

Powerful Choices — the know-how for a shift to a biofuel economy in Australia

By Andrew Campbell¹ and Barney Foran²

About eight years ago, Land & Water Australia funded Barney Foran (then of CSIRO) and colleagues to undertake a detailed analysis of how Australia could shift to a biofuel economy using woody vegetation as a feedstock. At the time, salinity, rural tree decline and the clearing and fragmentation of native vegetation — and consequent loss of biodiversity — were seen as significant problems. This research was predicated on the potential economic opportunities and the environmental imperatives for Australia to invest in large-scale revegetation of rural landscapes for multiple purposes.

At that time, the concept of ‘peak oil’ was broadly dismissed as resource pessimism. Biomass energy was not seen as a priority by the Australian government, and in 1996 the Howard government had abolished the Energy R&D Corporation (ERDC).

Energy security is now seen in a different light. Australia faces crucial choices about how best to respond to and plan for the converging insecurities of water, energy and food in a carbon- and nutrient-constrained world.

The conservative International Energy Agency — along with major corporations like Shell, BP and Mercedes — now acknowledges that conventional oil will soon require supplementation from non-conventional sources. In Australia, our yearly oil import bill was recently \$10 billion and is projected to grow to \$20 billion annually by 2020, as domestic oil stocks approach depletion.

The major research project undertaken by Foran and colleagues called “*Powerful Choices; transition to a biofuel economy in Australia*” (<http://lwa.gov.au/products/pn30178>) has just been completed. It has delivered very useful and strategically important information, generating solid data on which new land use, energy and climate change mitigation strategies can be developed.

The *Powerful Choices* study subjects the Australian economy to the laws of thermodynamics and mass balance. It is based on an embodied energy model of the Australian economy, where the financial description of the economy’s structure and function has been reshaped to access, transform and deliver energy, energy services and other physical products to final consumers. Since we know the relationship between energy use and economic productivity in every sector of the economy, the interchange of energy and dollars allows the fluent computation of economic, energy, emissions and other physical indicators, calibrated on 25 years of real data from 1981–2006, simulating the evolution of the economy out to 2051.

This biophysical-economics model of the Australian economy has been applied to explore the capability of discrete low-carbon technologies to maintain economic growth, ensure

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energy security and reduce CO₂ emissions out to 2051. Renewable electricity (bio-electricity, wind, solar thermal and solar photovoltaics) and advanced fossil electricity (high efficiency generators, carbon capture and storage, and nuclear), and the effect they might have if infused into the future economy at a large scale, are examined alone and in various combinations. Alternative transport fuel cycles are explored through renewable fuels (bio-methanol and bio-ethanol) and fossil-based oil replacements (compressed natural gas and shale oil).

The rationale here is that investors and decision makers, be they corporations, governments or superannuation funds, make decisions on individual projects. The thermodynamics and mass balance calculations central to this approach give insights to investors that a commercial prospectus might avoid. For example, the carbon capture and storage (CCS) technology central to retaining thermal electricity generators probably won't deliver economy-wide greenhouse targets, unless it is applied to highest efficiency generators, such as combined cycle gas turbines and solid oxide fuel cells. For carbon-neutral transport fuels, 'second generation' biofuel systems should only use thermochemical technologies with wood or waste feedstocks. First generation biofuels such as ethanol from corn or sugar cane are simply not very profitable from an energy perspective — you consume almost as much (sometimes more) energy than you generate.

In summary, the Powerful Choices study found that:

The best biofuel production chains³ can avoid three to four billion tonnes of CO₂ emissions out to 2051, or 10–15% of the 29 billion tonnes of base case emissions.

Bio-methanol from wood feedstocks is capable of meeting Australia's transport fuel needs.

- Biomethanol substitutes effectively for both petrol and diesel and has clean combustion properties.
- 40–60 million hectares of wood production on currently cleared farmlands would be required by 2051.
- Increased landscape transpiration from these trees decreases national runoff by 8,000–12,000 gegalitres (GL), which is large in relation to currently managed water, but less than 3% of average total runoff.

Bio-ethanol is feasible, but less attractive than bio-methanol.

- First and second generation ethanol produced from crop and lignocellulose feedstocks respectively is feasible, but requires more arable land and has low energy profits.
- The thermochemical approach using wood and waste feedstock has similar feasibility to bio-methanol but the technology is not yet mature.

³ The Future Farm Industries Cooperative Research Centre (<http://www.futurefarmcrc.com.au/programs.html>) is currently researching and developing new harvesting technologies to improve the efficiency of bioenergy production chains based on oil mallee eucalypts in the sheep-cereal belt.

Both compressed natural gas (CNG) and shale oil are feasible routes to transport energy security but have less possibility for greenhouse gas mitigation.

- CNG helps avoid 700 million tonnes of CO₂ emissions, but increased gas use brings forward depletion of gas stocks by five years.
- A more radical gas scenario that combines export caps at current levels (i.e. the levels prior to the recent Gorgon deal coming on line) with mandatory engine efficiencies, can maintain gas supply to 2051 and avoid three billion tonnes of CO₂ emissions, equivalent to a bioalcohol transition using woody feedstocks.
- Current shale oil technology using above-ground retorts increases emissions by more than eight billion tonnes (+30%) while an electricity driven in-situ process gives increases of over three billion tonnes or 12% of base case.

Advanced shale oil could offer medium-term fuel security while preparations are made for a more radical set of carbon mitigation options.

- Emissions loadings point to shale oil's infeasibility in a carbon-constrained world, but combining advanced conventional electricity (see below) with the in-situ shale process reduces economy-wide emissions to 20 billion tonnes or 30% below the base case.

Despite higher costs and lower load factors, a renewable electricity transition with 20% each of wind turbines, bio-electricity, solar photovoltaics and solar thermal is feasible and could supply 80% of electricity requirements by 2035.

- This avoids 10 billion tonnes (40%) of CO₂ emissions.
- The weakest aspect of renewables — their relatively low productivity compared to energy-dense fossil fuel systems — becomes an asset in whole-economy terms if most of the fabrication occurs within the domestic economy.
- The scale of the transition revitalises the industrial sector, while the utilities sector increases its proportion of national capital stocks.

A transition to advanced conventional electricity with equal shares of four technologies (nuclear, carbon capture and storage (CCS)-equipped advanced coal, combined cycle gas turbines and solid oxide fuel cells) could also avoid 10 billion tonnes (40%) of CO₂ emissions over the scenario period, subject to three major uncertainties:

- The enabling technology for CCS is prospective and requires the fluent implementation of the most complex engineering project yet attempted in Australia.
- It only reduces net emissions if applied to high-efficiency generators.
- The absolute requirement that CO₂ emissions stay permanently underground and that medium-level radioactive waste is safely managed in perpetuity.

Admittedly, these are modeled outputs and the real world is invariably more complex.

The tightly-coupled nature of production chains in the real economy, means that policy prescriptions which add technological 'wedges' to construct a low-carbon economy, probably overstate the potential. Quality-corrected energy drives economic growth, and is

the physical essence behind multi-factor productivity. Any block to energy growth thereby blocks economic growth, and this will frustrate well-meaning energy efficiency policies.

Moreover, in practice, achieving bio-fuel plantings on this scale is a formidable challenge:

- there is a limit to the distance over which the harvested woody resource can be transported to a processing plant for conversion to bio-energy or bio-fuel, measured in dollars, kilojoules or CO₂, which means that many processing plants will be required;
- industrial and municipal waste, plantation residues and so on may be seen as more reliable resource supplies in some regions;
- woody crops in low-medium rainfall areas, if planted over more than ~10% of the landscape, compete significantly with food crops for soil moisture and groundwater;
- the distribution of woody crops for beneficial uses is likely to be patchy — feeder areas clustered around processing nodes, with the area planted worked out farm by farm, the opportunity cost of current enterprises and land type variability as dominant determinants — and biofuel will have to compete with permanent plantings for carbon sequestration.

That said, this study shows that with good strategic planning, sufficient investment and competent implementation, either ‘renewable’ or ‘advanced conventional’ electricity, with a second generation biofuel and land management or biochar, can displace 10, 4 and 2 billion tonnes respectively (in total 16 billion tonnes), a 60% reduction against the base case CO₂ emissions of 29 billion tonnes. Finland illustrates that these results are not in the realm of fantasy. With about the same area and population as Victoria, but a much tougher climate, shorter growing season and slower growth rates, thinnings and prunings from private forestry and biofuel plantings produce 23% of Finland’s primary energy, over 75% of its thermal energy needs, and 20% of Finland’s electricity.

The *Powerful Choices* simulations have shown that, using the current and emerging technologies explored in this study, reductions of 80–90% in energy-related CO₂ emissions are not possible within a growing economy driven by expanding real incomes and growing personal consumption.

The *Powerful Choices* study also highlights a number of domestic resource depletion issues. The first depletion is conventional oil, mostly gone by the mid-2020s here. Australia has an urgent need to develop alternative transport fuel options, yet the renewable energy debate thus far has been dominated by the renewable energy target as an interim measure to reduce greenhouse gas emissions until emissions trading and rising carbon prices displace its need. The second is natural gas, potentially depleted by the mid-2040s due to rapidly expanding exports. Its potential as an interim buffer for transport fuel and for mid-carbon electricity is immense, provided we have not sold it off in the meantime. The third is uranium, if export volumes triple and a domestic nuclear cycle is implemented. Black and brown coal will last for many centuries.

This study should be seen as the physical complement to many economics-based studies focusing on carbon mitigation leading to Copenhagen later this year. The transitions tested here obey the physical laws of thermodynamics and mass balance, where there is no escaping reality. Many prospective technologies have narrow technological windows

through which they can contribute at a whole economy scale, for example CCS with high efficiency generators, and bio-ethanol through thermochemical transformation. Learning curves and cheaper prices do little to alter these realities.

The *Powerful Choices* project started with the perception that Australian farmed landscapes needed to be re-clothed with trees to combat dryland salinity, improve wildlife habitat, and provide new enterprises for farm businesses through transport biofuel production. Times have changed. The driest thirteen year period since European settlement has seen dryland salinity recede, but biodiversity augmentation and carbon farming have become more important, as has energy security. Some of the results here challenge entrenched positions held by political parties, public servants and major corporations. How to launch these reasonably robust analytical positions into the crowded greenhouse policy and science marketplace leading up to Copenhagen in late 2009 is a challenge.

That challenge is even more difficult given that, in a perverse echo of the Howard government's myopia in shutting down ERDC, the primary national sustainable energy research funder in 1996, the Rudd government in its May 2009 budget abolished Land & Water Australia (LWA). Land & Water Australia was the national research funding body that specialised in rural sustainability issues across a broad spectrum from land, water and biodiversity to social, institutional and indigenous research. It funded (and promoted the outputs of) many projects like the *Powerful Choices* study that tend to be overlooked by the commodity-specific funding agencies that dominate rural research in Australia.⁴

Knowledge is most useful when it is needed, not before, and certainly not after. We only know what we need to know, when we need to know it.

These two axioms of knowledge management complicate the business of funding research. The lead-time of 3-10 years for most applied research projects — longer for more basic research — means that research funding agencies need to anticipate knowledge needs well ahead of time in determining their investment priorities. Then, when research outputs are delivered, it is equally important to ensure that they reach their target audience, in a useable form, on time — i.e. when that knowledge is needed. Land & Water Australia's funding for this research was a classic example of professional research investment, anticipating a knowledge need ahead of time through good strategic analysis.

As the agency that funded the research (and that would have managed and promoted its outputs) no longer exists, the *Powerful Choices* report has fallen into a vacuum.

This is deeply regrettable, for two reasons. Firstly, the findings thus far have major implications, and need to be promoted in a targeted and on-going manner. Secondly, much more could be delivered through extending this work. The *Powerful Choices* study would require relatively modest further research to form fully integrated scenarios elaborating the 'conventional wisdom' and 'renewable energy' world-views. A low-growth, low-consumption economy also needs to be assessed. Additional highly complementary components would include technology-specific studies on battery electric

⁴ The Rural Industries Research & Development Corporation (RIRDC) does have a modest Bioenergy, Bioproducts and Energy program, which in 2007-8 represented around 4% of RIRDC research investment and less than 0.2% of investment across the rural R&D corporations.

vehicles for urban travel, biochar as an integrated product from biofuel and bioelectricity production, and applying CCS to biofuel production to make it carbon-negative.

The *Powerful Choices* study also highlights the critical dilemmas facing Australia around how we allocate land, water and financial resources to food and energy production in a more difficult climate, while mitigating greenhouse gas emissions. The continental scale biophysical-economics modelling of this study needs to be combined with farm-level economic and optimisation modelling, in a spatially explicit manner region by region. This would help to tease out the implications for rural landscapes and regional communities of the transition to a biofuel economy, and in planning infrastructure investments such as processing plants, energy grids and low-emission transport networks.

This is the sort of research that Australia needs to give us the best possible knowledge base on which to construct a portfolio of viable alternative renewable energy supplies. It would enable us to consider energy, carbon, water, food and biodiversity in a more integrated way, and to think through how these public policy imperatives interact, both with each other, and with rural landscapes and regional and national economies.

This is much more powerful and useful than the more usual approach of considering carbon, water, energy and food separately, both in science and in policy.