NATIONAL
DEMAND RESPONSE POTENTIAL
MODEL GUIDE

Prepared for

Federal Energy Regulatory Commission

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INTRODUCTION

The National Demand Response Potential Model is a flexible tool that is useful for estimating the amount of demand response (DR) that could potentially be achieved under a variety of assumptions about installed technology, programs pursued, market acceptance of the programs, opt-in versus default dynamic pricing, and the overall cost-effectiveness of programs. The model is designed to provide a bottom-up assessment of demand response potential, taking into account state specific information on customers, load mix, existing demand response, advanced metering infrastructure deployment, air-conditioning saturation, and other relevant factors.

By constructing demand response potential scenarios by state and across various program types, the model enables comparisons across different regions of the U.S. to identify areas where there is opportunity for substantial growth and adoption of demand response and also enables the identification of programs with the most room for growth. In addition, demand response potential estimates are provided by customer segment, enabling assessments of potential within each segment.

The model is an Excel spreadsheet tool designed to provide users with significant flexibility. It contains user friendly drop-down menus that allow users to easily change between demand response potential scenarios, to import default data for each state, and to change input values on either a temporary basis for use in "what if" exercises or on a permanent basis if better data are available. In addition, the flexibility of the model allows users to define their own demand response potential scenarios. A key feature of the model is that it contains state specific information and inputs. When it was developed, the model was populated with the best publicly available data and was designed to facilitate input updates as more accurate or new information becomes available. While the model was designed to produce state level estimates, the user interface can also accommodate inputs for utilities, municipalities or other levels of aggregation.

The model incorporates state specific data on four customer segments and five types of demand response programs. Retail customers are divided into four segments based on common metering and tariff thresholds.
- Residential: includes all residential customers.
- Small Commercial and Industrial (C&I): commercial and industrial customers with summer peak demand less than 20 kilowatts (kW).
- Medium C&I: commercial and industrial customers with summer peak demand between 20 and 200 kW.
- Large C&I: commercial and industrial customers with summer peak demand greater than 200 kW.

The model addresses five demand response program categories:
- Dynamic pricing without enabling technology,
- Dynamic pricing with enabling technology,
- Direct load control,

- Interruptible tariffs, and
- "Other DR" programs such as capacity/demand bidding and wholesale programs administered by Independent System Operators (ISOs) and Regional Transmission Operators (RTOs).

These demand response program categories are defined in the report to FERC titled <u>A National Assessment of Demand Response Potential</u> ("Assessment").

The balance of this model guide contains:
- Chapter 2: A Review of the Model's Architecture
- Chapter 3: Demand Response Potential Estimation and Key Inputs
- Chapter 4: The Summary Viewer
- Chapter 5: Model Updates and What-If Analysis - Scenario Specific Inputs, Results, and Calculations
- Chapter 6: Input and Results Databases

MODEL ARCHITECTURE

The model architecture discussion below provides general insight into how the National Demand Response Potential Model works. However, it should be noted from the outset that most users will be primarily concerned with how to use the summary viewer and how to update or conduct "what if" analysis for specific state level demand response potential scenarios. Once accomplished, a more advanced user may also want to know how to modify inputs for multiple states and/or scenarios by making changes directly to the inputs database. More advanced users may also be interested in making use of the inputs and results databases to make more detailed comparisons across states.

Figure 1:
Model Architecture
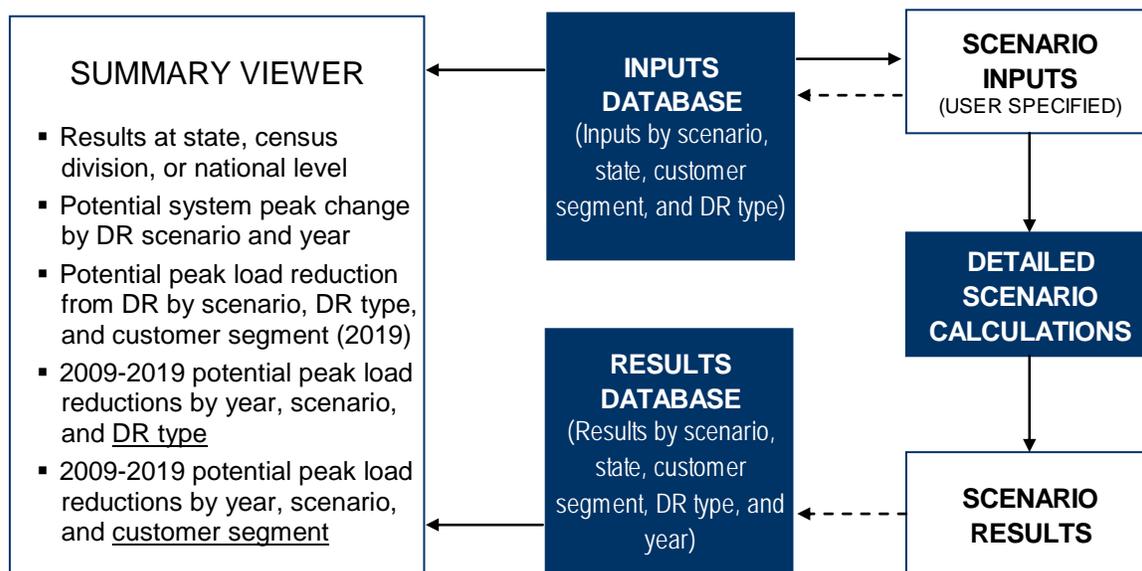
The Summary Viewer is the end product of state and scenario-specific calculations. It is designed to provide a high level summary of the nationwide, census division, or state level results across scenarios. It draws upon data stored in the results database and, to a lesser extent, the inputs database. These two databases contain the data on demand response potential – by state, scenario, customer type, and demand response type – that is subsequently aggregated to produce national and census division demand response potential estimates.

The scenario inputs tab is the starting point of the model and the cornerstone for developing state level demand response potential scenarios. The customer mix, critical peak load, AMI projections, and demand response programs offered can each be customized for each state and for each demand response potential scenario. For ease of use, users can automatically fill-in default inputs. Importantly, these settings can be tailored and/or updated to reflect

changes in the demand response or technology landscape, or to test different strategic decisions.

The scenario results and calculation tabs are directly linked to user defined inputs and are designed to provide immediate feedback on the effect of user defined inputs. As the name suggests, the Detailed Scenario Calculations tab calculates demand response potential based on selections made in the Scenario Inputs tab. These results are summarized in the Scenario Results tab. Jointly, the scenario inputs, detailed calculations, and results can be used independently to test different strategic decisions or technology landscapes, and to incorporate input and results updates into the inputs and result databases.

# DEMAND RESPONSE POTENTIAL ESTIMATION AND KEY INPUTS

Demand response potential estimation is inherently a "bottom-up" process. Load impacts associated with demand response programs are fundamentally driven by changes in consumer behavior, and demand response potential and load impacts vary significantly across customer segments.

There are three fundamental building blocks needed to estimate demand response potential:

- An estimate of average energy use during peak periods before demand response impacts take effect;

- An estimate of the change in energy use during peak periods resulting from customer participation in demand response programs and response to demand response price signals or incentives; and

- An estimate of the number of customers that participate in demand response programs.

These three building blocks are displayed in the blue shaded boxes in Figure 2 which also illustrates some of the primary input values that are needed to predict demand response effects.

Figure 2:
Key Building Blocks and Inputs for Demand Response Potential Model
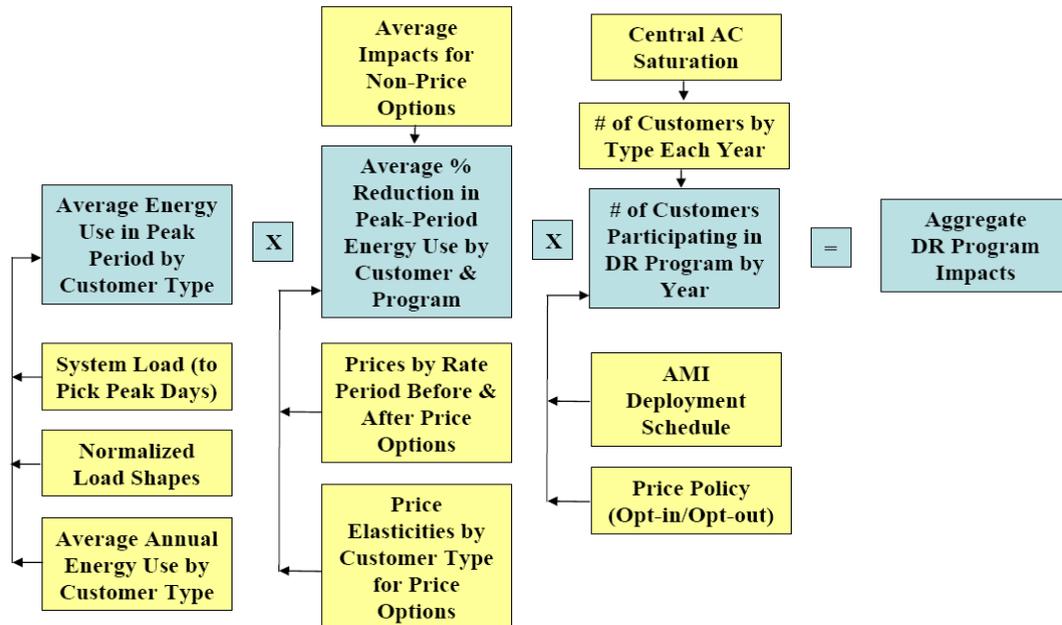
Average Energy Use in Peak Period by Customer Type

A significant challenge in developing demand response potential estimates is the general lack of data on energy use during peak periods, when demand response is needed most and benefits are greatest. Most utilities do not have hourly load data for a representative sample of customers and the lack of such information can be a stumbling block for developing demand response load impacts for utilities and states. Original work was done through this project to develop representative, hourly load data to use as input to the model for five customer segments: residential consumers with and without central air conditioning, Small non-residential consumers (demands less than 20 kW), Medium non-residential consumers (demands between 20 and 200 kW) and Large non-residential consumers (peak demands exceeding 200 kW). These load estimates were developed using regression analysis based on hourly load data from utilities in 21 states, representing a broad cross-section of customer segments and climate conditions. Normalized load shapes were developed using statistical analysis and combined with annual energy use, weather data and system load data (to identify top system load days) from each state to produce the starting values for energy use during peak periods shown in the first blue box in Figure 2. These estimates are primarily used as input to load impact estimates for price-based demand response. This original work could be a valuable resource for states and utilities that want to refine demand response potential estimates presented here or that might find hourly load data useful for demand response program planning or other purposes.

Average Percent Reduction in Energy Use in Peak Period

The demand response potential model uses two different approaches for determining load impacts for various demand response options. Load impact estimates for demand response options such as direct load control and interruptible rates are based on values determined through analysis of program impacts as reported in the 2008 FERC Demand Response survey. Load impact estimates for dynamic pricing demand response are determined using the normalized load shapes summarized above and estimates of the percent of change in energy use during peak periods based on price elasticities and assumed change in prices during peak periods for demand response tariffs relative to non-time varying rates.

Price elasticities depict the percent of change in energy use given a percentage change in price. Estimates from various studies were used to determine price impacts that vary across states and customer segments based on key drivers of demand response, such as air conditioning saturation, climate and the presence or absence of enabling technology such as programmable communicating thermostats that can help to automate some forms of price response in regions where technology is cost effective.

The percent reductions for price based demand response options used in each scenario are based on an assumption that prices during the peak period on high demand days are eight times higher on a dynamic time-varying rate than they are based on the average price associated with the non-time varying, otherwise applicable tariff.[1] However, percent load reductions associated with a wide range of changes in peak prices were calculated and are embedded in the model. The price elasticities were customized for each rate class, combined with the price ratios, and are employed to calculate percent load reductions for the average customer in each rate class. The percent load reductions are then multiplied by the critical peak period load to arrive at the critical peak period load reduction per customer by customer class. Figure 3 represents how individual price induced impacts are being calculated.

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[1] The price ratio used for the Large C&I customer segment is 5 to 1. This lower ratio is based on the fact that most Large C&I customers are already on static time-of-use rates and, thus, have a higher peak-period price as part of their standard tariff than do other customers. As such, the ratio between the standard (TOU) peak price and a price that more fully reflects the avoided capacity cost is less for this customer group than it is for the other customer segments.

Figure 3: Calculation of Dynamic Pricing Impacts
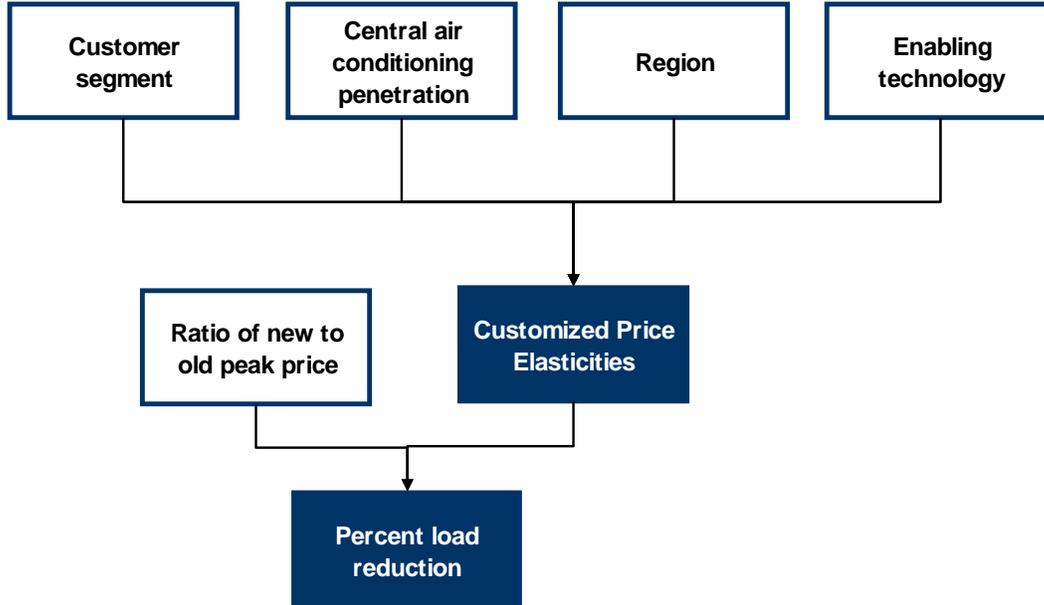
Number of Customers Participating

The third building block of demand response potential estimation is the number of customers that participate in each demand response program. The number of participants is a function of participation rates and the number of eligible customers. In addition, in order to accurately calculate demand response potential, it is necessary to avoid double-counting and to develop a hierarchy of demand response program offerings.

The participation rates that can be achieved for each scenario are based on a detailed analysis of market penetration of existing demand response programs as reported in the 2008 FERC Demand Response Survey. For most states, except for dynamic pricing, the achievable demand response participation for demand response programs is set at a level that a quarter of existing programs in the U.S. have exceeded. For dynamic pricing, there is limited experience on the participation rates and the expected participation varies substantially depending on whether opt-in or default enrollment is assumed. The main report provides more details about how target participation rates were calculated for each demand response type and scenario.

The number of eligible customers is based on the number of customers by segment and, in some cases, the number of customers with specific end use equipment, such as central air conditioning.[2] For residential customers, the breakdown between those with and without central air conditioning is determined from data on air conditioning saturation in each state. The eligible population for price based demand response options is also driven by the

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[2] Central air conditioning is a necessary condition to participate in air conditioning load control programs and also for the technology-enabled price responsive demand response options.

presence or absence of advanced metering infrastructure (AMI), which varies across years and scenarios.

The final factor affecting participation is the participation hierarchy necessary to avoid double-counting of participants. The hierarchy employed is described in detail in Figure 4 and the related discussion. Once the hierarchy has been detailed, an example is provided for Residential customers.

Figure 4:
Participation Hierarchy Employed in the Model

INTERRUPTIBLE TARIFFS

DYNAMIC PRICING

ENABLING TECHNOLOGY

NO ENABLING TECHNOLOGY

AMI

NO INTERRUPTIBLE TARIFFS

DIRECT LOAD CONTROL

NO DEFAULT DYNAMIC PRICING

OTHER DR

NO DIRECT LOAD CONTROL

NO PARTICIPATION

POTENTIAL PARTICIPANTS

DIRECT LOAD CONTROL

NO AMI

NO INTERRUPTIBLE TARIFFS

OTHER DR

NO DIRECT LOAD CONTROL

NO PARTICIPATION

INTERRUPTIBLE TARIFFS
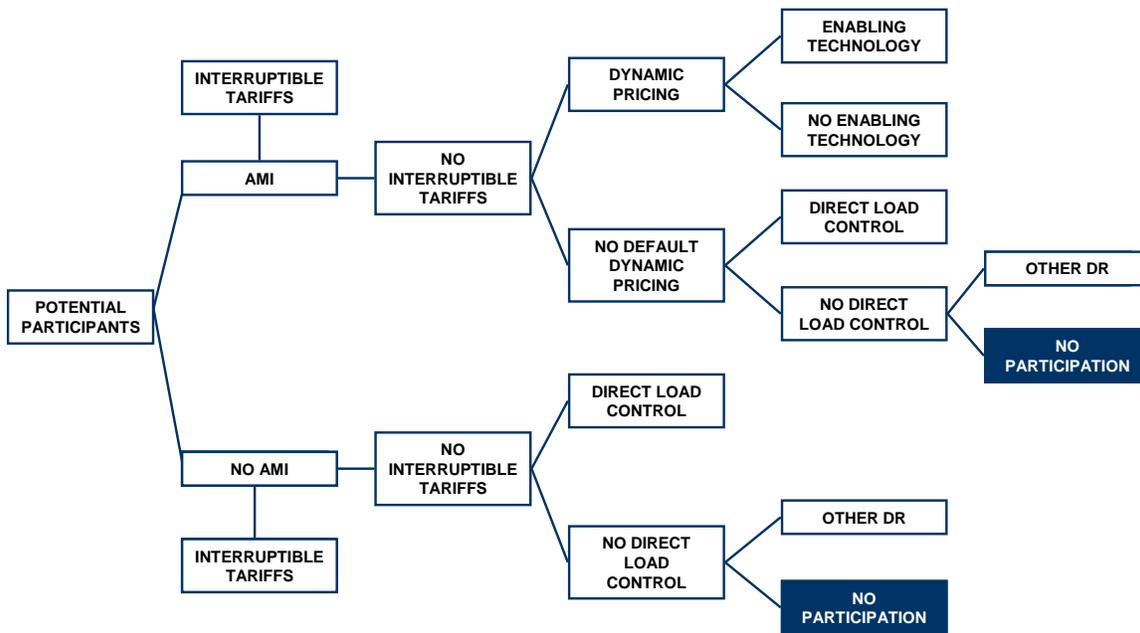
Interruptible tariffs are first in the hierarchy because they generally provide the largest percent load reduction and are contractual in nature. Dynamic pricing rates are second in the hierarchy. Pricing options are higher in the hierarchy than direct load control or other demand response programs since they are tariffs and there is limited overhead cost associated with them, particularly if they are offered on an opt-out basis. Dynamic pricing participation is not automatically linked to enabling technology. Most dynamic pricing pilot programs and actual rates deployed to date have enrolled customers without offering enabling technologies (e.g., programmable communicating thermostats) and customers have provided price response in the absence of enabling technologies. Direct load participation is third in the hierarchy, if offered to a customer segment, because the load response is automatic and the programs are cost-effective in most regions. Other DR is last in the hierarchy because it includes programs such as demand buy-back that do not involve penalties, or contractual obligations. That being said, the category also captures other types of demand response that involve higher levels of commitment – e.g., contracts between utilities and aggregators.

Example of Participation Hierarchy

The achievable potential for the residential sector is employed to illustrate the participation hierarchy and role of technology on the demand response potential calculations. The residential sector was selected because fewer demand response program options are available for Residential customers, making it easier to illustrate the logic. Specifically, demand response options such as interruptible rates and demand buy-back programs (i.e., Other DR) haven not been offered residential customers.

Figure 5:
Example of the Effect of Hierarchy and Technology on Participation
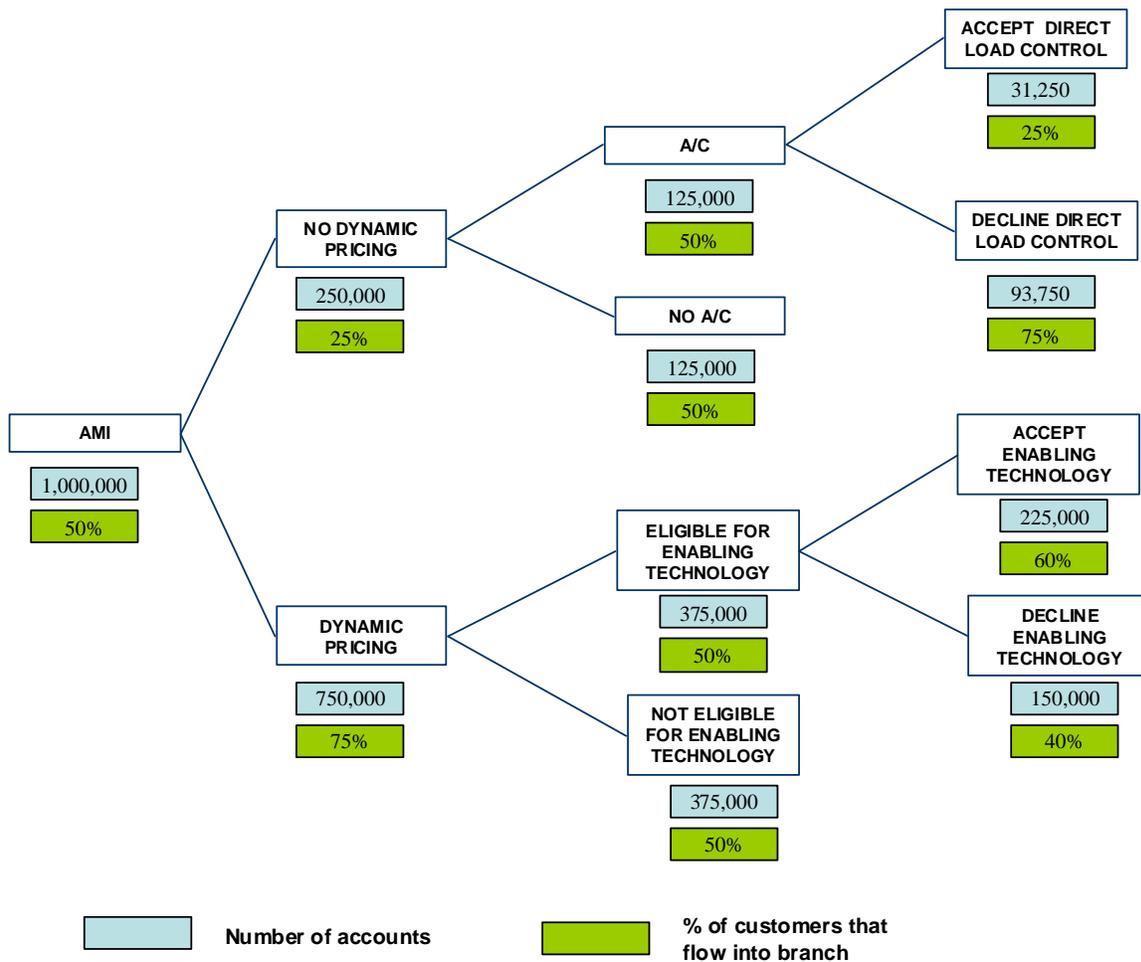
For the example, assume a population of 1,000,000 eligible Residential customers (they are not currently enrolled in demand response programs) and 50 percent central air conditioner saturation. For simplicity, all customers are assumed to have smart meters and data management systems capable of measuring and billing for energy usage at hourly intervals – a pre-requisite of dynamic pricing.

If customers with smart meters are placed on default (or opt-out) dynamic tariffs, 75 percent (750,000) of residential customers are expected to remain on dynamic pricing. Note that dynamic pricing participation is very different if opt-in participation is assumed. Of those that remain on the dynamic pricing tariffs, 50 percent, or 375,000 have central air conditioning and are eligible for programmable communicating thermostats (PCTs), an enabling technology that can automate load response and increase price responsiveness. If offered the ability to automate their load response for free using PCTs, 60% (225,000) accept the free PCT, and 40% (150,000) decline. The 60% value is based on pilots where PCTs were offered free of charge to participants in the dynamic pricing pilot. All customers with the central air conditioning have larger critical peak period loads, but those with enabling technology provide larger load reductions than those without them. Participants without central air conditioning are not eligible for our enabling technology (PCTs.) They also have smaller loads during critical peak periods and provide smaller percent load reductions than either customers with enabling technology and customers with central air conditioning but without enabling technology.

Of the 250,000 who declined dynamic pricing, half live in households with central air conditioners and are eligible for a direct load control program. Based on the data on existing air conditioner direct load control programs, an achievable participation rate among eligible customers is 25 percent, or 31,250 customers.

As can be seen, the participation in each demand response program category is affected by whether hourly meters capable of supporting dynamic pricing are available, what programs are offered to the customers, central air conditioner saturation, cost-effectiveness of enabling technology, and participation rates.

THE SUMMARY VIEWER

As the name suggests, the Summary Viewer is designed to summarize results across all four demand response potential scenarios and at various aggregation levels. To view results for a specific jurisdiction – including the United States, census divisions, or specific states – the user should:
1. Select the jurisdiction from the drop down menu
2. Click on the Update Viewer Results button.

Figure 6:
Summary Viewer Screenshot
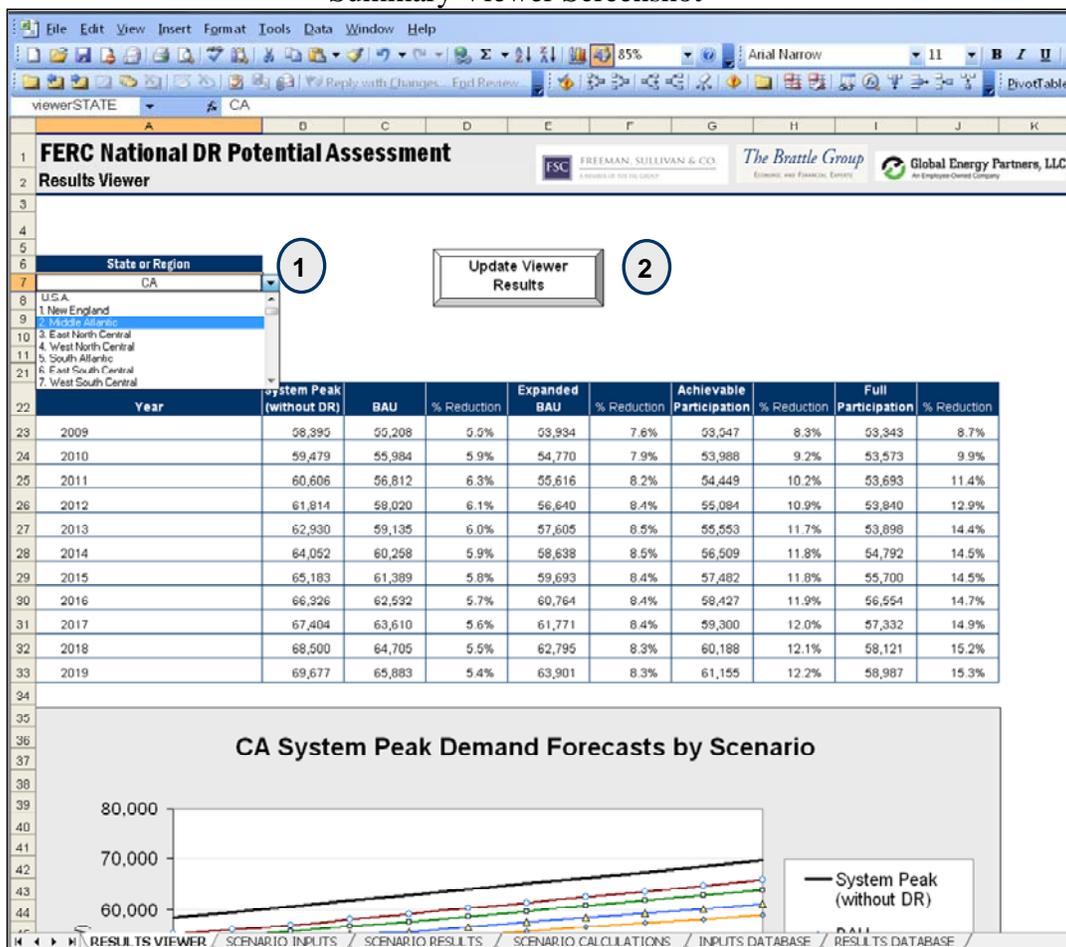
Once updated, the viewer provides a number of comparison and charts (not shown in screenshot), including:
- System peak load estimates from 2009-2019 and the impact of the demand response potential scenario on system peak.
- 2019 load reduction potential (10 year outlook) by scenario, customer segment, and demand response type.

- 2009-2019 load reduction potential by scenario and demand response type.
- 2009-2019 load reduction potential by scenario and customer segment.

The Summary Viewer displays the estimated demand response potential under each scenario for the selected jurisdiction. The results displayed in the viewer are summaries of data stored in the results database and, to a lesser extent, the inputs database. The data in the databases can be analyzed using Excel pivot tables and charts or can be exported into data analysis software (see "Analyzing the Inputs and Results Databases" section of this user manual.)

SCENARIO SPECIFIC INPUTS, RESULTS, AND CALCULATIONS

The scenario inputs, results, and calculation tabs work closely together. Combined, they are the engine of the model and develop the individual state level demand response potential estimates that are stored in the results database. They can also be used to update default inputs and update the state level results that feed into the summary viewer and the national demand response potential. In addition, they can also be used independently to assess the demand response potential for different jurisdictions – e.g., utilities, ISOs, etc. – provided the user has the input data required to make such estimates.[3] Lastly, the scenario inputs, results, and calculation tabs provide a quick approach for conducting "what if" or sensitivity analyses.

For ease of use, users can automatically load state level inputs for each of the four demand response scenarios. All of the options in the scenario inputs tab can be tailored and/or updated by the user to reflect changes in the demand response or technology landscape or to test different strategic decisions.

Figure 7 provides an overview of the Scenario Inputs tab. The Scenario Inputs tab is composed of five main sections:
- A. Load or Save Inputs – for uploading and saving state-specific demand response scenarios
- B. Program Participation Inputs
- C. Customer Population Inputs
- D. 2009-2019 System Peak Forecasts and AMI Deployment
- E. Participant Critical Day Load and Load Reductions

The balance of this chapter discusses the contents in each of the main input sections and provides an overview of the calculations and results tabs.

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[3] The model can identify the incremental potential at those aggregation levels. Customers already enrolled in demand response programs should be excluded from the starting population.

Figure 7:
Overview of Scenario Inputs Tab
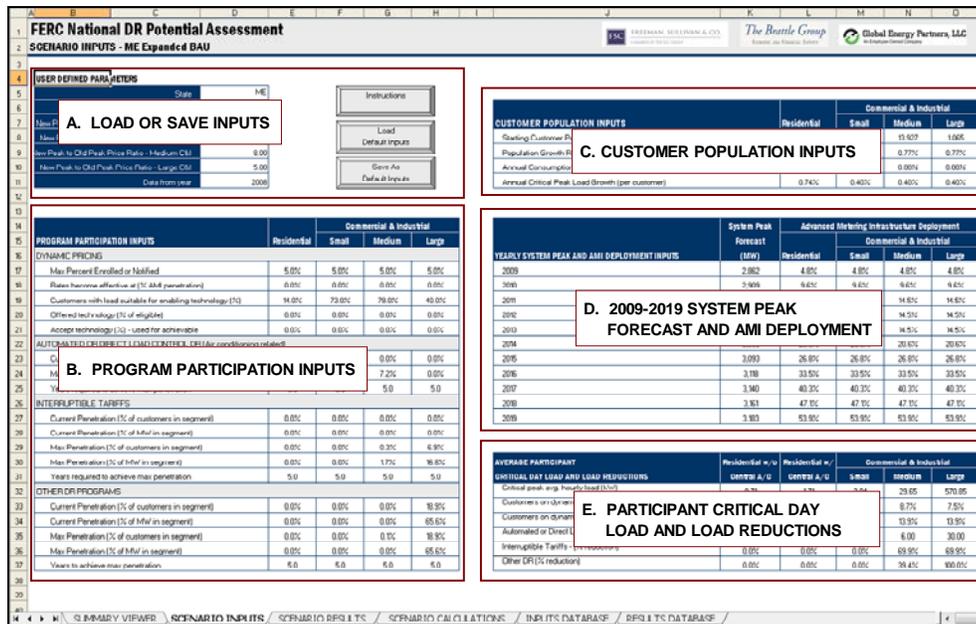
A. Load or Save Inputs

The easiest approach for calculating state specific demand response scenarios is to:
1. Select the state (drop down menu)
2. Select the demand response potential scenario (drop down menu)
3. Ensure the price ratio settings are adequate – this setting determines the percent load reductions for pricing options that are loaded as inputs[4]
4. Load the default inputs (click on button)
5. Modify specific inputs (if desired)
6. View the results (Scenario Results tab)
7. Save inputs and results to databases (use with caution)

Figure 8 displays these steps.

Steps one through three must be performed prior to loading the default inputs. Otherwise, clicking the *load default inputs* button will write over modifications made by the user. It is also possible to directly write in all inputs to the database. The last step – saving inputs and

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[4]   The price ratio refers to the relative difference between the new critical peak period prices and prior peak period prices. For example, a price ratio of 8 to 1 means that critical peak period prices are 8 times greater than the prices in effect before the dynamic rate went into effect (e.g., 96 cents/kWh versus 12 cents/kWh).   As the price ratio increases, the percent load reductions increase, but do so at a decreasing rate.

results to the databases – should be used with caution. The option is built into the model in order to facilitate model updates. Clicking on the *Save Inputs and Results to Databases* button will over ride the default inputs and write the results into the database used to produce the official results. However, the results are not final unless the Excel file containing the model is saved. The model provides additional safeguards to protect against accidental overrides of defaults inputs and results.

Figure 8:
Scenario Inputs – Load and Save Inputs Section
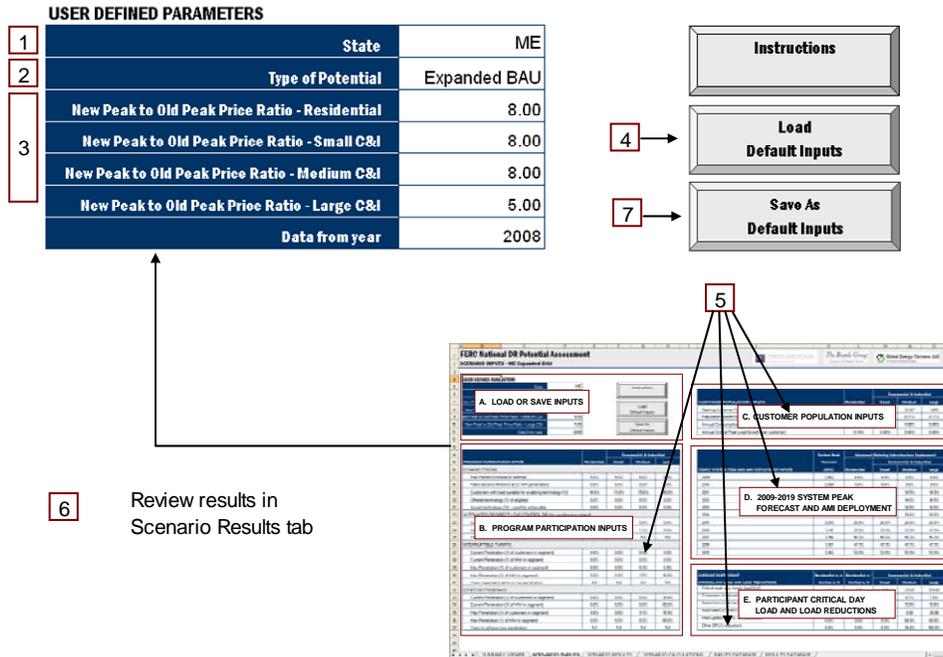
Table 1 provides descriptions for each of the load and save inputs.

Table 1:
Scenario Inputs – Inputs for Load and Save Inputs Section

Model Input Labels	Input Data Element
State	Drop down menu with available state selections
Type of Potential	Drop down menu with four demand response potential scenarios
New Peak to Old Peak Price Ratio (4 inputs, one per customer segment)	Drop down menu with a range of price ratios. The model uses price ratio to determine the percent load reductions for the dynamic pricing options. Generally, greater the difference in new peak price to old peak price results in greater customer load reduction response The load reductions are customized for each state based on central A/C saturation and regional differences

B. Program Participation Inputs

The inputs can be grouped into four categories: current participation, participation potential, eligibility factors and the ramp up from current participation to potential participation. For interruptible tariffs and Other DR programs – designed for demand buy back of capacity contracts – the model also allows users to specify the proportion of customer segment load associated with participants. These inputs are designed to reflect the variation among Medium and Large C&I participants and the practice of targeting customers with larger than average loads. The inputs are segmented according to the type of demand response program.

Participation Inputs for Pricing Programs

For pricing programs, participation rates and impacts depend on whether customers have hourly interval meters capable of supporting dynamic pricing and whether those tariffs are offered on a voluntary (opt-in), default (opt-out), or mandatory basis. Because the expected load reductions vary substantially depending on whether or not pricing is combined with enabling technology such as programmable communicating thermostats or energy management systems, participation rates for customers with and without enabling technology are tracked separately. Since not all customers will be eligible for enabling technology – e.g., they may not have air conditioning or it may not be cost-effective to provide enabling technology to all customers – the model allows users to customize inputs used to calculate the share of customers that are eligible for enabling technology. In addition, customers with central air conditioning are tracked separately because pricing pilots and actual pricing programs indicate that residential customers exhibit different levels of price responsiveness based on central air conditioning ownership and temperature conditions. Figure 9 summarizes the relationship between pricing inputs and how pricing participation is tracked.

Figure 9:
Pricing Participation Inputs and Tracking
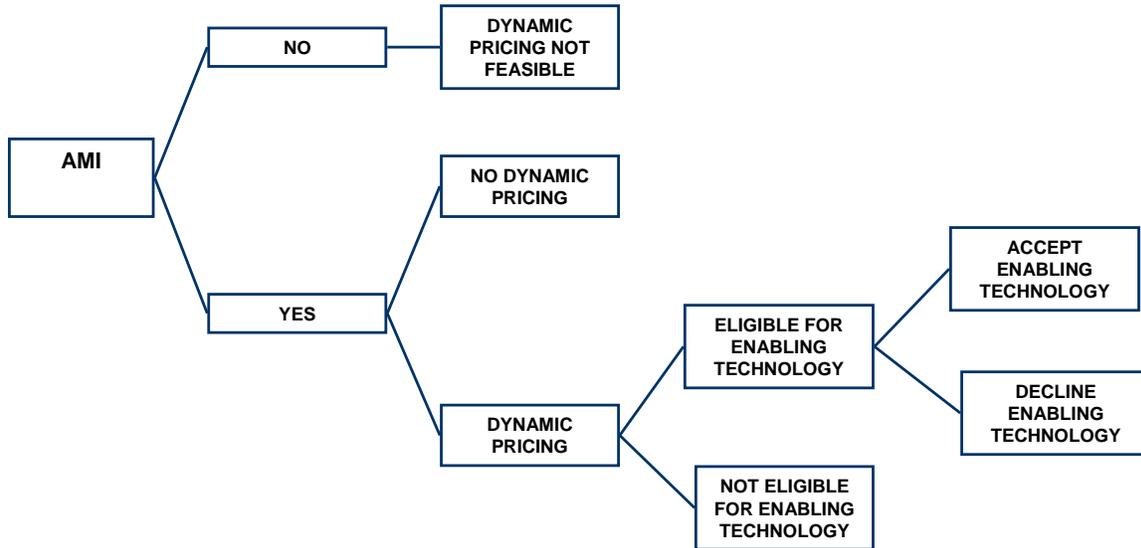
Table 2 provides descriptions for each of the dynamic pricing participation inputs.

Table 2:
Scenario Inputs – Pricing Participation Inputs

Model Input Labels	Input Data Element
Percent Enrolled or Notified	Percent of customers who enroll in dynamic pricing. The participation rate varies based on whether opt-in or opt-out participation is assumed.
Rates become effective at (% AMI penetration)	Determines whether a specific AMI deployment threshold needs to be met prior to offering dynamic pricing to customers.
Customers with load suitable for enabling technology (%)	Identifies the share of customers that are offered enabling technology or automated or direct load control. For Residential, Small C&I, and Medium C&I customers, enter the central air conditioning saturation. For Large C&I, enter the share of customers with system configurations and load suitable for AutoDR.
Offered technology (% of eligible customers where technology is cost-effective)	Affects the share of customers that are offered enabling technology (at no cost to the consumer) in conjunction with dynamic pricing. The estimate is based on cost-effectiveness analysis.
Accept technology (%)	Affects the share of customers that are expected to accept enabling technology, if offered to them at no cost. Default estimates are based on enabling technology acceptance observed in pricing pilots.

Participation Inputs for Automated or Direct Load Control Programs

The automated or direct load control demand response type is designed to capture the potential from air conditioning cycling programs, direct control programmable thermostat programs, and AutoDR (for Large C&I only). For both Residential and C&I customers, participation is specified as the percent of eligible customers. The input values for the percent of customers eligible for enabling technology is shared with the pricing participation inputs in order to ensure consistency. The number of eligible Residential, Small C&I, and Medium C&I customers is based on central air conditioning saturation. For Large C&I, not all customers have load or system configurations that are suitable for AutoDR. Table 3 provides descriptions for each of the automated or direct control demand response participation input values.

Table 3
Scenario Inputs - Participation Inputs for Automated or Direct Control Demand Response

Model Input Labels	Input Data Element
Customers with load suitable for enabling technology (%)	Identifies the share of customers that are offered enabling technology or automated or direct load control. For Residential, Small C&I, and Medium C&I customers, enter the central air conditioning saturation. For Large C&I, enter the share of customers with system configurations and load suitable for AutoDR.
Current Market Penetration (% of eligible customers)	Current participation rate estimate by customer segment
Max Market Penetration (% of eligible customers)	Program saturation potential among eligible customers by customer segment
Years required to achieve maximum penetration	Determines how quickly the program moves from current participation to max penetration

Interruptible Tariffs – Participation Inputs

For interruptible tariffs, the model allows users to specify the current and potential penetration as the percent of participants and percentage of load for each customer segment. Most interruptible programs have targeted the largest customers and typically their share of the customer segment load is larger than the share of customers in the segment that participates. Table 4 provides descriptions for each of the interruptible tariffs participation input values.

Table 4
Scenario Inputs - Participation Inputs for Automated or Direct Control Demand Response

Model Input Labels	Input Data Element
Current Penetration (% of customers in segment)	Estimate of the current share of customers in the segment that are participating in interruptible tariffs
Current Penetration (% of MW in segment)	Estimate of the load of current participants as a percent of the total segment load.
Max Penetration (% of customers in segment)	Estimate of the participation potential defined as the share of customers in the segment that would participate.
Max Penetration (% of MW in segment)	Estimate of the participation potential defined as the participant load as a percent of total segment load.

Other DR – Participation Inputs

The Other DR category is designed for demand buy-back programs, aggregator contracts, capacity contracts (also referred to as capacity bidding) and other types of demand response that reduce summer peak load. Historically, these programs have targeted Medium and Large C&I customers. The model allows users to specify the current and potential penetration as percentage of participants and as percentage of the load for the customer segment. Table 5 provides descriptions for each of the Other DR participation inputs.

Table 5
Scenario Inputs - Participation Inputs for Other DR

Model Input Labels	Input Data Element
Current Penetration (% of customers in segment)	Estimate of the current share of customers in the segment that are participating in other programs
Current Penetration (% of MW in segment)	Estimate of the load of current participants as a percent of the total segment load.
Max Penetration (% of customers in segment)	Estimate of the participation potential defined as the share of customers in the segment that would participate.
Max Penetration (% of MW in segment)	Estimate of the participation potential defined as the share of load as a percent of the total segment load.

C. Customer Population Inputs

Two key inputs for calculating demand response potential are the number of accounts and customer mix. The overall load and load reduction potential increase with the number of

customers. The customer mix affects the demand response programs that can be offered and also program participation, particularly because, to date, different customer segments have exhibited a different propensity to participate in demand response programs. In addition, demand response programs to date have primarily focused on Large C&I and Residential customers. Table 6 provides descriptions for each of the customer population inputs.

Table 6
Scenario Inputs – Customer Population Inputs

Model Input Labels	Input Data Element
Customer Accounts	Number of accounts in each customer segment
Account Population Growth	Annual growth rate in the number of accounts
Annual Consumption Growth (per customer)	Growth in annual consumption per customers. Please note that the input is different than the growth in consumption for the customer segment as whole and excludes growth associated with increases in the number of accounts.
Annual Critical Peak Load Growth (per customer)	Annual growth in critical peak load per customer. Please note that the input is different than the peak load growth for the customer segment as whole and excludes growth associated with increases in the number of accounts.

D. 2009-2019 System Peak Forecasts and AMI Deployment

The inputs for both system peak forecasts and AMI deployment are at a yearly level for 2009-2019. The system peak forecasts are employed to calculate the load reduction potentials as share of system peak and assess the extent to which load reduction potential can alter the system peak.

AMI deployment is a pre-requisite to widespread adoption of dynamic pricing. Meters capable of measuring usage at hourly intervals and corresponding data and billing systems are necessary for the adoption of dynamic pricing. The availability AMI fundamentally changes the type and amount of demand response potential within a given state.

The default AMI deployment inputs typically include a ramp rate for AMI deployment because states include multiple electricity providers and there is some uncertainty around when specific utilities will install smart meters. As AMI deployment plans become known, the model can be updated to reflect changes in the technology landscape. Because Large C&I customers in many states already have hourly interval meters capable of supporting dynamic pricing tariffs, the model allows users to separately specify for each customer segment the percentage of customers that have meters and systems capable of supporting hourly pricing.

Appendix D of the report <u>A National Assessment of Demand Response Potential</u> provides a detailed explanation of how the expected AMI deployments were calculated for each scenario. Table 7 summarizes the peak forecast and AMI deployment inputs

Table 7
Scenario Inputs – System Peak Forecasts and AMI deployment

Model Input Labels	Input Data Element
System peak forecast (2009-2019)	Enter the forecast <u>summer</u> system peak for each year
AMI deployment (2009-2019 for each customer segment)	Enter the share of the accounts, by customer segment and year, expected to have meters capable of supporting dynamic pricing.

E. Participant Critical Day Load and Load Reductions

The overall peak period load and load impacts per customer are key parameters that drive estimates of demand response potential. Load reductions are capped by the customer load available and, in practice, percent load reductions vary for different types of demand response programs. Table 8 summarizes the participant load and load impact inputs users can customize.

The critical peak period estimates reflect the expected average customer load, by segment, for the 2-6 pm period of the 15 days with the highest system load. They are a conservative estimate of load at the time of system peak. The critical peak period load estimates in the model were calculated based on a detailed regression analysis of available hourly load shape data by customer segments. Hourly load shapes were available for approximately thirty utilities across 20 states and provided a substantial amount of variation in the underlying climatic conditions, central air conditioning saturation, and geography. For each segment, the regressions were designed to predict as accurately as possible the variation of customer load as a function of temperature, hour, day of week, month, and other factors. The regression model developed was employed to predict hourly load shapes for all fifty states plus the District of Columbia, taking into account location specific weather, air conditioning saturation, and other factors. Appendix D of the Assessment provides a detailed explanation of the estimation methodology and the accuracy of the regression. The approach provides the best available estimates, but may result in some error for specific states. As a result, the model was designed to allow users with more precise information to customize the critical peak period load estimates.

Table 8
Scenario Inputs – Critical Peak Period Load and Percent Load Reduction Inputs

Model Input Labels	Input Data Element
Critical peak avg. hourly load (kW)	Enter/modify an estimate of the average demand, by customer segment, for the 2-6 pm period for the 15 highest system load days. Applies to all customer segments. For Residential customers, enter separate estimates for customers with and without central air conditioning.
Customers on dynamic pricing without enabling tech (% reduction)	Enter/modify the percent load reduction from customers on dynamic pricing without enabling technology (e.g., programmable thermostats). For Residential customers, enter separate estimates for customers with and without central air conditioning.
Customers on dynamic pricing with enabling tech (% reduction)	Enter/modify the percent load reduction from customers on dynamic pricing with enabling technology (e.g., programmable thermostats). Residential customers without air conditioning are not eligible for the default enabling technology – programmable communicating thermostats.
Automated or Direct Load Control demand response (kW reduction per customer)	Enter/modify the load reduction per participant (kW/participant). If the available information is on a per device basis, multiply by the average number of A/C units for the customer segment.
Interruptible Tariffs - (% reduction)	Enter/modify the expected percent load reduction per participant (kW/participant).
Other DR - committed load reduction programs (% reduction)	Enter/modify the expected percent load reduction per participant (kW/participant).

Price elasticity and percent load reductions for pricing options are customized for customer rate classes depending on whether they are equipped with enabling technology or not. For residential customers, price elasticity and impact estimations are further differentiated by central air conditioning ownership.

Overview of Scenario Calculations and Results

The scenario results and detailed calculations tabs are directly linked to user defined inputs and are designed to provide immediate feedback on the effect of user inputs without directly writing changes into the results database. In other words, users can see the effect of changing different inputs, conduct sensitivity analysis, or change the AMI deployment assumptions without altering the bottom-up final inputs and results stored in the databases.

As the name suggests, the Detailed Scenario Calculations tab calculates demand response potential based on selections made in the Scenario Inputs tab. The detailed calculations tab has separate tables for each customer segment. Each of these tables calculate on a yearly basis growth in the underlying population, AMI deployment, participation in each demand response type (following the hierarchy described in Figure 4), the critical peak period MW, and load reductions. These results are summarized in the Scenario Results tab.

The scenario results tab summarizes the following using tables and charts:
- The effect on system peak load

- Demand Response potential by customer type
- Demand Response potential by type of demand response program.

INPUT AND RESULTS DATABASES

Because demand response potential estimates are inherently a bottom up process – built by state, customer segment, demand response type, and scenario – the final inputs and results are stored in databases. Although a database format does not have an intuitive feel for users that have not been trained in database design, they have several advantages:
1. The data store in a consistent format that can be analyzed in Excel and various database and statistical analysis software.
2. Systematic changes can be easily incorporated for specific scenarios, customer segments, or both.
3. Comparisons across states can be conducted relatively easily.

The primary tools for more advanced updates and analysis involve the use of Excel filters and Pivot Tables and Charts (Several tutorials are available at microsoft.com). This model guide does not provide an extensive introduction to advanced use of Excel, but illustrates how systematic changes and additional analysis can be conducted quickly.

Table 9 summarizes the three main sections of the inputs database tab that may be updated or analyzed by a more advanced user.

Table 9
Inputs Database Tab – Descriptions of the three main sections

| Section	Description of Contents
System Peak Load Forecast Table	This section contains the summer peak load forecasts for 2009-2019 for each state plus the District of Columbia. The peak forecasts were calculated by allocating the NERC region peak load forecasts to individual states. 2018 and 2019 estimates were calculated based on the peak growth rates implicit in the NERC forecasts.
Inputs Database Table	This table contains all the specific inputs for each state, scenario and type of demand response program. The labels in the database mirror those on the Scenario Inputs tab.
Known Demand Response Participation Table	This table contains estimates of current demand response resources by State, type of demand response program, and customer segment. For some states and regions, forward projections of demand response are also available. For example 2009-2011 projections are available for California and 2009-2012 capacity market estimates are available for ISO-NE and PJM. These are included in the table.

The results database includes a single large table containing the results for each state, scenario, type of demand response program and customer segment.

Analyzing the Inputs and Results Databases

The inputs and results databases were intentionally designed to facilitate analysis via the use of Excel Pivot Tables and Charts, or through statistical analysis software. By clicking on the top row and creating a pivot chart or table (↳Data ↳PivotTable and PivotChart Report), users can quickly compare inputs or results across any combination of states, customer segments, and scenarios.

For example, the Excel pivot chart below in Figure 10 was created using the inputs database data in less than 2 minutes and illustrates substantial state-to-state variation in average Residential customer critical peak hourly load.

Figure 10:
Example Comparison Across States Using Inputs Database Data

| Scenario | (All) | Customer Type | Residential |

**Critical Peak Period Load
Per Residential Customer by State**
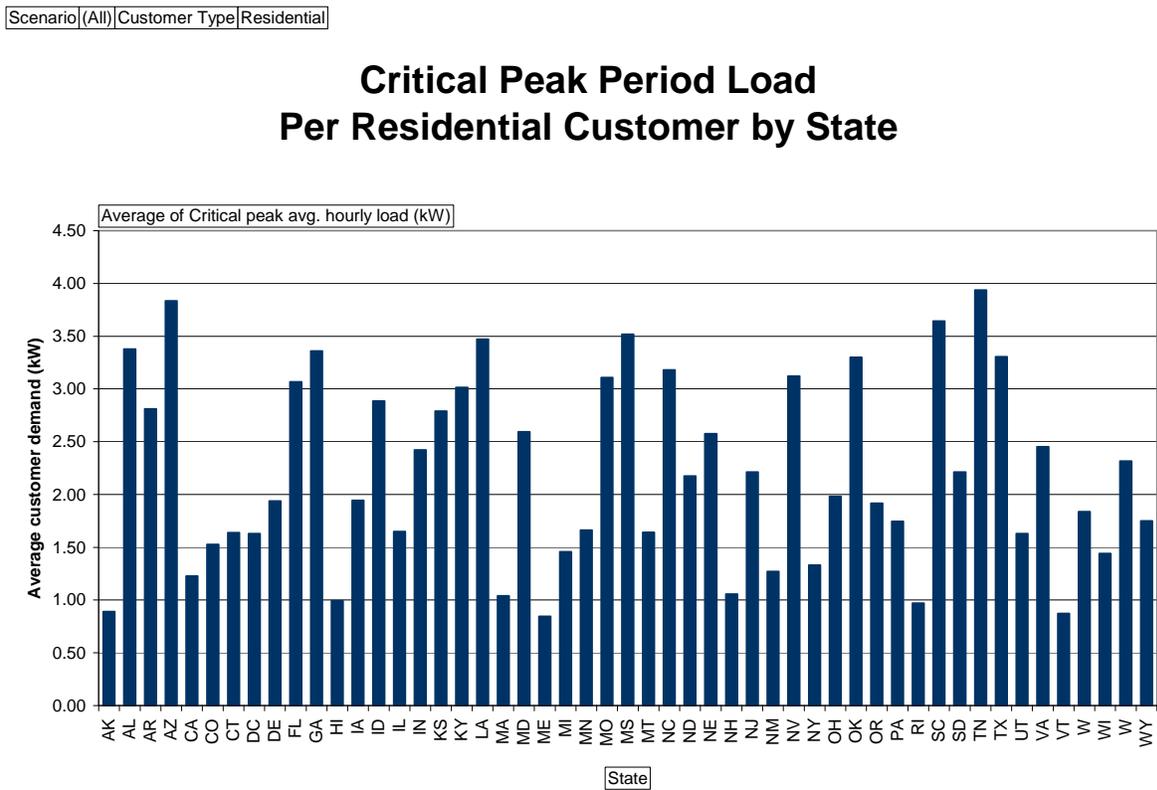
Comparisons of specific states and scenarios can be performed relatively easily using the results database and Excel's Pivot options. For example, Figure 11 below is a pivot chart comparing the four most populous states – California, Texas, New York, and Florida. Notably, the most populous state, California, has less demand response potential than the second and fourth most populous states, Texas and Florida. The difference is in part related to the overall load per customer and the central air conditioning penetration. More load

means more potential load reduction. Second, for both California and New York, the difference between the business as usual (BAU) and the expanded BAU is minor. Both states are nearing the maximum demand response potential that can be achieved without AMI deployment and/or default dynamic pricing. In contrast, Texas can substantially expand traditional demand response resources.

Figure 11:
Example Comparison across States Using Results Database Data

DR Potential in the Four Largest States
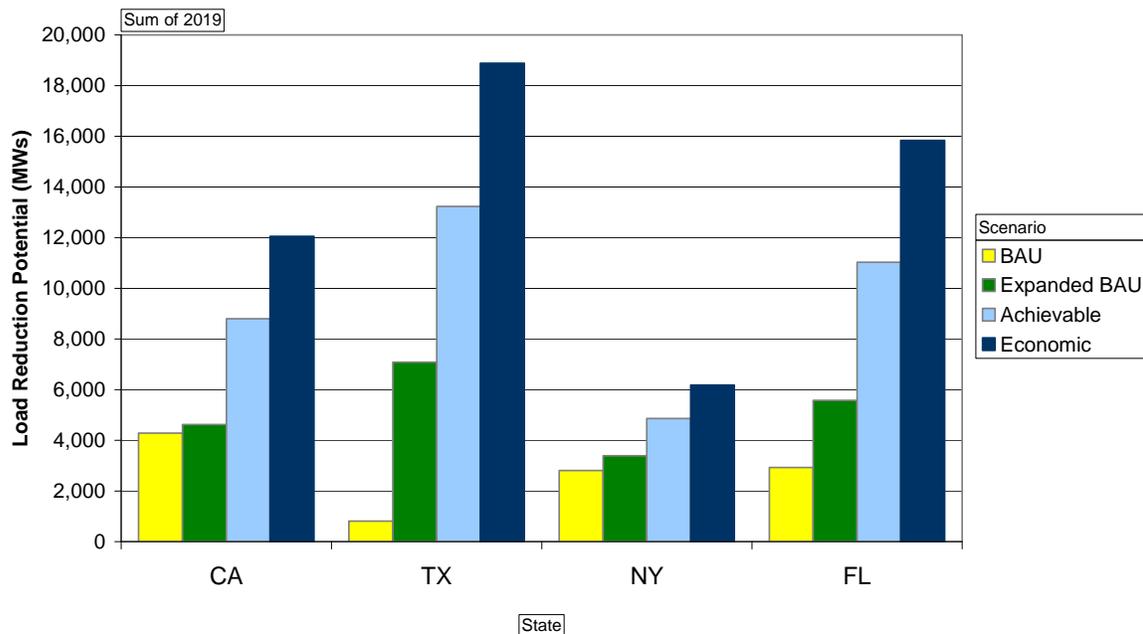
Systematic Changes to the Inputs Database

The scenario inputs tab allows users to view the inputs in comprehensive fashion, modify them and update the inputs database – one state and one scenario at a time. It does not facilitate changes across multiple states. In order to make changes for all states, users would have to upload settings for each state, make the modification, and save the inputs and results. A faster option is to make systematic changes directly into the inputs database and then click on the *Update Results Database* button in the Scenario Inputs tab.

The usefulness of the approach is best illustrated through an example. If a user wanted to change the potential dynamic pricing participation on an opt-in basis from 5% to 10% for all states (the Expanded BAU scenario), one option would be to upload the settings for each state, make the modifications, and save the inputs and results. Clearly, the process is time consuming. A faster option is to make systematic changes by:
1. Selecting the inputs database (or the top row)

2. Activating Excel AutoFilters
3. Selecting the appropriate scenario (e.g., Expanded BAU)
4. Making the change to the variable for the relevant states
5. Clicking the *Update Results Database* button which is located at the top of the page

The *Update Results Database* button is for advanced users only and is designed to update the results database when systematic changes are made directly into the inputs database. Clicking on this button causes the model to cycle through all 51 jurisdictions storing the new data in the official results database and re-calculating demand response potentials. In other words, it performs a bottom-up analysis based on the revisions to the state and scenario specific inputs made in the inputs database.