;
- Biomass, notably sugar cane waste; and
- Hydroelectricity.

These, as well as some emerging technologies are discussed in the sections below.

4.2. Why?

As discussed above, power generation is now driven by commercial interests as much as it is driven by any need to provide a public good. In Sections 4.5 and 4.6 below, the costs of sustainable generation are outlined and in some instances they are very high. Costs alone cannot drive the need for generating power this way.

4.2.1. Emissions

Reducing Greenhouse gas emissions is a key driver for considering sustainable technologies. Many key sustainable generation technologies emit at very low levels or not at all.

4.2.2. Socially acceptable

Public awareness of the global warming and climate change issues is rising. While generation of all types meets resistance in some quarters (visual amenity, noise, pollution etc), sustainable generation is in general well accepted, even at a premium cost. This is evidenced by evidenced by consumer uptake of "green power" schemes Australia wide. Some sustainable generation sites, particularly wind farms, also have an element of tourist attraction to them.

4.3. Defining sustainable generation

4.3.1. The definition in the Renewable Energy (Electricity) Act

Electricity Retailers in Australia are currently obliged to purchase a small percentage of their electricity from renewable resources, under the Renewable Energy (Electricity) Act. The energy sources classed under the act as renewable are:

(a) hydro;
(b) wind;
(c) solar;
(d) bagasse co-generation;
(e) black liquor;
(f) wood waste;
(g) energy crops;
(h) crop waste;
(i) food and agricultural wet waste;
(j) landfill gas;
(k) municipal solid waste combustion;
(l) sewage gas;
(m) geothermal-aquifer;
(n) tidal;
(o) photovoltaic and photovoltaic Renewable Stand Alone Power Supply systems;
(p) wind and wind hybrid Renewable Stand Alone Power Supply systems;
(q) micro hydro Renewable Stand Alone Power Supply systems;
(r) solar hot water;
(s) co-firing;
(t) wave;
(u) ocean;
(v) fuel cells;
(w) hot dry rocks.

All of these fuel sources can be regarded as sustainable.

Most of these are already represented in the Australian market, although some only on very small scales. The following section gives more detail on the fuels and technologies that have been (or are about to be) taken up in medium to large scale.

4.4. Sustainable Fuels in the Australian context

4.4.1. Biomass: Bagasse

The most significant biomass generation in Australia is based on sugar cane waste: Bagasse. Many Queensland sugar mills have small generators attached, in which bagasse is burned during the sugar cane crushing season in Winter and Spring. Bagasse is essentially free fuel. A further positive is that sugar cane is grown near the high voltage grid in Queensland, making these generators easy to connect. There is also potential for this type of generation in northern NSW.
Bagasse does have two downsides:

- It's energy content is low, comparable to brown coal; and
- Storage is problematic: bagasse can spontaneously combust if stockpiled.

Other biomass projects using different fuels are being actively pursued. Fuels include:

- pine forest waste (SA)
- malee scrub (WA)
- prickly mimosa (NT)

4.4.2. Solar

Australia houses enormous potential for harnessing the sun for generation of electricity and replacing electricity use with other solar powered devices such as hot water systems. On the latter, progress has been made with approximately 300,000 solar hot water systems in use in Australia, and annual sales of approximately 40,000 units pa.
Direct electricity generation from solar power has been less successful, mainly due to high capital costs. Solar power has a major advantage, in that it is produced most abundantly at times when power is needed most: hot sunny days. To this end, the solar cities trial, outlined in the Prime Minister's Energy White Paper earlier this year, is designed to encourage the uptake of such solar generation on a trial basis in Sydney and Adelaide.

An obvious downside of solar generation is that is it intermittent: if its cloudy, less power is generated.

4.4.3. Wind

Power is generated from wind by simply having a turbine turned by a set of blades, which are turned by energy from passing wind. Crucial to economic wind generation is high quality wind resource. These exist abundantly in Tasmania, South Australia and Victoria. In addition, most states have some potential at lower levels.
Very large amounts of wind generation are currently being constructed or planned, with further sites being evaluated. Should all these succeed, many thousands of MW of wind generation will be installed in Australia by the end of the decade.

Wind is perhaps the ultimate clean fuel, with no emissions associated with generation.

The major downside of wind power is its intermittent nature: wind speed and power generation is almost random in nature, which doesn't support the regular demand cycles shown above!

A further issue with wind is that some of the best quality resources or not located near the transmission grid, so delivering power to customers incurs significantly extra cost to provide these connections, making the economics of wind even more confounding.

4.4.4. Hydro

Australia has a number of well developed hydroelectric schemes. The key ones are the Snowy Mountains Scheme and the Tasmanian Scheme, both of which play significant mainstream roles in the Australian system and provide the majority of our sustainable energy at the present time.
A number of smaller schemes exist, including a number of generators in Victoria, and some smaller systems in Queensland and NSW. Beyond these, the potential for large scale hydroelectric developments in Australia seems limited. There are however, a number of small scale hydro developments being operated or planned, usually associated with dam spillways or water release programs.

4.4.5. Hot Dry Rocks

The Hot Dry Rocks concept is a relatively new one that is being actively pursued in the Cooper Basin in north east South Australia. The concept involves drilling two deep wells into a layer of subterranean granite at high temperature. Water is pumped down one well, reaches the granite and turns to steam, and is released up the other well where the steam is used to turn a turbine and generate power.
While the process is unproven at the scale planned in the Cooper Basin, wells are currently being drilled to a depth of 4000m to explore the process. Should this project and others like it be successful, it will provide large scale renewable power with a near zero fuel cost. The main disadvantage with the particular project being pursued is the long distance from any major centre of electricity demand.

4.5. Why not?

4.5.1. It's expensive

The primary issue preventing large scale uptake of sustainable generation types is its cost. As a broad comparison:

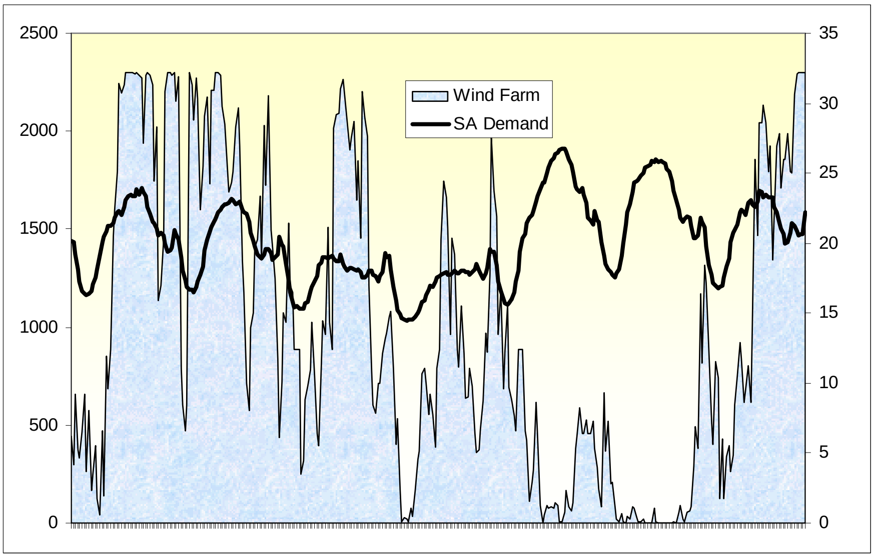
Fuel	Generation cost, $/MWh
Coal	<$40
Natural Gas	$45
Bagasse/Biomass	$67
Wind	$70 to $90
Solar	>$100, sometimes much higher
Hydro	From $40 to over $100

4.5.2. Its finite

Some sustainable fuel sources are finite, and even using them sustainably, the amount of power that can be generated from them is limited. This particularly applies to biomass, where generation relies on wither waste product from another industry, or on crops grown specifically for generation which are available in finite annual amounts.

4.5.3. Its intermittent

Intermittency and control presents a significant problem, particularly for wind and solar generation. In the case of wind, consider 7 days windfarm output compared to 7 days demand for electricity, using the South Australian region as an example:



Wind is clearly intermittent, and further, wind generation output is not easily controlled: note the current Australia system sees large scale generator output centrally controlled through the dispatch and pricing system.

Even with wind making up part of the power system, its intermittent nature presents other challenges, such as where to source generation to fill in the "valleys", the need for such generation to be able to start very quickly, and the associated difficulties in maintaining frequency and voltage at acceptable levels.

Solar power is also not easily controllable, and is intermittent depending on levels of sunshine.

Storage technologies are currently being investigated to smooth out the intermittent nature of these generation types, but at his stage it is only technically viable at small scales, and is prohibitively expensive.

4.6. Economics of sustainable options

4.6.1. What these technologies currently cost

Fossil fuel based options are capital intensive and also have substantial fuel and operations and maintenance components in their cost
Sustainable generation often has zero cost fuel, BUT much higher capital costs, and also has substantial O & M costs.

	Baseload Black Coal	Baseload Gas	Biomass	Wind	Solar*	Hot Dry Rocks**
Annual Costs, $/MWh						
Capital	18.85	14.10	60.00	70	165.00	40.00
Fuel	7.70	24.25	-	-	-	-
Operation and maintenance	3.50	7.00	7.00	7	-	-
TOTAL	**30.05**	**45.35**	**67.00**	**77.00**	**165.00**	**40.00**

* Example, assuming capital cost of $4m/MW installed, and 30% capacity factor.
**Estimated for the geodynamics project in South Australia. Due to large distance from transmission grid, delivered cost expected to be in excess of $60. Note A similar project in Germany has projected an energy cost of $A80 to $100/MWh

4.6.2. Cost changes into the future

Estimates have been made that the cost of these technologies will improve over time, as they mature and increase in scale, to the point that sustainable technologies can compete directly with fossil fuel based generators.

This remains to be proven. It is certainly true that wind generation has become cheaper in Australia in recent years, as technology improves and larger farms allow scale economies in individual equipment orders. It is not yet clear whether manufacturing scale economies can be achieved, as equipment is still substantially imported from overseas, and local production of components has not yet commenced.

4.7. Who pays?

This is perhaps the remaining vexing issue in the sustainable generation debate. If the scale economies mentioned above are not achieved, some form of subsidy will be required to facilitate sustainable generation to allow it to compete. This section discusses these issues.

4.7.1. The whole market is corporatised

Virtually every power generator in the current market is corporatised and many are privately owned. Stakeholder value and returns are a primary objective of being in business. In this environment it is clear that the incentive to generate sustainably needs to be a financial one – either driven by financial incentives or regulatory penalties.

4.7.2. Profits, profits, profits

Not only must generation return a profit, generation with new sustainable technologies is reasonably viewed as more risky than traditional methods, so stakeholder return requirements are commensurately increased for this risk profile. This further biases upwards the level of subsidy required to level the playing field between generator types.

A further complication in the current Australian context is the regulation of transmission connections. If a new power station is constructed, a transmission line is usually built to connect it to the grid at public expense, NOT at a cost to the station involved. For small scale generators and even some medium sized ones, this is not necessarily the case. Recently the ACCC ruled against Electranet (the SA transmission operator) including connections to remote windfarms in its allowed asset base. Rulings such as this significantly bias the system in favour of large scale fossil fuel based generators.

4.7.3. End user will ultimately pay...but how?

The end consumer of electricity must ultimately pay for this higher cost generation. The fundamental questions underlying the issue of higher cost generation and renewables in general are:

What value should be placed on clean air?
At what point, and via what mechanism should be used to allocate the right to pollute (or a consumer right not avoid pollution?)
How is this value distributed through the economy?

The question of how these costs should be recovered is a vexing one, and has been studied in great detail as a separate topic. There are a number of existing mechanisms in both Australia and overseas, and further mechanisms such as carbon tax or emissions permits and trading are being investigated actively in Australia, and are already planned overseas.

Irrespective of mechanism, the table below illustrates three different levels of carbon impost and the effect it would have on cost relativities of different generation types:

	Baseload Black Coal	Baseload Gas	Biomass	Wind	Solar	Hot Dry Rocks
Annual Costs, $/MWh	**30.05**	**45.35**	**67.00**	**77.00**	**165.00**	**40.00**
Carbon intensity kg CO_2e/MWh	0.85	0.35	0	0	0	0
Cost with $10/tonne carbon impost	38.55	48.85	67.00	77.00	165.00	40.00
Cost with $30/tonne carbon impost	55.55	55.85	67.00	77.00	165.00	40.00
Cost with $50/tonne carbon impost	72.55	62.85	67.00	77.00	165.00	40.00

At $50 per tonne, sustainable generation begins to compete not just with baseload coal, but also with baseload gas generation

4.7.4. Actuarial Issue 3: cost allocation and distribution

These issues are economy wide and indeed world wide in their full context. They also extend over long time periods. Both these aspects would require complex modelling with detailed inputs to consider fully, and the actuarial skill set may be a very appropriate one to apply to such questions, again in conjunction with other professionals.

At the individual project level, the decision to invest involves measuring uncertainty and risk over long time horizons. This is another area that lends itself naturally to the actuarial skillset.

5. Other options for Reducing Emissions

5.1. The demand side

Simply using less power can reduce emissions. Improving energy efficiency is something we can do now, and efforts are being made in this area. A number of formal initiatives in place or planned including:

- A proposed requirement for large energy users to report on energy efficiency regularly (included in the recent Government white paper);
- A proposed National Framework For Energy Efficiency;
- Proposed amendments to the Australian Building code in 2005 and 2006 mandating energy efficiency measures in multi residential buildings initially, then all other classes of building; and
- A number of state measures to improve energy efficiency of commercial and residential buildings.

A number of retailers are also active in helping consumers use energy efficiently. This might seem counter intuitive as retailers in other industries would normally want to maximise sales, but as demand increases linearly, cost of supply can increase exponentially - so increased sales can be loss making!

A key impediment to energy efficiency measures is that for those being asked to be more efficient, energy is usually not their primary focus, but simply one of many inputs into their business. Cost savings or penalty avoidance usually have to be demonstrated for measures such as this to be taken up.

5.2. Clean Coal and Carbon Sequestration

A great deal of effort in being made to investigate how we can generate cleaner with current fuels. A key drive for this is the desire to preserve the value held in current energy investments - there are many billions of dollars invested in fossil fuelled power stations. Carbon sequestration - the storage of waste CO2 - has attracted much attention in recent times. Focus was initially on biological sequestration, with large scale forest plantings being considered as a way to absorb CO2.
More recently, geological storage has come into focus. This is the storage of CO2 underground in suitable rock formations. Some small scale operations are currently underway, with the Sliepner operation in Norway currently being the only commercially operational venture of this type in the world, and even this would only reduce Australia's emissions by something like 1%, and we are only a small fraction of the world's power productions and emissions!

It has been suggested that it will be some time – of the order of 20 years – before this type of technology could be demonstrated at the large scale required in Australia. Further, not all areas have suitable underground formations, with NSW and SA identified as states without such geological features. Cost estimates vary widely, and figures well over $100/WMh have been quoted. Note the Sliepner operation in Norway quotes the cost of sequestration at about equal to the 40 British pounds per tonne carbon tax that applies in Norway – of the order of $A100.

New generation technologies are also being investigated to provide the next generation of fossil fuel power stations, which would burn fuel even ore efficiently. Combined with underground CO2 storage, these are viewed in some quarters as holding much promise.

5.3. Nuclear

Nuclear generation has been out of favour world wide, after accidents at Three Mile Island and Chernobyl, and more recently, with discoveries of faults in reactors in Japan. In the UK, the first commercial reactors, built in the 1950's, are being closed and no new reactors were planned to be built.
While a number of new reactors are planned worldwide, Nuclear Power is still forecast to decline in share of electricity production. The Australian government has described nuclear power as "not part of Australia's energy mix" and a "reserve option" only.

As the issue of Greenhouse gases and global warming has risen to prominence, nuclear power, which is emission free, has seen a resurgence of interest as a replacement for fossil fuels. Nuclear generation has its own well known issues, primarily safety and the consequences of a catastrophic failure, and also in the disposal of fuel waste.
There is only one small nuclear reactor facility in Australia at Lucas Heights, which is capable of producing 10MW of electricity.

In other countries where fossil fuels are more expensive, nuclear power competes for baseload supply. In the UK, Nuclear generators can provide baseload power at the equivalent of $A57/MWh, with coal quoted at over $60/MWh. As is shown above in 4.6.1, both coal and even gas give lower cost options in the current Australian context.

5.4. Exotics

A number of more exotic generation options have been proposed which are sustainable and low emission.

Hot Dry Rocks has been discussed above, and Geodynamics are well progressed with drilling activity in their SA operations and have tenancies in NSW as well.

Enviromission has proposed a concept known as the Solar Tower. This operates by heating air under a large glass "skirt" which then moves by convection up a chimney and turns turbines, producing electricity. A 50kW prototype operated in Spain from 1982 to 1987. The proposed Australian tower would produce 200MW of power, and the chimney at the centre would be 1km tall.

6. The Kyoto Protocol

6.1. Australia's target

Australia's overall CO_2e emission target for the first commitment period (2008 to 2012) under the Kyoto protocol would be national emissions of 586.5 Mt CO_2e pa. This is 108% of our 1990 baseline of 543.1Mt CO_2e.
While Australia has not yet signed the protocol and seems unlikely to under the current government, the target has been informally agreed to.

6.2. How we are going

The 2002 National Greenhouse Gas Inventory (NGGI) includes an appendix showing progress since 1990 using Kyoto accounting principles, which differ from those used in the body of the NGGI (which follow the UNEFP accounting method: they key difference is the accounting of land clearing effects).

The 2002 overall emissions level is shown as 550.1Mt CO_2e for the year, which leaves significant headroom under the 586.5Mt target in the 2008/2012 period.

Some lower level trends should be observed to gain a truer picture of progress:

- Emissions from the Energy sector have increased by 29.7% from 286.2Mt in 1990 to 371.4Mt in 2002;
- Land use change and forestry emissions have reduced from 120.4Mt to 29.2Mt, almost completely offsetting the increase in the Energy sector
- If Emissions from Energy continue to grow at this rate, they will grow another 70Mt pa by 2010. If Land use change decreases to nil, the net change is still over 40Mt;
- This will place Australia at 590Mt CO_2e in 2010, ABOVE its Kyoto target. Note that since 2002 two large coal fired power stations have been completed in Queensland at Milmerran and Tarong North, and a further station is planned at Kogan Creek: These three new stations alone will add in the vicinity of 14Mt CO_2e pa.

6.3. Where sustainable generation can fit

In the Kyoto context, the need for sustainable, low emission generation becomes clear. Replacing one large black coal fired power station with sustainable generation could save of the order of 5Mt CO_2e pa of emissions.

As an example, to replace a 500MW baseload coal fired station, 1,000MW to 1,500MW of wind turbines would need to be built, and a similar (slightly higher) amount of solar power would also provide the same amount of energy. This is well within the scope of the level of wind generation already planned in Australia.

Making deep cuts to emission levels using sustainable generation becomes problematic due to scale. To remove 50Mt pa (nearly 10% reduction) would require 10,000 to 15,000MW of wind. This is substantial in a number of ways:

- It requires $20 billion of investment at current capital cost levels
- It would displace existing assets, destroying capital
- Intermittency and control of wind generator output would become a major issue.

7. Can we power Australia Sustainably?

Using the 2001 figures, we have 184 TWh of consumption to supply, which is likely to mean closer to 200TWh of generation, allowing for system losses.

- 200TWh of wind generation would require the construction of 30,000 wind turbines, assuming 2MW each, at a cost of over $100 billion (although scale economies would surely reduce this figure!). Intermittency remains a problem, and large scale energy storage costs have not been factored into this equation at all.
- 200TWh of solar power would cost over $200 billion at current estimated prices (once again scale economies would appear). Once again storage costs have not been allowed for.
- 200TWh of biomass generation at, say, a combustion efficiency of 33% (a heat rate of 11) and an energy content of 8Gj/tonne of fuel would consume 275 million tonnes of biomass every year. This has an advantage over other scenarios in that existing generators could be converted to burn the biomass at lower cost, BUT fuel transport logistics could become formidable.

Each of these scenarios is daunting. Even a combination of all three leaves enormous financial, technical and logistics challenges.

8. Conclusions

Without taking immediate action, Australia's level of CO_2e emissions will rise dramatically. If we accept that this is a genuine environmental issue - and most scientists now do - doing nothing is not an option. Continuing to do what we have always done will increase greenhouse gas emissions rapidly. The power generation sector remains a major contributor to Australia's overall greenhouse gas emissions footprint. Most of these assets are in privatised or at least corporatised hands, where economic return is a key business consideration. Without placing an economic value on emissions, there is no logical incentive for these entities to reduce emissions.

There are a number of things we can do in response: reduce demand, generate cleaner, or generate differently.

While generating differently - and sustainably - cannot resolve the whole emissions issue, it can play a part. Most importantly it can play an immediate part, as the key technologies of wind, biomass, hydro generation are proven and already operating at large scale around the world, and others such as solar power have been demonstrated technically, and simply await scale economies to appear in larger volumes.

Sustainable power generation will play an important part in our future.

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