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NEW ZEALAND CENTRE FOR ADVANCED ENGINEERING

Liquid Fuels Trust Board

Review and Commentary

Report for the EnergyScape Research Programme
NIWA Science

January 2009

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Acknowledgements & Statement of Interest

The contribution of John Duncan, Consultant, Wellington, in peer reviewing the report is gratefully acknowledged. Both George Hooper (1978-84) and John Duncan (1979-81) are former staff members of the Liquid Fuels Trust Board. Views expressed in this report reflect the personal experience and opinions of the author.

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Introduction

The EnergyScape project funded by the Foundation for Research, Science and Technology is a collaborative research programme that has as its aim the development of an evaluation framework for future energy policy and research investment.

The programme is led by NIWA Science and involves research contributions from Scion, CRL Energy, GNS Science, IRL and their associates[1].

One of the clearest messages heard from the EnergyScape steering committee and stakeholder engagement meetings is that energy planning in New Zealand must learn from previous endeavours and not continuously 're-invent the wheel'. As was discovered, this should consider both the framework within which energy is delivered to a nation and the investigative/institutional approach adopted in meeting defined needs.

To demonstrate the value of this approach the EnergyScape team commissioned the New Zealand Centre for Advanced Engineering (CAENZ) to undertake a review of the relevance and applicability of the previous Liquid Fuels Trust Board (LFTB) activities to the current New Zealand context. The review was intended as a commentary on specific aspects of the LFTB work including:

- Review of LFTB findings.
- Consideration of the relevance and applicability of the large body of technical information assembled by the LFTB to the current New Zealand context.
- Assessment of LFTB methodologies for priority setting.
- The Board's role in establishing expert and knowledgeable people and its function in promoting local capability to enhance professional and commercial practice.
- Modus operandi of the LFTB and supporting institutional arrangements.

It is intended that the review be reported in the EnergyScape *"Summary of Findings"* document, yet to be published.

[1] See www.niwascience.co.nz/ncces/projects/energyscape for more about the EnergyScape project

Learning from the Liquid Fuels Trust Board

The Liquid Fuels Trust Board (LFTB) was established under the Liquid Fuels Trust Act 1978 and came into being in October 1978 with the mandate to "promote encourage, finance, undertake and cooperate in any activity that had as its purpose, or one of its purposes, the reduction of the use of transport fuels for transport purposes in New Zealand". The organisation operated over a period of nine years during an era of significant international uncertainty on future oil supplies and considerable national attention to energy matters.

During this time the Board was responsible for some 400 plus commissioned studies and in-house reports that, together, significantly enhanced New Zealand's knowledge of its indigenous energy resources, and the technologies for their conversion and use as transport fuels. As well, the Board left behind a valuable legacy of technical information and insight on the NZ transport fuels system and, a cadre of experienced professionals well informed on energy matters and national policy formulation.

The span of it the board's activities covered the production and conversion of natural gas to transport fuels, assessments of peat, lignite, agricultural biomass, forest biomass and wastes as transport fuels sources through to examination of the use of tallow esters, methanol, LPG and CNG as substitute fuels. Such a comprehensive body of information is recognised internationally as being unique in both its scope and breadth of analysis, and offers future researchers and policy analysts important insight into the nature and extent of New Zealand energy resources as well as the practicalities of their conversion and possible implementation.

Of critical strategic importance, however, was that arising from the LFTB work the New Zealand government took action and supported investment in alternative fuel's options that resulted in the country shifting from being 85 percent dependent on foreign oil for its transport fuel needs to becoming almost 60 percent self-sufficient; a transformation at country level that remains unique in the modern era.

This transition was not solely due to the work of the LFTB[2] but the role it played in the reshaping of New Zealand's energy infrastructure and the frameworks it employed in determining both priorities for investigation and the studies that underpinned decision making offer important lessons that have continuing relevance to today's energy situation. The decisions taken at the time affected not only the performance of the energy system but had also an enduring effect on New Zealand's competitive position in an emergent global market place.

Background and need for the LFTB

Before reviewing the legacy of the LFTB it is important to understand the background to its formation and how its mandate came about.

The aftermath of the 1973 Arab-Israeli war lead to an extensive period of uncertainty in international oil supply. This period of the so-called "oil shocks" coincided with the development of the Maui gas field which, when discovered, was one of the largest natural gas fields in the world. The economic fall-out for NZ of the increasing price of crude oil meant that the cost of imported products to New Zealand increased from 5 percent of export earnings in 1970 to more than 20 percent by 1974.

Government, in consideration for gaining a 50 percent stake in the Maui Development (though the Offshore Mining Company Ltd), was committed to a 30-year take-or-pay agreement signed by the Labour Government in 1973. The primary intended target for this gas was electricity generation, which at the time was carried out exclusively by a government department.

By the late 1970s it was evident that the forecast use of natural gas for electricity generation was unlikely to be realised because of the economic conditions in the country, and thus the proposal was made to allocate the expected unused portion of the take-or-pay natural gas to replace imported oil. Early work undertaken by a government think tank - the Interdepartmental Committee on Petrochemicals - led to the concept of creating an expert group free from bureaucratic constraint and with the autonomy to choose its own mode of operation to bring together the technical and resource information required to secure for New Zealand its future transport fuels needs.

Whilst the immediate objective of the Board's work was to address the Maui gas issues, its work in due course evolved into a three-phase programme to address broader opportunities for the supply and utilisation of transport fuels:

- *Phase 1:* the detailed early assessments of what to do with Maui Gas which lead to the recommendations to the Minister of Energy in October 1979 for the manufacture of Synthetic Fuels via the Mobil MTG process, plus the separate development of a stand alone methanol plant, and a reduction in the size of the planned Marsden Point refinery expansion to accommodate the synthetic petrol from the Mobil plant as well as including a hydro cracker as the basic conversion unit.
- *Phase 2:* a long term investigation programme and research strategy to address the question on how New Zealand might best increase the degree of self-sufficiency above the anticipated 50-55 percent level the initial decisions were expected to achieve, and
- *Phase 3:* which focused primarily on the potential for near term commercialisation and deployment of transport fuels options driven in part by the accumulated knowledge and understandings that was derived from the ongoing research programmes.

The structure and role of the LFTB

The LFTB was established by Act of Parliament and consisted of three appointed members together with the four heads of government departments, namely; Energy, Treasury, Trade & Industry, and the Deptartment of Scientific &

[2] It is also important to acknowledge the contribution and work of the New Zealand Energy Research and Development Committee (NZERDC) formed in 1974 by the then Labour Government in association with the signing of the US/NZ Joint Agreement on Scientific and Technological Cooperation. Over its thirteen year life the Committee undertook forefront work on CNG implementation and research into energy efficiency and improved energy use across the various sectors of the New Zealand economy.

Industrial Research. The Board's finances derived from a levy on the wholesale sales of liquid fuels, set at one-tenth of a cent per litre (approximately NZ$3.25 million per year).

Under its founding legislation the Board was established as a body corporate with perpetual succession and a common seal, and was capable of acquiring, holding, and disposing of real and personal property, of suing and being sued, and with the necessary powers to carry out is functions. This mandate extended not only to the promotion, financing and undertaking of research and investigations into alternative transport fuel opportunities but also to the financing, undertaking and cooperating in the installation or improvement of plant and equipment in New Zealand for the efficient and economical supply, processing, distribution, storage and use of petroleum, alternative indigenous fuels and alternative means of propulsion.

From the outset, the Board establish an executive arm (the Programme Management Group) made up of technically qualified individuals capable of designing, implementing, managing and evaluating the required investigations; with the Board maintaining oversight on the investigation programmes and responsibility for recommendations to the Minister of Energy in respect of its work.

At its height the Programme Management Group comprised seven technical personnel headed by a Technical Director and supported by an administrative and clerical staff of four headed by a Director of Administration. The day-to-day work of the Board focused on the management and execution of contracted studies, and reporting on the results of its investigations.

The Board's statutory functions allowed it a wide discretion in determining appropriate subjects for investigation. However, by precedent, the Board essentially limited its scope to subjects or desired actions that would have a significant consequential effect on imported fuel substitution. This encompassed not only the technical and economics effects of fuel substitution options but also assessment of the social and environmental effects associated with such alternatives.

Basis for programme formulation and execution

The information requirements for commercial decision-taking are broad, multi-faceted and generally highly interactive. Basic to the LFTB's investigational strategy was that all reasonable options should be kept open; and that specific options should only be closed off if they were demonstrably unreasonable; either for technical, economic or social reasons.

Whilst not formally adopted a stage gate process typified the investigational approach taken to development planning so as to ensure that the full range of options available were properly canvassed and that the "state" of technological/commercial maturity was adequately defined. This required that the Programme Management Group had a high degree of technical competence available to it within the management team members and that options were themselves broadly tested.

There was also a need for flexibility in order to be able to respond to changing circumstances and government decisions, and to ensure the ability to respond to advances in technology as they arose or improved knowledge of the indigenous resource base. It must be remembered that this was a period of significant scientific and engineering advance in alternative fuels technologies.

Important factors that guided of Board's decision making on future direction included:

- the relative technical and economic merits of alternative options;
- diversity of sources of energy;
- diversity of routes of conversion;
- sustainability;
- efficiency of conversion;
- effects on employment and regional development; and
- promotion of national security.

In addressing the question of how best to increase the level of self-sufficiency the Board took account of:

- the attainable levels of substitution;
- time scales for achieving the desired targets;

- the effects of changes in demand with time;
- the effect of depletion of the Maui gas field with time; and
- the means by which further substitution may be achieved.

A key criterion applied to the forward strategy adopted by the Board was the goal that natural gas utilisation should be constrained to a rate which would limit depletion of the Maui field to about 50 percent by 2000 so as to allow for further exploration, discovery and development of potential additional gas resources before Maui depleted.

In line with this view, natural gas supplies were expected to be in decline by about the year 2010 and thus an earliest goal for New Zealand to look for 100 percent substitution was set at around the year 2000; which timeframe offered a sufficient window of opportunity for the introduction of further self sufficiency measures should there be no further gas discoveries and the Maui gas field declined over time.

This goal of 100 percent self sufficiency was not seen as a policy goal but as a strategic vision against which the Board's research programmes could be timed and designed.

An important objective of the Board's programme was to encourage the early involvement of commercial interests in the development and implementation of technology where this was in the national interest with relevant programmes of investigation structured in such a way so as to be "taken over" by other interests once sufficiently advanced.

For projects at the point of implementation there were, at times, *ad hoc* interventions to promote or participate in the implementation of alternative fuels options if such assistance was deemed desirable and assistance could be demonstrated as being cost effective or where Government retained some areas of responsibility in the roll out and utilisation of alternative fuels. This was particularly so for the CNG and LPG implementation programmes.

However, the Board's role was essentially confined to the pre-competitive stages of development with research requirements generally concentrated on narrowing down development options to a select number of preferred options and carrying out the associated resource evaluations.

The LFTB investigational approach

The LFTB's investigations were directed towards specific defined objectives and emphasised the work required to bridge the gap between scientific research and implementation with studies targeting critical areas where there was insufficient information for confident decision-making. The Board's Programme Management Group retained close links with DSIR and other Government departments and had access to related work or investigations from these sources and, thus, was able to avoid duplication of effort or ensure that its work built upon existing knowledge.

In evaluating a fuel substitution option it was recognised that a variety of different questions may need to be addressed. With relation to development of an indigenous energy resource for transport fuels manufacture, the Board's view was that the following information should be established:

1. The extent and characteristics of the resource.
2. The feasibility of resource recovery.
3. The technical feasibility of fuel production on a commercial sale.
4. The economic feasibility of fuel production and utilisation.
5. The sociological and environmental acceptability of fuel production and utilisation.
6. The availability of the necessary infrastructure requirements and workforce availability.
7. The factors involved in implementation of any option and initial strategies for that implementation.
8. The compatibility of the alternative fuel with the contemporary and forecast transport fuels supply system.

The above did not need to be addressed in chronological order; instead the Board's strategy was to:

1. identify the areas of primary importance in determining the viability of an option;
2. establish a general framework within which to conduct the overall programme of investigation. Such a framework would generally incorporate designated review points;
3. commission and conduct the studies within the several areas of investigation identified so that information enabling evaluation at each of the review points was available at a given point of time; and
4. on conclusion of the programme to prepare a summary report as a basis for recommendation to Government.

Board experience reinforced the importance of anticipating early those issues likely to affect development. This was particularly so when undertaking the various studies that led to the development of a Government strategy for the utilization of natural gas for transport fuel. An awareness of the critical issues ensured that the analysis net was cast sufficiently widely to provide the fullest possible information on termination of the programme.

Finally it was well recognised by the Board that the introduction of any new transport fuel is vitally dependent on its public acceptance, and the general compliance of vehicle manufacturers and suppliers. However advantageous introduction of any particular fuel may seem from a national benefit perspective, its introduction will not be successful without public acceptance and strategies in place for managing the downstream risks of technical obsolescence or changed economic/environmental conditions.

In its programme planning therefore the Board often made the point that ultimately the "doing of the project" was better in the hands of those who had the capacity to carry a significant share of the market risks involved.

A subsequent Treasury review[3] of the public sector equity involvement in the major projects embarked upon by Government in the late 70s /early 80s expresses the view that the most appropriate approach for Government was to ensure that a commercial environment exists in which the incentives facing firms lead to consumption and investment decision on their part which also correspond to the national interest.

In the Treasury view, if the Government is expected to accept a greater financial risk than the private sector is prepared to bear, then the question must be asked as to whether the project being proposed is indeed in the national interest.

The LFTB's investigative legacy

In summary, the LFTB left a huge legacy of technical analysis and factual information on the NZ transport fuels system, as well as a considerable literature, analysis and data describing this country's primary energy sources for conversion to transport fuels, and the range of options available for commercial implementation or fuel's substitution.

This coverage necessarily was not evenly distributed as emphasis was given to those transport fuels routes that were identified as having the greatest potential for commercial exploitation in the near-to-medium term. In addition considerable emphasis was given to determining the nature and structure of the transport system to provide a sound basis for the implementation of any possible future fuel substitution option.

The Board's programmes were thus divided into five major areas of investigation:

- fuels from natural gas and petroleum;
- fuels from coal and related materials;
- fuels from biomass and wastes;
- fuel utilisation (including alcohol fuels, fats and oils and electric vehicles); and
- transport system data and analysis (including implementation).

In formulating its programme of work the LFTB based its work on a number of major premises that both reflected the reality of the day (circa 1980) and the considerable uncertainty in supply and demand forecasts for the, then, forward 10-15 years. The outlook at the time, or at least until 1985, was for a continuation of high oil prices and petrol being the primary

[3] *Review of the Major Projects*, Report to the Minister of Finance, The Treasury, 22nd November 1984.

constraint in the transport supply mix, reflected in large margins between petrol and crude oil prices.

The following assumptions were thus instrumental to the Board's thinking:

- No new discoveries of crude oil would be made in New Zealand over the planning horizon.
- No new major discoveries of natural gas, again, during this period.
- No major changes in vehicle propulsion technology will occur.
- Options for the production of indigenous transport fuels should constitute the best use of the resource, taking into account social, political and strategic aspects.
- An emergency situation in Transport Fuels supply would occur prior to the year 2000.
- Any new fuel must be compatible with the contemporary transport fuels supply system up to 2010.
- Priority should be given to transport fuel supply options which offer the opportunity for low-cost, short-term implementation as well as making a substantial contribution to self-sufficiency or to a vital sector of the transport fuels market (e.g. diesel for freight movement).

These assumptions were highly conservative but were deemed to be a prudent and pragmatic basis for research investment rather than any likely "desirable" future scenario. In simple terms the name of the game was energy security as this was where the national benefit was seen to lie. A core component was to maintain a state of readiness and awareness of the substitution options in which rapid substitution for the current fuel supplies might be best accomplished, and to identify possible ways of reducing demand.

The LFTB *Final Report of Activities* (report No LF6020) published in 1990 by the Energy Resources Division of the then Ministry of Commerce offers an excellent summary of the activity of the Board over its nine-year life. The assembled information provides succinct descriptions of the work undertaken and the key findings, but it is in the content of the Technical Reports and Contractor Studies where the bulk of the detail and knowledge lies.

Unfortunately, of the over 400 reports that arose out of the Board's investigation and investment in feasibility assessment, pilot testing, demonstration and the development of new knowledge there are only around 100 titles now held in public repositories throughout New Zealand. The bulk of these (some 67 reports) comprise the 2000 series Technical Summary reports and the 6000 series Programme Summary reports.

It is presumed that the former Ministry of Energy library holdings will be deposited somewhere inside Government. There will be, in addition, individual reports held by the original contractors or contributors to the technical work, but it is understood that David Natusch, the Board's last Technical Director, now holds the only complete set of LFTB reports.

Figures 1 and 2 (taken from the *Final Report of Activities* LF6020) set out the fuel production routes examined by the Board plus the estimated fuel supply, cost and potential contributions to NZ's transport fuel requirements.

The hierarchy defined by these diagrams reflects the emphasis on rapid deployment and major contributions. Notable is the absence of electric vehicles and ethanol derived from agricultural biomass from this future. The Board saw little prospect for electric vehicles because of technical limitations in battery technology and the lack of any technical infrastructure to support their introduction, and ethanol because the work of the Board showed that the opportunity value associated with conventional agricultural production was too great to support the widespread diversion of land to fuel production.

The following sections set out a synopsis of the key findings taken in part from the "*Summary Report of Activities*". (LF6020)

Fuels from natural gas and petroleum

Transport fuels options considered were the direct use of compressed natural gas (CNG), the use of LPG, the use of methanol (either as a 15 percent blend or near neat (85 percent plus)), the production of synthetic petrol and diesel from natural gas, the production of

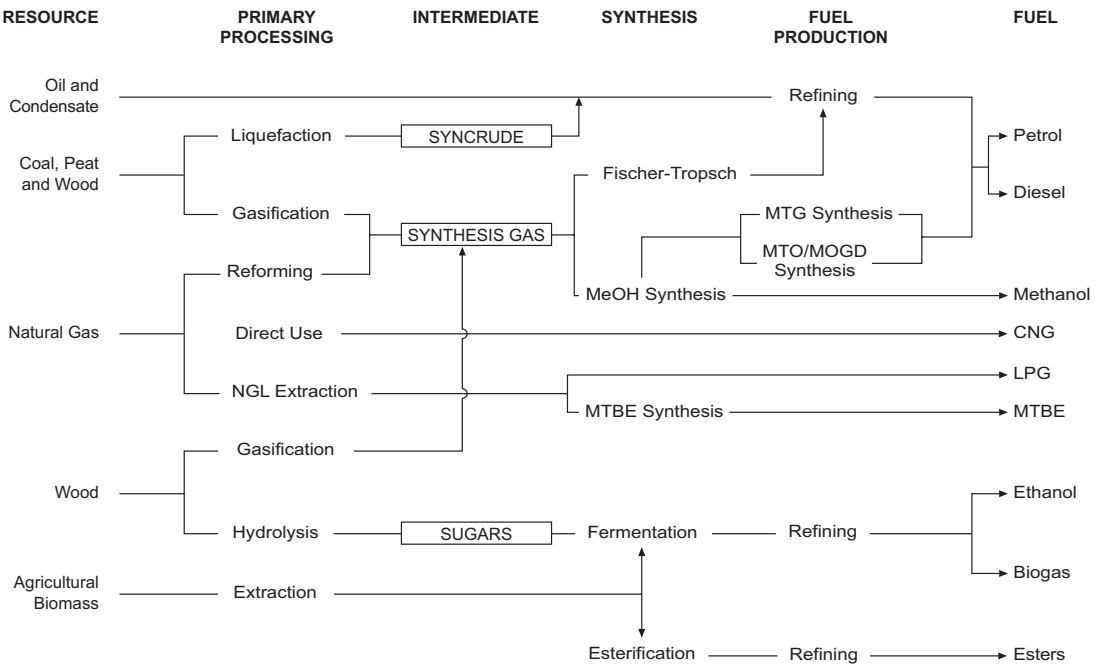

Figure 1: Fuel Production Routes (from LFTB report No. LF6020)

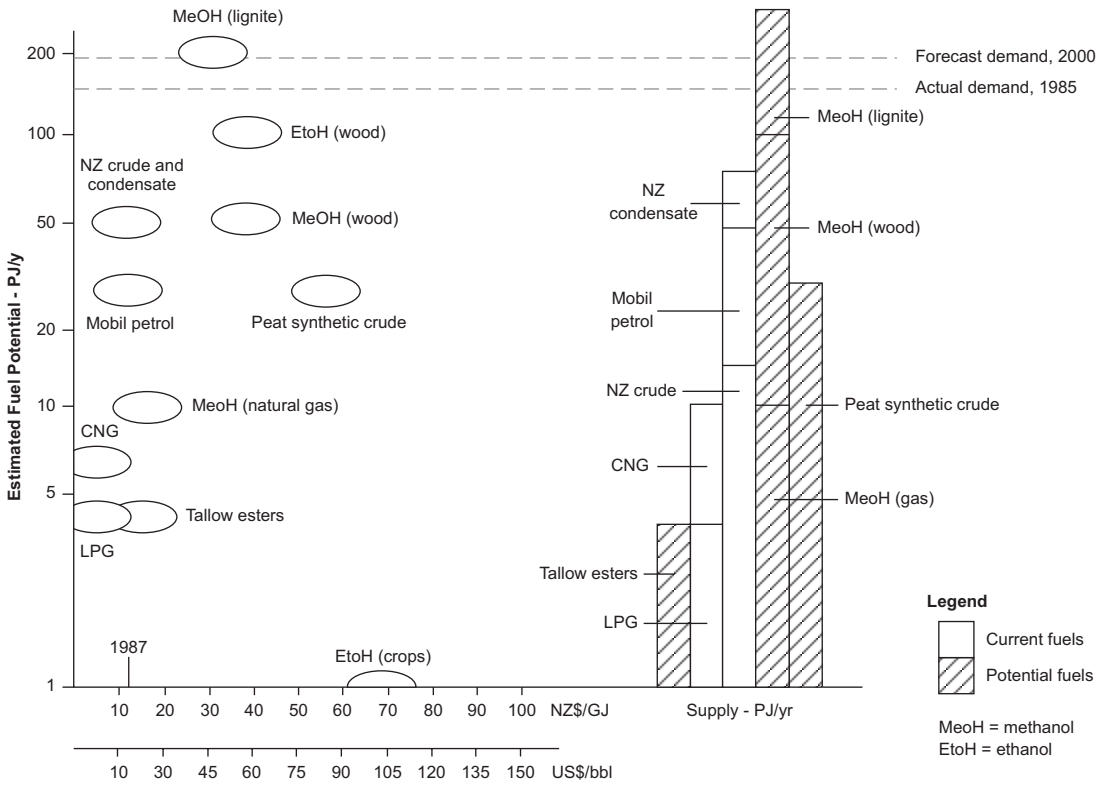

Figure 2: Transport Fuels Supplies, Demand and Costs (from LFTB report No. LF6020 – note logarithmic scale)

MTBE and synthetic avtur from natural gas liquids.

In these early studies emphasis was given to establishing the optimum mix of opportunities as an integral part of the development strategy for the Maui gas field and also to meet government's desire to reduce New Zealand's dependence on foreign oil for its transport needs.

The major findings of these studies are encapsulated into the recommendations that went to Government in October 1979 and reported in LFTB report LF2006. In essence the detailed engineering, refinery studies and economic assessments led to recommendations to allocate 50 to 60 PJ/y of natural gas to Mobil gasoline manufacture via methanol as well as an active Government promotion of CNG for transport use. The Board estimated that CNG and LPG together should be able to replace about 11 PJ/y of gasoline demand by 1985.

The Board took a very proactive stance in respect of facilitating CNG uptake, developing CNG metering tables, investing in the establishment of a CNG flow meter test facility, as well as undertaking a wide range of technical studies examining the performance and improved systems for duel fuel CNG/petrol and CNG/diesel operation. Whilst the work of the Board showed that the conversion of diesel engines to CNG operation could be accomplished without any deleterious effects, from a technical stand point it was considered that the use of CNG or LPG as a diesel substitute offered the greatest potential when using purpose-built natural gas vehicles.

The recommendation for the Mobil process over the competing Fischer Tropsch synthesis route was predominantly due to Mobil synthetic petrol being more compatible with the NZ transport fuels market and the recommended optimal refinery configuration. Detailed examination of the natural gas liquids processing options demonstrated a significant national benefit from their extraction and upgrading to higher value products, with the manufacture of MTBE from butanes for use as a petrol additive showing the greatest potential. Whilst subsequent consideration was given to this, and other upgrade options, by a number of commercial parties a business case for investment was never realised.

In addition to synthetic fuels production, the Board investigated the production of petrochemicals from natural gas both as a means of adding value to the gas as (predominantly) export products and to help mitigate the take or pay obligations and produce more condensate by the increased consumption of gas. A wide range of options were considered from utilising the full gas stream, ethane or heavier components. The Board subsequently recommended the building of methanol production capacity for export and its potential to provide methanol as a transport fuel if that option were to be favoured at a later date. As a result of this recommendation, the Waitara methanol plant was constructed.

Fuels from coal and related materials

LFTB investigations in this area focused predominately on the lignite coals of Southland and Otago. In addition to this work, however, there were also two other significant studies; the first involved a study of the potential for pyrolysis of Huntly coal to extract coal liquids and subsequent utilisation of the pyrolysis char as feedstock to the sponge iron process utilised at the NZ Steel manufacturing plant. The second area of study was the pyrolysis of Chatham Island peat, again for the manufacture of synthetic crude.

As part of its expansion plans then under consideration NZ Steel proposed the use of multi-hearth furnaces for devolatisation of the Huntly coal at the front end of its iron making plant. The volatile gases recovered from the furnace where then used for fuel and steam raising within the plant. The concept examined was to replace the multi hearth with pyrolysis to extract valuable liquids with the residual char going to iron sands reduction. However, it was shown that whilst a pyrolysis process was technically feasible the additional refinery costs for upgrading the pyrolysis liquids and likely difficulties associated with integration of pyrolysis within the proposed steel plant energy systems meant that investment was unlikely to be justified.

Large deposits of peat exist on the Chatham

Island. Preliminary studies were undertaken with Fletcher Challenge to better prove the peat resource and assess the prospects for peat development. The process scheme envisaged involved the pyrolysis of the peat for crude oil manufacture with the residual char from the pyrolysis process used to dry the peat for processing, including tests on drying and retorting of the peat material. A major study on the environmental and social issues suggested a number of significant issues related to the likely scale of such an enterprise, which whilst resolvable might limit the amount of peat that could be economically recovered.

Investigations of the South Island lignite resource extended over almost 6 years. The work included a wide range of studies covering deposit geology, resource and reserve estimates, mining assessments, lignite quality, conversion methods, engineering evaluations, infrastructure requirements, pre-feasibility studies and environment and sociological issues. The work is described in various reports, totally almost 80 in all. There were in addition significant additional data deposited with Crown Minerals related to down-hole logging and geological assessments.

The work was undertaken in two phases. The Phase 1 study included extensive fieldwork and investigation of ten major deposits (identified by earlier government exploration) as well as process selection studies designed to establish the potential for development of these resources to produce transport fuels. The key findings from these investigations were that at least five of the deposits could support the development of a major project and that it was in the national interest to proceed with further more detailed investigation of a select number of deposits to enable a full feasibility assessment study to be undertaken.

The second phase focused on the short listing of the deposits (Hawkdun, Benhar and Ashera-Waituna) followed by further extensive evaluation of their potential conversion to either methanol or Fischer -Tropsch liquids via lignite gasification, with consideration also given to the direct liquefaction conversion route.

This work led to recommended preferred lignite to methanol project based on the Ashers-Waituna deposit and producing 2.4 million tonnes of fuel grade methanol per year from 12.1 million tonnes per year lignite. A total capital cost of NZ $4.5 billion (1987 dollars) was estimated for the project with an annual operating cost of NZ $600 million. The required selling price of methanol for the most favourable case identified was assessed at $550/tonne, at a real internal rate of return of 10%.

Whilst this proved not to be an economic proposition against prevailing prices at the time, the studies clearly established that a lignite conversion project based in New Zealand could offer similar returns to those indicated for like ventures overseas, and that lignite conversion remained an important potential opportunity for New Zealand.

It is worthy to note, that over the recent past, increasing world oil prices has once more attracted commercial interest in the lignite deposits and there has been significant studies undertaken by commercial interests examining their future use for conversion to either fuels or chemicals. The LFTB work has been of major importance to these studies and has formed the backbone of the geological and mining assessments undertaken. The engineering studies have largely been superseded by technological advance and improvement in the conversion technology; in particular gasification and Fischer-Tropsch catalyst technologies (which are now tailored specifically for diesel production).

Mining approaches would nowadays also be significantly different from that envisaged in the LFTB studies. However, again, this work was important in establishing the engineering requirements for such a project and the key risk elements influencing mining costs.

The findings from the two phases of activity are fully described in Report LF2028 *"Lignite as a Source of Liquid Transport Fuels in New Zealand"* (Phase 1) and Report 2043 *"Lignite to Methanol Fuel - Deposit Selection Studies Final Report"* (Phase 2).

Fuels from biomass and wastes

The LFTB recognised the potential importance of biomass as a source of alternative transport fuels. These sources included forest biomass, agricultural crops, and waste materials. In

addition fats and oils derived from animal or vegetable matter were also considered potential fuels on their own right.

In considering agricultural crops it was the Board view that production of ethanol from agricultural biomass was likely only to be economically viable if the feedstock was extremely cheap, or if the associated by-products had a sufficiently high value that would offset processing and feedstock costs. To this end, in its early, work the Board undertook extensive planting and processing studies involving a number of fodder crops (maize and lucerne) and sugar beet. It also pursed a limited study investigating the enzymatic conversion of high cellulose residues from lucerne fibre to sugar for subsequent conversion to ethanol. The results of these trials established that production of ethanol from these materials was unlikely to be economic and the work was concluded.

The production of vegetable oils (in particular rape seed oil) gained considerable public recognition in New Zealand and the Board embarked on a number of studies examining the technical problems associated with the use of these fuels. This work established that rape seed oil could be used successfully as a diesel extender, but not as a neat fuel.

Forest-derived biomass offered another resource opportunity as it provided the availability of a significant resource base at low cost utilising the waste materials derived from conventional harvesting and processing regimes. To this end a number of initial studies were undertaken concentrated on resource measurement and conversion technology. The primary focus was on gasification of wood to produce synthesis gas although investment was also directed to the development by Forest Research of a novel process, which combined the production of ethanol from wood with anaerobic digestion of the residual hemi-celluloses to biogas as a co-product from the process. This process was taken to pilot plant stage but ultimately proved uneconomic.

Whilst the work concluded that forestry could make a potentially significant contribution to transport fuels supply, there were significant uncertainties tied to technology maturity and competition for supply from conventional timber markets. The emergence of an international log market and new markets for reconstituted fibre products placed increasing pressure on waste residue availabilities.

The most significant work in the programme area was the Board's assessment of the conversion of animal tallow to methyl esters as a diesel substitute. Tallow esters (TME) offer a higher effective cetane number than conventional diesels and thus the potential for increased refinery margins. The Board's work encompassed:

- pilot scale development of the TME production and purification technology;
- development and testing of TME/diesel blending characteristics; and
- engine test and vehicle trials.

The production costs of TME were found to be primarily dependent on the international market for glycerol - a by-product from the process - and work extended to defining the likely impacts on world glycerol markets from the development of a tallow ester industry in New Zealand.

Examination of this work offers an excellent case study of the considerations required to introduce a new fuel type into the market. The research effort and investigations were supported by the extensive expert knowledge that resided with the technical staff of the LFTB through their active involvement in vehicle fleet trials and technical development of other alternative fuel solutions, thus providing a benchmark against which the performance of TME as a fuel blend could be appropriately measured.

It is clear from this work that TME/diesel blends could be used to substitute for diesel without any observable effects on vehicle performance, that long term storage of the blend was at least equal to and generally better than the neat fuel, engine performance was essentially indistinguishable from using pure diesel, exhaust emissions were generally found to be equal or better. In other words the technical work was done fully, competently and to the satisfaction of users.

The failure of the fuel to move from trial to commercial implementation can simply be put

down to economics and the competition for the feedstock from alternative uses.

Fuel utilisation (including alcohol fuels, fats and oils and electric vehicles)

At the onset it was recognised by the LFTB that ethanol would have little use as a petrol blend stock in New Zealand due to unavailability of supply. For this reason methanol was the preferred choice because of its prospective availability and the capacity to divert methanol from the synthetic fuels plant if the economics or strategic imperatives so determined.

Consequently the Board pursued an active programme of investigation to assess the feasibility of utilising M15 blends and to gain practical experience in the blending, distribution and handling of the fuel. Whilst at the time a final decision was made not to proceed with the introduction of the fuel the possibility remained open to proceed with low methanol blends (combined with Tertiary Butyl Alcohol as a co-solvent) up to the 5 percent blend level.

In the longer term the Board envisaged the use of methanol-based fuels (greater than 85 percent methanol) as the most likely replacement fuel for petrol and diesel in New Zealand; combined with other alternatives as fuel pricing and energy policy might dictate. Substantive work was done to explore the technical and vehicle requirements for such an eventuality. An important attribute in support of the methanol fuels option was its capacity to substitute for both petrol and diesel, thereby maintaining refinery balances.

As already stated methanol, can be used in Otto-cycle and Diesel-cycle engines as a low-blend, high blend or neat. In respect of the low blend options the LFTB studies clear established that for the Otto-cycle an M15 fuel could be used satisfactorily with only modest changes to vehicle fuel systems susceptible to methanol attack and minor adjustments to carburation to improve performance. However substitution for just petrol could not be justified on a national basis because of the costs of distribution and likely refinery imbalances. Accordingly the Board gave priority to a number of studies designed especially to evaluate fleet operation of retrofitted petrol engines operating on M85 or neat.

With regards diesel substitution, possible approaches to operating diesel engines on methanol studied by the Board included the use of cetane improvers and emulsions as well as single vehicle trails of selected engine modifications. What was remarkable about these studies (as well as the evaluation of methanol fuel pathways) was the design of the experimental programme and the vehicle testing procedures undertaken.

In order to ensure validity in a real world situation four different testing approaches were undertaken:

- dynamometer testing to establish precise and reproducible performance over short periods under standardised conditions;
- single-vehicle testing designed to provide assessments of vehicle fuel characteristics (driveability, wear etc.) over a long period;
- fleet tests over long periods to provide statistically valid data on vehicle and fuel performance in selected patterns of use; and
- testing of vehicle fuel system components for compatibility with alcohol fuels.

This span and depth of analysis that was undertaken with these trials was unique and is in stark contrast, for example, with current assessments of the introduction of renewable energy forms into the NZ market - none of which have been subject to engineering evaluation, testing or extensive trials that was the hallmark of the LFTB work. To often today, so-called trials and implementation studies are run by people (whilst well intentioned) ill-equipped to undertake the depth of appraisal required to arrive at informed decisions.

Transport system data and analysis (including implementation)

The overriding factor for either accommodating a new fuel within an existing transport fuels infrastructure or introducing a permanent shift in vehicular type is having the national capacity to achieve implementation of the desire change and to establish the necessary institutional arrangements that can support introduction.

To this end the LFTB gave early recognition to

the need to have the modelling capability required to assess the impacts of different fuel types or changes in fuel demand patterns on the transport fuels system. Its forward programme of investigations gave effect to ensuring the in-house capability to provide:

- information on the structure of the transport fuel supply/demand system (e.g. fleet composition and dynamics, patterns of fuel use, operation of the Marsden Point refinery etc.);
- information on the distribution and logistics associated with fuels supply in New Zealand; and
- development of the required tools for the interpretation and analysis of input data arising from its technical studies.

It was recognised that much of this activity could well overlap with functions of the Ministry of Energy and thus to ensure consistency and a common approach a staff member from the Ministry was seconded into the Programme Management Group with responsibly for a number of these areas.

In particular the Board developed a linear programme model of the NZ Transport Fuels Supply system capable of modelling the operations and optimum configuration of the Marsden Point refinery. This model was calibrated against the in-house models deployed by SIPM and the Refinery Company and was used to support Government negotiations with the Refinery Company on the preferred configuration and scale of the refinery upgrade then taking place. A key criterion was to ensure sufficient flexibility in the refinery operation to accommodate synthetic petrol, CNG and other desired fuels substitution options.

Beyond this work, studies were instigated to examine the refinery economics related to the introduction of MTBE, methanol/ petrol blends and, amongst the many others, the potential eventual use of methanol fuels.

Additional contributions included development of the NZ vehicle/fuel use data base and detailed analysis of the drive patterns associated with the different transport modes. Other significant work included assessments of the modification of the national storage and distribution systems to handle alterative fuels and study of the economic effects of different distribution options.

An important outcome from this programme was the establishment and promulgation of a number of standards and regulatory codes of practise necessary to ensure the safe and efficient use of these new fuels. Also, through the engagement with the Ministry of Energy it was possible to assess and compare alternatives for the supply of energy on an on-going basis and thus contribute directly to the preparation of the national energy plan and a number of the other statutory planning functions of the Ministry.

Comparison with today's energy situation

The problem of oil supply dominated transport fuel strategy in New Zealand for over a decade following the first oil shock of 1973. In 1981, the time at which CNG was introduced into the fuel market, imported oil accounted for almost 50 percent of New Zealand's totals energy requirement and 85 percent of its transport fuels needs. Demand totalled about 165 PJ/y.

A comparison of the transport fuels mix at the time with current demand is given in Table 1. Notable is the significant reduction in fuel oil requirements and the variability seen in the relative petrol and diesel demand.

Setting aside the increased growth rate in fuels demand over the latter period (a probable legacy of cheap fuel) the increasing penetration of diesel into the road transport fleet and reduction in coastal shipping has seen diesel becoming a much more important fuel component in the modern era. The emphasis given by the LFTB on petrol substitution thus is probably of reduced relevance in today's world.

The growing demand for diesel (see Table above) is shifting the fuels market with middle distillates nowadays comprising close to 45 percent of world oil consumption. The production ratio of diesel to gasoline that one can manufacture from crude has a limit - and we are moving beyond this limit. This, in turn, is requiring more severe refinery operation and investment in new refinery technology. The decision, therefore, in 1981 to shift to a

	1981	1990	2007
Total Consumption (PJ/y)	165	178	272
Petrol/CNG/LPG (%)	47.5	58.2	48.4
Aviation Fuels (%)	7.9	8.2	5.6
Diesel (%)	27.8	28.2	43.0
Fuel Oil (%)	15.0	5.3	3.0
Petrol/Diesel ratio	1.71	2.06	1.13

Source: *New Zealand Energy Data File*, Energy Information and Modelling Group, Ministry of Economic Development, 2008

Table 1: Comparison of the transport fuels mix

hydrocracker configuration at the expanded Marsden Point refinery has served NZ very well, albeit this trend was not anticipated at the time. (This is one of the reason's that NZ can export its light waxy crudes and import heavy aromatic crude at an incremental refinery margin gain).

It is also worthwhile reflecting that diesel has a unique place in the fuels market because, over and above the shift towards diesel vehicles in the private transport fleet, industrial diesel is critical to many key productive sectors in the growing economies (especially agriculture in New Zealand). The scenario is for tighter supply and higher diesel prices worldwide. This should give emphasis to the need to secure investment in direct alternatives for diesel (such as Fischer-Tropsch (FT) liquids, bio diesel, and potentially methanol) unlike the 1980s where CNG and petrol substitution was the strategic imperative. There are also the added economic benefits to the country from operating with reduced refinery constraints.

The approach of the LFTB, which aimed at achieving fuels self-sufficiency and economic efficiency, contrasts with current policy settings and directions for meeting this country's future transport fuel requirements. Today's approach appears simply to look to extend current petrol and diesel supplies through the introduction of biofuels (and electric vehicles for urban travel), with strategy largely driven by environmental concerns and a desire to meet carbon emissions targets. Missing is an integrated strategy that takes full account of all aspects of the transport fuels supply system and utilisation.

Whilst important, energy policy cannot be driven purely by environmental needs alone. Such a strategy approach ignores the compelling realities of the global vehicle and fuel markets and the fact that countries not keeping pace with emergent trends will find that they do not have access to state-of-the-art transport technologies and the capacity to remain competitive in the international market place.

Final considerations

In conclusion, the LFTB's legacy is its technical information and the investigative approaches it adopted to bring together the requisite scientific, technical, economic, and institutional capacity required to support government and private sector decision making in respect of NZ's transport fuel supply and its transport system. The Board's influence went beyond just establishing the technical basis for fuels substitution but, importantly, through its expert capacity and technical leadership it established itself as a highly efficient and cost effective task force for meeting national goals.

Also, importantly, the Board was mindful of the role that it could play in bringing resource opportunities to a possible commercial project and properly focused its work at the pre-competitive stages of national decision-making; providing an independent and authoritative technical perspective on the supply, processing and distribution of alternative indigenous fuels for transport purposes in New Zealand, as well as alternative vehicle propulsion systems.

In this aspect the influence and commercial experience of the Board's. Chairman, Sir Colin Maiden, as well as the other private sector members of the Board should not be underestimated. Through their role the LFTB could engage with the energy business community at a meaningful level and cut through competing interest and conflicting agendas to present well thought out solutions and outcomes to the

Minister of Energy that could be implemented. The role of the various Head's of Departments was also important in ensuring national objectives were well understood and fully considered.

The effectiveness of the oversight thus provided by the Board, the alignment of its work with national strategy objectives, and its technical and policy contributions could well be used to inform present day research strategies.

It is also worthy of note that many of the individuals involved in the LFTB research and activities, including a number of its technical staff, established considerable international reputations for their contributions in these fields. Whilst this expertise has not been lost to New Zealand it is largely absent from much of our current CRI's and university energy research effort. This represents a significant loss of institutional history that at times appears to result in some of the current funded research effort seeking to re-invent the wheel.

In this respect there are a number of valuable lessons that can be taken from the ways in which the LFTB operated, namely:

- the Board's methodology for priority setting;
- its specific role in establishing expert and knowledgeable people capable of supporting a national action plan;
- its focus on applying rigorous; practical, innovative and experienced analysis; and
- its functions in promoting local capability to implement those options demonstrated to have merit.

The resultant success that the Board had in providing pertinent energy policy advice backed up by a substantial body of technical, economic and social information and analysis can be put down to a number of factors:

- The Board had a clear mandate to carry out this function, backed up by appropriate legislation and top-level representatives from key government departments. With this level of representation it was able to maintain close liaison with relevant government ministers and play an active part in decision-making. The Board always had relevance and an obligation to perform.
- The Board was sufficiently funded to carry out its programme and, importantly, to become world leaders in transport fuels technology through carrying out research and development programmes of its own and hiring in consultants of international standing. The funding allowed the Board to develop its own expertise rather than be reliant on other parties, providing it with significant credibility and originality.
- The status of the Board resulted in significant buy-in to its programme from the private sector. This was manifested by participation in some of the Board's programmes often at no cost, subsequent commercialisation of policies adopted by government and providing consulting services to the Board. The participation of industry in the programme enhanced the quality of the programme and improved the general level of expertise available to the New Zealand transport fuels and energy resource sectors.
- The Board had very clear objectives from the start and was able to develop a comprehensive work programme from an early date. It was dealing with tangible concerns such as the utilisation of Maui gas and a genuine potential for fuel supply constraints, which lent a realism and clarity to the work programme. The Board's priorities were set by it what it saw as being do-able within the near to medium term and did not pursue aspiration nor did it engage in blue-sky research.
- The Board adopted an objective and goal-orientated view of New Zealand's transport fuels options. Free from the operational constraints of a normal government department and with its own dedicated funding, it could operate independently of the government bureaucracy and provide unbiased advice that was respected by all stakeholders.
- Government played a much more participatory role in the energy sector prior to the deregulation process set in place by the government elected in 1984. This facilitated the implementation of many of the Board's initial policy recommendations.

A stage-gate process was employed commensurate with the information needs for a normal commercial investment decision. If, after assessment, options could not meet the requirements to move to the next stage of

development, then the work was discontinued. On the other hand there remained sufficient flexibility to adopt new lines of enquiry should circumstance dictate.

By maintaining a clear focus on the requirements for implementation, the technical issues required to be resolved before adoption and completion risk, the LFTB contributed significantly to government actions on improving New Zealand's transport fuel self sufficiency as well as doing much to improve this country's knowledge of its indigenous resources and the ways they could be utilised.

The current EnergyScape project has many of these dimensions. However, strategy for the project remains largely a negotiated outcome between the research providers and the Foundation for Research Science and Technology. Alignment with national energy policy or engagement with the government politic is not obvious.

There is also no obvious development pathway that can guide its science direction and thus the work is seen as being driven by science interests rather than offering a broader, more inclusive, national view.

The lesson from the LFTB experience would be to reconstitute EnergyScape into a different organisational structure, with an independent Advisory Board to provide oversight of the research effort and with a dedicated Research Management Team to establish the broad framework for the funded research effort. So doing would ensure an improved status, consistency of purpose, and adoption of a research methodology better aligned with national needs.

There is no reason within such a framework that the direction could be more aspirational than the pragmatism called for at the time of the LFTB work given the extraordinary pressures that then embroiled the New Zealand economy but, importantly, the desired output should be a focus on applying rigorous, practical, innovative and experienced analysis to current issues as well as development of the required tools for the interpretation and analysis of the information and data arising from the research.

Such a structure would do much to maximise the independence and efficacy of the EnergyScape programme.