New Zealand's Energy Efficiency Potential - A "Top Down" Analysis

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Introduction

New Zealand, as well as every other country, needs to develop its energy efficiency resources in the first decade of the twenty-first century.

Very large savings from energy efficiency are possible in New Zealand. This study, using assumptions believed to be realistic and conservative, shows that, for "fast" implementation of efficiency, a cumulative benefit of up to $75 billion dollars could be achieved by 2020, at a cost of only $12 billion (both amounts undiscounted).

Beyond the financial drivers, there are three main strategic drivers, which will impact the supply – demand balance in energy in New Zealand in this time frame.

These external drivers are:

1) The depletion of Maui gas – containing about 80% of New Zealand's available methane resources – is expected in the next few years, and will mean an energy supply shortage is very possible in New Zealand. Even if a similar quantity of other gas (Pohukura) becomes available, it will not necessarily be available to New Zealand at a reasonable price, due to world demand and the potential to convey gas by ocean transport. In other words, overseas concerns may be willing to bid to purchase our gas reserves at prices much higher than New Zealanders are used to paying.

2) International restrictions on carbon emissions will begin through the Kyoto accord or what follows it. Although the Bush administration in the United States has stated they will not accept these accords at present, future American administrations would be expected to. For "fast" implementation of efficiency, this study shows New Zealand's CO_2 emissions would reduce by 200 MT by 2020.

3) Petroleum products may become much more expensive, as supply falters while demand continues to increase. This is widely expected in this decade as the "Hubbert peak" is reached, leaving the majority of world oil supplies in the hands of Muslim nations in the Middle East. This will likely stimulate dramatic changes in the transport sector.

The only possible sustainable solution to these problems in New Zealand, or indeed any other developed country, is to dramatically increase its end-use energy efficiency.

To maximise cost-effective energy savings, projects should be aimed at achieving optimal energy efficiency. Optimal energy efficiency would achieve the least-cost energy use for any situation. In effect, this would balance the future energy cost reduction with the present capital costs to achieve the lowest annual cost at a specified level of service (i.e., temperature, lighting level, etc).

Questions to be answered in this study

An analysis of the potential for energy efficiency to reduce the demand for energy in New Zealand was performed, to determine:

How quickly can efficiency be implemented?
How much will it cost?
How much will it save?
Will it get us to our Kyoto target?

Assumptions used in this study

The assumptions in this analysis are:

- Only the "built environment" sectors – domestic, commercial and agricultural/industrial are analysed, where the solutions are generally similar.
- Transportation is specifically excluded, as the solutions to reducing the demand there are driven by external sources (the supply of motor vehicles, and their efficiency, etc.).
- All the sectors that were analysed are grouped together, and only differentiated by "new" and "retrofit" measures. This is called a "Top Down" analysis.
- Likewise, all fuels and energy sources are lumped together.
- Energy prices are 10¢/kWh for the duration of this analysis.
- 0.6 kg of carbon dioxide is released for each kWh of energy consumed.
- The demand for energy services grows at 2%/year.
- New infrastructure is developed at a rate of 3%/year of that existing.
- The independent variable is investment in energy efficiency, year by year.
- The amount of energy savings is driven by investment only.
- Optimal energy savings in new construction are 80% of existing energy consumption, at an average "simple payback" of 4 years.
- Optimal energy savings in retrofits are 30% of existing energy consumption, at an average "simple payback" of 2 years.
- Savings are maintained throughout the period of analysis.

The real value of this analysis is heuristic, as an indicative example of what is possible, rather than predictive, because the specific measures implemented are not specified. It must be noted that the costs to achieve these savings may be overstated, for conservatism, as discussed in detail later in this paper. This would cover significant administration or other extra costs above the implementation costs of the measures.

Analysis

Three separate scenarios were analysed, looking at fast, moderate and slow implementation of energy efficiency. In the "fast" scenario, the target was to ensure that in ten years time, most new infrastructure was being installed at optimally cost-effective levels of energy efficiency, and in twenty years time, most cost-effective retrofits had been done. Ten year seems like a long time, and these targets intuitively feel reasonable, but this analysis shows that only very fast and sustained growth in efficiency investment will achieve these targets. The spreadsheet for this and the other scenarios are included at the end of this paper.

New construction was chosen for the earlier target, because it is assumed that larger, lower cost savings can be achieved in new construction than in retrofit, where some inefficiencies are locked in, and difficult and expensive to remedy.

The "moderate" scenario considered a growth in investment that was faster than conventional wisdom, but less so than the "fast" implementation. This might be the quickest practical efficiency scenario.

Finally, the "Slow" scenario considered sustained slow growth in efficiency investment, at about the rate projected in the 2001 Draft National Energy Efficiency and Conservation Strategy. Using the assumptions in this analysis, it would only significantly impact the demand for energy supply in twenty years time.

Result

The energy efficiency gains resulting from each year of the three scenarios, and the effect on the demand for energy supply in New Zealand, with a constantly increasing demand for energy services, is shown in Figure 1, below. As can be seen, under the "fast" scenario, the demand for energy supply (the line titled "Net Energy Demand") peaks about 2005, and declines after that. In the "moderate" scenario, energy demand peaks about 2010 then goes into decline, and in the "Slow" scenario, the growth in demand slows, but demand never declines.

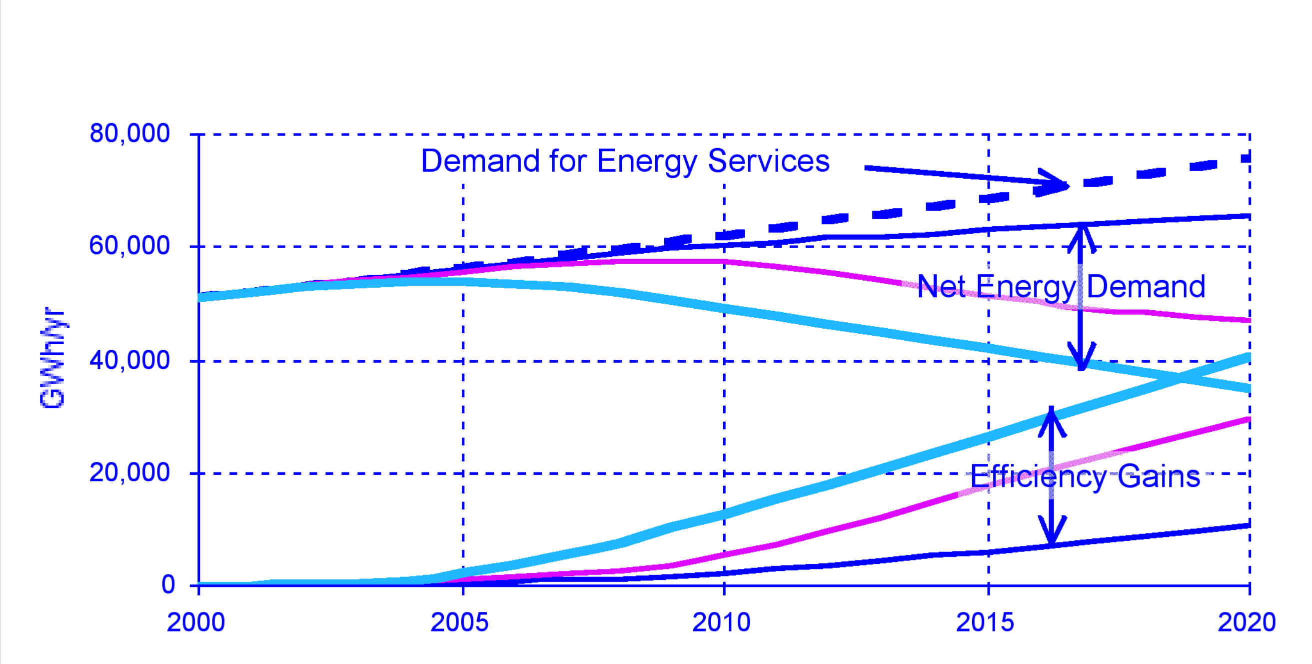


Figure 1 – Efficiency gains from three scenarios reducing energy demand

The amount of new energy efficiency and retrofits upgraded to optimal levels in each of the three scenarios are shown, year-by-year, in Figures 2 and 3 below.

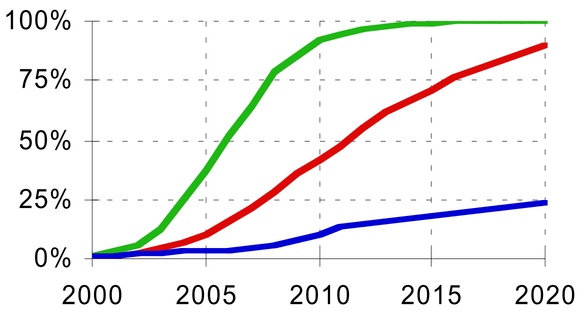


Figure 2: New potential achieved

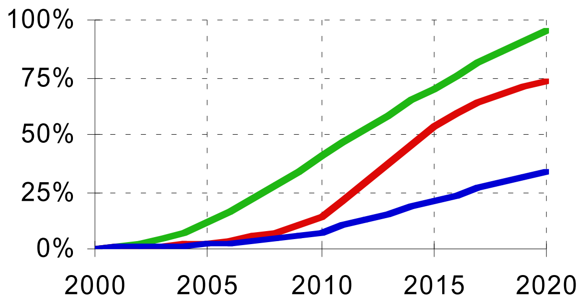


Figure 3: Retrofit potential achieved

Annual financial savings

The financial benefits of energy efficiency are certainly the main driver for energy efficiency in New Zealand today. The financial benefits of the efficiency programmes analysed here, in reduced retail energy costs, are as shown in Figure 4, below.

At the same time these energy cost savings were achieved, there would be other associated benefits gained as natural accompaniment to the energy efficiency improvements. In the domestic sector, these include health benefits, which appear to have a financial value up to ten times that of the energy savings[i]. In the commercial sector, these associated savings would come from increased productivity of commercial staff, measured in ways like reduced absenteeism, quicker time to prepare standard work, and reduced error rate. Studies have shown the productivity enhancements are often worth ten or more times the value of the energy savings[ii]. In the industrial sector, these would be due to increased productivity and reduced waste costs, and are up to three times the value of the energy savings[iii].

In this analysis, the associated savings are taken to have a value one and a half times as large as the energy savings. Figure 4 shows the annual energy cost savings from each of the scenarios, and Figure 5 the annual energy and associated cost savings. As can be seen, each of these scenarios yields very large savings, more than a billion dollar per year, in time. The cumulative value of all these savings is over $75 billion for the "fast" scenario. This is the financial benefit to New Zealand of energy efficiency.

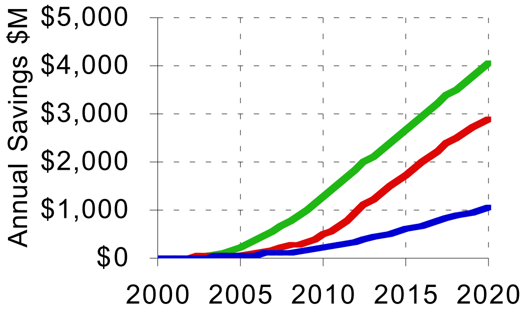


Figure 4: Annual energy cost savings

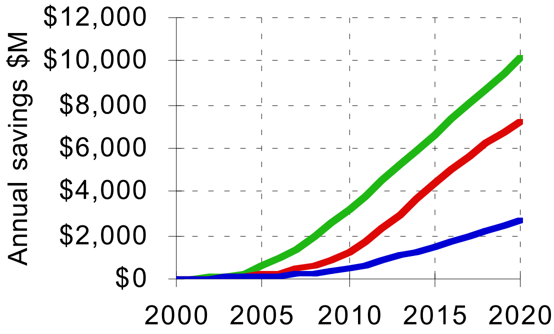


Figure 5: Energy plus associated savings

The costs to achieve these savings were also calculated. The total investment required to achieve these savings are shown in Figures 6 and 7 below, as the annual and cumulative amounts. These show that energy efficiency, while very beneficial, is not free. The fast scenario posits an investment of $800 million per year by 2010, the moderate $400million per year, and the slow one $60 million per year.

All these amounts are much higher than current planning recognises, to achieve the targets shown in figures 2 and 3. As previously mentioned, the costs may have been overstated, to keep the analysis "conservative". However, note that the cumulative investment of the fast case by 2010, of about $4 billion, is nearly the same as the annual savings shown in figure 5.

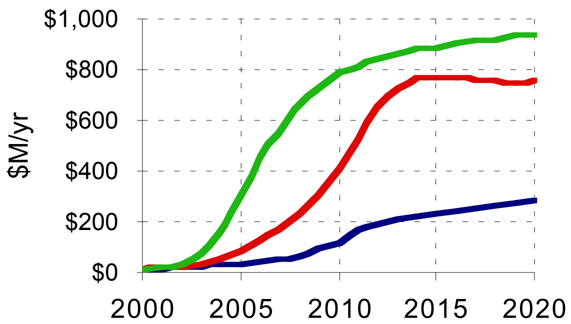


Figure 6: Annual investment in efficiency

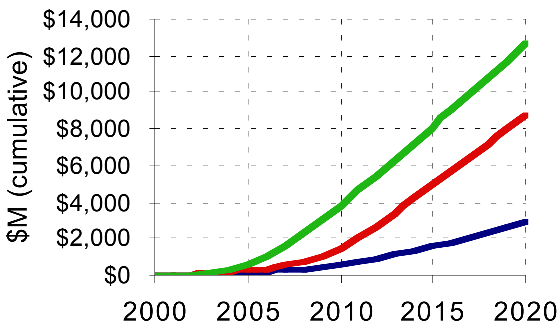
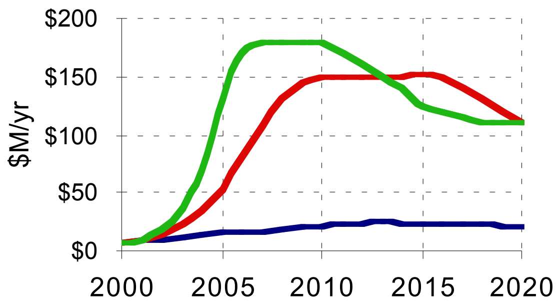


Figure 7: Cumulative efficiency investment

The source of these investment funds was a combination of government and private investment. The split between them was estimated, almost purely intuitively. It was felt that the government would need to lead the investment, to "stimulate the market" and prove the value of efficiency to the private sector. Then it was felt that the private sector would follow, and invest much more than would government. The estimates of public and private investment in these scenarios are shown in figures 8 and 9.

Note that the source of the investment is not considered in this analysis, only the total each year.



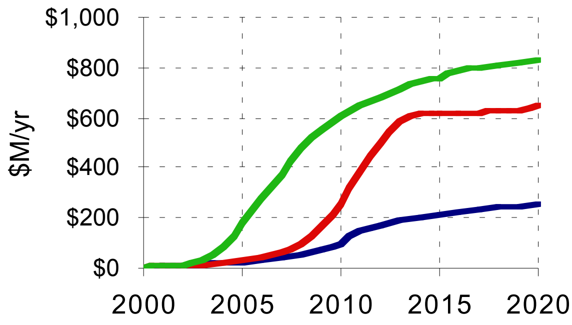


Figure 8: Annual government investment

Figure 9: Annual private investment

There is some evidence that private sector investment in energy efficiency closely follows government investment there. When the annual budgets for EECA (the New Zealand Energy Efficiency and Conservation Authority) and its precursor are analysed for the past decade[iv], and compared to the annual technical improvement in New Zealand energy efficiency[v], it is seen that there is a good correlation between the year to year change in EECA funding and the measured improvement in New Zealand's energy efficiency, twelve months later. This is shown in Figure 10, below.

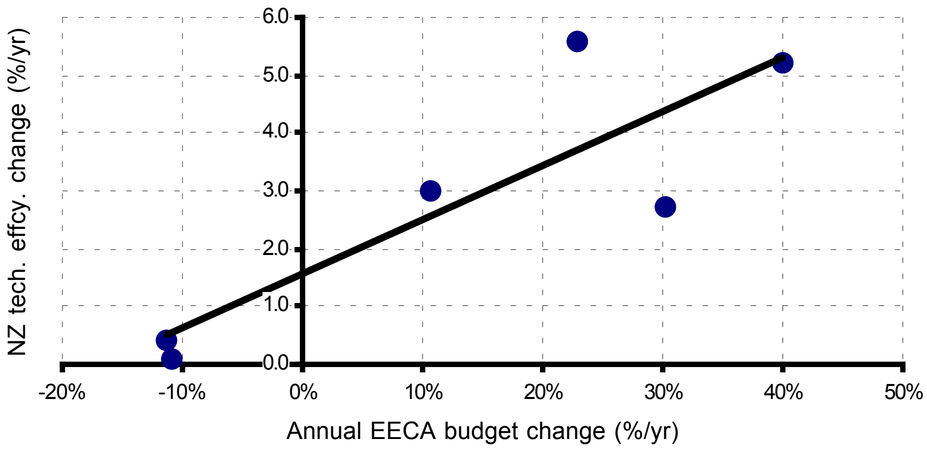


Figure 10: Efficiency improvement follows EECA activity increase

The points show the technical energy efficiency improvement in the New Zealand economy for each calendar year, as a function of the change in EECA budget for the previous calendar year. The line is an approximate trend. The change in efficiency for the third year that their budget was reduced is not yet available. Although this does not prove that private investment follows that of government, it at least indicates a correspondence.

Figures 11 and 12 show the reduction in carbon dioxide emissions for each of these scenarios, compared to emissions rising in step with the demand for energy services. As can be seen, these savings are very significant and will almost allow New Zealand to meet its Kyoto target, by themselves (i.e. without counting any effects from forestry or renewable energy supply). However, this analysis does not consider the effects of either methane emissions or carbon sequestration from agriculture, or the energy use of the transportation sector, where emissions may continue to increase.

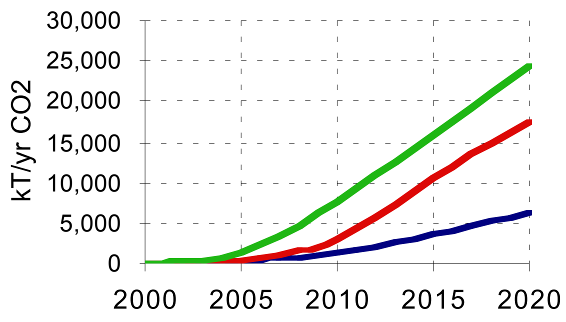


Figure 11: Annual CO_2 Savings

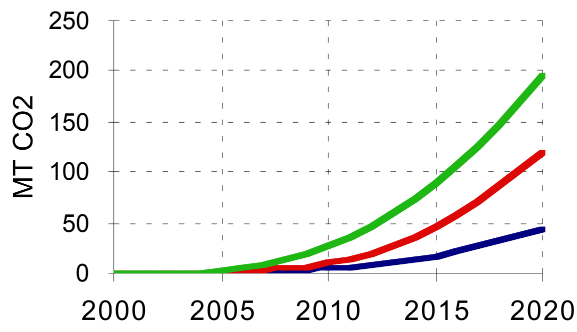


Figure 12: Cumulative CO_2 Savings

Justifying efficiency cost assumptions

The assumptions of 80% energy savings being cost-effective in new construction, and 30% being cost-effective in retrofit, may seem optimistic to some people, so the following section discusses where these estimates originate.

New construction

1) E Source[vi] is an American research organisation, which was formerly owned by the Rocky Mountain Institute, who presented analyses of the technical and cost-effective potential for energy efficiency technologies in six major end-uses.

The energy savings found as cost-effective for each end-use, compared to standard U.S. early-nineties technology were:

Lighting	90%
Heating (space and water)	90%
Cooling (and air handling)	90%
Appliances	75%
Motors	45%

These assume that the best available technologies are applied during construction, when it is most cost-effective to do so.

Because the New Zealand infrastructure is considered to be less efficient than the U.S. (where most houses are already insulated and double-glazed, for example), it is expected that the potential cost-effective savings would be even larger in New Zealand.

2) A study[vii] examined the costs and energy performance of five different levels of efficiency for two sizes of houses and two sizes of commercial buildings in Wellington. This analysis showed that for a new house heated to a healthy 16°C temperature at night and a comfortable 20°C during the day, the "least cost" situation was at 60% less energy use than the standard new house of that time, and the "Long term least cost" (LTLC) was at about 88%% less energy use than standard.

The least-cost new house used double-glazing, solar water heating, and slightly improved insulation compared to the standard house. The "LTLC" house used gas-filled, low-e triple glazed windows, a larger solar water heater, and 150 mm thick insulated walls.

The same analysis showed that the least cost commercial building would use 71% less energy than standard, and the "LTLC" building 77% less energy.

Figures 13 and 14 show the annual costs associated with each of these levels of building. The line marked "ΔCap cost" is the change in capital costs, expresed as extra dollar per year expended (for domestic buildings, extra mortgage costs). The line marked "Op cost" is the annual operating (basically, energy) cost. The "Total" line is the sum of the two, the total annual cost relating to energy (either buying or saving).

As can be seen, the costs for domestic houses drop slowly, as they are compared to standard new houses which are already insulated, but the LTLC level is at almost 90% energy savings compared to them. For commercial buildings, the total costs drop quickly, as commercial buildings at that time had no energy standards applying, but the LTLC level is at less than 80% savings (lower than domestic) because of the inherent energy intensity of most commercial buildings, with continuous lighting, and significant equipment use.

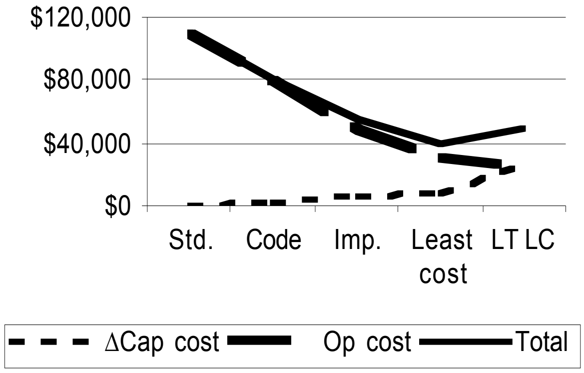


Figure 13: Commercial efficiency costs

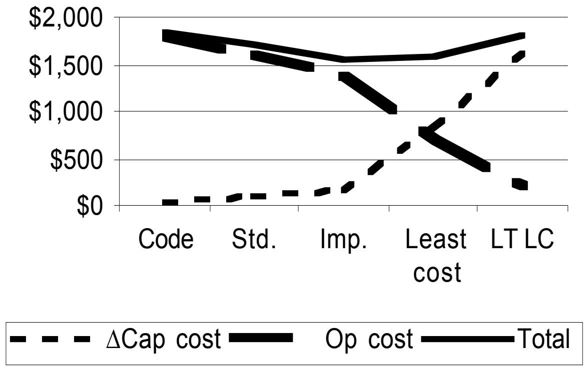


Figure 14: Domestic efficiency costs

3) Similar analyses for the industrial sector are not commonly available, but overseas conference papers[viii] have described techniques for dramatically reducing the energy use in metal smelting (for instance, by reduction of bauxite to aluminium by direct use of coal, rather than electricity and graphite) and wood pulp production (by "biopulping" the wood to soften it before pulverising it).

It must be noted that the "technical" potential for energy efficiency is much higher than the cost-effective potential. For example, technically a house could have almost infinite wall and ceiling insulation, multi-paned windows, very large air-to-air heat exchangers and solar water heating systems, passive refrigerators and other exotic technologies to reduce its energy use to nearly zero – perhaps 99% compared to standard technology.

Retrofits

The cost-effective energy savings in retrofit situations are typically less than for new construction, due to limitations in completed buildings. However, the savings can still be very significant.

1) A study of New Zealand energy audit reports in EECA's files[ix] showed identified savings, all at under "two year paybacks" for commercial buildings across New Zealand, as shown in Figure 15.

Figure 15 shows the identified savings from each report, as a function of the building's energy use benchmark (the kWh of annual energy use divided by the floor area, called EPI for Energy performance Index). Obviously, buildings with higher energy use benchmarks would generally have higher savings potential. Figure 15 also differentiates between the more experienced auditors (as the filled data points) and less experienced (as the hollow data points). As can be seen, for typical commercial buildings, with EPIs of about 200 – standard for New Zealand, the savings are about 30%.

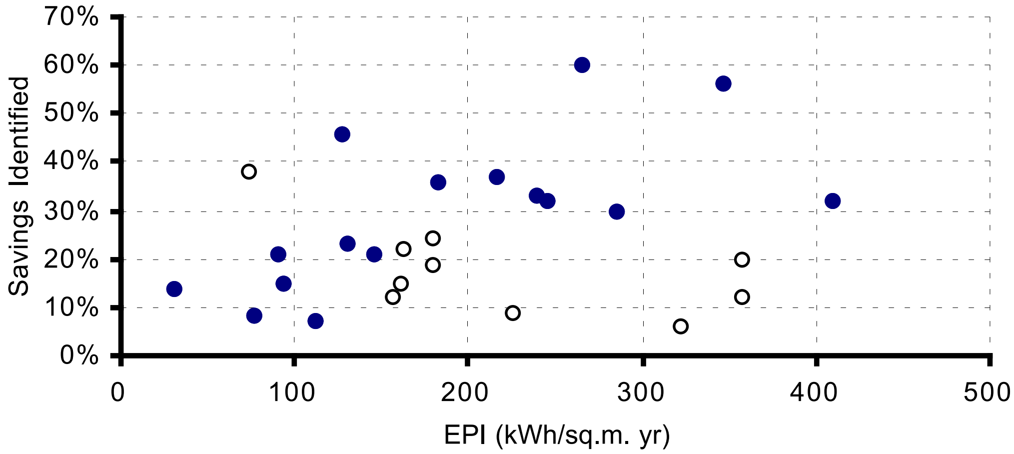
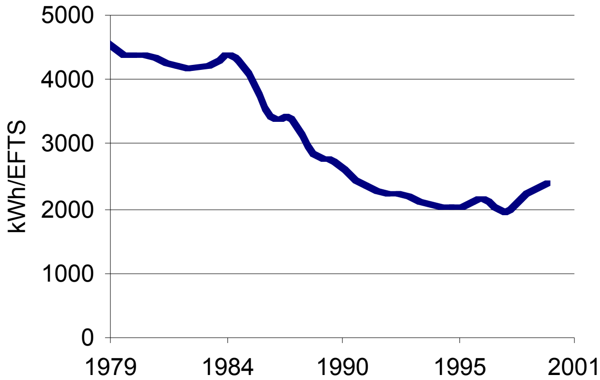


Figure 15: Energy audit identified energy savings as a function of energy use benchmark

2) There are a number of organisations that have radically reduced their energy use over time, by simply consistently seeking and implementing opportunities. The best documented local example is the University of Auckland, where a twenty year programme of energy management has reduced their energy cost per "equivalent full-time student" (EFTS) by half, as shown in Figure 16, and their CO2 emissions per student by about 60%[x].



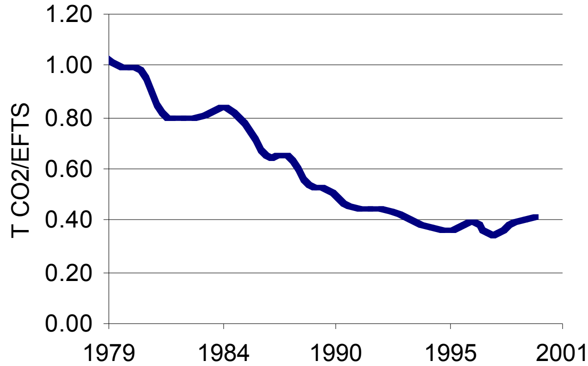


Figure 16: Auckland U. Energy use per student

Figure 17: Auckland U. CO_2 emission per student

There are numerous overseas examples of organisations that have saved similar amounts of energy over similar time frames. Firestone, a leading tyre manufacturer, has been systematically reducing its energy use since the first "oil shock" of 1973, and has apparently reduced the energy consumed per tyre manufactured by over two-thirds. The Louisiana division of Dow Chemicals ran a ten-year programme of energy use reductions, and was able to find more and more sub one-year payback opportunities each year, until they stopped reporting.

3) Dr. David Claridge at Texas A&M University has developed a technique called "Continuous Commissioning" for systematically developing operational improvements in buildings, that has led to achieving 200% of audit predicted energy savings. This is documented in a number of papers[xi]. Dr. Claridge visited Canterbury University last year and gave several public seminars around New Zealand on this technique.

Summary of costs

It must be noted that although "simple payback" is the commonly used financial indicator for energy efficiency, it is the only one that does not consider the time value of money, and thus is not suitable for optimising (finding the point of least-cost). However, this can be done if the marginal payback for individual measures is considered, and compared to a suitable indicator, like the Uniform Capital Recovery factor (in years, the total amount of a loan divided by its annual repayments).

Typically, a number of improvements are possible for any project, with a range of costs and benefits. These are normally ranked in terms of payback, or other financial indicator. Then all the improvements with paybacks less than some (marginal) chosen value are selected to be implemented. When this is done, the aggregate of improvements will have an average payback significantly less than the marginal one used to select which are to be implemented. This can be seen from Figure 18, which graphically ranks and displays the costs and savings of identified energy efficiency opportunities in a recent energy audit report.

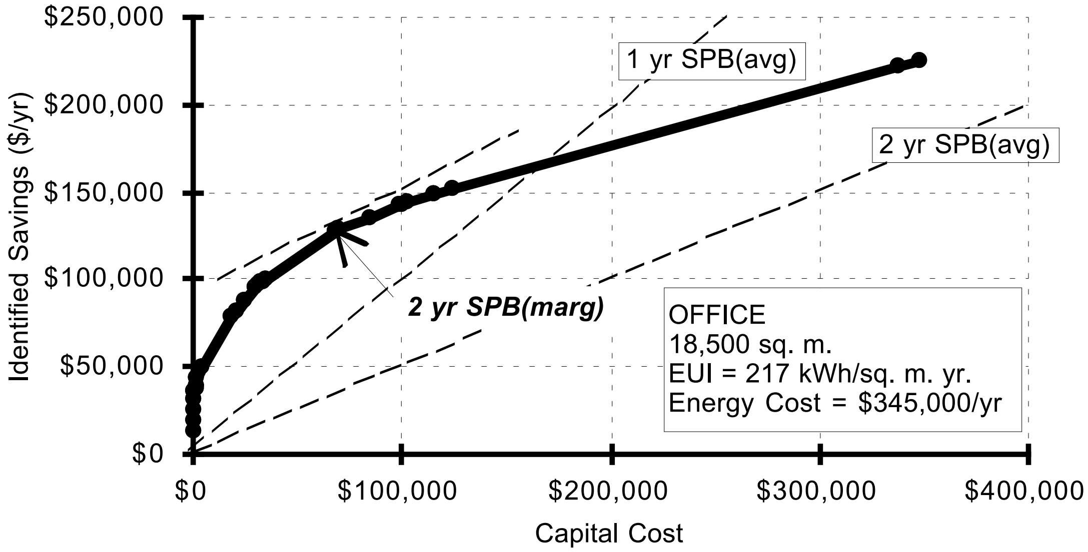


Figure 18: Typical "Supply Curve" for savings identified in an energy audit report

In this figure, the heavy line represents the opportunities in order of cost-effectiveness (call this the savings curve). The dashed lines on the graph have slopes reflecting their averaged simple paybacks (SPB). In this case, if only measures with SPBs less than 2 years were to be implemented, then only measures to the left of the point where the slope of the savings curve becomes shallower than the "2 yr SPB" line (indicated by the 2 yr SPB(marg) point and the tangent line with a slope equal to a 2 yr SPB) would be implemented. This would be at about $70,000 cost, and would result in about $130,000/yr (37%) energy savings.

As can be seen, the aggregate of these measures is an average 0.5-year SPB, significantly less than the chosen marginal 2 yr SPB. This is a typical result.

As a result of these data, the following assumptions are made for the costs and savings from optimal energy efficiency:

In retrofit, opportunities will be implemented up to a marginal "simple payback" of 4 years; at that point the average "simple payback" will be 2 years, and savings will be 30%.

In new construction, opportunities will be implemented up to a marginal "simple payback" equal to the "Uniform Capital Recovery" discounting factor (about 8 years for typical loans); at that point the average "simple payback" will be 4 years, and savings will be 80%.

Conclusions

Energy efficiency appears to have a much higher potential for reducing energy costs and carbon emissions in New Zealand than conventional analyses indicate. The limiting factors are probably not technology nor money, but customer demand and the ability of the efficiency industry to grow quickly.

The scenarios here presume government stimulation of the industry to achieve the potential savings. If the benefits can be sold well enough, this may be forthcoming. The analysis showed that in all cases except the fast growth one, the net benefits each year (energy cost savings minus implementation costs) are always positive. However, for energy supply investments, net benefits are negative during the construction years, and only become positive when the supply improvement is completed and working. The development of an efficiency industry can be thought of the same way.

Although there are many simplifications present in this analysis, this should not compromise the value of this work. Clearly, a more sophisticated simulation, analysing the uptake of efficiency sector by sector, and fuel by fuel, and looking at several levels of returns from efficiency investments would yield more detailed results.

One of the main differences between this analysis and the conventional energy supply / demand projections considering energy efficiency, is that this is a "top down" analysis, where savings are aggregated for entire sectors, rather than "bottom up" like the Energy Efficiency Resource Assessment (EERA) analysis used in New Zealand. Bottom up analyses look at individual measures and their predicted market penetration, and necessarily miss counting any improvements that are not specifically included, some of which may be potentially significant.

NOTES:

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[i] This is based on anecdotal evidence from pilot studies in New Zealand housing. A study of the health of the occupants of about one thousand New Zealand houses before and after efficiency improvements is expected to commence shortly.

[ii] Romm, J. and Browning, W., "Greening the Building and the Bottom Line – Increasing Productivity Through Energy-Efficient Design", Rocky Mountain Institute, Snowmass, Colorado, 12/1994. www.rmi.org.

[iii] Pye, M., and Elliot, R.N., "Energy Efficiency, Pollution Prevention, and the Bottom Line", and "Making Business Sense of Energy Efficiency and Pollution Prevention", American Council for an Energy-Efficient Economy, October 1997. Web address: http://aceee.org/p2/

[iv] From EECA annual reports, adjusting the July – June financial year budgets to calendar years.

[v] From EECA's "Energy Monitoring Quarterly" and "Dynamics of Energy Efficiency in New Zealand".

[vi] Web address: www.esource.com. The most detailed information is in the Technology Atlases. Only the first editions counted the overall energy savings potential, with later editions only looking at individual measures. Perhaps to avoid appearing to overstate the potential savings?

[vii] Bishop, R., "Building Standard Initial Stringency Study" performed for EECA and the Building Industry Authority, February 1995. As reported in Bishop, R. "Least Cost Energy Efficient Design", Proceedings of IPENZ Conference 1997, p. 129, Institution of Professional Engineers of New Zealand Inc., Wellington.

[viii] For example, in the ACEEE Summer Studies on Energy Efficiency in Industry.

[ix] As summarised in EECA's "Energy auditing: A guide for building managers" March 2001.

[x] Agate, D., Energy Manager, University of Auckland, personal communication, April 2001.

[xi] Claridge, D.E., et.al., "Can you achieve 150% of predicted retrofit savings? Is it time for recommissioning?" Proceedings of ACEEE Summer Study 1994, p. 5.73, and "Implementation of Continuous Commissioning in the Texas LoanSTAR program: 'Can you achieve 150% of estimated retrofit savings' revisited", Proceedings of ACEEE Summer Study 1996, p. 4.59.