Residential Statistically Adjusted End-Use (SAE) Spreadsheets – 2023 AEO Update

The Residential SAE spreadsheets and models have been updated to reflect the Energy Information Administration's (EIA*) 2023 Annual Energy Outlook (AEO)*. The 2023 projections start in 2015 based on the 2015 Residential Energy Consumption Survey (RECS). Between 2015 and 2023 model parameters and inputs are adjusted to reflect actual end-use shipments data, weather conditions, number of households, prices, economic conditions, and state and federal energy efficiency policies. Going forward the end-use forecasts are driven by forecasted prices, end-use costs, efficiency standards, and expected impact of current state and federal efficiency programs including the recently passed Inflation Reduction Act (IRA). The SAE spreadsheets are based on the EIA Reference Case forecast. The Reference case reflects the impact of current efficiency programs, laws, and end-use standards.

The forecast incorporates the impact of the federal efficiency investment tax incentives associated with the IRA. As a result, overall residential intensities (kWh per household) are slightly lower than last year's forecast. In some Census Divisions, there is very little change in intensity projections from last year as other factors including slightly stronger heat pump sales associated with electrification activity counter stronger efficiency gains.

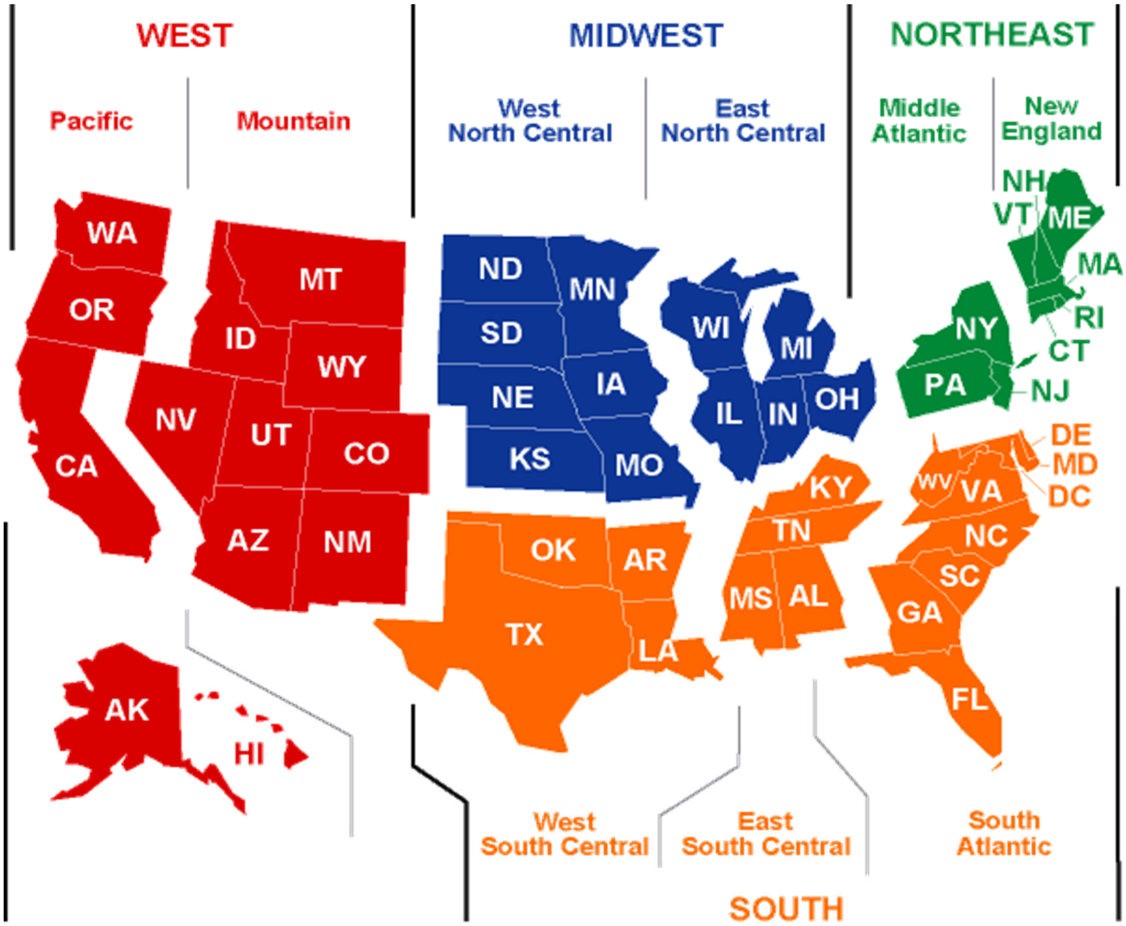
End-use intensity projections are constructed from end-use consumption data (12 end-use categories and three housing types), number of existing units (e.g., number of air conditioners), average end-use stock efficiency, average square footage, and heating and cooling thermal shell integrity trends. The data is used in developing end-use saturations, efficiencies projections, and end-use intensities that are inputs into SAE residential forecast models. The intensity projections reflect current and expected market conditions through the ongoing data collection that includes appliance shipment data, appliance characteristic data, appliance standards, thermal shell information, regional energy efficiency (EE) program expenditures and rebates, electricity and gas prices, stock utilization, weather conditions, and EIA's calibration to actual residential customers and sales.

The 2023 residential SAE spreadsheets and MetrixND project files include:

- Updated equipment efficiency trends
- Updated equipment and appliance saturation trends
- Updated structural indices
- Updated annual heating, cooling, water heating, and non-HVAC indices
- Updated regional sales forecasts

EIA provides end-use detail for nine census divisions, depicted in **Figure 1**.

Figure 1: Forecast Census Divisions



Forecasts are generated from the National Energy Modeling System (NEMS). The NEMS model tracks appliance stock, stock efficiency, and usage change over time as appliances are replaced, new appliances are purchased, and utilization changes with changing economic, price, and weather conditions. Appliance choice decisions are driven by appliance costs, efficiency options and standards, natural gas availability, and fuel prices for electricity and natural gas. Forecasts are developed for three housing types – single family, multi-family, and mobile homes, for twenty end-uses, including:

- Resistance heating/furnaces
- Air-source heat pumps (heating)
- Ground-source heat pumps (heating)
- Secondary heating
- Central air conditioning
- Air-source heat pumps (cooling)
- Ground-source heat pumps (cooling)
- Room air conditioning
- Water heating
- Cooking
- 1st refrigerators

- 2nd refrigerators
- Freezers
- Dishwashers
- Clothes washers
- Clothes dryers
- TVs and related equipment
- Furnace fans
- Lighting
- Miscellaneous

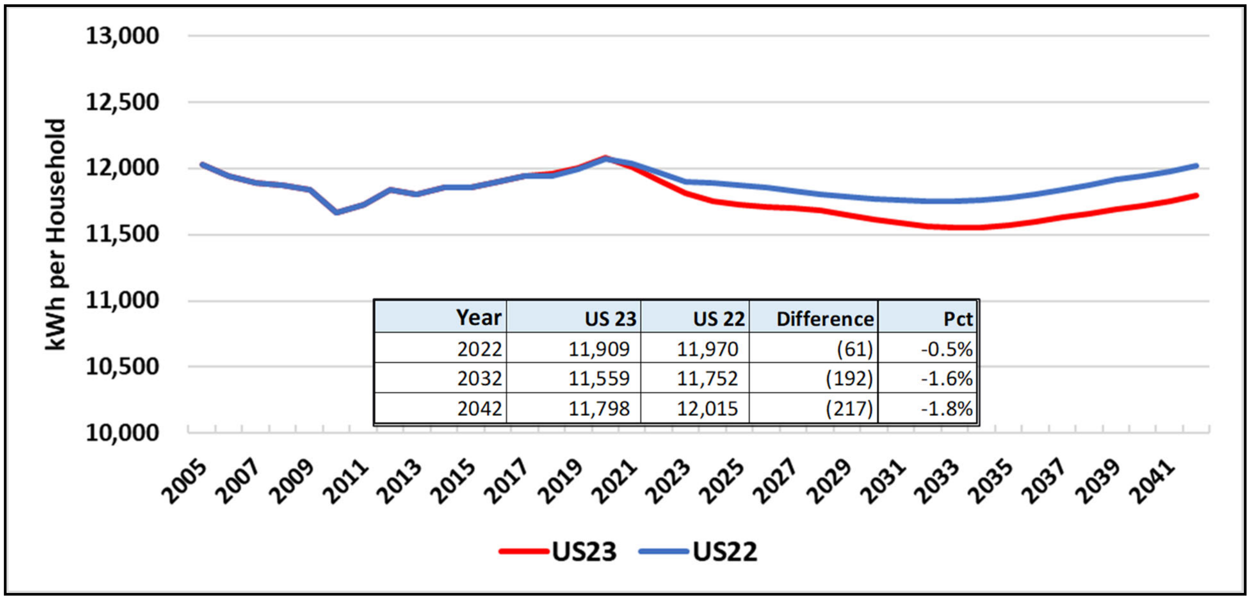
In the Statistically Adjusted End-Use (SAE) model, detailed end-use data derived from the EIA forecasts is used to construct end-use intensities (kWh per household) that are then integrated into monthly heating, cooling and other use model variables. These variables are then used to forecast utility-level residential and commercial sales through estimated linear regression models. Through the constructed model variables, the forecast captures improvements in end-use efficiency driven by new standards, declining cost of high-efficiency technology options and availability of new end-use technologies.

To support econometric modeling, Itron maintains and updates historical end-use data trends that are consistent with the 2015 RECS and earlier RECS (i.e., the 2005 and 2009 RECS). Doing so sometimes requires adjusting historical end-use saturation and efficiency trends to reflect what EIA believes is the current state of appliance ownership, stock efficiency and housing characteristics. The 2023 SAE spreadsheets reflect Itron's best estimates of historical end-use saturations, efficiency and usage given EIA's 2015 base-year starting point and past estimates of end-use stock characteristics.

Electricity

On the national level, total household intensity is lower than in 2022 largely as a result of expected improvements in end-use efficiency resulting from the IRA. **Figure 2** compares the 2023 and 2022 U.S. household energy intensity projections.

Figure 2: U.S. Residential Total Intensity Trend (kWh/household)

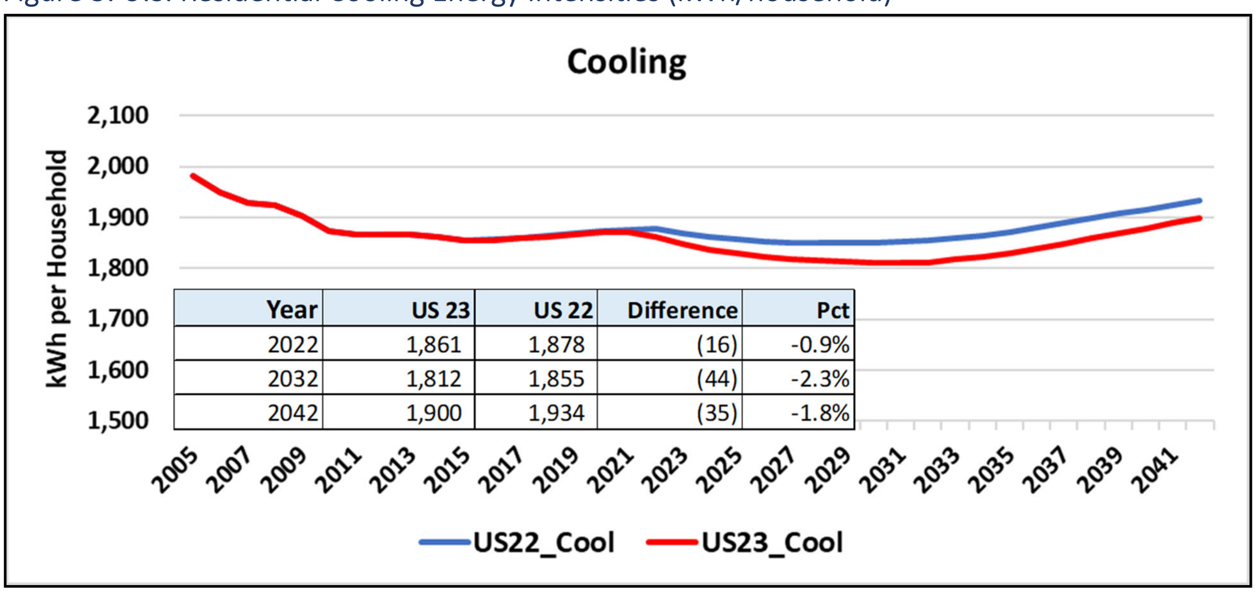


Year	US 23	US 22	Difference	Pct
2022	11,909	11,970	(61)	-0.5%
2032	11,559	11,752	(192)	-1.6%
2042	11,798	12,015	(217)	-1.8%

Over the next ten years, average residential intensity is projected to decline 0.3% annually; this compares with a 0.2% decline in the 2022 forecast.

Figure 3 shows the 2023 and 2022 cooling intensities. The cooling intensity is also lower in the 2023 forecast, declining 0.3% per year over the next ten years compared with 0.1% annually in the 2022 forecast. The stronger intensity decline is largely due to higher heat pump and central air conditioning efficiency projections. IRA-related rebates reduce the costs of the more efficient technology options resulting in a higher mix of the more efficient technology options.

Figure 3: U.S. Residential Cooling Energy Intensities (kWh/household)



Year	US 23	US 22	Difference	Pct
2022	1,861	1,878	(16)	-0.9%
2032	1,812	1,855	(44)	-2.3%
2042	1,900	1,934	(35)	-1.8%

Cooling intensities turn positive after 2033 as cooling efficiency levels out and saturation of central cooling continues to increase (replacing room air conditioning). **Figure 4** shows the expected central cooling system efficiency trend.

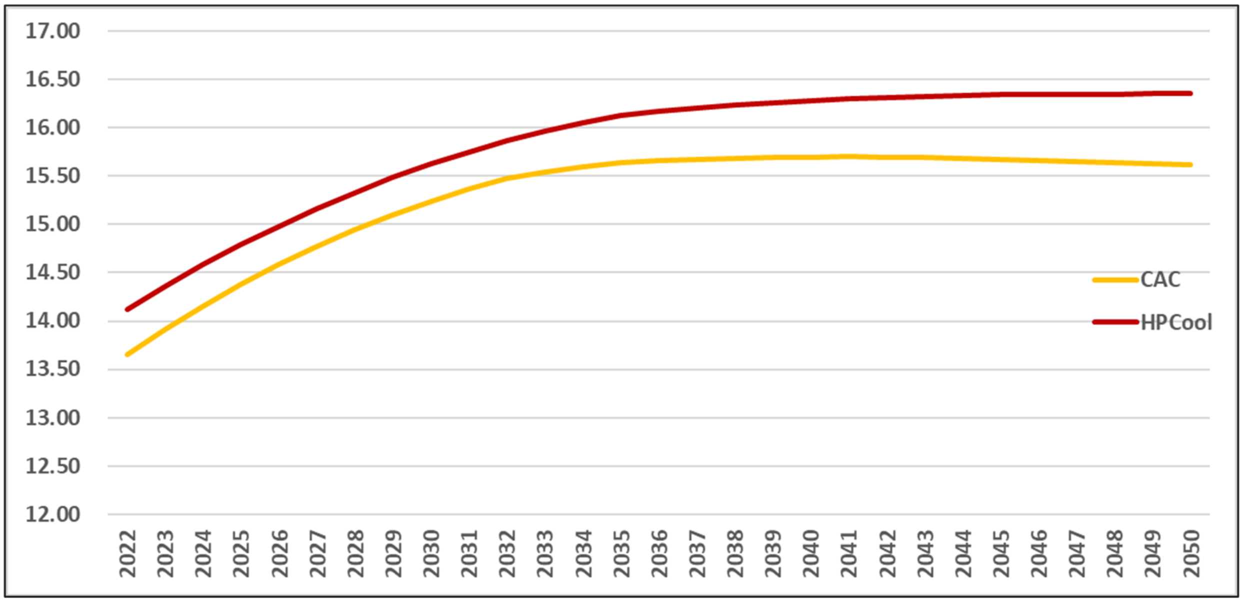
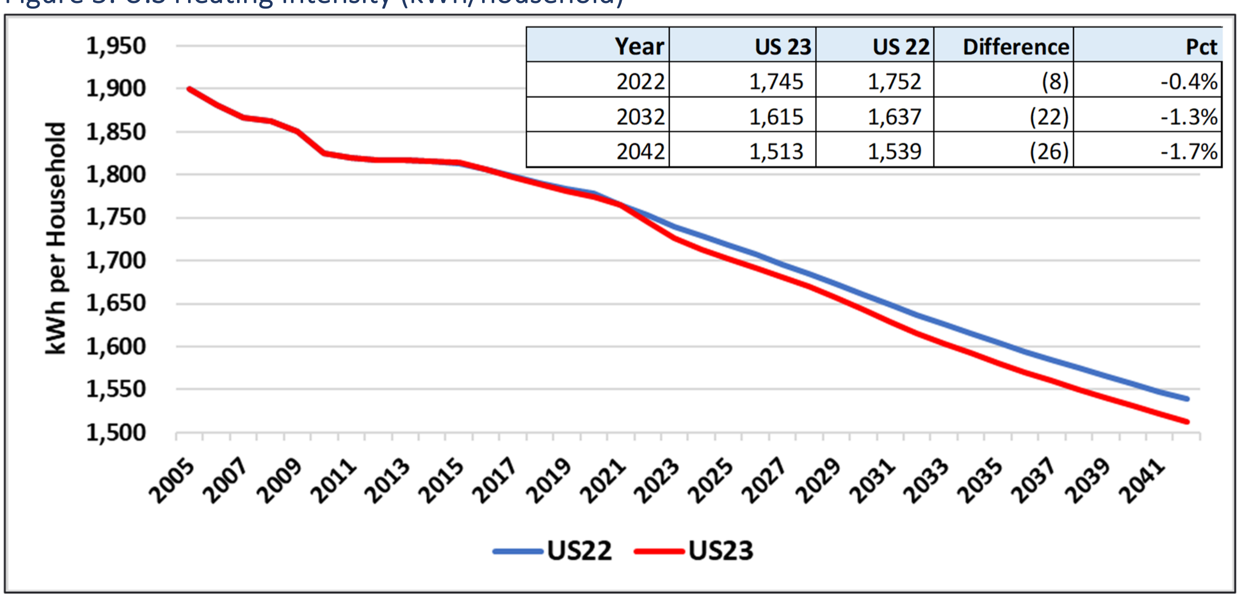


Figure 4: Central Cooling System Efficiency (SEER)

Heating intensity continues its long-term decline as resistant heat saturation drops, and furnace fan and heat pump heating efficiency improves. Overall U.S. heating saturation increases slowly from 35% in 2020 to 37% by 2050. at the US level is relatively flat at roughly 35%. **Figure 5** shows U.S. heating intensity projection.

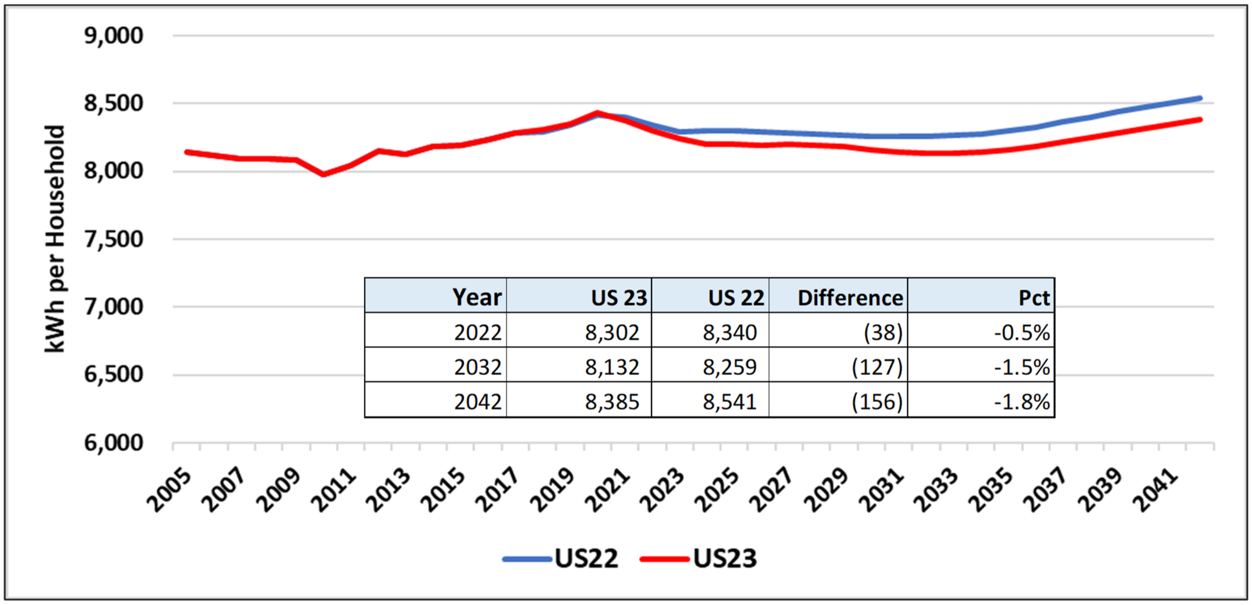
Figure 5: U.S Heating Intensity (kWh/household)



Year	US 23	US 22	Difference	Pct
2022	1,745	1,752	(8)	-0.4%
2032	1,615	1,637	(22)	-1.3%
2042	1,513	1,539	(26)	-1.7%

Figure 6 shows total intensity for the non-weather sensitive end-uses (*OtherUse*).

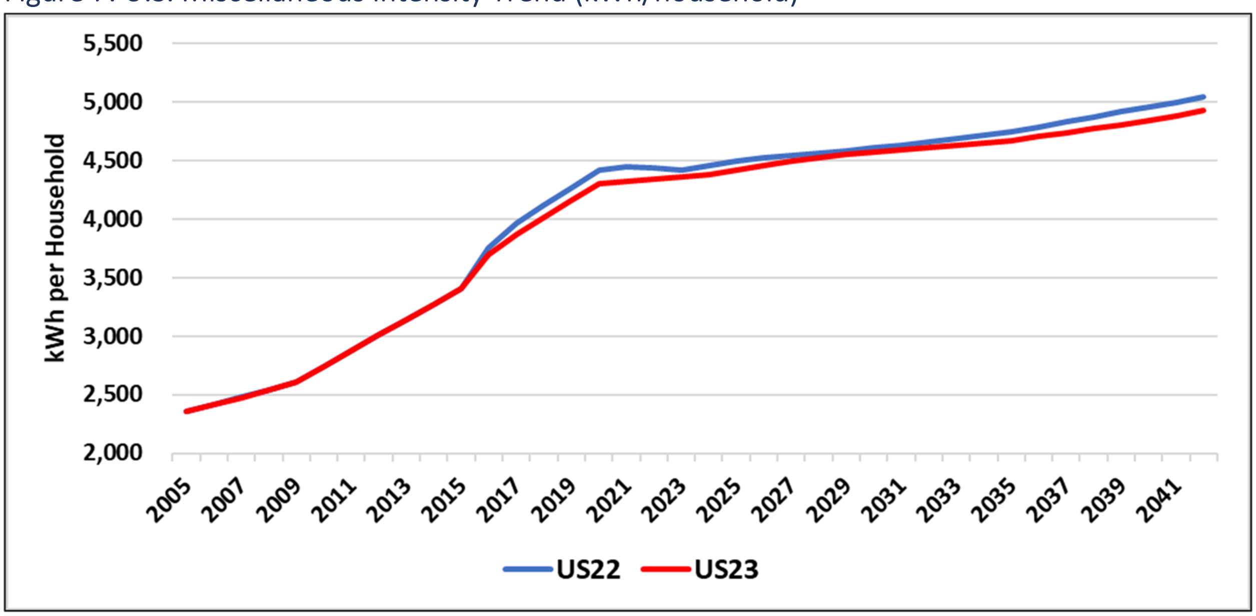
Figure 6: U.S. OtherUse Intensity Trend (kWh/household)



Year	US 23	US 22	Difference	Pct
2022	8,302	8,340	(38)	-0.5%
2032	8,132	8,259	(127)	-1.5%
2042	8,385	8,541	(156)	-1.8%

The 2023 OtherUse forecast is slightly lower than the 2022 forecast. OtherUse declines 0.2% annually through 2032. OtherUse turns positive after 2032 as appliance stock efficiency levels off and small gains in end-use saturation coupled with relatively strong miscellaneous sales growth drives OtherUse and total house intensity positive. **Figure 7** shows the miscellaneous intensity trend.

Figure 7: U.S. Miscellaneous Intensity Trend (kWh/household)



Since 2005, miscellaneous sales have increased from 20% of sales to over 35% of sales. By 2042 miscellaneous sales account for 40% of sales.

Electric Vehicle (EV) and Photovoltaics (PV) Input Worksheets

As in last year's forecast, the 2023 spreadsheets include EV and PV forecast tabs. Forecast data is derived from EIA 2023 EV and PV forecasts. **Figure 8** shows the electric vehicle (EV) worksheet.

Figure 8: EV Worksheet

Year	Households	Vehicles Per HH	Vehicles	Elec Stock Share	Elec Vehicles	AnnualMiles	MilesPerkWh	UEC	Sales	Intensity
2020	18,475,139	2.08	38,476,517	0.6%	223,071	12,000	3.08	3,895	868,907	47.0
2021	18,595,831	2.06	38,302,557	0.7%	253,055	12,000	3.00	3,995	1,011,047	54.4
2022	18,716,069	2.04	38,265,592	0.7%	285,221	12,000	2.95	4,061	1,158,385	61.9
2023	18,832,472	2.03	38,266,490	0.8%	317,951	12,000	2.93	4,097	1,302,487	69.2
2024	18,948,043	2.02	38,324,073	0.9%	352,472	12,000	2.92	4,112	1,449,536	76.5
2025	19,067,257	2.02	38,432,108	1.0%	391,500	12,000	2.91	4,123	1,614,334	84.7
2026	19,185,904	2.01	38,535,465	1.2%	443,427	12,000	2.92	4,114	1,824,201	95.1
2027	19,300,338	2.00	38,598,483	1.3%	499,937	12,000	2.93	4,098	2,048,513	106.1
2028	19,411,864	1.99	38,645,462	1.5%	560,897	12,000	2.94	4,083	2,290,403	118.0
2029	19,521,151	1.98	38,671,258	1.6%	625,184	12,000	2.95	4,072	2,545,819	130.4
2030	19,629,134	1.97	38,681,680	1.8%	694,663	12,000	2.95	4,063	2,822,301	143.8
2031	19,735,350	1.96	38,691,919	2.0%	769,648	12,000	2.96	4,055	3,121,195	158.2
2032	19,840,592	1.95	38,688,564	2.2%	850,650	12,000	2.96	4,050	3,444,768	173.6
2033	19,942,910	1.94	38,691,245	2.4%	938,116	12,000	2.97	4,045	3,794,622	190.3
2034	20,042,312	1.93	38,704,711	2.7%	1,032,268	12,000	2.97	4,041	4,171,581	208.1
2035	20,141,631	1.92	38,717,511	2.9%	1,132,777	12,000	2.97	4,038	4,574,628	227.1
2036	20,238,442	1.91	38,722,361	3.2%	1,239,285	12,000	2.97	4,036	5,002,164	247.2
2037	20,333,673	1.90	38,731,368	3.5%	1,352,300	12,000	2.97	4,035	5,455,879	268.3
2038	20,428,323	1.90	38,745,562	3.8%	1,471,953	12,000	2.98	4,033	5,936,726	290.6
2039	20,522,184	1.89	38,754,018	4.1%	1,596,275	12,000	2.98	4,033	6,437,380	313.7
2040	20,616,078	1.88	38,756,935	4.5%	1,725,293	12,000	2.98	4,033	6,958,312	337.5

The data shown in red are inputs from the EIA's transportation forecast. The values shown in blue are calculations. The calculations are from left to right. The first two columns are census-level number of households (column B), and the average number of vehicles per household (column C). The product gives the total number of vehicles (column D). Column E is EIA's EV saturation forecast. Total EVs are the product of total vehicles and expected EV saturation (column F). The other key inputs are expected annual miles driven (column G) and projected kWh per mile (column H). While EV efficiency is expected to improve the average kWh per mile increases as a result of total electric or battery electric vehicles (BEV) gaining market share over plug-in hybrid electric vehicles (PHEV). The annual use per car (UEC, column I) is calculated as the annual miles divided by average vehicle efficiency (kWh per mile). Total EV sales (column J) are calculated as the product of EV vehicle stock and vehicle UEC. The EV chagrining intensity is derived by dividing total EV sales by the total number of Households (column K). You can add EV to the XOther model variable or translate to a monthly EV charging sales and add to your residential average use forecast.

The PV worksheet is shown in **Figure 9**.

Figure 9: PV Worksheet

Year	PVInstalls	PV Stock	AvgPVSize	PVStockKW	PVDecayRate	AdjPV_KW	CapacityFactor	Generation MWh	OwnUse Share	OwnUse MWh	Excess MWh	OwnUse Intensity
2020	161,737	1,480,572	5.69	8,427,376	0.01	8,353,615	16.3%	11,950,441	80%	9,560,353	2,390,088	(517.5)
2021	168,564	1,649,136	5.78	9,539,898	0.01	9,455,624	16.3%	13,473,487	80%	10,778,789	2,694,697	(579.6)
2022	136,616	1,785,751	5.85	10,455,222	0.01	10,359,823	16.2%	14,666,519	80%	11,733,215	2,933,304	(626.9)
2023	130,108	1,915,859	5.92	11,339,953	0.01	11,235,401	16.1%	15,812,419	80%	12,649,935	3,162,484	(671.7)
2024	126,292	2,042,151	5.97	12,198,741	0.01	12,085,341	16.0%	16,916,846	80%	13,533,477	3,383,369	(714.2)
2025	126,655	2,168,806	6.03	13,072,661	0.01	12,950,674	15.9%	18,046,720	80%	14,437,376	3,609,344	(757.2)
2026	130,489	2,299,295	6.08	13,986,083	0.01	13,855,356	15.9%	19,240,777	80%	15,392,621	3,848,155	(802.3)
2027	130,945	2,430,240	6.13	14,902,700	0.01	14,762,839	15.8%	20,439,922	80%	16,351,938	4,087,984	(847.2)
2028	130,855	2,561,095	6.18	15,831,768	0.01	15,682,741	15.8%	21,660,012	80%	17,328,009	4,332,002	(892.7)
2029	131,441	2,692,536	6.23	16,764,996	0.01	16,606,678	15.7%	22,887,264	80%	18,309,811	4,577,453	(937.9)
2030	133,668	2,826,203	6.27	17,727,400	0.01	17,559,750	15.7%	24,162,616	80%	19,330,093	4,832,523	(984.8)
2031	138,523	2,964,726	6.32	18,724,768	0.01	18,547,494	15.7%	25,495,225	80%	20,396,180	5,099,045	(1,033.5)
2032	140,343	3,105,069	6.36	19,749,272	0.01	19,562,024	15.7%	26,872,751	80%	21,498,200	5,374,550	(1,083.5)
2033	142,981	3,248,050	6.40	20,793,032	0.01	20,595,539	15.7%	28,282,121	80%	22,625,696	5,656,424	(1,134.5)
2034	144,976	3,393,026	6.44	21,865,852	0.01	21,657,922	15.7%	29,740,184	80%	23,792,147	5,948,037	(1,187.1)
2035	147,081	3,540,107	6.48	22,954,248	0.01	22,735,590	15.7%	31,223,908	80%	24,979,127	6,244,782	(1,240.2)
2036	148,160	3,688,266	6.52	24,065,444	0.01	23,835,902	15.7%	32,745,884	80%	26,196,707	6,549,177	(1,294.4)
2037	149,685	3,837,951	6.56	25,188,080	0.01	24,947,426	15.7%	34,287,059	80%	27,429,647	6,857,412	(1,349.0)
2038	150,079	3,988,030	6.60	26,328,676	0.01	26,076,795	15.7%	35,858,452	80%	28,686,761	7,171,690	(1,404.3)
2039	151,399	4,139,429	6.64	27,479,312	0.01	27,216,025	15.7%	37,447,143	80%	29,957,714	7,489,429	(1,459.8)
2040	152,841	4,292,270	6.68	28,656,188	0.01	28,381,395	15.7%	39,079,937	80%	31,263,949	7,815,987	(1,516.5)

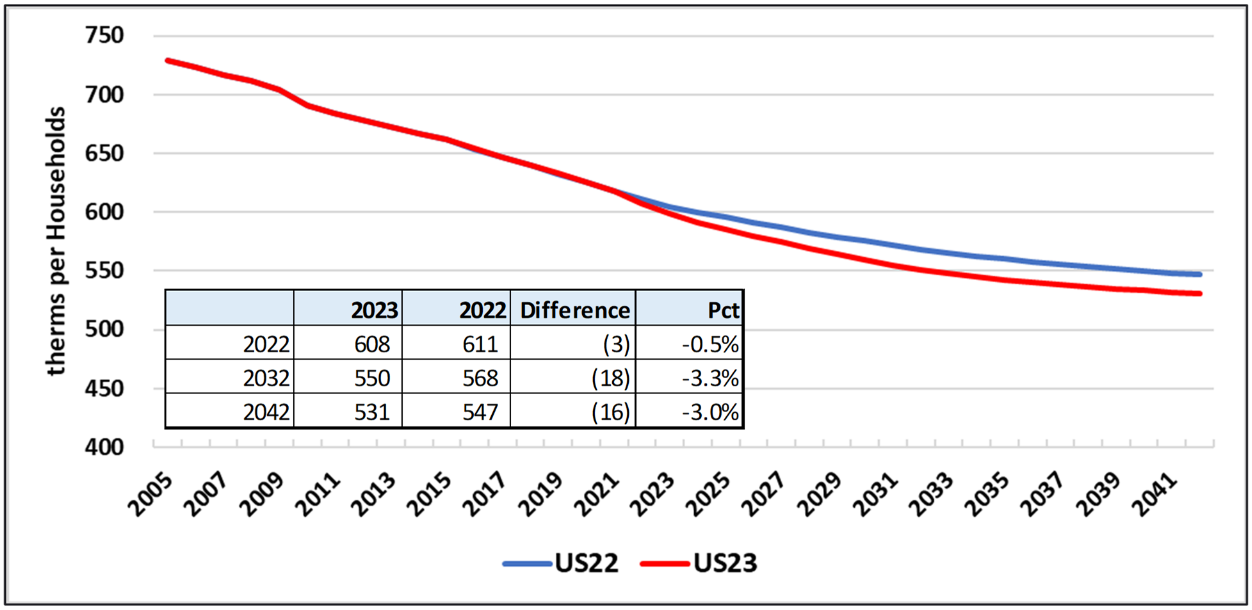
The calculations are left to right, starting with the number households (column B) and number of installed systems (column C). EIA inputs are shown in red, the data shown in green illustrates the user-defined inputs and the calculations are shown in blue. Total stock (column D) is calculated as the cumulation of the number of installed systems (column C). Installed kW capacity (column F) is the product of PV Stock and average PV size (column E). Capacity projection can be adjusted for solar degradation by setting a decay rate (column G); Adjusted kW capacity (column H) is calculated by applying the decay rate to the prior year's PV capacity estimate. Solar Generation (column J) is derived by applying the capacity factor (column I) to adjusted installed capacity. Total solar generation is split into own-use (that is consumed by the customer) and excess (that is sold back to the grid). Own-use intensity (column N) is calculated by dividing own-use generation by the number of households. The PV own-use intensity can be imported into your residential forecast file and used to adjust your residential average use forecast.

Natural Gas

Space heating and water heating account for over 95% of residential natural gas usage, with cooking and clothes dryers accounting for the remainder. At the U.S. level, roughly 50% of households have gas space and water heating. The share of homes with gas space heat has been relatively constant and is expected to increase just slightly over the next 20 years.

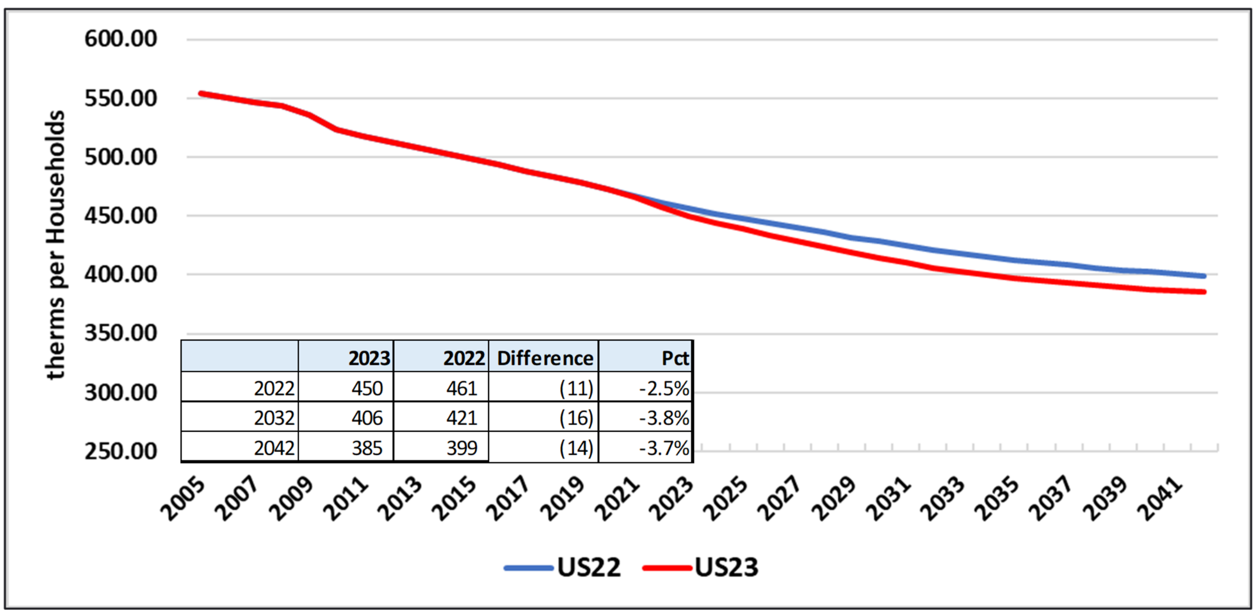
Over the last 10 years, there have been significant improvements in heating system efficiency and housing thermal insulation; these gains are expected to continue over the next thirty years. Given a relatively small increase in gas heat saturation, efficiency improvements drive gas intensity lower. In comparison with the 2022 forecast, the 2023 heating intensity (which represents 75% of gas use) and as a result total household intensities are lower. The 2023 intensities are lower reflecting higher real gas prices, The IRA encourages the adoption of more efficient gas heating systems and improvements in thermal shell efficiency, and slower saturation growth as EIA projects stronger electric heat pump saturation in several regions of the country. **Figure 10** and **Figure 11** compares the 2022 and 2023 total and gas heating intensity projections.

Figure 10: U.S. Total Gas Intensity (therms/household)



	2023	2022	Difference	Pct
2022	608	611	(3)	-0.5%
2032	550	568	(18)	-3.3%
2042	531	547	(16)	-3.0%

Figure 11: U.S. Gas Heating Intensity (therms/household)

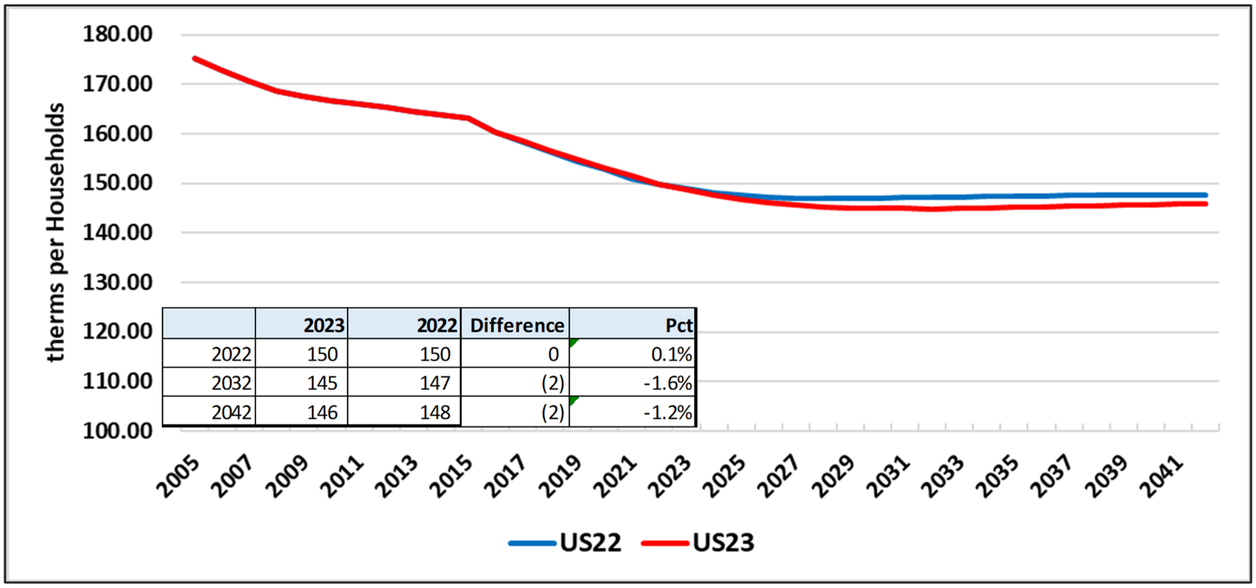


	2023	2022	Difference	Pct
2022	450	461	(11)	-2.5%
2032	406	421	(16)	-3.8%
2042	385	399	(14)	-3.7%

Gas heating intensity declines 1.2% annually over the next ten years compared with 0.9% per year in the 2022 forecast.

Water heating, dryers, and cooking account for the remaining 25% of gas use. While efficiency continues to improve across all three technologies, the impact is more muted with the 2023 average intensity declining 0.3% per year. This compares with 0.2% per year in the 2022 forecast. **Figure 12** compares the 2023 and 2022 intensity projections for the other non-weather-sensitive end uses (water heat, cooking, and dryers).

Figure 12: U.S. Other Gas Use Intensity (therms/household)



	2023	2022	Difference	Pct
2022	150	150	0	0.1%
2032	145	147	(2)	-1.6%
2042	146	148	(2)	-1.2%

Summary

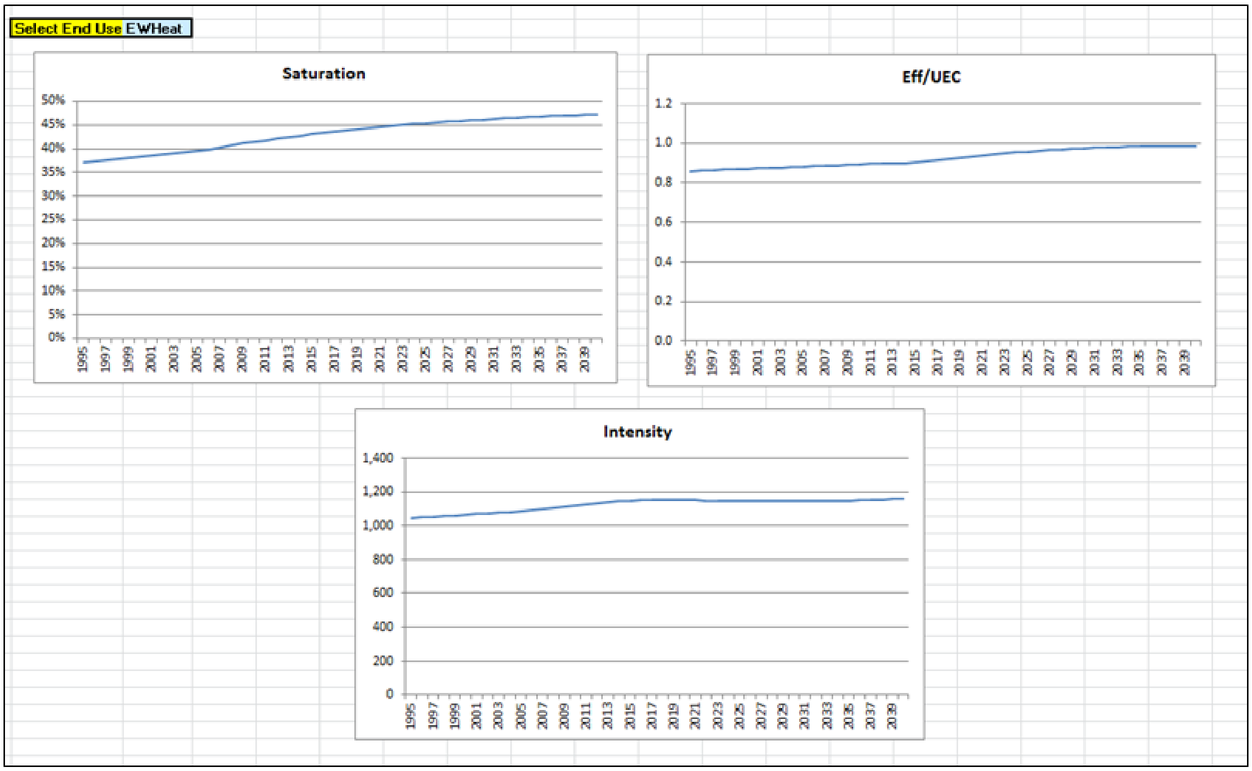
The 2023 electric and gas intensity projections are in general lower than 2022. The primary factor is the recent passage of the IRA that provides significant funding in terms of tax credits at the federal level and incentives/technology rebates at the state level. Higher real energy prices also contribute to adoption of more efficient technology options, and in some regions electrification results in higher electric heat saturation and conversely lower gas heat saturation.

Appendix A:
Using the SAE Spreadsheets

Updates to the SAE Spreadsheets

Itron continually works to simplify and improve the SAE spreadsheets to allow analysts to view end-use intensity trends, to understand how the indices are calculated and to customize the SAE inputs (such as end-use saturations and starting UEC) to their own service area. In 2015, Itron added a new *Graph* tab that allows the analyst to select an end-use and graph the end-use saturation, efficiency/UEC, and calculated intensity. **Figure 13** shows this feature for electric water heaters.

Figure 13: SAE Spreadsheet End-use Graph - Electric Water Heat



SAE Spreadsheet Organization

The SAE spreadsheets are organized to allow the analyst to calibrate end-use intensities to a specific utility service area organization where service area specific saturation and UEC estimates are available. The spreadsheet tabs include:

- **Definitions** provides descriptive information about end-uses, units and brief descriptions of the other worksheets.
- **EIAData** contains EIA efficiency, consumption, equipment stock, household, floor space and price projections.

- **Calibration** provides base year usage information. It can also be used to customize the spreadsheet to the user's service territory. Figure 14 shows the layout of the Calibration worksheet.

Figure 14: Calibration Worksheet

	A	B	C	D	E	F	G	H	I	J	K
1	Base Year (2009)	EFurn	HPHeat	GHPHeat	SecHt	CAC	HPCool	GHPCool	RAC	EWHeat	ECook
2	Consumption (mmBtu)	295,156,965	49,006,093	3,298,852	60,466,462	469,614,726	92,426,664	4,189,994	68,043,412	428,267,637	104,815,834
3	Equipment Stock (units)	29,626,185	9,099,838	699,168	28,312,038	61,707,187	9,099,838	699,168	49,101,682	46,763,693	68,137,629
4	UEC (kWh/unit)	2,920	1,578	1,383	626	2,230	2,977	1,756	406	2,684	451
5	Share (%)	26.0%	8.0%	0.6%	23.4%	54.2%	8.0%	0.6%	43.1%	41.1%	59.9%
6	Raw Intensity (kWh/year)	760	126	8	147	1,209	238	11	175	1,103	270
7	Model-Scaled Intensity (kWh/year)	760	126	8	147	1,209	238	11	175	1,103	270
8											
9	Observed Use Per Customer (kWh/year)	11,909									
10	Adjustment Factor	1.010									
11	Adjusted Intensity (kWh/year)	768	127	9	148	1,222	240	11	177	1,114	273
12											
13	XHeat	1.000									
14	XCool	1.000									
15	XOther	1.000									
16											

Base-year use-per-customer (kWh) for the utility service area is depicted in Row 9 and can be used to calibrate the spreadsheet to the user's service territory. To do this, substitute your weather-normalized average use for the Census Division average-use in Cell B9.

In addition to basic calibration to observed usage, in 2017 Itron added another layer of calibration to better tailor the regional data to utility-specific conditions. In order to get better starting estimates of electric usage by end use, we have utilized MetrixND models to "true up" EIA estimates to the regions. You can do this on the utility level by substituting the adjustment factors in cells B13-15 with estimated coefficients on SAE variables in your residential model. **Figure 15** below provides an example.

Figure 15: Model-Based Calibration

	A	B	C	D	E	F	G	H	I	J	K
1	Base Year (2009)	EFurn	HPHeat	GHPHeat	SecHt	CAC	HPCool	GHPCool	RAC	EWHeat	ECook
2	Consumption (mmBtu)	295,156,965	49,006,093	3,298,852	60,466,462	469,614,726	92,426,664	4,189,994	68,043,412	428,267,637	104,815,834
3	Equipment Stock (units)	29,626,185	9,099,838	699,168	28,312,038	61,707,187	9,099,838	699,168	49,101,682	46,763,693	68,137,629
4	UEC (kWh/unit)	2,920	1,578	1,383	626	2,230	2,977	1,756	406	2,684	451
5	Share (%)	26.0%	8.0%	0.6%	23.4%	54.2%	8.0%	0.6%	43.1%	41.1%	59.9%
6	Raw Intensity (kWh/year)	760	126	8	147	1,209	238	11	175	1,103	270
7	Model-Scaled Intensity (kWh/year)	1,853	308	21	358	2,389	470	21	346	677	166
8											
9	Observed Use Per Customer (kWh/year)	11,909									
10	Adjustment Factor	0.999									
11	Adjusted Intensity (kWh/year)	1,852	307	21	357	2,387	470	21	346	677	166
12											
13	XHeat	2.438									
14	XCool	1.975									
15	XOther	0.614									
16											

In this case, model-based calibration adjusts heating and cooling starting year usage up based on model coefficients estimated from observed use per customer data. Other usage is adjusted downward.

Resulting end-use intensities are written to the *Intensities* tab. MetrixND project files can link to the *Intensities* tab as the source-data for the constructing of SAE model variables.

StructuralVars

This worksheet contains data about the size of homes and their building shell efficiencies. The results of the calculations on this tab are used in the development of energy intensities for heating and cooling end-uses.

Analysts can substitute local household and floor space estimates for the regional estimates to reflect local conditions in the final energy intensities. Total floor space can be modified in Column E and number of households in Column I.

Shares

The *Shares* tab contains historical saturation estimates and forecasts developed by the EIA. Data from appliance saturation surveys can be used to modify the default saturations. Depending on data availability, these changes can either shift the projections up or down (one survey) or modify the growth rate in the trends (two or more surveys).

Efficiencies

The *Efficiencies* tab provides historical and forecasted end-use efficiency. UEC estimates are used as a proxy for efficiency where specific technology efficiency data (as central air conditioner SEER) are not available. Efficiency trends can also be modified to reflect the utility service area. As a practical matter however, average efficiency for most equipment varies little between regions.

Intensities

Intensities are per-household end-use energy estimate derived from combining end-use saturation, efficiency, and starting UEC. If the user changes saturation and/or efficiency, the changes are reflected in the end-use intensity calculations.

MonthlyMults

The *MonthlyMults* tab provides seasonal multipliers for non-HVAC end-uses. This allows us to accurately gauge seasonal usage for such non-weather-sensitive end-uses as water heating, refrigeration and lighting.

Graphs

The *Graphs* tab provides an interface to select an end-use and view historical and projected end-use saturation, efficiency (or UEC where an efficiency measure is not available) and resulting end-use intensity.

EV

Electric vehicle load is added to the base (other) end-use in the SAE model. Input data rows are highlighted in red and include:

- **Households.** Historical and forecasted number of households (column B)
- **Vehicle Per HH.** Number of EV vehicles per household C)
- **Electric Stock Share.** Share of total vehicle stock that is electric (column E)
- **AnnualMiles.** Annual average miles driven (column G)
- **MilePerKwh.** Average vehicle efficiency (column H)

A	B	C	D	E	F	G	H	I	J	K
Year	Households	Vehicles Per HH	Vehicles	Elec Stock Share	Elec Vehicles	AnnualMiles	MilesPerkWh	UEC	Sales	Intensity
2021	125,186,350	2.08	260,088,654	0.8%	2,027,185	12,000	2.95	4,069	8,247,932	65.9
2022	126,418,217	2.07	261,614,075	1.0%	2,692,315	12,000	2.93	4,092	11,015,792	87.1
2023	127,585,097	2.06	263,155,182	1.3%	3,445,136	12,000	2.92	4,104	14,139,023	110.8
2024	128,751,412	2.06	264,624,603	1.6%	4,239,405	12,000	2.91	4,121	17,470,854	135.7
2025	129,905,708	2.05	266,039,459	1.9%	5,036,759	12,000	2.90	4,138	20,843,918	160.5
2026	131,027,415	2.04	267,527,405	2.2%	5,842,365	12,000	2.89	4,157	24,286,183	185.4
2027	132,095,814	2.04	268,921,509	2.5%	6,645,326	12,000	2.88	4,173	27,727,843	209.9
2028	133,141,475	2.03	270,105,042	2.8%	7,440,173	12,000	2.87	4,183	31,124,750	233.8
2029	134,187,069	2.02	271,163,879	3.0%	8,240,417	12,000	2.86	4,195	34,565,545	257.6
2030	135,223,275	2.01	272,095,886	3.3%	9,058,522	12,000	2.85	4,206	38,104,667	281.8
2031	136,225,784	2.00	272,870,117	3.6%	9,899,825	12,000	2.84	4,218	41,761,974	306.6
2032	137,216,319	1.99	273,519,409	3.9%	10,762,057	12,000	2.84	4,230	45,526,874	331.8
2033	138,191,808	1.98	274,087,067	4.2%	11,641,597	12,000	2.83	4,242	49,381,000	357.3
2034	139,144,771	1.97	274,537,354	4.6%	12,534,116	12,000	2.82	4,253	53,305,976	383.1
2035	140,091,309	1.96	274,910,645	4.9%	13,432,770	12,000	2.81	4,264	57,274,358	408.8
2036	141,023,554	1.95	275,302,734	5.2%	14,338,602	12,000	2.81	4,275	61,291,792	434.6
2037	141,953,932	1.94	275,814,850	5.5%	15,253,786	12,000	2.80	4,285	65,365,673	460.5
2038	142,879,748	1.93	276,447,144	5.9%	16,178,392	12,000	2.79	4,296	69,498,745	486.4
2039	143,801,384	1.93	277,204,498	6.2%	17,103,489	12,000	2.79	4,306	73,642,768	512.1
2040	144,729,616	1.92	278,150,269	6.5%	18,036,897	12,000	2.78	4,316	77,840,730	537.8

Additional columns include:

- **Vehicles (column D).** Total number of vehicles calculated as the product of Households (Col B) and Vehicles per household (Col C).
- **Electric Vehicles (column F).** Total number of electric vehicles calculated as total number of vehicles (Column D) times the electric vehicle stock share (column E).
- **UEC (column I).** The Unit Energy Consumption (kWh) for those households that own an EV. Calculated as the annual miles driven (column G) by the average vehicle miles per kWh (column H).
- **Sales (column J).** Total EV sales calculated as number of electric vehicles (Column F) times the UEC (column I).
- **Intensity (column k).** EV kWh per household calculated as total EV electric sales (column J) divided by number of households (column D).

PV

The SAE spreadsheets also include a worksheet for calculating PV (photovoltaic) energy impacts. Input data rows are highlighted in red and include:

- **Households.** Historical and forecasted Households or customers (column B)
- **PVInstalls.** Number of new PV installations (column C)
- **AvgPVSize.** Average PV kW capacity (column E)
- **PVDecayKW.** PV capacity decay in kW (column G)
- **CapacityFactor.** Capacity Factor (column I)
- **OwnUseShare.** Percent of solar generation for own-use (column k)

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Year	Households	PVInstalls	PV Stock	AvgPVSize	PVInstalledKW	PVDecayKW	PVStockKW	CapacityFactor	Generation MWh	OwnUse Share	OwnUse MWh	Excess MWh	OwnUse Intensity
2021	125,186,350	376,697	3,478,279	6.13	2,308,952	-	20,193,878	18.0%	31,868,030	100%	31,868,030	-	(254.6)
2022	126,418,217	327,079	3,805,358	6.17	2,018,049	-	22,211,928	18.4%	35,708,486	100%	35,708,486	-	(282.5)
2023	127,585,097	328,054	4,133,413	6.21	2,037,866	-	24,249,794	18.6%	39,579,511	100%	39,579,511	-	(310.2)
2024	128,751,412	239,552	4,372,964	6.24	1,495,807	-	25,745,601	18.9%	42,565,019	100%	42,565,019	-	(330.6)
2025	129,905,708	238,167	4,611,131	6.27	1,493,997	-	27,239,599	19.1%	45,549,801	100%	45,549,801	-	(350.6)
2026	131,027,415	242,659	4,853,790	6.30	1,529,783	-	28,769,381	19.3%	48,592,667	100%	48,592,667	-	(370.9)
2027	132,095,814	249,927	5,103,718	6.34	1,584,120	-	30,353,502	19.5%	51,722,272	100%	51,722,272	-	(391.6)
2028	133,141,475	259,288	5,363,006	6.37	1,651,743	-	32,005,245	19.6%	54,961,867	100%	54,961,867	-	(412.8)
2029	134,187,069	266,585	5,629,590	6.40	1,707,439	-	33,712,684	19.7%	58,291,068	100%	58,291,068	-	(434.4)
2030	135,223,275	271,004	5,900,594	6.44	1,744,397	-	35,457,080	19.9%	61,681,677	100%	61,681,677	-	(456.1)
2031	136,225,784	287,765	6,188,359	6.47	1,862,495	-	37,319,575	20.0%	65,262,044	100%	65,262,044	-	(479.1)
2032	137,216,319	297,374	6,485,733	6.51	1,934,608	-	39,254,184	20.1%	68,960,880	100%	68,960,880	-	(502.6)
2033	138,191,808	326,550	6,812,282	6.54	2,136,850	-	41,391,034	20.1%	72,984,574	100%	72,984,574	-	(528.1)
2034	139,144,771	353,668	7,165,951	6.58	2,327,508	-	43,718,542	20.2%	77,319,081	100%	77,319,081	-	(555.7)
2035	140,091,309	355,581	7,521,531	6.62	2,353,860	-	46,072,402	20.2%	81,693,403	100%	81,693,403	-	(583.1)
2036	141,023,554	374,480	7,896,011	6.66	2,492,826	-	48,565,229	20.3%	86,296,349	100%	86,296,349	-	(611.9)
2037	141,953,932	390,448	8,286,459	6.70	2,614,634	-	51,179,863	20.3%	91,094,931	100%	91,094,931	-	(641.7)
2038	142,879,748	396,183	8,682,642	6.73	2,667,568	-	53,847,431	20.3%	95,982,502	100%	95,982,502	-	(671.8)
2039	143,801,384	427,781	9,110,423	6.77	2,897,732	-	56,745,163	20.4%	101,241,632	100%	101,241,632	-	(704.0)
2040	144,729,616	450,811	9,561,234	6.81	3,071,293	-	59,816,456	20.4%	106,785,962	100%	106,785,962	-	(737.8)

Additional columns include:

- **PVInstalledkW (column F)**. PV Stock (column D) times average system kW (column E).
- **PVStockKW (column H).** Cumulative PV capacity, calculated by summing current and all past PV installed capacity (column F) and subtracting the decay (column G), calculated as:

$$(PVInstalls \times AvgPVSize) - PVDecayKW$$

- **Generation MWh.** PV MWh (column J) is derived by applying the capacity factor (column I) to the PV Capacity Stock (column H), calculated as:

$$(PVStockKW \times 8760 \times CapacityFactor)/1000$$

- **OwnUse MWh (column L)**. Calculated as total generation (column J) times own-use share (column K).
- **Excess MWh (column M). Calculated as total generation (column J) minus own-use generation (column L).**
- **OwnUse Intensity (column N)**. Calculated as own-use MWh (column L) divided by number of households (column B).

Appendix B:
Residential SAE Modeling Framework

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 this approach.

- The equipment efficiency and saturation trends, dwelling square footage, and thermal integrity changes embodied in the long-run end-use forecasts are introduced explicitly into the short-term monthly sales forecast. This provides a strong bridge between the two forecasts.
- By explicitly incorporating trends in equipment saturations, equipment efficiency, dwelling square footage, and thermal integrity levels, it is easier to explain changes in usage levels and changes in 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 incorporated into the final model.

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

Statistically Adjusted End-Use Modeling 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,

$$USE_{y,m} = Heat_{y,m} + Cool_{y,m} + \text{Other}_{y,m} \qquad (1)$$

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.

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

$XHeat_m$, $XCool_m$, 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 SAE spreadsheets, energy use by space heating systems depends on the following types of variables.

- Heating degree days
- Heating equipment saturation levels
- Heating equipment operating efficiencies
- Average number of days in the billing cycle for each month
- Thermal integrity and footage of homes
- Average household size, household income, and energy prices

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

$$XHeat_{y,m} = HeatIndex_{y,m} \times HeatUse_{y,m} \tag{3}$$

Where:

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

The heating equipment index is defined as a weighted average across equipment types of equipment saturation levels normalized by operating efficiency levels. Given a set of fixed weights, the index will change over time with changes in equipment saturations (*Sat*), operating efficiencies (*Eff*), building structural index (*StructuralIndex*), and energy prices. Formally, the equipment index is defined as:

$$HeatIndex_y = StructuralIndex_y \times \sum_{Type} Weight^{Type} \times \frac{\left(Sat_y^{Type} \big/ Eff_y^{Type} \right)}{\left(Sat_{15}^{Type} \big/ Eff_{15}^{Type} \right)} \tag{4}$$

The *StructuralIndex* is constructed by combining the EIA's building shell efficiency index trends with surface area estimates, and then it is indexed to the 2015 value:

$$StructuralIndex_y = \frac{BuildingShellEfficiencyIndex_y \times SurfaceArea_y}{BuildingShellEfficiencyIndex_{15} \times SurfaceArea_{15}} \tag{5}$$

The *StructuralIndex* is defined on the *StructuralVars* tab of the SAE spreadsheets. Surface area is derived to account for roof and wall area of a standard dwelling based on the regional average square footage data obtained from EIA. The relationship between the square footage and surface area is constructed assuming an aspect ratio of 0.75 and an average of 25% two-story and 75% single-story. Given these assumptions, the approximate linear relationship for surface area is:

$$SurfaceArea_y = 892 + 1.44 \times Footage_y \tag{6}$$

In Equation 4, 2015 is used as a base year for normalizing the index. As a result, the ratio on the right is equal to 1.0 in 2015. In other years, it will be greater than 1.0 if equipment saturation levels are above their 2015 level. This will be counteracted by higher efficiency levels, which will drive the index downward. The weights are defined as follows.

$$Weight^{Type} = \frac{Energy_{15}^{Type}}{HH_{15}} \times HeatShare_{15}^{Type} \quad (7)$$

In the SAE spreadsheets, these weights are referred to as Intensities and are defined on the *EIAData* tab. With these weights, the $HeatIndex$ value in 2015 will be equal to estimated annual heating intensity per household in that year. Variations from this value in other years will be proportional to saturation and efficiency variations around their base values.

For electric heating equipment, the SAE spreadsheets contain two equipment types: electric resistance furnaces/room units and electric space heating heat pumps. Examples of weights for these two equipment types for the U.S. are given in **Table 1**.

Table 1: Electric Space Heating Equipment Weights

Equipment Type	Weight (kWh)
Electric Resistance Furnace/Room units	916
Electric Space Heating Heat Pump	346

Data for the equipment saturation and efficiency trends are presented on the *Shares* and *Efficiencies* tabs of the SAE spreadsheets. The efficiency for electric space heating heat pumps are given in terms of Heating Seasonal Performance Factor [BTU/Wh], and the efficiencies for electric furnaces and room units are estimated as 100%, which is equivalent to 3.41 BTU/Wh.

Price Impacts. In the 2007 version of the SAE models and thereafter, the Heat Index has been extended to account for the long-run impact of electric and natural gas prices. Since the Heat Index represents changes in the stock of space heating equipment, the price impacts are modeled to play themselves out over a 10-year horizon. To introduce price effects, the Heat Index as defined by Equation 4 above is multiplied by a 10-year moving-average of electric and gas prices. The level of the price impact is guided by the long-term price elasticities:

$$HeatIndex_y = StructuralIndex_y \times \sum_{Type} Weight^{Type} \times \frac{\left(Sat_y^{Type} \big/ Eff_y^{Type}\right)}{\left(Sat_{15}^{Type} \big/ Eff_{15}^{Type}\right)} \times$$
$$\left(TenYearMovingAverageElectric\Pr ice_{y,m}\right)^{\varphi} \times \left(TenYearMovingAverageGas\Pr ice_{y,m}\right)^{\gamma} \quad (8)$$

Since the trends in the Structural index (the equipment saturations and efficiency levels) are provided exogenously by the EIA, the price impacts are introduced in a multiplicative form. As a result, the long-run change in the Heat Index represents a combination of adjustments to the structural integrity of new homes, saturations in equipment and efficiency levels relative to what was contained in the base EIA long-term forecast.

Heating system usage levels are impacted on a monthly basis by several factors, including weather, household size, income levels, prices, and billing days. The estimates for space heating equipment usage levels are computed as follows:

$$HeatUse_{y,m} = \left(\frac{WgtHDD_{y,m}}{HDD_{15}}\right) \times \left(\frac{HHSize_y}{HHSize_{15}}\right)^{0.25} \times \left(\frac{Income_y}{Income_{15}}\right)^{0.20} \times \left(\frac{Elec\,Price_{y,m}}{Elec\,Price_{15,7}}\right)^{\lambda} \times \left(\frac{Gas\,Price_{y,m}}{Gas\,Price_{15,7}}\right)^{\kappa} \quad (9)$$

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 2015
- *HHSize* is average household size in a year (*y*)
- *Income* is average real income per household in year (*y*)
- *ElecPrice* is the average real price of electricity in month (*m*) and year (*y*)
- *GasPrice* is the average real price of natural gas in month (*m*) and year (*y*)

By construction, the $HeatUse_{y,m}$ variable has an annual sum that is close to 1.0 in the base year (2015). The first two terms, which involve billing days and heating 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 reflect changes in the economic drivers, as transformed through the end-use elasticity parameters. The price impacts captured by the Usage equation represent short-term price response.

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 equipment saturation levels
- Cooling equipment operating efficiencies
- Average number of days in the billing cycle for each month
- Thermal integrity and footage of homes
- Average household size, household income, and energy prices

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

$$XCool_{y,m} = CoolIndex_y \times CoolUse_{y,m} \quad (10)$$

Where

- $XCool_{y,m}$ is estimated cooling energy use in year (y) and month (m)
- $CoolIndex_y$ is an index of cooling equipment
- $CoolUse_{y,m}$ is the monthly usage multiplier

As with heating, the cooling equipment index is defined as a weighted average across equipment types of equipment saturation levels normalized by operating efficiency levels. Formally, the cooling equipment index is defined as:

$$CoolIndex_y = StructuralIndex_y \times \sum_{Type} Weight^{Type} \times \frac{\left(Sat_y^{Type} \middle/ Eff_y^{Type}\right)}{\left(Sat_{15}^{Type} \middle/ Eff_{15}^{Type}\right)} \quad (11)$$

Data values in 2015 are used as a base year for normalizing the index, and the ratio on the right is equal to 1.0 in 2015. In other years, it will be greater than 1.0 if equipment saturation levels are above their 2015 level. This will be counteracted by higher efficiency levels, which will drive the index downward. The weights are defined as follows.

$$Weight^{Type} = \frac{Energy_{15}^{Type}}{HH_{15}} \times CoolShare_{15}^{Type} \quad (12)$$

In the SAE spreadsheets, these weights are referred to as Intensities and are defined on the *EIAData* tab. With these weights, the *CoolIndex* value in 2015 will be equal to estimated annual cooling intensity per household in that year. Variations from this value in other years will be proportional to saturation and efficiency variations around their base values.

For cooling equipment, the SAE spreadsheets contain three equipment types: central air conditioning, space cooling heat pump, and room air conditioning. Examples of weights for these three equipment types for the U.S. are given in **Table 2**.

Table 2: Space Cooling Equipment Weights

Equipment Type	Weight (kWh)
Central Air Conditioning	1,012
Space Cooling Heat Pump	306
Room Air Conditioning	277

The equipment saturation and efficiency trends data are presented on the *Shares* and *Efficiencies* tabs of the SAE spreadsheets. The efficiency for space cooling heat pumps and central air conditioning (A/C) units are given in terms of Seasonal Energy Efficiency Ratio [BTU/Wh], and room A/C units efficiencies are given in terms of Energy Efficiency Ratio [BTU/Wh].

Price Impacts. In the 2007 SAE models and thereafter, the Cool Index has been extended to account for changes in electric and natural gas prices. Since the Cool Index represents changes in the stock of space heating equipment, it is anticipated that the impact of prices will be long-term in nature. The Cool Index as defined Equation 11 above is then multiplied by a 10-year moving average of electric and gas prices. The level of the price impact is guided by the long-term price elasticities.

$$CoolIndex_y = StructuralIndex_y \times \sum_{Type} Weight^{Type} \times \frac{\left(Sat_y^{Type} \Big/ Eff_y^{Type}\right)}{\left(Sat_{15}^{Type} \Big/ Eff_{15}^{Type}\right)} \times$$
$$\left(TenYearMovingAverageElectric\,Price_{y,m}\right)^{\varphi} \times \left(TenYearMovingAverageGas\,Price_{y,m}\right)^{\gamma} \quad (13)$$

Since the trends in the Structural index, equipment saturations and efficiency levels are provided exogenously by the EIA, price impacts are introduced in a multiplicative form. The long-run change in the Cool Index represents a combination of adjustments to the structural integrity of new homes, saturations in equipment and efficiency levels. Without a detailed end-use model, it is not possible to isolate the price impact on any one of these concepts.

Cooling system usage levels are impacted on a monthly basis by several factors, including weather, household size, income levels, and prices. The estimates of cooling equipment usage levels are computed as follows:

$$CoolUse_{y,m} = \left(\frac{WgtCDD_{y,m}}{CDD_{15}}\right) \times \left(\frac{HHSize_y}{HHSize_{15}}\right)^{0.25} \times \left(\frac{Income_y}{Income_{15}}\right)^{0.20} \times$$
$$\left(\frac{Elec\,Price_{y,m}}{Elec\,Price_{15}}\right)^{\lambda} \times \left(\frac{Gas\,Price_{y,m}}{Gas\,Price_{15}}\right)^{\kappa} \quad (14)$$

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 2015.

By construction, the $CoolUse$ variable has an annual sum that is close to 1.0 in the base year (2015). 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 the economic driver changes.

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:

- Appliance and equipment saturation levels
- Appliance efficiency levels
- Average number of days in the billing cycle for each month
- Average household size, real income, and real prices

The explanatory variable for other uses is defined as follows:

$$XOther_{y,m} = OtherEqpIndex_{y,m} \times OtherUse_{y,m} \tag{15}$$

The first term on the right-hand side of this expression ($OtherEqpIndex_y$) embodies information about appliance saturation and efficiency levels and monthly usage multipliers. The second term ($OtherUse$) captures the impact of changes in prices, income, household size, and number of billing-days on appliance utilization.

End-use indices are constructed in the SAE models. A separate end-use index is constructed for each end-use equipment type using the following function form.

$$ApplianceIndex_{y,m} = Weight^{Type} \times \frac{\left(Sat_y^{Type} \Big/ \frac{1}{UEC_y^{Type}} \right)}{\left(Sat_{15}^{Type} \Big/ \frac{1}{UEC_{15}^{Type}} \right)} \times MoMult_m^{Type} \times$$
$$(TenYearMovingAverageElectric\,Pr\,i\,ce)^{\lambda} \times$$
$$(TenYearMovingAverageGas\,Pr\,i\,ce)^{\kappa} \tag{16}$$

Where:

- *Weight* is the weight for each appliance type
- *Sat* represents the fraction of households, who own an appliance type
- $MoMult_m$ is a monthly multiplier for the appliance type in month (m)
- *Eff* is the average operating efficiency the appliance
- *UEC* is the unit energy consumption for appliances

This index combines information about trends in saturation levels and efficiency levels for the main appliance categories with monthly multipliers for lighting, water heating, and refrigeration.

The appliance saturation and efficiency trends data are presented on the Shares and Efficiencies tabs of the SAE spreadsheets.

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

$$ApplianceUse_{y,m} = \left(\frac{BDays_{y,m}}{30.44}\right) \times \left(\frac{HHSize_y}{HHSize_{15}}\right)^{0.46} \times \left(\frac{Income_y}{Income_{15}}\right)^{0.10} \times$$
$$\left(\frac{Elec\,Pr\,ice_{y,m}}{Elec\,Pr\,ice_{15}}\right)^{\varphi} \times \left(\frac{Gas\,Pr\,ice_{y,m}}{Gas\,Pr\,ice_{15}}\right)^{\lambda} \tag{17}$$

The index for other uses is derived then by summing across the appliances:

$$OtherEqpIndex_{y,m} = \sum_k ApplianceIndex_{y,m} \times ApplianceUse_{y,m} \quad (18)$$

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 16**. 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 3.

Figure 16: Mapping of States to Census Divisions

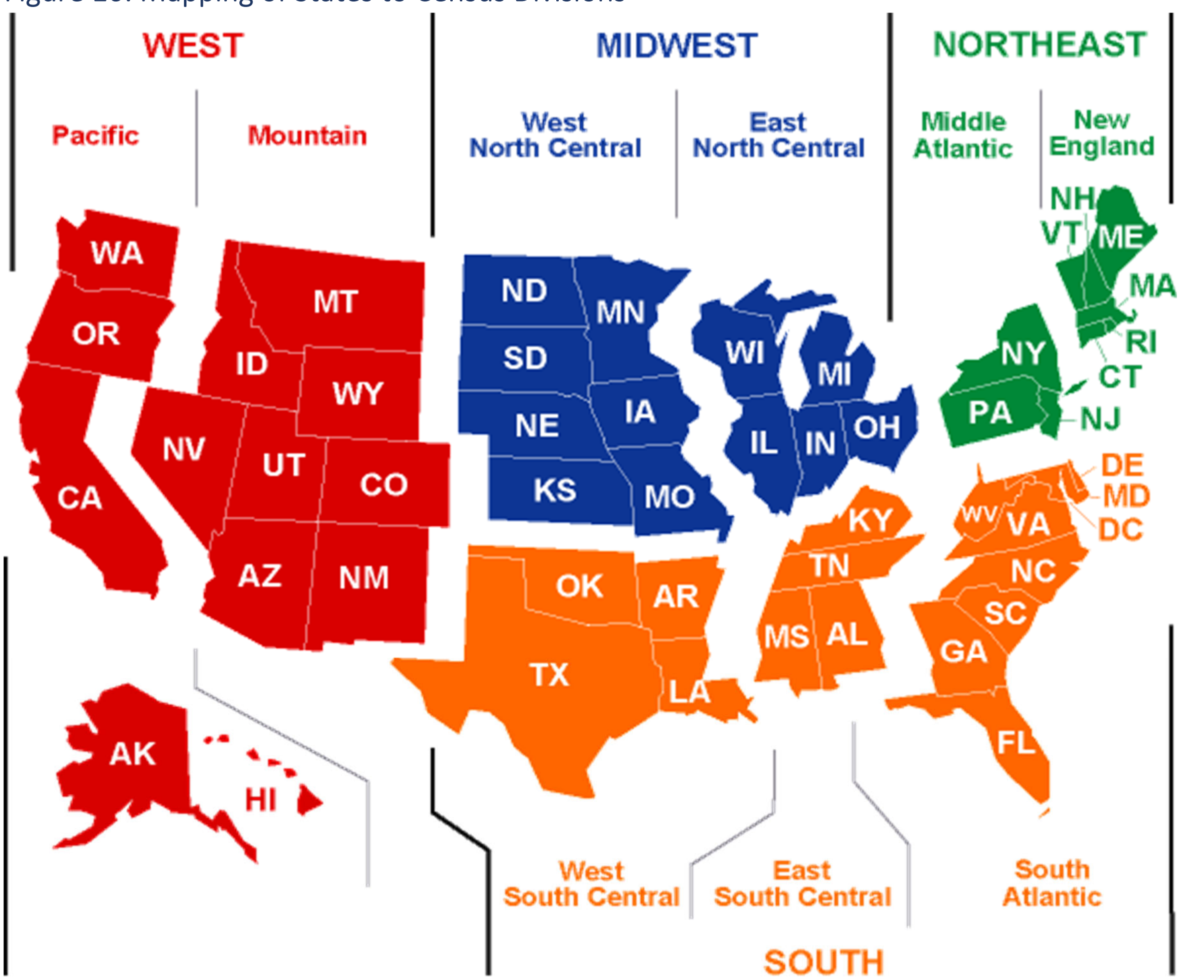


Table 3: List of SAE Files

Spreadsheet	MetrixND Project File
NewEngland.xlsx	SAE_NewEngland.ndm
MiddleAtlantic.xlsx	SAE_MiddleAtlantic.ndm
EastNorthCentral.xlsx	SAE_EastNorthCentral.ndm
WestNorthCentral.xlsx	SAE_WestNorthCentral.ndm
SouthAtlantic.xlsx	SAE_SouthAltantic.ndm
EastSouthCentral.xlsx	SAE_EastSouthCentral.ndm
WestSouthCentral.xlsx	SAE_WestSouthCentral.ndm
Mountain.xlsx	SAE_Mountain.ndm
Pacific.xlsx	SAE_Pacific.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 MetrixND project files link to the data in these spreadsheets. These project files calculate the end-use Usage variables are constructed and the estimated SAE models.

Each of the nine SAE spreadsheets contains the following tabs:

- **Definitions** contains equipment, end use, worksheet, and Census Division definitions.
- **Intensities** calculates the annual equipment indices.
- **Shares** contains historical and forecasted equipment shares. The default forecasted values are provided by the EIA. The raw EIA projections are provided on the *EIAData* tab.
- **Efficiencies** contains historical and forecasted equipment efficiency trends. The forecasted values are based on projections provided by the EIA. The raw EIA projections are provided on the *EIAData* tab.
- **StructuralVars** contains historical and forecasted square footage, number of households, building shell efficiency index, and calculation of structural variable. The forecasted values are based on projections provided by the EIA.
- **Calibration** contains calculations of the base year Intensity values used to weight the equipment indices.
- **EIAData** contains the raw forecasted data provided by the EIA.
- **MonthlyMults** contains monthly multipliers that are used to spread the annual equipment indices across the months.
- **EV** contains a worksheet for incorporating electric vehicle (EV) impacts.
- **PV** contains a worksheet for incorporating photovoltaic battery (PV) impacts.

The MetrixND Project files are linked to the *AnnualIndices*, *ShareUEC*, and *MonthlyMults* tabs in the spreadsheets. Sales, economic, price and weather information for the Census Division is provided in the linkless data table *UtilityData*. In this way, utility specific data and the equipment indices are brought into the project file. The MetrixND project files contain the objects described below.

Parameter Tables

- **Elas.** This parameter table includes the values of the elasticities used to calculate the Usage variables for each end-use. There are five types of elasticities included on this table.
    - Economic variable elasticities
    - Short-term own price elasticities
    - Short-term cross price elasticities
    - Long-term own price elasticities
    - Long-term cross price elasticities

The short-term price elasticities drive the end-use usage equations. The long-term price elasticities drive the Heat, Cool and other appliance indices. The combined price impact is an aggregation of the short and long-term price elasticities. As such, the long-term price elasticities are input as incremental price impact. That is, the long-term price elasticity is the difference between the overall price impact and the short-term price elasticity.

Data Tables

- **AnnualEquipmentIndices** links to the *AnnualIndices* tab for heating and cooling indices, and *ShareUEC* tab for water heating, lighting, and appliances in the SAE spreadsheet.
- **UtilityData** is a linkless data table that contains sales, price, economic and weather data specific to a given Census Division.
- **MonthlyMults** links to the corresponding tab in the SAE spreadsheet.

Transformation Tables

- **EconTrans** computes the average usage, and household size, household income, and price indices used in the usage equations.
- **WeatherTrans** computes the HDD and CDD indices used in the usage equations.
- **ResidentialVars** computes the *Heat*, *Cool* and *Other Usage* variables, as well as the *XHeat*, *XCool* and *XOther* variables that are used in the regression model.
- **BinaryVars** computes the calendar binary variables that could be required in the regression model.
- **AnnualFcst** computes the annual historical and forecast sales and annual change in sales.
- **EndUseFcst** computes the monthly sales forecasts by end uses.

Models

- **ResModel** is the Statistically Adjusted End-Use Model.

Steps to Customize the Files for Your Service Territory

The files that are distributed along with this document contain regional data. If you have more accurate data for your service territory, you are encouraged to tailor the spreadsheets with that information. This section describes the steps needed to customize the files.

Minimum Customization

- Save the MetrixND project file and the spreadsheet into the same folder
- Select the spreadsheet and MetrixND project file from the appropriate Census Division
- Open the spreadsheet and navigate to the *Calibration* tab
- In cell "B9", replace base year Census Division use-per-customer with observed use-per-customer for your service territory
- Save the spreadsheet and open the MetrixND project file
- Click on the *Update All Links* button on the *Menu* bar
- Review the model results

Further Customization of Starting Usage Levels

In addition to the minimum steps listed above, you can also utilize model-based calibration process described previously to further fine-tune starting year usage estimates to your service territory.

Customizing the End-use Share Paths

You can also install your own share history and forecasts. To do this, navigate to the *Share* tab in the spreadsheet and paste in the values for your region. Make sure that base year shares on the *Calibration* tab reflect changes on the *Shares* tab.

Customizing the End-use Efficiency Paths

Finally, you can override the end-use efficiency paths that are contained on the *Efficiencies* tab of the spreadsheet.