



SPECIAL LIFTOUT No.86

Summer 2009 Vol. 31 No. 4

Future-proofing Australia's economy: the case for bio-alcohols for transport

By Barney Foran

Australia's policy slumber on transport fuel security and timidity in greenhouse mitigation promise a significant and ongoing crisis for the next generation of our citizens. They will remember our boom times and consumption binge, as they contemplate worn landscapes, fractured transport systems and regional enterprise at the mercy of irritable world trading blocs.

Part of the solution proposed here is to supply 90% of our transport fuels by 2030 from bio-alcohols made from wood feedstocks. This could offer a \$10 billion turnover per year industry, possibly growing to \$20 billion as domestic oil depletes.

Bio-methanol or wood alcohol is the fuel of choice here because of higher energy-to-energy conversion rates, its clean combustion properties, its capacity to substitute for diesel and its potential as a hydrogen carrier for fuel cell driven vehicles. Practically, cocktails of alcohols are best for fluent combustion, opening the way for a number of bio-alcohol pathways and avoiding technology lock-in. Most importantly, thermochemical rather than biochemical conversion is seen as best because it offers continuous production, a range of synthesis products and can use different types and quality of feedstock from wood, to stubble and municipal wastes.

Australia will need 500-1,000 regional processing plants by 2050 offering wide opportunities for regional renewal and other products. The political and institutional hurdles are immense and will require the revamping of conventional economic wisdom and counter-cyclical investment by Australia's forest industries.



Barney Foran has degrees in agriculture and ecology, which led to professional eras spanning rangeland ecology, agricultural systems, environmental science and long term analysis of Australia's physical economy. He led research teams in CSIRO's Resource Futures group which produced long term analyses of Australia's physical economy focusing on human population (*Future Dilemmas*), marine fisheries (*Fish Futures*), land and water (*Decision Points*) and a triple bottom line analysis of the Australian economy (*Balancing Act*). His current work focuses on integrated solutions to Australia's challenges of energy security and greenhouse mitigation. He is a research fellow at the ANU's Fenner School of Environment and Society, the Institute of Land Water and Society at Charles Sturt University, and the Physics Department at Sydney University. He now lives in regional Victoria and tends small forest blocks of blue gum and spotted gum. This research is supported by Land and Water Australia.

This article is based upon the authors' personal views and is not necessarily representative of the views of any other group or individual.



Australian policy futures

At the time of writing, the petrol price in regional New South Wales was 99 cents per litre, seemingly dispelling the notions of peak oil that have been building for most of this decade. In parallel, our national flat earth broadsheet, *The Australian*, could hardly contain its glee that the national emissions trading scheme aimed at a 5% reduction by 2020, a hurdle so low, that legions of blue tongue lizards were lining up to clear it in a single bound. For whole-economy analysts used to timescales of forestry rotations or more, the global collapse was dispiriting as once again short termism attempted to save a wounded economic beast, which had long courted misfortune by living like boom times would last forever.

But for all the gloom, in 2008 the policy mandarins hatched some long term plans. Both the Garnaut Review and the Federal Government's Green and White Papers on the emissions trading scheme highlighted bio-sequestration or 'carbon capture and storage by biological means' as central to meeting whatever reduction targets were on the table. These insights came mainly from the economic perspective that bio-sequestration was large and potentially cheap, with the added advantage that the regions could be electorally sweetened with new income streams.

Unfortunately, bio-sequestration solutions maintain the end-of-pipe philosophy central to the industrial revolution, which assumes changes on the margin will enable humanity to carry on more or less as normal. Limited credence is given in greenhouse fuels policy to the industrial ecology premise that long term sustainability requires a circular loop whereby biological carbon replaces fossil carbon. A commitment to the industrial ecology premise would provide the ability to maintain a developing economy while achieving a 90% reduction of today's greenhouse emissions by 2050 – a goal that cannot be met by adopting end-of-pipe solutions.



While 'peak oil' has not been proven in a proper scientific sense, even the conservative International Energy Agency is now on written record noting that oil and natural gas are deemed finite resources.
SOURCE : www.businessfacilities.com/bf_07_03_moves1.php

A bad press for bio-fuels

For the last three years, making transport fuels from crops and plant residues have come under scrutiny from global environmental advocates and science analysts from a life cycle perspective. Environmental advocates linked food prices to ethanol expansion particularly in the US and Europe or biodiesel production to rainforest clearance for oil palm and oil grain feedstocks. The life cycle analysts pointed to poor energy profits over well-to-wheel assessments, particularly from corn-to-ethanol systems in the US giving only modest advantages in energy security and greenhouse reductions.

Countering the negatives were relatively good assessments of Brazilian cane-to-ethanol¹ systems and rapid technological developments in the ethanol-from-lignocellulose concept, which promised good yields and better lifecycles and, most importantly, an abundance of feedstock from lands that would not impinge on human food production. Australia was typically a follower in the global biofuels debate with modest government mandates for biofuel production, a range of scholarly and legislative reviews of energy security and production feasibility issues, and, most importantly, the development of distribution systems and fuel standards. While still a minor part of the national fuel mix, both ethanol and biodiesel are now part of the legislative and consumer lexicon.

The search for integrated solutions

Frustratingly, most policy development concentrates on marginal changes to the status quo ensuring that progress towards new settings is agonisingly slow. Regional renewal focused on biomass developments at sufficient scale for oil replacement is a typical case. The challenges to current structures and just-in-time economies posed by theories of peak oil or even an embargo on oil supply are scarcely acknowledged as perils domestically. Notwithstanding natural gas crises in Europe and the USA's war footing to maintain oil supplies, it may take a diesel supply crisis of several months duration to awaken Australia's policy slumber. Unfortunately, robust fuel solutions require decades rather than electoral cycles whether they be biomass-centric or based on natural gas and shale oil (see later).

Hopefully, such a diesel crisis might occur in parallel with mature insights that Australia's tamed lands require widespread re-clothing with deep-rooted woody crops providing ecological resistance and economic resilience in the face of commodity trade and global climate change. To date, farming lobbies have seen carbon sequestration and biofuels as a challenge to their embattled position, rather than a new land use industry providing alternative forms of cash flow and regional opportunity. A National Farmer's Federation press release late in 2008 cited the Federation's President David Crombie with the following view:

"In another whack for food production, according to federal Treasury modeling, the Government's 5-15% emissions reduction target by 2020 is likely to spark an expansion of between 5.7 million and 26.3 million hectares of plantation forestry in Australia. That means less land to produce food."²



There is nothing sacred about Australian farmed landscapes and the commodities they produce that can't change over time. The planting rules behind the bio-methanol transition assume that no more than 30% of each farm is planted to wood crop.

Consequently, the policy wildcard required to cement a new integrated policy direction is today, an unlikely one: the re-examination of the basis of globalised trade. It requires a re-balancing of goals such as 'the cheapest available', energy security, self sufficiency, national indebtedness, trade deficits and of course the national carbon trajectory. It is almost a political truism that dynamic allegiances in European parliaments provide more opportunities for seemingly opposed factions such as the far right and the far left to legislate for integrated solutions not visible to centrist parties dancing in each other's shadow. Most political theorists in Australia assume this is unlikely, although the Australian Senate provides a possible route if the National Party's Barnaby Joyce and the Greens Christine Milne can agree.

Beyond Economics 101

The perspectives throughout this article are guided by the principles of 'biophysical economics'³ where the perpetual growth machine known as the modern economy is constrained by the laws of thermodynamics and mass balance. Simply put 'you can't get something out of nothing' especially where energy transactions and greenhouse emissions are concerned. Biophysical economics combines the economic world with the underlying physical transactions that cause the dollars to flow. Thus the traditional business case for biofuels would emphasise the capital cost of the plant and the production cost of feedstock resulting in the price per litre at the factory gate. The biophysical economics viewpoint drives these processes by land requirements, tree growth rates, energy-to-energy conversion rates and a life cycle analysis of greenhouse emissions in the production chain. It is deeper and more realistic than the conventional view and avoids the 'market will fix it' myopia, normal in policy and media circles.

Biophysical economics adds five issues not covered in traditional Economics 101. Critically these principles determine whether modern economies like Australia's can escape their reliance on cheap energy-dense fossil fuels.

The first is that energy combustion drives economic growth, not the other way around. The second is that improvements in energy efficiency drive economic expansion through the rebound effect and allow us to have 'more for less' rather than the 'same for less'.

Third, to contain this rebound, we have to squirrel away those 'energy or dollar' savings in a future fund held outside the domestic economy, so the rebound can't cause more growth. The proposed emissions trading scheme could be part of the greenhouse solution, but not if all the monies are flushed back into the economy as compensation for poor householders and rich industrialists.

Fourth, the conventional wisdom that higher energy prices central to greenhouse solutions will 'cost' the economy at large, are not true. Central to any transition to biofuel and renewable electricity would be additional physical activity, stimulating and retaining economic activity within Australian regions. This is particularly important given the current national mindset where 'the need for cheap energy' is directed to 'making dumb products.'

Fifth, you 'can't eat your cake and have it too.' The 'lifestyle maintenance' promised in the Government's emissions trading White Paper promulgates the economic fairytale that technological innovation and economic instruments can restrain humanity's appetite for consuming the earth. A successful low emissions economy will require that the life cycle of our domestic consumption shrinks in energy terms, back to per capita levels Australia experienced in the 1980s.

So much for the lesson in theory, but what does this mean for energy security and emission reductions?



As well as traditional long rotation forestry, the bio-methanol transition would need well developed production regimes that suit environments on 60 million hectares of Australia's tamed landscapes.

Surely there are other transport fuels?

As an energy rich nation, Australia suffers from a plethora of energy options that hinders strategic decision making. Table 1 compares a number of practical options against a base case across four high level indicators such as GDP growth rate, accumulated CO₂ emissions, and indices of personal consumption and stocks of national infrastructure. These are whole-economy analyses extracted from the author's

forthcoming study *Powerful Choices*, which tests viable energy and greenhouse options for Australia out to 2050, using physical economics principles described in the previous section.

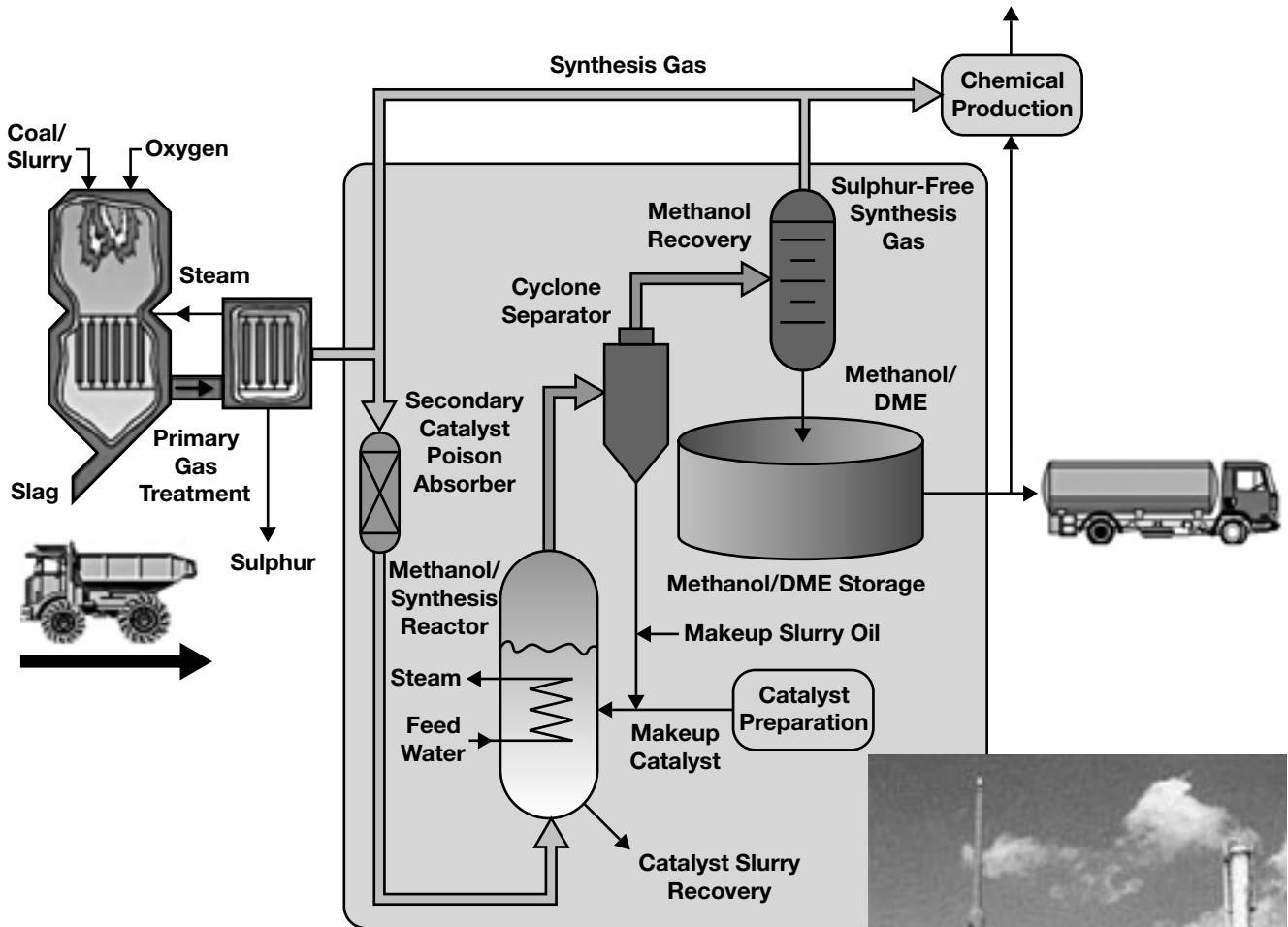
The 'base case' sets a benchmark for comparison purposes of an Australia committed to maintaining economic growth around 2% per year with lip service paid to energy security and greenhouse issues resulting in accumulated CO₂ emissions of nearly 29 billion tonnes out to 2050. Replacing petroleum with just bio-methanol (no other changes), maintains GDP, per capita consumption and increases infrastructure stocks. Emissions are reduced by an accumulated three billion tonnes or 12%. Adding a renewable electricity transition on top of bio-methanol decreases GDP and halves personal consumption, but shaves 15 billion tonnes or 53% off accumulated emissions. This design represents a good start to a reasonable greenhouse solution, but is still a way off the 80-90% reductions that developed countries will probably have to meet.

The alternatives of natural gas and shale oil give good outcomes except for greenhouse emissions where they fail miserably. Using extensive reserves of natural gas to replace oil and forgoing the export income gives base case outcomes, and might save one billion tonnes or 3% of greenhouse emissions. Developing central Queensland shale oil reserves with retort technology to liberate the oil, gives better than base case outcomes but blows the lid off greenhouse emissions by nearly ten billion tonnes or 30%. However, Royal Dutch Shell is developing an in-situ process⁴ where electricity heats shale underground to drive oil seepage towards collection points. If the electricity is of the 'advanced conventional' variety (carbon capture and storage plus nuclear), then eight billion tonnes or 30% of emissions are saved. This is well above the emission solution given by bio-methanol plus renewable electricity, but it does maintain consumption and infrastructure stocks.

This section puts the cart before the horse somewhat in that the case for biomass-based fuels has not yet been made (see next section). It shows however that energy abundance will maintain the traditional functions of the economy, but deny appropriate greenhouse solutions. Strategically, natural gas exports should be limited and a domestic cover be maintained well into the 2030s, when transport alternatives might be in place. Even under extreme technological assumptions promised by the Shell technology, shale oil will under-perform in greenhouse terms relative to a wide range of biomass based alternatives.

Table 1: A comparison of options for replacing transport petroleum by domestic alternative fuels.

Fuel Transition Scenario	Average GDP Growth Rate %	Accumulated Whole-Economy CO ₂ Emissions billion tonnes	Per Capita consumption Base Case Index = 100	National Infrastructure Stock: Base Case Index = 100
Base case	2.2	28.7	100	100
90% methanol alone	2.5	25.4	101	110
90% methanol with renewable electricity	1.9	13.6	53	94
90% natural gas	2.2	28.0	98	98
90% shale oil from retort technology	2.5	37.3	106	110
90% shale oil 'in situ' process and advanced conventional electricity	2.1	20.5	95	100



Industrially well-developed processes such as the liquid phase methanol synthesis are ready for application to produce carbon neutral bio-alcohols for Australian vehicle fleets.

The case for bio-methanol

Second generation or thermochemical processing of purpose-grown biomass provides many fuel choices. The Fischer-Tropsch process producing synthetic petroleum-like liquids is one variant of thermochemical processing. Methanol or wood alcohol (CH_3OH) is promoted here for seven reasons.

The first is that it is a simple molecule, relatively easy to synthesise and with superior combustion properties, although with half the energy content of petrol on a volumetric basis.

Second, its hydrated derivative, dimethyl ether or DME ($\text{C}_2\text{H}_6\text{O}$), is a direct substitute for diesel fuel, also giving low tailpipe emissions.

Third, methanol has four hydrogen atoms to one carbon atom, making it an efficient hydrogen carrier for a future 'hydrogen economy' that could power fuel cells should they replace internal combustion engines in the vehicle fleet. Hydrogen is difficult to transport and store whereas liquid methanol uses the same refuelling infrastructure as today, with some added safety requirements.

Fourth, methanol is made from natural gas, a common industrial feedstock. Consequently, bio-methanol provides a

fluent transitional route between the fossil and biomass-based economies. Coal feedstock could also be used as an interim

arrangement in the transition to full carbon neutrality.

Fifth, thermochemical synthesis methods are founded upon over a century of successful development, and can form the core of the 'energyplex' concept producing fuels, with electricity, green chemicals and soil ameliorants all derived from a common wood feedstock.

The sixth and related concept is that the wide array of varied quality feedstocks from municipal and industrial wastes to traditional forages could be used in addition to the core wood feedstock proposed for use here.

The seventh and final reason is that methanol-specific engines have many performance advantages with options for tradeoffs between performance and fuel efficiency. Additionally its cool combustion characteristics allow engines with minimal cooling systems.





Why not bio-ethanol?

Policy preferences currently favour bio-ethanol rather than bio-methanol as a low carbon biofuel. Recent greenhouse reduction reports from the Garnaut Review and the Federal Treasury uniformly quote ethanol as the petrol replacement, and methanol only as an input into the biodiesel production process. The place of hydrogen is frequently mentioned in a 'beyond the horizon' context, but with little technical depth as to its production origin, what possible carriers of hydrogen might be, or the transition process for the entire vehicle and refuelling infrastructure to use hydrogen.

Generally, ethanol benefits from its policy incumbency, and the fuel mixing and distribution outlets already in place. The Federal Government's recent car industry plan, *A New Car Plan for a Greener Future*⁵ does not mention specific fuels, only recommending that new cars be fuel efficient and have low carbon lifecycles. However, the Bracks Review, which underpins the 'greener future' policy, conducts a full discourse on fuel options both globally, and with respect to domestic vehicle manufacturing. Thus in policy terms, bio-methanol as a low-carbon fuel and as a petroleum replacement is scarcely on the policy horizon for either government or industry.

To overcome these disadvantages, bio-methanol will require unchallenged proof of technical and economic advantages to supplant ethanol domestically. More importantly, the global motor industry's focus on petroleum fuelled engines and in the near future, electric vehicles for urban use, potentially make it difficult for a bio-methanol transition to overcome the incumbent position of bio-ethanol.

Compared to the technical sophistication of methanol synthesis, the thermochemical conversion of biomass to ethanol is still in its infancy. Thus for all the implementation problems that might face the full scale bio-methanol transition, it is possible that an ethanol-from-biomass transition cannot yet promise physical yields required to maintain transportation services and resultant economic activity. The CSIRO *Biofuels in Australia*⁶ report assumes wood to ethanol yields of 200-300 litres per dry tonne or about 40% of the wood's energy content. Advanced process designs from NREL⁷ in the United States quote yields of 320-440 litres per dry tonne or up to 50% of the wood's energy content, the higher values requiring electricity supplied from the grid. By contrast, the energy-to-energy conversion ratios for methanol are assumed to be 60% in contemporary literature.

Conversion ratios aside, catalysis literature points to ongoing problems in achieving sufficient yields with ethanol-from-syngas. After 90 years of development, the ethanol-from-syngas options are dogged by process complexity, high



While the corn-to-ethanol building boom in the USA used the wrong feedstock and production process (in life cycle terms anyway), there is little doubt that it revitalised employment options and value adding options in corn belt America.

catalyst price, low catalyst selectivity and low yields. The process of forming the carbon to carbon bond required for thermochemical ethanol synthesis is more problematic than the synthesis of one carbon methanol. Nevertheless, the technical literature foresees that the problem can be solved possibly with nano-catalysts⁹, although recent breakthroughs in microchannel reactors¹⁰ for methanol synthesis promise methanol plants that can be downscaled economically to small local production facilities. However, commercial developments by Range Fuels¹¹ in Georgia USA promise that an 80 million litres per year wood-to-ethanol plant will be operational sometime in 2009.

Physical requirements for bio-methanol

That a bio-methanol transition works in a whole-economy sense is shown in Table 1 where economic productivity is maintained in a macro-sense, while significantly reducing accumulated CO₂ emissions. The next view of its feasibility rests on land use requirements and effect on water availability. At its peak in 2051, the bio-methanol transition for a growth economy requires 400-600 million cubic metres of feedstock annually, or 13-20 times today's national production of around 30 million cubic metres. In weight terms, this 300 million tonnes of wood is roughly equivalent to current coal exports.

Due to planting limits of landuse guidelines, 60% of the volume at 2051 comes from the mallee system used in the drier parts of the cropping zone. This seems an acceptable lesson from the future where whatever global change provides, the more marginal land for cropping now may at least have

Table 2: Land account in million hectares showing plantation land and major land use categories for the base case and three variations of the 90% methanol scenario.

Scenario	Arable cropping land	Improved pasture land	Plantation land	Rough land	Total national area
Base case	22.4	42.8	6.0	691.3	762.5
90% methanol	20.6	39.2	57.0	645.6	
90% methanol with transport efficiencies	21.2	40.3	38.6	662.4	
90% methanol, transport efficiencies and 'tough decisions'	22.0	41.7	21.0	677.7	



Catalyst chemistry is at the heart of the bio-methanol transition and will require significant skilling up of teaching and research facilities at Australia's regional universities.

SOURCE: www.statoilhydro.com/en/TechnologyInnovation/gas/Methanol/Pages/Syngasandmethanolicatalyst.aspx

lower land prices while higher rainfall zones will still be required for traditional food and fibre production.

Plantation land occupies six million hectares by 2051 in the base case scenario. The range of bio-methanol scenarios requires 21-57 million hectares of land under some form of wood production by 2051. The larger plantation area reduces arable cropping land and intensive pasture land by about two to four million hectares respectively. A rapid transition to a more efficient transport fleet reduces the land requirement by 20 million hectares, while the imposition of an austere low consumption economy (the 'tough decisions' scenario) reduces the plantation land to a peak of 21 million hectares at 2051, roughly seven times the level of the Vision 2020 goal and similar to the carbon sequestration land required for the Federal Government's carbon pollution reduction scheme.

Given the challenges of meeting the plantation targets, even the lowest of the bio-methanol land requirements seems improbably large in today's mindset. These analyses, however, test the physical feasibility of the transition and show that it can be achieved without major change to incumbent land use sectors. While the Australian land stock lacks large areas of highly productive soil types, the low soil fertility does not preclude wood cropping – provided that the tree gene pool gives suitably productive systems for lower rainfall areas, currently used for marginal crop production.

The impact of the bio-methanol plantation areas on national evapo-transpiration and subsequent surface runoff is noticeable at an aggregate level. National evapo-transpiration at the peak of the transition is around 400,000GL per year because perennial tree systems have replaced annual cropping and pasture systems. Thus these peak plantings restore the continental transpiration rates to levels similar to pre-European times. Simulated surface water runoff is also decreased by approximately 17,000GL. This is roughly similar to the yearly consumptive use of water in Australia, equal to one fifth of the total storage capacity for managed water use or about 7% of total national runoff.

Locating sites where runoff is decreased is obviously critical given a future in which global climate change promises decreases of more than 30% in runoff to streams in some areas. Even minor changes for threatened areas of wetlands, for example, may be critically important. For the largest decrease of 12,000GL in excess of the base case, the contribution is highest for New South Wales, Queensland and Tasmania with decreases of 2,700, 3,800 and 3,000GL respectively. In Western Australia, the largest planned areas of mallee planting will have little effect in aggregate on runoff, as much of that state's wheat belt has internal drainage and few major rivers.



In marginal and intensive farming zones, plantations for biomass will improve biodiversity by pursuing a mixed indigenous species approach when planting.

Analyses at this aggregated scale do not prove any non-impacts of such large plantings. Rather they sketch the physical plan of how a bio-methanol transition might work and highlight where the potential contribution of a region might be threatened by more important issues. Large scale sub-catchment modelling and regional land use plans would then be required before national feasibility in aggregate could be assured.

Improving biodiversity

Refurbishment of vast areas of Australia's tamed lands offers many opportunities for reclaiming the biodiversity complement removed by 200 years of traditional development, but there are three key provisos. The first is that plantings should not be done in monocultures or with exotic plants such as willows that promise high productivity but later escape to become weeds¹². The second is that landscape planning guidelines are developed for both traditional plantations¹³ and farm forestry¹⁴, which aim to balance biodiversity augmentation with tree productivity and final processed yield. The third is that the productive potential of many native species has scarcely been evaluated – although the Joint Venture Agroforestry Plan¹⁵ has made a good start.

Plantation managers point out that 25% of the plantation estate is available for biodiversity in addition to the cover and habitat provided by the plantation itself. Excluding seed eating birds, a woodscape is a vastly improved habitat compared to a wheat field or planted pasture. Harvesting wood for bioenergy on rotations of 3-30 years will affect habitat by periodic harvesting, but this need not be done by the horizon-to-horizon clearing that has characterised modern agricultural development. Catchment and landscape managers now have a rich enough arsenal of techniques at their disposal to ensure that most biological diversity is retained by maintaining buffers, corridors and no-go zones.

Minuses and pluses for bio-methanol

The perceived barrier to the widespread use of methanol as a fuel is its stated toxicity, both if consumed and if absorbed through the skin. This can be avoided with sealed delivery systems as used in LPG refuelling and would require that vehicle mechanics wear protective clothing. Ratings of chemical hazard assessment place both methanol¹⁶ and ethanol¹⁷ in the lowest quartile of risk when ranked against the many thousands of chemicals that surround our everyday lives. Nevertheless methanol with a combined hazard score of 25 has twice the hazard score of ethanol with 13, noting that ethanol itself is deemed toxic. Using methanol in normally combusted flexible fuel vehicles halves the life cycle emissions of volatile organic compounds compared to conventional petrol and diesel engines. Only in emissions of formaldehyde does methanol cause more emissions per kilometre compared to other fuel types¹⁸.

Generally, ethanol causes significantly more volatile emissions per kilometre than methanol under current technologies and testing regimes. A recent comparison of petrol and methanol fuelled exhaust gases on cell and DNA damage in China, showed that petrol exhausts caused considerable damage on both laboratory assays whereas methanol exhausts showed no



GR Davis's blue mallee distillery at West Wyalong, NSW: All feedstock should be produced within 50 km of a processing 'energyplex' to ensure that energy profits and greenhouse savings are maximised. The entire energy requirement of the bio-methanol transition will take 8% of usable fuel produced.

damage¹⁹. The Chinese conclusion was that methanol was the safer fuel. A full evaluation of methanol hazard or otherwise is beyond the scope of this article, but two things are clear. First, methanol's direct hazard is a little more than ethanol and can be contained by different fuel delivery systems and consumer training. Second, methanol is more cleanly and completely combusted in engines and fuel cells and thus releases appreciably less airborne toxics which impact on human health.

In appropriately modified diesel and internal combustion engines methanol gives equal performance and longevity to conventionally fuelled engines²⁰. Because of its high octane and cool burning characteristics it offers increased engine efficiency and performance options used by motor racing enthusiasts, but these opportunities can be reconfigured to improved distances per unit of fuel and lower pollution loadings.

Methanol's lower energy content, roughly half that of petrol, requires larger fuel tanks and fuel systems to deliver equal performance. The higher compression ratios and engine efficiencies in methanol engines confer system-wide advantages of up to 30% over petrol equivalents and thus fuel tanks do not have to be twice as large. The hydrated derivative of methanol, dimethyl ether or DME is a gas similar to LPG in use and is a direct substitute for diesel. It has the advantage

noted above that it can be co-produced with methanol in the same reaction vessels using biomass as a feedstock, thus allowing low carbon fuels to penetrate the vehicle fleet without revolutionary changes in infrastructure required for the hydrogen economy. A recent scientific review of DME highlighted its lack of toxicity and efficiency and pollution advantages over current petroleum fuel systems and also the competing alternative fuels²¹. In summary, the review found that the combined advantages of engine efficiency and greenhouse reduction for DME suggested it could act as the bridge to the hydrogen fuel cycle and also reduce dependence on oil imports. CIDI diesel engines (compression ignition direct injection) are judged as the core technology essential for the DME transition.

Outflanking possibilities

The bio-methanol transition proposed here could be outflanked by decisions made in Detroit, Tokyo, Beijing and Stuttgart. Global car makers are talking up electric cars or plug-in hybrids for cities where most car owners live. Their attention, however, is still invested in a century-long love affair with internal combustion engines.



Energy technologies change only slowly over time spans of human generations for good reasons, such as familiarity and reliability. Life cycle analyses in the US found that plug-in hybrids reduced greenhouse emissions by 40% compared to conventional vehicles, but that carbon neutral biofuels were superior to all other options²². The attractiveness of plug-in hybrids was confirmed in a regional Colorado study where life cycle greenhouse emissions were 35% lower than conventional vehicles if off peak power was used to efficiently charge the car batteries and displace petrol use²³. An electric charge of 3.5 kilowatt hours was required to displace one litre of petrol with a price equivalent of \$0.52 per litre at a unit price of \$0.15 per kilowatt hour. For the city motorist who might hire a traditional car for weekend travel, the possibility of at least halving fuel costs for the dominant travel mode may be hard to ignore.

Balance of payment and international indebtedness

For the simple-minded, running a national economy should be akin to running the household budget, with yearly incomings more or less in reach of yearly outgoings. Too much of an imbalance promises financial doom for the householder, and when writ large, for the global economy as we know it. The most recent financial year saw Australia with a petroleum products deficit of \$10 billion, and an acknowledgement that this will grow to perhaps \$20 billion as domestic oil production depletes. For the biofuel analyst, this suggests a latent industry opportunity of \$10-20 billion dollars in turnover available for the taking immediately, a significant addition to the rural sector, where the entire turnover in 2008 was worth \$24 billion²⁴.

But that's for the simple-minded. For the gnomes from the Federal Treasury, the yearly trade deficit of \$68 billion (6% of GDP) and the net international debt of \$600 billion (54% of GDP) are deemed the "outcomes of consenting adults making rational decisions" and thus judged defensible and sustainable. In a macro-sense they are said to reflect a robust belief by the international capital accumulators of Australia's continuing good fortune, so much so that indebtedness is projected to rise to nearly 90% of GDP, and still not increase the anxiety of decision makers. Attacks on this conventional wisdom are difficult to sustain when so much of the national psyche is driven by borrowing from tomorrow to spend today. The immediacy driving today's trade deficits and international debt levels, conspires to lessen the urgency for the bio-methanol transition and might require Australia to be on the brink of a meltdown crisis before it is properly considered.

Which transport technology will win the race?

Energy realists²⁵ remind us that power and propulsion systems change slowly over timescales of centuries. An internal combustion motor has little opinion as to whether ethanol, methanol, butanol or DME is injected into the combustion chamber. As the carbon neutrality transition happens, engine designs that can handle cocktails of fuels probably confer most fluency and robustness. Thus this article's preference for methanol not ethanol may be less important than the decision on transformation methods; that is, definitely thermochemical and probably not biochemical.

The case is made here for wood-to-methanol systems by thermochemical means because it is a continuous rather than a batch process²⁶, has high energy-to-energy conversion rates, and requires little water separation. Interestingly, a mix of alcohols makes engine combustion more controlled and less explosive than a 100% alcohol fuel and is further enhanced by some petroleum for lubrication. Today's wood-to-ethanol gasification systems preferentially produces more methanol than ethanol on the first pass through the synthesis chamber, as well as some three to five carbon mixed alcohols. Furthermore, different mixes of alcohols are required for summer and winter conditions.

From a technical standpoint, the fuel choice comes down to how well vehicle engines perform, the carbon neutrality of the entire system or well-to-wheel life cycle, and the fluency and speed of the wood-to-alcohol transformation process. In total, these physical parameters will drive the economic outcomes and thus consumer acceptability. The primary issue is developing enough stock of purpose-grown biomass to meet national transport requirements.

Systematic change for Australia's economy

As the year 2008 unfolded, those who viewed traditional economic theory operating in a globalised market place as the ultimate of confidence tricks were rewarded intellectually for their insights. They were, however, probably penalised for not being rich. In a world where perversity rules, how otherwise could governments reward failed bankers who did not protect their capital base, as well as carmakers that stayed locked into their embrace of 1970s technologies?

Australia's answer was to promote a Christmas boost to consumption and thus emissions, while designing greenhouse reduction solutions rewarding the industrial polluters who had corrupted government decision processes and extolled climate science as dangerous 'deep green' mythology. Australian consumers, the real drivers of greenhouse emissions, were beguiled by promises of lifestyle maintenance and conscience-salving programs of light bulb retrofitting and household solarising. Given the seeming perversity of policy directions where 'laggards mostly win,' proposing a systematic and revolutionary change to core parts of the nation's energy metabolism, seems therefore, something of a fool's errand, but something needs to be done.

Given current perversity, forest industries and their technologists might find optimism and strategy difficult to contemplate and thus fail to plan big for a future of wood-derived transport fuels. Month to month survival may be a reality for the next five years. Nevertheless industry strategists need to prepare and develop four areas:

- Policy's new found appreciation for bio-sequestration should be lauded by forest lobbyists, but only as a route to a sufficient feedstock supply to replace fossil carbon with biological carbon for bio-alcohols and bio-electricity;
- The contribution of forest wastes and thinnings should be used to test the feasibility of the fuel cycle. This achieved, planning and promotion should embrace energy security to 2050 and beyond, with an added focus on righting our trade balance. Enterprises such as Willmott Forests and Ethtec could promote their technical investments as the forerunner of 500 or more such plants that will power Australia into the new economy;



While this analysis uses a generic mallee type for the drier farming lands, Australia's domestic genetic resource has only been fleetingly developed for biofuel uses. Using the best endemic plants for each region offers a powerful economic incentive for augmenting our stocks of biodiversity.

- Industry planners should run their rule over most of settled Australia with a primary focus on selecting development regions where community opportunity requires enhancement, biodiversity needs improvement and where commodity production is export-focused and distant from domestic markets. Futurists indifferent to conventional economic wisdom see the current fragilities as the first death rattles of a globalised marketplace driven by continual growth. The alternative vision combines modest self sufficiency, a more resilient economy and environment, and quality development rather than volumetric consumption;
- Finally, industry's expertise with integrated paper and wood plants should be refocused on 'energyplexes' of the future, producing bio-alcohols, bio-electricity, bio-char, green chemicals, local employment and regional value-adding.

How to find a long term champion for this multi-product wood-based energy economy is perplexing given the 24 hours media cycle based on micro-snippets. If it takes a multi-pronged crisis to bare the skeleton of our predicament, then the sooner we have it the better for the nation long term. Strategically, the forest and wood industries should have well-prepared answers.



References

- 1 Wang M, Wu M, Huo H and Liu J (2008). Life cycle energy use and greenhouse gas emission implications of Brazilian sugarcane ethanol simulated with the GREET model. *International Sugar journal* 110,1317,527-545.
- 2 NFF (2008). Agriculture; Out of the CPRS but not out of the woods. National Farmers federation Press Release, 15th December 2008. <http://www.nff.org.au/read/2462749929.html> accessed 7-1-2009
- 3 Cleveland C.J. (1999). Biophysical Economics: From Physiocracy to Ecological Economics and Industrial Ecology. In *Bioeconomics and Sustainability: Essays in Honor of Nicholas Georgescu-Roegen*, J. Gowdy and K. Mayumi, Eds. (Edward Elgar Publishing, Cheltenham, England), pp. 125-154.
- 4 Shell Oil (2009). Mahogany Research Project: Doing Oil Shale the Right Way. http://www-static.shell.com/static/usa/downloads/about_shell/upstream/icp_factsheet.pdf accessed 7-1-2009
- 5 Commonwealth Government (2008). A New Car Plan for a Greener Future. 30pp. 10th November 2008. <http://www.innovation.gov.au/automotivereview/Documents/NEWCARPLANGREENERFUTURE.pdf> accessed 11-11-2008
- 6 O'Connell et al. (2007). Biofuels in Australia –Issues and prospects. A report for the Rural Industries Research and Development Corporation <http://www.rirdc.gov.au/reports/EFM/07-071.pdf> accessed 11-11-2008
- 7 Phillips S, Aden A, Jechura J, Dayton D and Eggeman T (2007). Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. National Renewable Energy Laboratory Technical Report NREL/TP-510-41168, April 2007, 132pp. <http://www.nrel.gov/docs/fy07osti/41168.pdf> accessed 26-08-2008
- 8 Subramani V and Gangwal SK (2008). A review of recent literature to search for an efficient catalytic process for the conversion of syngas to ethanol. *Energy and Fuels* 22,814-839.
- 9 He J and Zhang W (2008). Research on ethanol synthesis from syngas. *Journal of Zhejiang University SCIENCE A* 9,5,714-719.
- 10 Atkinson D and McDaniel J (2008). Honey, I shrunk the hardware. *TCE Today* November 2008, p42-43. <http://www.tcetoday.com/tcetoday/overview.aspx> accessed 16-12-2008
- 11 Range Fuels (2008). Technology. Web Site. <http://www.rangefuels.com/technology> accessed 17-11-2008
- 12 Low T and Booth C (2008). The Weedy Truth About Biofuels. Invasive Species Council Melbourne March 2008, 46pp. http://www.invasives.org.au/downloads/isc_biofuels_revised_mar08.pdf accessed 9-1-2009
- 13 Plantations 2020 (2005). Protecting and enhancing biodiversity in a plantation landscape. <http://www.plantations2020.com.au/assets/acrobat/GTRPCBiodiversityCaseStudies.pdf> accessed 9-1-2009
- 14 PIRSA (2002). Farm Forestry: Designing for Increased Biodiversity, Adelaide Hills and Fleurieu Peninsula. South Australian Government 2002, 24pp. <http://www.mlrfp.asn.au/files/Biodiversity.pdf> accessed 9-1-2009
- 15 RIRDC (2006). Joint Venture Agroforestry Program R & D Plan 2004-2009. RIRDC Publication 06/039, 33pp. RIRDC Publication <http://www.rirdc.gov.au/pub/06-039.pdf> accessed 9-1-2009
- 16 Scorecard (2008). The Pollution Information Site. Chemical Profiles-Hazard Rankings-Ethanol http://www.scorecard.org/chemical-profiles/hazard-indicators.tcl?edf_substance_id=67-56-1 accessed 17-11-2008
- 17 Scorecard (2008). The Pollution Information Site. Chemical Profiles-Hazard Rankings-Ethanol http://www.scorecard.org/chemical-profiles/hazard-indicators.tcl?edf_substance_id=64-17-5 accessed 17-11-2008
- 18 Winebrake J, He D and Wang M (2000). Fuel cycle emissions for conventional and alternative fuel vehicles: An assessment of air toxics. Argonne National Laboratory Report ANL/ESD-44, August 2000 87pp. <http://www.ipd.anl.gov/anlpubs/2000/11/37718.pdf> accessed 16-11-2008
- 19 Zhang Z, Che W, Liang Y, Wu M, Li N, Shu Y, Lui F and Wu D (2007). Comparison of cytotoxicity and genotoxicity induced by the extracts of methanol and gasoline exhausts. *Toxicology in Vitro* 21,1058-1065.
- 20 Vermillion B, Nguyen P and Tsan E (2001). Feasibility Study of Methanol as Transportation Fuel. Project Report by Methanol Conversion Group. <http://chemelab.ucsd.edu/methanol01/Feasibility.htm> accessed 18-11-2008
- 21 Semelsberger TA, Borup RL and Greene HL (2006). Dimethyl ether (DME) as an alternative fuel. *Journal of Power Sources* 156,497-511.
- 22 Samaras C and Meisterling K (2008). Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: Implications for policy. *Environment Science and Technology* 42,3170-3167.
- 23 Parks K, Denholm P and market T (2007). Costs and emissions associated with plug-in hybrid electric vehicle charging in the Xcel Energy Colorado service territory. NREL Technical report NREL/TP-640-41410 may 2007, 24pp. <http://www.nrel.gov/docs/fy07osti/41410.pdf> accessed 2-7-2008
- 24 ABARE (2008). Australian Commodity Statistics 2008. http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.pdf accessed 8-1-2009
- 25 Smil V (2008). Moore's curse and the great energy delusion. *The American Magazine Online*, November 19th 2008, 5pp. <http://www.american.com/archive/2008/november-december-magazine/moore2019s-curse-and-the-great-energy-delusion/> accessed 25-11-2008.
- 26 Wei L, Pordesimo LO, Igathinathane C and Batchelor WD (2008). Process engineering evaluation of ethanol production from wood through bioprocessing and chemical catalysis. *Biomass and Bioenergy* doi:10.1016/biombioe.2008.05.017 in press and currently published online.