

## Appendix A: Commercial Statistically Adjusted End-Use Model

The traditional approach to forecasting monthly sales for a customer class is to develop an econometric model that relates monthly sales to weather, seasonal variables, and economic conditions. From a forecasting perspective, econometric models are well suited to identifying historical trends and to projecting these trends into the future. In contrast, end-use models can incorporate the end-use factors driving energy use. By including end-use structure in an econometric model, the statistically adjusted end-use (SAE) modeling framework exploits the strengths of both approaches.

There are several advantages to the SAE approach.

- The equipment efficiency trends and saturation changes embodied in the long-run end-use forecasts are introduced explicitly into the short-term monthly sales forecast, thereby providing a strong bridge between the two forecasts.
- By explicitly introducing trends in equipment saturations and efficiency levels, SAE models can explain changes in usage levels and weather-sensitivity over time.
- Data for short-term models are often not sufficiently robust to support estimation of a full set of price, economic and demographic effects. By bundling these factors with equipment-oriented drivers, a rich set of elasticities can be built into the final model.

This section describes this approach, the associated supporting Commercial SAE spreadsheets, and MatrixND project files that are used in the implementation. The source for the commercial SAE spreadsheets is the 2020 Annual Energy Outlook (AEO) database provided by the Energy Information Administration (EIA).

### Statistically Adjusted End-Use Model Framework

The statistically adjusted end-use modeling framework begins by defining energy use ( $USE_{y,m}$ ) in year ( $y$ ) and month ( $m$ ) as the sum of energy used by heating equipment ( $Heat_{y,m}$ ), cooling equipment ( $Cool_{y,m}$ ), and other equipment ( $Other_{y,m}$ ). Formally,

$$USE_{y,m} = Heat_{y,m} + Cool_{y,m} + Other_{y,m} \quad (1)$$

Although monthly sales are measured for individual customers, the end-use components are not. Substituting estimates for the end-use elements gives the following econometric equation.

$$USE_m = a + b_1 \times XHeat_m + b_2 \times XCool_m + b_3 \times XOther_m + \varepsilon_m \quad (2)$$

$XHeat_m$ ,  $XCool_m$ , and  $XOther_m$  are explanatory variables constructed from end-use information, dwelling data, weather data, and market data. As will be shown below, the equations used to construct these X-variables are simplified end-use models, and the X-variables are the estimated usage levels for each of the major end uses based on these models. The estimated model can then be thought of as a statistically adjusted end-use model, where the estimated slopes are the adjustment factors.

### Constructing XHeat

As represented in the Commercial SAE spreadsheets, energy use by space heating systems depends on the following types of variables.

- Heating degree days,
- Heating intensity,
- Commercial output and energy price.

The heating variable is represented as the product of an annual equipment index and a monthly usage multiplier. That is,

$$XHeat_{y,m} = HeatIndex_{y,m} \times HeatUse_{y,m} \quad (3)$$

Where:

- $XHeat_{y,m}$  is estimated heating energy use in year ( $y$ ) and month ( $m$ )
- $HeatIndex_{y,m}$  is the annual index of heating equipment
- $HeatUse_{y,m}$  is the monthly usage multiplier

The heating equipment index is composed of electric space heating intensity. The index will change over time with changes in heating intensity. Formally, the equipment index is defined as:

$$HeatIndex_y = HeatSales_{13} \times \frac{(HeatIntensity_y)}{(HeatIntensity_{13})} \quad (4)$$

In this expression, 2013 is used as a base year for normalizing the index. The ratio on the right is equal to 1.0 in 2013. In other years, it will be greater than 1.0 if intensity levels are above their 2013 level.

$$HeatSales_{13} = \left( \frac{kWh}{Sqft} \right)_{Heating} \times \left( \frac{CommercialSales_{13}}{\sum_e kWh/Sqft_e} \right) \quad (5)$$

Here, base-year sales for space heating is the product of the average space heating intensity value and the ratio of total commercial sales in the base year over the sum of the end-use intensity values. In the Commercial SAE Spreadsheets, the space heating sales value is defined on the *BaseYrInput* tab. The resulting  $HeatIndex_y$  value in 2013 will be equal to the estimated annual heating sales in that year. Variations from this value in other years will be proportional to saturation and efficiency variations around their base values.

Heating system usage levels are impacted on a monthly basis by several factors, including weather, commercial level economic activity, and prices. Using the COMMENT default elasticity parameters, the estimates for space heating equipment usage levels are computed as follows:

$$HeatUse_{y,m} = \left( \frac{WgtHDD_{y,m}}{HDD_{13}} \right) \times \left( \frac{Output_y}{Output_{13}} \right) \times \left( \frac{Price_{y,m}}{Price_{13}} \right)^{-0.18} \quad (6)$$

Where

- *WgtHDD* is the weighted number of heating degree days in year *y* and month *m*. This is constructed as the weighted sum of the current month's HDD and the prior month's HDD. The weights are 75% on the current month and 25% on the prior month
- *HDD* is the annual heating degree days for 2013,
- *Output* is a real commercial output driver in year *y*,
- *Price* is the average real price of electricity in month *m* and year *y*,

By construction, the *HeatUse<sub>y,m</sub>* variable has an annual sum that is close to 1.0 in the base year (2013). The first terms, which involve heating degree days, serves to allocate annual values to months of the year. The remaining terms average to 1.0 in the base year. In other years, the values will reflect changes in commercial output and prices, as transformed through the end-use elasticity parameters. For example, if the real price of electricity goes up 10% relative to the base year value, the price term will contribute a multiplier of about .98 (computed as 1.10 to the -0.18 power).

### Constructing XCool

The explanatory variable for cooling loads is constructed in a similar manner. The amount of energy used by cooling systems depends on the following types of variables.

- Cooling degree days,
- Cooling intensity,
- Commercial output and energy price.

The cooling variable is represented as the product of an equipment-based index and monthly usage multiplier. That is,

$$XCool_{y,m} = CoolIndex_y \times CoolUse_{y,m} \quad (7)$$

Where:

- *XCool<sub>y,m</sub>* is estimated cooling energy use in year *y* and month *m*,
- *CoolIndex<sub>y</sub>* is an index of cooling equipment, and
- *CoolUse<sub>y,m</sub>* is the monthly usage multiplier.

As with heating, the cooling equipment index depends on equipment saturation levels (*CoolShare*) normalized by operating efficiency levels (*Eff*). Formally, the cooling equipment index is defined as:

$$CoolIndex_y = CoolSales_{13} \times \frac{\left( \frac{CoolShare_y}{Eff_y} \right)}{\left( \frac{CoolShare_{13}}{Eff_{13}} \right)} \quad (8)$$

Data values in 2013 are used as a base year for normalizing the index, and the ratio on the right is equal to 1.0 in 2013. In other years, it will be greater than 1.0 if equipment saturation levels are above their 2013 level. This will be counteracted by higher efficiency levels, which will drive the index downward. Estimates of base year cooling sales are defined as follows.

$$CoolSales_{13} = \left( \frac{kWh}{Sqft} \right)_{Cooling} \times \left( \frac{CommercialSales_{13}}{\sum_e kWh / Sqft_e} \right) \quad (9)$$

Here, base-year sales for space cooling is the product of the average space cooling intensity value and the ratio of total commercial sales in the base year over the sum of the end-use intensity values. In the Commercial SAE Spreadsheets, the space cooling sales value is defined on the *BaseYrInput* tab. The resulting *CoolIndex* value in 2013 will be equal to the estimated annual cooling sales in that year. Variations from this value in other years will be proportional to saturation and efficiency variations around their base values.

Cooling system usage levels are impacted on a monthly basis by several factors, including weather, economic activity levels and prices. Using the COMMEND default parameters, the estimates of cooling equipment usage levels are computed as follows:

$$CoolUse_{y,m} = \left( \frac{WgtCDD_{y,m}}{CDD_{13}} \right) \times \left( \frac{Output_y}{Output_{13}} \right) \times \left( \frac{Price_{y,m}}{Price_{13}} \right)^{-0.18} \quad (10)$$

Where:

- *WgtCDD* is the weighted number of cooling degree days in year (*y*) and month (*m*). This is constructed as the weighted sum of the current month's CDD and the prior month's CDD. The weights are 75% on the current month and 25% on the prior month.
- *CDD* is the annual cooling degree days for 2013.

By construction, the *CoolUse* variable has an annual sum that is close to 1.0 in the base year (2013). The first two terms, which involve billing days and cooling degree days, serve to allocate annual values to months of the year. The remaining terms average to 1.0 in the base year. In other years, the values will change to reflect changes in commercial output and prices.

### Constructing XOther

Monthly estimates of non-weather sensitive sales can be derived in a similar fashion to space heating and cooling. Based on end-use concepts, other sales are driven by:

- Equipment intensities,
- Average number of days in the billing cycle for each month, and
- Real commercial output and real prices.

The explanatory variable for other uses is defined as follows:

$$XOther_{y,m} = OtherIndex_{y,m} \times OtherUse_{y,m} \quad (11)$$

The second term on the right-hand side of this expression embodies information about equipment saturation levels and efficiency levels. The equipment index for other uses is defined as follows:

$$OtherIndex_{y,m} = \sum_{Type} Weight_{13}^{Type} \times \left( \frac{Share_y^{Type} / Eff_y^{Type}}{Share_{13}^{Type} / Eff_{13}^{Type}} \right) \quad (12)$$

Where:

- Weight is the weight for each equipment type,
- Share represents the fraction of floor stock with an equipment type, and
- Eff is the average operating efficiency.

This index combines information about trends in saturation levels and efficiency levels for the main equipment categories. The weights are defined as follows.

$$Weight_{13}^{Type} = \left( \frac{kWh}{Sqft} \right)_{Type} \times \left( \frac{CommercialSales_{13}}{\sum_e kWh/Sqft_e} \right) \quad (13)$$

Further monthly variation is introduced by multiplying by usage factors that cut across all end-uses, constructed as follows:

$$OtherUse_{y,m} = \left( \frac{BDays_{y,m}}{30.44} \right) \times \left( \frac{Output_y}{Output_{13}} \right) \times \left( \frac{Price_{y,m}}{Price_{13}} \right)^{-0.18} \quad (14)$$

In this expression, the elasticities on output and real price are computed from the COMMEND default values.

### Supporting Spreadsheets and MetrixND Project Files

The SAE approach described above has been implemented for each of the nine census divisions. A mapping of states to census divisions is presented in Figure 1. This section describes the contents of each file and a procedure for customizing the files for specific utility data. A total of 18 files are provided. These files are listed in Table 1.

Figure 1: Mapping of States to Census Divisions

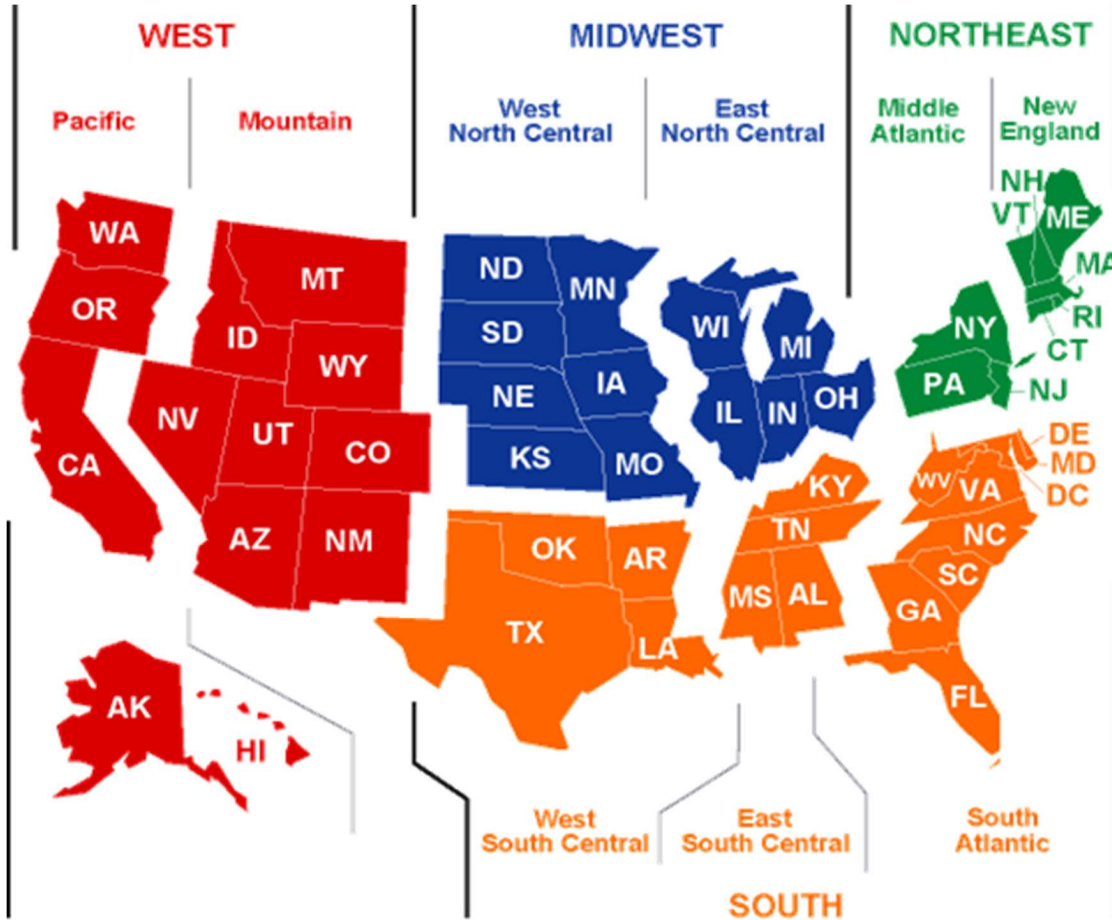


Table 1: List of SAE Electric Files

Spreadsheets	MetrixND Project Files
NewEnglandCom23.xlsx	NewEnglandCom23.ndm
MiddleAtlanticCom23.xlsx	MiddleAtlanticCom23.ndm
EastNorthCentralCom23.xlsx	EastNorthCentralCom23.ndm
WestNorthCentralCom23.xlsx	WestNorthCentralCom23.ndm
SouthAtlanticCom23.xlsx	SouthAtlanticCom23.ndm
EastSouthCentralCom23.xlsx	EastSouthCentralCom23.ndm
WestSouthCentralCom23.xlsx	WestSouthCentralCom23.ndm
MountainCom23.xlsx	MountainCom23.ndm
PacificCom23.xlsx	PacificCom23.ndm

As defaults, the SAE spreadsheets include regional data, but utility data can be entered to generate the *Heat*, *Cool* and *Other* equipment indices used in the SAE approach. The data from these spreadsheets

are linked to the MetrixND project files. In these project files, the end-use *Usage* variables (Equations 6, 10 and 14 above) are constructed and the SAE model is estimated.

The nine spreadsheets contain the following tabs.

- **EIADData** contains the raw forecasted data provided by the EIA.
- **BaseYrInput** contains base year Census Division intensities by end-use and building type as well as default building type weights. It also contains functionality for changing the weights to reflect utility service territory.
- **Efficiency** contains historical and forecasted end-use equipment efficiency trends. The forecasted values are based on projections provided by the EIA.
- **Shares** contains historical and forecasted end-use saturations.
- **Intensity** contains the annual intensity (kWh/sqft) projections by end use.
- **AnnualIndices** contains the annual *Heat*, *Cool* and *Other* equipment indices.
- **FloorSpace** contains the annual floor space (sqft) projections by end use.
- **PV** incorporates the impact of photovoltaic batteries into the forecast.
- **Graphs** contains graphs of Efficiency and Intensities, which can be updating by selecting from the list in cell B2.

The MetrixND project files contain the following objects.

#### Parameter Tables

- **Parameters.** This parameter table includes the values of the annual HDD and CDD in 2013 used to calculate the Usage variables for each end-use.
- **Elas.** This parameter table includes the values of the elasticities used to calculate the Usage variables for each end-use.

#### Data Tables

- **AnnualIndices.** This data table is linked to the *AnnualIndices* tab in the Commercial SAE spreadsheet and contains sales-adjusted commercial SAE indices.
- **Intensity.** This data table is linked to the *Intensity* tab in the Commercial SAE spreadsheet.
- **FloorSpace.** This data table links to *FloorSpace* tab in the Commercial SAE spreadsheet.
- **UtilityData.** This linkless data table contains Census Division level data. It can be populated with utility-specific data.

#### Transformation Tables

- **EconTrans.** This transformation table is used to compute the output and price indices used in the usage equations.
- **WeatherTrans.** This transformation table is used to compute the HDD and CDD indices used in the usage equations.
- **CommercialVars.** This transformation table is used to compute the *Heat*, *Cool* and *Other* Usage variables, as well as the *XHeat*, *XCool* and *XOther* variables that are used in the regression model. Structural variables based on the intensity/floor space combination are also calculated here.
- **BinaryVars.** This transformation table is used to compute the calendar binary variables that could be required in the regression model.

- **AnnualFcst.** This transformation table is used to compute the annual historical and forecast sales and annual change in sales.
- **EndUseFcst.** This transformation table breaks the forecast down into its heating, cooling, and other components.

#### Models

- **ComSAE.** The commercial SAE model (energy forecast driven by end-use indices, price, and output projections).
- **ComStruct.** Simple stock model (energy forecast driven by end-use energy intensities, and square footage).