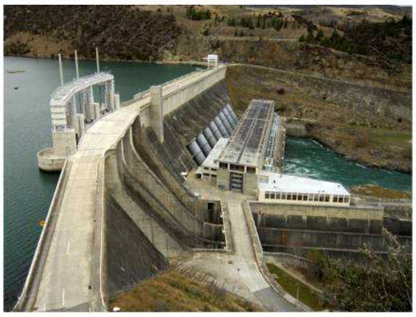
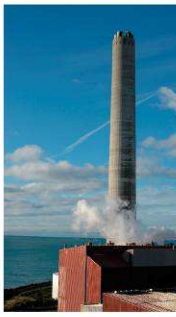
New Zealand's EnergyScape™



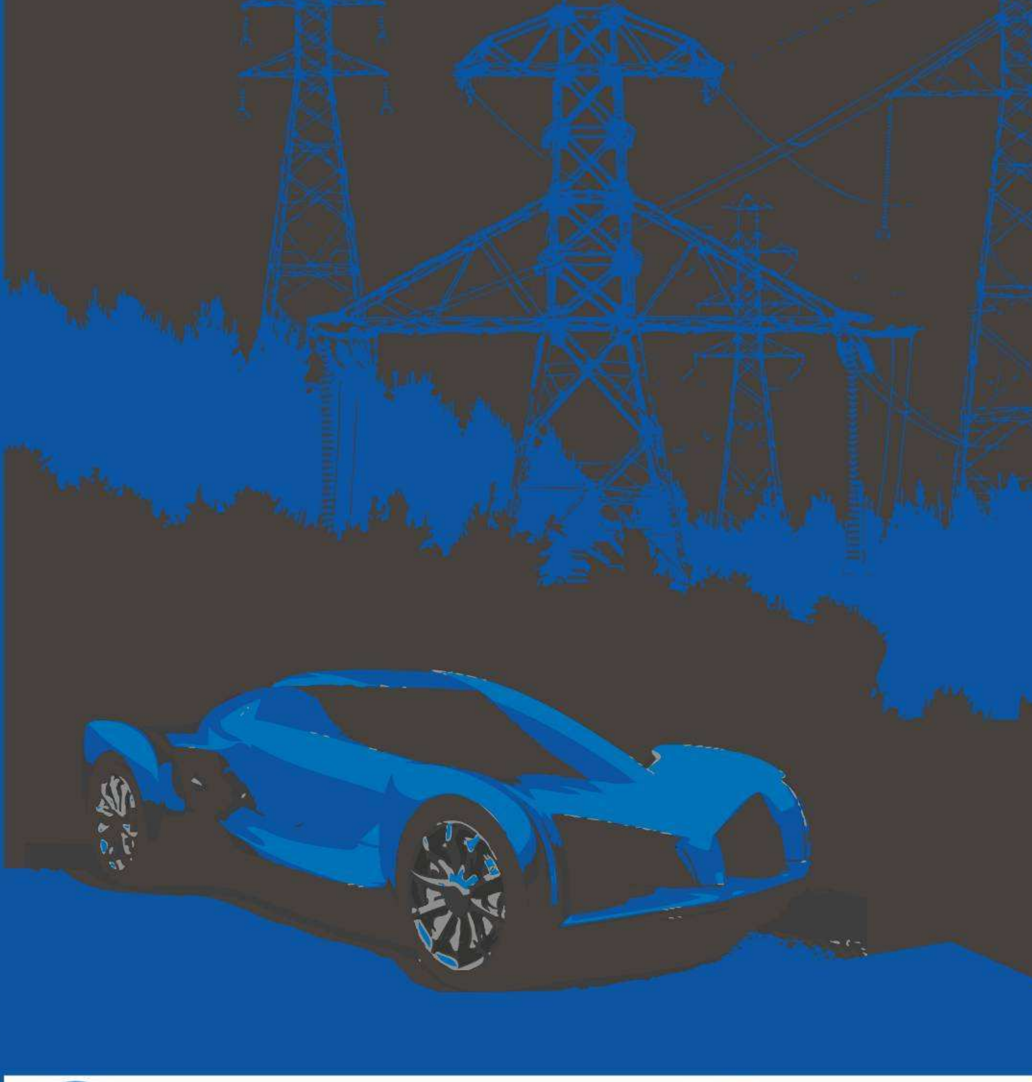




2000 2005 2030 2050

EnergyScape™ Programme Overview

August 2009



CRL Energy Ltd | INDUSTRIAL RESEARCH LIMITED IRL | SCION | GNS SCIENCE TE PŪ AO | NIWA Taihoro Nukurangi

EnergyScape™ Programme Overview

Authors

Rilke de Vos, NIWA

Prepared for

Foundation for Research, Science & Technology (FRST)

Project:

NZES091- New Zealand's EnergyScape

Document number:

AKL-2009-042

Publisher:

NIWA, Auckland
August 2009

Reviewed:

Georgina Griffiths
Senior Climate Scientist

Approved:

Ken Becker
Regional Manager - Auckland

NIWA Taihoro Nukurangi
41 Market Place
Auckland Central 1010
☎+64 9 375 2050
+64 9 375 2051
www.niwa.co.nz

CRL Energy Ltd
68 Gracefield Road
Lower Hutt
☎+64 4 570 3700
+64 4 570 3701
www.crl.co.nz

GNS Science Te Pū Ao
1 Fairway Drive,
Avalon, Lower Hutt
☎+64 4 570 1444
+64 4 570 4600
www.gns.cri.nz

Scion
Te Papa Tipu Innovation Park
49 Sala Street, Rotorua
☎+64 7 343 5899
+64 7 348 0952
www.scionresearch.com

Industrial Research Limited
69 Gracefield Road
Lower Hutt
☎ +64 4 931 3000
+64 4 566 6004
www.irl.cri.nz

TABLE OF CONTENTS

1. INTRODUCTION

The EnergyScape portfolio of programmes was funded by the Foundation for Research Science and Technology (FRST) in 2007. The broad aim of this suite of programmes was to enhance New Zealand's long-term energy system planning by developing an energy analysis framework and visualisation tools. These tools will help New Zealand to explore the potential energy pathway options, and dynamics that will ultimately drive New Zealand's energy future. More specifically, the portfolio of programmes aimed to:

- Quantify New Zealand's energy resources in a consistent and unbiased manner.
- Collaborate to provide a collective understanding of national energy data, and possible energy futures (scenarios).
- Provide a mechanism for science to inform the National Energy Strategy and help realise national objectives.
- Supplement the framework with detailed analysis of biomass opportunities and possible hydrogen futures.
- Identify outstanding energy research questions, the capabilities required to address them, and provide some basis for prioritising future research.
- Allow the development of an energy research strategy that aligns with government's strategic directions for energy.
- Make energy system understanding more accessible to the public, in particular: explaining conversion processes in accessible language.

The challenge of covering the technical complexity and the breadth of the energy pathways to be reviewed was addressed by forming an Energy Research Alliance of five key research providers - NIWA, Scion, CRL Energy, GNS Science and IRL – and the scope divided into three programmes.

EnergyScape™ (led by NIWA) developed the energy analysis framework tools and collated baseline data for all of the key New Zealand energy pathways that exist or may emerge;

Bioenergy options for New Zealand (led by Scion) collated information of what indigenous bioenergy opportunities exist, and developed a strategy for utilising these;

Transitioning to a hydrogen economy (led by CRL Energy) considered how hydrogen might best contribute to the New Zealand's energy system.

All programmes were very well supported by contributions from experts from across New Zealand, in particular: Landcare Research, Waste Solutions, Infometrix, HortResearch, Centre for Advanced Engineering New Zealand, University of Canterbury, Transfield Worley, Woodward Consulting, GeoSphere, Motu, Crown Minerals, Ministry of Economic Development, Energy Efficiency and Conservation Authority, amongst others.

2. RELEVANCE TO STAKEHOLDERS

Energy availability has very strong links to economic prosperity and environmental impact. Consequently, the formulation of national energy policy plays a key role in defining how New Zealand will cope with: volatility of commodity markets, societal and business expectations, and the demands of environmental care. Finding an appropriate balance between the numerous competing objectives requires vision and quality supporting information.

> **The next decade may well be one of energy crisis, or at least of competing energy planning objectives. Although it may be confusing, in the end, we really only have one objective – to sustain our quality of life.**
>
> **Don Elder, CEO Solid Energy**

New Zealand policy makers and planners (echoed by industry) have signalled that current tools for long-term, inter-regional planning are inadequate, and that there is need for visualisation tools that can inform the wider community of energy issues. This suite of programmes seeks to address this need by identifying and describing all energy pathways[1] relevant to New Zealand's future.

This programme has relevance to a wide range of stakeholders (see Section 4.2), which were represented by a steering committee. One of the highest priorities identified by this group was the need for mechanisms to better define the relationship between energy systems and economic prosperity. The EnergyScape framework achieves this, by considering all of New Zealand's energy systems including for export and non-energy uses. New Zealand currently exports significant quantities of energy, both as a primary resource (e.g. coking coals and petroleum) and as manufactured products such as methanol, aluminium, dairy and timber products.

Accordingly, the key aims of the EnergyScape programmes were:

- Development of tools that could support policy makers and planners to balance competing objectives, with considerations well beyond the current planning horizon2, and beyond the domestic energy sector e.g. energy exports and non-energy use of fuels.
- Development of a relatively complete, 'order of magnitude' quantification of New Zealand's resource endowment, asset repository and end-use demand, in a consistent and unbiased manner.
- Identification and description of all energy pathways relevant to New Zealand's future as currently understood, written so as to make energy concepts accessible to an informed reader. This includes the development of energy visualisation tools that capture: energy flow, capital flow and emissions profile.

[1] An energy pathway is the thread that connects an energy resource through various conversions, infrastructure and transport processes to the end user demand.

[2] The predominant planning authority (Ministry of Economic Development) has a planning window that is less than a decade.

In bringing this programme together, a key consideration was how best to frame an analysis process that is intended to go well beyond conventional planning horizons, and represent an existing energy asset base that in all probability will have been replaced or updated within the time frames being considered. Also there is the problem of how to adequately represent the new or emergent technologies, yet to reach maturity, which might in future replace current assets. These technologies are subject to significant uncertainties in respect of both performance and cost and thus comparisons with known technology can be fraught with difficulty. The EnergyScape Framework addressed these issues by developing a system that can readily consider the impact of ‘new’ disruptive technologies, and focus on getting ‘order of magnitude’ and ‘physical limitations’ right, rather than focussing on detail.

A second consideration was to adequately represent New Zealand’s national objectives for energy. It was not the role of the EnergyScape team to seek to arrive at a consensus view on any preferred energy pathway or determine what economic trade-offs might be entertained in exchange for, say; reduced environmental impact; climate change abatement; energy security; improved quality of life; asset stranding; improved social equality, etc. The EnergyScape Framework addressed these issues by developing an analysis framework that keeps all options open and focuses analysis on the implications that might arise from particular policy directions or economic settings.

The third consideration pertains to a general lack of understanding amongst the wider population of the nature of energy systems, the technical and commercial risks that can reside in the uptake of new technology, and the complexities that arise when introducing alternative energy forms into the New Zealand market; e.g. distributed generation; demand side management; energy substitution. The steering committee proposed that key EnergyScape literature (e.g. Basis Review) would be written so as to make the energy options and consequences accessible to a wide audience, with an active effort to de-mystify public myths surrounding the sector and its options. Furthermore, a significant effort was made to translate energy concepts from tables into visual, comprehensible material that capture: energy flow, capital flow and emissions profiles.

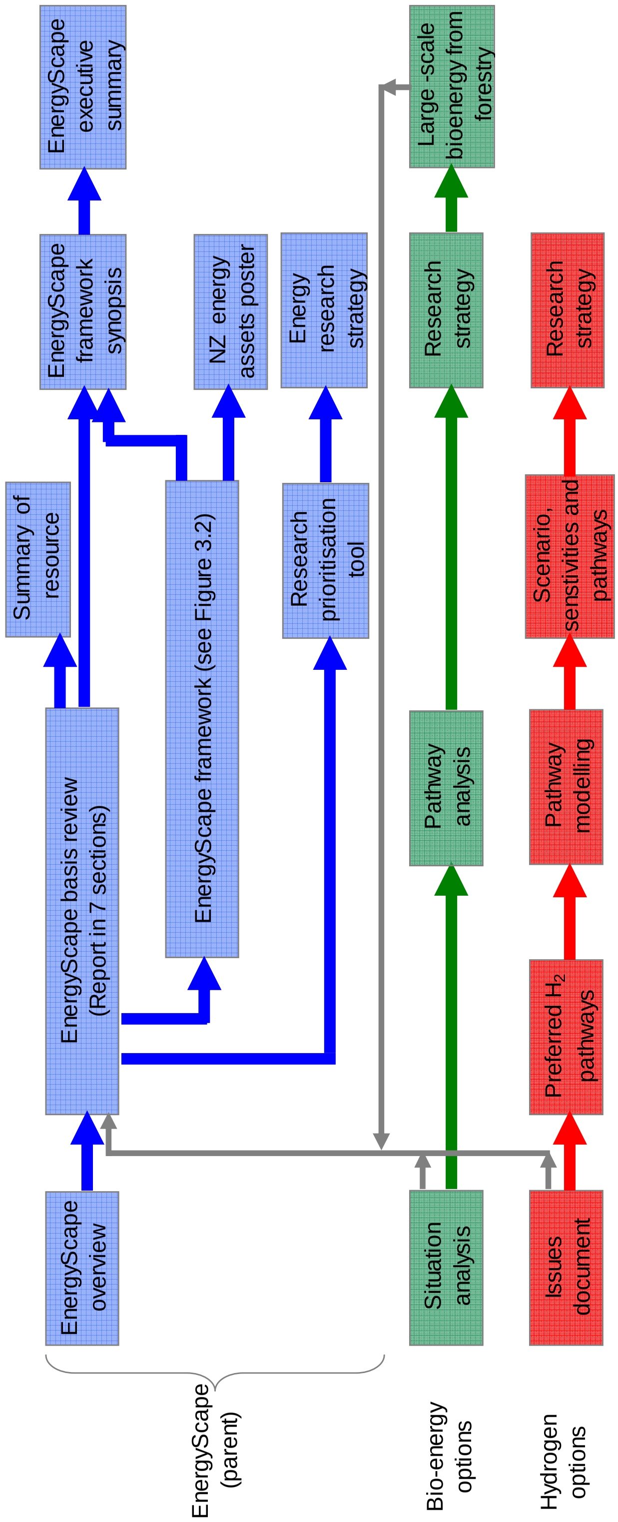
Within this context, specific attention was given to ensuring that demand side management was adequately represented within the EnergyScape framework rather than simply focussing on supply-side solutions. In order to model the impacts of demand side management initiatives, the EnergyScape framework was developed to take into consideration changes in demand for energy services and changes in energy intensity, rather than simply projecting trends in fuel demand.

Finally, one of the key objectives of the EnergyScape suite of programmes was to quantify New Zealand’s energy endowment in a consistent and unbiased manner. It was intended that these data sets would be obtained through the collation of existing literature. There were gaps in the literature; in particular in the area of renewable energy resources, hence the EnergyScape team undertook research to develop data to fill the gaps.

3. PROGRAMME DELIVERABLES

The suite of EnergyScape programmes progressively built knowledge and tools in a staged manner. Reports were generated, and presentations made to stakeholders, at the completion of the relevant stages. The relationship between the key deliverables that were generated is summarised in Figure 3.1 below.

Figure 3.1 – Relationship between EnergyScape programme deliverables



The Bio-Energy Options for New Zealand and Transitioning to a Hydrogen Economy programmes, both sought to identify key pathways and opportunities from the bio-energy and hydrogen sectors, respectively. For both programmes this was achieved in three stages:

1. Situation analysis, which reviewed the current use of energy in this sector (refer to Bio-energy situation analysis and Hydrogen issues documents)[3],
2. Pathway analysis, which reviewed which energy pathways have the greatest capacity to contribute to New Zealand's energy future (refer to Bio-energy pathway analysis; Preferred hydrogen pathways; Pathway modelling; and, Scenario sensitivities and pathways), and,
3. Research strategy development, which identified what research would be required to develop the energy potential of these sectors (refer to Bio-energy research strategy and Hydrogen research strategy).

The EnergyScape (parent) programme had a significantly broader mandate, to identify pathways and collate data from all energy sectors. The EnergyScape Basis Review report defines all of New Zealand's key energy pathways. This document is intended to provide a broad introduction[4] to New Zealand's energy infrastructure. The seven (7) sections of the report cover the full spectrum of the energy system from resources, through generation, distribution, conversion and end-use:

Section 1 – Energy end-use
Section 2 – Renewable resources
Section 3 – Bioenergy resources
Section 4 – Earth resources
Section 5 – Distribution infrastructure
Section 6 – Secondary conversion
Section 7 – Hydrogen options

All energy sectors (e.g. industrial end-use, wind power, coal to liquids) are given separate chapters in the relevant section. Each chapter has been written so that if the reader only has interest in one particular area, an appreciation for how that area contributes to New Zealand's energy portfolio, now and in future, can be gained by reading that section in isolation. In addition to describing the current status of public domain knowledge pertaining to energy resources, each chapter also deals with the efficiencies, risks and research applicable to this energy sector. These chapters provide the philosophy for populating the New Zealand energy asset and end-use databases.

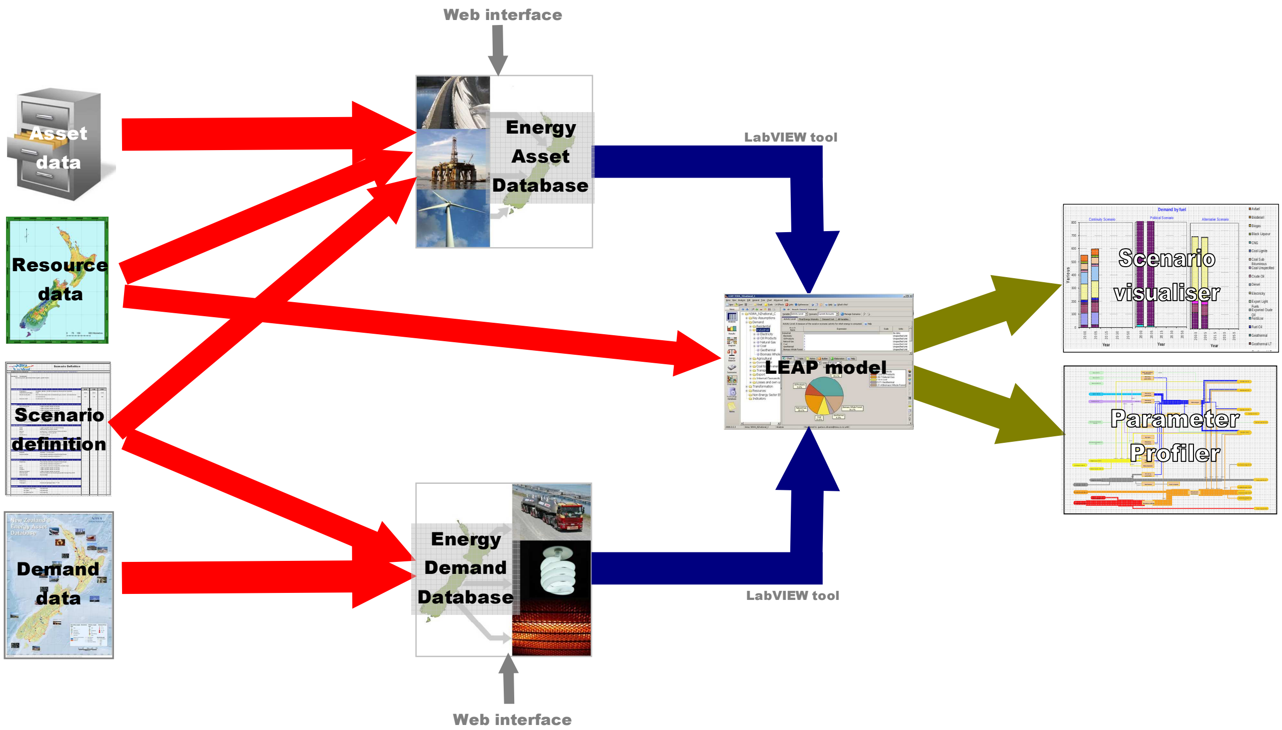
The next significant deliverable from the EnergyScape (parent) programme was the development of the EnergyScape framework - a collection of energy analysis tools that translates collated energy asset, resource and end-use forecasts into (visual) outputs that are accessible and amenable to

[3] All reports associated with the Bio-energy options and Transitioning to a hydrogen economy programes can be found at www.niwa.co.nz\energyscape under sub-project deliverables.
[4] Capable of being read by the interested public i.e. those with some familiarity with energy system concepts.

further analysis. The key elements of the framework are illustrated in Figure 3.2 and summarised below:

- The New Zealand energy asset database (NZEAD) – a repository of information regarding supply, distribution and conversion assets in New Zealand, both current and future.
- The New Zealand energy demand database (NZEDD) – a repository of information regarding the demand for services and energy intensity of services by fuel source, at regional level.
- LEAP[5] model – a software interface that displays and collates energy information specific to energy pathways, regions and fuels.
- Scenario visualiser – a tool that extracts data from the LEAP model and generates graphical outputs that allow visual identification of the differences between scenarios.
- Parameter profiler – a tool that extracts data from the LEAP model and generates summary data tables in advanced Energy Data File (EDF) format[6] and Sankey diagrams[7].

Figure 3.2 – Elements of EnergyScape framework



[5] LEAP, the Long-range Energy Alternatives Planning system, is an advanced Windows-based software tool for integrated energy-environment mitigation analysis. LEAP (www.energycommunity.org) has been developed by the Stockholm Environment Institute-Boston (www.sei-us.org) to meet the needs of researchers, NGOs and government agencies worldwide.

[6] An internationally recognised table of data that characterises energy demand by sectors (primary, secondary, import and export) and by fuel type. MED annually produces the national Energy Data File with supporting documentation in the Energy Data File report (www.med.govt.nz).

[7] The diagram is named after the Irish Captain Matthew Henry Sankey, who is considered to have developed the first diagram of this type in 1898.

A summary of new material developed during the preparation of the EnergyScape Basis Review, and a review of findings associated with preparing the EnergyScape Framework, are captured in the EnergyScape Framework Synopsis report.

Finally, in response to the need to identify research gaps, the team developed a research prioritisation matrix (refer to Research Prioritisation Tool Development report), and provided energy researcher commentary on New Zealand's energy research strategies.

4. PROGRAMME APPROACH

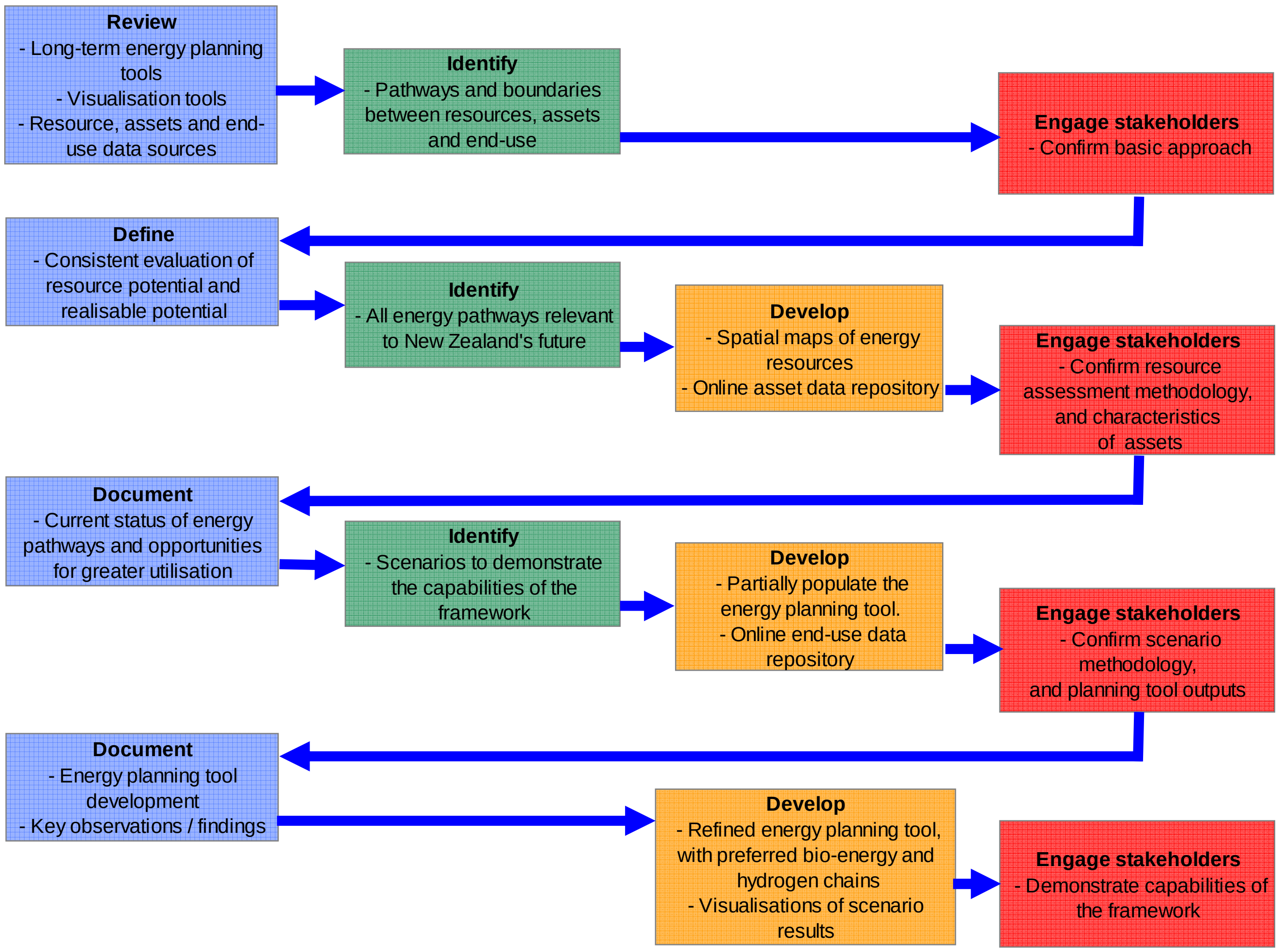
In addition to the technical challenge of developing an energy framework for New Zealand, the EnergyScape suite of programmes needed to make the resulting framework relevant to the intended stakeholders. The suite of programmes therefore had two distinct elements to advance, namely:

- Technical development
- Stakeholder relevance

4.1 TECHNICAL DEVELOPMENT

The technical challenge for the EnergyScape programmes was to develop an energy analysis framework and visualisation tools which could define New Zealand's potential energy pathway options. A phased approach to the development of technical data, which involved stakeholder review at critical milestones, was considered appropriate for this suite of programmes. The phases were:

Figure 4.1 – Phases of EnergyScape framework development

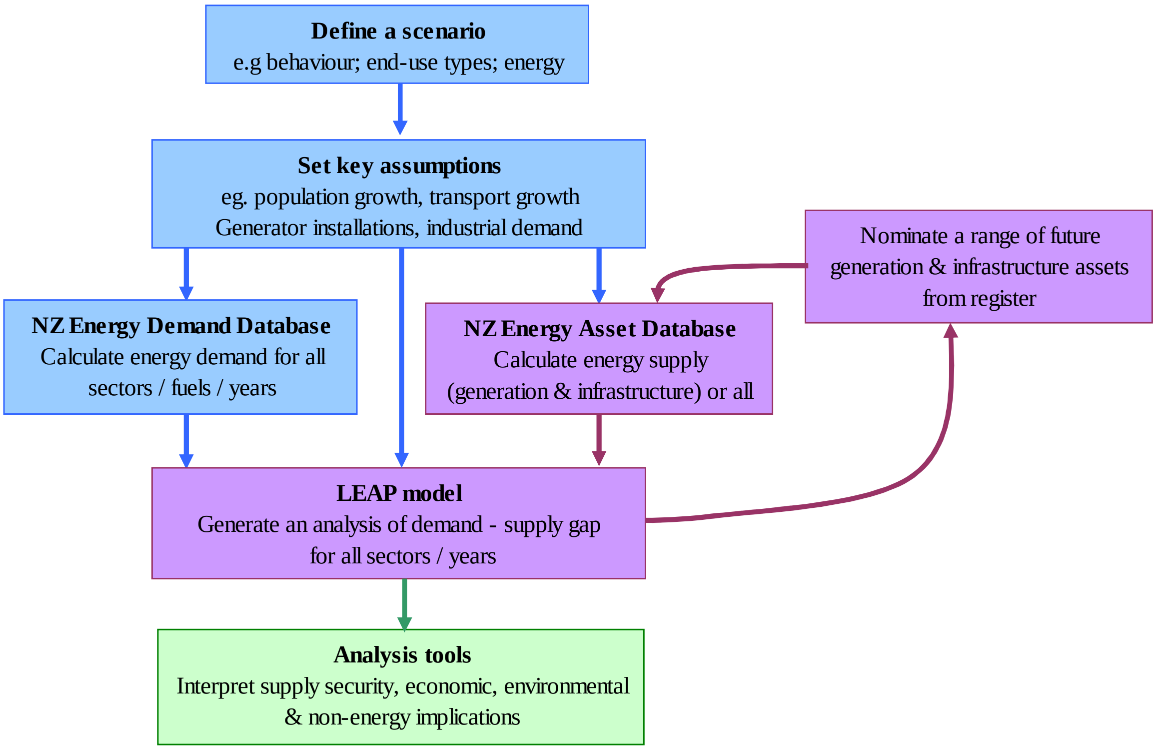


From the outset, there was strong consensus from stakeholders, that the framework must operate at a 'high level', and definitely should not be a model. Strategic thinking is most appropriate, when considering the framework is intended to support forecasting and analysis at decadal scales. It was essential therefore, that users of this framework be able to readily and easily interpret 'order of magnitude' effects, without getting bogged in the detail.

Since the data framework is intended to assist national (and regional) strategy, the focus of data collation was on developing a complete repository of credible data. It is noted, that absolute accuracy is not as important when considering potential large scale, structural changes that can (and are likely to) occur over the long planning horizon. Where possible, data collation and the development of energy pathway summaries was undertaken by experts in the relevant fields. To ensure consistent analysis of resources and pathway characterisation, all data were populated into defined templates. Initial framework integrity was assured through reviews by sector representative bodies e.g. Solar Energy Association of New Zealand (SEANZ), Wind Energy Association of New Zealand (WEANZ), Aotearoa Wave and Tidal Energy Association (AWATEA).

The framework was set up to provide exogenous definition of scenarios i.e. the framework is set-up in such a way that the available supply (generation and infrastructure) will be determined independently of the demand for each fuel type. A scenario in the EnergyScape Framework is initialised by definition of scenario intention and assumptions. Based on these data, the energy demand is calculated. The framework operator then nominates the commission date and capacity for all assets in the asset database. Based on the resulting gap between demand and supply, the asset selection is modified (i.e. iterated) until demand is satisfied. The series of operations required (by the framework user) to complete a scenario energy forecast are summarised in Figure 4.2 below.

Figure 4.2 – Framework order of operations



The framework and supporting documents are intended to remain as ‘living documents’ open to update. Both the energy asset and energy demand databases can be accessed via the internet (see www.niwa.co.nz/energyscape) and updated by registered parties. All suggested updates are audited (i.e. approved, modified or rejected) by the database managers (NIWA and CRL Energy respective) before being committed to the database. Changes to the LEAP model basis are managed by NIWA in response to user requests. The master LEAP model is maintained by NIWA, with updates distributed to key users upon request.

Four (4) scenarios were developed in order to demonstrate the capability of the framework, namely: Continuity, Political, Redevelopment and Biomass. The above scenarios are not offered as predictions, rather, they were chosen to help test and compare the consequences of different policy choices. In reality, there are many energy futures open to the nation, and it is not likely that the real energy future will closely resemble any of the scenarios. The purpose of the defined scenarios is to spotlight a few possibilities among the many, in order to clarify the usefulness of the framework.

4.2 STAKEHOLDER RELEVANCE

Considering that the key stakeholders involved in planning New Zealand’s energy future include: government planners / advisors; private enterprise decision makers; energy consultants and the broader public; it was necessary to undertake a broad range of engagement. Upon completion of key milestones, the programmes operated collectively to engage with the following groups:

- Government stakeholders
- Steering committee
- Targeted stakeholders
- Open stakeholders

The government stakeholders group provided high level steering on policy direction and government thinking. The steering committee brought key central government and industry leaders together to provide a high level overview of the research work. The targeted stakeholder meetings enabled the programmes to engage with a wider-range of industry and expert contributors to provide feedback on the research outcomes. Finally, the broadest engagement was open to all interested parties. This engagement was facilitated via meetings with the Energy Federation of New Zealand (EFNZ).

4.3 DEFINING PRINCIPLES

The methodology for developing an energy system planning tool was adapted during the course of the programme in response to input from stakeholders. The key thoughts and observations that strongly influenced the final form of the EnergyScape framework were identified in Section 2. Some further considerations are identified below:

- National economic prosperity depends on the endowment of natural resources as well as the ability to add value to these resources and use them efficiently. Energy solutions are part of New Zealand's long term technology innovation policy and offer new opportunities for economic development and an improved quality of life. This study is largely predicated on the vision that New Zealand has abundant energy options available to it which should be able to provide us with all the energy needed for growth of our economy and to sustain our future well-being as a nation.

- A shift from highly concentrated forms of energy (such as oil) to more diffuse sources of energy (such as solar, biomass and wind) will require the development of energy systems that can concentrate and store captured energy. Inherently, following thermodynamic and logistic principles, these systems have greater direct 'costs' than the systems they displace, but the 'price' we pay for them may still be less. Resource depletion, environmental externalities, as well as sentiment are likely to define future directions, not least cost. The EnergyScape framework seeks to develop an improved understanding of feasibility and order of magnitude effects, rather than just providing cost comparisons.

- Because regional councils have legislative responsibility for infrastructure planning, there is a need for regional-level resolution of energy data in New Zealand. All energy asset data were tagged with at least regional-level geographic detail.

- The old adage of 'it is difficult to compare apples with oranges' is certainly true for New Zealand's energy system. To minimise the complications associated with using different units, the EnergyScape framework standardised on: petajoules (PJ), megawatts (MW), kilo-tons of carbon dioxide equivalent ($ktCO_{2EQV}$).

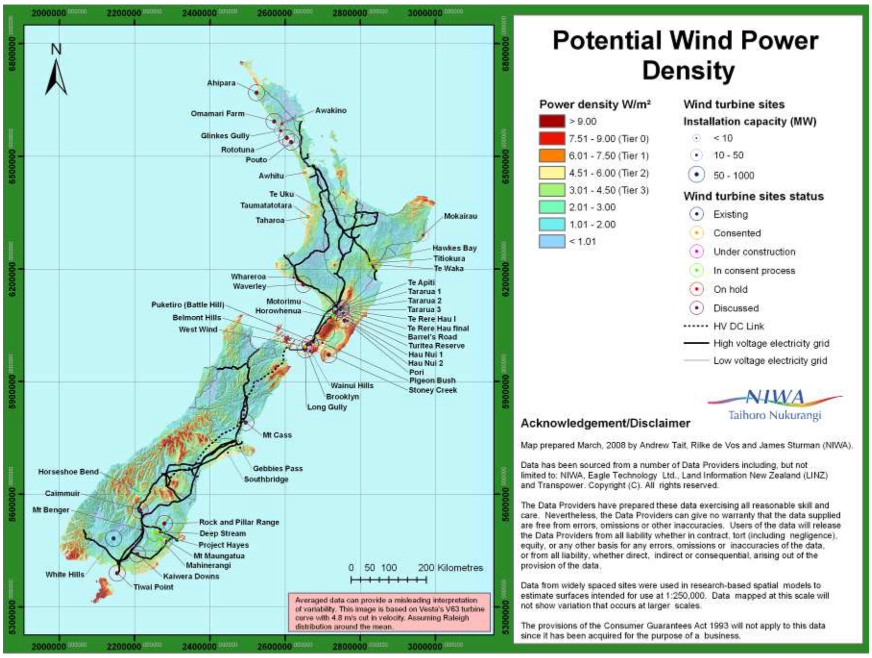
- As a matter of principle, an attempt has been made to apportion the research effort in rough proportion to the magnitude of the asset (i.e. cost and capacity) and opportunity to change. On this basis, since transport currently is nearly 45% of our energy consumption, and is expected to undergo significant change, we have applied commensurate effort to researching and documenting this area.

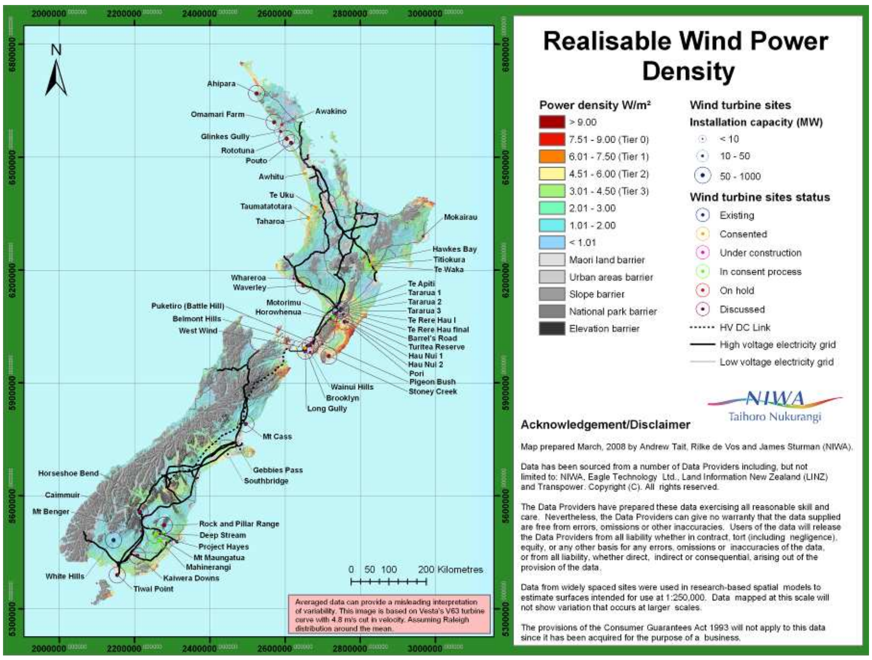
5. PROGRAMME ACHIEVEMENTS

The EnergyScape portfolio of programmes developed a tool capable of supporting planning well beyond the conventional planning horizon, which can contribute to improved national energy system planning. The key achievements of the programmes were:

1. Assessment of indigenous energy potential by applying a consistent methodology to all resources, so as to enable comparison between resources, and matching with energy pathways, within identified regions. The resulting analysis was interpreted in potential and realisable potential resource maps - see examples in Figure 5.1.

Figure 5.1 – Example of potential and realisable potential resource mapping





2. Engaging in dialogue between government and private industry to derive clarification of the prioritisation of national objectives – the key first step towards advanced planning, and thinking of the energy system as a key part of the whole economy.

3. Development of online data repositories (assets and end-use demand) that enable collaboration between researchers / consultants, and access to regionalised data. The end-use database provides data on both the underlying services and energy intensity, with the flexibility of developing demand forecasts with a variety of methodologies. Rather than simply projecting trends in fuel demand, the EnergyScape framework takes into consideration changes in demand for energy services. End-use demand is characterised using both: bottom up proxies (e.g. forecast industrial activity, passenger kilometres travelled, number of dwellings); and economic drivers (e.g. GDP, gas price) for all ANZSIC[8] sectors / sub-sectors[9] at both a national and regional level. The transparency of the model, and responsiveness to user preference, greatly improves the understanding of associated uncertainties.

4. The development of an EnergyScape framework that provides a unified repository of economic data, energy data and system assumptions that facilitates improved understanding of the complexities and dependencies of: resource depletion, energy substitution, transmission costs, conversion efficiencies, locality effects, scale, demand controls, as well as, environmental impact (on land, water and the atmosphere) and risk. The effect of capturing data across the supply, distribution and storage chain enables calculation of resource price rather then just supply cost. The EnergyScape framework considers both energy and non-energy systems, hence the impacts of manufactured energy products such as methanol, aluminium, dairy and timber products are considered.

5. The development of a framework that is 'living', and can be easily updated to reflect changes across the supply chain e.g. new resource finds, conversion technology parameters, asset commissioning date, regional transport demand. This flexibility is required, to ensure that the uncertain data pertaining to new or emergent technologies can be updated as changes occur. These data sets can be accessed and updated by the energy research community, subject to change audit control by database managers (NIWA and CRL Energy).

6. The basis documents have been written so as to make energy concepts accessible to an informed reader, with an active effort to de-mystify public myths surrounding sector options. The framework tools are designed to translate energy concepts from tables into visual, comprehensible material. This literature seeks to improve understanding (amongst the wider population) of the nature of energy systems, and the technical and commercial risks that can reside in the uptake of new technology.

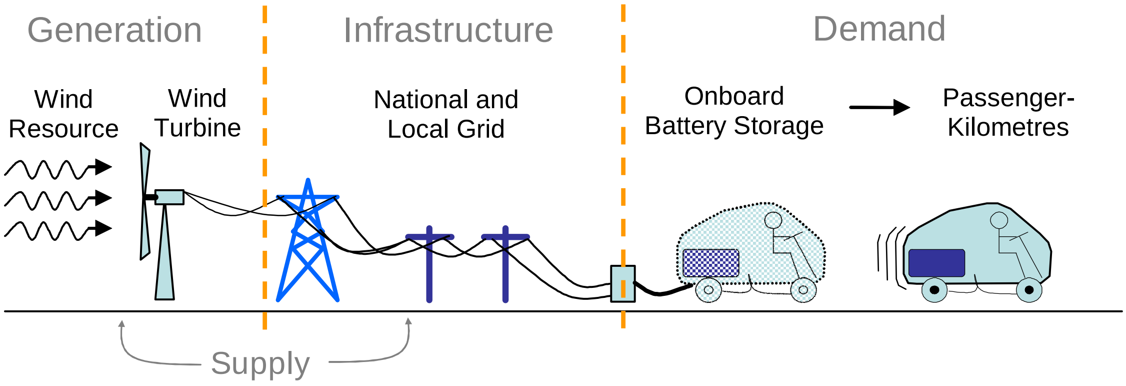
---

[8] Australia New Zealand Standard Industrial Classification (ANZSIC) system

[9] For further clarity, the end-use demand of nationally significant consumers e.g Huntly power station, Aluminium smelter and NZ steel are characterised separately.

7. Encouraging New Zealanders to think of energy systems as complete pathways, and engage in national dialogue. This is achieved through documenting New Zealand's energy system in layman's language and numerous visual interpretations (see the EnergyScape Basis Review, website, posters and presentations).

Figure 5.2 – Illustration of divisions in a typical energy pathway



8. The development of an energy research prioritisation matrix, which quantifies the value of proposed research strings, in the context of the government's strategic directions for energy. Based on an initial population of this matrix, some commentary on the national energy research strategy was developed.

9. A comparison of the impacts of various hydrogen and biomass developments with the status quo.

10. These programmes demonstrate the benefit of the collaborative approach that brought together five research institutes (NIWA, CRL Energy, Scion, GNS Science and IRL) and a large number of sub-contractors to support three linked programmes. This programme has demonstrated that running parallel programmes within a collaborative environment can access and unify a broad range of skills.

The EnergyScape tools and resources will enable New Zealanders to advance our understanding of the strong relationship that exists between the energy we use and economic prosperity. The portfolio of programmes also initiated active engagement with the general public and increased the interaction between science providers, government stakeholders and private industry. To this end, the EnergyScape programme has successfully advanced New Zealand's ability to cope with an ever-changing energy future.