Electricity Demand-side Management

October 2005

Prepared by the Treasury

THE TREASURY
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Electricity Demand-side Management

Executive summary

This report identifies and assesses the range of electricity demand-side measures available, for both peak trimming and load reduction. It quantifies the potential electricity savings as well as the value for money of potential measures, with the aim of informing Treasury's advice regarding the potential contribution of managing electricity demand to maintaining security of supply. The quantitative analysis was undertaken by Jonathan Lermit, an independent energy specialist.

For peak trimming, we look at the potential from rolling outages in the four regions where transmission capacity is of most concern: Northland; Auckland; Nelson-Marlborough and Canterbury.

For total load reduction, we evaluate the potential contribution of energy efficiency measures under three scenarios:

- *Possible* – those measures that are cost-effective (cost less than new generation capacity)
- *Optimistic* – a subset of the “possible” measures, which assumes uptake of relatively hard to encourage people to implement, and
- *Realistic* – assuming uptake of those measures representing “low hanging fruit”, that are relatively easy to get people to implement.

Our analysis is by electricity end-use, and considers total demand (i.e. residential and commercial/industrial). We also examine the direct implementation costs, assess the rationale for Government intervention and identify key implementation risks and issues.

The load curves in the regions in question are relatively flat, suggesting that there is limited scope for further peak management in these areas. Our analysis revealed that peak trimming could only be achieved by load shedding for four or more hours a day over winter months. This clearly raises issues of acceptability and practicality to consumers.[1]

[1] Further and more detailed consideration of the scope for peak management via interruptible loads is available on the Electricity Commission’s website www.electricitycommission.govt.nz . See in particular: http://www.electricitycommission.govt.nz/opdev/transmis/pdfsconsultation/contractstructureandcounterparties/skm-report.pdf and http://www.electricitycommission.govt.nz/pdfs/opdev/transmis/pdfsgeneral/Auck-Elect-Demand-Characteristics-V2.pdf

However, there is considerable potential for achieving load reduction via energy efficiency measures. Economically justifiable measures represent around 22% of current consumption (built up over five years). The realistic savings are considerably lower, at around 6.5%. A comprehensive energy efficiency campaign which included all identified measures could be expected to reduce electricity demand growth from an average of 1.6% per annum to around 1.0% per annum over the next five years. These measures could also have the effect of reducing current peak load by around 4.7%. Savings are regionally dependent, due to variations in climate and load mix, and are greater in the four regions facing transmission constraints (with peak savings from energy efficiency ranging from 5.10% to 5.75%).

The biggest potential gains in *total demand reduction* relate to motive power (more efficient motor drives), water heating, lighting and refrigeration. The best *value for money* measures are in:

- *Lighting* (replacing incandescent bulbs with compact fluorescents)
- *Pumping* (replacing constant speed drives and power pumps with variable speed drives), and
- *Electrical and refrigeration* (replacing the existing stock of electrical and electronic equipment with more efficient models, and the existing stock of fridges with better insulated models).

Many of the barriers to uptake of energy efficiency relate to information – be it electricity pricing issues (average versus marginal pricing; fixed versus variable tariffs), or regarding the availability, quality, reliability or effectiveness of efficiency measures and their technologies. Limited access to capital may restrict users' ability to invest in measures which require a large upfront investment. There are also environmental externality arguments for Government intervention in this area.

There is a wide range of tools available to Government and the private sector, for overcoming these barriers and encouraging uptake of DSM measures. They include contractual tools for managing peak demand (such as ripple control), regulation, information provision, and price-based measures (such as taxes and financial incentives). The Government already has in place a broad suite of measures, spanning regulation (mandatory standards), labelling, information provision, audits, grants and the planned carbon tax. Existing measures are targeted at those end-uses that our analysis shows represent good value for money. Several electricity generators are also working, either independently, or in partnership with Government, on providing information and subsidising products to enhance energy efficiency.

Implementation of any additional policies would need to take into consideration not just the potential electricity savings and value for money of individual measures, but also:

- Rationale for Government intervention
- Fit with existing programmes
- Synergies with other measures

- Industry capability and capacity
- Risk of displacing/duplicating private sector initiatives, and
- Dynamic, technical implementation issues.

Further work would be required to devise suitable, detailed policy packages of additional measures. However, given the potentials we have identified, the extent and range of existing policies, and the rationale for further intervention, possible measures include: an extended and sustained education campaign; an expanded MEPS/labelling programme; and perhaps additional, targeted financial assistance. The relatively flat load curves suggest that contractual peak trimming tools are unlikely to be cost effective.

There also looks to be potential to refine existing energy efficiency programmes, to ensure that the benefits from these activities are maximised. From an administrative perspective, it is attractive to fine-tune existing programme that have potential to deliver good, value for money results, rather than establish new ones. Critical to this is adequate monitoring and evaluation, including good quality data on programme efficacy. In addressing behavioural change, there will always be an element of "learning by doing", and programmes should be sufficiently flexible in design as to allow refinements in delivery and targeting.

Background

In 2004, Treasury undertook research on the potential for sustained, economy-wide energy efficiency gains in New Zealand. This was a top-down, largely theoretical analysis, and concluded that there looks to be limited scope for additional, sustained energy efficiency improvements across the New Zealand economy. The work looked at total energy use (as opposed to electricity only) and suggested that, whilst energy efficiency improvements are likely to continue on an incremental basis, major or rapid gains are unlikely to occur autonomously in the economy. However, given the current structure of New Zealand's comparative advantage (in energy intensive industries), more drastic policy responses are unlikely to be cost effective.

This previous work highlighted the desirability of a more quantitative, bottom-up assessment of the potential for achieving further gains in energy efficiency.

Purpose of report

We have a particular interest in electricity efficiency, as reducing growth in the *total* electricity load can defer the need for investment in additional generation capacity. And reducing *peak* electricity load can defer investment in additional transmission capacity.

This report seeks to provide a quantitative, bottom-up assessment of the potential gains for electricity load management and reduction. We do this in the following way:

- Examine what is sought from demand-side measures.

- Assess the business as usual path of projected electricity demand.
- Estimate the potential electricity savings (both total demand and peak load) from the range of potential measures. We do this by considering cost effective measures – i.e. that cost less than investment in new generation capacity – and provide three scenarios representing the range from what is economically possible to what is likely to occur in the market.
- Identify and assess the range of mechanisms for achieving these savings, giving particular consideration to their relative value for money and intervention logic.
- Presenting a range of packages for improving demand-side management, highlighting some key risks and implementation issues.

The quantitative estimates were prepared for Treasury by an independent consultant, Jonathan Lermit. Data were provided by the Ministry of Economic Development (MED), the Energy Efficiency and Conservation Authority (EECA) and the Electricity Commission (EC).

What is demand-side management?

Demand-side management (DSM) is joint control of electricity supply and electricity demand. It includes a broad range of tools for changing electricity load shape. Objectives include:

- reducing price volatility/flattening spot prices
- improving system security and reducing the risk of black-outs
- reducing network congestion
- delaying construction of additional generation, and/or grid and network upgrading
- reducing greenhouse gas emissions, and
- improving market efficiency by enhancing consumers' ability to respond to changing prices.

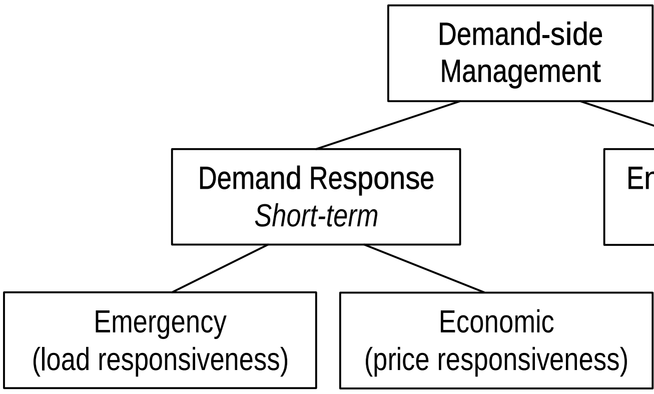
DSM measures can also lower consumers' total electricity costs.

Measures fall into roughly two categories: those can that reduce total load, and those that change load shape by shifting demand into other periods throughout the day.

Measures that lock-in reductions in total load (such as energy efficiency measures) can be considered long-term options. Measures that reduce peak loads via load responses can be considered short-term, and may not reduce total load. The two sets of measures can be complementary.

Differing definitions and categorisations of DSM abound in the literature. In particular, there seems to have been a move towards referring to the broad gamut of measures as "demand-side participation", moving the responsibility for response away from the generators or distributors, on to the end-user. One useful definition framework proposed by the Wedgemere Group Inc (2004)[2] distinguishes the various measures as follows.

Figure 1: Definition framework

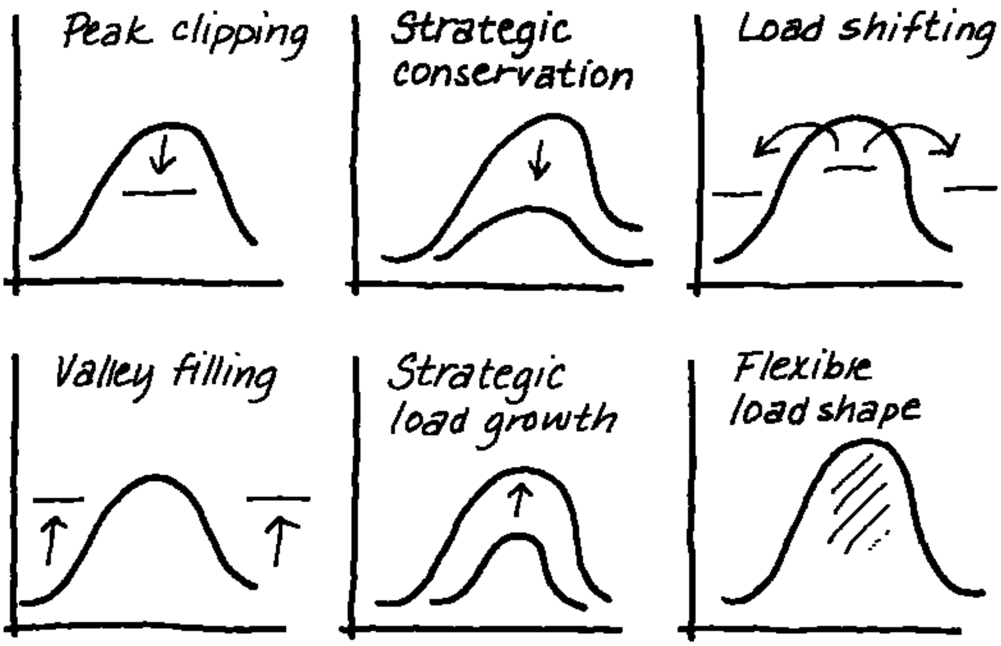


Source: Adapted from Wedgemere Group Inc., 2004

For the purposes of our analysis, and for convenient short-hand, we will use the general catch-all of DSM. Our analysis will cover the full electricity market – i.e. both residential and commercial/industrial sectors.

The following diagrams illustrate the variety of ways DSM can impact on total load. Time of day is on the x-axis, and electricity use (volume) on the y-axis.

Figure 2: Pictorial representation of DSM measures



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2 *Demand Response in the United States: An Overview*. Report prepared for EECA by Wedgemere Group Inc., 2004.

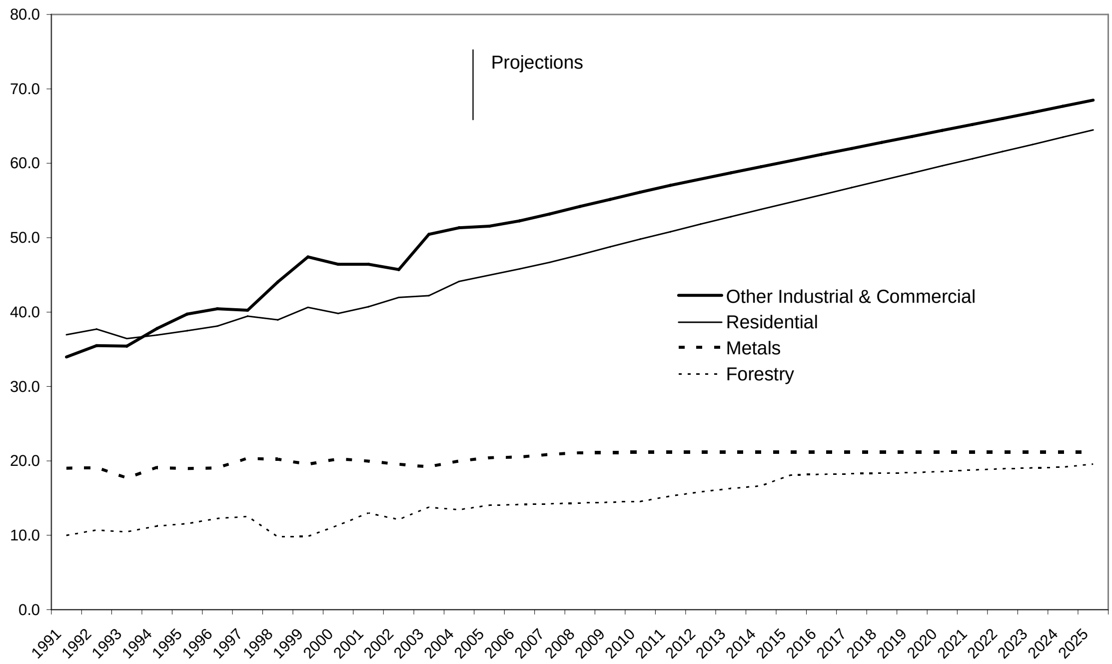
Source: “Perspectives on Demand-Side Energy Efficiency”, Olof Björkqvist. http://www.bjorkqvist.nu/thesis/llodshps.gif

What’s the status quo?

Total demand for electricity in New Zealand is expected to grow by an average of 1.4% per annum over the next twenty years, increasing to 174 net PJ by 2025. Growth is higher in the short term, averaging 1.6% per annum over the next five years.

Growth will be highest in the residential sector, which will increase by around 43% over this period. Strong growth is also expected in the forestry sector, although this comprises a much smaller proportion of total electricity demand.

Figure 3: Projected electricity demand by sector (net PJ)



Source: anticipated update for *Energy Outlook* to be published in 2006 by MED.

Table 1: Projected growth in electricity demand, net PJ

	Total growth, 2005-2025	Annual average growth, 2005-2025	% total electricity demand, 2005	% total electricity demand, 2025
Residential	43%	1.8%	34	37
Other Industrial and Commercial	33%	1.4%	39	39
Metals	4%	0.2%	16	12
Forestry	39%	1.7%	11	11
TOTAL	**33%**	**1.4%**	**100**	**100**

Table 2: Projected electricity generation by source

	Level of generation (TWh)		% of generation	
	2005	**2025**	**2005**	**2025**
Hydro	23.86	24.02	60	45
Coal	5.26	10.74	13	20
Cogeneration	1.04	3.74	3	7
Gas combined cycle	5.34	3.02	13	6
Geothermal	2.72	5.84	7	11
Wind	0.68	5.71	2	11
Fuel oil/distillate	0.82	0.00	2	0
TOTAL	**39.71**	**53.08**	**100**	**100**

Source: MED (anticipated update for *Energy Outlook* to be published in 2006). NB, the variation between demand and generation figures is due to transmission losses (~10%).

Note: 3.6 PJ = 1 billion kWh. 1 TWh = 10^{12}

Assumptions

The Government currently has in place a range of policies aimed at achieving the National Energy Efficiency and Conservation Strategy (NEECS) target of a 20% increase in energy efficiency uptake by 2012. This baseline electricity scenario assumes no impact from NEECS-related policies, but includes a $15/tonne carbon tax[3] and the first two rounds of Projects to Reduce Emissions.[4]

Autonomous energy efficiency is incorporated into the baseline in terms of the way it features in capital investment decisions. Investment projections are based on historical investment rates, and in this way extrapolate forward historic rates of autonomous energy efficiency, of about 0.75% per annum. This takes the “natural” rate of growth to around 2.15% per annum.

Objectives of measures

The appropriate package of DSM measures will depend on whether we are primarily concerned with addressing total load, peak load or network congestion issues (or a combination). This analysis seeks to design different packages of measures that are suited to focusing on different objectives. Because of the interplay between short-and long-term measures, some measures may address multiple objectives.

Various measures will also impact on other areas of policy interest, such as greenhouse gas emissions, ambient air quality and health benefits. We do not give explicit consideration to these impacts here. However, further work could further extrapolate our results e.g. by applying emissions factors.

More generally, we may be interested in the impact of DSM on the scope for decoupling of energy use from economic growth.

Intervention logic

Measures which are economically justifiable may not actually get implemented. Why the gap between economic potential and actual (market) potential?

Previous work by Treasury distilled the potential barriers to uptake of energy efficiency measures into four main categories:

- information problems

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3 This assumption was current at the time of analysis. The Government has subsequently rescinded its carbon tax proposal.

4 The Projects to Reduce Emissions programme involves the Government granting Kyoto emissions units (carbon credits) to firms undertaking projects that reduce emissions of greenhouse gases. A key selection criterion is that the Projects would not proceed under a business as usual scenario, and are unviable without the value of the units. Firms can trade these units internationally.

- incentive problems
- principal-agent problems, and
- pricing problems resulting from externalities (i.e. where the social or environmental costs/benefits exceed private costs/benefits).

The distinction between information and incentive problems is somewhat fluid. Behavioural/attitudinal barriers can be broadly grouped under "information", as most of these factors relate to the dissemination, acquisition, comprehension and application of information (be it regarding payback periods, potential benefits, marginal energy prices or the implementation of energy efficient products and systems). "Incentives" cover aspects such as energy comprising a small proportion of total expenditure, management incentive structures and consumer preferences (i.e. relative weighting of end-use values).

In the New Zealand context, our history of relatively low electricity prices is likely to be a key driver of attitudinal barriers. This is because low prices translate into electricity comprising a relatively small proportion of total operating/input costs. In most industries, electricity is therefore an essential but proportionally small input to the industrial process and is hence not a high priority for management. Apart from electricity-intensive industries, electricity typically accounts for less than 5% of total operating costs. End-users are likely to be more concerned with making large savings in significant cost areas, than achieving relatively small gains from low cost components.

There may be split incentives between the investor (responsible for the fixed costs of energy efficient investment) and the person facing the resulting operational energy costs (benefits). For example, a property owner may have little incentive to install energy efficient fittings when it is their tenant that will reap the benefits of lower energy bills.

Where investment is not part of an industry's core business, a much higher than standard rate of return may be required. This may serve to limit the introduction of energy efficient measures. Limited information (or misinformation), uncertainty and associated risk may also contribute to the apparently high discount rates applied to energy efficient investments.

In terms of appliances, consumers can be largely in the hands on manufacturers – who may be unwilling to produce energy efficient models (which may be more expensive relative to competing models). The costs of investing in such production could outweigh the benefits if energy efficiency features benefits are a minor concern in purchase decisions (e.g. because energy use represents a small proportion of total expenditure), or if there is likely to be free-riding by other firms on the provision of such information.

More efficient use of electricity has environmental benefits. Some of these benefits (such as reduced emissions) accrue beyond the investor, to society at large (i.e. social benefits exceed private benefits). The investor is not compensated for these aspects, and is therefore unlikely to factor them in to their private decision-making – the so-called "principal-agent problem". The socially optimal level of energy efficient investment may therefore exceed that which is optimal for the private decision-maker.

These characteristics of external effects are sometimes described in the literature as public goods. Public goods are a discrete category of market failures. The first best policy response for addressing external effects involves internalising costs (imposing costs on polluters, e.g. via taxes or regulation) so the prices faced by consumers reflect the environmental as well as production costs. In the case of energy efficiency, pricing in negative environmental effects of energy generation/use would make efficiency measures relatively more attractive, as the cost of using energy would be higher. The planned carbon tax is an example of such pricing.

Another pricing problem occurs when electricity prices are based on average rather than marginal costs. This can distort decision-making, as it inhibits users' price-responsiveness and provides inadequate incentives to invest in energy efficiency. The structuring of tariffs (fixed rather than variable pricing) acts in a similar way.

The issue of pricing is likely to be a key barrier to uptake of energy efficiency measures, particularly in the New Zealand context where consumers have historically faced relatively low electricity costs.

Limited access to capital may restrict users' ability to invest in energy efficiency, particularly where this requires a large initial investment. Energy efficient devices (including household appliances) typically have higher initial purchase prices (but lower operating costs) than their less efficient counterparts. This may be more of a constraint for low-income households and small firms.

Options analysis

DSM measures can be broadly divided into two categories:

- **Behavioural measures** – actions which require little or no investment, but which require time, thought and action by the end-user. These are largely "good housekeeping" measures (such as draught stopping and switching off appliances/lights when not in use), which can be encouraged by publicity campaigns, and
- **Economic measures** where some investment is required but are cheaper than investment in new generation and transmission systems. For example, replacement of incandescent lightbulbs with compact fluorescents.

There is no hard and fast separation between these categories, for example energy efficiency measures undertaken in the home at no cost may require the appointment of an "energy manager" in industry. Some measures at a residential level which are technically no cost, such as the use of a clothesline instead of a clothes dryer, nevertheless require what would otherwise be leisure time, and so have an opportunity cost.

Peak management

Peak reduction by load management is already highly developed in New Zealand. In particular, control of residential water heating is almost universal. Our analysis focuses, on a regional basis, the possibility of *additional* load management to reduce peak demand. The regions of interest are where transmission capacity is of most concern: Auckland; Northland; Canterbury and Nelson-Marlborough.

We consider the potential for peak management in two ways:

- shifting load at targeted peak times by rolling cuts in electricity usage (either through voluntary/contractual means such as interruptible contracts, or mandatory means), and
- peak trimming resulting from measures that reduce total load (i.e. energy efficiency measures).

We do not explicitly consider the potential for short-term price responsiveness (the "economic – price responsiveness" category shown in Figure 1).

Load curves (other than major industrial loads) typically have separate morning and evening peaks. Since the intention is to *shift* load, rather than remove it entirely, any peak management scheme must allow for lost load to be replaced within a few hours.

Load reduction

Potential efficiency measures are best split by end use. The following table outlines the most significant measures that can be taken in each case.

The table below sets out the end use categories contained in EECA's Energy End Use Database. The following categories have been excluded:

- aluminium production and steel production – these represent specialised technologies already near optimal conversion level
- high temperature heat (>300^{0}c) process requirements and low temperature heat (<100^{0}c) process requirements – represent very small specialised use
- motive power (mobile) – no electricity use
- transport (air, sea) – no electricity use
- transport (land) – negligible electricity use
- transport (rail) – electricity is assumed to be more efficient than alternatives such as diesel.[5]

Measures which would cost more than the cost of new generation are excluded from consideration. In New Zealand, this includes double glazing, the reason being that our relatively temperate climate makes this less cost effective than in countries subject to more extreme temperatures.

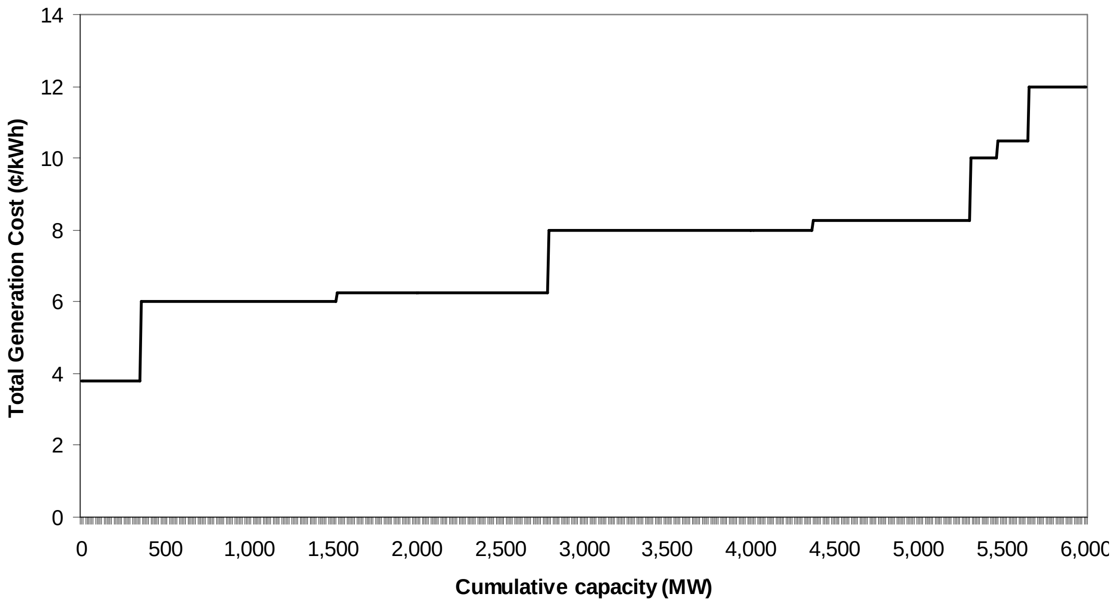
[5] However, diesel technology has been closing this gap. Furthermore, a decision on urban electrification in Auckland is yet to be taken.

Assumptions

Cost of new generation

Assumptions regarding the cost of new generation are taken from MED's *Energy Sector CO_2 Projections to 2020* (see Figure 4, below). Transmission and distribution costs are additional (assumed to be around 4 cents per kilowatt hour). In practical terms, the marginal generation cost is not critical to our analysis, as most efficiency measures are significantly cheaper than the marginal cost of supply.

Figure 4: Indicative New Plant Generation Costs (cents per KWh)



Source: MED Energy Sector CO_2 Projections to 2020.

Uptake of measures

The assumptions regarding behavioural change are based on several international studies, in particular the Canadian study *BC Hydro Conservation Potential Review* (May 2003). The essential definitions are:

- Most likely (realistic) scenario – assumes uptake of the measures representing the "low hanging fruit" – i.e. measures that are likely to be taken up by around 50% of consumers.
- Optimistic scenario – assumes successful uptake of relatively harder to implement measures, that are only likely to be taken up by 5% of consumers.

Table 3: Potential measures by end-use

End use	Measure
Ambient heat	• Capturing ambient heat and transforming it into useful energy, e.g. heat pumps
Electronics and other electrical uses	• Shutting off electronic appliances when not in use • Replacement with more energy efficient appliances
Intermediate heat (100-300^{0}C) cooking	• Increasing use of microwave technology
Intermediate heat (100-300^{0}C) process requirements	• Conversion to other fuels
Lighting	• Shutting off when not in use • Replacement of incandescent bulbs with compact fluorescent bulbs
Low temperature heat (<100^{0}C) clothes drying	• Replacement of dryers with more efficient (better insulated) models
Low temperature heat (<100^{0}C) space heating	• Replacement of resistance heating with heat pumps
Low temperature heat (<100^{0}C) water heating	• More widespread use of solar power • Transfer to gas
Motive power (stationary)	• Improved efficiency of motors as they are replaced • Introduction of electronic variable speed drives
Pumping	• Introduction of variables speed drives to replace valves that restrict flow
Refrigeration	• Replacement of fridges with more efficient (better insulated) models

Source: Lermit (2005)

Potentials

Load shifting

To analyse load shifting, we examine the days of maximum demand in 2004 for the various regions.[6] The assumption is that load will cut for up to a few hours, and replaced immediately afterwards. This may require other load to be cut later when the earlier load is restored. This is the typical pattern used in water heating, when heaters will need additional energy after a period of control. It is assumed that the energy used will remain unchanged in total.

6 Note that it is not suggested that these regional load curves are representative of New Zealand as a whole. Indeed other regions can have quite different load curves (for example Alpine Energy in Timaru sees summer rather than winter peaks).

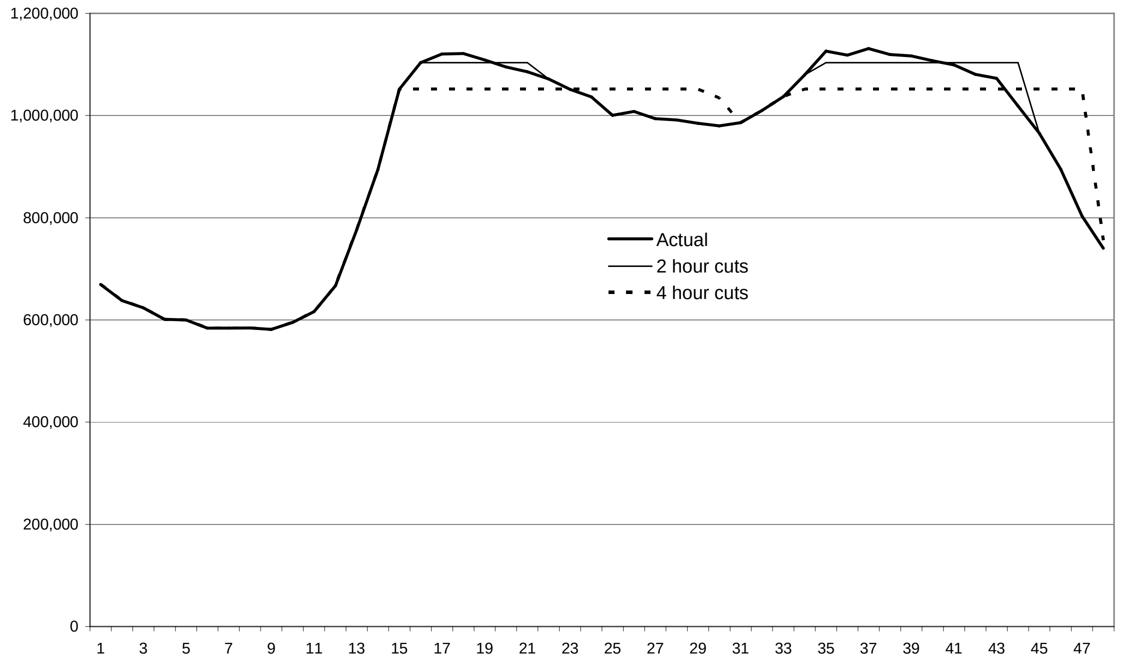
The potential for peak load savings is regionally dependent, due to both climate and load mix (the latter due to industry composition and mix of residential and commercial/industrial demand).

The charts below plot actual load data in kW for the peak demand day of 2004. The x-axis shows the time of day, at half-hourly intervals (from midnight). Actual data are sourced from the Electricity Commission.

As shown, the Auckland load is already fairly flat. Imposing 2-hour cuts therefore reduces the load only slightly, saving around 2.5% or 28MW. A more severe 4-hour rolling cut reduces maximum demand by around 7.6% or 80MW.

Figure 5: Auckland Load, kW, half-hourly data

Peak day for 2004

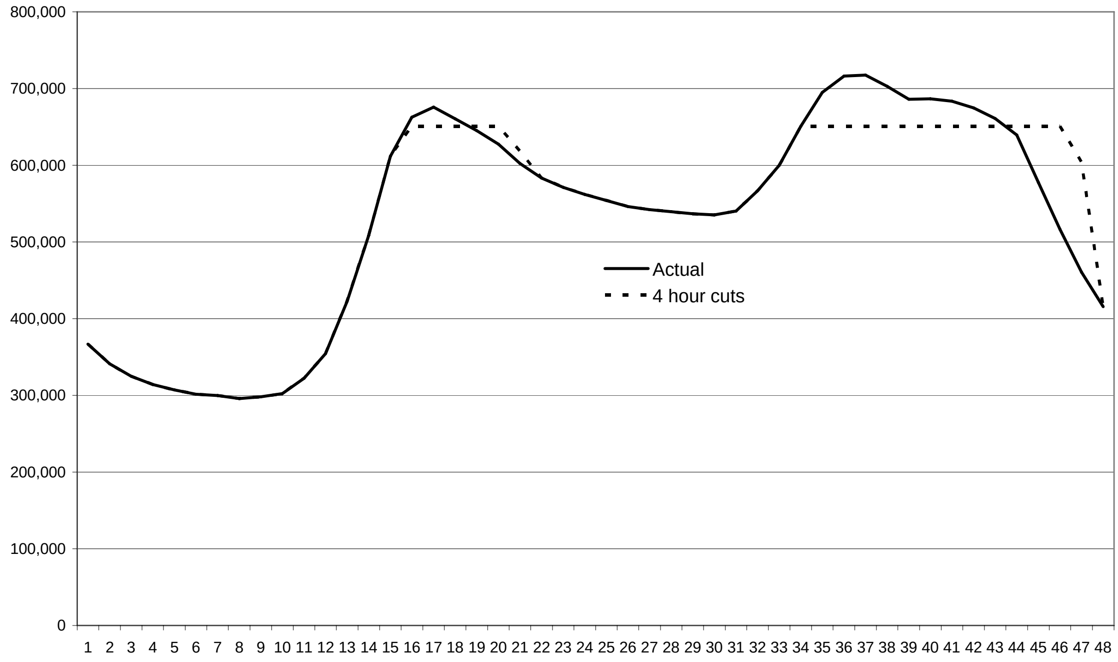


Source: Electricity Commission and Lermit (2005)

The Northland load offers more scope for load control, due to a high proportion of residential load. However, this can only be achieved via long load interruptions, of about four hours, in the evenings.

Figure 6: Northland Load kW, half-hourly data

Peak day for 2004

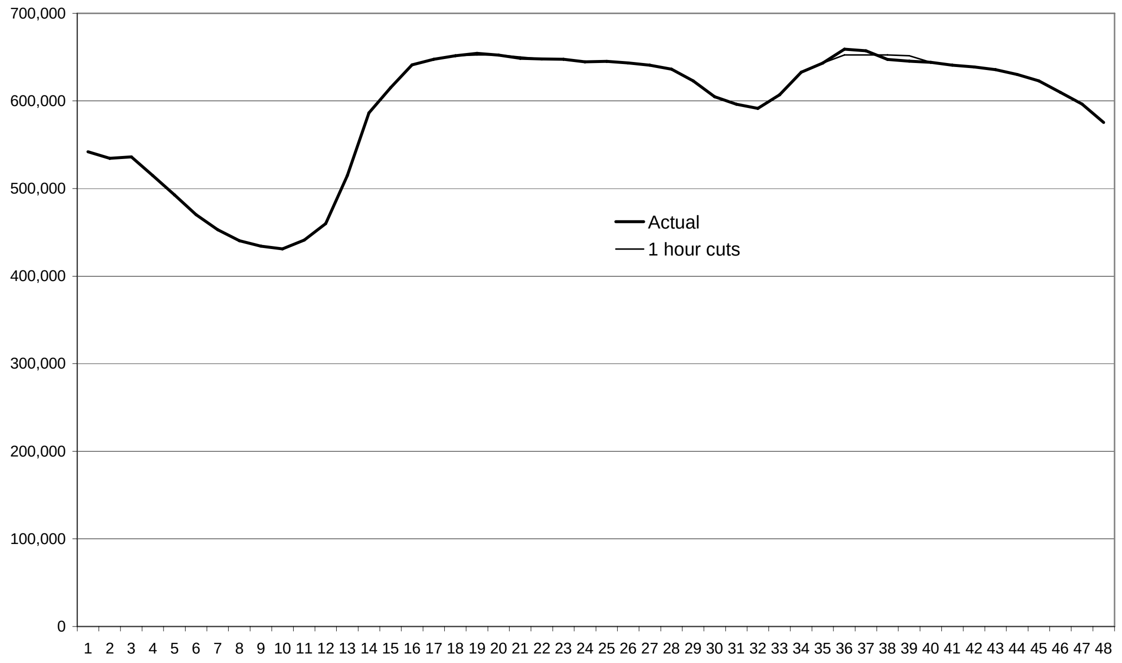


Source: Electricity Commission and Lermit (2005)

The Canterbury load is extremely flat throughout most of the day. This makes significant peak savings impossible. Moving to 1-hour controls saves 1.0% or 6.5MW. Saving more would require moving to rolling cuts of at least six hours.

Figure 7: Canterbury Load kW, half-hourly data

Peak day for 2004

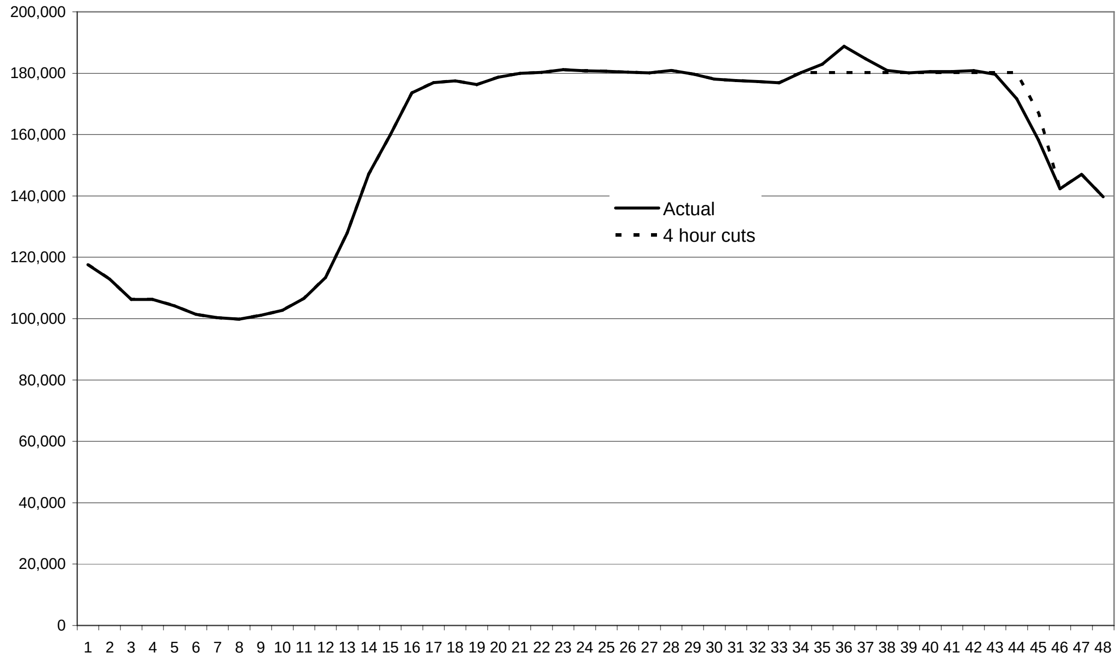


Source: Electricity Commission and Lermit (2005)

The Nelson-Marlborough load is also extremely flat. The only opportunity to reduce the peak load is to manage the occasional "rogue" peak as shown in the chart. This would have required a 4-hour control period.

Figure 8: Nelson-Marlborough Load kW, half-hourly data

Peak day for 2004



Source: Electricity Commission and Lermit (2005)

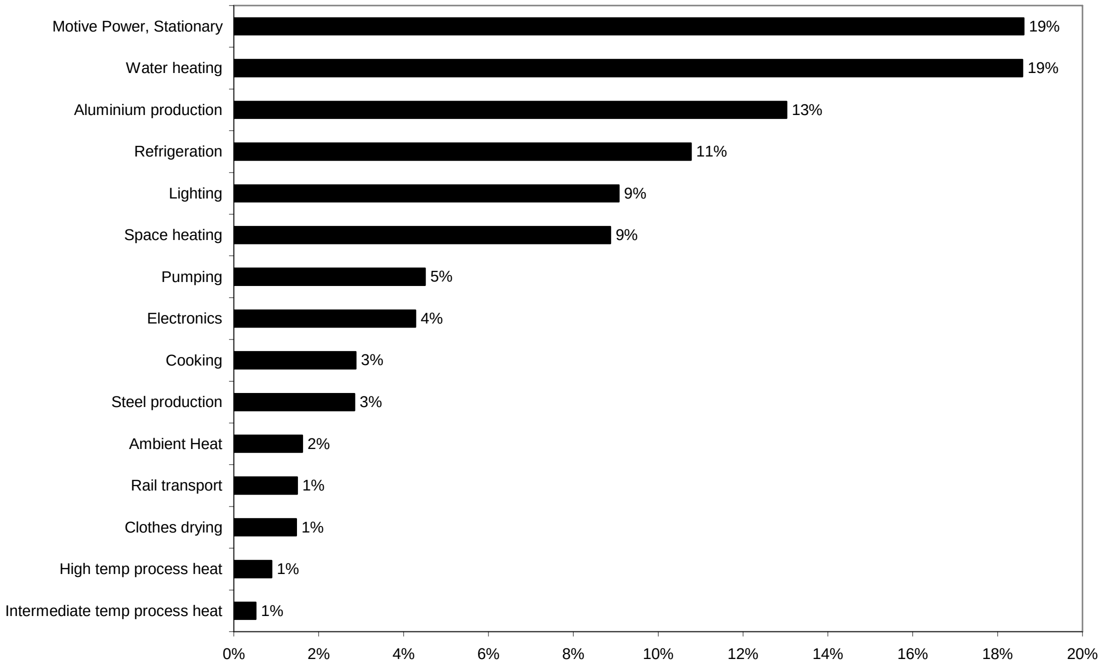
Energy efficiency

We obtained electricity end-use data from EECA's energy database, for the calendar year 2004. Our estimates of potential savings will therefore take into account the impact of EECA's programmes that were in place over this time, by estimating *additional* savings. However, they will not include the impact of the Electricity Commission's electricity efficiency programmes, as these were still in the design stage over this period.

Data were split by both class of user (residential, commercial and industrial users by industry) and by type of energy use (lighting, heating and so on). The chart below shows annual electricity use for 2004, by end use.

Figure 9: Annual electricity use by category

Per cent of total use, calendar year 2004



Source: Energy End Use Database, Lermit (2005)

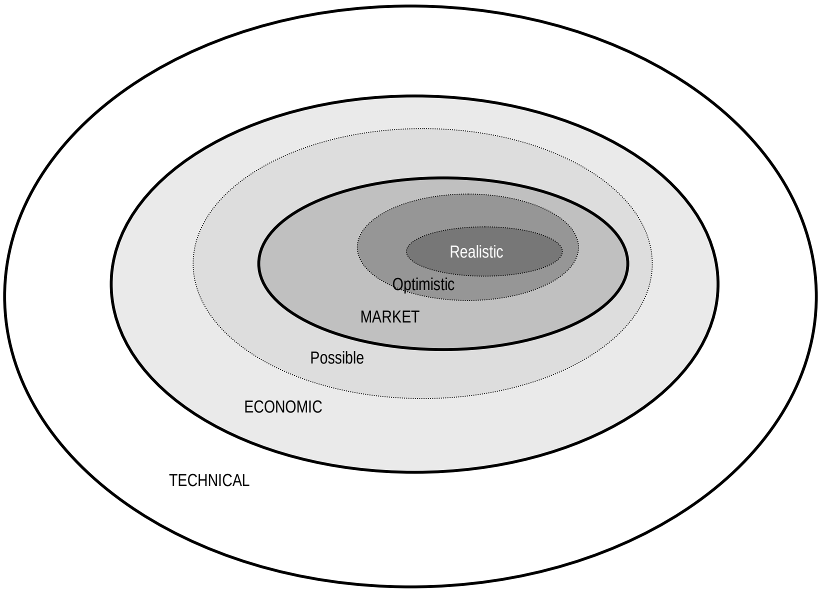
The potential energy savings are based on information from both EECA studies and overseas research. Estimates effectively include the implicit costs of behavioural change, such as the opportunity cost of time taken to hang washing outside instead of using a clothes dryer. They can thus be considered fairly conservative estimates. Figures relate to potential savings over a five-year period (with savings being built up roughly linearly over this period).

Three sets of figures were derived:

- **Possible** – those savings which are economically viable (i.e. less than the cost of new generation)
- **Realistic** – the “most likely” savings, based on behavioural studies, and
- **Optimistic** – an “upper” estimate of the savings achievable in practice.

These scenarios can be thought of as subsets of the “technical potential”. Where the technically potential refers to the gamut of measures which are technically feasible from an engineering perspective, economic potential refers to only those which are economically justifiable on a cost-benefit basis. Our “possible” scenario is a subset of this economic potential, as we only consider those economically viable measures which are cheaper than the counterfactual in this case – new generation/transmission investment. The optimistic and realistic scenarios can be considered two estimates of the “market” potential – that is, those measures that are actually likely to be taken up by end-users.

Figure 10: Energy Efficiency Potentials



Our estimates show that economically efficient savings are about 22% of current consumption, built up over a five-year period. The realistic estimate is for savings of 6.5%, with an upper (optimistic) estimate at 11%.

The key areas for proportionally large gains are in lighting, water heating, stationary power (electric motors) and pumping. The savings in water heating assume no further switching to gas.

On a nationwide basis, implementing the full range of energy efficiency options, and assuming the "most likely" savings, could reduce annual average electricity demand growth from 1.6% to around 1.0% per annum. The potential savings are greater in the four regions facing transmission constraints. Annual growth in electricity use in these areas is expected to be around 1.8%. This could be reduced to around 0.3% per annum.

The optimistic scenario estimates that demand growth could be pulled down to just 0.1% per annum. Implementation of all possible cost effective measures would see demand *decline* by around 2.1% per annum.

Table 4: Estimated potential nationwide load reduction (GWh)

Savings built up over 5-year period

End use	Current annual use	Possible	Realistic	Optimistic
Ambient heat	603	-30	-15	-21
Electronics and other electrical uses	1599	-38	-15	-30
Intermediate heat (100-300^{0}C) cooking	1074	-83	-14	-42
Intermediate heat (100-300^{0}C) process requirements	192	0	0	0
Lighting	3390	-1624	-244	-406
Low temperature heat (<100^{0}C) clothes drying	549	-143	-13	-18
Low temperature heat (<100^{0}C) space heating	3315	-103	-21	-41
Low temperature heat (<100^{0}C) water heating	6943	-3470	-1239	-1859
Motive power (stationary)	6954	-1738	-695	-1391
Pumping	1684	-477	-93	-184
Refrigeration	4026	-503	-71	-116
TOTAL	**37354**	**-8209**	**-2420**	**-4108**

Note: components of electricity use do not sum to total, as some categories excluded.

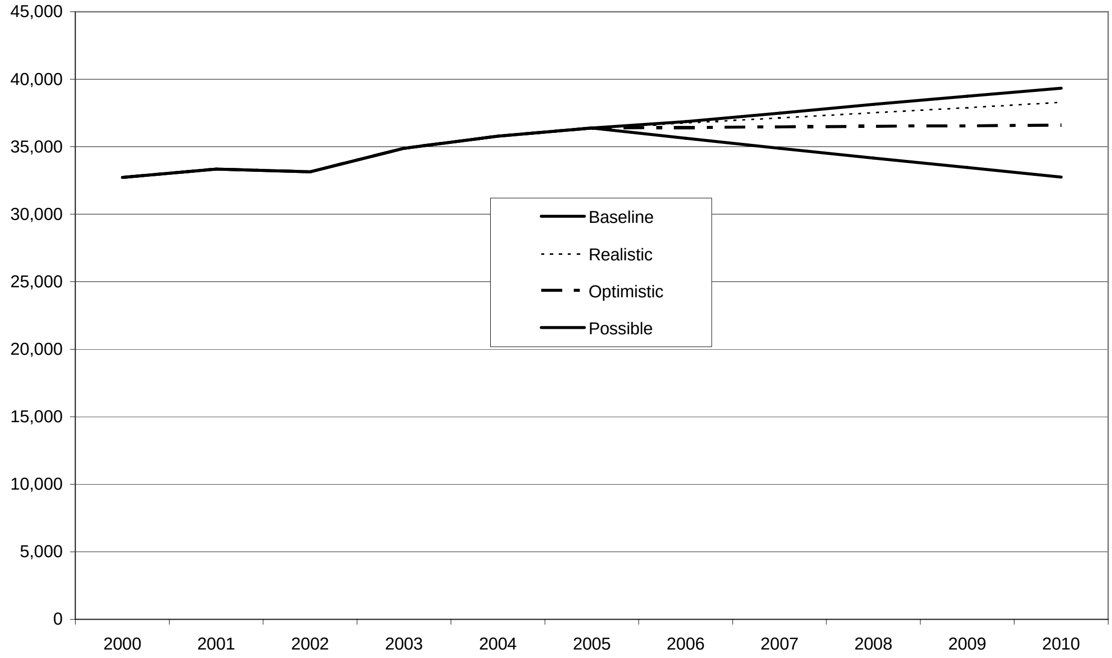
Table 5: Potentials as percentage of total current NZ annual use (%)

End use	Possible	Realistic	Optimistic
Ambient heat	0.08	0.04	0.06
Electronics and other electrical uses	0.10	0.04	0.08
Intermediate heat (100-300^{0}C) cooking	0.22	0.04	0.11
Intermediate heat (100-300^{0}C) process requirements	0.00	0.00	0.00
Lighting	4.35	0.65	1.09
Low temperature heat (<100^{0}C) clothes drying	0.38	0.03	0.05
Low temperature heat (<100^{0}C) space heating	0.28	0.06	0.11
Low temperature heat (<100^{0}C) water heating	9.29	3.32	4.98
Motive power (stationary)	4.65	1.86	3.72
Pumping	1.28	0.25	0.49
Refrigeration	1.35	0.19	0.31
TOTAL	**21.98**	**6.48**	**11.00**

Table 6: Potentials as percentage of current annual use by category

End use	Possible	Realistic	Optimistic
Ambient heat	5.00	2.50	3.50
Electronics and other electrical uses	2.35	0.94	1.88
Intermediate heat (100-300^{0}C) cooking	7.75	1.29	3.88
Intermediate heat (100-300^{0}C) process requirements	0.00	0.00	0.00
Lighting	47.90	7.20	11.98
Low temperature heat (<100^{0}C) clothes drying	26.00	2.33	3.33
Low temperature heat (<100^{0}C) space heating	3.11	0.62	1.25
Low temperature heat (<100^{0}C) water heating	49.98	17.85	26.77
Motive power (stationary)	25.00	10.00	20.00
Pumping	28.33	5.52	10.90
Refrigeration	12.49	1.75	2.88
TOTAL	**21.98**	**6.48**	**11.00**

Figure 11: Projected impact on electricity use
Baseline vs All measures scenarios, GWh
Savings built up over 5-year period



Source: Lermit (2005)

Energy efficiency measures which lock in sustained load reductions can also contribute to peak management. The biggest potential for peak trimming is in the lighting, water heating and motive power categories. Implementing the full range of options would deliver 4.7% per annum reduction in current peak load, under a “realistic” scenario.

Peak savings are greater in the four regions facing particular transmission constraints. The realistic peak savings range from 5.10% to 5.75% per annum in these four regions.

Table 7: Potential peak load reduction, total NZ (MW)
Savings built up over 5-year period

End use	Current peak load	Possible	Realistic	Optimistic
Ambient heat	98	-5	-2	-3
Electronics and other electrical uses	261	-6	-2	-5
Intermediate heat (100-300^{0}C) cooking	175	-14	-2	-7
Intermediate heat (100-300^{0}C) process requirements	31	0	0	0
Lighting	553	-265	-40	-66
Low temperature heat (<100^{0}C) clothes drying	90	-23	-2	-3
Low temperature heat (<100^{0}C) space heating	540	-17	-3	-7
Low temperature heat (<100^{0}C) water heating	1132	-283	-101	-152
Motive power (stationary)	1134	-283	-113	-227
Pumping	274	-39	-8	-15
Refrigeration	656	-82	-12	-19
TOTAL	**6089**	**-1016**	**-286**	**-503**

Source: Lermit (2005)

Additional benefits

Our analysis has not considered the secondary benefits of potential savings, such as lower operating costs (via lower electricity bills) or reduced greenhouse gas emissions.

Costs

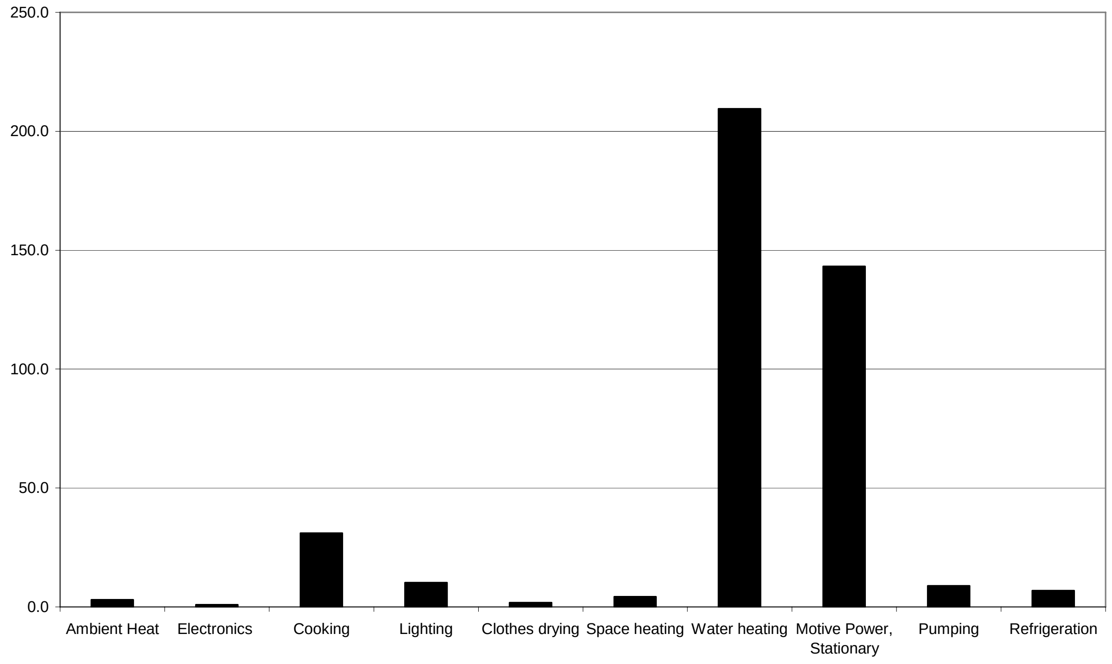
The direct costs of implementing these measures are estimated over a five year period, using a 10% discount rate. These measures all cost less than the commensurate investment in new generation capacity. Less cost effective measures (i.e. measures that cost more than investment in new generation), such as double glazing, are excluded from analysis. Costs shown exclude implementation and administration costs.

Table 8: Direct implementation costs, $ million over five year period 10% discount rate applied

End use	Possible	Realistic	Optimistic
Ambient heat	30.2	15.1	21.1
Electronics and other electrical uses	11.3	4.5	9.0
Intermediate heat (100-300^{0}C) cooking	932.5	155.4	466.3
Lighting	341.0	51.2	85.3
Low temperature heat (<100^{0}C) clothes drying	100.0	9.0	12.8
Low temperature heat (<100^{0}C) space heating	108.4	21.7	43.4
Low temperature heat (<100^{0}C) water heating	2932.3	1047.2	1570.9
Motive power (stationary)	1790.6	716.2	1432.5
Pumping	229.0	44.7	88.1
Refrigeration	246.4	34.6	56.8
TOTAL	**6721.5**	**2099.6**	**3786.1**

Source: Lermit (2005)

Figure 12: Annual implementation costs, “realistic” scenario
$ million



Source: Lermit (2005)

The following table sets out the relative cost of each measure. The most relatively low cost measures address lighting and electronics use. Pumping and refrigeration also offer relatively good value for money. The most expensive measures (out of those considered) are those targeting cooking.

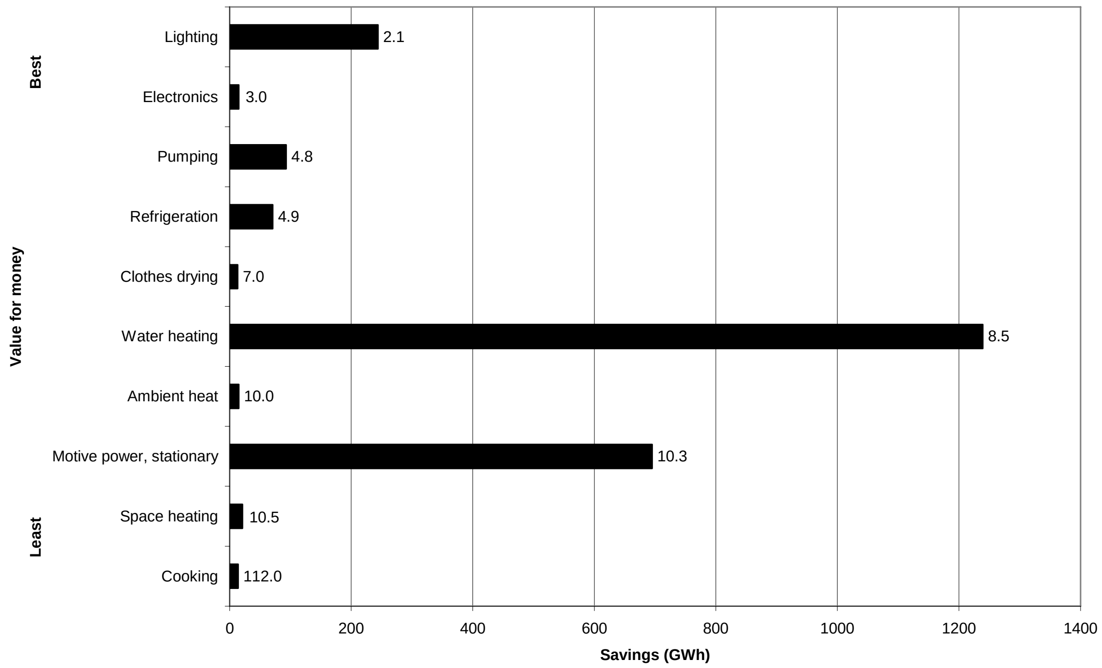
Table 9: Value for money of measures

Cents per kWh of reduction

End use	Cents per kWh
Lighting	2.1
Electronics and other electrical uses	3.0
Pumping	4.8
Refrigeration	4.9
Low temperature heat (<100^{0}C) clothes drying	7.0
Low temperature heat (<100^{0}C) water heating	8.5
Ambient heat	10.0
Motive power (stationary)	10.3
Low temperature heat (<100^{0}C) space heating	10.5
Intermediate heat (100-300^{0}C) cooking	112.0

Source: Lermit (2005)

Figure 13: Value for money (cents per kWh) against "realistic" savings (GWh) Data labels shown on columns are cents per kWh



Source: Lermit (2005)

How could these measures be implemented?

Many of the potential barriers to energy efficiency uptake relate to information. Information problems cited refer to the quality, price and future impacts of energy efficiency investments. In terms of quality, the reliability and effectiveness of a new technology may be unclear, particularly if it has not been proven through broad market penetration. Energy prices may be obscured through average pricing, and this may distort consumers' preferences for energy efficiency measures. And the future impacts may be uncertain; not just the efficacy of measures, but also the payback period.

Government may intervene to rectify information problems, they may require or encourage (e.g. through subsidies) the provision of information, such as energy performance labelling on products (indicating their energy efficiency rating). Government could also act as a provider of information itself, e.g. through public education/awareness campaigns. The IEA (2003) recommend that a public awareness campaign is an important part of any energy efficiency strategy. In particular, measures that seek a demand response require effective communication with consumers to address the problem of behavioural inertia.

Government intervention in the case of externalities may involve regulation (e.g. setting minimum environmental performance standards), taxes (subsidies) to discourage (encourage) a more optimal level of production, or fines.

There is a wide range of tools available to Governments and the private sector, for encouraging uptake of DSM measures.

Contractual tools

- **Ripple control** – contracts with electricity suppliers and lines companies which enable certain loads to be switched on and off automatically by a ripple signal. Typically imposed on residential customers, on hot water heating or night store heaters. Air conditioning, cool stores and some water pumps may also have a degree of energy storage and thus be able to be subject to ripple control.
- **Call options** – arrangements under which users either automatically or at their discretion reduce load when requested and are reimbursed for shedding load or generating their own power. Under certain circumstances there may also be a payment for availability.
- **Demand exchanges** – a trading mechanism allowing users to sell back portions of their load at certain times to retailers or lines companies, usually via an automated website or electronic system.
- **Spot market buying** – larger users may choose to expose some or all of their load at market or Time of Use rates in liaison with their retailer, and shift or limit their electricity use to benefit from low-price periods or high spot market prices.
- **Contract for Difference** – users on fixed quantity (hedged) contracts can choose to sell part of the contract at spot prices, potentially at a profit, then reduce their load to an agreed level.

Energy efficiency tools

- **Smart metering** – metering which allows end-users to monitor the cost of their electricity usage in real time. It gives consumers greater information, and hence control over the time and level of their electricity usage and hence their overall electricity costs.
- **Regulation** – includes **MEPS** – regulated Minimum Energy Performance Standards of energy-using products. Also **Building regulations** – regulations requiring minimum environmental performance standards (e.g. insulation, water usage) in houses and other buildings at the design/construction stage.
- **Education/information** – such as providing **audits** to identify potential electricity savings available to a consumer. Audits should cover the cost of suggested measures, and hence highlight cost effective measures. **Labelling** is a way of informing consumers of products' energy performance (e.g. the EnergyStar rating).

Financial incentives and price-based measures

- **Subsidies and loans** – to assist consumers implement energy efficiency measures that have high installation costs (e.g. solar hot water systems) by providing access to low or no interest finance, or by some degree of subsidy.
- **Taxes** – Pigouvian taxes such as the carbon tax aim to "price in" external effects of energy use, and hence better align demand with its true costs (i.e. including negative environmental effects).

Assessment

Ripple control for domestic hot water heating is already widespread in New Zealand. The remaining potential for direct peak trimming in the residential sector would therefore lie with improving cost information via smart metering. Enforced rolling cuts are unlikely to be acceptable to consumers.

There is a concern that, despite ripple control being fairly widespread, this capacity is being eroded by lack of maintenance, and declining rates of install of relays on new homes. This raises the issue of who owns the right to interrupt supply (retailer or network company) and whether this debate is inhibiting maintenance and new investment.

Another issue is that network companies are making significant revenue from bidding this controllable load into the reserves market, meaning it is unavailable for peak reduction or responding to spot price signals, as it must remain available to support the system in the event of, e.g. a plant failure. An ideal level of coordination would allow for both.

Economy-wide, the relatively flat load shapes in the regions where transmission capacity is a concern, means that there is relatively little opportunity for significantly reducing peaks. This suggests that, in general, the variety of contractual tools available (both those aiming to encourage price and/or load responsiveness) are unlikely to be cost effective to implement, given their relatively complex administration and implementation requirements.

Previous Treasury analysis showed that regulation, through mandatory minimum energy performance standards and building regulations can deliver relatively good value for money. This is partly because incorporating efficiencies at the design stage tends to be far cheaper than retrofitting improvements (e.g. incorporating for insulation at the design stage of a house as opposed to subsequently retrofitting wall cavity insulation). EECA's current MEPS programme delivers nearly half of the energy savings expected across their programmes, with just 9% of their total funding.

Work is on-going across Government to improve the regulations governing new buildings (the Building Code). This work will explicitly include consideration of energy efficiency.

Mandatory standards are complemented by labelling – a combination recommended by overseas research. Other forms of information provision, for instance through tailored energy audits, also rank as a relatively high value measure. Indeed, research suggests that a critical component of any programme aimed at modifying behaviour is an information/education campaign. For measures such as labelling, promulgation of information is required for maximum effectiveness.

New funding provided in the 2005 Budget will see both the MEPS and labelling initiatives expanded.

In terms of information provision, EECA's Home Energy Rating Scheme provides targeted information to residential energy users, via home energy audits. Their Emprove programme provides energy management, support and monitoring to high energy-using firms, and their business marketing project disseminates energy efficiency information to industry.

EECA has in place a programme providing low cost loans for installation of solar hot water systems. They also provide financial assistance (grants) to high energy-using firms for energy audits and Crown loans for energy efficiency investment.

The Government has announced the introduction of a carbon tax from April 2007. This will begin to introduce a price of carbon into the economy. Its impact on electricity supply and demand has been incorporated into MED's baseline projections.[7]

Our analysis here considers the potential for measures in *addition* to those already in place, to achieve the types of potential savings identified. Given the extent and range of measures already in place or under development, and the key potential rationale for intervention discussed above, the scope for additional measures appears to lie chiefly in the following:

- an extended and sustained information/education campaign, possibly including audits
- expanded/more stringent MEPS, with accompanying information provision/labelling
- additional, targeted financial assistance (through either subsidies or low cost loans) to assist with upfront capital costs and accelerate replacement of the capital stock.

[7] As noted earlier, the carbon tax policy was rescinded subsequent to this analysis being undertaken.

There also looks to be potential to refine existing energy efficiency programmes, to ensure that the benefits from these activities are maximised. From an administrative perspective, it is attractive to fine-tune existing programme that have potential to deliver good, value for money results, rather than establish new ones. Critical to this is adequate monitoring and evaluation, including good quality data on programme efficacy. In addressing behavioural change, there will always be an element of "learning by doing", and programmes should be sufficiently flexible in design as to allow refinements in delivery and targeting.

Packages

The following table summarises the best value packages of measures. All figures relate to savings/costs accrued over a five year period. Possible tools for implementation are also identified.

Table 10: Potential packages of measures

Suite of measures	Total load reduction (GWh)	Peak load reduction (GWh)	Direct economic cost, excluding admin ($ m)	Potential mechanism
Extended solar hot water heating	1239	101	1047.2	• Subsidy/loan • Information campaign
Upgrade to more efficient motors	695	113	716.2	• Regulation (MEPS) • Audits/education
Replace incandescent lighting stock	244	40	51.2	• Subsidy • Information campaign
Upgrade to more efficient pumps	93	8	44.7	• Regulation (MEPS) • Audits/education
Upgrade stock of refrigerators	71	12	34.6	• Regulation (MEPS) • Labelling • Information campaign
Upgrade electrical appliance stock	15	2	4.5	• Regulation (MEPS) • Labelling • Information campaign
Upgrade stock of clothes dryers	13	2	9.0	• Regulation (MEPS) • Labelling • Information campaign

The Electricity Commission has three years of funding for a series of electricity efficiency investment pilot programmes targeting:

- domestic and commercial lighting
- fridges
- hot water heating (cylinder wraps and shower heads)
- industrial motors.

The combined electricity savings from these programmes is expected to build up to 132 GWH per annum. As these programmes are still under development, our estimated savings *include* the potential impact from these programmes. Any development of additional energy efficiency policies would therefore need to take these pilot programmes into account. It would be desirable to build on the experience gained from these initial programmes when designing any future policies aimed at locking in sustained, long-term energy savings.

Table 11: Estimates electricity savings from Electricity Commission's Planned Investment Incentive Programme, GWh

Programme	2004/05	2005/06	2006/07	Outyears
Compact fluorescent lighbulbs (lighting)	6	21	42	42
Cylinder wraps and shower heads (hot water heating)	1	8	17	17 (lasts for 15 years)
Fridges	1	4	9	9 (lasts for 7 years)
Commercial lighting	3	16	34	34 (lasts for 10 years)
Industrial motors	3	13	30	30 (lasts for 7 years)
TOTAL	**15**	**62**	**132**	**132**

Responsibility for implementation – who bears the costs?

The suggested mechanisms are not the sole domain of Government. For instance, Meridian Energy provides information on ways to save electricity free of charge on their website, and also in their newsletters to customers. Contact Energy has recently instigated a nationwide advertising campaign. This "Healthy Homes" campaign is a partnership with renovation and appliance retailers Noel Leeming and Mitre 10, promulgating the benefits of energy efficiency. Other private sector initiatives include Alpine Energy's efficient lighting project in South Canterbury, which subsidises energy efficient lightbulbs for its customers.

Different mechanisms have different implications for cost bearing. An information campaign would represent low fiscal cost (in addition to the direct costs indicated in the table), and, if successful in changing behaviour, would shift the bulk of direct costs onto the end-user. If accompanied by subsidies or loan assistance, some of this cost could be borne by Government.

MEPS shift the cost of development onto appliance producers, who can in turn be expected to pass costs through to the consumer. As with Alpine's initiative (noted above), some of cost of the end product can be shared by Government and/or electricity retailers. Such assistance could be targeted, if the regressive impact of cost bearing was a concern.

Risks

Displacement/duplication

A key risk of Government intervention is that of displacement (or unnecessary duplication) of private sector initiatives and innovation. This risk can be mitigated by partnerships between delivery agents, with Central Government working closely with a wide range of partners. For example, Meridian works directly with EECA to provide free energy savings advice and products to customers (including free installation).

Industry capacity

Some industries, such as the solar hot water heating industry, are relatively nascent. As such, they may be too immature to support more rapid expansion than is currently occurring. Industry capability and capacity would need to be assessed prior to any further expansion of existing schemes.

Uptake

Another risk is that measures will not effect the desired behavioural change. Our analysis has attempted to mitigate this risk by including relatively conservative estimates of the likely actual uptake (the "realistic") scenario. As discussed above, these estimates incorporate information provided by studies of behavioural and attitudinal change.

The success of information provision is highly dependent on the perceived credibility of the source. Consistency of messages, achieved through a co-ordinated approach, can assist with enhancing credibility.

Technical implementation issues

It is important to note that this analysis has not quantified the potential dynamic implications of measures on load. It is possible that the interplay of factors surrounding some measures or combinations of measures could in fact result in increased load. For example, some energy savings devices (in particular heatpumps and compact fluorescent lightbulbs) can have undesirable electricity characteristics. Most of these relate to the harmonics created on start up (in particular the current drawn on starting large heatpump motors). Widespread adoption of such devices could therefore diminish the potential benefits of reduced peak loads on the transmission system (although not the total energy savings) if these were all switched on at peak times. These disadvantages can be overcome through effective product design. Such technical issues would need to be identified and addressed before any package of additional measures was introduced.

Conclusions

Peak management

Because of the already flat nature of electricity load in the capacity-constrained regions, there looks to be limited scope for further additional gains in direct peak reduction in these areas, via load shifting. Our analysis has shown that peak trimming in these regions could only be achieved by load shedding for four or more hours a day over the winter months. This clearly raises issues of acceptability and practicality to consumers. Furthermore, many supply agreements specify a minimum level of service, which would preclude the possibility of extended outages.

Since reliability of supply is a critical issue, the role of peak management may be more for emergency use than for normal operation. For example, if the normal reliability criterion is to require a full supply in the event of the largest transmission line, or the largest generator being unavailable, then additional peak management can only really be considered as an emergency procedure for handling outages.[8]

However, energy efficiency measures which reduce total load can contribute to reducing peak loads. Implementing the full range of energy efficiency measures could reduce current

8 The usual electricity supply requirement is that full demand must be able to be met in the event of the failure of the largest generating unit attached to the system, or the largest transmission link on the system. The electricity market allows for reserve capacity to meet these requirements. It may be possible for interruptible load to supply, at least in part, these requirements.

peak load by around 4.7%, built up over five years. Savings are regionally dependent, due to variations in climate and load mix.

Load reduction

There is considerable "economic potential" for achieving load reduction via energy efficiency measures. Economically justifiable measures (i.e. that cost less than investment in new generation) represent around 22% of current consumption. However, the "realistic" savings are considerably lower – around 6.5%. A comprehensive energy efficiency campaign which included all identified measures could reduce electricity demand growth from an average of 1.6% per annum to around 1.0% per annum over the next five years.

The best *value for money* measures are:

- **Lighting** – replacing incandescent bulbs with compact fluorescents
- **Pumping** – replacing constant speed and power pumps with variable speed drives
- **Electrical and refrigeration** – replacing the existing stock of electrical and electronic equipment with more efficient models, and the existing stock of fridges with better insulated models.

The biggest potential gains in *total demand reduction* relate to motive power (more efficient motor drives); water heating, lighting and refrigeration.

Implementation

Implementation of any additional policies would need to take into consideration not just the potential electricity savings and value for money of individual measures, but also:

- Rationale for Government intervention
- Fit with existing programmes
- Synergies with other measures
- Industry capability and capacity
- Risk of displacing/duplicating private sector initiatives, and
- Dynamic, technical implementation issues.

Further work would be required to devise suitable, detailed policy packages of additional measures. However, given the potentials we have identified, the extent and range of existing policies, and the rationale for further intervention, possible measures include: an extended and sustained education campaign; an expanded MEPS/labelling programme; and perhaps additional, targeted financial assistance.

Further work

A key message emerging from this work is that there is a need for better data. Assumptions regarding behavioural change have been based on the best available information from overseas and adjusted to domestic circumstances using what we know about the New Zealand context. However, much can only be tested by application. This highlights the importance of monitoring and evaluation of existing and pilot programmes.

It would be useful to quantify the extent and state of existing ripple control and smart metering investment. This would help assessment of whether it would be cost effective to optimise the value of this existing investment, by maintaining/upgrading, or whether new investment is warranted. Such assessment would require consideration of the related ownership issues – i.e. who stands to benefit and where should responsibility lie?