Innovation in energy technology

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This paper is in response to Issues Paper 4 of the Garnaut Review, Research & Development: Low Emissions Energy Technologies.

Summary

1. The Government cannot provide world-scale innovation support for all low emission technologies, and should therefore pick a small number of low emission energy winners. These should be photovoltaics, solar thermal, geothermal and carbon capture & storage.
2. Sustainable energy (photovoltaics, solar thermal, geothermal) should be accorded greater innovation support than fossil fuels, taking into account all investment in CSIRO, Universities, CRCs, Geoscience Australia, tax breaks and similar.
3. Education & training needs to be front and centre of any sensible innovation and industry development policy for sustainable energy because of the current narrow skills base.
4. Solar, geothermal and wind energy have very small environmental impacts compared with fossil and nuclear energy
5. The MRET scheme could be considerably improved by setting aside substantial tranches for technologies with particularly good future prospects.
6. A close examination of forestry and bio energy from the greenhouse emissions point of view is warranted. The associated greenhouse gas emissions have been seriously underestimated.

Energy Options

The available energy options are:

1. Fossil fuels: gas, oil, coal
2. Renewables: photovoltaics (PV), solar thermal electricity (STE), solar heat, wind, wave, bio energy, hydro, ocean energy etc
3. Geothermal
4. Tidal
5. Nuclear: fission and fusion

Of these, many can be excluded as significant sources of energy for Australia within a 20-year time frame:

- The Government has decided not to pursue nuclear fission energy.
- Nuclear fusion is still several decades from technical readiness, and Australia has only a small part in international technology efforts in this area. It may be desirable to join ITER as part of a long term strategy, since fusion power is practically unlimited in terms of fuel supply.
- Tidal energy is limited except in the north west of the continent, and will encounter strong environmental opposition since it amounts to a coastal hydroelectric scheme.

- There is little scope for additional hydro, and other forms of ocean energy are unlikely to provide significant sources of energy for decades.

For the purposes of this paper, renewables and geothermal are grouped together and referred to as sustainable energy (SE), while fossil fuels are referred to as FF. This leaves the following as potential low emission energy sources for Australia:

- Fossil fuels (FF): gas, oil, coal with carbon capture & storage (CCS)
- Sustainable energy (SE): PV, STE, solar heat, wind, wave, bio energy, geothermal

Incumbency advantage for fossil fuel

Fossil fuels dominate traded energy production in Australia. There is a large investment in support mechanisms for FF. Provision of innovation and related government assistance (including exploration) comes from four CSIRO divisions, several CRCs, Geoscience Australia, Rio Tinto Foundation, NCRIS, University Departments, tax breaks etc. This far exceeds the equivalent support available for SE. Creating a "level playing field" now, and avoiding "picking winners", will actually pick winners, by locking in the past – fossil fuel. For example, providing Government support on a $ for $ basis with industry will favour FF because that industry is far larger and better financed than SE and has the support of the organisations mentioned above.

Recommendation: Ensure that SE technologies receive at least half of Government innovation and related assistance. This means that support for SE must be enormously increased.

Education and training

The SE industry is very small, but will need to grow very rapidly to supply 20% of Australia's electricity by 2020. The current skill base is far too narrow to service a large industry. A large and sustained investment in education and training will be required at every level: school, TAFE, University undergraduate, PhD. The UMPNER report into the nuclear industry arrived at a corresponding conclusion.

Recommendation: Education & training needs to be front and centre of any sensible innovation and industry development policy for sustainable energy.

Environmental impacts

It is important to favour investment in energy technologies that are truly large scale and truly sustainable in the very long term. Solar, geothermal and wind energy have very small environmental impacts compared with fossil and nuclear energy.

Solar water heaters, solar air heaters and photovoltaic solar electric systems located on building roofs alienate no land at all. There is enough roof space on Australian homes to supply all of Australia's electricity from solar energy. Gram for gram, advanced thin film silicon solar cells produce the same amount of electricity over their lifetime as nuclear fuel rods. Only 0.1% of the world's land surface area would be required to supply all of the world's electricity from solar, geothermal and wind energy - mostly in arid regions and on building roofs.

The area alienated by the towers of a wind farm is less than 1% of the area spanned by the wind farm. Wind farms amount to a second cash crop for the farmer, with farming operations continuing largely unaffected around the towers. Increasingly, windfarms will be offshore and will therefore not alienate any land at all.

Per tonne of mined material, solar, geothermal and wind energy systems have 100-fold larger lifetime energy yield than either nuclear or fossil energy systems. The principal elements required for solar, geothermal and wind energy systems (silicon, oxygen, hydrogen, carbon, sodium, potassium, calcium, aluminium and iron) are among the most abundant on earth. Carbon dioxide emissions per unit of useful energy produced are among the lowest of all energy systems, and continue to decline. Solar, geothermal and wind energy can supply most of the world's energy needs with small environmental cost.

Picking winners for the provision of Government innovation support

Australia is fortunate in having excellent solar, wind, wave and geothermal resources, and a low population density (which aids the use of bio energy). However, Australia has a relatively small economy. The Australian Government cannot sensibly invest heavily in innovation in all of the sustainable energy technologies. Choices have to be made.

However, it is also important that there are mechanisms in place to ensure that "winners" that turn out to be losers in the future can be discarded. For example, FF (without CCS) was a "winner" that is now a loser. Its incumbency advantage has allowed the FF ship to sail on for many years past the date at which Australia should have been investing in alternatives.

Objective metrics for picking winners include:

- Sufficient Australian resource to realistically supply >20% of Australia's energy
- Very low environmental impact, and sustainable in the long term
- Australia has a realistic chance to generate valuable IP, which can be used to displace imported products, or exported as manufactured goods, or exported as protected IP. In this way there is potential for a commercial return on the Government's investment.

On this basis, PV, solar thermal and geothermal emerge as winners. These technologies have enormous and sustainable resource bases, low environmental impact and the opportunity for IP generation.

Australia is well behind the game in wind and wave energy technology. However, wind will be a major energy technology in Australia because of its low cost and our large wind resource.

Bio energy, when used on a large scale, has major environmental impacts as outlined below.

The R, D, D and C continuum

Sustained, large scale and reliable Government support is required throughout the R, D, D and C continuum for sustainable energy innovation. The elements are in place - it is not necessary to "invent" new methods of providing Government support. However, the scale will need to be greatly enhanced over the next 5 years.

Basic and applied R&D

Basic research is supported by the Australian Research Council. However, typical grant size is $0.5 million over 4 years, and the success rate is about 20%. It is difficult to run a coherent program on this basis.

Several internationally competitive sustainable Energy Research Institutes, each funded with $25-50 million per year, should be established. These Institutes should be built around groups with excellent R&D track records in sustainable energy, as attesting to by objective metrics: numbers of published papers, citations of papers, patents, grants, commercial research income, royalty earnings, commercialisations, prizes & awards, numbers of PhD students, referee reports from international experts. Large Institutes gather critical mass of staff and facilities, which is important for the complete innovation cycle. The Board of the Institute, and its Key Performance Indicators, should be such as to encourage work throughout the R, D, D & C continuum, including close collaboration with industry, and the spinning out of ideas & companies.

In addition to the Institutes, project granting bodies, to assist groups outside the Institutes, should be established, such as a Solar Energy R&D Corporation, with funding of $50-100 million per year in the first instance. This will allow sustainable energy R&D outside of the mainstream to be fostered. This amounts to insurance against the possibility that the "winners" embodied in the Institutes turn out not to be.

Demonstration and commercialisation

Support from bodies such as Commercial Ready, the Renewable Energy Fund and the Renewable Energy Development Initiative, assist this phase of innovation. Quality control mechanisms from related existing schemes are adequate. Funding will need to be steadily ramped up as additional innovation flows out of the basic and applied R&D phase.

Market support

The 20% MRET target for 2020, in conjunction with carbon pricing, is an effective market-pull mechanism. However, the scheme could be considerably improved by setting aside substantial tranches for technologies with particularly good future prospects. These comprise photovoltaics, STE and geothermal. This would obviate the need for feed-in tariffs, PV rebates and other market support programs.

The Government, through its 20% target, has recognised that renewable energy as a whole needs special support to overcome the incumbency advantage of FF. It is only a small extra step to set aside special tranches within the 20% target.

Conclusion

Photovoltaics, wind energy and solar thermal are each likely to be \$100 billion/year industries within 5-7 years. These technologies are relatively free of adverse environmental impacts, and have the potential to dominate the traded energy market over the next 50 years.

Dedicated and strategically directed funding of sustainable energy R&D, and research & professional training, together with reliable long-term commercialisation support for Australian-based manufacturing, is required if Australia is to become a major player in this vast new industry.

APPENDIX

Bio energy

Unfortunately, the conversion of solar energy into chemical biomass energy has very poor overall efficiency: the conversion of solar energy to bio chemical energy has an efficiency of 0.2-0.5%, and conversion of solar energy to electricity (eg by combustion of biomass) has efficiency of 0.1-0.2%. This is 100-300 times smaller than for photovoltaics, solar heat or wind energy. This means that a large area of arable land is required. When used on a large scale, biomass competes with ecosystem preservation, with food & timber production, and with bio sequestration of CO_2, for the supply of arable land, water, pesticides & fertiliser. Pressure on food supply from the bio energy industry is already apparent.

A fundamental objection to large scale bio energy as a method of reducing greenhouse gas emissions is that the land could be much better used as mature forests to sequester carbon (both above and below ground).

Mature forests can hold the equivalent of 2000-5000 tonnes of CO_2 equivalent per hectare. Simplification of a forest by wood harvesting causes vast emissions of CO_2, since an immature forest (a direct result of regular cutting) has a much smaller carbon store (above and below ground) than a mature forest, averaged over the 15-20 year cutting cycle.

Consider a bio energy plantation forest, 15 years after planting, which is ready for harvesting. The question, from a greenhouse emissions point of view, is should the forest be harvested, or should it be allowed to mature? Unfortunately, the efficiency of conversion of the harvested biomass to electricity is only about one third. Calculations show that the forest is best left to mature. Similar considerations apply to other energy crops – it is best to replace them with mature forest as a CO_2 store, and use solar, wind and geothermal energy to displace fossil fuels.

Intermittency is a second order issue

Energy storage is not likely to be a major obstacle to mass utilisation of SE. Although considerable work will be required on storage over the next four decades, this is a secondary issue compared with energy supply. The question to be considered is how to ensure that the probability of failure of energy supply in an SE-dominated energy mix is similarly small to that in a fossil fuel dominated energy mix.

Wide geographical dispersal minimises storage requirements. If the wind or sun is not available in one region then it might well be available in another region. The use of satellites and other means allows for a high degree of predictability for unavailability of solar or wind energy, which allows alternative generators (eg gas turbines) to be brought on-line.

Technology diversity (the use of a variety of energy conversion technologies) minimises storage requirements. For example, the probability that neither wind energy nor photovoltaic energy will be available at a particular time is lower than the probability that either is not available.

Storage of renewable energy electricity is not a serious issue until penetration of the grid reaches 10-20%. This will not happen (except in a few places) for many years, giving time for improved storage technologies to be developed. A number of storage options are available, including fly wheels, compressed air and pumped hydro. The latter can be very large scale, and is fully commercial. Water is pumped uphill to a reservoir during times of low power demand, and released through a turbine during periods of high demand, with a round trip efficiency of 85%. A river is not actually needed, since water can go around the cycle from upper to lower reservoir and return an indefinite number of times. For example, seawater and a some local hills are sufficient.

There are many options for the storage of low temperature solar heat (for water & space heating) that are simple and cheap. Another method of solar energy storage is via thermochemistry.

To a substantial extent, biomass and geothermal are dispatchable.

If one particular renewable energy technology, such as photovoltaics, is a large component of annual energy supply, then the fact that the sun does not shine at night can be accommodated for by shifting loads to daytime (for example by time-of-day energy pricing).

Climate scientists believe that on-going use of fossil fuels at a rate of about 20% of current use is compatible with stabilisation of CO_2 emissions. Reservation of this tranche of energy supply for night time use (when solar is not available) and for peaking (eg from fast-response natural gas) allows considerable flexibility in managing a national grid.