The Oil Drum: Australia & New Zealand
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Trouble With Energy - Part 2.

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Part 1 can be found here. This series of posts will be co-authored by phoenix, who is an Engineer heavily involved in the energy sector. It will be based on a submission we made recently to the Australian Government. Obviously, projections of this type are difficult. This is an attempt to provide a model for this kind of projection. We then use the model to provide some insights into just how hard the conversion will be for Australia.

How Much Time Do We Have?

Since Australia has one of the largest per capita endowments of energy resources, it is easy to be lulled into a false security that this benefit will last forever. This impression is boosted by quoted production vs. demand figures exceeding 100 years. The reality of our energy security is not so rosy.

As discussed above, most production vs. resource figures are established by assuming a continuation of the current demand or extraction rate. While this may be a reasonable methodology for determination of the life of a mine or the value of the resource it is patently false for determination of our overall resource security. Demand rates for all of our energy resources are climbing year by year.

The paradigm of continually increasing growth driven by an increasing population and an expectation of improving standards of living demands a continuing increase in production of our natural resources. The following table shows Australia's major non renewable energy resources together with their expected life calculated on this basis.

	Coal	Oil(inc all liquids)	Gas	Uranium
Unit	Million Tonnes	Billion Litres	Billion M3	Tonnes
Base Year	2006	2005	2006	2005

Resource	39,600	668	3022	1,143,000
Production	405	42	42	12,360
Growth Rate	4.0%	2.0%	2.1%	4.7%
Life Expected	47 years	14 years	47 years	46 years
Resource Exhausted	2053	2019	2053	2051

Sources: Australian Coal Association

Australian Coal Industry

GeoSciences Australia

BP World Energy

UIC - Australian Uranium and who buys it.

IAEA &OECD-NEA Uranium 2005 Production and Demand

Note 1: All of the above numbers including growth rates have been established from the recognised sources listed above. Long term growth rates have been used and the last two years data excluded from the information as these would have skewed the rates to an even higher level.

Note 2: The quantity of gas resources was increased by a nominal 20,000 PJ to take into account newly identified CSM resources. The exact magnitude of this resource could not be firmly established from published data.

The above calculations take no account of the effects that EROEI will have on net energy recovered. As we approach the bottom of the resource barrel for each of the fuels EROEI will have two effects:

1. The net energy liberated will decrease and the consumption rate will skyrocket.
2. The exponential aspect of EROEI means that once the problem of energy cost of extraction and refining really kicks in there will be very little time remaining for the resource to provide usable net energy.

Of course there will be continual additions to the current proven reserves that will have the potential to extend the above calculated life expectancies. On the other hand the rest of the world does not have the per capita abundance of energy resources that exist in Australia. As the world runs short of energy earlier than Australia, there will be increased
pressure, both economic and strategic, for Australia to increase production to meet this shortfall.

The figures quoted above do not take into account any restriction in fuel use as a result of greenhouse gas limitations. The effect of these limitations on global and even domestic consumption rates is entirely subject to political considerations and therefore very difficult to predict. As a concession to this effect the usage rate and reserves of brown coal has been removed from consideration in this table.

On balance then the above figures therefore represent a reasonable view of the expected life of our non-renewable energy resources in a business as usual scenario.

We have until around 2050 to put in place renewable technologies to provide for our energy needs.

Of particular note is the very short timeframe whereby the entire Australian demand for oil will need to be entirely met by foreign imports. Strategically this represents the greatest challenge. Competing in a global market for a diminishing product will prove very expensive and will in the medium term drive Australia to use a range of conversion technologies to reform coal and gas resources to more valuable liquid forms of energy. This in turn will further decrease the resource life expectancies for these other fuels.

The size of the task

In order to establish the time required to put in place renewable sources for energy supply, it is necessary to make assumptions with regard to the infrastructure that needs to be constructed. This is a very difficult task given that much of the technology is in a developmental phase. Picking winners is not easy and frequently not wise. We can however, by taking an average developmental cost for a range of possible technologies, be fairly confident about the expected developmental and implementation effort and time required.

The following table represents one possible scenario in respect of the conversion of demand from fossil based energy to renewables. The table indicates both a growth in demand up to the year 2050 and the effects in energy efficiency terms of conversion from one form of energy base to an alternate renewable source.

Possible Scenario for conversion of Energy Demand to Renewable Sources

Energy uses (Non-electricity based)	**Current Source**	**Usage PJ/y**	**Growth Rate**	**Usage 2050 PJ/y**	**Renewable Source**	**Conversion Efficiency Gain**	**Usage 2050 PJ/y**
Agriculture	Oil	101	1.2%	164	Biofuels	-33%	218
Mining	Oil	97	2.5%	267	Electricity	60%	107
	Gas	149	2.5%	410	Electricity	10%	369
Industry/Commerce	Oil	179	2.5%	491	Electricity	10%	442
	Gas	464	2.5%	1277	Electricity	10%	1149
Road Transport Personal	Oil	866	0.0%	866	Electricity	60%	346
Road Transport Goods	Oil	297	2.5%	818	Biofuels	-33%	544
					Electricity	70%	123
Public Transport	Oil	28	7.0%	449	Electricity	70%	135
Rail Transport	Oil	26	5.0%	188	Electricity	70%	57
Air Transport	Oil	219	0.0%	219	Biofuels	-33%	292
Water Transport	Oil	55	2.5%	151	Biofuels	-33%	201
Products	Oil	82	2.5%	225	Biofuels	-33%	299
Heating	Oil	5	1.2%	8	Electricity	60%	3
	Gas	187	1.2%	305	Electricity	60%	122
Metal smelting	Coal	264	2.5%	727	Electricity	20%	581
Electrical demand		792	2.5%	2180	Electricity	0%	2180
Sub-total Electricity							5122
Sub-total Biofuels							1553
Total		3809		8745			6675

Notes

1/ The basis of GDP growth has been assumed to be a very modest 2.5% p.a.. This value is below general governmental economic policy. The authors believe that, even this low level of growth is difficult, given the energy constraints that will be place on the Australian and world economies. However, in order for energy policy to be in line with other government policy the 2.5% figure has been retained.

2/ In line with other analysis described in this paper the energy demand forecast has been kept in direct proportion to the projected GDP figures for all industry and commercial based energy uses.

3/ Population related energy uses have been kept in line with Australia's current 1.2% p.a. population increase rate.

4/ In anticipation of the dramatic increases in energy pricing the growth figures for personal transport has been forecast at 0%. As a complimentary allowance the growth in public transport has been increased to 7%. The balance between these growth numbers represents a reasonable transference of energy use between these two categories.

5/ Again in anticipation of the effects of high energy costs the level of air transport growth has been limited to 0% and correspondingly the rate of growth in rail transport has been boosted to 5%.

6/ The efficiency gain nominated for all conversions from oil based fuel to biofuels is a loss of 33%. This represents a nominal loss due to EROEI effects. It assumes an EROEI for future biofuels of around 3. Given the current analysis from the USA on ethanol based biofuels this is very optimistic assumption.

7/ The conversion efficiency for most oil to electricity conversions has been assumed to be 70%. This figure represents a combination of a number of factors including:

- change in mechanical efficiency between electric and Internal combustion engine drives
- losses due to transmission and storage of electricity
- reduction in vehicle weights due to energy cost drivers

8/ No currently viable technology exists for large scale smelting of iron ore using renewable energy sources. The figures for energy efficiency therefore represent a nominal allowance that this technology when developed will be based on electrically derived heat.

Therefore under this scenario to completely replace Australia's energy sources with renewables will require the construction of the appropriate infrastructure to produce:
5,122 PJ or 1,423,000 GWHr of electricity and
1,553 PJ or approximately 47,000 megalitres of biodiesel

The cost of the task

With respect to the electrical demand, our future energy requirements will undoubtedly come from a range of renewable sources. These will include hydro, wind, biomass, solar thermal and solar PV. The table below indicates a possible mix of sources and their respective capital construction costs.

Renewable Electricity Generation

Electricity Generation						
					Capital	
Source	Proportion	Generation	Utilisation	Capacity	Cost	
		GWhr/y		MW	$/kW	$Billion

Hydro	10%	142,281	70%	23,203	3500	81
Wind	30%	426,842	25%	194,905	2500	487
Biomass	20%	284,562	70%	46,406	2500	116
Solar Thermal	30%	426,842	20%	243,631	3000	731
Solar PV	10%	142,281	20%	81,210	5000	406
Total		1,422,808		589,356		1,821

1/ Utilisation factors indicated above should be viewed in the light of the current overall system utilisation of the Australian power generation industry of 56%. This reflects the relationship between the average working generation capacity and that needed to provide a consistent reliable grid supply.

2/ Utilisation factors for Solar Thermal and Solar PV are indicative of current technologies in these respective fields with an overlay of system reliability. While a number of proposals exist for extending the daily range of solar thermal. While these heat storage technologies may enhance the application of solar thermal they will not significantly alter the capital cost per MW delivered.

3/ The utilisation factor attributed to Wind is probably low by current wind farm development standards which aim for an availability of between 30% and 35%. This number has been reduced to reflect the fact that in order to achieve the overall output required, wind-farms will need to be developed at locations not currently considered viable.

4/ Utilisation of both Hydro and Biomass have been kept low to recognise that these two technologies will probably fulfil the role of peaking power plant.

The infrastructure required for provision of biofuels will be a significant challenge, hence the limitation of this fuel source for all uses except where it is irreplaceable because of energy density. The production of biofuels on the scale required is unprecedented. Production of sugar or grain based ethanol for this volume could not be contemplated. It appears that the only viable biofuel at this level of production will be production of algal based biodiesel. Research has indicated that this form of biodiesel production will involve plant capital costs in the region of $8 Million per megalitre of production capacity. The capital cost of the infrastructure to produce 47,000 ML per year will therefore be
approximately $377 Billion.

The total direct cost of revamping Australia's energy production infrastructure will be in the order of $2,200 Billion.

Some points to note in respect to this number:

- Although the cost has been based on a range of assumptions concerning energy technologies, it is unlikely that a different mix of conversions or replacement technologies would greatly affect the bottom line price.
- The figure quoted only represents the major energy production plant required. In parallel with this will be a similar cost associated with the changes made by energy users (i.e. electric vehicles, mining and manufacturing equipment, rail lines, power transmission, etc, etc....)
- The cost assumes a single transition from the current energy production infrastructure to the final renewable infrastructure. This won't happen. As successive governments are

driven by the need to maintain the power on and the fuel tanks full there will be a staged series of interim technologies implemented. Depending on the quality of vision of political and industry leaders these interim technologies could consume as much or more than the cost indicated for the final conversion.

What can we afford to spend?

Total Australian
GDP is currently around $1070 Billion per year. This GDP is growing in real terms at a long term average rate of around 3.5%. A growth rate of 1.2% is required to maintain a stable GDP per capita.

Given the imperative of making the conversion to a renewable energy economy let us look at the outcome if we expend all of the differential GDP growth per capita. This is a considerable commitment involving the expenditure at current values of 2.3% of GDP or $25 billion per year and will mean that Australians are to spend all of the additional wealth we create on this project for as long as it lasts.

Unfortunately this will only complete the conversion task in around 160 years. In fact the conversion will never be achieved because the rate of gain in renewables is lower than the forecast increase in consumption. Clearly, the expenditure required must be re-examined in this light.

Let us assume we expend 5% of the entire Australian GDP on the conversion to renewable energy. This expenditure amounts to $54 Billion (2009 Dollars) per year. At this rate we will complete the task in around 74 years. Unfortunately as indicated in the preceding sections we only have around 38 years of proven reserves of fossil fuel energy remaining in the ground.

It could be argued that the progressive conversion of the fossil fuel based economy to renewables will extend life of known reserves and therefore the time we have for conversion. While this is a valid argument the effect is only marginal. Only 29% of the fossil fuel energy we extract is used for domestic consumption. Thus if we immediately commenced a full scale construction program as indicated above we would only extend the available resources out from 2047 to 2049.

As another approach we could elect to undertake the transition in the period dictated by our remaining fossil fuel reserves. In this case we would need to expend $95 Billion per year or around 9% of GDP to complete the exercise by 2051. For comparison purposes, during the recent mining boom Australia's peak expenditure on all engineering/industrial infrastructure was around $60 Billion per year. The expenditure required on a single industry sector is therefore not possible in any normal economic environment.

There is no net gain in wealth from this expenditure it is simply replacing the energy infrastructure we already have. This expenditure would therefore represent a huge erosion of individual wealth.

Obviously none of the options indicated above is acceptable but they indicate the crisis that Australia faces over the coming few decades and the complete error in the premise that Australia has abundant energy resources.

This post has provided a model for evaluating the cost, time and difficulties associated with a transition to alternate and renewable energy infrastructure. Our next post will apply the model to the International situation. We will then discuss solutions.