Appendix C. Michigan 2021-2040 Statewide Potential Study Modeling Methodology

Prepared for:

LARA
MPSC

State of Michigan

Department of Licensing and Regulatory Affairs

Submitted by:
Guidehouse Inc.
South State Commons
2723 South State Street
Ann Arbor, MI 48104

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Energy Waste Reduction

Guidehouse used a custom-designed version of its DSM Potential tool – DSMSim™ – to estimate technical, economic, and achievable energy waste reduction (EWR) potential using best practice methods that have been vetted with many other clients. DSMSim™ is a bottom-up technology diffusion and stock/flow tracking model implemented in a powerful, flexible, modeling platform that can readily deal with high degrees of dimensionality and the evolving needs of potential studies.

The DSMSim™ model has been widely used to forecast energy and demand potential across the United States and Canada, and adheres to all the current best practices in the evaluation industry. Key features include:

- Ability to accommodate standard or customized cost test protocols, such as those outlined in national standard practice manuals[1]
- Ability to seamlessly assess sensitivities on avoided costs, retail rates, and a variety of other key model input variables
- Handles any number of measures, programs, sectors, program periods and savings types (electric energy/demand, gas, water, emissions, etc.)
- Accounting for three measure replacement types (i.e., retrofit, ROB, and new construction measures) and the effects of similar technologies competing for market share
- Results based on planned input assumptions (incentives, administrative costs, non-energy benefits, participation, etc.) can be compared against those derived from actual values after program implementation is finalized
- Can easily switch between net and gross savings and cost-effectiveness results
- Provides cost-effectiveness metrics at the measure, program, sector, portfolio, end-use or building type level, including combinations of these levels of granularity
- Powerful sensitivity and scenario analysis capability to identify key assumptions and largest leverage points
- Input data is imported from an Excel spreadsheet for portability, version control, and scenario analysis
- All summary results and intermediate calculations are immediately available in tabular or graphical form, in specified units, and can be exported to Excel

Guidehouse developed EWR potential estimates starting with technical potential, followed by economic, and then finally achievable potential scenarios. 0 illustrates the key inputs and the layers of the potential modeling approach.

[1] E.g., the 2001 California Standard Practice Manual (CASPM); subsequent 2007 revision to the CASPM; 2017 National Standard Practice Manual by the National Efficiency Screening Project; etc.

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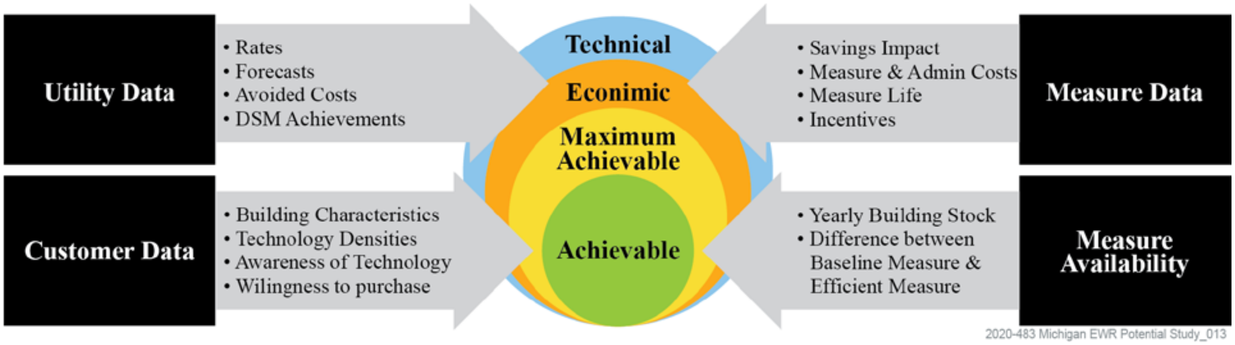
Figure 1. ***Approach to Achievable Potential Analysis***



Source: Guidehouse 2020

Developing Technical Potential

Technical potential is defined as the energy savings that can be achieved assuming that all installed measures can immediately be replaced with the efficient measure/technology, wherever technically feasible, regardless of the cost, market acceptance, or whether a measure has failed and must be replaced.

Guidehouse's modeling approach considers an energy-efficient measure to be any change made to a building, piece of equipment, process, or behavior that could save energy. The savings can be defined in numerous ways, depending on which method is most appropriate for a given measure.

The calculation of technical potential in this study differs depending on the assumed measure replacement type, since technical potential is calculated on a per-measure basis and includes estimates of savings per unit, measure density (e.g., quantity of measures per home), and total building stock.

The potential forecast estimates the incremental annual and cumulative technical potential of energy and peak demand savings capable through EWR, without consideration of any non-engineering constraints, and include all possible efficient measures, disregarding economic feasibility and market acceptance. Technical potential also considers how any anticipated future codes and standards will affect the baseline.

The DSMSim™ model accounts for three replacement types, where technical potential from **retrofit** and **replace-on-burnout** measures are calculated differently from technical potential for **new construction** measures. The formulae used to calculate technical potential by replacement type are discussed in the following two subsections.

Retrofit (RET) and Replace-On-Burnout (ROB) Measures

Retrofit (RET) measures, commonly referred to as advancement or early-retirement measures, are replacements of existing equipment before the equipment fails. RET measures can also be efficient processes that are not currently in place and that are not required for operational purposes. RET measures incur the full cost of implementation rather than incremental costs to some other baseline technology or process because the customer could choose not to replace the measure and would, therefore, incur no costs. In contrast, replace-on-burnout measures (ROB), sometimes referred to as lost-opportunity measures, are replacements of existing equipment that have failed and must be replaced, or existing processes that must be renewed. Because the failure of the existing measure requires a capital investment by the customer, the

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cost of implementing ROB measures is always incremental to the cost of a baseline (and less efficient) measure.

RET and ROB measures have a different meaning for technical potential compared with NEW measures. In any given year, the entire building stock is used for the calculation of technical potential. This method does not limit the calculated technical potential to any pre-assumed rate of adoption of retrofit measures. Existing building stock is reduced each year by the quantity of demolished building stock in that year and does not include new building stock that is added throughout the simulation.

For RET and ROB measures, annual potential is equal to total potential, thus offering an instantaneous view of technical potential. The equation used to calculate technical potential for retrofit measures is provided below.

Annual/Total Savings Potential *= Existing Building Stock $_{YEAR}$ (e.g., households) X Measure Density (e.g., widgets/building) X Savings $_{YEAR}$ (e.g., sq.ft.[3]/widget) X Technical Suitability (dimensionless)*

New Construction (NEW) Measures

Similar to replace-on-burnout measures, the cost of implementing new measures is incremental to the cost of a baseline (and less efficient) measure. However, new construction technical potential is driven by equipment installations in new building stock rather than by equipment in existing building stock. New building stock is added to keep up with forecasted growth in total building stock and to replace existing stock that is demolished each year. Demolished (sometimes called replacement) stock is calculated as a percentage of existing stock in each year and can be specified to market conditions. New building stock (the sum of growth in building stock and replacement of demolished stock) determines the incremental annual addition to technical potential, which is then added to totals from previous years to calculate the total potential in any given year.

The equation used to calculate technical potential for new construction measures is provided below.

Annual Incremental Technical Potential (AITP): *$AITP_{YEAR}$ = New Buildings$_{YEAR}$ (e.g., buildings/year[10]) X Measure Density (e.g., widgets/building) X Savings$_{YEAR}$ (e.g., sq.ft./widget) X Technical Suitability (dimensionless)*

Competition Groups

The study defines competition as efficient measures competing for the same installation as opposed to competing for the same savings (e.g., window A/C vs. split-system A/C) or for the same budget (e.g., lighting vs. water heating). For instance, a consumer may install a condensing water heater or a tankless water heater; both of which belong to the same competition group, as only one of these would be installed. General characteristics of competing technologies used to define the competition groups proposed for this study include:

- Competing efficient technologies share the same baseline technology characteristics, including baseline technology densities, costs, and consumption
- The total (baseline plus efficient) maximum densities of competing efficient technologies are the same
- Installation of competing technologies is mutually exclusive (i.e., installing one precludes installation of the others for that application)
- Competing technologies share the same replacement type (RET, ROB, or NEW)

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To address the overlapping nature of measures within a competition group, Guidehouse's analysis only selects one measure per competition group to include in the summation of technical potential across measures (i.e., at the end use, customer segment, sector, service territory, or total level). The measure with the largest savings potential in a given competition group is used for calculating total technical potential of the competition group. This approach ensures that double counting is not present in the reported technical potential, though the technical potential for each individual measure is still calculated.

Technical Potential

For technical potential, the overall modelling framework is shown in 0. The chart identifies the data inputs, the resource potential module, and the specific output types provided from the various modules. 0 also summarizes the various dimensions of outputs produced from the potential model, including type of potential (technical) reported at various levels (sector, end use, etc.) and in certain units (GWh, MW, therms, etc.).

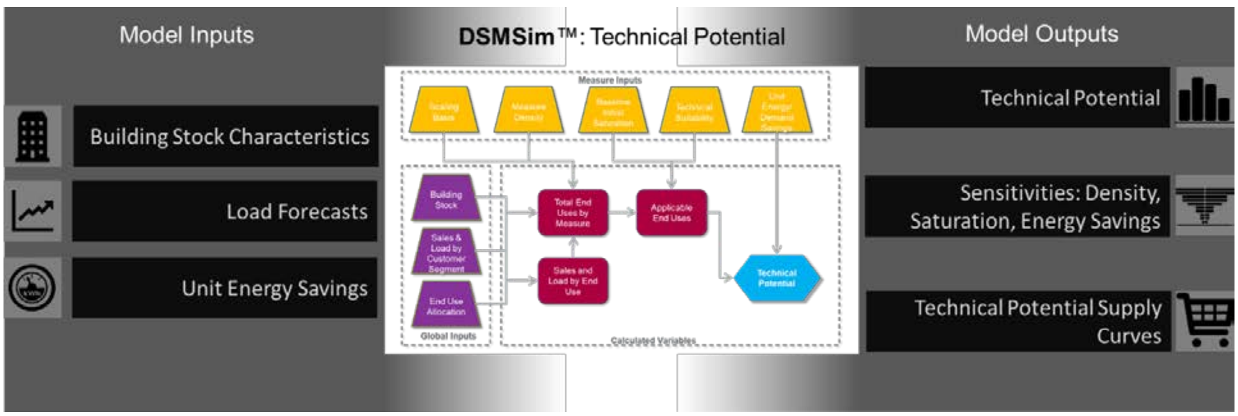

Figure 2. Guidehouse's Technical Potential Model Data Flow

Developing Economic Potential

Economic potential is a subset of technical potential and uses the same assumptions regarding immediate replacement as in technical potential. However, economic potential only includes those measures that have passed the benefit-cost (B/C) tests chosen for measure screening. A measure with a B/C ratio greater than or equal to 1.0 is a measure that provides present value monetary benefits greater than or equal to its present value costs. If a measure's B/C meets or exceeds the threshold, it is included in the economic potential.

DSMSim™ can calculate the five standard tests,[2] and use any of these tests for economic screening. It can also allow the economic potential threshold value to be adjusted (set at 1.0, or higher or lower). As with technical potential, Guidehouse recognizes codes and standards, replacement types, and competition groups in the development of economic potential.

Similar to technical potential, only one economic measure (meaning that its B/C ratio meets the threshold) from each competition group is included in the summation of economic potential across measures (e.g., at the end use, customer segment, sector, service territory or total level). If a competition group is composed of more than one measure that passes the chosen

2 The California Standard Practice Manual (CASPM) defines five standard cost tests for cost-benefit analysis: Participant Cost Test, Program Administrator Cost Test, Ratepayer Impact Measure Test, Total Resource Cost Test, and Societal Cost Test.

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screening cost test, then the economic measure that provides the greatest savings potential is included in the summation of economic potential. This approach ensures that double counting is not present in the reported economic potential, though economic potential for each individual measure is still calculated.

Within DSMSim™, Guidehouse used Michigan specific avoided cost forecasts based on utility data, and other financial inputs to apply cost-benefit screens for all measures considered in the technical potential analysis. 0 illustrates the overall economic potential modelling framework, with the resulting economic potential outputs outlined on the right-hand side.

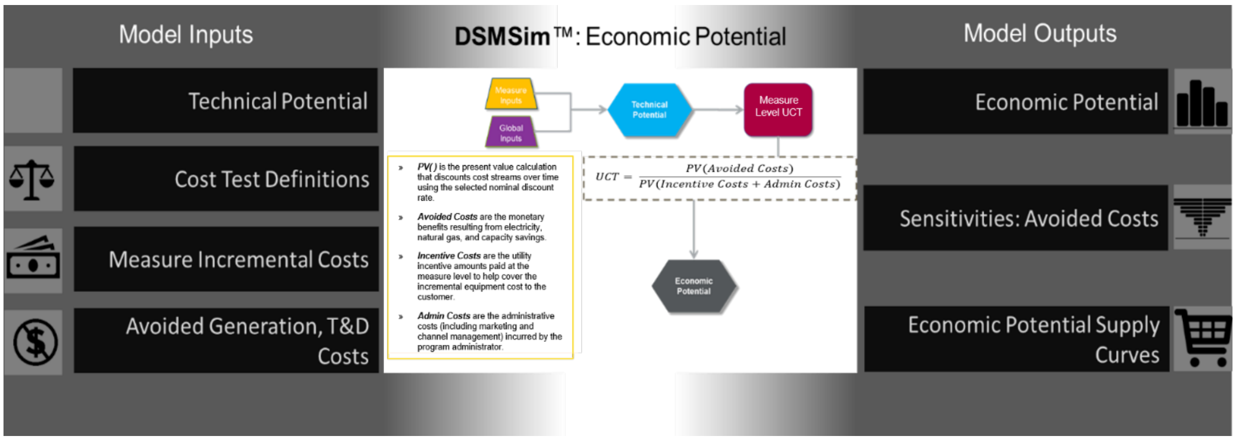

Figure 3. Guidehouse's Economic Potential Model Data Flow

Develop Achievable Potential

Achievable potential further considers the likely rate of efficient measure acquisition, which is driven by a number of factors including the rate of equipment turnover (a function of measure's lifetime), simulated incentive levels, budget constraints, consumer willingness to adopt efficient technologies, and the likely rate at which marketing activities can facilitate technology adoption. This section provides a high-level summary of the approach to calculating achievable potential, which is fundamentally more complex than calculation of technical or economic potential.

The critical first step in the process of accurately estimating achievable potential is to simulate market adoption of efficient measures. Annual program participation is modeled through technology adoption and diffusion algorithms. The long-run equilibrium market share[3] (i.e., how quickly a technology reaches final market saturation) is calculated by comparing a measure's payback period to a customer payback acceptance curve. Each measure's payback period is derived from subtracting the energy bill savings (retail rates multiplied by energy savings) and incentive from the measure's incremental participant cost. Guidehouse's model employs an enhanced Bass Diffusion model[4] to simulate the S-shaped growth toward equilibrium commonly seen for technology adoption. The Bass Diffusion model describes the process of the adoption of products as an interaction between users and potential users. In the model, achievable

3 This term, although something of a misnomer due to the fact that the long run market share is dynamic, changing with building stocks, technology prices, and avoided costs for example, is used to describe the percentage of the market that would participate in a program if perfect information was available to the customer. As awareness of each measure increases, the market will move toward this point.

4 Bass, Frank (1969). "A new product growth model for consumer durables". Management Science 15 (5): pgs. 215–227.

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potential adopters "flow" to adopters by two primary mechanisms – adoption from external influences, such as marketing and advertising, and adoption from internal influences, such as word-of-mouth or peer-effects – with differences in stock turnover captured for replace-on-burnout measures relative to retrofit and new construction.

Guidehouse typically uses payback acceptance curves to estimate equilibrium market share. Payback acceptance curves have been developed in the past by presenting decision makers with numerous choices between technologies with low upfront costs but high annual energy costs, and measures with higher upfront costs but lower annual energy costs. Figure 4 shows payback acceptance curves for the Lower Peninsula low cost measures in the Michigan 2021-2040 EWR study at the customer segment. Each curve represents the percentage of customers willing to purchase a technology based on its payback time. Separate curves were developed for high upfront cost and low upfront cost measures for the Lower and Upper Peninsulas.

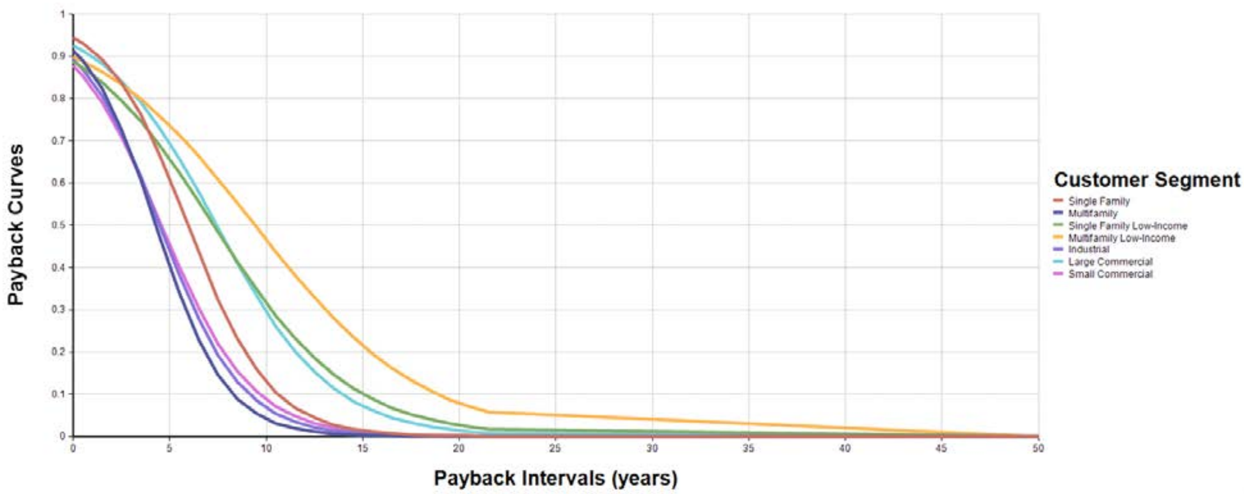

Figure 4. Lower Peninsula Low Cost Measure Payback Acceptance Curves

Since the payback time of a technology can change over time; as technology costs and/or energy costs change over time, the equilibrium market share can also change over time. The equilibrium market share is, therefore, recalculated for every time-step within the market simulation to make certain the dynamics of technology adoption considers this effect. As such, the term "equilibrium market share" is a bit of an oversimplification and a misnomer, as it can itself change over time and is, therefore, never truly in equilibrium; it is used nonetheless to facilitate understanding of the approach.

Calculation of the Approach to Equilibrium Market Share

Two approaches are used for calculating the approach to equilibrium market share (i.e., how quickly a technology reaches final market saturation): one for new technologies or those being modeled as a retrofit (a.k.a. discretionary) measures, and one for technologies simulated as ROB (a.k.a. lost opportunity) measures.

The retrofit and new technologies adoption approach uses an enhanced version of the classic Bass diffusion model to simulate the S-shaped approach to equilibrium that is commonly observed for technology adoption.

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Figure 5 provides a stock/flow diagram illustrating the causal influences underlying the Bass model. In this model, achievable potential adopters flow to adopters by two primary mechanisms: adoption from external influences, such as program marketing/advertising, and adoption from internal influences, including word-of-mouth. The fraction of the population willing to adopt is estimated using the payback acceptance curves shown above.

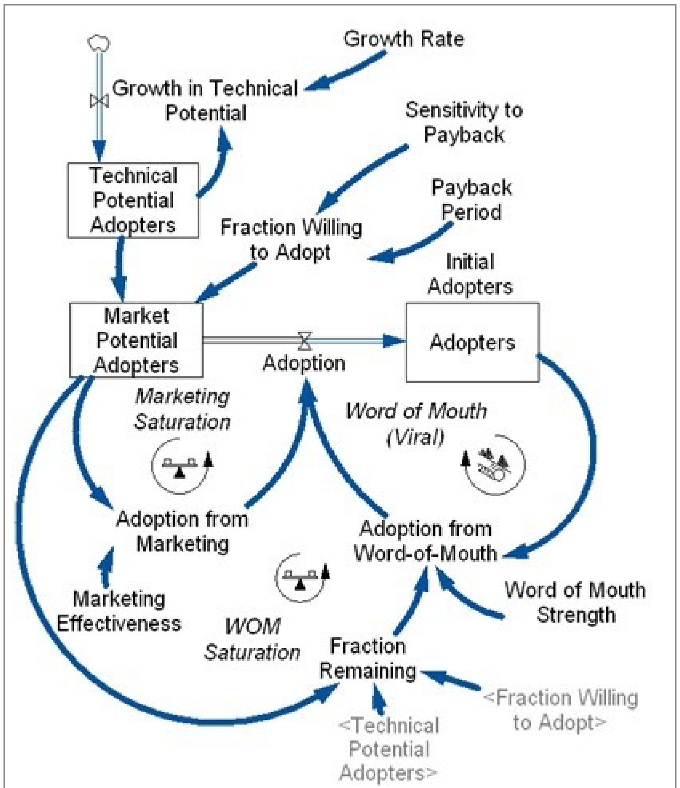

Figure 5. Stock/Flow Diagram of Diffusion Model for New Products and Retrofits

The marketing effectiveness and external influence parameters for this diffusion model are typically estimated upon the results of case studies where these parameters were estimated for dozens of technologies. Recognition of the positive, or self-reinforcing, feedback generated by the word-of-mouth mechanism is evidenced by increasing discussion of the concepts such as social marketing as well as the term viral, which has been popularized and strengthened most recently by social networking sites such as Facebook and YouTube. However, the underlying positive feedback associated with this mechanism has been ever present and a part of the Bass diffusion model of product adoption since its inception in 1969.

The dynamics of ROB technology adoption is somewhat more complicated than for new/retrofit technologies since it requires simulating the turnover of long-lived technology stocks. To account for this, the DSMSim™ model tracks the stock of all technologies and explicitly calculates technology retirements and additions consistent with the lifetime of the technologies. This approach considers the technology churn in the estimation of achievable potential, since only a fraction of the total stock of technologies are replaced each year, which affects how quickly technologies can be replaced. A model that endogenously generates growth in the familiarity of a technology, analogous to the Bass approach described above, is overlaid on the stock-tracking model to capture the dynamics associated with the diffusion of technology familiarity. A simplified version of the model employed in DSMSim™ is shown in Figure 6.

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Model Calibration

Another critical step in the process is the model calibration. We begin calibrating the model's marketing effectiveness and word-of-mouth parameters at the sector and end use level using Michigan historical and forecasted program participation.

As noted, key inputs for the achievable potential assessment are payback acceptance curves that represent the percentage of customers from different sectors willing to purchase a technology based on the time it takes the technology to pay back the upfront cost after incentives through annual cost savings.

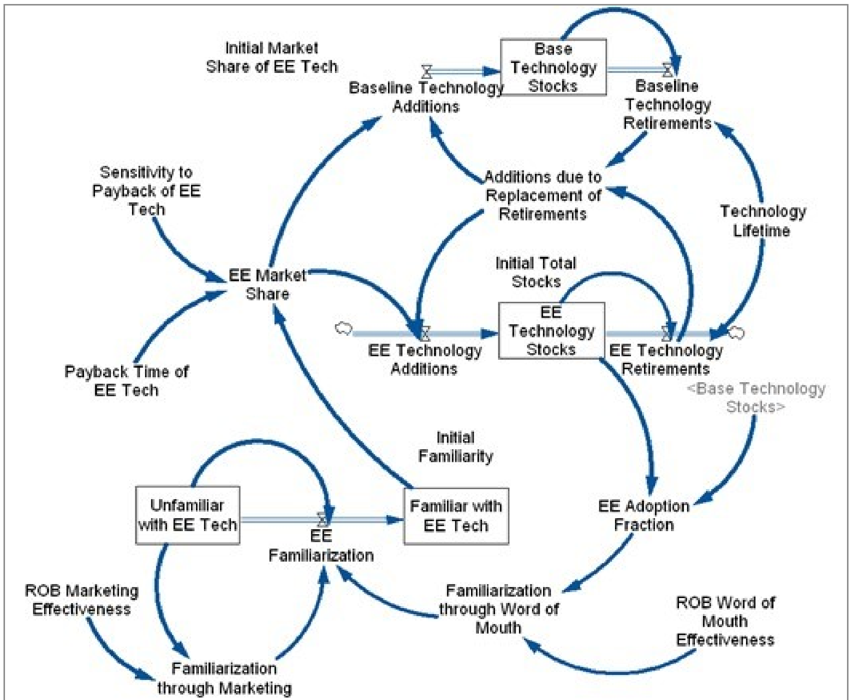

Figure 6. Stock/Flow Diagram of Diffusion Model for Replace-on-Burnout Measures

Calibration of a predictive model imposes unique challenges, as future data is not available to compare against model predictions. While engineering models, for example, can often be calibrated to a high degree of accuracy since simulated performance can be compared directly with performance of actual hardware, predictive models do not have this luxury. Demand-side management models, therefore, must rely on other techniques to provide the recipient of model results with a level of comfort that simulated results are reasonable. Guidehouse takes a number of steps to make sure that the initial, base year projected portfolio achievements used (2021) for the forecast model are reasonable and consider historic adoption, including:

- Comparing forecast values, by sector and end use, against historic achieved savings (e.g., from program savings for 2019 and projected achievements in 2020 and 2021). Although some studies indicate that demand-side management potential models are calibrated to check first-year simulated savings precisely equal to prior-year reported savings, we have found that forcing such precise agreement has the potential to introduce errors into the modeling process by effectively masking the explanation for differences—particularly when the measures included may vary significantly. Additionally, there may be sound reasons for first-year simulated savings to differ from prior-year reported savings (e.g., savings estimates have changed). Thus, while we will endeavor to achieve agreement to a degree that is reasonable between past results and forecast first-year results, our approach does not force the model to do so.
- Identifying and ensuring an explanation existed for significant discrepancies between forecast savings and prior-year savings, recognizing that some ramp-up is expected, especially for new measures or archetype programs.

The overall achievable potential modelling framework is shown in Figure 7. Guidehouse draws on the results of the economic potential analysis (and any sensitivity parameters identified) to

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develop the achievable potential outputs in the manner outlined on the right-hand bar of Figure 7.

Figure 7. Guidehouse's Achievable Potential Model Data Flow

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