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Residential Distributed Generation

Decision Support Software to Evaluate Opportunities in the
Residential Market

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Abstract

The residential market in New Zealand consumes a significant proportion of our electricity production and is one of the fastest *growing* sectors. As a vertically integrated generator-retailer in the New Zealand electricity industry, Meridian Energy Ltd is concerned at retaining and growing their customer base. They recognise that utilisation of emerging distributed generation [DG] technologies can provide a competitive advantage in the market place.

A decision tool was developed to help Meridian identify opportunities within the residential market for applications of DG. The model compares the cost to serve a household's energy needs using a business as usual case with a DG case on an annual basis for a single household or a neighbourhood. A modular approach was used for ease of development and to enable future enhancements. The main modules were: load profile development, DG technology, operation control, costing and a calculation engine.

The load profile module estimated space heating/cooling, water heating and other electrical loads for each 30 minute period for 8 representative days of a year based on national end-use statistics and a set of 40 reference profiles. A Gamma distribution was used to simulate diversity between houses.

The calculation engine computed the amount of demand that could be met by the DG technologies and hence the residual demand or surplus for export.

The pricing module estimated the annual cost including aspects such as: capital cost, fuel cost, maintenance, value of export and cost of import.

The technology modules allowed different DG technologies, as well as a range of parameters to be selected. It included renewable energy resource modelling.

The performance module allowed different operation control of the heat engine technologies including: base load, electrical peaking, heat peaking, load following (heat-led) and load following (electricity-led).

The model was implemented using Microsoft Visual Basic for Applications, in Excel. A series of user-forms were developed to enable the model to be run with a minimum of user input.

Three case studies were undertaken. In the first, five technology types were modelled, with the heat pump and Stirling engine looking the most promising. The second case study involved these two technologies in a Christchurch urban area study. A hypothetical network analysis showed the benefit that these technologies could have in reducing peak loading on the network. The third case study examined the sensitivity of the results to the value of specific variables. Load size and capital cost had the strongest influence on NPV.

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To God.

"Praise the Lord. I will extol the Lord with all my heart in the council of the upright and in the assembly. Great are the works of the Lord; they are pondered by all who delight in them. Glorious and majestic are His deeds and His righteousness endures for ever. The fear of the Lord is the beginning of all wisdom; all who follow His precepts have good understanding. To Him belongs eternal praise."

Psalm 111

Acronyms

AC	Alternating current
APC	Annual production cost
BAU	Business as usual
BCHP	Building combined heat and power
BRANZ	Building Research Association of New Zealand
CAIDI	Customer average interruption duration index
CHP	Combined heat and power
CCGT	Combined cycle gas technology
CNG	Compressed natural gas
COP	Coefficient of performance
CPI-X	Consumer price index
DC	Direct current
DG	Distributed generation
DN	Distribution network
DHW	Domestic hot water
DPS	Dispersed power source
DSM	Demand side management
ECNZ	Electricity Corporation of New Zealand
EGB	Electricity Governance Board
EIRA	Electricity Industry Reform Act
EPRI	Electric Power Research Institute
GIP	Grid import point
GRI	Gas Research Institute
GXP	Grid exit point
HEEP	Household End-use Energy Project
HVAC	Heating, ventilation and air-conditioning
HVDC	High voltage direct current
IPO	Independent power operator
IRL	Industrial Research Limited
kW	kilo Watts (Joule per second)
LHV	Lower heating value

LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MACQS	Multilateral Agreement on Common Quality Standards
MARIA	Metering and Reconciliation Information Agreement
MCFC	Molten carbonate fuel cell
MED	Ministry of Economic Development
MEL	Meridian Energy Limited
NZEM	NZ Electricity Market
NPAT	Net profit after tax
NPV	Net present value
OECD	Organisation for Economic Development & Co-operation
ODV	Optimal deprival value
O&M	Operating and maintenance
PAFC	Phosphoric acid fuel cell
PEM	Proton exchange membrane
PV	Photovoltaic
RAPS	Remote area power systems
RMA	Resource Management Act
ROC	Renewable obligation certificate
ROI	Return on investment
RPM	Revolutions per minute
RTP	Real time pricing
SAIDI	System average interruption duration index
SC	Space cooling
SEF	Sustainable Energy Forum
SHWH	Solar hot water heating
SH	Space heating
SME	Small medium enterprise
SOE	State Owned Enterprise
SOFC	Solid oxide fuel cell
SNZ	Statistics New Zealand
SPD	Scheduling Pricing and Dispatch
T&D	Transmission and distribution
TOU	Time of use
TN	Transmission network
TSM	Traditional supply mechanism
VAR	Voltage amps reactive
WTG	Wind turbine generators

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Chapter 1

Introduction

This Chapter gives some perspective of where the Thesis sits in relation to distributed generation as a whole. It provides an overview of the Chapters contained in the Thesis, highlighting their main objectives.

1.1 Electricity in New Zealand

The electricity industry in New Zealand has recently undergone significant change. It has moved from state-owned, regulated and vertically integrated utilities (Electricity Corporation of New Zealand [ECNZ] plus regional distribution companies) into a competitive market where the monopoly activities (lines businesses) have been separated out from the competitive services of generation and transmission. After 12 years of almost continual reform, there still exists the possibility of further changes, as proposed by the recent Ministerial Inquiry into the Electricity Industry (MED 2000_a).

In parallel with these reforms, the concept of distributed generation [DG] has re-emerged. A new term, replete with many new technologies that describes an old method of delivering power to end users. DG consists of small energy converting devices such as fuel cells, micro-turbines and Stirling engines that can be located close to the load source and often deliver not only electricity but also thermal energy (heat, cold). Meridian Energy, the largest of the 3 state owned utility companies and the privately owned Contact Energy that were created after

the split of ECNZ, wants to investigate how to take advantage of this new way of providing energy to its customers.

1.2 Objectives

The overall objective of this thesis is to provide Meridian Energy with a decision tool to assist them in their process of identifying DG opportunities, particularly in the residential market. This thesis had two aspects. Firstly, a model¹ to quantitatively assess various DG technologies under multiple scenarios and secondly, a qualitative description of the issues involved with the application of DG in the residential sector.

1.3 Scope

This thesis concentrates on assessing how the energy requirements for residential buildings are provided. Therefore it examines both technologies and demand-side issues that are relevant to domestic² applications. However, it is envisaged that the analysis would also be applicable to the study of other sectors in the economy (i.e. the commercial sector and in particular small, medium enterprises [SME]) with minor modifications. Since Meridian Energy is a generator, trader and retailer market participant, issues are viewed by the effect they have on this type of company and not from the transmission and distribution company perspective. Importantly, the scope is future focused to allow the decision tool to address issues likely to change as the electricity industry evolves, but are not yet apparent.

1.4 Thesis Structure

Chapter II Literature Review

Describes the overall drivers that are creating an environment of change in the electricity industry both world wide and in New Zealand, particularly those that affect the introduction of DG. The intention of this chapter was to provide a basis on which to assess the factors affecting DG.

¹ The terms decision tool and model are used interchangeably

² The terms domestic and residential are used interchangeably

- Chapter III DG and Meridian Energy
An overview of the New Zealand electricity industry and the role that Meridian Energy plays in it. This Chapter also explores how a DG business case may be developed by Meridian Energy.
- Chapter IV Residential Distributed Generation
This Chapter looks specifically at the market for residential DG in New Zealand. It examines the characteristics of this market as well as the likely technologies to be deployed in it.
- Chapter V Model Charter
The model charter clarifies the objectives and purposes of the Thesis in terms of the decision tool that was developed. The model charter is a reflection of the results of the literature study as well as the commercial goals of Meridian Energy.
- Chapter VI Conceptual Model Development
The basic premise on which the analysis was conducted on (i.e. the value proposition) is identified and the framework on which this analysis will be carried out is described. It outlines the specific modules (Chapters VII to X) and their position in the model framework.
- Chapter VII Load Profile Development
This Chapter describes the concept of load profiling and represents the demand side aspects of the model. It shows the importance, yet difficulty in achieving accurate load profiles that reflect socio-economic factors.
- Chapter VIII DG Selection
Describes the technical aspects of the different DG technologies that are modelled. This module highlights the variables that are included in the analysis, the reasons why they were chosen, the assumptions made about them and their impact on the model.
- Chapter IX Operational Control
This Chapter shows what different operating regimes could be employed for DG and how this control is achieved.

- Chapter X Costing
The mechanism used to cost the supply of energy to a residential consumer, both via the traditional supply means and also with the use of DG technologies is described.
- Chapter XI Model Implementation
This Chapter shows how, using a computer programme the formulation developed in the preceding Chapters is implemented. It addresses the practical issues of the system architecture as well as providing a description of the calculation sequence.
- Chapter XII Case Studies
Three case studies are conducted showing the model's ability to analyse real market scenarios. The model's functionality is demonstrated and used to discover a range of important insights into the current use of DG.
- Chapter XIII Conclusions and Recommendations
This Chapter provides a summary of the model's capabilities. In addition it reflects on the original objectives of the Thesis and provides a commentary on areas that warrant further analysis.

Chapter 2

Literature Review

This Chapter addresses the historical use of DG for energy supply and attempts to put into perspective why the application of DG is again an option for the electricity industry

2.1 Structure

The purpose of the literature review is to give an understanding of how DG sits in the electricity industry landscape and in particular what the scenarios are for the residential application of DG from Meridian's [MEL] point-of-view (Figure 2-1).

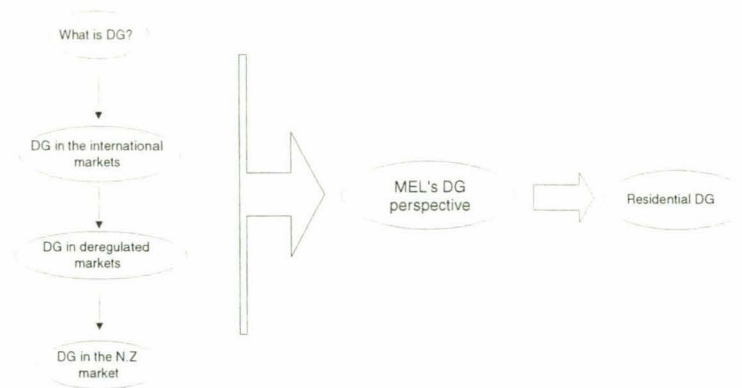


Figure 2-1: Literature Review Progression

2.2 What is DG?

In reviewing the literature, there are a number of definitions used for DG. Factors that can affect the classification of a generating entity as *distributed generation* include:

- Purpose
- Location
- Power rating
- Power delivery area
- Technology
- Environmental impact
- Mode of operation
- Ownership

A contemporary definition of DG (Ackermann et al, 1999³) states:

*‘Distributed generation is an electric power source connected to the distribution network³
or on the customer side of the meter.’*

However, this definition does not cover the full application intended in this Thesis. By defining DG technologies as “distributed energy converting mechanisms⁴”, it includes more diverse technologies such as solar water heaters and heat pumps, even though they do not produce electric power in their own right but reduce the consumption of it. In addition many existing and emerging DG technologies can run in combined heat and power [CHP] mode, where the 'waste' heat can be utilised as a valuable energy resource.

Therefore the definition of DG in this thesis is:

‘Distributed generation is an energy source, or conversion mechanism which provides useful energy, that is located in the distribution network or on the customer side of the meter.’

It is an essential aspect in building a DG model for the purposes of Meridian Energy that the definition used is compatible with the company’s interests. However, because of the dynamic nature of the trends in DG it is probable that the application of DG in the market place will be

³ The distribution network is distinct from the transmission network.

⁴ No device can create energy according to the 1st Law of Thermodynamics.

subject to change, not only explicitly, with new technologies being developed that fit into this class but also implicitly i.e. with a change in definition of DG⁵.

Figure 2-2 illustrates the positioning of DG in the network. It was felt that this aspect, its location, was the most important criteria in its definition.

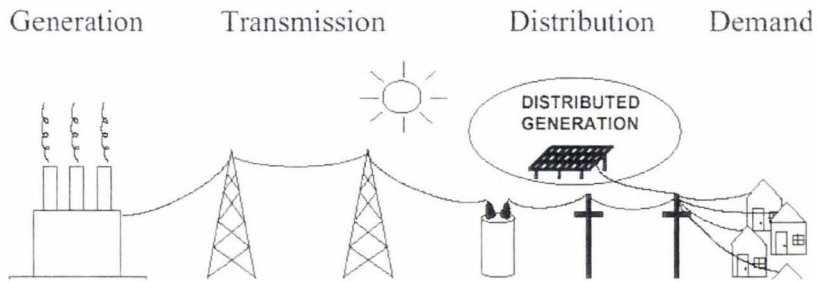


Figure 2-2: Spatial Representation of DG in the Network

Figure 2-3 gives an overview of the size, cost and technology types that may suit the criteria for DG. There is also a time factor (moving from left to right) indicating the drop the dollars per kW cost as technologies mature between 2000 and 2015. If the residential market appears to be suited to by only a narrow band of technologies (below 200 kW) which also happen to be the more expensive.

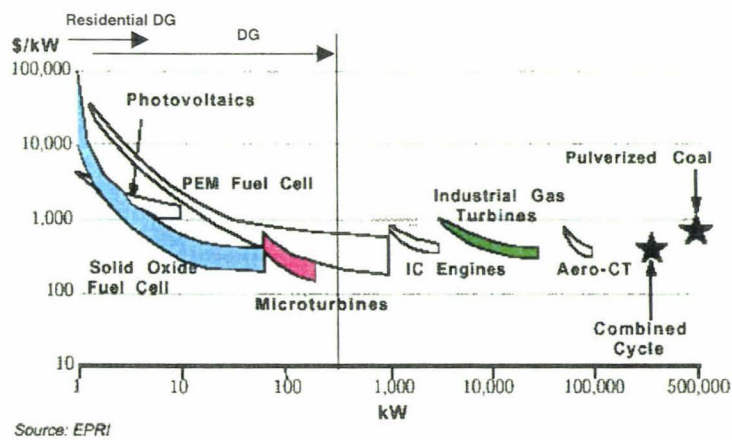


Figure 2-3: Size, Cost and Various Technologies for Power Generation

⁵ DG is not to be confused with embedded generation. All embedded generation is DG (as it is located in the distribution network). However if it is located on the utility side of the meter, it would more accurately be classified as 'fully embedded'.

2.3 DG in International Markets

2.3.1 Historical Trends

DG is not new. The idea to install and operate a power system was first utilised by Thomas Edison in the 1880s. Subsequently a trend developed with generating units being sited close to loads. Because the low-voltage direct current [DC] systems had high losses, thus limiting the distance between load and source. But the advent of transformers and higher voltage alternating current [AC] with lower associated line losses, allowed large generators to be located far from loads. Over the years as transmission line technology increased and economies of scale (due to higher thermal efficiency) became a factor, fewer but larger power stations were built, often connected by high voltage transmission systems. Technological developments were not the only drivers. Institutional and organisational structures such as government owned utilities favoured long term investment and large scale power generation.

Figure 2-4 shows the progression of power production as a function of delivered cost over time. Clearly, economies of scale are evident with costs decreasing with increasing size of plants. However this trend has begun to reverse. The oil price crises in the 1970's showed that many countries depended on imported fossil fuel from abroad to keep their economies alive. This prompted the development of non-fossil fuel technologies including nuclear and renewables⁶ to provide a hedge against future oil price rises. This interest in new technologies allowed a shift away from the traditional 'bigger is better' mentality to consider alternatives which were previously thought to be uneconomical. Combined cycle gas technology [CCGT⁷] development in the 1980s led to an optimal plant size of around 100MW, which significantly lowered investment costs and lead times. The late 1990s have seen new technologies such as fuel cells, micro-turbines and Stirling engines in the size range of a few kW to a few hundred kW appear on the market. These technologies, partly because of their small capacity, make them an option for DG in the residential market, though at present they make expensive options.

⁶ Using the power of nature i.e. wind, solar, biomass, geothermal and tidal as sources of 'clean, sustainable fuel'

⁷ Combined cycle refers to the sequential production of electricity, initially by a gas turbine and secondly with a heat recovery steam turbine

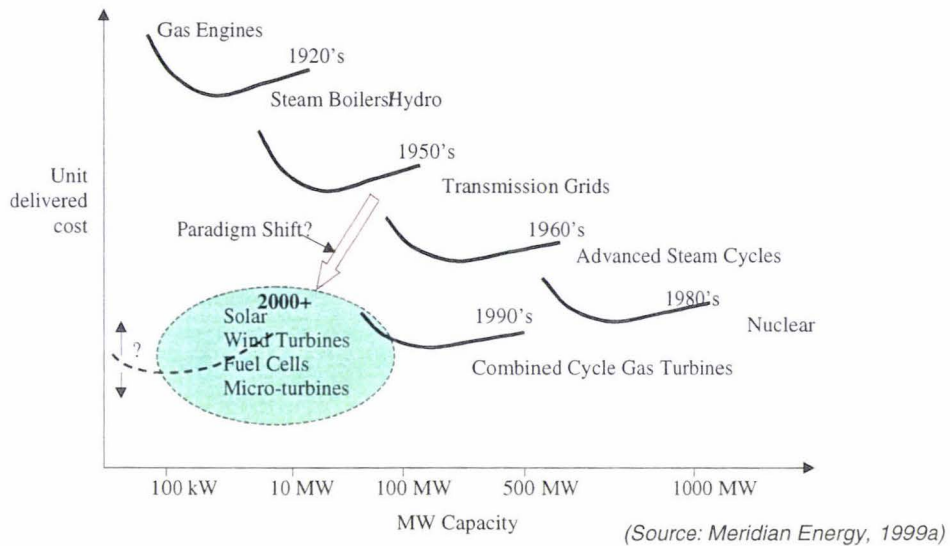


Figure 2-4: Evolution of Electricity Power Production

2.4 Drivers

There are a number of factors affecting the application of DG. Many literature sources convey the common theme outlined below (Willis & Scott, 2000):

2.4.1 Environmental Issues

There is a perception that 'green' power is better. Policies driven by public awareness place restrictions on the impact on the environment. Reduced emissions for example, has forced the development of cleaner technologies. Large power projects, requiring resource consents which are becoming more difficult to obtain, are becoming less feasible as the lead time increases. The Kyoto Protocol is broadening the scope for renewable energy developments, which often lend themselves to DG applications (e.g. solar and wind based). In California they have a million roofs programme which aims to install PV panels on a million residential roofs. On the retail side customers are becoming educated as to how 'green' their electricity they consume is. For example in Victoria, Australia it is proposed that a CO₂ metric be included on customer's bills. Carbon tax and cash subsidies for 'green' projects are becoming important issues when assessing project feasibility. Environmental and economic policy shifts are moving towards fully costing externalities, which in some cases favour (e.g. solar water heating) but in others decrease (e.g. large scale hydro electric) the value of renewable projects.

2.4.2 Privatisation and Deregulation

The electricity industry world-wide is evolving, led by a trend towards privatisation and deregulation. Large investment of venture capital into new generation technologies is occurring. This phenomena has been previously observed in the telecommunications industry when it was de-regulated and the resultant growth that occurred in technology development and ultimately in customer use and market capture. Large multinationals such as Shell and BP are entering the market and raising the profiles of new technologies. Deregulation of the electricity market lowers entry barriers for new and smaller specialist energy companies that are looking to deploy DG. This however is not always the case. For example some lines companies may be reluctant to allow third parties to connect DG units to their networks by imposing stringent interconnection standards. The presence or absence of such barriers often depends on who receives the benefit of any particular installation of DG as these more competitive markets are focussed on satisfying specific customer needs and capturing the 'added value' benefits. Further deregulation and competition is moving investment risk and incentives nearer to customers.

2.4.3 Increased Electricity Demand

World wide electricity demand is increasing. This is especially apparent in the developing world, where not only is the demand increasing the fastest but established transmission and distribution systems do not exist. This is providing growth opportunities for DG technologies as an alternative to large high voltage transmission systems. In the U.S. alone the Electric Power Research Institute (EPRI, 2001) estimates that the market for distributed resources would grow between 2,500 to 5,100 MW annually by 2010, which will account for about 25% of new generation. In addition, world wide electricity forecast shows electricity consumption increasing from 12 trillion kWh in 1996 to 22 trillion kWh in 2020 (U.S. DOE, 1999). It can be seen that there is an obvious need for new electricity generation capacity. It is proposed that DG will provide a portion of the increase without having to replace existing large scale power plants.

2.4.4 Increased Need for Power Quality

The 'new' economy industries that provide the nerve centres for the 'information age' we live in, such as network servers, telecommunication exchanges, data processing facilities for banks and governments, all require high quality power. In addition, many manufacturing and process industries are reliant on computer controlled critical manufacturing processes. The widely quoted example of silicon-wafer manufacturing, incurs losses in the millions of dollars for momentary power fluctuations. The cost justification for installing DG at a particular site is often not based on the cost of the electricity provided but on the cost of not having

electricity or electricity of sufficient quality. Different DG technologies allows a customised solution that meets the power requirements for its host. The 'solution' is defined in terms of the response speed and sensitivity to voltage fluctuations and the duration that the load can be sustained.

2.4.5 New Technologies

Whether technology development drives market reform or the other way round is open for debate. However the reality is that the long awaited commercialisation of some technologies such as fuel cells, external combustion engines and micro-turbines is happening. It is no longer a question of if, but when technology will meet the increasing demand for cleaner, more efficient small scale power systems. Further, the huge advances in information and communication technologies are both enabling networked systems approaches and overcoming earlier barriers to the widespread application of DG. Recent performances of micro-turbine manufacturers Capstone and Plugpower in the USA, and the increasing flows of venture capital into development companies, signal investors' near term expectations of significant industry change (Little, 2000).

2.4.6 Natural Gas

Gas is fast becoming the premium fuel for power and heat generation, which many DG technologies utilise. Its cleaner burning characteristics (compared with coal) often lower price and suitability for state-of-the-art CCGT power plants have heightened the awareness of gas as a fuel choice in the market place. Further the gas networks that are often quite extensive with high levels of penetration, are in many cases operating below their maximum capacity. The opportunity to exploit this marginal gas line capacity in highly reticulated urban areas warrants further exploration. However it must be cautioned that as gas demand increases so inevitably does the price. In fact in the past 14 months natural gas prices have quadrupled in the USA, a fact now ironically quoted by nuclear industry proponents.

2.4.7 NZ Situation

The drivers above are operating at global levels. Technology that is being developed as a result of them may not find application at all national or regional levels. In other words what is economically the best option in Asia, where established large-scale generation and transmission systems don't exist and there is a massive shortfall in generating capacity, will not necessarily apply in New Zealand where there is currently a generation surplus (wet year) and electric power is cheap and reasonably reliable by comparison with other countries. Concerning natural gas in NZ, the anticipated demise of the Maui field by 2007 has placed

greater emphasis on the discovering and bringing into production of additional fields, with an associated rise in gas price to facilitate further exploration expected.

2.5 Benefits

The benefits of DG are numerous, however it is important to address them in correct context, which some proponents of DG have failed to do. Moreover the benefits experienced may be specific to the type of 'player' in the market; be it generator, retailer, lines company, transmission company or end-user. The difficulty in performing a cost-benefit analysis is that DG resources produce benefits that typically flow to more than one entity. This produces a split incentive where no single entity sees all the benefits, meaning their desire to introduce DG is likewise affected.

2.5.1 Avoided Transmission and Distribution Costs

The defining characteristic of DG is its location, close to the load. The electricity therefore has to travel a relatively short distance, consequently avoiding transmission and distribution [T&D] line losses which in NZ typically account for 8% of the electricity produced. The line losses are a result of the heat dissipation that occurs in cables transporting electricity as well as in transformers which convert the voltage level. Avoiding these losses and consequent recovery costs mean cheaper electricity. Another consequence is the avoidance of use of system charges of the T&D networks. For example, if the DG unit was embedded in the distribution network the total power drawn from the relevant grid exit point [GXP] could be lower, meaning lower charges paid to the transmission company. Deferral or avoidance of system capital investment by way of transformer, substation or line capacity upgrade is an option open to network companies by employing DG technologies in constrained areas of their network. These points of constraint (an imbalance of supply and demand) can either be due to the market (competitive) or lack of line carrying capacity (physical) which result in volatile and high prices.

Depending on whether the load is connected to the grid will determine the extent to which T&D costs can be avoided. If the grid is used as back-up, a connection fee will be incurred, whereas if the lines are cut, all costs associated with the grid can be eliminated. However, this last option appears unlikely for the mass residential market where frequent load variations, the low likelihood of customers investing in multiple redundancy and cost of storage devices often mean staying grid connected is likely to make economic sense in the foreseeable future.

There may be another set of T&D costs to consider; those of the gas network. If, as many anticipate, natural gas is used to provide the fuel for many of the DG technologies like fuel cells and Stirling engines, the gas network costs may become a constraining factor to consider. At present in New Zealand the gas network is only at 50% capacity factor in places but this could change with the advent of wide spread deployment of gas fuelled DG.

2.5.2 Bundle the Customers' On-site and Market Needs

Locating a DG unit on the customer's premises allows for greater flexibility in meeting the energy requirements. Customers can specify what their needs are in terms of power quality, reliability and cost. A number of solutions can be designed which may include various DG technologies and different configurations. An example of this is the Bank of Omaha, USA , which required a reliability of 99.999997% for its Data Technology Centre. This equates to less than one second of predicted downtime each year because a one hour outage is estimated to cost around US\$ 6 million (HDR, 2001). A four fuel cell configuration (2 being adequate to completely supply the critical base load) was used. The utilisation of waste heat can lead to a more complete 'energy package' being offered which not only includes electricity but water heating, space heating, space cooling and even refrigeration.

2.5.3 Increased Efficiencies with Combined Heat and Power

Most electricity production has associated heat generation with it. The utilisation of this heat for process or heating needs for example can lead to lower heating value [LHV] efficiencies of between 75-85%. This compares to efficiencies of some non-CHP configurations of 25-35% for some DG units (Meridian 1999_a). CHP is achieved only where the heat load is in close proximity to the DG source and where efficient heat transport mechanisms exist.

Figure 2-5 gives a numeric example of this: 696 units of energy to provide 400 units of delivered energy via the traditional supply chain versus 500 units needed for a CHP system.

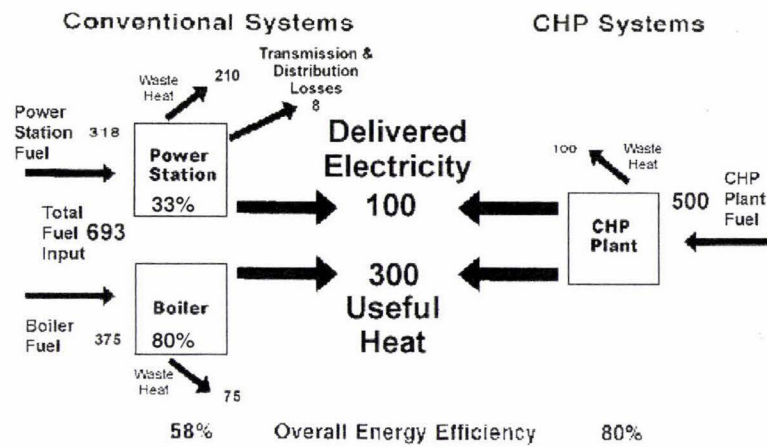


Figure 2-5: An Example of CHP Efficiency Compared with Conventional Supply Systems

Not only can the 'waste' heat be used as a thermal source, in some instances it can be used to generate additional electricity in a co-generation configuration. An example of this is the solid oxide fuel cell [SOFC], which operate at temperatures of around 1000°C where hybrid fuel cell-steam generator systems are used (Lee & Sudhoff, 2001). However, this normally requires high grade heat (high temperature and pressure steam) which is normally outside the domain of units sized for domestic applications.

2.5.4 Utilise Low Cost Process Waste Fuels

Industries that have suitable waste streams such as forestry, dairy and petrochemical can transform a possibly costly waste management issue into a low cost fuel (e.g. timber waste). It would however be unlikely that residential use of such fuels could occur in New Zealand. Industrial DG applications of this variety have occurred in NZ recently. For example Meridian Solutions (a subsidiary of Meridian Energy) is actively pursuing such opportunities and Biogrid (a subsidiary of Carter Holt Harvey) is currently working with Golden Bay Cement to use wood waste to replace some of the coal used at their cement works.

2.5.5 Short Lead Time

The 'off the shelf' availability of many DG technologies minimises lead times and reduces design costs. In addition, their modularity can minimise large capital expenditure by avoiding the need to invest in redundant capacity. By incrementally purchasing additional capacity the risk of uncertain demand can be decreased. Importantly the difficulty in obtaining resource consents in countries like NZ, under the Resource Management Act [RMA], can be eased e.g. avoid having to secure right-of-way access for power lines and consents for large, high impact plants.

2.6 Modes of Application

The different modes of applications of DG are widely known (Table 2-1). In reality the best mode might be a combination of these. For residential applications, the continuous power, CHP and peak shaving modes may be best at different times and locations.

Application Mode	Description
Continuous Power	Unit runs continuously either as: <i>Back-up</i> - running in parallel with the grid <i>Uninterrupted</i> - running independent of the grid
CHP	Utilising waste heat as a useful thermal output
Peak shaving	Operating when demand and/or charges are high
Standby/emergency generation	Periodic use to provide power whenever grid fails
Mechanical drive	Units drive shaft-driven equipment
Grid support	Applications may use DG to defer T&D system upgrade or to provide ancillary services
Emerging applications	Premium or green power

(Source: Distributed power, 2000)

Table 2-1: DG Application Modes

2.7 DG in Deregulated Markets

Various countries world-wide have and still are undergoing market deregulation. A number are reviewed here (Ackermann et al, 1999_a)

2.7.1 England and Wales

An important issue in these countries was the development and commissioning of the Non Fossil Fuel Obligation (NFFO) bidding system. The implementation of NFFO contracts was slower than anticipated due to difficulties with planning mechanisms and has been replaced by a new Renewable Obligations arrangement (suppliers have to include a specified 3% of electricity generated from renewable sources). In addition Renewable Obligation Certificates (ROC's) will be generated and traded.

- Introduction of green pricing mechanisms are expected to lead to a greater number of smaller projects, which may be classified as DG due to their size and/or location.

- In December 1997 the Labour government introduced a moratorium on planning consents for new gas fired power stations, which may slow down new large-scale gas turbines and CHP units.
- A country wide target to achieve 10% electricity generation from CHP plants by 2010 has been introduced. Installed capacity of CHP grew by 62% (1439 MW) from 1991 to 1997.

2.7.2 California

- The state of California has been the subject of much interest due to their second consecutive summer of rolling blackouts in 2001. As one of the pioneers of deregulation in the United States it is interesting to note the small role that DG has played in the power crises.
- The two regulatory issues that are influencing how DG is applied are the funding by the California State Energy Commission and green pricing schemes. The funding for projects which have wind, geothermal, small hydro, landfill gas and biomass technologies. The green pricing schemes include a commitment to build new renewable generation plant when a sufficient amount of customers have signed their commitment to purchase 'green' electricity.
- California has 11% non hydro renewable generating capacity which suggests a significant share of DG. Wind may be an obvious exception as it often feeds into the transmission network and hence cannot be classified as DG.
- It should also be noted that there are other states that have begun to reform their electricity industries such as New York and Texas.

2.7.3 Norway and Sweden

- In Norway the nature of the population distribution has lead to a large number of power companies which in the past developed their own networks and power generation, resulting in wide use of DG. In late 1998, financial support for projects such as wind were introduced which led to a total of 600 MW of wind power now being in the planning stage (Ackermann, 1999). In 1999 the government announced restrictions on CO₂ emissions from new gas plants making them less economically viable. No special regulations for small scale DG exist.
- In Sweden there are a large number of small and micro-hydro stations, some of which are owned by distribution companies. Renewable technologies including wind, that have received special support in the past are now under review making their future uncertain. Biomass as a fuel for DG units has great potential, particularly within the paper industry which includes applications for CHP with electricity being fed into the grid in some cases. Sweden has a CO₂ energy tax for which renewables and DG producing less than 1.5 MW

will be reimbursed for CO₂ tax paid. There are also concessions for small scale generation (up to 1.5 MW), in which the concession holder is required to buy all the power supplied by these small DG units at a tariff that represents the avoided costs of the concession holder.

2.7.4 New South Wales and Victoria

- For the period 1995 to 2000, 1470 MW of new grid connected DG was added in New South Wales, increasing its share to 13.7%. A pollution levy is proposed to be the main driver for DG.
- In Victoria over the same period, 247 MW of DG was added resulting in a 7% share of total generating capacity. A special government program promoting CHP was responsible for about a third of all new DG systems, however with no pollution levy DG has less incentive to be developed.
- A green pricing scheme introduced has led to approximately 19MW of new distributed renewable energy [RE] being employed since 1997 in both states. In addition the nation wide quota for renewable energy which requires retailers 2% of generation to come from RE by 2010 is expected to lead to further installations of renewable distributed energy technologies.

It has been noted during the review of other electricity industries, that they do differ markedly, not only in their physical makeup of generation type and transmission systems but even more so in their restructuring. The 'life' of DG in NZ is difficult therefore to predict from overseas experience.

2.8 DG in the New Zealand Market

2.8.1 Historical

DG in New Zealand is not a new phenomenon. Following the historical overseas trend, electricity was produced at or near the load site, until centralisation of the industry began in the 1930s. Since then, the government and power boards have developed a backbone of high voltage transmission lines, distribution infrastructure, and generation plants using fossil fuels, hydropower and geothermal energy to bring networked electricity to almost every part of the country. New Zealand's reliable T&D system and comparatively low electricity prices as well as its highly reticulated electricity network has led to a low impact of DG on the market.

Figure 2-6 illustrates how the percentage of DG has fallen from 100% in the early 1900s to a low in the 1970s. At this point, following overseas trends, DG (particularly industrial DG) began to be used for more electricity generation. However, it is only from recent times that the percentage of DG has significantly increased mainly due to industrial co-generation plants and the Tararua wind farm.

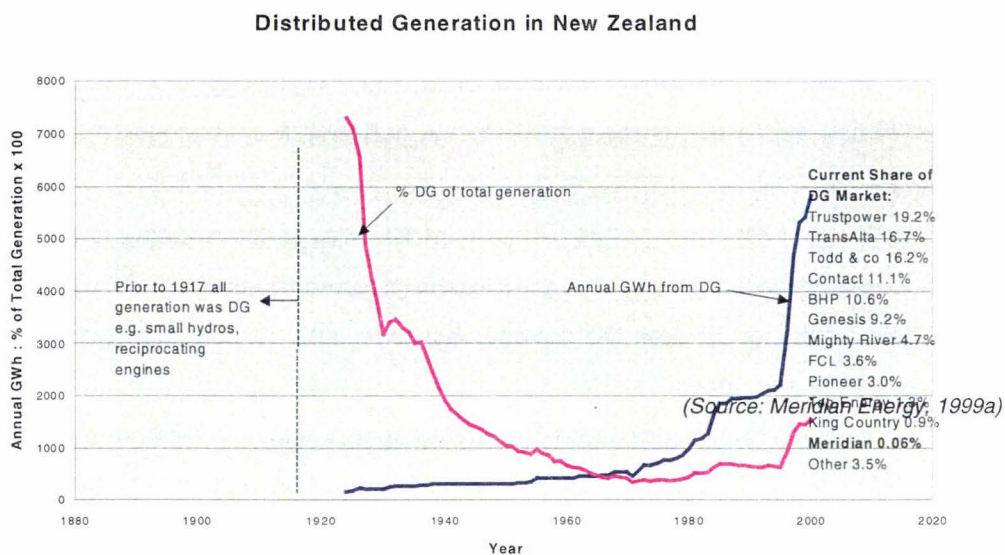


Figure 2-6: DG Development in NZ

2.8.2 Reforms

There have been a progression of reforms in the New Zealand electricity industry. The more recent significant developments are shown in Figure 2-7.

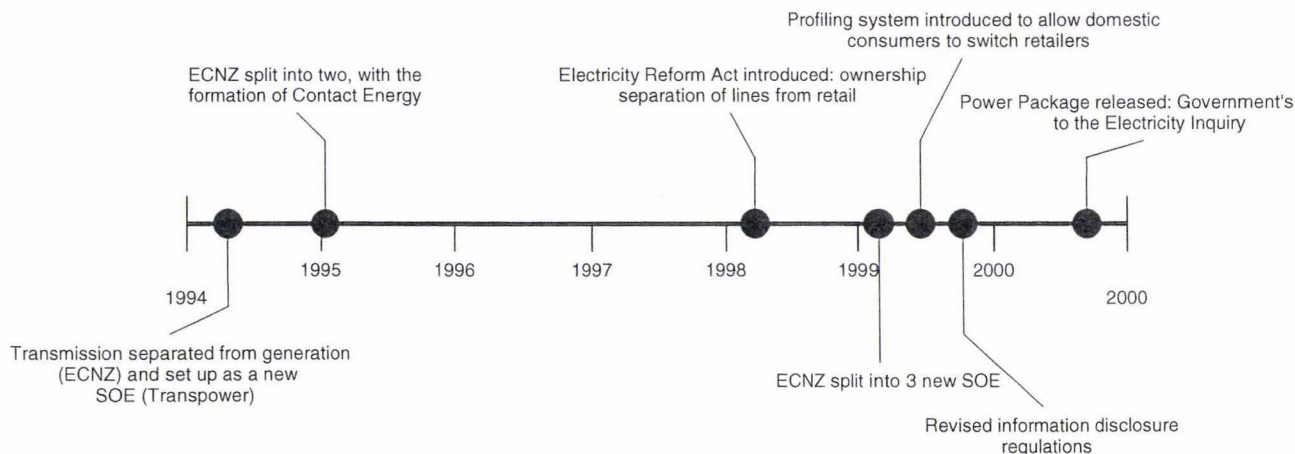


Figure 2-7: Evolution of Electricity Reform in NZ since 1994

In essence the reforms were designed to give smaller consumers a choice of power suppliers and lower prices; lower electricity costs for business and industry; guard against privatisation; and be better for the environment. As indicated above a major component of the reforms was

the Electricity Industry Reform Act [EIRA] 1998, which required the separation of vertically integrated companies into distinct line businesses or generator/retailer businesses. This was to prevent integrated companies from using their monopoly lines position to prevent competition in their area by restricting access to customers, cross subsidising some customers and also by cross subsidising their generation from their monopoly line position. Before the onset of competition wholesale prices averaged 3.35 c/kWh, in a wet year. For the later half of 1999 after the reforms came into play prices dropped to 2.58 c/kWh indicating that, at least at the wholesale level, the government's objective of lower prices was being achieved.

It is vital for any study on DG that the proposed reforms are understood because changes in the regulatory framework can have significant impact on who the players are in the DG market and to what extent that will be mandated.

2.8.3 Ministerial Inquiry into the Electricity Industry

The purpose of this inquiry in 2001 was to "evaluate whether the current regulatory regime (EIRA) meets the government's objective of ensuring electricity is delivered in an efficient, reliable and environmentally sustainable manner". It was undertaken in response to the perception that the previous reforms had not delivered sufficient benefit to consumers. Importantly the discussion on how DG is to be treated is very significant as the economics and therefore application of DG can be greatly enhanced by a favourable regulatory regime.

2.8.4 Power Package

A number of issues were identified in the Inquiry and responded to by the Government in the Power Package (released in 2001), that related to DG. They include:

Ownership of DG

DG should be allowed to be utilised where it is most economically efficient. Lines companies, although having strong drivers to use DG were currently prohibited from owning DG. The government believed that this restriction should be removed to allow lines companies to own DG up to 2 percent of the network's maximum demand or a maximum of 5 MW, provided that the source of such generation is a new renewable and that the generation activity is carried out in a separate company. They believe that this would not endanger the underlying objectives of the EIRA. However some industry participants have questioned whether this will be possible. New legislation enabling this change in ownership has recently been passed.

Construction and implementation of DG plant

Obviously line companies are in a good position to identify opportunities for the implementation of DG within their network. Therefore provision will be made to require that line companies publicise their intentions to construct DG 30 days prior to entering binding contracts. It must be questioned though whether this will allow competitors sufficient time to respond.

Connectivity with the network

It is proposed that the Electricity Governance Board⁸ develop generic terms and conditions for the connection of DG to distribution networks.

However not all points highlighted by the Inquiry with respect to DG were addressed by the Government's response. These include:

Functionality of DG - DG should be allowed to participate in the provision of ancillary services such as demand shedding or frequency support.

Transpower's stand-by charges - Customers utilising on-site generation are required to pay for their off-take based on peaks during the preceding 12 months, even if they only utilise Transpower's services for a fraction of that time. A differential standby facility charge is proposed.

2.8.5 National Energy Efficiency and Conservation Strategy

As Figure 2-8 indicates the National Energy Efficiency and Conservation Strategy (NEECS) is another aspect of the government's energy policy.

Its goals are to (EECA, 2001_a):

- Reduce CO₂ emissions
- Reduce local environmental impacts
- Improve economic productivity
- Promote industry development
- Improve economic resilience
- Reduce energy deprivation

⁸ The Electricity Governance Board [EGB] is the amalgamation of the NZEM, MARIA and MACQS

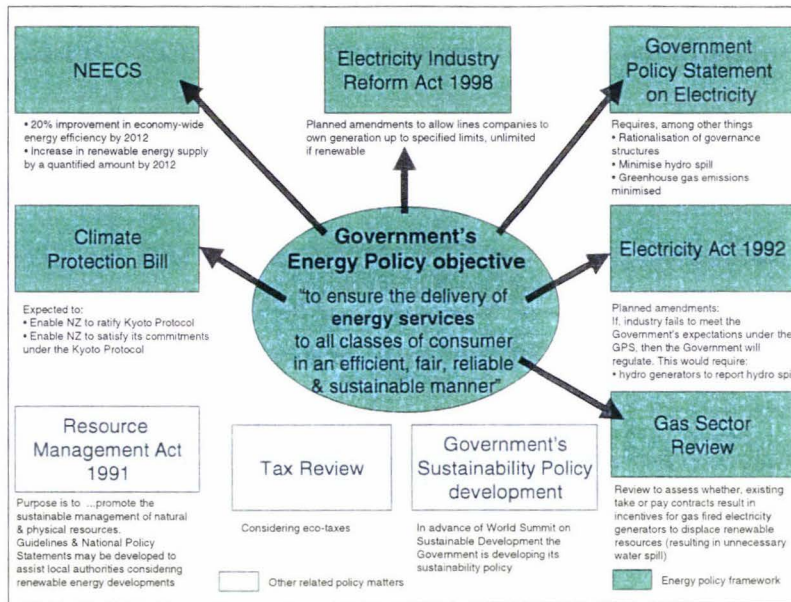


Figure 2-8: Government's Energy Approach (Source: Meridian Energy, 2001)

Its targets which are required to be measurable, reasonable and practical include:

- Energy efficiency: At least 20% improvement in economy-wide energy efficiency by 2012
- Renewable energy: Increase renewable energy supply by 30PJ by 2012.

What is of interest to DG proponents and Meridian Energy is how technologies, including renewables that lend themselves to DG applications are going to be supported as a result of the government policy? Some of the possible measures that may be employed are:

Energy Supply	Renewables	<ul style="list-style-type: none"> • Facilitate use of wood waste in forestry processing sector • Evaluate mechanisms to increase proportion of electricity from renewables
	Electricity sector	<ul style="list-style-type: none"> • Improve understanding of DG and Demand Side Management [DSM] • Introducing pricing to facilitate energy efficiency
	Industry development	Develop support mechanism for solar water heating industry
Buildings		Home energy rating scheme
Industry		Direct grants to carry out energy audits

2.8.6 Current Environment

The current environment provides both encouragement and uncertainty to DG proponents. As shown earlier, proposed changes to legislation, particularly relating to lines companies are addressing some of the issues facing DG. Ironically as the name suggests 'distributed' generation has significant benefits for the distribution network in terms of system capital deferment for line upgrade. But with restricted DG⁹ ownership, lines companies are reluctant to give over control of potentially hundreds of units to third parties. High entry and membership fees into the market have put small companies wanting to specialise in DG at a disadvantage and the lack of common interconnection standards have meant that unforeseen expense and delay can reduce the feasibility of a DG applications.

In the New Zealand market, DG has made an impact. Growth in energy demand over the last five years has averaged around 2% per year i.e. a total of around 500 MW. Approximately half of this has been DG. Table 2-2 (Meridian Energy, 1999_b) summarised the DG installations that have occurred in New Zealand.

Plant	Type	Size (Electric)	Market
Te Rapa	Gas Turbine	60 MW	Dairy Co-gen.
Te Awamutu	Gas Turbine	80MW	Dairy Co-gen.
Bay Milk	Gas Turbine	65 MW	Dairy Co-gen.
Haunui	Wind	3.5 MW	Distribution support
Brooklyn WTG	Wind	225 kW	Embedded generation
Tararua	Wind	32 MW	Embedded generation, distribution support
Blue Mountains Lumber	Biomass Steam	1.5 MW	Industrial co-gen.
Kinleith Pulp and Paper	Biomass Steam	40 MW	Industrial co-gen.

Table 2-2: Recent DG Installations in NZ

The installations fall into two categories: a) Large industrial applications, primarily in the dairy and wood processing industries and network support such as voltage regulation using wind turbine generators. This initial uptake was expected, particularly in the industrial sector where the most profitable sites are 'cherry-picked'. These sites are typically viable because they can utilise low cost fuel and/or the heat produced in a co-generation configuration.

⁹ DG for the use of network reinforcement and peak demand management would probably be dominated by non-renewable generating technologies because of their higher availability.

b) Network support has been provided by WTG, able to supply both active and reactive power. The large increase in units produced, particularly overseas, has resulted in WTG becoming more cost-effective and hence a growing application. Apart from these two categories, DG applications have been minimal, the challenge, if DG is to gain widespread application in New Zealand, is to explore the smaller end user i.e. the small commercial and residential user.

Table 2-3 shows a study conducted by ECNZ's Technology Research Strategic Development Group that shows the number of potential sites in relation to their energy requirements that may be serviced by DG. The domestic market sector represents the greatest potential in terms of the number of sites but the smallest on an energy per site basis.

Market Sector	Annual Growth Total GWh	Average Site Usage GWh	Average Site Load kW	Est. Annual Potential Sites
Industrial	265	10	1,000-3,000	5
Commercial	265	2	50-1000	30
Domestic	265	0.008	3-5	1250

(Source: TRSDG 1998_b)

Table 2-3: ECNZ Study on the Potential Market for DG in NZ

2.9 Previous NZ Distributed Generation studies

The main published studies into the NZ market for DG are reviewed below. Presumably there been more but given the relatively recent interest in DG applications and the previous limited number of interested parties (with a single ECNZ and past prohibition on lines company ownership) the scarcity of work is not surprising.

2.9.1 Industrial Research Limited (IRL)

Numerous studies have been conducted by IRL into different aspects of DG (Table 2-4).

Area	Scope	Detail	Result
Dispersed Power Source (DPS) model	Regional across all of NZ and concentrating on residential market	NZ divided into regional: <ul style="list-style-type: none"> ▪ Resource data ▪ Energy consumption ▪ Electricity price 	Which regions in NZ best support which technologies, based on financial return. They are:

Area	Scope	Detail	Result
<i>Gardiner & Sanders (1999).</i>		<p>Compared different pricing mechanisms:</p> <ul style="list-style-type: none"> ▪ Tariff ▪ Line replacement costs ▪ GXP 	<p>New Plymouth - Photovoltaics</p> <p>Wellington - Wind</p> <p>Palmerston North - Biomass</p>
<i>Sanders & Gardiner (2000).</i>	<p>Two case studies done in the Wellington region:</p> <ul style="list-style-type: none"> ▪ Commercial site ▪ Cluster of small businesses 	<p>Demand profiles simulated against single generating profile</p> <p>Excess power sold to grid</p>	<p>Comparison of different turbine sizes with ROI and payback years. Optimum turbine size of 230 kW with payback periods of between 12 and 20 years, depending on price of electricity saved.</p>
<i>Sanders. (2000).</i>	Regional	Uses retail cost to compare payback time for different regions and technologies.	<p>Provide 'hot spot' map of network areas where renewables are most economical. They are:</p> <p>Marlborough Lines- Solar thermal, Solar PV & Biomass</p> <p>United Networks (Waitemata) Wind energy</p>
<i>Ackermann, et al. (1999_b)</i>	11kV distribution network	<p>2 step process:</p> <ol style="list-style-type: none"> 1) Overall system optimisation model 2) Electrical system simulation 	<p>Embedded WTGs, capable of supplying reactive and active power can improve power quality in low voltage distribution systems. (It is shown that a 280 kW WTG has a similar influence to two 900 kVAr capacitor banks)</p>

Table 2-4: Summary of IRL's Work on DG

It is interesting to note the differences between Sanders (2000) and Sanders & Gardiner (2000) in terms of the optimal regions for various technologies.

The work involved in producing the DPS model appeared to be the most relevant to this thesis. It was designed to simulate and compare the use of various DG technologies in residential applications by considering a number of factors:

- Operating conditions
- Operating capacity
- Import/export of electricity
- Storage and heat recovery
- Demand
- Weather patterns
- Fuel prices
- Technology and fuel types

Significant factors found to impact the feasibility of DPS technologies were:

- geographic availability and cost of renewable energy
- equivalent cost of grid purchase
- comparative cost of network upgrade

The model highlighted the sensitivity of simple economic indicators like payback period to these factors.

Weaknesses in the DPS model include:

- The load profiles are limited in scope and flexibility i.e. they are not linked to any socio-demographic factors and are not sensitive to varying individual end uses i.e. the IRL's model is limited in its ability to reflect demand side changes.
- Economic analysis is simple discounted cash flow and may not take account of other factors e.g. CO₂ tax, and avoided network reinforcement.
- Some of the DG technology descriptions are quite simplistic and the model cannot consider combinations of DG technologies.
- Does not provide an estimate of effect on network in terms of net power flows.
- Does not model diversity between houses.
- Does not offer the capability to perform a network analysis, with a number of houses, each having a DG unit installed.

2.9.2 ECNZ

Before the ECNZ was split into three SOE's a number of investigations into DG were carried out:

Area	Scope	Detail	Result
Ceramic Fuel Cell Ltd <i>ECNZ (TRSDG 1998_a)</i>	ECNZ's fuel cell investment strategy	Comparison of different fuel cells & SOFC in various operating modes	Detailed mass, steam and energy balance on plant
ONSI Power Plant <i>Center for Technology. (1997)¹⁰.</i>	Fuel cell application in NZ	Comparing different applications of: <ul style="list-style-type: none"> ▪ On-site energy ▪ Continuous power ▪ Independent power ▪ Power quality with and without the application of the waste heat	Output of 20yr life giving NPV and IRR. E.g. Fuel cell serving a computer centre as a continuous uninterruptible power supply: NPV \$265 ¹¹ IRR 29.5%
Rutherford House: Case Study Meridian 2000_b	Fuel Cell Application Case Study	Explores different fuel cell types for different sectors of the economy	Suitability of fuel cell type for commercial building and industrial facilities in rank are: <ol style="list-style-type: none"> 1. PAFC 2. PEM 3. SOFC 4. MCFC

Table 2-5: Previous DG Studies by ECNZ

The work carried out by ECNZ centred around their investment in fuel cells. The studies investigated different types of fuel cells, under different operating configurations and for different applications. The study on Rutherford House, a commercial building (10,043 m² floor area), appears to be the most relevant as it analysed how the daily power and thermal component of the load profile could be met with micro-turbine or fuel cell technologies.

¹⁰ Conducted on behalf of ECNZ by the University of Waikato

¹¹ Interest rate of 9%

2.9.3 Transpower

A recently completed study gave a general overview of DG and how it may impact New Zealand's transmission system (Table 2-6).

Area	Scope	Detail	Result
Impact of DG <i>Fuge et al. (2000)</i>	Transpower and the transmission network	High level review of DG	DG impact will be less than growth in demand and most applications will be grid connected

Table 2-6: Transpower's Recent Study on DG

An important aspect considered was the interconnection issues faced by DG, particularly since most applications will be grid connected. The report describes interconnection standards and market mechanisms to determine but the optimal siting of DG within the network.

2.9.4 Other Studies

Numerous works have been carried out in the area of remote area power supply [RAPS] (Irving 2001). These involved rural loads where the significant cost of line upgrades make DG a more viable option. Given that these applications are typically not grid connected and electrical storage facilities are employed, this type of application is a significantly different proposition to urban residences, which this thesis considers.

Overall it was noted that there had been relatively few studies into DG, particularly at the residential level. The studies were either at a high level-general overview or concentrated on a particular technology type. For example, Appendix A.3.3 contains results from a solar hot water heater study (EECA, 2001_a). IRL have done the most wide ranging in-depth studies and have created a model for the assessment of DG economics, unfortunately the DPS model was not available to Meridian Energy.

There are also a number of commercial software models that have been developed to assess DG (Table 2-7). They are primarily sourced from overseas and have a broad range both in the depth of analysis of a particular technology type as well as the number of scenarios and variables examined (E source, 2001).

Model name	Producer
DG Argus	Apogee Interactive
D-Gen Pro	Architectural Energy Corp.
Cogeneration Ready Reckoner	Australian Department of Industry, Science and Resources
Disgenie	e2thermax
Spreadsheet Screening Tool	Energy and Environmental Economics
SOAPP-CT.25	EPRI
DIRECT	Kreider and Associates
RETScreen International	Natural Resources Canada
Quickscreen	Sandia national Laboratories

Table 2-7: Commercially Available Tools to Evaluate DG

These models, whilst providing useful information, did not address the integration of the supply and demand side in the residential marketing sufficient depth and as such could not be used further in this study.