APPENDIX E-1. UNCERTAINTY AND VARIABILITY

TABLE OF CONTENTS

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To account for the uncertainty and variability, the LCC model was developed using Microsoft Excel combined with Crystal Ball (a commercially available add-on). The model uses Monte Carlo simulations to perform the analysis considering uncertainty and variability.

The analysis explicitly specifies both the uncertainty and variability in the model's inputs using probability distributions. The Monte Carlo simulation then takes thousands of random samples from the probability distribution for each input within the model to calculate the outputs. The distribution of the values calculated for the model outcome therefore reflects the probability of the values that would occur. This technique provides solutions to a broad range of questions and helps provide an insight into the likelihood of various possible outcomes.

An importance analysis is also produced which shows the relative contribution of each of the inputs to the total range of outputs.

A variety of graphic displays are used to illustrate the implications of the analysis results. These include: a) a cumulative probability distribution and barcharts showing the percentage of US households which would have a net life-cycle cost savings by owning a more energy-efficient water heater or b) a chart that depicts importance to the various elements of the cost for each design option considered.

One major assumption has been made throughout the analysis. One of two probability distributions, triangular or normal, will be used where a specific form of uncertainty or variability is totally or partially unknown. The triangular distribution is one of the simplest forms of probability distributions. It uses three simple parameters, minimum, most-likely, and maximum, to describe the probability distribution for a given set of data. It is commonly used in cases where the knowledge about the factor of interest is limited. Normal distribution, on the other hand, is based on an underlying assumption that the data follow a bell-shaped distribution. This is usually the case in which a variable is influenced by many factors but none of them is dominant. When nothing but a mean and variance about a random variable is known, the Department used a normal distribution to describe the variable.

E-1.1 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by a particular appliance type (such as the average U.S. water heater) has not been directly recorded very often. Rather, energy consumption is usually estimated based upon available information. Even direct laboratory measurements have some margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

E-1.2 VARIABILITY

Variability means that different applications or situations produce different numerical values for a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, the amount of hot water used per day by a household depends upon the specific circumstances and behaviors of the occupants (e.g., number of persons, personal habits about hot water use, etc.). Variability makes specifying an appropriate value more difficult. One's personal experience may not be representative of the entire population. On the other hand, variability provides more information about the population under study. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (e.g., gallons of hot water use per day) to other variables that are better known or easier to forecast (e.g., persons per household).

E-1.3 APPROACHES

Two approaches to consider uncertainty and variability are described here:

Scenario analysis uses a single numerical value for a quantity in the calculation, then changes the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of an appliance could be calculated for electricity prices of 2, 8, and 14 cents per kWh.

The advantages of scenario analysis are that the calculation is simple; a range of estimates is used; and crossover points can be identified. When examining a given design option, a crossover point occurs when the energy price rises to a point at which the savings in operating cost compensate for the increased purchase expense of the design option. The disadvantage of scenario analysis is that there is no information about the likelihood of each scenario.

In this analysis of water heaters, the only variables treated as scenarios are future energy prices. These prices are taken from forecasts by DOE's Energy Information Administration (EIA)[1] and the Gas Research Institute (GRI).[2]

Probability analysis considers the probabilities within a range of values. For quantities with variability (e.g., electricity prices in different households), surveys can be used to generate a frequency distribution of numerical values (e.g., the number of households with electricity prices at particular levels) to estimate the probability of each value. For quantities with uncertainty, statistical or subjective measures such as a triangular probability distribution can be used to provide probabilities (e.g., manufacturing cost to improve energy efficiency to some level may be estimated to be $10 +/- $3).

The advantage is that the probability approach provides the greatest information about the outcome of the calculations, that is, the probability that the outcome will be in any particular range is provided. The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

REFERENCES

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2. Gas Research Institute, *1998 Edition of the GRI Baseline Projection,* 1998. Arlington, VA.