Review of the EECA residential Net Benefit Model and Technical Manual

A report prepared for EECA
June 2008

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1 Introduction

This report presents a review of EECA's residential net benefit model and technical manual. In undertaking that review Concept and CRESA have been concerned to assess the model in relation to four key and inter-related issues:

- The extent to which the model can be used to assess EECA's evolving set of programmes directed to residential energy efficiency.
- Whether the model provides an adequate representation of benefits given current knowledge and data availability.
- Whether the model captures the range of key energy, environmental, health and other benefits that may be generated by residential energy efficiency programmes.
- Whether the structure of the model allows for on-going improvement and amendment as the dynamics between energy efficiency interventions, dwelling performance, household consumption patterns and environmental, health, social and economic benefits respectively become better understood.

This review has been undertaken by Concept and CRESA. The report is structured as follows:

- Section 2 describes the purpose of the net benefit model, its use to date and the possible uses of a net benefit model into the future. It also comments on some of the overall limitations of the model's current structure.
- Section 3 considers the adequacy of how the model deals with the energy and environmental performance benefits of energy efficiency interventions.
- Section 4 considers the modelling of health benefits from energy efficiency interventions.
- Section 5 comments on the manner in which the model accounts for other potential benefits.
- Section 6 addresses a few general issues with the structure of the model.
- Section 7 summarises those areas identified within this report where EECA may want to consider altering the model and/or undertaking further research on underlying data.

2 The Net Benefit Model

This section describes the high-level method, purpose and changing policy context in which it is used.

2.1 Method, Purpose and Context

A detailed discussion of the methodological approach of the NBM is set out in 3, however at the highest level the approach is as follows:

- Users input information on proposed measures and their associated costs (both overall costs, and the fraction which is to be directly funded by EECA).
- The benefits are determined by various formulae and performance variables. In many cases the user has no discretion as to performance variables, but in some cases the user is required to input appropriate values from the associated technical manual.
- The model then calculates a simple NPV cost: benefit analysis of the proposed energy efficiency measures.

The net benefit model was developed and has largely been used to determine which proposals for EnergyWise Grants funding should be selected. It has also had an important role for EECA in setting out the justification for budget allocation under the annual Treasury funding round.

In both contexts, the purpose of the net benefit model is to ensure scarce public money is targeted at those energy measures which deliver the greatest net public benefit.

The importance of an effective net benefit model is likely to increase into the future for a number of reasons. In particular:

- The number of different residential energy efficiency programmes EECA is delivering on behalf of the Government has expanded, and is likely to continue to expand across wider ranges of products and energy efficiency options.
- The targeting of EECA's residential energy efficiency programmes is shifting to embrace different types of households. The EnergyWise Grants are targeted to low income households whose eligibility is defined by holding a Community Services Card. Households with somewhat higher incomes, however, are eligible for assistance with solar water heating subsidies and for EnergyWise Loans. Landlords have also become eligible for Government assistance in relation to their residential rental stock.
- The range of financial mechanisms used to deliver residential energy efficiency measures is diversifying.
- There is increasing understanding, and consequent public policy focus, on the improvements which energy efficiency measures can deliver with respect to living conditions and human health and welfare.

Under those conditions, the ability to establish the relative benefits of different programmes and delivery mechanisms will be increasingly necessary to decision-making. In particular, the range of energy performance, environmental benefits, health, social and economic benefits likely to be leveraged by different interventions will be a key criteria in decision-making. The way in which benefits are distributed across different households will also be critical to the Government's decisions around levels of subsidy, co-payment regimes and the relative merits of using different mechanisms such as grants, loans or incentive payments.

2.2 The Current Net Benefit Model's Adaptive Limitations

The current net benefit model has limited ability to be adapted for application to programmes other than the EnergyWise Grants programme. Many of the issues around the measurement of particular benefits are discussed in more detail in relevant sections latter. This sub-section details the major limitations to the model's adaptability arising from the structural characteristics of the current model.

This most obvious limitation on the current net benefit model is the static nature of the model and its reliance on simple inputs. This is evident in the calculation of benefits whether related to energy performance, environment, health, or other benefits such as reduced maintenance requirements.

The problems of simplification arise in four areas.

2.2.1 Modelling of technical performance

Firstly, the performance of energy efficiency interventions are simplistically modelled. The actual, in-the-field performance of a particularly energy efficiency measure is highly situation-specific. For example, the reduction in energy consumption for a loft insulation measure will vary significantly depending on a number of key variables, principally:

- geographic location (and hence the ambient temperature)
- size of the property
- extent of shading of the property
- number of stories
- whether the property is attached or detached
- extent of any initial insulation
- thickness of the insulation installed
- heating regime of the house (achieved temperature and periods during the day)

Moreover, the variation in energy performance along these various dimensions is non-linear. For example the kWh/m^2 energy consumption of a property will decrease in a non-linear fashion with the size of the property (due to a decreasing surface area to volume ratio). Similarly, the kWh/m^2 energy losses from a ceiling will reduce in a non-linear fashion with the thickness of the insulation.

However, the current Net Benefit Model has a very basic approximation of the performance of the different measures such that the only degrees of variation are geographical location (for which four regions are allowed, the thickness of the insulation (although this requires manual input to vary the values appropriately which can introduce error), and (for ceiling insulation only) a crude approximate of the level of any existing insulation. None of the other determinants outlined above are considered. This will likely result in a material variation between the ‘modelled’ and actual performance of energy efficiency measures.

2.2.2 Limited range of energy efficiency options considered

The second area in which the current net benefit model is limited relates to the constraints placed on the range of energy efficiency options that can be accommodated in the model. There will inevitably be a trade-off between having a modelling framework that is suitably broad and flexible in scope so that it can cover all possible energy measures, and having a framework that is sufficiently simple in order that it does not become overly cumbersome to use. Such a trade-off will likely result in the framework limiting the options, to a greater or lesser extent, to those that can be evaluated using ‘standard’ approaches.

Currently energy efficiency options are limited to:

- Ceiling insulation
- Floor insulation
- Draught-proofing of doors / windows
- Hot water cylinder lagging
- Hot water pipe lagging
- Low-flow shower heads
- Energy efficient lighting

EECA, however, is involved in delivering assistance on a range of other devices including solar water heating, other water heating options, space heating options, and encouraging the removal of inefficient refrigerators. If EECA is to have the ability to target its resources at the options that provide the greatest net benefits, its net benefit model would desirably be able to allow for the benefits of different options and packages to be modelled.

2.2.3 Little or no factoring of socio-demographic influences

The third area in which the current net benefit model could be strengthened is in the handling of household characteristics and behaviours. The consumption patterns of households reflect a variety of socio-demographic characteristics including life stage, household composition, and household income. Those factors are not accommodated in the modelling of effects that are likely to be critically affected by them – health, maintenance or employment. This not only raises some questions about the robustness of the values emerging from the net benefit model, it also inhibits the ability of the model to take account of changes in the demographic and compositional profile of New Zealand’s population.

2.2.4 Little or no factoring of building stock condition

The final area in which the net benefit model has limitations is the capture of dwelling stock type and stock condition. There is some evidence from retrofit programmes and dwelling renovation programmes that stock condition impacts on energy use in complex ways. Poor dwelling condition tends to decrease the energy efficiency and thermal performance of a dwelling. It also, however, encourages householders to under-heat. Consequently, changes in dwelling condition may impact energy use through complex dynamics. There may be increased take-back in dwellings that are subject to both energy efficiency interventions and improved house condition.

Overall, the net benefit model is highly simplified. It does not accommodate the full range of variables that may affect the nature or level of benefits. Nor does it easily accommodate shifts in EECA's activities either in relation to household targeting or the energy efficiency options it promotes. Indeed one of the most immediate problems with the net benefit model is that it is based on the ALF building model which has, for most of EECA's programmes, been succeeded by Accurate. Those issues are discussed in more detail later in the report as they affect the modelling of energy, environmental, health and other social and economic benefits.

3 Modelling of Energy and Environmental Benefits

This section of the report discusses the difficulties with the net benefit model in relation to the calculation of energy and environmental benefits associated with residential energy efficiency options.

3.1 Divergence of results between NBM and HERS

The NBM is based on ALF, yet almost all other residential building energy efficiency modelling undertaken by EECA, including the high-profile home energy rating scheme (HERS) initiative, is now being based on Accurate. To the extent that the results from ALF and Accurate diverge, this is clearly a problem. As we understand it from discussions with individuals in EECA, Accurate may be delivering more realistic results. Further, EECA is devoting time and effort on continuing to improve Accurate, whereas such effort is not being devoted to ALF.

Under those conditions, it seems appropriate to base the net benefit model on Accurate rather than ALF.

3.2 Modelling of performance of energy efficiency options

The modelling of energy efficiency options is quite simplistic. As illustrated in section 2.2.1 above, there are complex inter-relationships between non-linear factors in the dynamics between energy efficiency interventions and dwelling performance. Indeed, it is that very complexity that makes sophisticated modelling tools such as Accurate so important. Yet it would be impractical to incorporate a sophisticated modelling tool such as Accurate whose focus is individual-building specific, within a tool such as the NBM whose purpose is to consider likely aggregate benefits across many hundreds or thousands of properties at the same time.

Having the ability to sufficiently accurately capture the situation-specific nature of energy efficiency measures within a framework that is not overly cumbersome is one of the key challenges of the NBM approach.

One solution that could square this circle is to undertake many thousands of pre-run Accurate runs through a batch process that stores the results in a comprehensive results lookup table. The runs would be defined to span the range of possible situations as defined by the combination of the different key variables indicated above.

To then determine the change in energy consumption for a given measure, all that would be required would be for the NBM tool to lookup the results for the run that most closely matched the pre-measure situation, and the results for the post-measure situation. The difference between the two would represent the performance of the energy efficiency measure. The key benefits of such an approach are:

- More accurate modelling of the performance of measures.
- More accurate modelling of take-back factors and subsequent valuation of the benefits of improvements to health / social welfare. This is because of pre- and post-

measure temperature outcomes being explicit input parameters (discussed further in Section 3.11 below).

- Facilitating easy updates of the NBM model following changes to Accurate which may alter the results of the simulated energy performance of buildings. All that would be required would be for Accurate to re-run the batch process and the resulting results lookup table(s) be updated in the NBM.
- A more flexible and robust approach to accommodating the different situations through having common lookup formulae to accommodate all situations. At the moment, the NBM has to have different formulae to cope with the four different location scenarios and the two different ceiling insulation scenarios. This raises risks of inconsistent formulae for the different situations.
- Enabling interpolation between results to cope with situations where factors such as the size of the house, thickness of insulation, house temperature achieved, etc. are not the same as the values modelled in the batch run. For example, if the size of the house being considered is 120m^2 but the results table only has results for a 100m^2 house and a 150m^2 house, the value for the 120m^2 house can be interpolated from the 100m^2 and 150m^2 houses.

However, there are two key challenges associated with this approach. Firstly, developing the batch functionality to run thousands of Accurate runs. The second challenge is determining which key variables to vary on such a scenario basis.

With regards to developing the batch functionality, Accurate already has the ability to run through multiple input files and save the results in an aggregate output file. However, a tool would need to be developed to automate the process of creating the many thousands of input 'scratch' files (basically text files) that define the parameters for each run. Having looked at Accurate, it would appear that this should not be onerous. A relatively simple Excel / VBA tool could be used with a spreadsheet front-end that enabled the user to specify all the different options they would like to be run through, and a visual basic back-end that looped through all the different options to create the complete set of combinations and saving the corresponding text file.

The issue of which key variables to vary on a scenario basis is more significant. If you have multiple variables, each of which can have multiple values for consideration, the number of combinations can rapidly escalate. For example, the following example table for ceiling insulation scenarios shows that if you have six variables, each of which has many options to be considered, the number of combinations can be many thousands.

Variable	**Number of options**	**E.g.**
Geographic location	8	Spanning main population centres
Ceiling area	4	50, 80, 120, 170
Attached / detached	3	Detached, Semi-detached, Attached
Insulation	4	None, Some, Good, Very good
Temperature level	5	12, 14, 16, 18, 20
Temperature regime	3	All day, morning & evening, evening only
Total combinations	**5,760**	

From an NBM tool perspective, having tens of thousands of combinations need not be a problem. However, it is likely to be more of a problem for undertaking the Accurate runs. Accordingly, if this approach were to be considered, there will need to be a judicious choice of which degrees of freedom to vary, and how many options to consider for each one.

It should be appreciated that, from a building performance modelling perspective, this proposed approach is fundamentally no different to the current NBM approach. i.e. the performance of individual insulation measures are assumed to be isolated from each other, with the performance variables determined through using either ALF or Accurate.

Instead of having four different situation options to choose from (the four different geographic regions within the current NBM), the proposed approach will enable many hundreds or thousands of different situations to choose from (comprised of the different combinations of six or seven input parameters) that better approximate reality.

3.3 The limited range of allowable measures considered

As indicated in 2.2.2, not including space and water heating options, or appliances could limit the effectiveness of EECA's delivery across the range of domestic energy interventions.

It should be noted that including these other measures needn't materially increase the model's complexity (indeed through rationalising multiple models and frameworks used to asses such measures for other EECA interventions it could be argued that it reduces complexity), but could deliver significant benefits around ensuring coherence of assumptions and approaches.

For example, if key assumptions were to change as a result of superior information (e.g. fuel and CO2 price projections, electricity emissions factors, the value of health benefits associated with take back, etc.) they would only need to be changed once within the NBM model framework, rather than multiple different frameworks associated with different programmes.

3.4 Assumed heating efficiencies for the different energy sources

At the moment there is no explicit identification of assumed heating efficiencies for the c/kWh cost of useful heat for the different energy sources. This makes the model more opaque, and harder to relate a c/kWh cost of useful heat, to a published c/kWh figure for delivered fuel to the property.

Further, it makes it much harder to evaluate different heating options if, as per 2.2.2 above, they were to be included within the NBM framework as allowable measures.

Accordingly it is recommended that the NBM has *delivered* c/kWh fuel costs as an input, along with explicitly identifying the heating efficiency of the heater.

This should make the model much more transparent and auditable, as well as making it more flexible in terms of being able to evaluate many different heating options.

3.5 The modelling of hot water

Currently the NBM assumes the same kWh savings for each hot water measure (cylinder wrap, hot water pipe lag, and low-flow shower head).

However, this ignores the fact that the actual level of savings can vary significantly depending on the age/type of the existing cylinder and, the occupancy of the building.

Therefore, it would seem appropriate to drive modelled hot-water demand off occupancy. This will deliver more accurate estimations of the value of low-flow shower heads, cylinder wraps (assuming that occupancy will dictate the size of the cylinder), and will enable accurate estimation of the value of alternative water-heating measures such as solar water heating if it is determined they should be included within the NBM framework (see 2.2.2 above).

Similarly, explicitly identifying the assumed cylinder age, size and type within the NBM should improve the accuracy of the benefits from cylinder wraps.

3.6 Identification of the within-year and within-day patterns of consumption.

Currently there is no identification of the within-year and within-day patterns of consumption in the NBM. This is despite the fact that both electricity and gas costs are likely to show increasing patterns of differentiation at the different times of day and year due to fundamental changes in the underlying drivers in the electricity and gas markets. Thus consumption at times of peak demand is likely to be increasingly more costly compared with consumption at other periods.

Similarly, it is likely that the CO_2 emission factors of electricity will show differentiation at different times of the day and year due to differences in which plant is marginal (from both a point-in-time operational sense, and a long-run new investment sense).

The scale of likely price / cost differentiation is such that the results are likely to materially under-estimate the benefits of those measures whose avoided consumption is principally at times of peak demand, and vice versa.

Accurate calculates energy loads on an hourly basis for the different days of the year. Accordingly, it would seem appropriate to identify within-day and within-year patterns of consumption through splitting energy loads within the NBM into different time period blocks. In order to capture the vast majority of the impact it should only require splitting the year into nine periods:

- breaking years into summer, winter and shoulder periods; and
- breaking days into weekday day, weekday peak, and night + weekend periods.

Only having nine periods would not materially add to the complexity of the NBM. However, it would require a revision to the Accurate batch processing approach to effect such a change in terms of recording results in this format. It is not known how much effort this would involve, but Concept would be surprised if it were substantial.

3.7 The assumed avoided cost of electricity and gas

Electricity and gas prices to consumers comprise a fixed element and a per kWh variable element. Energy efficiency measures will result in the per kWh variable element being avoided by the *consumer*.

However, at the moment, the NBM uses a weighted average price published by the MED which incorporates the fixed charge[1]. Accordingly, the NBM will tend to over-estimate the value of avoided electricity consumption to the *consumer*.

It has not been possible to verify whether the gas prices used similarly include the fixed charge.

Accordingly, it is recommended that only the variable element of energy prices are counted in the cost: benefit equation.

Another issue is that there is no regional differentiation of electricity prices, even though there can be significant regional variation[2]. Accordingly, it is recommended that the NBM introduce regional differentiation in the fuel prices, particularly electricity.

Both recommendations should not be onerous to effect from a modelling perspective, but will require sourcing the input data from the Electricity Commission as it can be time consuming to acquire.

3.8 The distinction between avoided energy *prices* to consumers versus avoided economic *costs* to New Zealand

The previous sub-section dealt with the net benefit to consumer. This may differ from the net benefit to New Zealand if there are benefits or costs that a consumer doesn't face, but which fall to other parties.

In particular, the prices faced by consumers may not properly reflect the underlying costs with respect to the split between fixed and variable charges. For example, costs which are variable over the long-term (e.g. investment in new transmission and distribution capacity to meet growing demand), may be recovered via fixed charges in the short-term.

In such a case, simply using the variable component of consumer prices will under-estimate the value of energy efficiency from the perspective of avoided costs to New Zealand as a whole.

Accordingly EECA may want to consider having two avoided supply-side cost elements

One supply-side cost element should be the variable component of consumer prices. The other should be the avoided supply-side economic costs over the long-run (i.e. over investment timeframes for generation and network investment).

Such an approach will properly capture the economic benefit to New Zealand of energy efficiency benefits, as well as highlighting the individual financial benefit to consumers.

That said, calculating the avoided supply-side economic costs is a non-trivial exercise. EECA will need to coordinate with agencies such as the Electricity Commission, Gas Industry Company and MED to ensure values which are both appropriate, and consistent across different branches of government.

[1] The $/annum fixed charge is simply divided by the annual kWh consumption of the assumed average customer to give a c/kWh price.

[2] For example, the bill for an 'average' 9,000kWh/annum customer is some 50% higher in the most expensive region compared with the cheapest region.

3.9 Forward projections of energy and environmental costs

The costs of the different input fuels (particularly electricity and gas), and the emissions factors of electricity, could change considerably over time.

However, at the moment the only treatment of this in the NBM is a 1% per annum escalation factor for all fuel costs, with little supporting evidence validating such an assumption. There is also no explicit identification as to whether cost excalations are assumed to be real or nominal.

Accordingly it is recommended that fuel prices, CO2 prices, and CO2 emissions factors are explicitly projected forward on a year-by-year basis, and that the extent to which inflation is incorporated in such projections is explicitly identified.

This will help make the NBM more transparent and auditable, and hopefully more accurate (to the extent that the underlying forecasts are accurate).

Another issue relates to the extent to which CO2 prices are assumed to have flowed through into fuel prices.

New Zealand currently faces a CO2 cost liability through its Kyoto obligation, yet current electricity prices don't fully[3] incorporate a cost of CO2. Thus any energy savings should arguably be valued at the avoided fuel price plus the avoided CO2 cost.

However, if a future electricity price (e.g. for 5 years hence, say) is assumed to have incorporated the price impact of the cost of CO2 on the electricity sector, then it would be double counting to add the avoided cost of CO2 onto the avoided fuel price.

Accordingly, it is recommended that the extent to which CO2 prices have been assumed to flow through into the fuel price projections is explicitly identified, and that avoided CO2 costs are only treated as an additional benefit if the cost of CO2 hasn't been assumed to flow through into fuel prices.

3.10 Treatment of take-back and rebound spending

The fact that many consumers decide to take the benefit of efficiency measures as increased warmth / comfort (referred to as take-back[4]) is explicitly identified within the NBM model via the energy and environmental benefits being discounted by the assumed level of take-back.

However, the very fact that such householders have decided to take the benefits as increased warmth rather than reduced bills indicates that the value of such take-back is greater to them than the monetary value of the bill reduction they could have enjoyed.

It could therefore be argued that, at a minimum, the valuation of such take-back within the cost: benefit analyses of public policy tools such as the net benefit model should be no less than the monetary value of the energy savings that could have been enjoyed.

One way to understand this argument is to consider that energy efficiency measures will deliver monetary savings to <u>all</u> householders for delivery of the *same* level of energy

[3] Although generators aren't currently subject to a CO2 charge, it is possible there may be some 'anticipation' reflected in current tariff and contract prices.
[4] Take-back refers to situations choose to take the benefits of an efficiency measure as improved comfort (e.g. warmer or lighter rooms; warmer, longer or more frequent baths / showers).

service as they enjoyed prior to the energy efficiency measures. It is then up to each individual household what to do with this extra money. Some may decide to spend it on food, or clothes, or holidays, or indeed anything.

However, some may decide to spend it on household heating to get an *improved* energy service to what they enjoyed before. It is this spending of income released by efficiency measures on improved heating energy services that is referred to as take-back.

Such take-back consumption on improved energy services should not be subtracted from the cost: benefit analyses of such spending, in the same way that consumers deciding to spend their extra money on food, clothes etc, is not be regarded as a negative.

The exception to this is if the policy justification for the energy efficiency intervention was to correct for externalities not being reflected in the price of energy. In such a case the take-back energy consumption should be subtracted from the benefit stream but only valued at the cost of the externality.

In New Zealand, the principal externality is CO2 costs. According, the CO2 costs of take-back consumption should be subtracted from the benefit stream, but only whilst the cost of CO2 isn't reflected in fuel prices (refer to 3.9 above). All the other variable costs of energy shouldn't be subtracted from the benefit stream.

The treatment of take-back is the other side of the coin from the treatment of so-called rebound spending, whereby householders decide to spend the money they saved from the efficiency measures on other goods and services.

Again, it has been argued that to the extent such rebound spending results in increased energy consumption (e.g. from going on a foreign holiday), then such energy consumption should be subtracted from the cost: benefit of the efficiency measures.

However, again, it is only if the policy justification is to correct for externalities not being reflected in the price of energy should such rebound energy consumption be subtracted from the cost: benefit.

Accordingly, the CO2 implications of rebound spending *should* be incorporated within the NBM, but only be to the extent that energy prices don't reflect the cost of externalities.

3.11 Modelling of take-back

At the moment, the amount of take-back assumed for a measure is a single number (e.g. 30% for space heating measures) for all situations. However, the reality is that the level of take-back is likely to exhibit a huge range of values depending on the situation.

For example, properties which are currently only heated to a very low temperature may exhibit very large levels of take-back, as occupants chose to take almost all the benefits via warmer living temperatures. Indeed, in some observed situations the level of take-back has been greater than 100%[5].

[5] In such situations, previously occupants chose not to heat the house at all because the lack of insulation meant such heat would be wasted, whereas after the introduction of insulation

Similarly, the level of take-back is also likely to be a function of the income of building occupants. For example, at low income levels, individuals may have little or no *discretionary* disposable income – i.e. it is all spent on life essentials (i.e. food, clothing, rent/mortgage, transport, fuel). In such situations, the amount of money spent on fuel will be a function of what it 'left over' after meeting the other essential requirements. Thus, after an insulation measure a household may still budget for $20 a week on fuel, say, but enjoy the benefit as higher living temperatures (which may still be below desired / recommended living temperatures).

It is only when the measure results in desired / recommended living temperatures being achieved *within* the original budgetary constraint that measures will start to deliver savings in terms of reduced energy consumption.

Accordingly, one of the most important changes to the NBM that should be considered is making achieved temperature an input parameter – i.e. specifying the current level of achieved temperature, and the post-measure level of achieved temperature. Such a structure has two major benefits:

- It completely does away with the need to make assumptions around take-back. (Noting that the level of inferred take-back can be derived from the pre- and post-measure energy consumption data); and
- If facilitates much more transparent and/or accurate determination of the incidence of adverse health / social welfare and building maintenance outcomes. (Detailed further in Sections 4, 5.1 and 5.2 below).

Such a change should be simple to effect, given that this is consistent with the way in which Accurate and ALF are currently structured (i.e. they deliver energy consumption outcomes for achievement of a pre-determined temperature level).

EECA may also want to consider making the post-measure *achieved* temperature a function of *desired* temperature <u>limited by available disposable income</u>.

This should be possible without too much modelling complexity (subject to reasonable input assumptions), and would add greater transparency and understanding to the determination of assumed temperature outcomes.

3.12 The ability to concurrently consider multiple different building / socio-demographic situations

It is possible that a programme under consideration for EnergyWise funding will comprise multiple different building situations (both building typology, and occupancy typology). However, as currently structured, the NBM effectively assumes that every building situation within one of the four regions is the same.

As well as forcing unnecessary averaging and simplification for programme evaluations, this characteristic will frustrate the ability of the tool to be used for more strategic issues such as evaluating EECA's total residential programme for the purposes of making a budget bid in the annual Treasury funding round.

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measures it was actually worth their while to start heating the property, and as a result their energy consumption increased.

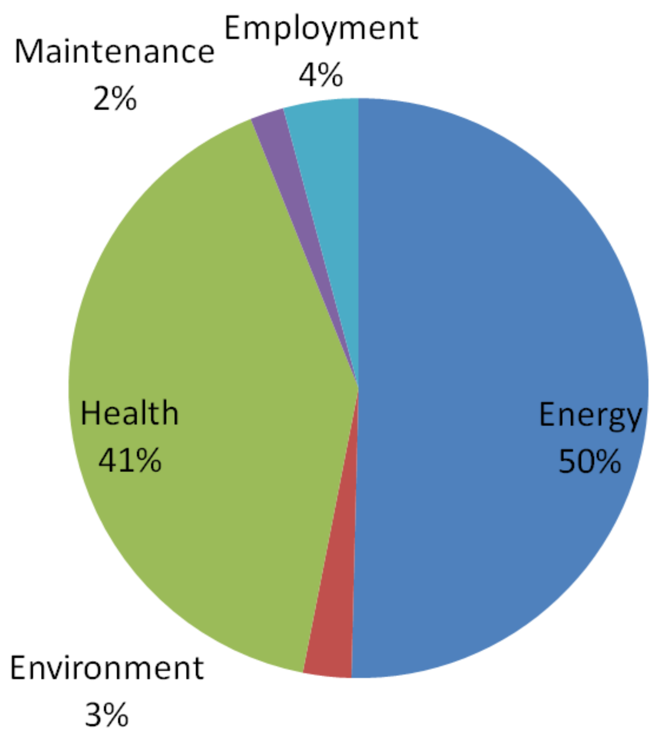
Accordingly it is recommended that the NBM be able to consider multiple building situations concurrently.

It should be easy to design an input sheet within the model such that a user could input as few or as many different building situations they would like evaluated, with a visual basic routine being used to run through each situation to calculate the cost: benefit.

4 Modelling Health Benefits

As illustrated by the following chart, the health benefits within the current NBM can account for a significant proportion of the lifetime NPV benefits of interventions.

Figure 1 – Current NBN-derived lifetime benefits of a sample energy efficiency programme[6]



The current net benefit model bases its valuation of health benefits largely on research into the impact of insulation on health conditions. However, three issues arise in relation to the modelling.

- the relationships between dwelling performance, thermal comfort and energy efficiency and adverse health of various population sets.
- the valuation of health benefits.
- the data and research on which the valuations incorporated into the model are based.

[6] To derive these numbers the NBM was populated with dummy data where 100 houses were considered, spread evenly across the four regions, with each house having one of each allowable measure (assuming that there was no existing ceiling insulation).

4.1 Modelling the linkage between dwelling performance and human health

Energy efficiency and heating measures can improve the quality of the living environment in terms of warmer living temperatures, and improved air quality (in terms of reduced moisture, mould and un-burnt hydrocarbons). The impact of such improved living environments can yield benefits in terms of a reduction in adverse health conditions. Increasingly, Governments are valuing such benefits as 'extra' to the energy and environmental savings achieved. The policy justification for adding such additional benefits is:

- Many of the costs of such adverse conditions are socialised among society (e.g. health-care costs)
- The costs of adverse housing conditions are often borne by those who are not responsible for making energy-related decisions (e.g. children bear the consequences of decisions made by their parents).

However, the treatment of health benefits within the NBM is simplistic – i.e. every building is ascribed the same $ value for reduced hospital admissions, reduced days off school, and reduced days off work, with that value accruing to a building only if ceiling insulation is installed. This ignores:

- The fact that different building situations are likely to have different levels of improvement in the building environmental metric (i.e. temperature or air quality) that drives the adverse health outcomes;
- The different possible socio-demographic compositions of building occupants and corresponding differences in:
  - prevalence of adverse health outcomes (e.g. infants and the elderly are likely to be more susceptible to low temperatures than adults); and
  - costs of such adverse outcomes to such individuals (e.g. time off work or time off school is irrelevant if the individual is too old/young to go to work or school).

Accordingly, it would be desirable to change the NBM so as to link the incidence of a health outcome (e.g. prevalence of asthma), to an explicit environmental metric of the house such as temperature or air quality.

This could be effected by a series of 'cause and effect' lookup tables such that for a given achieved household temperature, say, X% of the population would likely suffer some health / social welfare impact (e.g. stroke).

In addition to temperature, other key metrics could include un-burnt hydro carbons and moisture. Thus, the presence of an unflued gas heater, say, could be assumed to result in higher levels of unburnt hydro-carbons and moisture, both of which could be linked to increased prevalence of adverse health conditions using the same lookup table approach as for temperature.

From a modelling perspective, this lookup-table approach should be relatively straightforward to achieve (noting that there are degrees of sophistication that could be effected). The benefits of such an approach would be to make the results:

- much more transparent, aiding auditing and understanding; and

- *potentially*[7] more accurate.

Currently, 'health' benefits are lumped under a single catch-all number. However, in reality there are many different possible health outcomes because the thermal performance of dwellings is known to be associated with a variety of adverse health condition. In particular:

- Respiratory conditions and illnesses
  - colds and flu
  - asthma
  - bronchitis
  - pneumonia
- Infectious diseases
  - gastro enteritis
  - meningitis
- Cardio-vascular
  - strokes
  - high blood pressure
  - heart attack
- Mental illness

In addition, household composition, and the socio-demographic characteristics of household members also have important associations with morbidity and mortality (e.g. infants and the elderly are much susceptible to low-temperature related health outcomes).

Given the above, separately identifying the different adverse health affects and the different socio-demographic prevalences within the model, rather than lumping them together under a catch-all 'health' impact, should make the results of the modelling:

- much more transparent, aiding auditing and understanding;
- ideally more aligned with other government agency data gathering and reporting exercises (e.g. Ministry of Health);
- more future-proofed and easily updatable as and when better information becomes available; and
- *potentially* more accurate.

4.1.1 The trade-off between model complexity and data limitations

The *potential* accuracy enabled by the more sophisticated approach outlined above will only translate into *actual* accuracy to the extent that the underlying input data is accurate with respect to the relationship between house temperature and air quality and adverse health conditions.

[7] See Section 4.1.1 below for the discussion on the extent to which data availability will determine the extent to which such *potential* for increased accuracy results in *actual* improvements in accuracy.

This is an area where the health science is complex. The quality and availability of data is mixed in relation to attributing changes in health to energy efficiency interventions and improved living environments. Further, measuring the value of health in relation to school and workplace participation is even more complex.

Given the paucity of good information on the above factors, it begs the question as to why make a model more complex to accommodate phenomena where the range of uncertainty is so large.

However:

- the modelling approaches described above needn't be that much more complex (and indeed would likely be completely 'behind the scenes' for users);
- there is no inherent reason why superior information will not be available in the future building on the initial studies which have started to look at these factors, and thus such an approach future-proofs the model such that it can be populated with more accurate data as and when it emerges[8];
- the modelling makes explicit those assumptions which are effectively implicit in a more simple approach, thereby aiding auditing and understanding of the results and the degree of uncertainty; and
- the act of developing the modelling framework can itself inform decisions as to where data gathering initiatives are likely to yield greatest benefit.

Thus, given there is this reasonable expectation that data will be improved, it is recommended the model be structured in anticipation of such superior data even if it is initially populated with 'best guess' aggregate data whose accuracy is no greater than from adopting a simplistic modelling approach.

Exactly how complex the model should be made in anticipation of such superior data is in part a judgement call based on views on how costly it would be to collect such data, and the significance of the issue in question with respect to influencing cost: benefit analyses. It is outside the scope of this work to make such detailed recommendations as it would require more research on the data issues than is within the current scope of this work.

Thus a key related recommendation is that EECA participate in cross-agency initiatives with organisations such as the Ministry of Health, Pharmac, the Ministry of Social Development, and the Ministry of Education to improve understanding in these areas.

4.2 The Value of Health Benefits

The current net benefit model values health benefits in three ways:

- The value of avoided health care.
- The value of reduced absenteeism from paid work.
- The value of reduced school absenteeism.

Each of these are discussed below after an initial discussion on issues around the data on which the valuations incorporated into the current net benefit are based.

[8] It should be noted that even if the science is complicated, all that is required is empirical evidence linking an energy efficiency intervention to observed health outcomes, even if causality between the many different factors is not properly understood.

4.2.1 Issues with the current NBM data

The current net value model incorporates annual household benefits and present value for benefits with a discount rate over 20 years for health benefits. The health benefits appear to be activated where there is 30 percent take-back or better for space-heating efficiency options. The data settings appear to be calculated on the basis of the New Zealand Housing Insulation and Health Study led by the Wellington School of Medicine and reported in 2004.[9]

With regard to the data on house environment 'cause' and health / absenteeism 'effect', the generalisability of the data from this study to the total population of New Zealand households must be treated with considerable caution. The study has considerable strength in so far as it involves measuring the impacts of interventions using a randomised control trial. However, the study was undertaken in a particular set of communities characterised by high levels of deprivation and in a set of households eligible for fully subsidised grants for energy retrofit. The high deprivation of the communities in which these households lived, given the phenomenon of neighbourhood affects, could prompt a question about the generalisability of the results of the study even to the households holding Community Service Cards that have been targeted by energy retrofit grants to date. This is especially the case given the very poor condition of many of the dwellings in the sample compared to the national stock.

If the net benefit model is to be extended to other energy efficiency programmes and, thus, to middle and higher income households, the problems of generalisability are considerably increased. This is not a criticism of the study itself, but simply a warning about the limitations of the data and is application outside the targeting of the current grants programme. We simply do not know how the dynamics of health, thermal comfort and school absenteeism express itself in higher income households.

4.2.2 The Value of Avoided Health Care

It has already been noted that the treatment of health benefits within the NBM is simplistic. The lumping together of a variety of different conditions with quite different treatment requirements may serve to cover up considerable variation in relation to health costs incurred both by individuals through private health care or co-payments, and by Government's public health funding. Primary health care prices and costs are significantly different to secondary and tertiary health care. There are significant permutations between the adverse conditions identified with poor thermal performance including exposure to mould and the provision of primary, secondary and tertiary services.

Consequently, it is desirable for differentiation to be made between adverse health conditions and also the settings and levels of services provided to address those conditions. If appropriate data was available this could be achieved within the model by sub-modules based on primary, secondary and tertiary care costs by condition. The research necessary to underpin such a model has not yet available. However, Michael Baker's study into the impacts of shifting households from overcrowded to less crowded

[9] Howden-Chapman, P., Crane, J., Matheson, A., Viggers, H., Cunningham, M., Blakely, T., O'Dea, D., Cunningham, C., Woodward, A., Saville-Smith, K., Baker, M., and N. Waipara, 2006, Retrofitting houses with insulation to reduce health inequalities: aims and methods of a clustered, radnomised community-based trial, *Social Science and Medicine*, 61(12).

housing conditions provides an example of how research can produce useful findings at that level of detail.[10]

Further, it should be noted that agencies such as the Ministry of Health, New Zealand Health Information Service, Pharmac, Ministry of Social Development and the Ministry of Education have some data on the prevalence of health / social welfare conditions and the costs incurred as a result of such conditions. Plus they have a number of different techniques to ascribe value to conditions and/or allocate funding to their treatment[11]. In addition, it is noted that these agencies and Treasury have been considering ways to better coordinate and make coherent the techniques and assumptions for such valuation exercises.

Accordingly, it is recommended that EECA work with such agencies to determine what data is available, and whether / how some of the more sophisticated valuation techniques could be used in the NBM context.

As well as sharing the costs of such research, it is likely that if values within the NBM were based on published metrics from other agencies, it would make the model more transparent / auditable, and more readily updatable.

A final issue relates to the discount rate used for valuing health benefits. In the recent GPS on the electricity sector, the Government has stated that the discount rate to be used for valuing energy efficiency investments should be 5%. However, with regards to the annual Treasury budget round for allocating health spending between DHBs, Pharmac and the like, the government uses an 8% discount rate.

Accordingly, to the extent that the NBM is used to determine EECA's funding relative to other calls upon tax funds, it is recommended that the health benefits of energy efficiency investments are valued at the same discount rate as other government agency health funding.

4.2.3 The Value of decreased workplace absenteeism

The problems of data generalisability have already been rehearsed in Section 4.2.1 above, in particular the cause and effect between house environment and incidence of time off work. In addition to those data limitations, there are some questions about the manner in which the *value* of reduced days off work have been modelled.[12]

The New Zealand Housing Insulation and Health Study (the current basis for the numbers within the NBM) recognises that school absenteeism represents a cost in forgone education and in, some cases, also reducing the productivity of parents who may have to take a day off work to care for a sick child. It is unclear whether the valuation of the latter is taken account of in the estimates of the value of fewer days off work. It appears that it is. The cost-benefit approach to insulation assumes, rightly, that because insulation provides on-going benefits, the dwelling will continue to convey

[10] Michael Baker, Jane Zhang, Philippa Howden-Chapman, Tony Blakely, Kay Saville-Smith, Julian Crane**,** 2006, Housing, Crowding and Health Study: Characteristics of cohort members and their Hospitalisations -February 2003 to June 2005

[11] For example, the Quality Adjusted Life Year (QALY) approach used by Pharmac for allocating its pharmaceutical budget.

[12] Chapman, R., Howden-Chapman, P., O'Dea, D., Viggers, H., and M. Kennedy, 2004, Retrofitting houses with insulation: a cost-benefit analysis of a randomised community trial, Wellington, NZ Housing and Health Research Programme.

benefits over a long period of time. The value of a lost day at work is calculated as 66 percent of the average daily wage rate for New Zealand workers.

Recent work on the value of health undertaken by Marsden and Moriconi (2008) suggests that this approach to valuing days lost is likely to lead to a significant under-estimate.[13] Firstly, Marsden and Moriconi use the average daily salary of an employee and account for a full 100 percent of that day's wage. Secondly, Marsden and Moriconi identify a number of 'hidden', longer term benefits associated with reducing the number of workers' days lost. Their research in Royal Mail has found that reductions in absenteeism:

- increases productivity and probability of meeting productivity targets
- increases profitability
- decreases costs.

In particular reductions of replacement labour usage contribute to benefits because replacement, casual or agency staff, both generate managerial costs and are less productive than permanent staff. Absenteeism is also associated with reduced quality service and reputation and forgone future income from business expansion.

In other words, there are genuine economic costs associated with replacing an employee who is off sick – either temporarily replacing them with another individual during the sick employee's absence, or replacing the time at which the work is delivered (i.e. the sick employee delivering their work when they get back).

The modelling of absenteeism and the value of avoided work-off days can be extended beyond a single organisation. Marsden and Mariconi applied the approach they developed in relation to Royal Mail to the cost benefit and potential savings that could be generated across the 13 sectors in the British economy worst hit by absenteeism. The quantum of cost savings was substantial - £1.45bn.

In terms of the current net cost-benefit model, the work of Marsden and Mariconi suggest that there is merit in:

- using 100 percent of average daily wage rates according to socio-economic groupings
- generating a sector by sector model of absenteeism
- developing a more robust profile of absenteeism and the impacts of energy efficiency by households with different socio-demographic characteristics and labour market positions.

The latter two bullet points could involve significant amounts of research which would likely need to be coordinated with other interested agencies (e.g. MSD and MED).

4.2.4 The Value of Lost School Days

The problems of data generalisability have already been rehearsed in Section 4.2.1 above, in particular the cause and effect between house environment and incidence of time off school

[13] Marsden, D and Moriconi, S., 2008, The Value of Rude Health: A Report for Royal Mail Group, London School of Economics, Centre for Economic Performance and Department of Management.

In addition there are some questions about the manner in which the *value* of school days has been modelled within the NBM.[14] The New Zealand Housing Insulation and Health Study recognises that school absenteeism represents a cost in forgone education and in, some cases, also reducing the productivity of parents who may have to take a day off work to care for a sick child. It is unclear whether the valuation of the latter is taken account of in the estimates of the value of school days or estimates of fewer days off work or neither.

In relation to the value of a child or young person's days off school, however, those are valued as if the value per day of education to a young person is equivalent to 66 percent of the youth minimum wage. For a child at primary school, the valuation is set at half the value of a young person's absence. In estimating the present value of future benefits, two key assumptions are implicitly made with the current NBM approach: (a) that because insulation provides on-going benefits, the dwelling will continue to convey benefits to any school age children over a period of 30 years, and (b) on average the proportion of dwellings with school age children will stay about the same over a 30 year period.

The latter assumption is particularly questionable. Statistics New Zealand provided up-dated projections of families and households in 2005 for 2001(base)-2021.[15] Those projections suggest that the greatest growth in families will be in 'couple-without-children' families and that type of family will become the most prevalent. The projections indicate there will be absolute growth in the number of families with dependent children but that that growth will be slow with a decline in the rate of growth from 2012-2011. In terms of households, it is expected that one-person households will be the fastest growing household type. In absolute terms, the number of one-person households is expected to increase by 154,000 between 2001 and 2021. The projections suggest that households without dependent children will increase proportionately. From 2001-2021, one-person households are likely to increase from 23 percent to 26 percent.

The calculation of value could also be revised. The current approach to valuation is effectively a substitution model in which a day at school is valued as having a value of a day at work (or in this case a proportion thereof). MacMillan (2000), however, suggests that the value of school days lost for adolescents should be undertaken from a 'life-course' perspective[16] that recognises lifetime forgone:

- wages owing to lack of education
- non-pecuniary benefits of education
- social benefits owing to lack of education.

In addition, it could be argued that there is a direct cost associated with the wastage of Government funding for children and young people absent from school. That cost is in addition to any costs over the life course of the individual although the costs persist only for the funding year in which absenteeism falls. It is a specific cost to Government where

[14] Chapman, R., Howden-Chapman, P., O'Dea, D., Viggers, H., and M. Kennedy, 2004, Retrofitting houses with insulation: a cost-benefit analysis of a randomised community trial, Wellington, NZ Housing and Health Research Programme.
[15] Statistics New Zealand, 2005, *National Family and Household Projections 2001(base)-2021 Update*, Statistics New Zealand, Wellington.
[16] MacMillan, R., 2000, Adolescent Victimization and Income Deficits in Adulthood: Rethinking the costs of criminal violence from a life-course perspective, *Criminology* 38.

Government makes an investment – effectively a sunk cost – in providing education to an individual that does not take it up. Those costs can be valued by establishing the funding per child in primary and secondary school settings on a daily basis and calculating the value of the reduced wastage through insulation. Any calculation of reduced wastage should take into account the additional, 'compensatory' funding Government attaches to schools in low decile communities.

However, further thought would need to be given as to whether counting this wasted government funding cost as well as the lost 'life-course' value of education would be double counting. It is likely that the 'life-course' approach will yield higher numbers than wasted government funding of education approach, but be harder to calculate.

Overall, it is suggested that EECA consider developing a sub-module for valuing school days lost that takes into account:

- costs to individuals over the life-course of school days missed[17]; and / or
- direct benefits to Government reducing the funded wastage associated with school absenteeism generated through reductions in school days lost.

With regard to the latter, that valuation should take account of funding differentials between primary, intermediate and secondary schools as well as between schools of different deciles.

In addition, to ensure that both individual life course and Government benefits from reduced school days are more robustly calculated, it is important that research into the pattern of school absenteeism associated with dwellings with poor thermal performance but higher income households is established. There may be some opportunities to pursue this through Beacon's Renovation 1000 project which has samples of dwellings with higher income households. The latter is particularly important as the Government moves towards targeting incentives such as EnergyWise Loans to middle income and higher income households.

4.2.5 Health Benefits and QALYS

Quality adjusted life years have been developed by economists to capture the benefits of both the quantity and quality of life implications of medical treatments. They were developed to promote the efficient allocation of scarce health service resources. QALYS allow the comparison of treatments according to criteria such as the extent a treatment is unpleasant, the extension of life, whether any extension of life is painful, uncomfortable or characterised by marked disability, and the cost of treatment. Still somewhat controversial within the specific realm of health care, QALYs may provide some future functionality to modelling health benefits associated with energy efficiency. However, more traditional approaches to valuing health benefits may be more appropriate in the short to medium term.

[17] A dry economic perspective may discount such benefits as accruing to the individual concerned, not society as a whole, and thus not warranting societal funding. However, there are likely to be public policy justifications for including such benefits including:

- The fact the child's absenteeism from school due to poor housing conditions is as a result of factors which they cannot influence (i.e. the decisions of the parent impact on the child); and
- There are likely to be overall improvements to wealth generation in society from having a more educated workforce.

5 Modelling Other Benefits

The net benefit model also includes benefits around dwelling maintenance and employment. The modelling of those benefits is overly and unnecessarily simplistic. In addition, there are other potential benefits that could be captured, especially benefits in relation to improved intra-family interactions. This section considers the modelling of family violence effects – an effect not dealt with by the model. It then turns to the modelling of maintenance effects and employment effects, both of which are inadequately modelled in the net benefit model.

5.1 Family Violence Effects

There are a range of evaluative studies in New Zealand that suggest that improving the thermal performance of dwellings and increasing thermal comfort has pronounced positive impacts on interactions within the home. Those include evaluations of a number of programmes delivered by Housing New Zealand Corporation including the Healthy Homes Programmes and the Rural Housing Programme.[18] Those studies also include an evaluation of the energy retrofit programme in the Eastern Bay of Plenty[19] and householder interviews with the occupants of Beacon's Waitakere NowHome.[20] The data related to social interaction improvement tends to be qualitative.

Despite qualitative evidence that retrofit programmes can improve intra-household interactions, there is no parameter that accounts for those effects in the current net benefit model. There appear to be no estimates of the value of improved social interactions in general, although Sniveley (1995) has developed a model to estimate the cost of family violence in New Zealand. In 1995 dollars, the most conservative estimate of the economic costs of family violence in New Zealand was $1.187 billion. That estimate was based on 1-in-10 prevalence.[21]

Developing a sub-module to address such issues within the NBM will, no doubt, be challenging. However, with the apparent costs of family violence so high, it seems appropriate that some effort be made to explore and account for the possible family violence effects associated with energy efficiency interventions in New Zealand homes. This is particularly important given that there is a variety of New Zealand research that suggests that the characteristics of households targeted under retrofit grant programmes have similar characteristics to the households that are most likely to be exposed to violence. Families targeted by retrofit grants tend to be families in low socio-economic positions, often under deprivation or illness related stress, frequently with dependent children or older people within the household. Families subject to family violence also tend to be low income and characterised by economic, social and psychological stress.[22]

[18] Various evaluation reports for Housing New Zealand Corporation have been undertaken into both those programmes.
[19] Saville-Smith, K and D. Thorns, 2001, *Community-based Solutions for Sustainable Housing*,, CRESA, Wellington
[20] Beacon report in preparation.
[21] Sniveley, S., 1995, The New Zealand Economic Cost of Violence, *Social Policy Journal*,
[22] Lievore, D and P. Mayhew, 2007, *The scale and nature of family violence in New Zealand: A review and evaluation of knowledge*, Ministry of Social Development, Wellington.

Moreover, the perpetration of violence between family members varies over time and can be triggered by exposure to variety of acute and/or persistent stressors.

Sniveley's estimates of the economic cost of family violence used the following data:

- annual service provision costs
- unit costs
- profiles of typical service use
- ranges of violence prevalence data.

Spreadsheets were used to develop scenarios and direct costs calculated for:

- a base scenario in which police callouts was used to measure family violence incidents
- five times call out scenario in which it is assumed that police callouts for family violence account for only one in five of the actual incidence, and
- an income foregone scenario which imputed the costs of labour market income foregone because of assumed work days lost through family violence.

The first of those scenarios using a 1-in-10 prevalence is the most conservative of the scenarios considered.

More recent research suggests that life time prevalence of violence may be as high as 26 percent among 'ever-partnered' women and 18 percent among 'ever partnered' men. The annual incident appears to be more in the region of 2 percent for men and 3 percent for women.[23] That data, and data arising from future New Zealand Crime and Safety data could provide the basis for a family violence effects module for the net benefit model. Further research would be desirable over the long term to explore the relationship between housing stress (particularly persistent poor thermal performance and comfort and energy efficiency) on the incidence of intra-family violence. However, even with the current data drawn from the Healthy Homes and Rural Housing programme evaluation data, some initial conservative assumptions might be made around decreased risk of violence.

From a modelling perspective, it is suggested that the quantum of any modelled reduction in family violence outcomes is linked to explicitly modelled changes in the building environment, particularly temperature.

5.2 Maintenance effects

The current net benefit model provides for a limited recognition of the maintenance impact of the EnergyWise Grant Scheme. The model values that maintenance impacts entirely in terms of reduced requirements for painting of interior linings. There is evidence, however, from the Rural Housing Programme evaluation[24] and evaluations of the impacts of EnergyWise grant retrofits in the Eastern Bay of Plenty[25] that householders are more likely to undertake repairs and maintenance when they see the

[23] 2001 National Survey of Crime Victims cited in Lievore *et al*., 2007.
[24] Various evaluation reports for Housing New Zealand Corporation have been produced.
[25] Saville-Smith, K and D. Thorns, 2001, *Community-based Solutions for Sustainable Housing*,, CRESA, Wellington

performance of dwellings improved. Improved house condition is associated with increased energy efficiency.

In addition, successive national and local house condition surveys show that uncontrolled damp can have a broad spectrum of impacts on house condition that go far beyond deterioration of interior paint surfaces. It can affect the integrity of windows, contribute to the deterioration of plaster board linings, make timber framing vulnerable to rot and attack by certain types of borer. Effective retrofit interventions and heating reduce damp in dwellings and increase the moisture holding capacity of indoor air.

New Zealand has a rich array of datasets in relation to house condition, energy efficiency and renovation including:

- New Zealand National House Condition Surveys – BRANZ (1995, 1998 and 2004)
- Household Energy End-use Project – BRANZ
- National Landlord's Survey – CRESA (2004)
- National Repairs and Maintenance Survey – CRESA (1998 and 2004)
- High Energy Users Survey – Beacon Pathway Ltd (2008)
- Recent Movers Survey – Beacon Pathway Ltd (2008)
- Landlords Survey – Beacon Pathway Ltd (2008).

Those provide an opportunity to explore the dynamics of damp, dwelling dilapidation, energy efficiency and the value of avoided repair/maintenance costs across dwellings of different ages, conditions and occupied by households with different socio-demographic characteristics.

From a modelling perspective, it is suggested that the quantum of improved maintenance outcomes are linked to explicitly modelled changes in the building environment, particularly temperature and moisture.

5.3 Employment Effects

The current net benefit model provides for a limited recognition of the employment impact of the EnergyWise Grant Scheme. The model values that employment impact entirely in terms of reduction in the Government's exposure to unemployment benefits. The model assumes that there is a one-off reduction in unemployment benefits because the employment durations and probability of sustained employment of installers was unknown at the time of the model's development.

The model's focus on reduced unemployment benefit expenditure is consistent with the predominant mode of delivery at the time through community-based organisations. Many of those organisations emerged out of Private Training Enterprises (PTEs) and community employment programmes. In the context of a whole of government approach, retrofit grants were also seen as an opportunity to leverage multiple outcomes from the Government's investment in energy conservation and efficiency. In this case, provision of employment opportunities and skill development.

In this respect, New Zealand's retrofit programme is strongly reminiscent of the United Kingdom's early energy efficiency grant schemes such as the Home Energy Efficiency Scheme (HEES) and Heatwise. Heatwise was specifically designed to generate employment for marginalised, low skilled individuals. HEES was targeted to low income, vulnerable households and, in its original form, was also expected to generate training and employment for low skilled people in areas suffering from high regional unemployment.

The strong policy link between retrofit investment, employment generation and training provision does not, however, imply that the employment effects of energy efficiency interventions should only be measured and valued in relation to employment positions created for installers and reductions in unemployment benefit.

Indeed, this is an issue where there are likely to be different perspectives as to whether / how such employment effects should be valued within the NBM framework. From the point of view of choosing between different projects for EnergyWise funding the question is largely academic as all projects are treated the same. However, if the model is to be used for helping bid for budget funding from Treasury, the issue is a real one.

Accordingly, a couple of different approaches are set out for EECA's consideration. One where the employment benefits are valued more comprehensively, and another where the employment benefits are substantially discounted.

Ultimately, the extent to which such benefits are valued for budget allocation purposes will be decided by Treasury. Accordingly, it is suggested that EECA discuss with Treasury which approach they believe is appropriate. In addition, the Ministry of Economic Development and Department of Labour are likely to be agencies with an interest in, and view of, such matters.

5.3.1 Comprehensive input / output modelling of employment effects

There are a variety of direct and indirect employment effects. A 1999 European study identified four mechanisms critical to determining the net employment resulting from energy conservation investments.[26] Those being effects arising from:

i. Initial investments in energy efficiency.
ii. Savings on energy expenditure and consequent shifts in household expenditure from the energy sector with its low labour intensity to sectors in which the labour intensity is higher.
iii. Net impacts of money transfers from one sector to another.
iv. Changes in Government budgetary position and expenditure generated by changes in tax revenue and exposure to employment related social security claims.

That study used input/output modelling techniques to assess the employment effects of energy conservation and efficiency investments in France, Germany, the Netherlands, Spain and the United Kingdom. They concluded that employment effects must be considered secondary to the environmental value of energy efficiency and conservation investments. Nevertheless, net employment benefits generated by residential energy efficiency and conservation programmes can be substantial. That is, investment in the energy efficiency of residential dwellings can have a positive effect on total employment. That study also suggests that the quantum of net employment benefit differs in relation to the mechanisms i-iv set out above. The quantum of net employment effects is also

[26] Jeeninga, H., Weber, C., Maenpaa, I., Rivero Garcia, F., Wiltshire, V., and J. Wade, 1999, *Employment Impacts of Energy Conservation Schemesin the Residential Sector: Calculation of direct and indirect employment effects using a dedicated input/output simulation approach*., Report for the Commission of European Communities. ECN-C-99-082

influenced by the profitability of investment, the type of investment and the method of financing that investment.

The financing of investment in energy conservation and efficiency options can be broadly divided into four categories. Those are financing through:

- reallocation of household budgets
- loans
- grants and subsidies, and
- private savings.

Jeeninga *et al* (1999) develop a generic model and specific country models. Those are then applied to energy conservation schemes in the European Union. There are substantial employment benefits with most of the schemes they tested.

It must be concluded, then, that focusing on the reduction of benefits directly generated by retrofit providers employing previously unemployed people is not an adequate representation of employment effects. Indeed, New Zealand's net benefit model probably seriously understates the employment effects of retrofit investments.

Just as importantly, New Zealand's current net benefit model would also have the potential to understate possible negative employment effects of residential energy efficiency and conservation programmes. It is conceivable that energy efficiency investments may draw investment away from labour intensive sectors (directly or indirectly) and, consequently, generate net employment losses.

Overall, the problem with the way in which the current model deals with employment effects is similar to the problems that the current net benefit model has with other components. That is, the model does not deal with, or adjust to, the dynamics that underpin the outcome value incorporated in the model. With regard to employment effects, there seems to be little reason why this should continue to be the case.

An input/output model for employment effects could be developed to underpin the net benefit model. There seems to be every reason to believe that the parameters of the modelling used in Europe could not be replicated in New Zealand. Broadly those models involve calculating total energy effects and employment effects of the consumption behaviour of households in the context of prevailing production structures. The impact of energy efficiency measures on employment are calculated in relation to:

- Employment induced through the demand for and purchase of energy-efficient products – Direct purchase effects.
- Employment induced by demand for products from others sectors needed to manufacture, distribute or service energy-efficient products – Indirect purchase effects.
- Changes in energy consumption associated with increased energy efficiency which may reduce employment demand in the energy supply sector and ancillary sectors – Consumption effects.
- Changes in household expenditure arising from expenditure on energy efficiency products and/or reductions in energy costs will have direct and indirect employment effects – Household budget effect.
- Changes in Government expenditure patterns through investment in energy efficiency may have impacts on employment – Government budget effect.

It should be noted that in the New Zealand context it is possible that energy (largely reticulated electricity) consumption effects may be relatively muted. The HEEP and other studies suggest that improved thermal performance of New Zealand dwellings may increase energy use as users take advantage of 'comfort' returns on their energy consumption/expenditure. Consequently, there may not be an employment loss in the energy sector. This is particularly the case if the energy sector diversifies and expands by way of distributed energy supply.

The modelling of employment effects typically use data on:

- household characteristics (household composition and income), expenditure and consumption patterns
- labour intensity characteristics of production and market sectors
- energy consumption patterns, thermal performance and typology of the residential dwelling stock and the performance impacts of various energy efficiency interventions

In the United Kingdom, the input/output model was developed at the level of national accounting data, rather than cross-section data. While this allowed the United Kingdom modelling to be undertaken on a long time series of data, it also meant that distinctions in the expenditure and consumption patterns of different household types is not made. Modelling undertaken for France, Germany, and the Netherlands, however, has been undertaken in such a way as household composition and other socio-demographic data is incorporated. The latter allows for a better understanding of both the:

- aggregate net employment effects, *and*
- implications of targeting different household groups in relation to employment effects.

New Zealand has very similar datasets available to those available in the United Kingdom. New Zealand also has strong affinity with the United Kingdom's policy settings. Both the United Kingdom and New Zealand are characterised by energy efficiency programmes designed to address environmental concerns and anxieties about energy supply. As such, there seems little reason why New Zealand could not, at the very least, develop a similar employment module for the net benefit model using national accounting data.

However, New Zealand does have some data and datasets that could contribute to developing a cross-sectional module for employment effects more akin to those applied to France, Germany and the Netherlands including:

- Household Economic Survey – Statistics New Zealand (time series)
- Household Labourforce Survey – Statistics New Zealand (time series)
- SOFIE – Survey of Family Income and Employment – Statistics New Zealand (repeated panel survey)
- Industry and Business Surveys – Statistics New Zealand (various time series including LEED – Linked Employer-Employee Data)
- Living Standards Survey – Ministry of Social Development (snapshot survey)
- Annual Enterprise Survey – Statistics New Zealand (time series)
- New Zealand National House Condition Surveys – BRANZ (1995, 1998 and 2004)
- Household Energy End-use Project – BRANZ
- National Landlord's Survey – CRESA (2004)
- National Repairs and Maintenance Survey – CRESA (1998 and 2004)

- High Energy Users Survey – Beacon Pathway Ltd (2008)
- Recent Movers Survey – Beacon Pathway Ltd (2008)
- Landlords Survey – Beacon Pathway Ltd (2008)
- NowHome Waitakere Monitoring – Beacon Pathway (house-based case study)
- NowHome Rotorua Monitoring – Beacon Pathway (house-based case study).

In addition, EECA itself has commissioned a variety of reports that may be helpful in establishing changed expenditure and purchase behaviours associated with energy efficiency and conservation programmes in the residential sector. Of course, the development of an employment effects module would also be dependent on EECA sourcing robust information on the quantum, nature, financing and energy outcomes of investments associated with each energy efficiency and conservation programme.

It should be noted that while the models for employment effects used by Jeeninga *et al* (1999) measure the effects on employment of energy efficiency and conservation options in terms of labour years (both over a specified 15 year period and over the average life of the energy saving option), those labour years could be converted into dollar values. Some consideration would need to be given to whether average cross-labour dollar values are used or dollar values are tied to occupational structures within the labour.

5.3.2 Limited modelling of employment effects

An alternative viewpoint would suggest that using tax dollars to pay for people to undertake energy efficiency work rather than receive unemployment benefit is 'just' a wealth transfer, and therefore should not be regarded as an 'extra' credit in addition to valuing the usefulness of the work undertaken (i.e. the energy, environmental and health benefits outlined previously).

Further, to the extent that changed patterns of energy consumption result in demand shifting between more or less labour intensive sectors, it could be argued that such effects are already captured within the prices of the different energy products and services. Further, to the extent that demand shifts to less labour-intensive products and services, this is not necessarily a 'bad' thing in that it frees-up labour to engage in other productive activities.

Where an argument could be made for including the value of employment generated would be if it could be shown that the funding kick-started a wealth-generating activity (i.e. the business of retrofitting energy efficiency measures in homes) that wouldn't have otherwise occurred.

In addition, there may also be a case for valuing some employment benefits if it could be shown that such initiatives manage to bring some individuals out of a state of long-term unemployment, that wouldn't likely to have occurred via other means.

Similarly, other government agencies such as the Treasury, MED, Department of Labour, and MSD may be interested in the likely employment consequences of energy efficiency programmes, even if from a national accounting perspective shifting tax spending from paying unemployment benefits to paying for people to retrofit homes is regarded as 'just' a transfer.

Given the range of perspectives on this issue, it is recommended that EECA discuss with Treasury, MED, DoL, MSD and the like as to the appropriate methodology.

6 General issues

6.1 Treatment of data uncertainties

Given the poor data and high degrees of situation-specificity, there are likely to be significant margins of error. However, at the moment the NBM doesn't record the range of uncertainties for individual data points, and as a consequence provides little useful information to users as to the scale of uncertainty for the final result, or indications of which assumptions give rise to the most significant margins of error.

Accordingly it is recommended that, rather than record a single value for each data point, upper, lower and central values are recorded.

This not just with respect to the modelling of the technical performance of the building, but also the issues discussed in Section 4, namely:

- the cause and effect relationship between building environment 'causes' and health / social welfare 'effects' ; and
- the valuation of these health / social welfare effects.

With regards to valuation, it is likely that different government agencies will use different valuation approaches in different areas. It is also likely that each approach will have a significant range of uncertainty.

It is recommended that where there are alternative approaches to valuing an aspect of a health / social welfare outcome, such alternatives are explicitly included within the model, with the extent to which each alternative is included in the overall valuation (either solely, or as part of an averaging approach) explicitly identified. This will aid both auditability and updatability of the model – i.e. if updated information about an approach comes out of work from another government agency, this will be easier to feed into the NBM.

Further, to the extent that such valuation approaches have a range of uncertainty this should also be recorded within the model in such a way as to facilitate ranges for the cost: benefit analyses.

Because of the above uncertainties, it is recommended that reporting sensitivity tools are developed such as tornado diagrams to highlight those assumptions which have greatest bearing on the range of uncertainty.

6.2 User-friendliness of model

The current NBM requires users to type all sorts of data, including assumptions about the performance of measures, and sometimes having to type the same type of data twice.

As well as not being particularly user-friendly, this increases the possibility of user error.

Accordingly it is recommended that the model is structured to make user input limited to specifying which building situations are being considered, not to typing in assumptions around the technical performance of measures

The use of lookup formulae, and the ability to lock cells should aid integrity, whilst at the same time make the model more user-friendly.

7 Summary issues and recommendations

Issue	Recommended alternative approach
The NBM is based on ALF, yet almost all other residential building energy efficiency modelling undertaken by EECA, including the high-profile home energy rating scheme (HERS) initiative, is now being based on Accurate.	Base the net benefit model on Accurate rather than ALF.
Overly simplistic modelling of complex inter-relationships between non-linear factors in the dynamics between energy efficiency interventions and dwelling performance.	Undertake many thousands of Accurate runs spanning the range of possible situations, storing the results in a lookup-table within the NBM.
Space-heating, water-heating and appliances are not included within the NBM framework	Extend the functionality of the NBM to include such energy uses.
No explicit identification of assumed heating efficiencies for the c/kWh cost of useful heat for the different heating sources.	Explicitly identify: • *delivered* c/kWh fuel costs; and • the heating efficiency of the heater.
Simplistic modelling of hot-water	Drive modelled hot-water demand off occupancy, and explicitly identify the assumed cylinder age, size and type.
No identification of the within-year and within-day patterns of consumption	Split energy loads within the NBM into nine periods: • Three within-year periods (summer, winter and shoulder); and • Three within-day periods(weekday day, weekday peak, and night + weekend).
Avoided electricity costs included fixed charges	Ensure that avoided fuel costs are only based on variable costs
No distinction between energy *prices* to consumers, and avoided economic *costs* to New Zealand	Separately identify consumer prices, and long-term avoided economic costs.
Crude treatment of future changes in energy costs	Explicitly project future fuel and CO2 prices, and the extent to which inflation is incorporated in such projections. Explicitly identify the extent to which CO2 prices have been assumed to flow through

	to fuel costs.
No assumptions for changes in electricity carbon intensity	Explicitly project future changes in electricity carbon intensity
Excessive discounting of benefits due to take-back	Only subtract the CO2 price externality associated with take-back consumption from the efficiency benefit stream.
No treatment of rebound spending on energy consuming products and services	Subtract the CO2 price externality associated with rebound consumption from the efficiency benefit stream. Undertake research to estimate the size of the rebound effect.
Crude modelling of take-back	Make pre- and post-measure building temperature an explicit input Consider making achieved post-measure temperature a function of desired temperature and household income.
Inability to consider multiple different building / occupancy situations for a given evaluation	Enable multiple different building / occupancy situations to be considered concurrently
No cause and effect modelling between altered building situations and health, social welfare, and building maintenance outcomes	Structure the model to link the achievement of beneficial outcomes to explicitly identified building environmental metrics (temperature and air quality)
No distinction between the socio-demographics of building occupants and the prevalence or cost of health / social welfare outcomes	Structure the model to: • explicitly make occupancy and socio-demographics an input parameter; • make cause and effect modelling differentiated by socio-demographics
Health impacts are lumped within a single catch-all number	Explicitly identify the main different health conditions for both attributional and cost impact modelling
Other social effects such as reduced domestic violence are not covered within the model	Include such aspects using the same modelling approach as for health benefits
The health benefits of energy efficiency investments are valued at the 5% discount rate for general energy efficiency investments, whereas other health benefits by other government agencies are valued using an 8% discount rate.	Value the health benefits of energy efficiency investments at the same discount rate as other government agency health funding.
The implied numbers within the model for	Work with other government agencies

both prevalence of health conditions, attribution to energy efficiency interventions, and subsequent cost impact valuation are extremely crude	including MoH, MSD, Pharmac, MoE, and Treasury to get better data on both: • the relationship bewteen building environmental conditions and health / social welfare outcomes; • the attribution of health and social effects to energy efficiency interventions; and • the value to be ascribed to reduced adverse health / social welfare outcomes.
The implied numbers within the model for valuing maintenance benefits are simplistic	Work with other organisations to get better data on the cause and effect of improved building environmental conditions and improved maintenance outcomes;
The treatment of employment benefits is questionable	Work with Treasury to determine the extent to which employment outcomes should be counted.
There are significant uncertainties in the underlying data, yet input data is only recorded as single central values	Record upper and lower ranges as well as central values for the data. Make explicit the underlying data sets where averaging of different valuation approaches has been used. Develop sensitivity reporting tools such as tornado charts to highlight the range of uncertainty, and the factors causing the greatest uncertainty.
The model requires users to input performance parameter data rather than just data defining the housing situations.	Structure the model in a way which is more user-friendly and robust. Techniques such as drop-downs with associated 'behind-the-scenes' lookup formulae, and the ability to lock non-input cells will support this.

Lastly, it should be noted that the *potential* accuracy enabled by some of the more sophisticated modelling approaches outlined above will not initially translate into *actual* accuracy due to inadequacies with the available input data. This is particularly with respect to deriving cause and effect relationships between improvements in the house environment (temperature and air quality) and adverse health and social welfare conditions.

Given the paucity of good information on the above factors, it begs the question as to why make a model more complex to accommodate phenomena where the range of uncertainty is so large.

However:

- the modelling approaches described above needn't be that much more complex (and indeed would likely be completely 'behind the scenes' for users);
- there is no inherent reason why superior information will not be available in the future, and thus such an approach future-proofs the model such that it can be populated with more accurate data as and when it emerges;
- the modelling makes explicit those assumptions which are effectively implicit in a more simple approach, thereby aiding auditing and understanding of the results and the degree of uncertainty; and
- the act of developing the modelling framework can itself inform decisions as to where data gathering initiatives are likely to yield greatest benefit.

Thus, given there is this reasonable expectation that data will be improved, it is recommend the model be structured in anticipation of such superior data even if it is initially populated with 'best guess' aggregate data whose accuracy is no greater than from adopting a simplistic modelling approach.

Exactly how complex the model should be made in anticipation of such superior data is in part a judgement call based on views on how costly it would be to collect such data, and the significance of the issue in question with respect to influencing cost: benefit analyses. It is outside the scope of this work to make such detailed recommendations as it would require significantly more research on the data issues than is within the current scope of this work.

A key related recommendation is that EECA work in a cross-agency approach with organisations such as the Ministry of Health, Pharmac, the Ministry of Social Development, Ministry of Economic Development, the Department of Labour, and the Ministry of Education to improve understanding in these areas.