11. Innovative Scenarios for Beyond 2040

As discussed in Chapter 1, before the end of the 21st Century, Australia and other rich countries may have to reduce their anthropogenic greenhouse gas emissions by 80% or more. Furthermore, the energy sector, as the principal cause of these emissions, must carry the principal burden of this reduction.

The first step is for Australia to move to an economy where there is no longer any increase in the consumption of materials and energy. Any growth in GDP must be decoupled from these flows. There are examples where this has been achieved partially and temporarily, without a decline in living standards: Denmark enjoyed steady economic growth in the 1980s without growth in stationary energy; China's economy in 1996-1999 grew at over 7% p.a. while reducing greenhouse gas emissions. So, for all scenarios beyond 2040, we assume that the main drivers of energy demand are exhausted: energy intensive industries have peaked; economic structure has shifted further towards the service sector, within which travel has peaked; population has stabilised at around 25 million; and efficient energy use has been further implemented. The result is that energy consumption has been reduced to the 2001 level by 2050.

In our Clean Energy – Scenario 2, the main contributions to stationary energy come from natural gas, biomass, wind power and solar heat at low temperatures. But, in the long run, probably before the end of the 21st century, Australia's reserves of natural gas will become scarce. Biomass energy may have to take on a major role in fuelling transport and would then be making substantial additional demands on land use. Furthermore, wind power above 20 GW of capacity may be reaching the limits of available land.

Therefore, to gain further reductions in CO_2 emissions post-2040, it is essential that, in parallel with the further development of existing commercial technologies -- such as energy efficient appliances, equipment and buildings, wind and biomass -- that innovation is sought in new and existing technologies. To this end, we sketch three scenarios for 2040-2100 that are based on major improvements to existing technologies. In each case we assume that by 2040:

- Scenario 3 (i.e. zero coal-fired electricity) has been implemented;
- population growth has ceased;
- decline in household size has ceased;
- growth in GDP has been almost completely delinked from energy consumption.

First it is necessary to consider a scenario that is unlikely to work in the long term.

11.1 Scenario 5: Geosequestration of CO_2 from distributed sources

This scenario continues with the same energy supply mix as our Scenario 3 discussed in Chapter 10. The only difference is that CO_2 emissions from power stations and other large point sources that produce or burn natural gas or biomass are captured and subject to geosequestration.

Biomass energy produced in an environmentally sound manner should have no net CO_2 emissions, because the emissions produced by combustion are balanced by the CO_2 absorbed during regrowth.[1] So, in theory, geosequestration of emissions from the combustion of biomass produces net emission reduction that can be offset against emissions from fossil fuels in the rest of the energy supply mix.[2]

In practice this would be an expensive scenario, because:

- CO_2 emissions from point sources in NSW would have to be piped 500-700 km to southern Victoria for geosequestration;
- instead of about 25 large centralised power stations, there would be hundreds of smaller natural gas and biomass fuelled, distributed power stations from which to separate the CO_2 emissions and pipe them into a pipeline distribution system that feeds into the main transmission pipelines.

Furthermore, this would only be a temporary solution, because natural gas is expected to become scarce in the second half of C21, especially if LNG exports continue at high levels.

11.2. Scenario 6: Low-cost renewable electricity without additional storage

Electricity

There are several possibilities for generating large quantities of low-cost electricity in the longer term future, which are not restricted by land-use limits. These sources include rooftop and building-integrated photovoltaics, solar thermal electricity and hot-rock geothermal, as discussed in Chapter 7. Here we focus on cheap photovoltaics.

If current R & D on thin film and other innovative solar PV systems is successful, we might obtain modules at US$0.5 per watt, inverters at A$0.5 per peak watt and installation atA$0.5 per peak watt (compare prices in Section 7.5), giving a price of electricity generated on suburban roofs of around 10 c/kWh in Australian currency. This would be competitive with centralised supply in every capital city and so all households with sufficient insolation on roofs or walls could switch to solar.

At first thought, this suggests that all natural gas-fired power stations, apart from cogeneration plants, could be replaced with direct solar. However, there would be times when the skies are overcast and there is little wind. Clearly, in the absence of cheap electricity storage, electricity generation comprising 39% solar and 20% wind cannot be backed up by 33% biomass and 7% stored hydro-electricity, especially since a significant fraction of the biomass would be in the form of cogeneration. In addition, a large amount of peak-load back-up would be required. This could take the form of gas turbines fuelled with (say) biofuels 67% and natural gas 33%. The largest contribution to capacity would be from gas turbines backing up the wind and solar. Although the capacity of these peak-load generators would have to be high, the capacity factor would be low. If this back-up provided (say) 15% of total grid

[1] See Azar et al. (2003). In practice, there will be some CO_2 emissions if the biomass crops are harvested and transported by means of fossil fuels. However, with good system design, these can be kept small.

[2] If there are no fossil fuels in the energy supply mix, then geosequestration of emissions from biomass combustion could be used to reduce the concentration of CO_2 in the atmosphere.

electricity generation, and the 1% petroleum is replaced with biodiesel, the final electricity generation mix would become: 44% biomass, 24% solar, 20% wind, 7% hydro and 5% natural gas. Since electricity demand is postulated to be at the 2001 level, the quantity of biomass used annually for electricity generation would be only slightly greater than that of Scenario 3. In Scenario 6, the only CO_2 emissions from electricity generation would come from the small quantity of natural gas burnt as part of the peak-load back-up, amounting to about 4.1 Mt or 2.3% of the CO_2 emissions from electricity in 2001.

All other energy

Cheap photovoltaics would not be able to reduce emissions from the rest of stationary energy which come from natural gas, petroleum and coal in that order. Most of the 24 Mt of CO_2 emissions from petroleum could be replaced completely with bio-diesel, and this would be encouraged by the high prices of diesel expected in 2040. If the coal used (as coke) in metallurgical processes (about 130 PJ) could be replaced by either charcoal (produced from biomass, see Section 7.1) or hydrogen (produced by electrolysis using renewable electricity), then a further reduction of about 13 Mt CO_2 would be achieved. This would of course require the adoption of different metallurgical processes from blast furnace iron and steel production. The result is that CO_2 emissions from stationary energy that is not electricity are reduced to about 53 Mt (including energy used in oil refining and gas processing to supply natural gas and petroleum fuels for transport), which is a reduction of about 42% compared with 2001 emissions from the same category of stationary energy.

Total stationary energy

Scenario 6 starts with Scenario 3 and replaces most natural gas used for electricity generation with PV and all coal and petroleum for stationary energy with bioenergy or electricity. The net effect on stationary energy is that CO_2 emissions are reduced to 22% of the 2001 level. So, even without the assumption of additional low-cost storage, a reduction of nearly 80% in emissions from stationary energy could be achieved. Even greater reductions would be possible by using solar thermal systems with concentrators to produce both high-temperature heat and electricity.

11.3. Scenario 7: Cheap renewable electricity with cheap storage

As discussed in Sections 7.8 and 7.9, several kinds of storage are possible, for instance:

Advanced batteries with low-cost residential PV systems.

In this case an electricity supply mix of 39% direct solar, 33% biomass, 20% wind, 7% hydro and 1% biofuels is feasible and zero CO_2 emissions could be achieved from electricity generation. Low-cost advanced batteries would make solar energy a ‘dispatchable’ source of electricity, thus increasing its economic value. But, since PV systems do not address the non-electricity part of stationary energy, they are at best a partial solution.

Hydrogen produced by means of the electrolysis of water by low-cost renewable energy.

With low-cost storage the only limitation on total wind power capacity is the availability of sufficiently windy sites. Hydrogen may be converted back into electricity in fuel cells. However, since we can eliminate almost all emissions from electricity generation with low-cost solar and no storage (as in Section 11.2), our main interest in hydrogen is for the production of process heat at high temperature by combustion (substituting for natural gas), as a chemical reductant in metallurgical processes, and for mechanical energy (substituting for petroleum or biodiesel in stationary energy). To satisfy this demand and also to fuel large motor vehicles[3] (trucks and buses), would require substantial production of hydrogen, taking into account the low efficiencies involved. Currently wind power appears to be potentially one of the lowest cost renewable energy sources. To meet the kind of hydrogen demand envisaged here, the development of off-shore sites may be required.[4]

Low-cost, high temperature solar thermal systems with low-cost thermal storage

These technologies would directly address the non-electricity part of stationary energy, as well as electricity. Together with biomass energy, wind power and some hydro-electricity, they would enable a complete elimination of CO_2 emissions from stationary energy. Because thermal storage is potentially much less expensive than electrical storage, this pathway could turn out to be one of the most cost-effective.

11.4. Concluding remarks

Simply by considering some major improvements in a few existing technologies, such as PV or high-temperature solar thermal with thermal storage, it is clear that there are several alternative pathways to 80% (or more) reductions in CO_2 emissions from stationary energy. Furthermore, Scenarios 2 and 3, that led to 50-55% reductions (as discussed in Chapter 10), can form the foundations of Scenarios 6 and 7 which achieve 80-100% reductions. The scenarios take account of limited land area and limited reserves of oil and, in the long term, natural gas. Entirely new technologies do not have to be postulated, although no doubt they will appear, giving us even more choices.

The main conclusion is that Australia should keep open its future energy options by:

- fostering the cleaner, youthful energy industries that form the basis for Scenarios 2 and 3, namely efficient energy use, biomass, wind and solar hot water; and
- expanding R & D support for a small portfolio of technologies that have the capacity to lead us from Scenarios 2 and 3 to a completely clean energy future. Among these are PV, thermal energy storage, high-temperature solar thermal, off-shore wind and further work on gasification and pyrolysis of biomass.

The R & D that is needed is not simply science and engineering, but must also encompass socio-economic, business development and policy aspects, which are most important for implementation. Specific policies and strategies are recommended in the next Chapter.

[3] Hydrogen is less suitable for motor cars because of its low energy density which entails a much larger fuel tank than for liquid petroleum or liquid biofuels, unless there is a substantial improvement in fuel efficiency.

[4] To the best of our knowledge there have been no published studies of Australia's off-shore wind energy potential. However, on the basis of near-coastal ocean depths, the potential is likely to be less than that of Europe.