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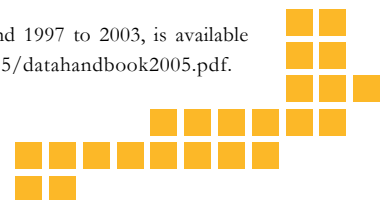
MODELS AND METHODS RESEARCH

Each year CBEEDAC undertakes a number of projects for its sponsors, and although many of these are data-based, in some cases the studies involve surveys or reviews of particular issues, or analysis of the assumptions or method of analysis underlying particular calculations relevant to the building sector. A previous newsletter reported on a CBEEDAC study of domestic water heating and water heater energy consumption in Canada, which was undertaken to provide input into a review of some of the assumptions on which Natural Resource Canada's Residential End-Use Model (REUM) is based. This model underlies a number of the calculations contained in the *Energy Use Data Handbook* for Canada, an annual publication produced by the Office of Energy Efficiency of Natural Resources Canada.¹ It is clearly necessary to review the assumptions and methodologies embodied in such a model periodically in order to ensure that the model reflects any technology and/or use patterns that may have evolved.

In this newsletter we again highlight a recent study by CBEEDAC researchers, in this case one that focuses on the methodologies and calculations used in the determination of Minimum Energy Performance Standards (MEPS) which apply to a wide range of household and commercial appliances, and which represent one of the main methods used to increase energy efficiency in households and commercial operations. The analysis underlying these standards is also based on calculations that require a number of underlying assumptions which in some cases embody considerable uncertainty.

In subsequent newsletters we will focus more on some recent data-oriented CBEEDAC studies that are either recently completed or currently underway.

¹The latest version of this publication (June 2005), with data for 1990 and 1997 to 2003, is available at oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/handbook05/datahandbook2005.pdf.



MINIMUM ENERGY PERFORMANCE STANDARDS (MEPS)

Michael Lockerbie & David L. Ryan

Like many other nations of the world, Canada has become increasingly aware of the consequences of inefficient energy consumption, particularly the emissions of greenhouse gases. This global awareness, in addition to a general desire to meet economic and environmental objectives, has resulted in the adoption and evolution of a set of policies designed to promote efficient energy consumption. One of the main methods used to enforce energy efficiency in households in Canada is through the implementation of Minimum Energy Performance Standards (MEPS) for household appliances. A review of the methodologies used to determine MEPS in Canada and elsewhere, focusing in particular on how uncertainty concerning the values taken by key variables can be incorporated into the analysis, was the subject of a recent study completed by CBEEDAC researchers.

Several different methods that have been used to determine MEPS are examined in this study. The most common approach involves calculating the incremental benefits and costs associated with various proposed standards, and then choosing a standard that ensures that over the life of the appliance in question, the present value of the incremental benefits exceeds the present value of the incremental costs. Of course many of the variables included in this net present value (NPV) calculation have uncertain values, including such factors as the discount rate, the life of the appliance, the energy prices in future years that are used to calculate the energy savings, etc., so that the specific NPV value that has been calculated is unlikely to eventuate. Thus, a key issue in the methodology used to determine MEPS concerns how to deal with this uncertainty.

Various methods for dealing with uncertainty are reviewed in the study, with the most common approach involving discrete sensitivity analysis, in which the value of some key variable is altered and the NPV is re-evaluated to ensure that it is still positive. Typically the values of more than one variable are changed, and in some cases (known as scenario analysis) these adjustments are made

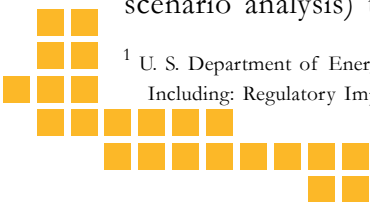
simultaneously. Provided the NPV remains positive under these variations, the proposed standard is robust – it will still yield positive net benefits even if the expected outcomes for the uncertain variables do not arise.

However, in many cases the extent of any sensitivity or scenario analysis that can be conducted manually (the alternative values that are chosen for the uncertain variables) is quite limited, and if some negative NPV values occur as a result of this process, it is difficult to evaluate the likelihood of these negative NPV values (indicating a net cost of the proposed MEPS) occurring in practice. Recent software developments have meant that these drawbacks can be overcome by conducting continuous sensitivity analysis, or probability analysis, in which scenario analysis is combined with subjective probabilities regarding the values of the uncertain variables. By using continuous sensitivity analysis, a probability distribution for the NPV of a proposed MEPS is generated, thereby providing a precise measure of risk (that is, the possibility of making consumers worse off) associated with the implementation of such a MEPS. However, these procedures also have potential disadvantages, including the need to specify distributions and key parameters of these distributions for variables with uncertain values.

In the study, a recent amendment to the MEPS for fluorescent lamp ballasts in Canada is used as an example to illustrate how the *Crystal Ball* software (an add-on to *Microsoft Excel* spreadsheet), which was used by, among others, the U.S. Department of Energy in their determination of the appropriate MEPS for residential water heaters,¹ can be used to undertake continuous sensitivity analysis. In addition, the example is also helpful in pointing out some of the advantages and disadvantages of this approach, and in demonstrating the extent to which the assumptions that are made in this analysis might affect the outcome. The remainder of this article contains an illustration of this approach.

Essentially, the NPV problem is set up in an Excel spreadsheet in exactly the same way as would

¹ U. S. Department of Energy, "Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Water Heaters, Including: Regulatory Impact Analysis", (Washington, DC: Energy Efficiency & Renewable Energy, 2000)



be done in the absence of *Crystal Ball*. Here it is important, however, to ensure that every variable that is to have its value varied (such as the discount rate, usage rate, etc.) is defined in a specific cell, with any formulas that use these values referring to that cell location rather than to a specific value of the variable. By defining each variable that has an uncertain value in a single cell location, it is possible using *Crystal Ball* to specify a probability distribution for each of these variables.

These distributions and their associated parameters (such as mean, standard deviation, minimum, etc.) can be simply assumed, or they can be determined by *Crystal Ball* as the best fitting distribution given historical data. For example, the real discount rate may be viewed as having a triangular distribution with a minimum of 5%, a maximum of 10% and a most likely value of 7%, while an appliance lifetime might be assumed to be normally distributed with a mean of 50,000 hours and a standard deviation of 5,000 hours. Similar specifications are made for other uncertain variables using a variety of distributions. Depending on the uncertainty associated with the variable, the probability distribution that is specified can be made more or less precise. *Crystal Ball* then calculates the NPV for a large number of simulations (e.g., 10,000), in each case drawing a value randomly from the specified distribution for each uncertain variable that is used along with fixed values of other variables in the NPV calculation. This process

yields a distribution for the NPV from which it is possible to calculate the mean, the standard deviation (a measure of risk) as well as measures of the probability that the NPV will be in a specific range (e.g., positive).

In the fluorescent lamp ballast example, the analysis underlying the determination of the MEPS (which essentially involved replacing magnetic ballasts with electronic ballasts) used a real discount rate of 7%, with values of 5% and 10% used in the (discrete) sensitivity analysis.² In the context of continuous sensitivity analysis, if it was thought that the discount rate had an equal probability of taking any value in the range 5% to 10%, it would be appropriate to specify a uniform distribution for the discount rate with a maximum value of 10% and a minimum value of 5%. However, if it is believed that 7% is the most likely value for the discount rate, although the range is from 5% to 10%, then a triangular distribution could be specified with a minimum value of 5%, maximum value of 10%, and most likely value of 7%. As can be seen from the Crystal Ball output in Figures 1 and 2 for the low electricity price (Manitoba) scenario, these different choices for the distribution of the discount rate were found to have little effect on the outcome, although this may not necessarily hold in all applications. Where there is uncertainty about the distribution of a particular variable, it may be useful to repeat the continuous sensitivity analysis using several different distributions, or using the same

Figure 1: Uniform Distribution for the real discount rate

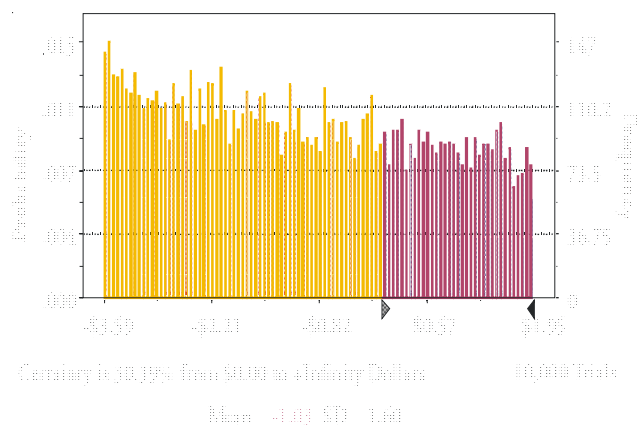
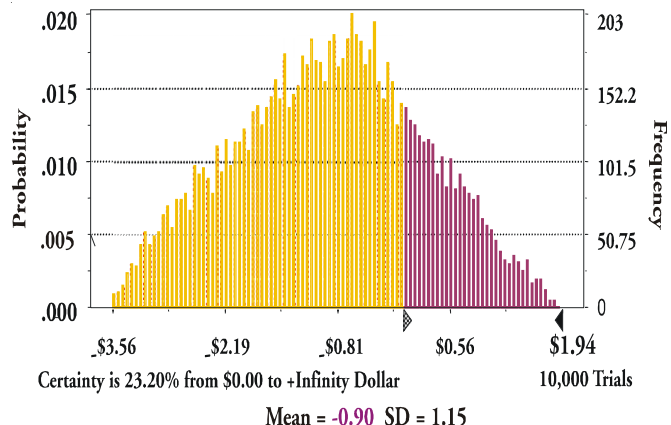


Figure 2: Triangular Distribution for the real discount rate



² “Energy Efficiency Act: Regulations Amending the Energy Efficiency Regulations”, Canada Gazette, P.C. 2003-511, April 10.

(continued on next page...)



(MEPS, *cont'd*)

distribution with different parameters, to determine the extent to which the outcomes are affected.

Continuous sensitivity analysis can be particularly useful if the incremental price and energy savings are distributed differently for different levels of MEPS implementations, since its provision of both the expected NPV and the risk associated with each level of MEPS enables a risk-averse policy-setter to choose a level of implementation with a lower NPV and lower variance of NPV, as opposed to a standard with a higher NPV and higher variance of NPV. This information, regarding the risk or probability distribution of the NPV, is not available using discrete sensitivity analysis.

Another advantage of using continuous sensitivity analysis when determining MEPS is that it enables the analyst to easily allow for different situations that may exist in different regions, and to take into account uncertainty even in variables that are typically taken as being fixed in discrete sensitivity analysis. For example, in the sensitivity/scenario analysis underlying the actual determination of the MEPS for fluorescent ballasts, the base case used forecast average Canadian electricity prices, while the high price scenario used forecast electricity prices for Saskatchewan and the low price scenario used corresponding forecast prices from Manitoba. Even had the average NPV remained positive in all these cases, which would have indicated the robustness of the MEPS in some general sense, this may not have applied in all re-

gions. For example, in a lower price region such as Manitoba, the risk of a negative NPV is probably much higher than in a high price region like Saskatchewan. Since each region experiences the prices applicable for their region rather than “average Canadian prices”, knowing that there is little risk of the NPV being negative using these “average Canadian prices” is of limited usefulness to fluorescent ballast users in these regions. By using continuous sensitivity analysis the risk of a negative NPV outcome can be evaluated separately for each region, thereby revealing the trade-offs involved in the adoption of a national standard.

Furthermore, since forecast electricity prices are used, it is clear that there is uncertainty in the values that they take. Hence, rather than simply taking these prices as given, a preferable approach would be to explicitly incorporate the uncertainty that is embodied in price forecasts when calculating the NPV of a proposed MEPS. Such a procedure is easily handled using continuous sensitivity analysis.

Further details are contained in the complete paper, entitled “Minimum Energy Performance Standards (MEPS) (CBEEDAC 2005–RP-03), which is available on the CBEEDAC website.

BUILDING SERVICES

CBEEDAC has the expertise to provide services to the building sector in the area of data storage and analysis. For more information regarding these services, on becoming a sponsor of CBEEDAC, or about the services provided by other Data and Analysis Centres contact CBEEDAC or see our Web site (www.ualberta.ca/~cbeedac).

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