Hasten slowly into renewable energy

For more than 200 years, modern society has been built on the back of cheap energy taken from the ground. That energy has been used to deliver improved life expectancy, better health care, personal mobility, intellectual opportunity, universal access to information and egalitarianism. In the meantime, and perhaps because of it, we have become dependent on motor vehicles and round-the-clock electricity.

It took the Earth millions of years to develop those stores of high energy density fossil fuels (coal, oil and gas). In the last 150 years, big holes have been made in those fuel stores. For oil, at least, production may soon peak and start to fall. Gas may be in short supply this century and, eventually, coal will meet the same fate. All this at a time of growing energy demand from countries like China and India.

As if this were not concern enough, we are now told that these high carbon fuels are damaging the atmosphere and warming the planet and we need to quickly replace them with other forms of energy. Further, to avoid the same problem happening again, we need these energy sources to be low-carbon and sustainable. This is a Herculean task. We are trying to do in a few decades what the earth took millions of years to do.

All energy sources come from the sun, directly or indirectly. Before man started digging huge quantities of coal out of the ground, energy use was largely sustainable. Populations were much smaller and people burned wood and peat for heating and cooking and there was no mass production. There was some mechanisation in the form of windmills and water wheels and animals or humans to pull ploughs and carts but all these devices sourced their energy indirectly from the sun.

Renewables - wind, moving water, geothermal hot water, solar heating and biomass (burning woody material) - have been sources of energy for millennia. Now we need to leave our fossil fuels behind and go back to renewable energy - from renewables to renewables in 15 generations.

Motor vehicles provide challenges when it comes to sustainable energy. Biofuels (like ethanol and biodiesel) made from plants, are renewable energy that can power motor vehicles. Currently, biofuels provide 1 per cent of all transport fuels and use 1 per cent of all the available arable land worldwide. Even at this relatively low level, they are already blamed for food shortages and are generally recognised as not sustainable.

Hydrogen is another renewable energy that can be used in vehicles but it must be made from low-carbon electricity if it is to reduce greenhouse gas emissions.

A third alternative is electric cars. Whether the vehicles are powered by hydrogen from electricity or electricity directly, replacing oil for transport will significantly increase the demand for electricity. The average family with two cars recharged at home will increase their electricity use by 50 per cent.

Renewable electricity is key to a sustainable energy future. Innovations have proceeded over the last 150 years. In the 19th century, electricity was generated from wind and moving water (hydropower). Electricity from natural geothermal steam was first generated in the early 20th century. In the early 1950s, the photovoltaic (PV) solar cell was developed to generate electricity directly from sun light. Engineered geothermal systems (EGS), sometimes called hot dry rocks, were developed in the 1970s and electricity from concentrated solar power (CSP) using solar thermal energy began commercial generation in the 1980s. Electrical energy has also been harnessed from tides.

These renewable energy sources all have natural cycles varying from decades (geothermal) to seasons (hydropower, biomass) to daily (wind, solar thermal) to hours and minutes (wind, solar PV). Some of these cycles are more predictable than others. We can have a reasonable level of confidence when a dam will have sufficient water to produce hydroelectricity but we cannot be so confident about when the wind will be blowing. This variability makes them less than ideal for every day, round-the-clock electricity supply. The Earth's fossil fuels provide a huge store of energy that is continuously available and, apart from the occasional power plant breakdown, we can be confident about the amount of electricity we can generate at any one time. Until the fuel runs out of course.

Electricity cannot easily be stored in large quantities. This means it has to be generated at the same time as it's used. Mass production has led to 24 hours a day factories that demand large quantities of electricity continuously. We want to turn on the lights or watch TV anytime of day or night. This means that the electricity supply companies have to generate electricity at a certain level, 24 hours a day. In Australia, the minimum supply needed round-the-clock (sometimes referred to as baseload) is about two thirds of the total electricity demand.

How are we to supply this round-the-clock demand using renewable sources that have natural cycles that, in most cases, preclude continuous supply?

This situation is not quite as bleak as it seems. As the sources have different cycles, when one is unavailable another may be available. For example, solar power will not work at night but the wind may be blowing. By using a broad mix of renewable technologies we can reduce the variability problem. Although the wind does not always blow strongly in one location it may be blowing somewhere else. By distributing the wind turbines over a wide geographic area we can smooth out the variations in supply from each turbine. But we can never eliminate the problem completely.

The existing electricity networks in Australia have been designed to handle a relative small number of large coal fired generators, mainly located near the coal mines, with some dispersed gas plants all connected by a large grid on the eastern and southern seaboards and a separate grid in the west. Renewable generators like wind farms will generally produce much less power than a coal plant and be more widely distributed and, as discussed, not always available when needed. This means costly upgrades to the existing electricity infrastructure to interconnect and manage all these disparate, smaller renewable energy generators to improve the chance of getting a continuous, uninterrupted supply of renewable electricity everywhere.

Australia's renewable energy will largely rely on wind and solar power in the short term with some existing hydropower. Even distributing the renewable generators and investing in a more sophisticated electricity network system will not provide the current level of availability of supply that we have grown to expect. With fossil fuels, we are protected against the occasional power station shutdown due to maintenance or unexpected problem by having spare capacity in the network. We can have spare capacity in a renewable network but solar power never works at night and works poorly in very cloudy conditions and wide area wind calms could incapacitate a significant part of the wind supply so our protection against blackouts is substantially reduced.

So how do we deal with this problem if we need to shut down the fossil fuel generators?

We need either gigawatt scale electricity storage or non-renewable reserve capacity. The only proven technology for gigawatt electricity storage is pumped storage where surplus electricity is used to pump water from a large lower reservoir to a higher reservoir. When there is an electricity shortage, the water can be released back into the lower reservoir through a hydroelectric plant. Given Australia's water supply problems, it seems unlikely that we will build more hydro dams or new large pumped storage systems.

The CSP industry is working on ways to achieve the same thing by storing surplus heat to generate electricity during the night or cloudy days. So far only small plants with eight hours of storage have been demonstrated. Both the wind and the CSP industry recognise that they need fossil fuel reserve capacity (preferably gas) to reliably produce baseload electricity. Even with distributed wind farms, the reserve gas capacity may need to be as much as 25 per cent of the power output of the wind farms.

Any transition to renewable electricity will require the continued use of fossil fuels for some time. Technology improvement to renewable energy continues, so the longer the transition takes, the better the outcome for electricity generation if not the environment.

For example, hot dry rocks - where water is pumped into hot underground granite and the steam brought to the surface to produce electricity - is still in the development phase with demonstration plants being built in Australia. It may take a further two decades to bring this technology to maturity but it has the big advantage of low variability (in the order of decades as the hot rocks cool down) and doesn't need electricity storage or fossil fuel backup. It has relatively low land use and environmental impact and could save thousands of wind turbines, CSP mirrors and gas reserve plants. Unfortunately, the hot rocks tend to be in regions well away from the electricity demand (like the Cooper Basin) so extensions are still needed to the grid.

Hasten slowly into renewable energy. The technology has a long way to go and there are other ways of reducing greenhouse gas emissions from electricity generation such as carbon capture and storage and nuclear power. Neither of these technologies are ideal but they could buy us time to get sustainable energy right.

Written by Martin Nicholson and first published in On-line Opinion 26 June 2009