

New Zealand's energy future

Table of Contents

New Zealand's Energy Future.....	2
Appendix One – Tidal & Hydro Synergy.....	6
Appendix Two – Diesel from Biomass: Land Requirement.....	8
Appendix Three – Other Technologies.....	10
Appendix Four – Yield Comparison: BGFTS Diesel and Cellulosic Ethanol.....	12
Bibliography.....	13

New Zealand's Energy Future

The Prime Minister has said she wants New Zealand to become carbon neutral. It seems reasonable to expect that a document purporting to outline a strategy for New Zealand's energy future would lay out a roadmap toward a sustainable, carbon-neutral, and nuclear-free energy system.

Powering our Future fails to do this.

I suggest we begin with one or more realistic energy futures which meet the desired goal. These will act as reference scenarios which will be a useful guide to the social, economic, political, and diplomatic costs and benefits of success. There is, after all, little point planning to fail.

If some other, as yet, unknown, scenario later becomes technically feasible, then it can be compared with the reference scenarios. Perhaps, in the light of new technology, it may be desirable to change some policy settings, perhaps not. But the policy will always be working toward the desired goal.

In the case of New Zealand's energy future, the goal has been defined. It is clear that some economic adjustment will be required as we work toward that goal. For example, we know that the civilised world is increasingly accepting that climate change can be mitigated by reducing or eliminating the use of fossil fuels. This trend will almost certainly lead to a levelling off, and perhaps even a reduction, in the demand for coal, oil, or gas from the Western countries. Whether or not this potential reduction will be enough to offset the rapid growth in fossil fuel demand from fast-growing economies such as China is unclear. However, we know that if demand for coal, oil, and/or gas begins to fall, prices will fall much more rapidly than demand.

It is also apparent that biofuels tend to be more expensive than fossil fuels. Oil may, or may not, be cheaper in 2030 than it is at present, but for strategic reasons, it will be undesirable to base our energy system on oil. By setting itself the goal of achieving a carbon-neutral energy system, New Zealand is turning away from this potential opportunity. There are very good reasons for doing so, which is why carbon-neutrality is the goal.

These ideas suggest very strongly that the New Zealand economy will have to adjust to the economic changes brought on by the change to a sustainable energy system, irrespective of what energy sources we use. The interesting question is not, *what will energy cost?* because we know it will probably cost more than it does at present. The interesting question is *how will we get enough energy, and what do we need to do to ensure that we will have enough energy when we need it?*

This submission describes an energy future that, on present information, is known to be technically feasible, and is capable of meeting the projected needs of New Zealand society in 2030. The technologies upon which this scenario is based have been selected because they satisfy the following criteria:

- The technology requires no new scientific discoveries and draws on well-proven techniques.
- In the New Zealand environment, the technology has the potential to supply sufficient energy to achieve a truly carbon-neutral energy system
- The technology should be consentable

The first criterion is vital. Scientific discoveries cannot be scheduled, because there is never any guarantee that research will successfully discover what it seeks. Science can be described

as searching through a haystack to see if it contains a needle. It is never clear whether there is a needle to be found, which is perhaps, the most exciting and intriguing aspect of scientific research.

This means that although pie-in-the-sky technologies may be very interesting to New Zealand scientists, they cannot contribute be included in practical plans. There may be uncertainties in the process of building a new power station, but if that power station employs technology that is known to work, then at least the uncertainties can be managed.

This submission describes a scenario covering the two major segments of New Zealand's energy system: electricity and transport.

To achieve a carbon-neutral electricity supply, New Zealand must replace or modify the portion of its existing generating capacity which relies on fossil fuels, and it also requires about 3.4 GW of additional generating capacity¹. A cluster of tidal power stations in Cook Strait, managed synergistically with existing hydro-electric power stations, can easily achieve this goal. The technology comes from two well-established sources: naval architecture, especially as it relates to submarine design; and oil exploration. This concept is described in Appendix One.

A carbon-neutral transport system requires total replacement of the 3.24 million tonnes of petrol and 3.127 million tonnes of diesel expected to be consumed in 2030². By adopting a technique I shall refer to as Biomass-Gasification-and-Fischer-Tropsch-Synthesis (BGFTS), New Zealand can readily achieve this goal. BGFTS is a three stage process: biomass gasification; Fischer-Tropsch (FT) synthesis of synthetic petroleum; and the refinement of that petroleum into petrol, diesel, and jet fuel. The last two stages have been in use since the early to mid-twentieth century. FT synthesis is used to manufacture synthetic fuel from coal and natural gas. The conversion of synthetic petroleum into petrol, diesel and jet fuel employs well-proven oil-refining techniques, the major difference being that FT synthetic petroleum yields mostly diesel and jet fuel, with a relatively small proportion of petrol.

The biomass gasification process is presently being scaled up from pilot to commercial scale by Choren Industries, based in Germany. A Finnish company, UPM-Kymmene, is also investing in a BGFTS diesel facility. As with tidal power, no new inventions are required to bring this technology to commercial reality. Appendix two outlines the application of BGFTS technology to New Zealand's energy system.

It is possible to describe an energy future based on these two technologies. In this future, electricity will be relatively more abundant than at present, even allowing for the increased demand.

A promoter of a Cook Strait tidal power station has claimed that their system will produce electricity at a cost somewhere between that for coal, and hydro-electric power. If they can substantiate this claim, then in real terms, electricity costs need not consume a greater share of GDP than they do today.

Because BGFTS favours diesel, diesel cars would be ubiquitous. Fortunately, clean-diesel has already advanced to the point where we can be assured that these diesel cars will produce negligible smog. Petrol will be too scarce to supply a significant proportion of the transport system, although small amounts would be available, possibly enough to supply small engines like outboard motors, lawnmowers, and chainsaws, provided that these small engines did not have to compete with a motorcar fleet for fuel. Some LPG would also be

1 Based on 2005 generating capacity of 8539 MW (MED, 2006c: 29). This is expected to increase by 40% by 2030 (MED, 2006a: 7).

2 2006 consumption of petrol (2,400,000 tonne) and diesel (2,316,290 tonne). This is expected to increase by 35% by 2030 (MED, 2006a: 7).

available, possibly sufficient to assure the gas barbecue of its place in Kiwi backyards.

Cost projections for BGFTS are necessarily uncertain, however, it seems that fuel costs will consume a bigger share of the average New Zealand household's income in 2030 than they do today. It has been observed, however, that the demand for fuel is relatively inelastic, and so it is quite likely that New Zealanders will absorb this economic adjustment with little long-term change in their general patterns of behaviour, especially since it is very unlikely to be as radical as the sharp increases in fuel costs during the 1970's and early 1980's. This suggests that in 2030, New Zealand's transport system will be very similar to today's, assuming that roading improvements keep pace with the growth of the vehicle fleet.

Several much-publicised future technologies have not been included in this scenario. This is because these "technologies" await new scientific discoveries before they can be considered technically feasible. Although the promoters of these technologies often claim that the requisite scientific discoveries will soon be made, these claims should be dismissed as extravagant and unprovable. There is no proof that these future technologies will be any more advanced in 2030 than they are today (see Appendix Three).

On the other hand, we know for sure that an energy future based upon synergistic tidal & hydro power and BGFTS diesel is not only technically feasible, it will permit the traditional Kiwi lifestyle to continue largely unchanged. Electricity has not been abundant for at least a decade, but the Cook Strait tidal resource is big enough to promise electrical abundance. Diesel cars are wowing the critics. After blitzing petrol entries in the the 2006 Le Mans series, Audi's diesel sports cars have returned to take the first race in the 2007 Le Mans series, at Sebring. By 2030, it seems, clean-diesel cars are likely to satisfy the flamboyant, as well as the frugal.

This energy future is almost certainly consentable, even under the RMA as it now stands. Tidal turbines suitable for Cook Strait are mounted well below the surface, so that they are not subject to the potentially damaging forces of waves. This means that they do not present a hazard to shipping, and that they create no visual pollution.

Feedstocks for BGFTS can come from specially grown crops, or they can come from green waste. The land use calculations in Appendix Two show that New Zealand can replace its projected diesel and petrol requirements by committing to fuel crops about 13% of the land which is currently used for farming or forestry. This is a worst case estimate, since it ignores the potential for making BGFTS diesel from waste biomass.

This scenario depends on two of New Zealand's unique characteristics. The Cook Strait tidal resource is unique. There are few tidal streams, anywhere in the world, which offer such a large and concentrated source of tidal energy. As a bonus, the transmission lines that carry hydro power from the southern lakes to the northern population centres cross Cook Strait very close to where these tidal power stations would be located. This existing infrastructure would eventually require upgrading, but that is likely to be less expensive than constructing new infrastructure for remote power stations such as wind-farms.

BGFTS can support our transport system because we have a relatively low population density, which means we don't have to commit a large proportion of our productive land to fuel crops. In comparison, Choren Industries have estimated that BGFTS would supply only about 25% of Germany's diesel requirements.

Some clear conclusions can be drawn from this scenario. In the electricity sector, tidal/hydro synergy requires an appropriate governance structure which can control the production from tidal and hydro power stations.

In the transport sector, BGFTS diesel requires that the New Zealand vehicle fleet be

progressively converted to diesel. Because this might seem radical, an alternative scenario has been explored in Appendix Four. This is based on the possibility that cellulosic ethanol could become a practical reality, allowing petrol to be replaced with ethanol. As in the BGFTS scenario, an ethanol-based future requires that the vehicle fleet be entirely replaced, in this case with vehicles capable of running on pure ethanol. However, as pointed out in Appendix Three, the practical realisation of cellulosic ethanol requires a scientific breakthrough that may never happen.

It is clear that New Zealand will need to dedicate a significant proportion of its productive land to biofuel crops, and that it will need to change the make-up of its vehicle fleet. The opportunity cost of doing this must be weighed against two direct benefits: the elimination of the need for imported oil; and the avoidance of carbon emission charges.

Powering our Future fails to achieve its goal, but the document can be rewritten. This submission outlines one approach by which a practical energy strategy can be developed that will provide useful guidance for policy-makers as they make the difficult decisions that must be faced if the New Zealand way of life is to continue in its present form up to, and beyond, 2030. It outlines one practical scenario. The challenge for the authors of *Powering our Future* is to find other scenarios that achieve the goal of a sustainable, carbon-neutral, and nuclear-free energy system, while promising less economic and/or social rebalancing than the Tidal&Hydro / BGFTS scenario outlined here.

Appendix One—Tidal & Hydro Synergy

To replace its thermal power stations, New Zealand requires about 2.2 GW of carbon-neutral generating capacity. It also needs an additional 3.4 GW to cover the expected growth in demand by 2030. This means we need a total of 5.6 GW of new capacity. This is well within the capabilities of the Cook Strait tidal resource.

The promoter of one particular scheme for harnessing this resource, Neptune Power Ltd., has estimated that it is technically feasible to extract an average of about 7 GW. This appears to be conservative. It is based on the application of machines which were designed for much smaller tidal streams. It is quite likely that this company, or a competitor, will be able to increase the capacity of the machines, which would improve the potential yield from this resource. However, it is quite clear that the 5.6 GW target is achievable.

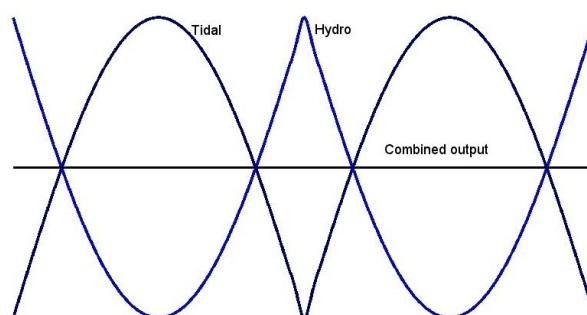
Tidal power is the most reliable of all renewable energy sources. The tides flow continually, and unlike wave, hydro, or wind, they are almost entirely unaffected by weather conditions.

Normally, the Cook Strait tidal flow is very approximately sinusoidal, changing direction approximately twice every 24 hours. Occasionally, it is subject to storm surges, which can result in the tide running in the same direction for long periods of time. It appears, however, that even in the most extreme storm surge conditions, the average energy output would be relatively unchanged.

Because of the predictable fluctuations in output from a tidal power station, it is necessary to design and manage the wider electricity generating system so that other energy sources work in harmony with the tidal resource.

This is the underlying principle of tidal/hydro synergy. Twice per day, the tidal power stations will run at maximum output, and twice per day, their output falls to zero. The hydro-electric stations adjust their output so that the total generating capacity remains constant.

The following diagram illustrates the approximate variation of tidal energy over a twenty-four hour period. The pale blue curve shows the amount of hydro energy required to produce a constant output from the combined tidal/hydro system.



This simplistic model of tidal/hydro synergy does not take into account the role of wind and wave power stations. Clearly, however, if electricity is available from wind, wave, and tidal power stations, it is desirable to use that electricity while it is available and to save the hydro resource for times when the output of wind and wave power stations is low. In general, tidal power stations should always run at maximum available capacity

To make tidal/hydro synergy a real part of New Zealand's carbon-neutral energy system, it will be necessary to boost the generating capacity of existing hydro stations. This is because their duty cycle will necessarily be reduced. It does not require the construction of new

dams. It does require the existing dams to be fitted with extra generators.

In principle, each MW of tidal capacity requires approximately one MW of extra hydro capacity to make this synergistic system work.

Tidal power stations located in Cook Strait will be significantly different to the type of tidal power stations envisaged for small harbours such as the Kaipara. One of the most notable differences is that the turbines are located in midwater, at least 30-40 metres below the surface and well above the bottom.

Shallow water tidal power stations require a different type of turbine, and these tend to obstruct the channel, leading to significant ecological, navigational, and aesthetic impacts. There is no doubt that NZ can obtain some of its energy from these sources. However, they are not large enough to satisfy the entire requirement, and under the existing RMA it will be difficult to obtain consents for such schemes.

For Tidal & Hydro Synergy to become a reality, it will be necessary to establish a governance structure covering the Cook Strait tidal power station(s) and the existing hydro-electric power stations, which is able to ensure that these power stations work together. It will be desirable, from the perspectives of risk management and energy security, for several power stations to be constructed in the Cook Strait area, and this suggests that the governance regime should be independent of the management of individual power stations. It seems, therefore, that Government involvement will be justified.

Appendix Two—Diesel from Biomass: Land Requirement

A large body of reputable scientists claim that biofuels offer a solution to the climate change problem. The basis of this idea is that burning biofuels does not involve adding extra carbon to the biosphere, whereas burning fossil fuels involves digging up carbon that had been permanently sequestered.

The critical question with biofuels is *how much land must be allocated to fuel crops?*

By 2030, New Zealand will need the equivalent of 3.24 million tonnes of petrol and 3.127 million tonnes of diesel to run its transport system. The Biomass-Gasification-and-Fischer-Tropsch-Synthesis (BGFTS)³ system can satisfy this need.

The BGFTS process can draw its feedstock from specially grown crops, or it can use agricultural, forestry, or urban waste. In order to estimate the potential land requirement, this document uses a biomass yield of 15 tonnes/ha/yr⁴, and ignores the potential contribution from waste streams.

The Fischer-Tropsch process produces a light, synthetic petroleum that consists predominantly of middle distillate, which is used for diesel and jet fuel. It has a relatively low proportion of the lighter hydrocarbons required for petrol. For this reason, a transport system based on BGFTS would favour diesel and gas-turbine (jet) engines.

Like all Fischer-Tropsch diesel, BGFTS diesel will be high in paraffins and olefins, and low in the less desirable aromatic hydrocarbons. Because it is a high-quality hydrocarbon fuel, existing diesel and jet engines will not need any modifications to use BGFTS fuel.

However, like the low-sulphur diesel presently available at New Zealand filling stations, BGFTS diesel will require a lubricity additive. In order to ensure that the transport system is entirely carbon-neutral, it is desirable that fuel additives are made from biomass rather than from fossil petroleum. The most promising candidate for a biomass-based lubricity additive is the FAME group of chemicals, which are made from vegetable oils or animal fats and sold as “biodiesel”. Unfortunately, the term “biodiesel” has also been used for BGFTS, as well as for synthetic diesel made by hydrogenating animal fats. For this reason, I have avoided this term.

It has been shown that an FAME content of six percent is sufficient to satisfy the European specification for diesel lubricity. The main feedstocks used for manufacturing FAME in New Zealand are tallow and rapeseed (canola). It has been estimated that New Zealand can produce up to 107,000 tonnes of FAME from tallow⁵. The FAME yield from canola crops is 640kg/ha⁶.

By 2030, all types of cars, SUVs, and light commercials will be available with clean diesel technology. However, there may be some small engines that still require petrol: for example, small outboard motors, lawnmowers, and chainsaws. Also, there will be a need for small amounts of aviation gasoline for light aircraft. I have assumed that five percent of the current petrol demand is used for these purposes, and that this element of the demand will grow by 35% by 2030. This means that around 162,000 tonnes of petrol will be required.

3 BGFTS manufacturers use a variety of names for the fuel. The Finnish company UPM call it *second generation biodiesel*. Choren industries, of Germany, market it under the tradename *Sundiesel*.

4 Judd, 2003: 24.

5 Judd, 2003: 24, 41. Based on 115,000 tonnes tallow/yr (pg. 24), and a tallow methyl ester yield of 932 kg per tonne of tallow (pg. 41).

6 Judd, 2003: 35.

Diesel engines are, on average, thirty percent more efficient than petrol engines⁷. Corrected for the small difference in net calorific value, 781 kg of diesel will replace a tonne of petrol⁸. Replacing 95% of the projected 3.24 million tonnes of petrol required in 2030 will take 2.404 million tonnes of diesel, in addition to the project diesel requirement of 3.127 million tonnes. In total, we will need 5.531 million tonnes of diesel. To allow for possible uncertainty in the percentage of FAME required as a lubricity additive, this land use estimate allows for an FAME content of seven percent.

Based on these figures, it is possible to estimate the amount of land required to grow the fuel crops which will power our transport system in 2030:

Fuel	Component	Quantity tonnes	Yield t/ha	Land area hectares	Total land area
Diesel	BGFTS Diesel	5,143,830	3 ⁹	1,714,610	
	FAME (from tallow)	107,000	-	-	
	FAME (from canola)	280,170	0.64	437,766	
	Total diesel	5,531,000	-		2,152,376
Petrol	BGFTS Petrol	162,500	3		54,167
Total		5,693,500			2,206,543

This is a worst case scenario. It is based on conservative estimates for fuel yield. For example, Choren Industries claim a yield *exceeding 4 tons per hectare*¹⁰. It also ignores the potential for waste biomass to be used as a feedstock.

According to Environment Ministry figures, about 17.3 million hectares of New Zealand land is used for farming and forestry¹¹. To supply our transport fuel requirements, about 13% of this land would need to be converted to fuel crops.

This land use estimate may be used to compare the opportunity cost of the BGFTS diesel scenario with other practicable transport fuel scenarios, if such alternative scenarios can be found.

In order to make this option into a reality, Government action would probably be required in two areas:

- Car, SUV, and light commercial vehicle buyers would need to be given very strong incentives to purchase clean diesel vehicles. These incentives would need to be sufficiently powerful to ensure that clean diesel technology achieves a 95% share of the new vehicle market by around 2015, so that normal turnover ensures that petrol vehicles form a negligible proportion of the total vehicle fleet by 2030.
- There may be some justification for investment incentives to ensure that adequate supplies of BGFTS diesel are available by 2030. This is less important than ensuring that the vehicle fleet changes over to diesel, as BGFTS diesel is practically interchangeable with diesel made from crude oil.

⁷ MED, 2006b: 57.

⁸ Using EERE figures for net calorific value of petrol (43.44 MJ/kg) and diesel (42.784 MJ/kg).

⁹ Choren, 2007 gives 200kg BGFTS per tonne biomass(pg. 15).

¹⁰ Choren, 2005: 6.

¹¹ <http://www.mfe.govt.nz/publications/ser/ser1997/html/chapter8.3.html>

Appendix Three—Other Technologies

In preparing this document, I have rejected several highly publicised technologies. These are listed below, with the reasons for rejecting them:

Wave Power

Although New Zealand has abundant wave energy resources, there are serious concerns about the environmental impact of wave energy systems. Promoters of wave energy have been pressing for changes to the RMA. The present document confines itself to systems which would be consentable under the existing legal environment.

Carbon Capture and Storage

Some scientists have expressed reservations about the technical feasibility of capturing carbon dioxide from the exhaust streams of coal-fired power stations. This suggests there could be a risk that, after constructing new coal-fired power stations, the carbon capture system proves ineffective. This would leave New Zealand in the undesirable position of either running these power stations without capturing and sequestering the carbon dioxide, or else scrapping them.

A second concern is that carbon sequestration represents an on-going hazard. Carbon dioxide sequestration may be compared with underground sequestration of nuclear wastes. However, an important difference is that nuclear waste becomes less hazardous as time goes on. Carbon dioxide does not decay.

Accidental release of sequestered carbon dioxide poses two threats: first, because it is heavier than air, the gas suffocates all animal life (including humans) in the area surrounding the leak.

Second, a large-scale leak could materially influence the carbon dioxide concentration in the atmosphere.

Considering that carbon sequestration is technologically unproven, and considering the associated risks, it has not been considered in this document.

Cellulosic Ethanol

Ethanol is a proven substitute for petrol. Because of its high octane rating, it has been used in motor-racing for almost a century.

Ethanol is normally distilled from a variety of feedstocks, however, the earth does not have enough land to grow enough feedstocks to power the world's car fleet with ethanol made by this method.

Cellulosic ethanol is widely promoted as a solution. However, the practical realisation of cellulosic ethanol awaits the discovery of a suitable enzyme. New Zealand scientists are participating in this fascinating and exciting search. However, there is no guarantee they will be successful. Also, given the nature of scientific research, even if such an enzyme is eventually found, it is impossible to say when this might happen.

For this reason, cellulosic ethanol cannot be considered a viable option.

Hydrogen

Hydrogen can be used as a transport fuel, either in internal combustion engines, or in hydrogen fuel cell vehicles. Numerous scientific discoveries are required to solve the problems of fuel storage, and to make the fuel cells competitive with diesel engines in terms of ruggedness and longevity.

It is, of course, impossible to say when such discoveries might be made, but it is widely accepted that hydrogen will not be a viable transport fuel by 2030.

Appendix Four—Yield Comparison: BGFTS Diesel and Cellulosic Ethanol

If the cellulosic ethanol manufacturing process ever becomes a practical reality, then it might seem that ethanol would be a practical alternative to petrol. After all, it has been well-proven as a racing fuel, and is a popular alternative to petrol in Brazil and the US.

The following analysis assumes that of New Zealand's projected petrol requirements in 2030 would be replaced by ethanol. BGFTS would be able to satisfy the diesel requirement, with FAME diesel used as a lubricity additive, as for the analysis in Appendix Two.

Because ethanol has a significantly lower calorific value than petrol, it takes 1.6 tonnes of ethanol to replace one tonne of petrol¹². The higher octane rating permits a slight increase in compression ratio, which can give a slight improvement in fuel efficiency, **provided that the vehicle is specifically designed for ethanol fuel**. The following analysis assumes that, by 2030, New Zealand's entire fleet of petrol-driven vehicles has been specifically designed for ethanol, and that this has the effect of reducing fuel demand by 5% (an optimistic assumption).

As in Appendix Two, the projected demand for petrol is taken as 3.24 million tonnes, which is equivalent to 5.184 million tonnes of ethanol. Assuming the fleet is composed of vehicles which are optimised for ethanol, this would be reduced to 4.925 million tonnes of ethanol.

The projected demand for diesel is taken as 3.127 million tonnes, composed of 93% BGFTS and 7% FAME, as in Appendix Two.

Also, as in Appendix Two, the biomass yield is taken as 15 t/ha/yr. The conversion yield is taken as 295 kg ethanol per tonne of biomass¹³. This leads to a yield of 4.425 tonnes of ethanol per hectare per year.

Fuel	Component	Quantity tonnes	Yield t/ha	Land area hectares	Total land area
Diesel	BGFTS Diesel	2,908,110	3	969,370	
	FAME (from tallow)	107,000	-	-	
	FAME (from canola)	111,890	0.64	174,828	
	Total diesel	3,127,000	-		1,144,198
Petrol	Ethanol	4,925,000	4.425		1,112,994
Total		8,052,000			2,257,192

Note that a transport system based on BGFTS and cellulosic ethanol involves the distribution of a considerably higher total fuel tonnage than one based on BGFTS alone (see Appendix Two).

It must also be noted that this land use estimate is based upon the projected yield of a process that has not yet been demonstrated at a large scale. The figures should be treated with considerable caution.

¹² Using EERE figures of 26.947 MJ/kg for ethanol and 43.44 MJ/kg for petrol.

¹³ Judd, 2003: 44.

Bibliography

- Choren, 2005 Blades, T.; Rudloff, M.; & Schulze, O.: Sustainable SunFuel from CHOREN's Carbo-V® Process. Stuttgart / Ostfildern, Germany: Choren Industries GmbH, 2005.
- Choren, 2007 Advanced Biofuel for Transport- BTL-Technology, Environmental Impact and Market Access. Stuttgart / Ostfildern, Germany: Choren Industries GmbH, 2005.
- Judd, 2003 Judd, B.: Feasibility of producing diesel fuels from biomass in New Zealand. Wellington, NZ: Energy Efficiency and Conservation Authority, 2003.
- MED, 2006a Draft: Powering our future - Towards a sustainable low emissions energy system. Wellington, NZ: Ministry of Economic Development, 2006.
- MED, 2006b New Zealand's energy outlook to 2030. Wellington, NZ: Ministry of Economic Development, 2006.
- MED, 2006c New Zealand energy in brief: March 2006. Wellington, NZ: Ministry of Economic Development, 2006.