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SMUD Load Forecast
Methodology and Assumptions

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Overview

This forecast was designed using an umbrella strategy. A bottom up method of combining monthly sales energy models is reconciled with a top down hourly system model. The long-term monthly sales energy models are combined with short-term hourly models by rate class for residential, small non-demand commercial <20 kW, small demand commercial 20-299 kW, GS-TOU3 commercial 300-499kW, GS-TOU2 commercial 500-999 kW, GS-TOU1 commercial > 1000 kW, agriculture, streetlights, and night lights. The hourly system model is comprised of a peak, daily, and 24-hourly system models. Monthly sales data is based on the SAP 21 Day Sales Report, hourly system data is from the Energy Management System (EMS), and load shapes are developed from multiple sources using data available in-house with customer interval meter data, as well as from outside consultants.

Regression models were created using MetrixND, a forecasting software, to normalize usage for weather.

The single largest impacts to SMUD's load in the short term is weather and the economy. A hot summer or cold winter increases sales while mild weather decreases sales. Long term impacts to SMUD's load include changes in the number of customers, as well, how much energy each customer uses, and adoption rates of new technologies.

Different combinations of assumptions are combined to create multiple scenarios. Below is a summary of the scenarios. The following sections provide additional details about each set of assumptions. **SMUD's IRP uses the Zero Carbon Plan scenario.**

	Expected	Optimistic	Pessimistic	Zero Carbon Plan
Weather	Typical			
Economics	Mid-case	High case	Low case	Mid-case
DER Adjustments	Scenario 2	Scenario 2	Scenario 2	ZCP Scenario
Additional Commercial Growth	High confidence only			

Figure 1. Scenario Summary

Economics

The load forecast uses economic variables in both the customer count forecast and the monthly sales models. SMUD contracts with IHS Markit for economic research and analysis which includes forecast of certain economic variables. Previously, SMUD used the Sacramento County forecast, but this forecast is only produced quarterly. Given the volatile economic situation from COVID-19, the Sacramento Metro forecast was used last year and again this year. It includes parts of El Dorado and Placer County but is produced monthly. By using the Sacramento Metro forecast, the most current economic conditions were reflected in the load forecast.

Last year's forecasts were used to develop a high case for the optimistic scenario, and a low case for the pessimistic scenario while the IHS July 2021 forecast was used as the mid-case used in the Expected and ZCP scenarios. The IHS April 2020 forecast reflected the originally expected quick "V" shaped recovery. The IHS May 2020 forecast reflected the horrible unemployment rates that were reported. The high case is based largely on the IHS April 2020 forecast but incorporates more recent data as well. The low case is based largely on the IHS May 2020 forecast but also incorporates more recent data and an additional year of recovery was added forecast and pushing out the remaining years. All scenarios used the same values through July 2021 from the IHS July 2021 forecast.

Different models use different economic variables depending on which was the best predictor. In general, the customer count forecast uses population and households. In addition to the IHS forecast, the Department of Finance population forecast for Sacramento County is used. The monthly sales models tend to use Consumer Price Index, Gross Domestic Product (for local area), employment, unemployment rate, income, and vacancy rates. Following are charts of some of the key economic variables used in the load forecast models.

Models

Customer Count Forecast

The customer count forecast captures standard system growth. Customer growth outside of standard growth is captured as an adjustment. This is generally related to commercial customer growth which could be a larger than usual new customer or large expansions of existing customers. The following charts show the customer count assumptions made by rate class along with the historical customer counts to show the customer growth trends. (Note there was a change to commercial rate classes in 2013-2014 which causes customers to be changed into different rate classes.)

The forecast for residential customer accounts is based on historical growth, the population forecast for Sacramento County (population divided by persons per household), and population and household forecasts from economic scenarios. During the last residential building cycle, Sacramento county population acted as a leading indicator for new residential customer growth. For the forecast period, however, residential customer growth is expected to keep pace with the population growth.

The forecast for commercial customers generally follows the population forecast but also includes historical growth factors. Even in a bad economy, customer counts do not generally decrease. Customers that go out of business remain an active account in the landlord's name. Usage does decrease which can result in customers shifting between the rate classes.

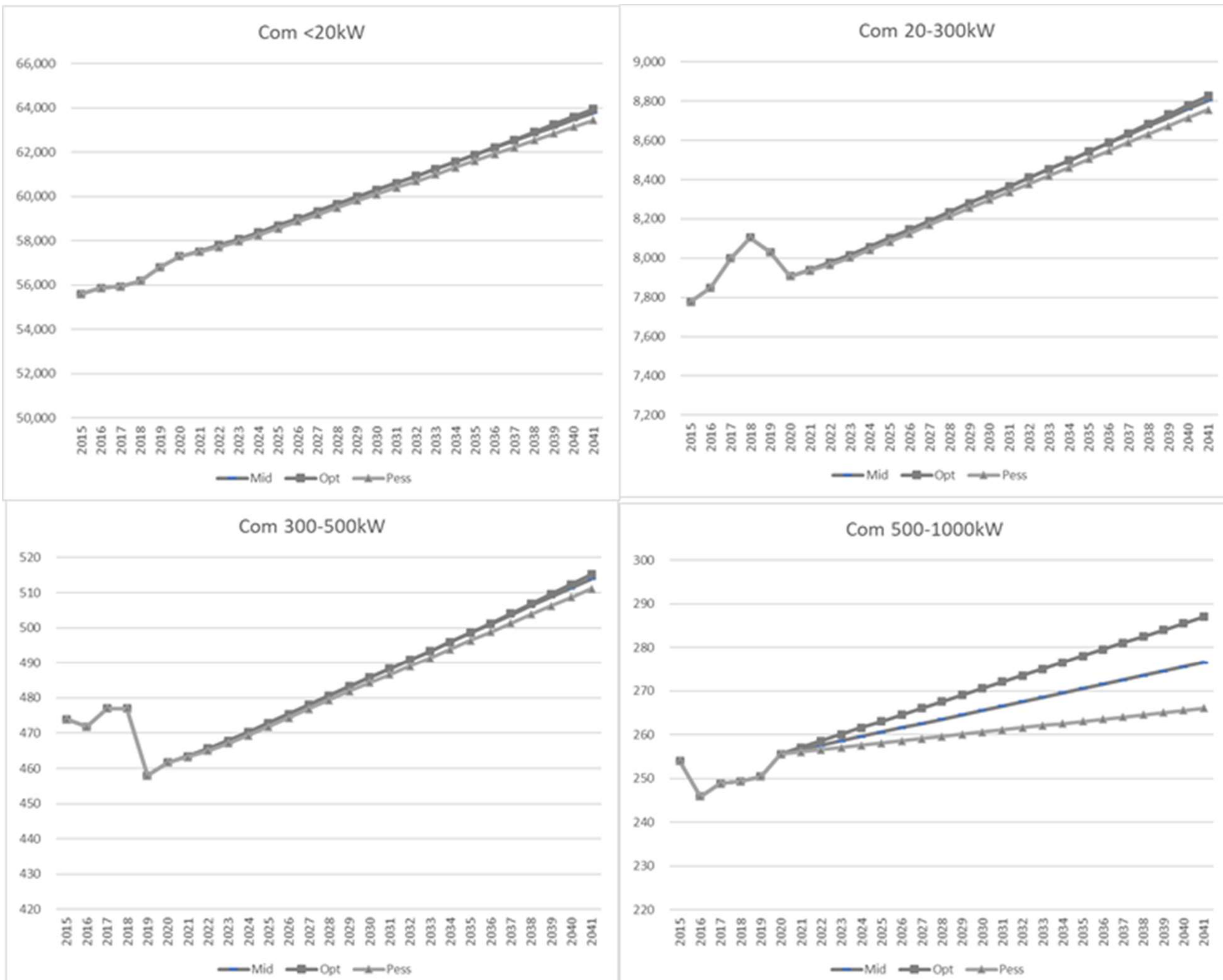

Figure 2. Average Annual Customer Count by Rate Class

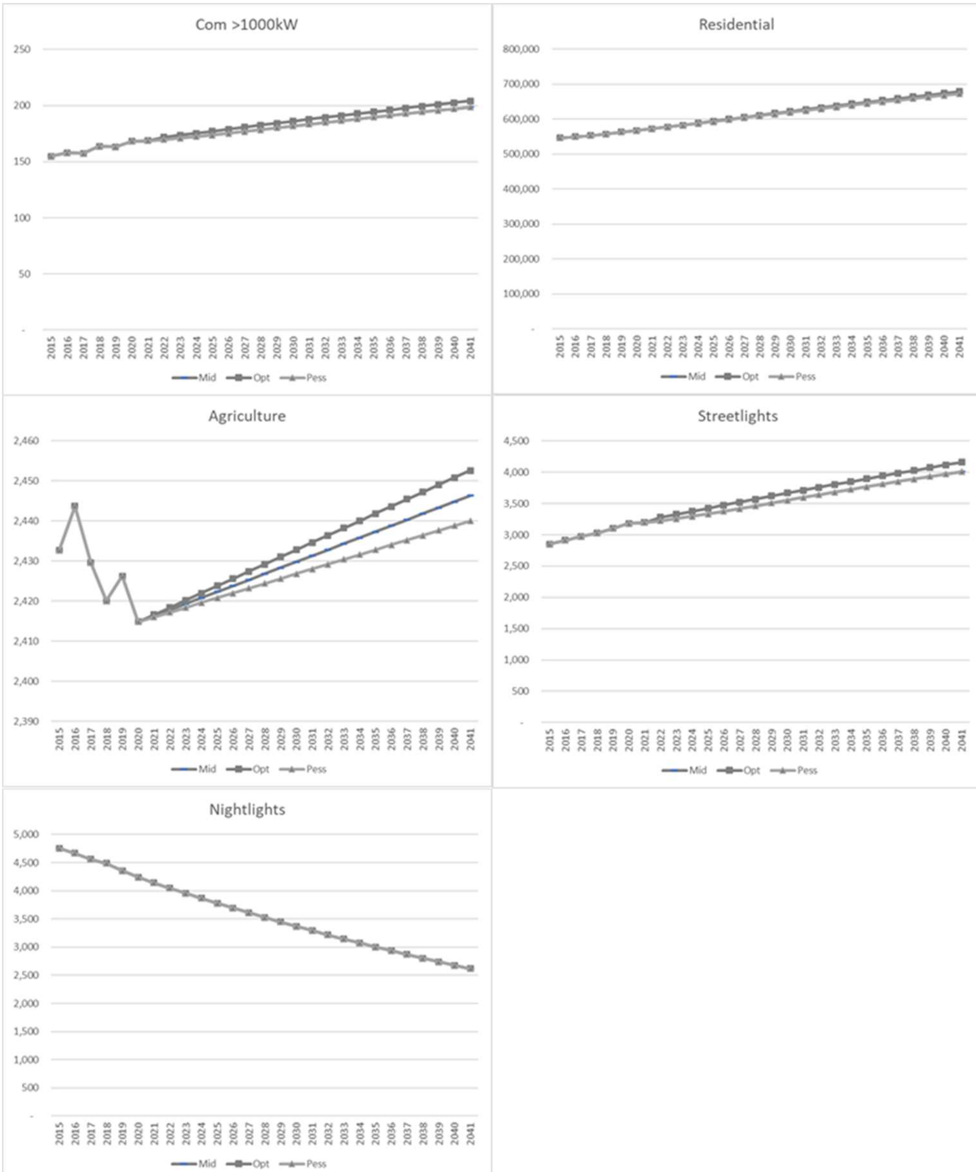

Figure 3. Average Annual Customer Count by Rate Class (cont.)

Sales Models

The retail sales models include separate regression models for each major rate class. They are:

- Residential
- Small General Services with maximum demands below 20 kW (Small Non-Demand)
- Small General Services with maximum demands between 20 and 299 kW (Small Demand)
- Small General Service Time of Use with maximum demands between 300 and 499 kW (GSTOU3)
- Medium General Service Time of Use with maximum demands between 500 and 999 kW (GSTOU2)
- Large General Service Time of Use with maximum demands greater than 1,000 kW (GSTOU1)
- Agricultural (AGR)
- Streetlights (ST and TF)
- Night Lighting (NL) account

SMUD uses two types of monthly retail sales models depending on the rate class. Both model types predict the energy sales (kWh) per customer per billing period and normalized for variations in monthly use and temperature conditions (monthly heating and cooling degree days). The Statistically Adjusted End-Use (SAE) model simulates end-use saturations and efficiency standards; while the "classic" regression models use a combination of sales trends and economic indicators (see Economics section for more details). The SAE model is used for the Residential, Small Demand, Small Non-Demand Commercial, and GSTOU3 Commercial class. The retail sales models are multiplied by the customer count forecast to produce the unmanaged sales forecast. Sales are adjusted to account for leap years. The monthly models are used to create an index that is then applied to the hourly retail sales models.

The monthly retail sales models use many years of history to pick up economic sensitivities. Hourly retail sales models are a combination of daily and hourly models, and use a shorter history to pick up the current load shape of each rate class which can change over time. The primary predictors for the hourly models are calendar identifiers (day of week, holidays, etc.) and weather. Predicting load on a daily basis is more accurate than a monthly model especially in the spring and fall when months have a combination of types of weather. Because of Covid, the hourly models used 2019 as a pre-Covid baseline. The economic index from the SAE model was used to adjust the residential model, and the average of the SAE and "classic" economic models were used to adjust the three smallest commercial rate classes. The "classic" model economic index was used to adjust all remaining models.

The economic index was applied to the hourly model in addition to a Covid adjustment. The Covid adjustment is based on ongoing Covid impact analysis. It reflects the assumed ongoing impact of Covid associated with increases in people working from home who will not return to full time office work ("new normal"). The following tables summarize the Covid adjustment assumptions. The load is multiplied by the adjustment factors to get the adjusted load so an adjustment factor of 1 has no impact while 1.03 increases load by 3%.

Residential						
	Pessimistic		Mid-case		Optimistic	
Hour Ending	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
9	1	1	1	1.03	1	1.04
10	1	1	1	1.055	1	1.06
11	1	1	1	1.06	1	1.065
12	1	1	1	1.06	1	1.065
13	1	1	1	1.06	1	1.065
14	1	1	1	1.07	1	1.07
15	1	1	1	1.07	1	1.07
16	1	1	1	1.075	1	1.075
17	1	1	1	1.075	1	1.075
18	1	1	1	1.06	1	1.065
19	1	1	1	1.05	1	1.055
20	1	1	1	1.04	1	1.045
21	1	1	1	1	1	1.04
22	1	1	1	1	1	1.035
Annual Impact	No adjustment		2.1-2.2% increase		2.6% increase	

Figure 4. Residential Covid Adjustment

Commercial 20-300kW						
	Pessimistic		Mid-case		Optimistic	
Hour Ending	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
7	0.98	0.97	0.98	0.97	1	1
8	0.98	0.97	0.98	0.97	1	1
9	0.98	0.96	0.98	0.96	1	1
10	0.98	0.95	0.98	0.95	1	1
11	0.98	0.95	0.98	0.95	1	1
12	0.98	0.95	0.98	0.95	1	1
13	0.98	0.95	0.98	0.95	1	1
14	0.98	0.96	0.98	0.96	1	1
15	0.98	0.96	0.98	0.96	1	1
16	0.98	0.97	0.98	0.97	1	1
17	0.98	0.97	0.98	0.97	1	1
18	0.98	0.97	0.98	0.97	1	1
19	0.98	0.97	0.98	0.97	1	1
20	0.98	0.97	0.98	0.97	1	1
21	0.98	0.97	0.98	0.97	1	1
Annual Impact	2.3-2.4% decrease		2.3-2.4% decrease		No adjustment	

Figure 5. Commercial 20-300kW Covid Adjustment

Commercial 300-500kW						
	Pessimistic		Mid-case		Optimistic	
Hour Ending	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
7	0.98	0.96	0.98	0.96	1	1
8	0.98	0.96	0.98	0.96	1	1
9	0.98	0.95	0.98	0.95	1	1
10	0.98	0.94	0.98	0.94	1	1
11	0.98	0.94	0.98	0.94	1	1
12	0.98	0.94	0.98	0.94	1	1
13	0.98	0.94	0.98	0.94	1	1
14	0.98	0.95	0.98	0.95	1	1
15	0.98	0.95	0.98	0.95	1	1
16	0.98	0.96	0.98	0.96	1	1
17	0.98	0.96	0.98	0.96	1	1
18	0.98	0.96	0.98	0.96	1	1
19	0.98	0.96	0.98	0.96	1	1
20	0.98	0.96	0.98	0.96	1	1
21	0.98	0.96	0.98	0.96	1	1
Annual Impact	2.8% decrease		2.8% decrease		No adjustment	

Figure 6. Commercial 300-500kW Covid Adjustment

Commercial 500-1,00kW						
	Pessimistic		Mid-case		Optimistic	
Hour Ending	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
7	0.98	0.97	0.98	0.97	1	1
8	0.98	0.97	0.98	0.97	1	1
9	0.98	0.96	0.98	0.96	1	1
10	0.98	0.95	0.98	0.95	1	1
11	0.98	0.95	0.98	0.95	1	1
12	0.98	0.95	0.98	0.95	1	1
13	0.98	0.95	0.98	0.95	1	1
14	0.98	0.96	0.98	0.96	1	1
15	0.98	0.96	0.98	0.96	1	1
16	0.98	0.97	0.98	0.97	1	1
17	0.98	0.97	0.98	0.97	1	1
18	0.98	0.97	0.98	0.97	1	1
19	0.98	0.97	0.98	0.97	1	1
20	0.98	0.97	0.98	0.97	1	1
21	0.98	0.97	0.98	0.97	1	1
Annual Impact	2.3% decrease		2.3% decrease		No adjustment	

Figure 7. Commercial 500-1000kW Covid Adjustment

Another new addition this year was to create two hourly residential load models – one for all residential and one for non-DER residential. The non-DER residential models attempts to exclude customers that already have DER technologies; at this point this is primarily solar and customers with EV rates. The separate models are applied differently to the counts to prevent double counting of existing DERs in the system. The results are recombined for the total rate class.

The following charts show the actual sales per customer class through 2019 and normal weather forecasted sales per customer prior to adjustments (unmanaged forecast) for future usage. The Agriculture and Lighting rate classes are not impacted by the economic scenarios.

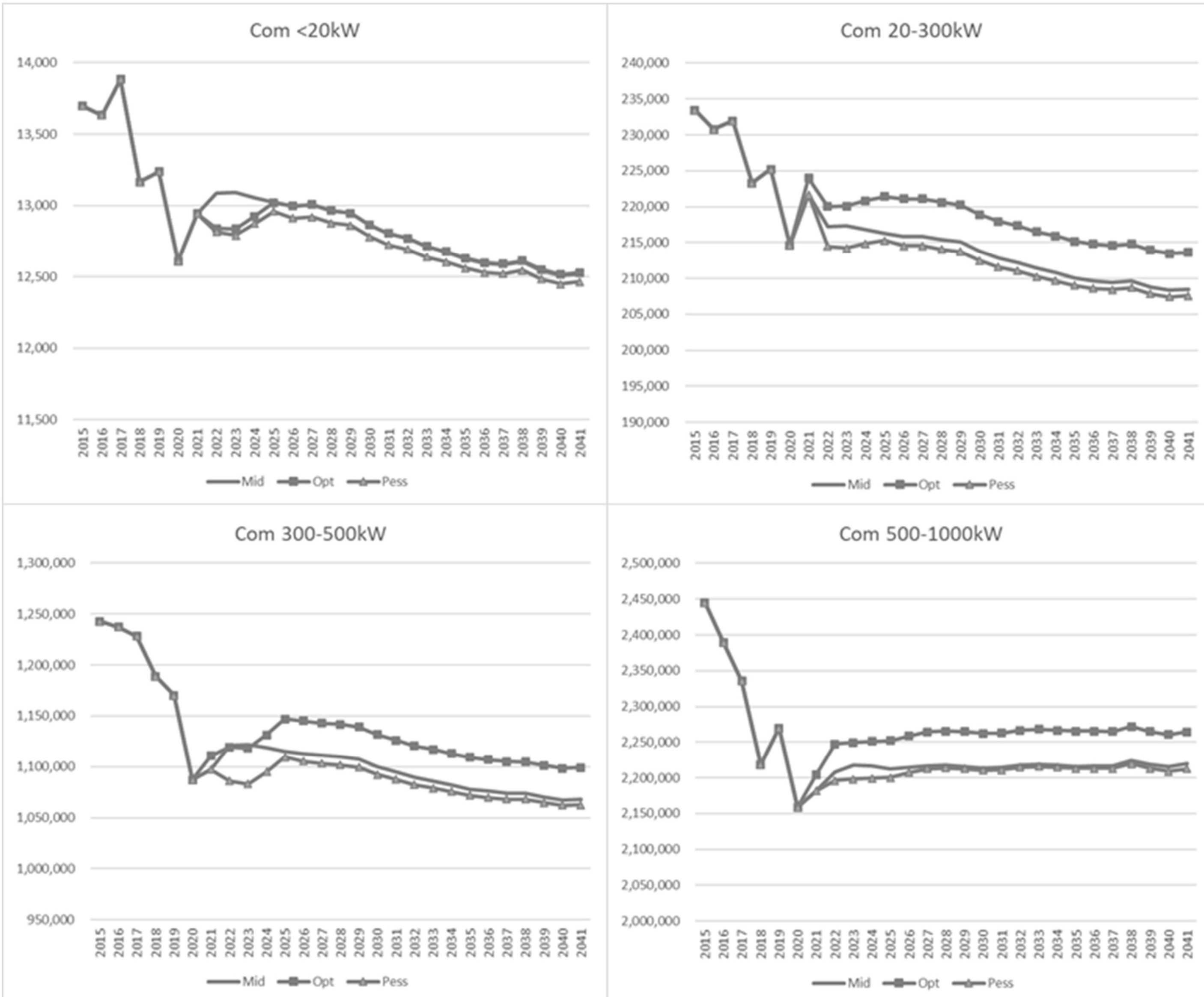

Figure 8. Unmanaged Annual Sales Per Customer by Rate Class

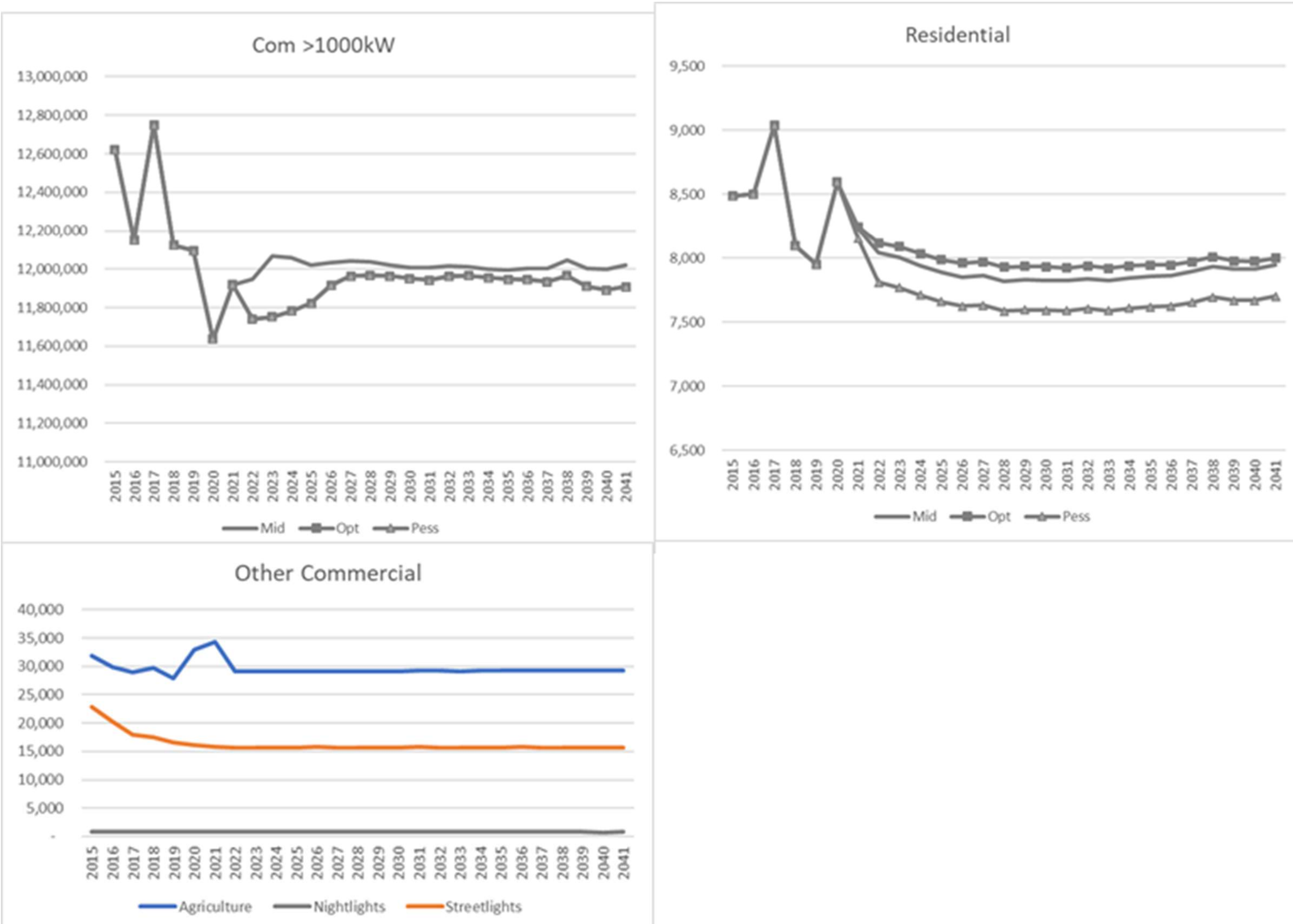

Figure 9. Unmanaged Annual Sales Per Customer by Rate Class (cont.)

The regression models' estimated parameters are presented in the table below.

Residential Sales - SAE

Variable	Definition	Coefficient	StdErr	T-Stat	P-Value
RSAE_Vars.XOther	Res XOther SAE Variable	27.355	0.521	52.495	0.00%
RSAE_CycWthr.XHeat	Res XHeat Cycle Month	16.33	1.129	14.458	0.00%
RSAE_CycWthr.XCool	Res XCool Cycle Month	35.256	1.327	26.577	0.00%
Bin.Feb	Binary = 1 in Feb	-62.837	8.695	-7.226	0.00%
Bin.Mar	Binary = 1 in Mar	-88.88	9.638	-9.222	0.00%
Bin.Apr	Binary = 1 in Apr	-102.867	11.16	-9.218	0.00%
Bin.May	Binary = 1 in May	-94.283	11.403	-8.268	0.00%
Bin.Jun	Binary = 1 in Jun	-36.856	9.098	-4.051	0.01%
Bin.Oct	Binary = 1 in Oct	-88.171	9.614	-9.171	0.00%
Bin.Nov	Binary = 1 in Nov	-96.533	11.47	-8.416	0.00%
Bin.Dec	Binary = 1 in Dec	-35.042	8.804	-3.98	0.01%
Bin.Jul	Binary = 1 in Jul	35.41	7.556	4.687	0.00%
Data series January 2010 to December 2019					

Residential Sales - Classic

Variable	Definition	Coefficient	StdErr	T-Stat	P-Value
CONST	Constant term	565.031	13.39	42.197	0.00%
Calendar.february	Binary = 1 in Feb	-65.999	6.433	-10.259	0.00%
Calendar.march	Binary = 1 in Mar	-97.464	7.54	-12.926	0.00%
Calendar.april	Binary = 1 in Apr	-113.469	9.423	-12.042	0.00%
Calendar.may	Binary = 1 in May	-101.167	9.452	-10.704	0.00%
Calendar.June	Binary = 1 in Jun	-53.596	7.288	-7.354	0.00%
Calendar.August	Binary = 1 in Aug	-17.152	6.559	-2.615	1.02%
Calendar.September	Binary = 1 in Sep	-34.387	6.614	-5.2	0.00%
Calendar.October	Binary = 1 in Oct	-88.713	8.121	-10.924	0.00%
Calendar.November	Binary = 1 in Nov	-96.302	9.698	-9.93	0.00%
Calendar.December	Binary = 1 in Dec	-40.371	6.584	-6.131	0.00%
Calendar.year_2019plus	if year >= 2019 then =1, else =0	-21.026	5.399	-3.894	0.02%
Account_Forecast.LED2018	if year >= 2018 then =1, else =0	-27.208	5.042	-5.396	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_HDD65_Sum	Sum HDD Base 65	0.426	0.024	17.822	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD65_Sum	Sum CDD bBase 65	0.816	0.065	12.57	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD75_Sum	Sum CDD bBase 75	0.663	0.176	3.768	0.03%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD85_Sum	Sum CDD bBase 85	2.106	0.689	3.057	0.28%
Account_Forecast.Unemployment	Unemployment rate	2.282	0.521	4.384	0.00%
Data series January 2010 to July 2021					

Small Non-Demand Commercial Sales (<20kW) - SAE

Variable	Definition	Coefficient	StdErr	T-Stat	P-Value
CSAE_Vars.XOther	Com XOther SAE Variable	6.865	0.055	125.883	0.00%
CSAE_CycWthr.XHeat	Res XHeat Cycle Month	20.693	2.114	9.788	0.00%
CSAE_CycWthr.XCool	Res XCool Cycle Month	19.256	0.664	29.009	0.00%
Bin.Apr	Binary = 1 in Apr	-59.689	10.715	-5.571	0.00%
Bin.May	Binary = 1 in May	-40.467	10.045	-4.028	0.02%
Bin.Oct	Binary = 1 in Oct	-98.102	9.687	-10.127	0.00%
Bin.Nov	Binary = 1 in Nov	-96.874	10.616	-9.125	0.00%
Bin.Dec	Binary = 1 in Dec	-58.496	9.825	-5.954	0.00%
Bin.Jul	Binary = 1 in Jul	24.73	10.012	2.47	1.62%
Data series January 2014 to December 2019					

Small Demand Commercial Sales (21-299kW) - SAE

Variable	Definition	Coefficient	StdErr	T-Stat	P-Value
CSAE_Vars.XOther	Com XOther SAE Variable	110.511	0.621	177.864	0.00%
CSAE_CycWthr.XHeat	Res XHeat Cycle Month	55.893	35.482	1.575	12.04%
CSAE_CycWthr.XCool	Res XCool Cycle Month	342.503	18.451	18.563	0.00%
Bin.Jan	Binary = 1 in Jan	874.696	196.94	4.441	0.00%
Bin.Feb	Binary = 1 in Feb	407.087	148.42	2.743	0.80%
Bin.Mar	Binary = 1 in Mar	539.738	137.49	3.926	0.02%
Bin.May	Binary = 1 in May	865.256	132.68	6.522	0.00%
Bin.Jun	Binary = 1 in Jun	1387.84	173.59	7.995	0.00%
Bin.Jul	Binary = 1 in Jul	1326.528	252.71	5.249	0.00%
Bin.Aug	Binary = 1 in Aug	785.631	273.01	2.878	0.55%
Bin.Sep	Binary = 1 in Sep	869.669	230.8	3.768	0.04%
Data series January 2014 to December 2019					

Small Commercial GS-TOU3 Sales (300-499kW) - SAE

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CSAE_Vars.XOther	Com XOther SAE Variable	646.967	8.201	78.887	0.00%
CSAE_CycWthr.XHeat	Res XHeat Cycle Month	-964.948	420.395	-2.295	2.53%
CSAE_CycWthr.XCool	Res XCool Cycle Month	2640.323	340.981	7.743	0.00%
Bin.Jan	Binary = 1 in Jan	5089.488	1978.687	2.572	1.26%
Bin.Apr	Binary = 1 in Apr	-5045.48	1662.405	-3.035	0.36%
Bin.May	Binary = 1 in May	-6111.16	2103.897	-2.905	0.52%
Bin.Jun	Binary = 1 in Jun	-11377.2	3539.052	-3.215	0.21%
Bin.Jul	Binary = 1 in Jul	-18786.1	5304.001	-3.542	0.08%
Bin.Aug	Binary = 1 in Aug	-24296.3	5719.123	-4.248	0.01%
Bin.Sep	Binary = 1 in Sep	-18163	4884.241	-3.719	0.05%
Bin.Oct	Binary = 1 in Oct	-13790.1	3110.808	-4.433	0.00%
Bin.Nov	Binary = 1 in Nov	-7657.47	1791.125	-4.275	0.01%
BillAdj.Jan2015	Binary = 1 in Jan 2015	-30719	3240.859	-9.479	0.00%
Data series January 2014 to December 2019					

Medium Commercial Gs-TOU2 Sales (500-999kW) - Classic

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CONST	Constant term	214710	3326.158	64.552	0.00%
Calendar.march	Binary = 1 in Mar	-6900.45	1939.833	-3.557	0.05%
Calendar.april	Binary = 1 in Apr	-17349	2224.949	-7.798	0.00%
Calendar.may	Binary = 1 in May	-13197.8	2268.92	-5.817	0.00%
Calendar.June	Binary = 1 in Jun	-5273.98	1956.648	-2.695	0.78%
Calendar.November	Binary = 1 in Nov	-5086.35	2350.452	-2.164	3.21%
Calendar.year_2012	if year = 2012 then =1, else =0	-9099.17	1909.485	-4.765	0.00%
Calendar.year_2013	if year = 2013 then =1, else =0	-11323.5	1892.546	-5.983	0.00%
Calendar.year_2015	if year = 2015 then =1, else =0	-5819.85	2051.306	-2.837	0.52%
Calendar.year_2016	if year = 2016 then =1, else =0	-9683.89	2110.017	-4.589	0.00%
Calendar.year_2017	if year = 2017 then =1, else =0	-15190.8	2196.644	-6.915	0.00%
Account_Forecast.LED2018	if year >= 2018 then =1, else =0	-23807.8	1730.299	-13.759	0.00%
Calendar.Feb2014	if Feb 2014 then =1, else =0	-30366.5	6157.54	-4.932	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD65_Sum	Sum HDD Base 65	51.327	8.204	6.256	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_HDD65_Sum	Sum CDD bBase 65	-21.496	5.438	-3.953	0.01%
Account_Forecast.Unemployment	Unemployment rate	-881.76	235.605	-3.743	0.03%
Data series January 2010 to July 2021					

Large Commercial GS-TOU1 Sales (>1000kW) - Classic

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CONST	Constant term	1114710	14156.84	78.74	0.00%
Calendar.march	Binary = 1 in Mar	-33414.1	13724.21	-2.435	1.60%
Calendar.april	Binary = 1 in Apr	-53902.9	13633.74	-3.954	0.01%
Calendar.may	Binary = 1 in May	-59781.3	13246.76	-4.513	0.00%
Calendar.year_2016	if year = 2016 then =1, else =0	-36918.2	14747	-2.503	1.33%
Calendar.Oct2011	if Oct 2011 then =1, else =0	192668.1	46655.8	4.13	0.01%
Account_Forecast.LED2018	if year >= 2018 then =1, else =0	-54883.4	11018.33	-4.981	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD65_Sum	Sum CDD bBase 65	197.241	28.158	7.005	0.00%
Account_Forecast.Unemployment	Unemployment rate	-14502.1	1455.301	-9.965	0.00%
Data series January 2010 to July 2021					

Agricultural Sales - Classic

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CONST	Constant term	1623.385	85.172	19.06	0.00%
Calendar.may	Binary = 1 in May	717.042	111.914	6.407	0.00%
Calendar.June	Binary = 1 in Jun	1591.259	162.995	9.763	0.00%
Calendar.July	Binary = 1 in Jul	1976.951	258.303	7.654	0.00%
Calendar.August	Binary = 1 in Aug	1955.413	265.91	7.354	0.00%
Calendar.September	Binary = 1 in Sep	1290.23	251.638	5.127	0.00%
Calendar.October	Binary = 1 in Oct	349.778	154.049	2.271	2.45%
Calendar.year_prior2012	if year<2012 then =1, else =0	-138.405	52.914	-2.616	0.97%
ActualAverageCycWthr_Sum.ActualAverageCyc_CDD65_Sum	Sum HDD Base 65	4.089	0.732	5.59	0.00%
ActualAverageCycWthr_Sum.ActualAverageCyc_HDD65_Sum	Sum CDD bBase 65	-1.324	0.218	-6.074	0.00%
Data series January 2007 to July 2021					

Streetlighs Sales - Classic

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CONST	Constant term	1503.999	5.261	285.894	0.00%
Calendar.january	Binary = 1 in Jan	66.361	8.078	8.215	0.00%
Calendar.february	Binary = 1 in Feb	41.221	8.078	5.103	0.00%
Calendar.may2017	Binary = 1 in May 2017	-197.644	17.86	-11.067	0.00%
Calendar.year_2018	if year = 2018 then =1, else =0	-60.429	7.125	-8.482	0.00%
Calendar.year_2019	if year = 2019 then =1, else =0	-125.805	7.125	-17.657	0.00%
Calendar.year_2020	if year = 2020 then =1, else =0	-168.604	7.125	-23.664	0.00%
Calendar.year_2021plus	if year => 2021 then =1, else =0	-203.856	8.275	-24.634	0.00%
Data series January 2017 to July 2021					

Nightlights Sales - Classic

Variable	Definition	Coefficier	StdErr	T-Stat	P-Value
CONST	Constant term	62.677	0.082	767.146	0.00%
Calendar.year_2008	if year = 2008 then =1, else =0	0.451	0.116	3.902	0.01%
Calendar.year_2009	if year = 2009 then =1, else =0	0.759	0.116	6.565	0.00%
Calendar.year_2010	if year = 2010 then =1, else =0	1.022	0.116	8.849	0.00%
Calendar.year_2011	if year = 2011 then =1, else =0	1.391	0.116	12.038	0.00%
Calendar.year_2012	if year = 2012 then =1, else =0	1.575	0.116	13.634	0.00%
Calendar.year_2013	if year = 2013 then =1, else =0	1.774	0.116	15.356	0.00%
Calendar.year_2014	if year = 2014 then =1, else =0	2.253	0.116	19.497	0.00%
Calendar.year_2015	if year = 2015 then =1, else =0	2.408	0.116	20.84	0.00%
Calendar.year_2016	if year = 2016 then =1, else =0	2.733	0.116	23.656	0.00%
Calendar.may2017	Binary = 1 in May 2017	-1.914	0.296	-6.476	0.00%
Calendar.year_2017	if year = 2017 then =1, else =0	3.099	0.118	26.233	0.00%
Calendar.year_2018	if year = 2018 then =1, else =0	4.098	0.116	35.468	0.00%
Calendar.year_2019	if year = 2019 then =1, else =0	3.968	0.116	34.345	0.00%
Calendar.year_2020	if year = 2020 then =1, else =0	2.404	0.116	20.806	0.00%
Calendar.year_2021plus	if year => 2021 then =1, else =0	1.455	0.135	10.811	0.00%
Data series January 2007 to July 2021					

Figure 10. Monthly Sales Models' Regression Statistics

Residential All - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	13.394	0.151	88.909	0.00%
DailyCalendar.Weekend	1.436	0.082	17.419	0.00%
DailyWeather.CDD60	0.318	0.021	15.233	0.00%
DailyWeather.HDD65	0.219	0.022	9.877	0.00%
DailyWeather.CDD70	0.836	0.025	33.448	0.00%
DailyCalendar.Y2017	2.075	0.076	27.197	0.00%
DailyCalendar.Y2018	0.629	0.076	8.244	0.00%
DailyCalendar.Monday	0.363	0.078	4.653	0.00%
DailyCalendar.Saturday	-0.651	0.098	-6.667	0.00%
DailyWeather.PriorDayCDD65	0.252	0.011	22.436	0.00%
DailyWeather.PriorDayHDD65	0.102	0.012	8.519	0.00%
DailyCalendar.Jan	2.677	0.158	16.939	0.00%
DailyCalendar.Feb	1.884	0.15	12.581	0.00%
DailyCalendar.Mar	1.449	0.206	7.029	0.00%
DailyCalendar.Jun	1.376	0.118	11.702	0.00%
DailyCalendar.Jul	1.885	0.128	14.755	0.00%
DailyCalendar.Aug	1.133	0.126	8.972	0.00%
DailyCalendar.Nov	0.98	0.129	7.597	0.00%
DailyCalendar.Dec	2.733	0.154	17.802	0.00%
DailyWeather.HDD55	0.085	0.028	3.056	0.23%
DailyCalendar.MarchDST	-0.894	0.217	-4.11	0.00%
DailyWeather.FallCDD65	-0.237	0.016	-15.257	0.00%
DailyHoliday.Christmas	1.635	0.489	3.345	0.09%
DailyHoliday.Thanksgiving	2.06	0.489	4.214	0.00%
DailyHoliday.PresidentsDay	1.284	0.493	2.606	0.93%
DailyHoliday.MemorialDay	1.813	0.561	3.23	0.13%
DailyHoliday.NewYearDay	1.672	0.489	3.421	0.07%
DailyCalendar.SummerTOD	-0.662	0.115	-5.779	0.00%
DailyHoliday.Christmas_Eve	1.817	0.562	3.234	0.13%
DailyCalendar.Y2020	-0.913	0.151	-6.054	0.00%
DailyCalendar.COVID	1.735	0.219	7.938	0.00%
DailyCalendar.COVID_WD	0.653	0.168	3.887	0.01%
DailyWeather.COVID_CDD65	-0.041	0.011	-3.65	0.03%
Data Series January 2017 to December 2020				

Residential Non-DER - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	13.82	0.143	96.369	0.00%
DailyCalendar.Weekend	1.442	0.079	18.347	0.00%
DailyWeather.CDD60	0.314	0.02	15.796	0.00%
DailyWeather.HDD65	0.196	0.021	9.3	0.00%
DailyWeather.CDD70	0.811	0.024	34.106	0.00%
DailyCalendar.Y2017	1.796	0.073	24.74	0.00%
DailyCalendar.Y2018	0.611	0.073	8.409	0.00%
DailyCalendar.Monday	0.363	0.074	4.887	0.00%
DailyCalendar.Saturday	-0.663	0.093	-7.138	0.00%
DailyWeather.PriorDayCDD65	0.239	0.011	22.333	0.00%
DailyWeather.PriorDayHDD65	0.105	0.011	9.242	0.00%
DailyCalendar.Jan	2.216	0.15	14.724	0.00%
DailyCalendar.Feb	1.639	0.143	11.499	0.00%
DailyCalendar.Mar	1.228	0.196	6.26	0.00%
DailyCalendar.Jun	1.636	0.112	14.618	0.00%
DailyCalendar.Jul	2.086	0.122	17.156	0.00%
DailyCalendar.Aug	1.203	0.12	10.01	0.00%
DailyCalendar.Nov	0.66	0.123	5.379	0.00%
DailyCalendar.Dec	2.245	0.149	15.066	0.00%
DailyWeather.HDD55	0.104	0.027	3.923	0.01%
DailyCalendar.MarchDST	-0.718	0.207	-3.468	0.06%
DailyWeather.FallCDD65	-0.252	0.015	-17.072	0.00%
DailyHoliday.Christmas	1.565	0.467	3.354	0.08%
DailyHoliday.Thanksgiving	2.008	0.465	4.316	0.00%
DailyHoliday.PresidentsDay	1.348	0.469	2.874	0.41%
DailyHoliday.MemorialDay	1.939	0.534	3.63	0.03%
DailyHoliday.NewYearDay	1.657	0.465	3.563	0.04%
DailyCalendar.SummerTOD	-0.478	0.109	-4.385	0.00%
DailyHoliday.Christmas_After	0.502	0.247	2.029	4.27%
DailyHoliday.Christmas_Eve	1.749	0.536	3.263	0.11%
DailyCalendar.Y2020	-0.658	0.144	-4.586	0.00%
DailyCalendar.COVID	1.641	0.208	7.886	0.00%
DailyCalendar.COVID_WD	0.576	0.16	3.6	0.03%
DailyWeather.COVID_CDD65	-0.031	0.011	-2.967	0.31%
Data Series January 2017 to December 2020				

Agriculture

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	84.382	1.14	73.999	0.00%
DailyCalendar.Jan	-41.857	1.902	-22.007	0.00%
DailyCalendar.Feb	-38.379	1.828	-20.991	0.00%
DailyCalendar.Mar	-43.925	1.751	-25.092	0.00%
DailyCalendar.Apr	-41.223	1.531	-26.919	0.00%
DailyCalendar.Jun	42.172	1.533	27.515	0.00%
DailyCalendar.Jul	68.69	1.738	39.522	0.00%
DailyCalendar.Aug	57.667	1.699	33.944	0.00%
DailyCalendar.Sep	22.359	1.439	15.543	0.00%
DailyCalendar.Nov	-27.363	1.668	-16.4	0.00%
DailyCalendar.Dec	-39.084	1.913	-20.431	0.00%
DailyWeather.CDD60	0.557	0.132	4.216	0.00%
DailyWeather.HDD65	-1.493	0.189	-7.907	0.00%
DailyWeather.HDD55	1.522	0.275	5.532	0.00%
DailyWeather.PriorDayCDD65	0.892	0.133	6.729	0.00%
DailyWeather.FallCDD65	-1.717	0.177	-9.676	0.00%
DailyHoliday.IndependenceDay	-12.532	5.776	-2.17	3.02%
DailyCalendar.SatMayToOct	-9.733	1.303	-7.469	0.00%
DailyCalendar.SunMayToOct	-29.304	1.303	-22.486	0.00%
DailyCalendar.Y2020	5.191	1.083	4.792	0.00%
DailyCalendar.COVID_WE	-4.426	1.829	-2.42	1.56%
DailyWeather.COVID_CDD65	0.439	0.113	3.867	0.01%
Data Series January 2017 to December 2020				

Streetlights

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	44.797	0.076	587.855	0.00%
DailyCalendar.Jan	2.581	0.106	24.246	0.00%
DailyCalendar.Feb	1.24	0.11	11.305	0.00%
DailyCalendar.Mar	0.232	0.108	2.16	3.09%
DailyCalendar.Apr	-0.492	0.108	-4.578	0.00%
DailyCalendar.Jun	-1.409	0.108	-13.1	0.00%
DailyCalendar.Jul	-0.518	0.106	-4.863	0.00%
DailyCalendar.Aug	0.4	0.106	3.761	0.02%
DailyCalendar.Sep	1.133	0.108	10.532	0.00%
DailyCalendar.Nov	2.542	0.108	23.636	0.00%
DailyCalendar.Dec	3.15	0.106	29.598	0.00%
DailyCalendar.Y2017	2.897	0.072	40.364	0.00%
DailyCalendar.Y2018	2.157	0.07	30.831	0.00%
DailyCalendar.Y2020	-1.482	0.07	-21.195	0.00%
Data Series January 2017 to December 2020				

Nightlighting

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	2.055	0	5438.005	0.00%
DailyCalendar.Jan	0.557	0.001	898.886	0.00%
DailyCalendar.Feb	0.464	0.001	728.255	0.00%
DailyCalendar.Mar	0.185	0.001	286.707	0.00%
DailyCalendar.May	-0.372	0.001	-575.199	0.00%
DailyCalendar.Jun	-0.369	0.001	-622.204	0.00%
DailyCalendar.Jul	-0.369	0.001	-628.656	0.00%
DailyCalendar.Aug	-0.092	0.001	-156.795	0.00%
DailyCalendar.Oct	0.37	0.001	629.638	0.00%
DailyCalendar.Nov	0.554	0.001	934.523	0.00%
DailyCalendar.Dec	0.739	0.001	1258.785	0.00%
DailyCalendar.Y2017	-0.034	0	-103.295	0.00%
DailyCalendar.Y2020	-0.07	0.001	-89.483	0.00%
DailyCalendar.COVID	0.009	0.001	10.348	0.00%
Data Series January 2017 to December 2020				

Commercial <20kW - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	32.454	0.156	208.412	0.00%
DailyCalendar.Weekend	-7.763	0.081	-95.902	0.00%
DailyWeather.CDD60	0.409	0.021	19.157	0.00%
DailyWeather.HDD65	0.097	0.022	4.338	0.00%
DailyWeather.CDD70	0.224	0.025	8.795	0.00%
DailyCalendar.Y2017	1.338	0.064	20.973	0.00%
DailyCalendar.Monday	-0.659	0.081	-8.187	0.00%
DailyCalendar.Saturday	2.108	0.099	21.351	0.00%
DailyWeather.PriorDayCDD65	0.194	0.011	16.95	0.00%
DailyWeather.PriorDayHDD65	0.089	0.012	7.284	0.00%
DailyCalendar.Jan	2.266	0.175	12.94	0.00%
DailyCalendar.Feb	1.59	0.166	9.577	0.00%
DailyCalendar.Mar	1.024	0.219	4.675	0.00%
DailyCalendar.Jun	0.472	0.121	3.911	0.01%
DailyCalendar.Jul	0.643	0.133	4.828	0.00%
DailyCalendar.Aug	0.95	0.13	7.304	0.00%
DailyCalendar.Nov	0.555	0.146	3.812	0.02%
DailyCalendar.Dec	1.629	0.172	9.471	0.00%
DailyWeather.HDD55	0.128	0.028	4.505	0.00%
DailyCalendar.MarchDST	-0.984	0.22	-4.474	0.00%
DailyWeather.FallCDD65	-0.033	0.016	-2.106	3.53%
DailyHoliday.Christmas	-9.958	0.496	-20.097	0.00%
DailyHoliday.Thanksgiving	-9.152	0.495	-18.497	0.00%
DailyHoliday.PresidentsDay	-1.626	0.498	-3.262	0.12%
DailyHoliday.MemorialDay	-7.711	0.568	-13.57	0.00%
DailyHoliday.NewYearDay	-7.602	0.495	-15.372	0.00%
DailyCalendar.SummerTOD	0.369	0.103	3.571	0.04%
DailyCalendar.Apr	-0.611	0.129	-4.732	0.00%
DailyHoliday.Thanksgiving_Afte	-5.265	0.495	-10.639	0.00%
DailyHoliday.MLK	-1.312	0.499	-2.628	0.87%
DailyHoliday.IndependenceDay	-8.412	0.495	-16.993	0.00%
DailyHoliday.LaborDay	-8.641	0.507	-17.058	0.00%
DailyHoliday.VeteransDay	-1.365	0.494	-2.762	0.58%
DailyHoliday.Christmas_After	-1.715	0.263	-6.528	0.00%
DailyHoliday.Christmas_Eve	-5.156	0.569	-9.055	0.00%
DailyWeather.COVID_CDD65	-0.17	0.011	-15.254	0.00%
DailyCalendar.Y2020	-0.489	0.147	-3.323	0.09%
DailyCalendar.COVID	-1.133	0.186	-6.096	0.00%
Data Series January 2017 to December 2020				

Commercial 20-300kW - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	589.526	2.003	294.307	0.00%
DailyCalendar.Weekend	-124.459	1.109	-112.177	0.00%
DailyWeather.CDD60	6.442	0.273	23.623	0.00%
DailyWeather.HDD65	-1.222	0.247	-4.951	0.00%
DailyWeather.CDD70	3.489	0.331	10.531	0.00%
DailyCalendar.Y2017	14.057	0.827	17	0.00%
DailyCalendar.Monday	-5.806	1.08	-5.376	0.00%
DailyCalendar.Saturday	25.882	1.276	20.29	0.00%
DailyWeather.PriorDayCDD65	2.745	0.146	18.773	0.00%
DailyCalendar.Jan	12.686	1.655	7.664	0.00%
DailyCalendar.Feb	10.511	1.633	6.436	0.00%
DailyCalendar.Mar	7.182	2.486	2.889	0.39%
DailyCalendar.Jun	2.882	1.418	2.032	4.23%
DailyCalendar.Aug	10.716	1.459	7.344	0.00%
DailyCalendar.Nov	-4.052	1.502	-2.698	0.71%
DailyWeather.HDD55	3.069	0.358	8.565	0.00%
DailyCalendar.MarchDST	-9.758	2.819	-3.461	0.06%
DailyWeather.FallCDD65	-1.195	0.194	-6.168	0.00%
DailyCalendar.SummerTOD	7.901	1.417	5.574	0.00%
DailyCalendar.Apr	-7.607	1.54	-4.94	0.00%
DailyCalendar.Sep	4.375	1.446	3.026	0.25%
DailyCalendar.Friday	-4.996	1.046	-4.775	0.00%
DailyHoliday.Christmas	-146.415	6.351	-23.055	0.00%
DailyHoliday.Thanksgiving	-138.818	6.39	-21.723	0.00%
DailyHoliday.Thanksgiving_Aft	-75.142	6.444	-11.661	0.00%
DailyHoliday.MLK	-38.549	6.447	-5.979	0.00%
DailyHoliday.PresidentsDay	-48.873	6.442	-7.587	0.00%
DailyHoliday.MemorialDay	-100.369	7.33	-13.693	0.00%
DailyHoliday.IndependenceDa	-97.291	6.33	-15.37	0.00%
DailyHoliday.LaborDay	-105.145	6.522	-16.122	0.00%
DailyHoliday.ColumbusDay	-14.029	6.394	-2.194	2.84%
DailyHoliday.VeteransDay	-25.601	6.39	-4.007	0.01%
DailyHoliday.NewYearDay	-97.664	6.383	-15.3	0.00%
DailyHoliday.Christmas_After	-35.213	3.335	-10.557	0.00%
DailyHoliday.Christmas_Eve	-71.223	7.335	-9.711	0.00%
DailyCalendar.Y2020	8.591	1.901	4.519	0.00%
DailyCalendar.COVID	-44.206	2.484	-17.794	0.00%
DailyCalendar.COVID_WE	16.097	2.186	7.365	0.00%
DailyWeather.COVID_CDD65	-2.434	0.144	-16.852	0.00%
Data Series January 2017 to December 2020				

Commercial 300-500kW - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	3234.818	7.499	431.37	0.00%
DailyCalendar.Jan	56.924	8.034	7.085	0.00%
DailyCalendar.Jul	-52.521	8.29	-6.335	0.00%
DailyCalendar.Aug	26.526	8.089	3.279	0.11%
DailyCalendar.Y2017	131.52	5.299	24.821	0.00%
DailyCalendar.Y2018	65.906	5.304	12.425	0.00%
DailyCalendar.Weekend	-812.282	6.252	-129.931	0.00%
DailyCalendar.Monday	-27.937	6.148	-4.544	0.00%
DailyCalendar.Friday	-53.03	5.956	-8.903	0.00%
DailyCalendar.Saturday	119.881	7.264	16.503	0.00%
DailyWeather.CDD60	22.174	1.057	20.987	0.00%
DailyWeather.HDD65	-3.08	0.538	-5.729	0.00%
DailyWeather.CDD70	16.301	1.416	11.513	0.00%
DailyWeather.PriorDayCDD65	11.071	0.834	13.274	0.00%
DailyHoliday.Christmas	-830.392	35.927	-23.113	0.00%
DailyHoliday.Thanksgiving	-723.313	35.904	-20.146	0.00%
DailyHoliday.Thanksgiving_After	-414.31	36.162	-11.457	0.00%
DailyHoliday.MLK	-306.045	36.683	-8.343	0.00%
DailyHoliday.PresidentsDay	-346.899	36.296	-9.558	0.00%
DailyHoliday.MemorialDay	-532.86	41.671	-12.787	0.00%
DailyHoliday.IndependenceDay	-523.116	36.425	-14.361	0.00%
DailyHoliday.LaborDay	-542.49	36.836	-14.727	0.00%
DailyHoliday.ColumbusDay	-77.346	36.242	-2.134	3.30%
DailyHoliday.VeteransDay	-189.109	35.901	-5.267	0.00%
DailyHoliday.NewYearDay	-640.16	36.371	-17.601	0.00%
DailyHoliday.Christmas_After	-242.174	18.518	-13.078	0.00%
DailyHoliday.Christmas_Eve	-370.588	41.563	-8.916	0.00%
DailyWeather.COVID_CDD65	-10.623	0.782	-13.591	0.00%
DailyCalendar.COVID	-178.645	13.003	-13.739	0.00%
DailyCalendar.COVID_WE	145.167	11.867	12.233	0.00%
DailyCalendar.Y2020	-96.834	10.5	-9.222	0.00%
Data Series January 2017 to December 2020				

Commercial 500-1000kW - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	6511.579	16.693	390.088	0.00%
DailyCalendar.Y2017	129.324	10.491	12.327	0.00%
DailyCalendar.Y2018	-115.861	10.507	-11.027	0.00%
DailyCalendar.Apr	-155.657	17.186	-9.057	0.00%
DailyCalendar.May	-80.593	17.186	-4.689	0.00%
DailyCalendar.Jun	-124.243	15.484	-8.024	0.00%
DailyCalendar.Jul	-205.147	16.36	-12.54	0.00%
DailyCalendar.Weekend	-1645.107	12.689	-129.648	0.00%
DailyCalendar.Sunday	-286.938	14.884	-19.278	0.00%
DailyCalendar.Monday	-88.638	12.487	-7.098	0.00%
DailyCalendar.Friday	-131.343	12.202	-10.764	0.00%
DailyCalendar.MarchDST	-140.393	20.116	-6.979	0.00%
DailyHoliday.Christmas	-2028.472	73.487	-27.603	0.00%
DailyHoliday.Thanksgiving	-1866.12	73.506	-25.387	0.00%
DailyHoliday.Thanksgiving_After	-1175.922	74.01	-15.889	0.00%
DailyHoliday.MLK	-661.553	74.347	-8.898	0.00%
DailyHoliday.PresidentsDay	-893.772	74.132	-12.057	0.00%
DailyHoliday.MemorialDay	-1761.778	86.488	-20.37	0.00%
DailyHoliday.IndependenceDay	-1460.883	74.568	-19.591	0.00%
DailyHoliday.LaborDay	-1671.81	75.047	-22.277	0.00%
DailyHoliday.VeteransDay	-420.515	73.565	-5.716	0.00%
DailyHoliday.NewYearDay	-1720.144	73.649	-23.356	0.00%
DailyHoliday.NewYearEve	-238.089	78.911	-3.017	0.26%
DailyHoliday.Christmas_After	-584.894	40.385	-14.483	0.00%
DailyHoliday.Christmas_Eve	-1119.786	84.996	-13.175	0.00%
DailyWeather.CDD60	41.288	2.235	18.474	0.00%
DailyWeather.HDD65	-11.509	1.115	-10.325	0.00%
DailyWeather.CDD70	19.192	2.946	6.514	0.00%
DailyWeather.PriorDayCDD65	23.888	1.695	14.093	0.00%
DailyCalendar.COVID	-486.884	18.547	-26.251	0.00%
DailyCalendar.COVID_WE	395.751	24.3	16.286	0.00%
DailyWeather.COVID_CDD65	-14.246	1.599	-8.91	0.00%
Data Series January 2017 to December 2020				

Commercial >1000kW - Daily Usage

Variable	Coefficient	StdErr	T-Stat	P-Value
CONST	33730.257	56.975	592.017	0.00%
DailyCalendar.Y2017	1652.146	55.083	29.994	0.00%
DailyCalendar.Apr	-811.579	99.693	-8.141	0.00%
DailyCalendar.May	-1124.612	98.856	-11.376	0.00%
DailyCalendar.Jun	-1100.742	89.971	-12.234	0.00%
DailyCalendar.Jul	-749.704	95.794	-7.826	0.00%
DailyCalendar.Weekend	-3526.213	72.143	-48.878	0.00%
DailyCalendar.Sunday	-903.156	87.146	-10.364	0.00%
DailyCalendar.Monday	-321.655	70.963	-4.533	0.00%
DailyCalendar.MarchDST	-829.348	118.111	-7.022	0.00%
DailyWeather.CDD60	157.106	7.961	19.735	0.00%
DailyWeather.HDD55	-86.402	9.111	-9.483	0.00%
DailyWeather.PriorDayCDD65	64.038	9.69	6.609	0.00%
DailyHoliday.Christmas	-5464.947	430.278	-12.701	0.00%
DailyHoliday.Thanksgiving	-4374.197	430.052	-10.171	0.00%
DailyHoliday.Thanksgiving_After	-3899.499	430.216	-9.064	0.00%
DailyHoliday.MLK	-1441.236	436.229	-3.304	0.10%
DailyHoliday.PresidentsDay	-2462.393	434.562	-5.666	0.00%
DailyHoliday.MemorialDay	-3735.615	506.495	-7.375	0.00%
DailyHoliday.IndependenceDay	-3958.411	436.114	-9.077	0.00%
DailyHoliday.LaborDay	-4111.437	439.247	-9.36	0.00%
DailyHoliday.VeteransDay	-1305.999	430.491	-3.034	0.25%
DailyHoliday.NewYearDay	-5474.372	431.511	-12.687	0.00%
DailyHoliday.Christmas_After	-2525.34	221.127	-11.42	0.00%
DailyHoliday.Christmas_Eve	-3040.022	498.141	-6.103	0.00%
DailyCalendar.Y2020	-1358.719	118.973	-11.42	0.00%
DailyCalendar.COVID	332.352	148.126	2.244	2.50%
DailyCalendar.COVID_WE	1059.949	142.208	7.454	0.00%
DailyWeather.COVID_CDD65	-89.677	9.211	-9.736	0.00%
Data Series January 2017 to December 2020				

Figure 11. Daily Energy Usage Sales Models' Regression Statistics

Hourly System Models

SMUD's hourly system load forecast models are based on statistical regression techniques which normalized electricity use for variation in temperatures, seasonal use, and recent trends in electricity use behaviors.

There is one model for each hour of the day, therefore there are 24 separate regression equations together. To account for the historical period before Residential Time of Day (RTOD), which is before summer of 2020, there are more than one equation for summer peak hours (Weekday afternoon hours, HE13 to HE24, from June to September). The following tables shows the model details for different seasons, day types and hours.

Season	**Day type**	**Hours**	**Model type**	**Model details**
Summer Peak (Jun to Sept)	Weekdays	HE13 to HE24	Hour by hour models for TOD days	Two stage regression equations: • Base models provide instrumental prediction for 2014 to 2018 (before RTOD) • Second stage regressions using the instrumental prediction to capture the difference of load before RTOD. Forecast produced here for 2020 and beyond will be post RTOD
		HE01 to HE12	One combined hourly model	Combined hourly model for off peak hours on TOD days
	Weekend/ Holiday (July 4th, Labor Day)	All hours	One combined hourly model	Combined hourly model for all hours of summer weekend and holidays
Other Months (1-5 and 10-12)	All day types	All hours	One combined hourly model	Combined hourly model for all day types and all hours of off-peak months

Figure 12. System Model Details

In each hourly model, the dependent variable is the system load normalized by net customer accounts. The specific measure of system load is not the conventional SMUD's EMS hourly loads, but a modified measure of system load called implied system load or gross system load.

Implied System Load = EMS hourly load + NEM PV generation (excluding super large NEM PVs) (S1)

The reason to exclude the super large NEM PVs (installed capacity >= 500kw) is that those PVs are already included in the EMS hourly load, so it will not be double counted. The implied load (or gross load) measures the total end-use power consumption of customers that are either delivered by SMUD generation or customer generation (NEM PV). The implied load captures the total (gross) consumption of customers and is invariant to the variation of PV generation due to the growth of PV over the years or the fluctuation of solar irradiance from season to season and day to day. So, this approach will help filter out the change and fluctuation of PV generation and produce more accurate hourly system load forecast.

The final forecast will still be made in terms of EMS load since that is the measure of system load directly observed or reported. To do that we will transform equation (S1) as:

$$\text{EMS load (forecast)} = \text{Implied load(forecast)} - \text{NEM PV(forecast)} \qquad \text{(S2)}$$

A representative regression model for HE17 and its estimated parameters are presented in the following table.

HE17_2S_Jun10 Regression Equation

Dependent variable: implied system load (HE17)

Variable	Coefficient	StdErr	T-Stat	P-Value	Definition
CONST	1.795	0.028	64.911	0.00%	Constant term
Sac_temp.Norm_CDD65	0.032	0.003	11.954	0.00%	Historical Average CDD65 for each day
loads.June	-0.033	0.017	-1.935	5.35%	if Month=June then=1, else=0
loads.September	-0.105	0.012	-8.894	0.00%	if Month=September then=1, else=0
loads.cdd65	0.034	0.002	18.042	0.00%	CDD65, Cooling degree days
loads.CRC	0.328	0.043	7.630	0.00%	Cooling Response Curve, a non-linear load - temperature response curve
loads.lag1_cdd65	0.020	0.001	23.091	0.00%	One day prior CDD65
loads.lag2_cdd65	0.002	0.001	2.275	2.32%	Two day prior CDD65
loads.lag3_cdd65	-0.001	0.001	-1.312	18.99%	Three-day prior CDD65
loads.lag4_cdd65	0.004	0.001	6.442	0.00%	Four-day prior CDD65
HourlyLoad_pred.Load17	0.009	0.002	3.737	0.00%	Estimated hourly load for 2014 to 2018
loads.monday	0.053	0.007	7.523	0.00%	if Day=Monday then=1, else=0
loads.Tuesday	0.044	0.007	7.523	0.00%	if Day=Tuesday then=1, else=0
loads.Wednesday	0.055	0.007	7.901	0.00%	if Day=Wednesday then=1, else=0
loads.Thursday	0.051	0.006	8.481	0.00%	if Day=Thursday then=1, else=0
loads.Y2014_2018_trend	0.074	0.005	14.783	0.00%	constrained year 2015 to 2018 trend
loads.cdd65_june	0.008	0.001	6.982	0.12%	CDD65*June
loads.maxtempCDD	0.036	0.002	20.460	0.00%	Maxtemp - 65

Loads.COVID_Adj	-0.309	0.034	-9.074	0.00%	For Year 2020: if (DATE>=#3/16/2020# and Month<6) then=1, else:
					if (Month>5 and month <10) then=0.35, else:
					if (Month>=10) then=-0.11, else=0.
					For Year 2021=0.16, else=0.

AR(1)	0.366	0.020	18.482	0.00%	auto correlation coefficient

Sample data: Summer Weekday, 2014 to 2021

Figure 13. System Model Sample Regression Equations

The following table shows the combined hourly regression model for non-summer hours.

Hourly Regression Model Coefficients for select hours

Dependent variable: implied system load

Variable	Definition	Hour1 to Hour7	Hour8	Hour9-Hour17	Hour18	Hour19-Hour23	Hour24
Constant	Constant term	not shown	1.872	not shown	1.503	not shown	1.363
Norm_HDD65	Historical Average HDD65 for each day		0.002		0.010		0.004
Norm_CDD65	Historical Average CDD65 for each day		-0.001		0.023		0.014
January	January (if Month=January, then=1, else=0)		0.038		-0.067		-0.038
February	February		0.025		-0.174		-0.043
March	March		0.073		-0.041		-0.007
May	May		0.020		0.134		0.054
October	October		0.075		0.068		0.020
November	November		-0.051		-0.043		-0.057
Friday	Friday		-0.011		-0.020		0.019
Saturday	Saturday		-0.282		-0.166		-0.007
Sunday	Sunday		-0.348		-0.141		-0.028
winter	Month 11, 12, 1, 2		0.099		0.179		0.035
winter_Sunday	Winter*Sunday		-0.020		0.023		-0.013
winter_Friday	Winter*Friday		0.006		-0.023		0.003
winter_Saturday	Winter*Saturday		-0.033		0.000		0.004
cdd65	CDD65, Cooling degree days		0.010		0.035		0.021
CRC	Cooling Response Curve, a non-linear load - temperature response curve				1.452		0.441
lag1_cdd65	One day prior CDD65		0.007		0.018		0.000
lag2_cdd65	Two days prior CDD65		0.001		0.004		0.001
lag3_cdd65	Three days prior CDD65		0.002		-0.001		0.001
lag4_cdd65	Four days prior CDD 65		0.000		0.004		0.002

cdd65_october	CDD65*October		-0.006		-0.020		-0.013
hdd65	HDD65		0.006		0.004		0.008
hdd50	HDD50		-0.007		0.016		0.014
lag1_hdd65	One day prior HDD65		0.007		0.001		0.001
lag2_hdd65	Two days prior HDD65		0.001		0.002		0.000
lag3_hdd65	Three days prior HDD65		0.001		0.001		0.001
mintemp	Min Temperature		-0.004		0.005		0.002
mintemphdd	Min Temperature HDD		0.018				
maxtemphdd	Max Temperature HDD				0.013		
Y2014_2018_trend_nonSummer	constrained years 2014 to 2018 trend		0.040		0.050		0.053
New Year	New Year's day		-0.396		-0.127		-0.018
MLK	MLK day		-0.176		-0.028		-0.016
Presidents	Presidents' day		-0.223		-0.007		-0.007
Memorial	Memorial day		-0.291		-0.099		0.001
Thanksgiving	Thanksgiving day		-0.265		-0.377		-0.066
Aft_Thx	Day after Thanksgiving		-0.287		-0.115		-0.035
B4Xmas	Day before Christmas		-0.159		-0.106		0.017
Christmas	Christmas day		-0.309		-0.295		-0.065
Smoke2020	if (DATE>=#9/1/2020# and DATE<=#10/18/2020#) then 1 else 0 endif		-0.065		-0.007		0.011
COVID_Adj	For Year 2020: if (DATE>=#3/16/2020# and Month<6) then=1, else: if (Month>5 and month <10) then=0.35, else: if (Month>=10) then=-0.11, else=0. For Year 2021=0.16, else=0.		-0.129		-0.100		-0.049

Sample data: Non-Summer days, 2014 to 2020

Figure 14. System Models' Regression Statistics

Weather

Weather can vary significantly year to year. All historical customer data used in the forecast is weather normalized to remove the year to year weather fluctuations. All future weather is forecast to be normal. Normal weather is the average number of cooling degree days and heating degree days[1] based on weather history and is spread over the year to create a typical weather scenario.

Both sales and load models use cooling degrees and heating degrees as independent variables in the regression equations. In the load model, daily high temperatures are also used to explain the rapid change in loads during heat storms.

Temperature data is from the National Weather Service's Sacramento City and Executive Airport weather stations. The daily temperatures from these weather stations are averaged to develop a composite temperature index for the Sacramento area. Daily composite temperatures are used to construct cooling and heating degree day variables in the regression models.

Historically, SMUD has used 30 years of history and updated its typical weather every 10 years. To better capture current weather trends, last year SMUD updated its typical weather to use 20 years of history (2000-2019). Additionally, a weather trend was added to it to take into account changes in the weather. Weather data was grouped by month and each year's hottest day from each month is averaged, then the second hottest day for each period is averaged, and so on until all days are ranked. The resulting weather is then assigned to dates based on when that type of weather occurs. For example, the hottest May days are assigned towards the end of the month. Days were also assigned so peaks occur on weekdays and clustered to create a July heat storm. This year, SMUD updated the typical weather to 2001-2020, and in future will update the typical weather every 5 years.

The traditional typical year was enhanced by applying a climate trend. The climate trend assumes the continued trend of increase or decrease in temperature. For each month, the average maximum and minimum temperature was calculated. The year to year trend was calculated into a formula for each month. The trend was continued out and the percentage

[1] Cooling degree days and heating degree days are calculated on a daily basis by averaging the high and low daily temperature, and then taking the difference between it and some base temperature (most commonly 65). For example, if the high was 100 and the low was 70, the cooling degree days with a base of 65 is ((100+70)/2)-65 = 20. Heating degree days are calculated when the average is below the base. (The forecast uses multiple base leveling depending on the rate class being forecast.)

difference from the base period (2001-2020) was calculated. The percentage change was then applied to the maximum and minimum temperatures in the traditional typical year.

While the high and low temperature is used to develop the typical weather year, Cooling Degree Days (CDD) and Heating Degree Days (HDD) provide a good indication of load impact. The following table presents the normal temperatures and degree days used in the forecast for 2022. The average daily temperature is the average of the daily high and low temperatures. The High and Low temperatures are the maximum and minimum daily temperatures, respectively, for each month. The cooling degree (CDD65) and heating degree (HDD65) variables are the sum of the daily cooling and heating degrees for the calendar month with 65 degrees Fahrenheit as the base temperature.

2022	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	66.68	69.50	79.52	89.22	95.70	104.30	106.31	104.72	102.14	90.85	76.64	66.66
Average High	58.72	62.34	67.99	73.28	81.16	89.73	94.29	93.21	89.49	79.17	66.49	58.54
Low	31.95	34.01	38.67	42.04	48.78	53.13	57.22	57.94	54.15	45.81	35.28	31.83
Average Low	40.50	41.65	45.61	48.85	53.68	58.73	61.42	60.92	58.39	51.46	43.57	39.63
CDD (base 65)	0.00	0.00	0.37	25.06	108.34	277.74	398.54	374.03	268.67	62.10	0.00	0.00
HDD (base 65)	477.18	364.17	254.63	143.18	33.47	0.87	0.00	0.00	0.44	52.31	299.18	493.40

2030	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	67.90	69.73	80.01	89.32	95.70	104.76	106.60	104.98	102.54	90.99	77.36	67.90
Average High	59.80	62.55	68.41	73.36	81.16	90.13	94.55	93.44	89.85	79.29	67.11	59.63
Low	32.07	33.74	38.63	42.20	49.01	53.51	57.63	58.32	54.42	45.67	35.07	31.86
Average Low	40.65	41.32	45.56	49.04	53.93	59.14	61.86	61.32	58.68	51.30	43.30	39.66
CDD (base 65)	0.00	0.00	0.59	26.19	110.92	289.51	409.37	383.77	278.08	61.78	0.00	0.00
HDD (base 65)	458.04	365.82	249.09	140.28	32.16	0.51	0.00	0.00	0.16	52.63	293.85	475.93

2040	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	69.44	70.02	80.63	89.44	95.70	105.34	106.96	105.30	103.05	91.15	78.26	69.45
Average High	61.15	62.89	68.94	73.46	81.16	90.62	94.87	93.73	90.29	79.43	67.89	61.00
Low	32.22	33.40	38.58	42.40	49.30	53.97	58.15	58.79	54.76	45.49	34.80	31.90
Average Low	40.84	41.03	45.50	49.27	54.24	59.65	62.42	61.82	59.04	51.11	42.97	39.71
CDD (base 65)	0.00	0.00	0.86	27.67	114.18	304.23	422.91	395.94	290.04	61.37	0.00	0.00
HDD (base 65)	434.12	378.06	242.16	136.72	30.57	0.07	0.00	0.00	0.00	53.04	287.19	454.10

Figure 15. Typical Weather for Select Years

The normal temperature scenario is referred to as the “1 in 2” load condition scenario. That is, there is a 1 in 2 chance of this weather scenario occurring. Because the Sacramento area often experiences extremes in temperatures during the summer months, extreme temperature scenarios are used to examine these changes in system peak loads. The table to the left presents the extreme temperatures for each load condition scenario and its impact relative to the 1 in 2 peak. The peak load forecasts under extreme conditions are estimated using the parameter estimates from daily peak model.

Weather Scenario	Temperature High	Impact to 1-in-2
1-in-2	106	100.0%
1-in-5	108	103.6%
1-in-10	110	107.5%
1-in-20	112	111.5%

Figure 16. Peak Weather Scenarios

Non-Standard Commercial Customer Growth

Most of the growth in SMUD’s service territory is included in the unmanaged forecast which is weather normalized sales per customer multiplied by the number of customers. Standard commercial growth is a combination of historical customer growth and economic indicators which reflects general system growth. Other commercial customer growth is included in the forecast as an adjustment to reflect knowledge of the customer base that is outside standard growth of the system. The load shapes for each growth adjustment is based on existing customer load shapes.

New and Incremental Commercial

New large commercial customers that are beyond the usual normal growth seen in SMUD’s service territory are forecast as additional growth if there is a high confidence in the additional load. Growth is split between the rate classes by project.

Significant changes to existing customers are forecast as incremental growth (or decrease) beyond standard growth. If there is high confidence in the change, it is included. Growth is split between the rate classes by project.

Cannabis cultivation is a relatively new industry to California. Cannabis was legalized in 2018 and the industry is still being established. There have been some permitting issues slowing growth after legalization and other areas have been more popular for cultivation. However, recently cannabis cultivation has experienced rapid growth, with loads increasing by over 30,000 MWh between 2019 and 2020, representing a 172% increase so additional cannabis growth has been added to the forecast this year.

The following assumptions were included in the 2022 load forecast for additional commercial growth:

	2022	2023	2024	2025	2026
Technology Company	15,000				
High Tech/Server Farms	15,000	15,000	15,000	15,000	15,000
Cannabis	20,000	20,000			
Newspaper	(6,000)				
Total Additional Growth	**44,000**	**35,000**	**15,000**	**15,000**	**15,000**

Figure 17. New and Incremental Commercial Annual Load Change (MWh)

Demand Energy Response Adjustments

The Distributed Energy Strategy (DES) department develops forecasts for the Demand Energy Response (DER) programs, including Energy Efficiency, Building Electrification, Electric Vehicles, Photovoltaics, and Energy Storage systems. Only resources operated by the customer are included in the load forecast. Resources operated by SMUD, such as community solar projects and energy storage systems (utility scale and customer owned) dispatched by SMUD, are not included in the load forecast. The DES department developed two forecast scenarios:

- Zero Carbon Plan Scenario – full implementation of SMUD's 2030 Zero Carbon Plan (ZCP)
- Scenario 2 – an alternative scenario with more conservative adoption rates of technologies (IRP goals can still be met with increased renewables procurement on the supply side which does not impact the load forecast)

The ZCP scenario for DER programs is used in the ZCP scenario of the 2022 Load Forecast. The alternative Scenario 2 for DER programs is used in the other three scenarios in combination with each of the economic scenarios. The load forecast only includes DER additions as the unmanaged forecast already includes what is currently in the system. The DER forecasts are annual and most of 2020 is already included and reflected in the system peak so only 2021 and beyond additions are incorporated into the adjustment. The following is a summary of the DER assumptions used in the 2022 Load Forecast.

Energy Efficiency

Energy efficiency includes the following programs and includes cumulative impacts with decay of the impacts over time:

- Advanced Commercial Solutions
- Express Energy Solutions
- Complete Energy Solutions
- Residential Education
- Appliance Efficiency
- Whole House Performance
- Multi-family Retrofit

Scenario 2 includes more energy efficiency as it is assumed that funds will be shifted from building electrification to energy efficiency if adoption of electrification is slower. All impacts are a decrease in energy sales. The annual cumulative impact of energy efficiency is:

	Residential						Commercial				
	Appliance Efficiency	Equipment Efficiency	Multifamily Retrofit	Residential Education	Retail Lighting	Whole House Perform	Advanced Commercial Solutions	Express Effic. Incent.	Savings By Design	Complete Energy Solution	Total
2022	(8,966.6)	-	(438.0)	(24,000.0)	-	(6,259.7)	(43,328.5)	(3,745.3)	-	(17,531.3)	(104,269.4)
2023	(16,138.4)	-	(1,029.7)	(24,000.0)	-	(11,894.4)	(82,348.4)	(7,124.3)	-	(32,705.1)	(175,240.3)
2024	(22,191.7)	-	(1,776.7)	(24,000.0)	-	(16,293.5)	(120,730.9)	(10,479.7)	-	(46,825.4)	(242,297.8)
2025	(27,140.6)	-	(2,706.3)	(24,000.0)	-	(21,181.8)	(158,946.8)	(12,051.0)	-	(61,065.4)	(307,092.0)
2026	(31,452.8)	-	(3,340.9)	(24,000.0)	-	(29,474.4)	(195,871.7)	(13,420.2)	-	(73,473.6)	(371,033.6)
2027	(35,207.6)	-	(4,271.7)	(24,000.0)	-	(38,714.2)	(231,575.1)	(10,867.1)	-	(84,277.7)	(428,913.4)
2028	(38,756.9)	-	(6,026.7)	(24,000.0)	-	(48,584.2)	(269,102.0)	(8,615.0)	-	(94,490.5)	(489,575.3)
2029	(42,306.1)	-	(8,761.6)	(24,000.0)	-	(61,100.4)	(306,629.0)	(6,386.5)	-	(104,703.3)	(553,886.9)
2030	(36,888.8)	-	(11,686.6)	(24,000.0)	-	(76,790.0)	(344,156.0)	(5,942.2)	-	(114,916.1)	(614,379.6)
2031	(33,266.3)	-	(14,611.6)	(24,000.0)	-	(92,479.6)	(381,683.0)	(5,699.9)	-	(125,128.9)	(676,869.2)
2032	(30,762.2)	-	(17,098.6)	(24,000.0)	-	(108,169.2)	(375,881.5)	(5,634.7)	-	(135,341.7)	(696,887.8)
2033	(29,362.6)	-	(19,431.9)	(24,000.0)	-	(123,858.8)	(374,388.6)	(5,634.7)	-	(145,554.5)	(722,231.0)
2034	(28,599.6)	-	(21,609.9)	(24,000.0)	-	(139,548.4)	(373,533.1)	(5,634.7)	-	(155,767.3)	(748,692.9)
2035	(28,394.2)	-	(23,605.2)	(24,000.0)	-	(155,238.0)	(372,844.1)	(5,634.7)	-	(145,752.5)	(755,468.6)
2036	(28,394.2)	-	(25,895.7)	(24,000.0)	-	(170,927.6)	(373,446.2)	(5,634.7)	-	(155,965.3)	(784,263.5)
2037	(28,394.2)	-	(27,889.9)	(24,000.0)	-	(180,357.5)	(375,269.8)	(5,634.7)	-	(166,178.1)	(807,724.1)
2038	(28,394.2)	-	(29,059.9)	(24,000.0)	-	(190,412.4)	(375,269.8)	(5,634.7)	-	(176,390.9)	(829,161.8)
2039	(28,394.2)	-	(29,542.5)	(24,000.0)	-	(201,702.9)	(375,269.8)	(5,634.7)	-	(165,980.1)	(830,524.1)
2040	(28,394.2)	-	(29,835.0)	(24,000.0)	-	(212,504.1)	(375,269.8)	(5,634.7)	-	(158,661.6)	(834,299.3)
2041	(28,394.2)	-	(30,127.5)	(24,000.0)	-	(213,811.6)	(375,269.8)	(5,634.7)	-	(153,700.6)	(830,938.3)
Useful Life of Program	8		10	1	8	15	10	5	20	14	

Figure 18. Energy Efficiency Programs Cumulative Impacts (MWh) – Scenario 2

	Residential						Commercial				
	Appliance Efficiency	Equipment Efficiency	Multifamily Retrofit	Residential Education	Retail Lighting	Whole House Perform	Advanced Commercial Solutions	Express Effic. Incent.	Savings By Design	Complete Energy Solution	Total
2022	(14,949.3)	-	(417.1)	(24,000.0)	-	(7,824.7)	(24,940.4)	(12,241.2)	-	(12,647.0)	(97,019.8)
2023	(27,622.5)	-	(885.2)	(24,000.0)	-	(14,868.0)	(51,743.7)	(24,451.2)	-	(25,265.1)	(168,835.7)
2024	(38,394.7)	-	(1,459.6)	(24,000.0)	-	(20,366.8)	(78,369.1)	(39,713.6)	-	(41,037.7)	(243,341.6)
2025	(48,089.7)	-	(2,095.5)	(24,000.0)	-	(26,477.3)	(105,009.2)	(51,923.6)	-	(54,628.6)	(312,223.9)
2026	(56,330.5)	-	(2,811.3)	(24,000.0)	-	(36,842.9)	(128,642.1)	(61,691.5)	-	(65,501.4)	(375,819.8)
2027	(64,571.2)	-	(3,706.9)	(24,000.0)	-	(48,392.8)	(152,275.1)	(59,218.3)	-	(76,374.1)	(428,538.5)
2028	(72,811.9)	-	(4,670.1)	(24,000.0)	-	(60,730.2)	(175,908.1)	(56,776.3)	-	(87,246.9)	(482,143.6)
2029	(79,404.5)	-	(6,047.7)	(24,000.0)	-	(76,375.5)	(194,814.5)	(49,328.2)	-	(95,945.1)	(525,915.5)
2030	(69,729.2)	-	(7,628.3)	(24,000.0)	-	(95,987.5)	(211,611.0)	(43,369.8)	-	(102,903.6)	(555,229.5)
2031	(61,275.3)	-	(9,436.1)	(24,000.0)	-	(115,599.5)	(226,552.7)	(38,603.0)	-	(108,470.5)	(583,937.1)
2032	(54,722.4)	-	(11,099.2)	(24,000.0)	-	(135,211.5)	(216,554.0)	(33,836.2)	-	(114,037.3)	(589,460.6)
2033	(49,246.6)	-	(12,956.6)	(24,000.0)	-	(154,823.5)	(204,692.4)	(29,069.5)	-	(119,604.2)	(594,392.8)
2034	(45,225.2)	-	(14,895.7)	(24,000.0)	-	(174,435.5)	(193,008.7)	(26,256.3)	-	(125,171.0)	(602,992.4)
2035	(41,203.7)	-	(16,975.9)	(24,000.0)	-	(194,047.5)	(181,310.4)	(25,006.0)	-	(130,737.9)	(613,281.4)
2036	(37,182.2)	-	(18,976.2)	(24,000.0)	-	(213,659.5)	(172,619.2)	(25,006.0)	-	(123,657.6)	(615,100.7)
2037	(34,808.9)	-	(20,796.6)	(24,000.0)	-	(225,446.8)	(163,927.9)	(25,006.0)	-	(116,606.4)	(610,592.6)
2038	(33,754.1)	-	(22,776.6)	(24,000.0)	-	(238,015.5)	(155,236.6)	(25,006.0)	-	(106,400.7)	(605,189.5)
2039	(33,754.1)	-	(24,342.2)	(24,000.0)	-	(252,128.7)	(151,272.0)	(25,006.0)	-	(98,376.6)	(608,879.5)
2040	(33,754.1)	-	(25,704.7)	(24,000.0)	-	(265,630.2)	(149,417.2)	(25,006.0)	-	(93,070.7)	(616,582.9)
2041	(33,754.1)	-	(26,840.1)	(24,000.0)	-	(267,264.5)	(149,417.2)	(25,006.0)	-	(87,764.8)	(614,046.8)
Useful Life of Program	8	0	10	1	8	15	10	5	20	14	

Figure 19. Energy Efficiency Programs Cumulative Impacts (MWh) - ZCP Scenario

Energy efficiency impacts are split between the rate classes by program and prior customer EE participation. The allocation assumptions vary by year as follows:

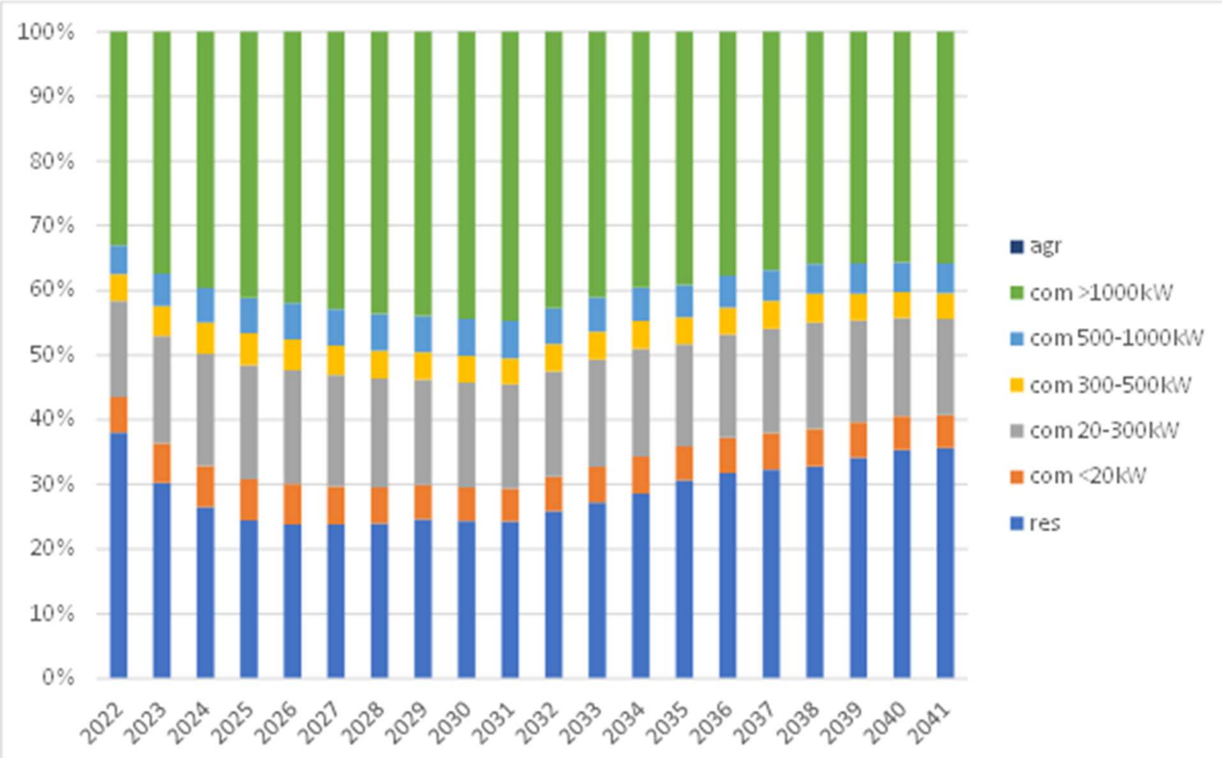

Figure 20. Energy Efficiency Rate Class Allocations – Scenario 2

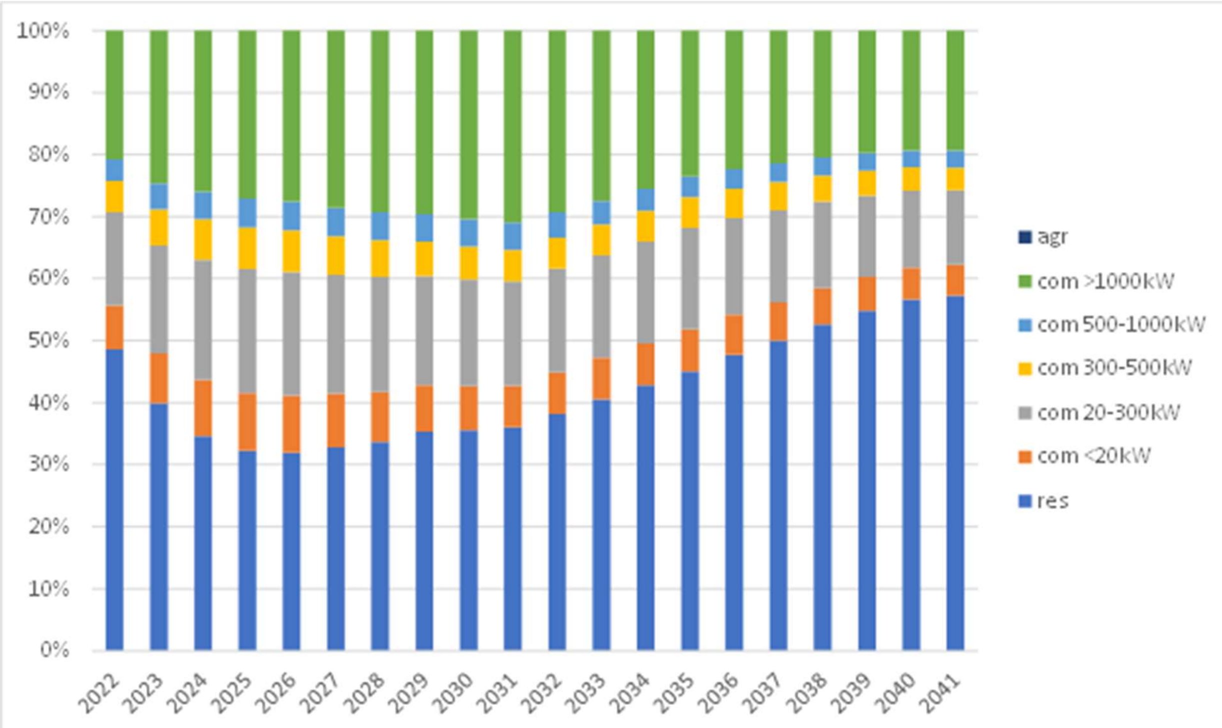

Figure 21. Energy Efficiency Rate Class Allocations – ZCP Scenario

The energy effieciency load shapes developed from multiple sources using data available in-house as well as outside consultants. The following chart breaks down the source of the EE load shapes

EE Programs	Load Shape Source
Custom Incentives (CI)	Navigant EE potential study with hourly savings shapes
EES (Express Eff - Presc Com)	Navigant EE potential study with hourly savings shapes
CES (Complete Energy Sol)	Navigant EE potential study with hourly savings shapes
Res Advisory (Home Elect Reports	Navigant EE potential study with hourly savings shapes
Appliance Efficiency	Navigant EE potential study with hourly savings shapes
Equipment Efficiency	In-house Study
Whole House Perf	In-house Study
MF Retrofit	Navigant EE potential study with hourly savings shapes

Figure 22. EE Load Shape Sources

The estimate of EE program impact on system peak is based on customer service EE program reports, which are part of CEC filings made in 2016. There were no changes made to these assumptions from last year as no new data is available. The peak impact estimate is used in the forecast model as a peak impact target. The model performs a scaling calibration that adjusts the initial EE savings shapes across the hours to meet both the annual energy savings target and peak impact target.

Photovoltaics

The photovoltaic (PV) forecast from the Distributed Energy Strategy (DES) department was developed with the DER Planning Tool (aka Wattplan Grid). It gives an energy impact for new PV systems installed behind the meter. The impact is negative because it decreases sales. The forecast estimates that 30% of new homes will participate in the future Solar Shares program instead of installing rooftop solar. Residential solar systems are 3 kW for new homes and 6 kW for existing homes. The Solar Shares program is not accounted for in the forecast; it is included as a supply resource. Existing PV systems and their impacts are captured in historical customer impacts in the unmanaged forecast. Compared to last year, the residential PV forecast has increased, and the commercial PV forecast has decreased. The following table translates the PV impacts into their equivalent quantity of PV and an estimate on the number of homes for residential based on PV having an 18% capacity factor and degrading a half a percent per year.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Residential										
Additional Homes	5,447	5,481	4,839	4,836	4,870	4,889	4,863	4,773	4,655	4,565
Additional PV (MW)	24	24	21	21	21	21	21	20	20	20
Cumulative PV (MW)	24	48	69	89	110	131	151	172	192	211
Cumulative PV (MWh)	38,066	76,293	108,643	140,983	173,482	206,072	238,537	270,577	302,058	333,111
Commercial										
Additional PV (MW)	12	13	8	6	6	7	5	4	4	4
Cumulative PV (MW)	12	25	34	39	45	52	57	61	65	68
Cumulative PV (MWh)	19,639	40,108	53,179	62,110	71,299	81,592	89,706	95,947	101,709	107,487
	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Residential										
Additional Homes	4,545	4,539	4,615	4,674	4,612	4,548	4,496	4,447	4,405	4,363
Additional PV (MW)	20	20	20	20	20	20	19	19	19	19
Cumulative PV (MW)	231	251	270	290	310	330	349	369	388	407
Cumulative PV (MWh)	364,071	395,004	426,295	457,867	489,143	520,119	550,848	581,345	611,641	641,740
Commercial										
Additional PV (MW)	4	3	3	3	2	2	2	2	2	2
Cumulative PV (MW)	72	75	78	81	82	84	86	88	90	91
Cumulative PV (MWh)	113,405	117,937	122,483	127,074	130,049	133,144	135,864	138,910	141,467	143,975

Figure 23. Additional Photovoltaics Assumptions – Scenario 2

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Residential										
Additional Homes	5,587	4,764	5,013	5,354	5,812	5,889	5,863	5,773	5,655	5,565
Additional PV (MW)	25	20	22	24	26	27	27	26	26	26
Cumulative PV (MW)	25	45	66	90	116	143	170	196	222	248
Cumulative PV (MWh)	39,391	70,835	104,829	142,060	183,471	225,522	267,448	308,948	349,890	390,404
Commercial										
Additional PV (MW)	19	22	10	8	8	9	10	11	9	9
Cumulative PV (MW)	19	41	51	59	68	77	87	97	107	115
Cumulative PV (MWh)	30,239	64,188	80,702	93,461	106,808	121,571	136,864	153,470	168,446	181,950
	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Residential										
Additional Homes	5,545	5,539	5,615	5,674	5,612	5,548	5,496	5,447	5,405	5,363
Additional PV (MW)	26	26	26	26	26	26	25	25	25	25
Cumulative PV (MW)	273	299	325	351	377	402	428	453	478	503
Cumulative PV (MWh)	430,825	471,218	511,970	553,003	593,740	634,177	674,366	714,324	754,081	793,641
Commercial										
Additional PV (MW)	8	8	7	6	5	6	4	4	4	4
Cumulative PV (MW)	124	131	138	144	150	155	160	164	168	172
Cumulative PV (MWh)	194,998	207,194	218,219	227,533	236,160	245,088	252,147	258,690	265,115	271,377

Figure 24. Additional Photovoltaics Assumptions – ZCP Scenario

Residential PV generation is allocated to the residential rate class while commercial PV generation is allocated to commercial rate classes based on the forecast prepared by DES. The allocation of commercial PV generation to rate classes in the ZCP Scenario is similar to the allocation in Scenario 2.

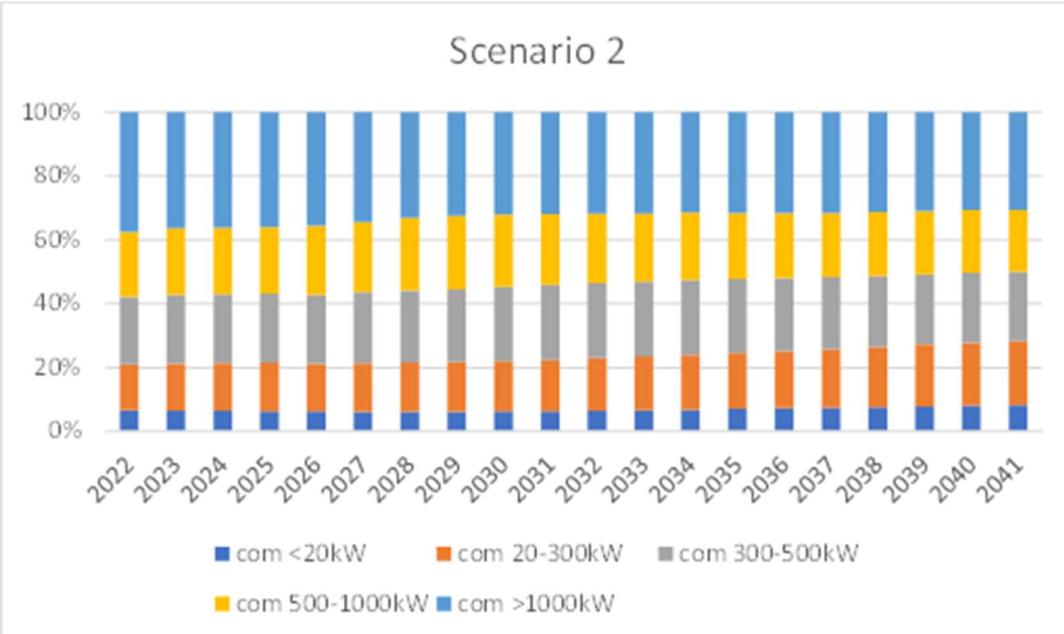

Figure 25. Additional Commercial PV Allocations

The NEM PV generation load shape methodology remains the same as last year.PV metered data from 2017 to 2019 was compiled for the update. A special subsample of a panel of PV meters were selected where all PV meters were installed at the beginning of 2017. This ensures a constant sample of PV meters for the entire study period. Multiple regression analysis was applied to three groups of PV meters, EMS PV (large PV with ratings above 500kw and metered in SMUD EMS system), COM PV(regular commercial PVs, <=500kw) and RES PV (residential PV). The regression analysis correlates the PV generation with hourly GHI, daily temperatures and monthly indicators. The regression shows positive correlation of PV generation with Global Horizontal Irradiance (GHI) and negative correlation with temperatures.

When forecasting PV generation for future years, two key inputs are used: GHI and Temperature. The temperature forecast is the same as those used in load forecast, i.e., the TMY temperature data discussed earlier. For the GHI forecast, historical average based on data from 2001 to 2018 was used to construct a Normal GHI. Days in each year is grouped into 24 half monthly periods(Jan H1, Jan H2, Feb H1, Feb H2, ……, Dec H1 and Dec H2). The hourly average

GHI for each period over the 18-year history was used as forecast for future years in the same half-monthly period. The combined TMY for temperatures and normal GHI for each hour/period, is the new augmented TMY. The regression relationship discussed above combined with this augmented TMY are used to produce forecast for future PV generation.

The following charts show a sample forecast of Residential PV for July 2022 and the entire year of 2022. The forecast PV generation varies from period to period (half month) and from day to day (due to temperature variations).

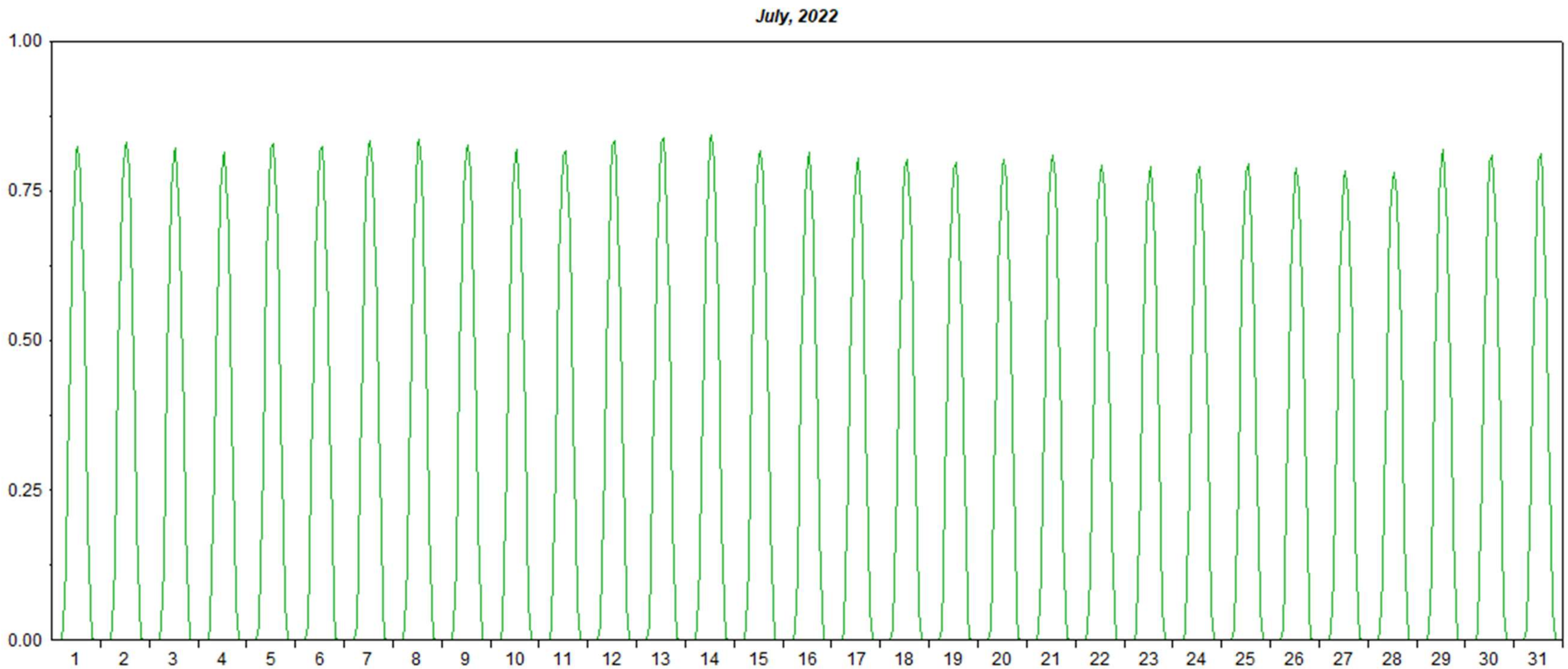

Figure 26. July 2022 Residential PV Shape

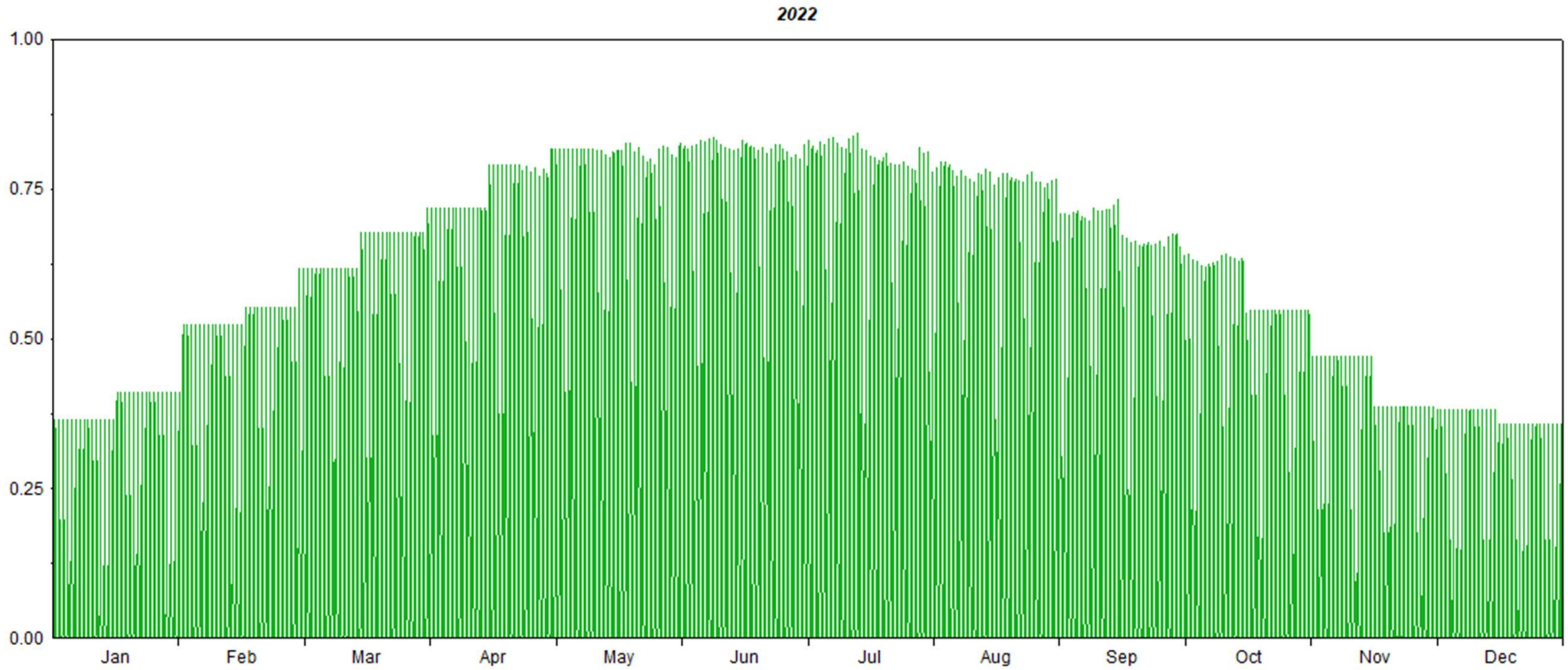

Figure 27. 2022 Residential PV Load Shape

Electric Vehicles

The electric vehicles (EV) forecast breaks out vehicles by type with the most common being light duty vehicles which are defined as Class One vehicles that weigh 6,000lbs or less. Non-light duty vehicles includes everything else. Below is a summary:

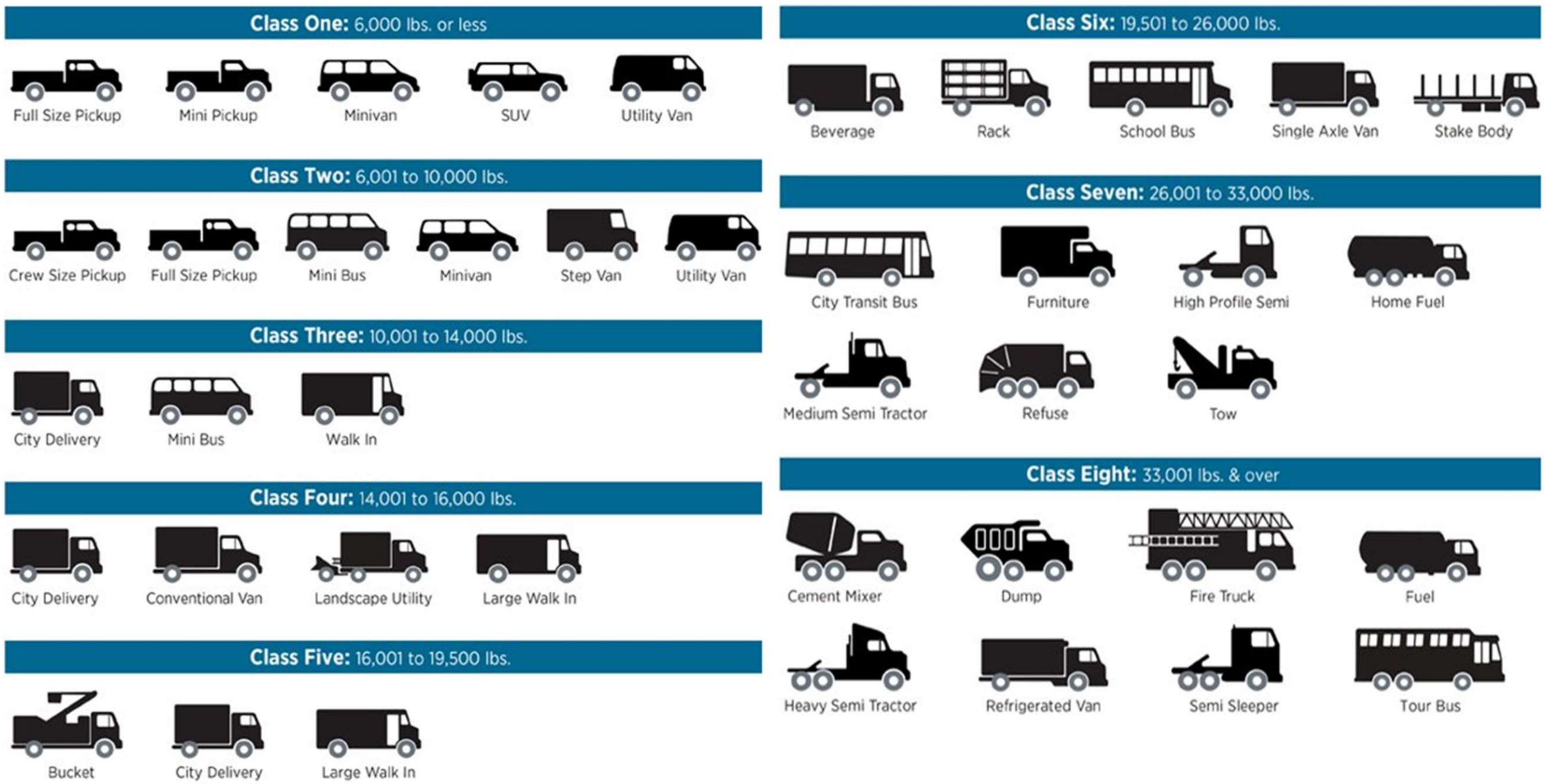

Figure 28. EV Categories

Existing EVs are represented in the historical average customer sales of the unmanaged forecast. The light duty EV forecast is similar to last year's forecast but the non-light duty EV forecast is much higher. The following table gives the quantity of additional EVs forecasted and the increase in energy sales.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Light Duty										
Additional Vehicles	4,000	6,000	7,000	8,500	10,703	12,906	15,109	17,313	19,516	21,719
Cumulative Additional Vehicles	4,000	10,000	17,000	25,500	36,203	49,109	64,219	81,532	101,047	122,766
Load Impact (MWh)	14,308	35,770	60,809	91,214	129,499	175,665	229,711	291,638	361,446	439,135
Non-Light Duty										
Load Impact (MWh)	1,756	5,878	13,226	24,175	44,855	60,443	79,709	97,934	115,462	134,741

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Light Duty										
Additional Vehicles	23,674	25,804	28,127	30,658	33,417	36,425	39,703	43,276	47,171	47,171
Cumulative Additional Vehicles	146,440	172,244	200,371	231,029	264,446	300,871	340,574	383,850	431,022	478,193
Load Impact (MWh)	523,816	616,117	716,726	826,390	945,924	1,076,215	1,218,233	1,373,033	1,541,764	1,710,495
Non-Light Duty										
Load Impact (MWh)	156,356	180,837	208,405	232,799	263,667	298,331	337,241	381,165	417,599	454,033

Figure 29. Additional Electric Vehicle Assumptions – Scenario 2

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Light Duty										
Additional Vehicles	6,465	9,050	12,929	18,100	24,565	32,968	42,665	54,694	63,605	64,644
Cumulative Additional Vehicles	6,465	15,515	28,444	46,544	71,109	104,077	146,742	201,436	265,041	329,685
Load Impact (MWh)	23,125	55,497	101,744	166,488	254,357	372,283	524,896	720,537	948,052	1,179,283
Non-Light Duty										
Load Impact (MWh)	1,756	5,878	13,519	37,417	67,566	104,657	145,182	193,681	249,917	298,840

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Light Duty										
Additional Vehicles	64,644	64,644	64,644	64,644	64,644	64,644	64,644	64,644	64,644	64,644
Cumulative Additional Vehicles	394,329	458,973	523,617	588,261	652,905	717,549	782,193	846,837	911,481	976,125
Load Impact (MWh)	1,410,515	1,641,746	1,872,978	2,104,210	2,335,441	2,566,673	2,797,904	3,029,136	3,260,368	3,491,599
Non-Light Duty										
Load Impact (MWh)	352,175	417,065	486,974	561,670	649,025	738,673	827,602	927,512	1,031,058	1,345,666

Figure 30. Additional Electric Vehicle Assumptions – ZCP Scenario

The following chart shows the charging assumptions for each type of electric vehicle. Each type also has an associated load shape.

	Annual kWh Charge Per Vehicle
Light Duty - Overnight (Home & MUD Depot)	3,577
Light Duty - Workplace	3,577
Light Duty - DCFC	3,577
Class 2 Depot	3,640
Class 2 DCFC	3,640
Class 3-8 Worksite Depot	15,517
Class 3-8 Urban Depot	15,517
Class 3-8 Rural Depot	15,517
Class 3-8 DCFC	15,517
Class 7-8 Short Haul Depot	10,588
Class 7-8 Short Haul DCFC	10,588
Class 8 OTR Long Haul Depot	80,124
Class 8 OTR Long Haul DCFC	80,124
School Busses	26,400
Transit Busses	74,917
Forklifts	2,920
TRUs	2,920

Figure 31. Charging Assumptions for Electric Vehicles

DES staff provided seventeen EV charging load shapes for twelve different vehicle categories. Load Research staff reviewed the EV charging load shapes and applied all except for light duty at-home charging and light duty at-work charging. Load Research staff chose to apply the at-home and at-work EV charging load shapes used in last year’s forecast to better reflect SMUD’s customers’ charging behaviors. Modifications were made to the at-work charging load shape last year to be more consistent for weekdays. The at-home charging load shape is using the load shape from the previous load forecast, which was developed using meter data on a sample of EV owners.

The peak impact from EV is moderate in the near forecasting years but will grow to the much higher targeted levels in the later years of the long-term forecast. At home charging will impact most in the late evening to early morning hours; at work charging will impact most during normal business hours; high speed charging will impact most from late morning to late afternoon. The following table shows the charging assumptions for light duty and non-light duty electric vehicles. Each charging profile is associated with a load shape.

	Res Overnight	Workplace	Public Charging
2022	79.6%	15.3%	5.1%
2023	79.2%	15.6%	5.2%
2024	78.8%	15.9%	5.3%
2025	78.4%	16.2%	5.4%
2026	77.9%	16.6%	5.5%
2027	77.5%	16.9%	5.6%
2028	77.0%	17.2%	5.7%
2029	76.6%	17.6%	5.9%
2030	76.1%	17.9%	6.0%
2031	75.6%	18.3%	6.1%
2032	75.1%	18.7%	6.2%
2033	74.6%	19.0%	6.3%
2034	74.1%	19.4%	6.5%
2035	73.6%	19.8%	6.6%
2036	73.1%	20.2%	6.7%
2037	72.5%	20.6%	6.9%
2038	72.0%	21.0%	7.0%
2039	71.4%	21.4%	7.1%
2040	70.9%	21.9%	7.3%
2041	70.3%	22.3%	7.4%

Figure 32. Allocations of Load Impacts of Light Duty EVs

The following chart shows how the EV load impact is allocated to the rate classes in the energy sales forecast using unmanaged energy sales to allocate across rate classes.

	Res	com <20kW	com 20-300kW	com 300-500kW	com 500-1000kW	com >1000kW
Lt Duty - Home Overnight	x					
Lt Duty - public charging			x	x	x	x
Lt Duty - workplace charging			x	x	x	x
Class 2a			x	x	x	x
Class 2b			x	x	x	x
Class 3-8 Worksite			x	x	x	x
Class 3-8 Rural-Intracity			x	x	x	x
Class 3-8 Urban			x	x	x	x
Class 7-8 Short Haul					x	x
Class 8 Long Haul					x	x
School Buses				x	x	x
Transit Buses				x	x	x
Forklifts			x	x	x	x
TRUs					x	x

Figure 33. Rate Class Allocation of EV Load

Building Electrification

Building electrification (EB) in the conversion of residential and commercial gas appliances to electric in accordance with California's initiative to reduce greenhouse gases. These are from the Distributed Energy Strategy department's forecast. Their forecast for the IRP Adoption scenario assumes that EB will be required by the building codes for new construction beginning in 2026 and 2029 for residential retrofits. The following charts show the unit and energy assumptions for building electrification.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Retrofit Single Family Water Heater										
Annual Addition (Units)	1,518	1,717	2,524	3,281	4,229	4,822	5,842	11,012	17,114	17,225
Cumulative Addition (Units)	1,518	3,235	5,759	9,040	13,269	18,091	23,933	34,945	52,059	69,283
Load Impact (MWh)	1,755	3,739	6,657	10,450	15,339	20,913	27,667	40,396	60,180	80,092
Retrofit Single Family Furnace										
Annual Addition (Units)	1,711	2,262	3,198	4,214	5,314	6,050	7,181	11,679	17,065	17,171
Cumulative Addition (Units)	1,711	3,973	7,171	11,385	16,699	22,750	29,930	41,609	58,674	75,845
Load Impact (MWh)	2,608	6,054	10,929	17,351	25,450	34,671	45,614	63,413	89,419	115,588
Retrofit Single Family Cooking										
Annual Addition (Units)	738	1,641	2,379	2,988	3,728	4,605	5,154	7,930	8,766	8,842
Cumulative Addition (Units)	738	2,378	4,758	7,746	11,474	16,078	21,232	29,162	37,927	46,770
Load Impact (MWh)	160	640	1,280	2,080	3,120	4,400	5,840	8,080	10,560	13,040
Retrofit Multi-Family										
Annual Addition (Units)	263	373	485	630	819	1,065	1,224	2,203	2,683	3,220
Cumulative Addition (Units)	263	636	1,121	1,750	2,570	3,634	4,858	7,062	9,745	12,965
Load Impact (MWh)	480	1,120	1,920	2,960	4,320	6,160	8,240	12,000	16,560	22,080
New Construction Single Family										
Annual Addition (Units)	471	667	1,000	1,500	2,100	2,310	2,800	3,132	2,973	2,909
Cumulative Addition (Units)	471	1,137	2,137	3,637	5,737	8,047	10,847	13,979	16,952	19,861
Load Impact (MWh)	1,360	3,360	6,320	10,720	16,880	23,680	31,920	41,120	49,840	58,400
New Construction Multi- Family										
Annual Addition (Units)	588	593	889	1,024	1,021	1,036	1,006	973	923	903
Cumulative Addition (Units)	588	1,181	2,070	3,094	4,115	5,151	6,157	7,130	8,053	8,956
Load Impact (MWh)	640	1,280	2,240	3,360	4,480	5,680	6,800	7,920	8,960	10,000
Total Residential Impact (MWh)	**7,002**	**16,194**	**29,346**	**46,921**	**69,588**	**95,504**	**126,081**	**172,929**	**235,519**	**299,200**
Commercial DHW - Heat										
Annual Addition (Units)	12	21	25	31	34	37	45	47	68	76
Cumulative Addition (Units)	12	33	58	88	123	159	204	251	319	395
Load Impact (MWh)	5	12	83	274	867	1,489	2,439	3,406	5,012	6,778
Commercial Central Furnace										
Annual Addition (Units)	16	23	30	38	42	45	55	58	80	87
Cumulative Addition (Units)	16	39	70	107	150	194	250	308	388	475
Load Impact (MWh)	-	-	160	800	1,680	2,640	4,000	5,360	7,520	10,000
Commercial New Construction										
Annual Addition (Units)	101	101	101	101	101	101	101	101	101	101
Cumulative Addition (Units)	101	202	302	403	504	605	706	806	907	1,008
Load Impact (MWh)	1,789	3,577	5,366	7,154	8,943	10,732	12,520	14,309	16,098	17,886
Total Commercial Impact (MWh)	**1,793**	**3,590**	**5,609**	**8,229**	**11,490**	**14,861**	**18,959**	**23,074**	**28,630**	**34,664**

Figure 34. Additional Building Electrification Assumptions 2022-2031 – Scenario 2

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Retrofit Single Family Water Heater										
Annual Addition (Units)	17,347	17,482	17,680	17,840	18,000	18,240	18,400	18,640	20,480	20,480
Cumulative Addition (Units)	86,631	104,112	121,792	139,632	157,632	175,872	194,272	212,912	233,392	253,872
Load Impact (MWh)	100,145	120,354	140,792	161,415	182,223	203,308	224,579	246,127	269,801	293,476
Retrofit Single Family Furnace										
Annual Addition (Units)	17,289	17,418	17,559	17,715	17,960	18,240	18,400	18,640	18,800	18,800
Cumulative Addition (Units)	93,134	110,552	128,111	145,826	163,786	182,026	200,426	219,066	237,866	256,666
Load Impact (MWh)	141,937	168,481	195,241	222,239	249,610	277,408	305,450	333,857	362,508	391,159
Retrofit Single Family Cooking										
Annual Addition (Units)	9,726	10,618	11,555	12,465	12,575	12,740	12,850	13,015	13,180	13,180
Cumulative Addition (Units)	56,496	67,114	78,670	91,134	103,710	116,450	129,300	142,315	155,495	168,675
Load Impact (MWh)	15,680	18,640	21,840	25,360	28,880	32,480	36,080	39,760	43,440	47,120
Retrofit Multi-Family										
Annual Addition (Units)	3,864	4,444	4,888	5,367	5,367	5,367	5,904	5,904	5,904	5,904
Cumulative Addition (Units)	16,829	21,273	26,161	31,528	36,895	42,262	48,166	54,070	59,974	65,878
Load Impact (MWh)	28,640	36,240	44,560	53,680	62,800	71,920	82,000	92,080	102,160	112,240
New Construction Single Family										
Annual Addition (Units)	2,904	2,892	3,073	3,054	2,941	2,900	2,819	2,780	2,721	2,721
Cumulative Addition (Units)	22,765	25,656	28,729	31,783	34,724	37,624	40,443	43,223	45,944	48,664
Load Impact (MWh)	66,960	75,440	84,480	93,440	102,080	110,640	118,960	127,120	135,120	143,120
New Construction Multi- Family										
Annual Addition (Units)	902	898	954	948	913	900	875	863	845	845
Cumulative Addition (Units)	9,858	10,756	11,710	12,658	13,571	14,472	15,347	16,210	17,055	17,900
Load Impact (MWh)	11,040	12,080	13,120	14,160	15,200	16,240	17,200	18,160	19,120	20,080
Total Residential Impact (MWh)	**364,402**	**431,235**	**500,033**	**570,294**	**640,793**	**711,996**	**784,268**	**857,103**	**932,150**	**1,007,196**
Commercial DHW - Heat										
Annual Addition (Units)	85	94	106	133	147	159	202	211	272	272
Cumulative Addition (Units)	480	574	680	812	960	1,118	1,320	1,531	1,803	2,075
Load Impact (MWh)	8,840	10,991	13,515	16,441	19,674	22,955	26,940	31,934	37,028	42,123
Commercial Central Furnace										
Annual Addition (Units)	102	110	126	152	172	207	282	290	414	414
Cumulative Addition (Units)	577	686	813	965	1,137	1,344	1,626	1,917	2,330	2,744
Load Impact (MWh)	12,800	15,760	19,040	22,720	26,640	30,640	34,880	39,360	44,320	49,280
Commercial New Construction										
Annual Addition (Units)	101	101	101	101	101	101	101	101	101	101
Cumulative Addition (Units)	1,109	1,210	1,310	1,411	1,512	1,613	1,714	1,814	1,915	2,016
Load Impact (MWh)	19,675	21,463	23,252	25,041	26,829	28,618	30,407	32,195	33,984	35,772
Total Commercial Impact (MWh)	**41,315**	**48,214**	**55,807**	**64,202**	**73,143**	**82,213**	**92,227**	**103,489**	**115,332**	**127,175**

Figure 35. Additional Building Electrification Assumptions 2032-2041 – Scenario 2

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Retrofit Single Family Water Heater										
Annual Addition (Units)	1,897	2,146	3,155	4,101	5,286	6,027	7,303	13,765	21,392	21,531
Cumulative Addition (Units)	1,897	4,044	7,198	11,299	16,586	22,613	29,916	43,681	65,073	86,604
Load Impact (MWh)	2,193	4,674	8,321	13,062	19,173	26,141	34,583	50,496	75,225	100,115
Retrofit Single Family Furnace										
Annual Addition (Units)	2,139	2,827	3,998	5,267	6,643	7,563	8,976	14,599	21,331	21,464
Cumulative Addition (Units)	2,139	4,966	8,964	14,231	20,874	28,437	37,413	52,012	73,343	94,807
Load Impact (MWh)	3,259	7,568	13,661	21,689	31,812	43,338	57,017	79,266	111,774	144,486
Retrofit Single Family Cooking										
Annual Addition (Units)	922	2,051	2,974	3,735	4,660	5,756	6,442	9,912	10,957	11,053
Cumulative Addition (Units)	922	2,973	5,947	9,682	14,342	20,098	26,540	36,452	47,409	58,462
Load Impact (MWh)	200	800	1,600	2,600	3,900	5,500	7,300	10,100	13,200	16,300
Retrofit Multi-Family										
Annual Addition (Units)	329	466	606	787	1,024	1,331	1,530	2,754	3,354	4,025
Cumulative Addition (Units)	329	795	1,401	2,188	3,212	4,543	6,073	8,827	12,181	16,206
Load Impact (MWh)	600	1,400	2,400	3,700	5,400	7,700	10,300	15,000	20,700	27,600
New Construction Single Family										
Annual Addition (Units)	588	833	1,250	1,875	2,625	2,888	3,500	3,915	3,716	3,637
Cumulative Addition (Units)	588	1,422	2,672	4,547	7,172	10,059	13,559	17,474	21,190	24,827
Load Impact (MWh)	1,700	4,200	7,900	13,400	21,100	29,600	39,900	51,400	62,300	73,000
New Construction Multi- Family										
Annual Addition (Units)	735	741	1,111	1,280	1,276	1,296	1,257	1,216	1,154	1,129
Cumulative Addition (Units)	735	1,476	2,587	3,868	5,144	6,439	7,696	8,912	10,066	11,195
Load Impact (MWh)	800	1,600	2,800	4,200	5,600	7,100	8,500	9,900	11,200	12,500
Total Residential Impact (MWh)	**8,753**	**20,242**	**36,682**	**58,651**	**86,986**	**119,379**	**157,601**	**216,161**	**294,399**	**374,000**
Commercial DHW - Heat										
Annual Addition (Units)	15	26	31	38	43	46	56	59	85	94
Cumulative Addition (Units)	15	41	72	110	153	199	255	314	399	493
Load Impact (MWh)	6	15	104	343	1,084	1,861	3,048	4,257	6,265	8,472
Commercial Central Furnace										
Annual Addition (Units)	20	29	38	47	53	56	69	73	100	109
Cumulative Addition (Units)	20	49	87	134	187	243	312	385	485	594
Load Impact (MWh)	-	-	200	1,000	2,100	3,300	5,000	6,700	9,400	12,500
Commercial New Construction										
Annual Addition (Units)	126	126	126	126	126	126	126	126	126	126
Cumulative Addition (Units)	126	252	378	504	630	756	882	1,008	1,134	1,260
Load Impact (MWh)	2,236	4,472	6,707	8,943	11,179	13,415	15,650	17,886	20,122	22,358
Total Commercial Impact (MWh)	**2,242**	**4,487**	**7,011**	**10,286**	**14,362**	**18,576**	**23,699**	**28,843**	**35,787**	**43,330**

Figure 36. Additional Building Electrification Assumptions 2022-2031 – ZCP Scenario

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Retrofit Single Family Water Heater										
Annual Addition (Units)	21,684	21,852	22,100	22,300	22,500	22,800	23,000	23,300	25,600	23,000
Cumulative Addition (Units)	108,288	130,140	152,240	174,540	197,040	219,840	242,840	266,140	291,740	314,740
Load Impact (MWh)	125,181	150,442	175,990	201,769	227,779	254,135	280,723	307,658	337,252	363,840
Retrofit Single Family Furnace										
Annual Addition (Units)	21,611	21,772	21,949	22,144	22,450	22,800	23,000	23,300	23,500	20,000
Cumulative Addition (Units)	116,418	138,190	160,139	182,283	204,733	227,533	250,533	273,833	297,333	317,333
Load Impact (MWh)	177,421	210,601	244,051	277,799	312,013	346,760	381,812	417,321	453,135	483,615
Retrofit Single Family Cooking										
Annual Addition (Units)	12,158	13,273	14,444	15,581	15,719	15,925	16,063	16,269	16,475	15,000
Cumulative Addition (Units)	70,620	83,893	98,337	113,918	129,637	145,562	161,625	177,894	194,369	209,369
Load Impact (MWh)	19,600	23,300	27,300	31,700	36,100	40,600	45,100	49,700	54,300	58,500
Retrofit Multi-Family										
Annual Addition (Units)	4,830	5,555	6,110	6,709	6,709	6,709	7,380	7,380	7,380	7,380
Cumulative Addition (Units)	21,036	26,591	32,701	39,410	46,119	52,828	60,208	67,588	74,968	82,348
Load Impact (MWh)	35,800	45,300	55,700	67,100	78,500	89,900	102,500	115,100	127,700	140,300
New Construction Single Family										
Annual Addition (Units)	3,629	3,614	3,841	3,817	3,676	3,624	3,524	3,475	3,401	3,401
Cumulative Addition (Units)	28,456	32,070	35,912	39,729	43,405	47,029	50,554	54,029	57,430	60,831
Load Impact (MWh)	83,700	94,300	105,600	116,800	127,600	138,300	148,700	158,900	168,900	178,900
New Construction Multi- Family										
Annual Addition (Units)	1,127	1,122	1,193	1,185	1,141	1,125	1,094	1,079	1,056	1,056
Cumulative Addition (Units)	12,322	13,445	14,637	15,823	16,964	18,090	19,184	20,263	21,319	22,375
Load Impact (MWh)	13,800	15,100	16,400	17,700	19,000	20,300	21,500	22,700	23,900	25,100
Total Residential Impact (MWh)	**455,502**	**539,043**	**625,041**	**712,867**	**800,991**	**889,995**	**980,335**	**1,071,379**	**1,165,187**	**1,250,255**
Commercial DHW - Heat										
Annual Addition (Units)	107	117	132	166	184	198	252	263	340	355
Cumulative Addition (Units)	600	717	849	1,015	1,199	1,398	1,650	1,914	2,254	2,609
Load Impact (MWh)	11,051	13,739	16,894	20,552	24,592	28,694	33,675	39,918	46,285	54,485
Commercial Central Furnace										
Annual Addition (Units)	127	137	158	190	215	259	353	363	517	532
Cumulative Addition (Units)	721	858	1,016	1,206	1,421	1,680	2,033	2,396	2,913	3,445
Load Impact (MWh)	16,000	19,700	23,800	28,400	33,300	38,300	43,600	49,200	55,400	62,000
Commercial New Construction										
Annual Addition (Units)	126	126	126	126	126	126	126	126	126	126
Cumulative Addition (Units)	1,386	1,512	1,638	1,764	1,890	2,016	2,142	2,268	2,394	2,520
Load Impact (MWh)	24,594	26,829	29,065	31,301	33,537	35,772	38,008	40,244	42,480	44,680
Total Commercial Impact (MWh)	**51,644**	**60,268**	**69,759**	**80,253**	**91,429**	**102,766**	**115,283**	**129,362**	**144,165**	**161,165**

Figure 37. Additional Building Electrification Assumptions 2032-2041 – ZCP Scenario

The annual impact of each building electrification measure is as follows:

	Water Heater	Furnace	Cooktop	Total
Existing Residential				
Single Family	1,156	1,524	277	2,957
Multi-Family				1,239
New Construction Residential				
Single Family - Detached				2,942
Multi-Family				1,120
Commercial impacts vary by year and scenario				

Figure 38. Annual Energy Impact (kWh) of Building Electrification Measures

DES staff provided the initial EB load shape in actual year 2017 format. This load shape represents the incremental impact of converting a home from gas heating and central air conditioning to electric heat pump. It was used in our previous forecasts for the overall EB load shape. Last year, we were able to define residential EB into three different load shapes, based on updated information from DES staff. The original 2017 actual year load shape was weather normalized to forecast future years. This year, a new TMY was developed to better reflect more recent weather and climate change; hence, this EB load shape was adjusted in our regression model to reflect the new TMY info.

The additional EB load shapes included a heat pump water heating (HPWH) load shape and a cooking load shape. These two EB load shapes were provided by DES staff last year. The HPWH load shape was based on 2009 data with 2009 weather data and calendar. The load shape contains random spikes due to variations in electric resistance backup heating within the data. To smooth out the random spikes in the HPWH load shape, it is averaged by seasons and by weekdays and weekends in our model. The cooking load shape is a simple 24-hour load shape.

This year, we included two new Commercial EB load shapes since DES group added Commercial EB targets. They are Commercial furnace and Commercial water heating load shapes. These two shapes were based on the End Use Load Shape Library from EPRI (Electric Power Research Institute). We extracted the data for the WSCC/CNV region for both peak and off peak seasons and by weekday and weekend. Then we further defined a shoulder season to be the average of the peak and off peak seasons.

The load impact is mostly for winter heating season and very little impact on summer peak hours. The peak impact is determined by the electrification load shape and projected annual energy impact in forecast model, which performs a scaling transformation to scale up the base EB load shape to match the projected annual energy.

Energy Storage

The forecast includes assumptions for an increase in energy storage on the system in the form of battery storage. Some energy storage systems will be linked with PV systems. Batteries will be charged during daylight hours and discharged in the evening peak hours when rates are highest. The shift in load will impact peak but will also increase energy usage because battery storage is not 100% efficient; there is a loss factor associated with charging the batteries. The efficiency of the systems is assumed to be 84.6% (based on 8% loss in battery charging and 8% loss in battery discharging).

The load forecast only includes customer owned and operated battery storage systems. Energy storage systems operating by the utility or by a third party on behalf of the utility are not included. Those systems are treated as supply side resources because how they are dispatched will be determined by the resource mix and can be used to integrate solar resources, load following, or peak reduction which may not coincide with the time-of-use rates used to incentivize customer operated systems.

DES group provided the base load shape for battery storage last year for both residential and commercial customers. The same load shape is used in this year's forecast. The base load shape is by seasons, weekdays, weekends, and holidays. Load Research staff discussed with DES group and adjusted the base load shape to have a longer discharging hours to align with TOD rates which lowered the peak impact. Both residential and commercial shapes reflect the TOD peak hours for residential and commercial customers respectively.

The offset of peak from energy storage begins in the weekday peak hour and the impact grows to much higher targeted levels in the later forecasting years. Load increases occur in the morning till early afternoon before the TOD peak hours.

		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Scenario 2																					
	Annual Additions (MW)	6.41	7.69	7.24	7.93	10.02	14.69	18.53	19.66	20.19	21.02	22.10	22.27	24.55	26.83	27.37	28.20	28.26	28.72	28.50	28.66
	Cumulative Additions (MW)	6.41	14.10	21.34	29.27	39.29	53.98	72.51	92.17	112.37	133.39	155.49	177.76	202.30	229.14	256.51	284.70	312.96	341.68	370.18	398.84
ZCP																					
	Annual Additions (MW)	1.07	1.87	4.42	6.44	7.29	11.35	14.49	15.48	14.41	13.34	12.59	11.64	11.31	10.58	9.80	8.61	6.44	4.63	2.95	1.23
	Cumulative Additions (MW)	1.07	2.94	7.36	13.80	21.10	32.45	46.94	62.42	76.83	90.17	102.76	114.40	125.71	136.29	146.09	154.70	161.14	165.77	168.72	169.95

Figure 39. Customer Owned and Operated Behind the Meter Energy Storage Capacity (MW)

Battery storage impact is allocated to rate classes based on the allocation used for PV impacts. This is based on the assumption that most battery storage systems will be co-installed with a PV system.

The following charts shows the loading and discharging of a 1kW energy storage system.

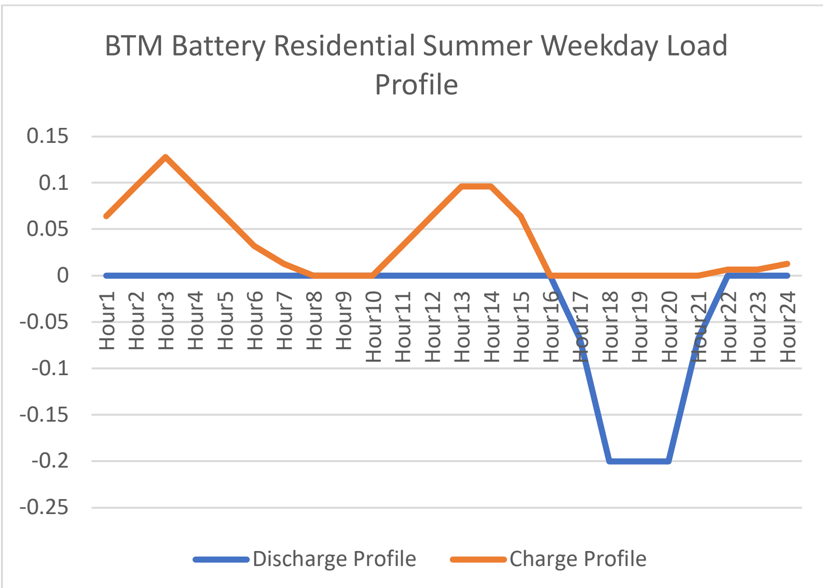

Figure 40. Residential Battery Storage Load Shapes by Discharge and Charge Profile for a Summer Weekday

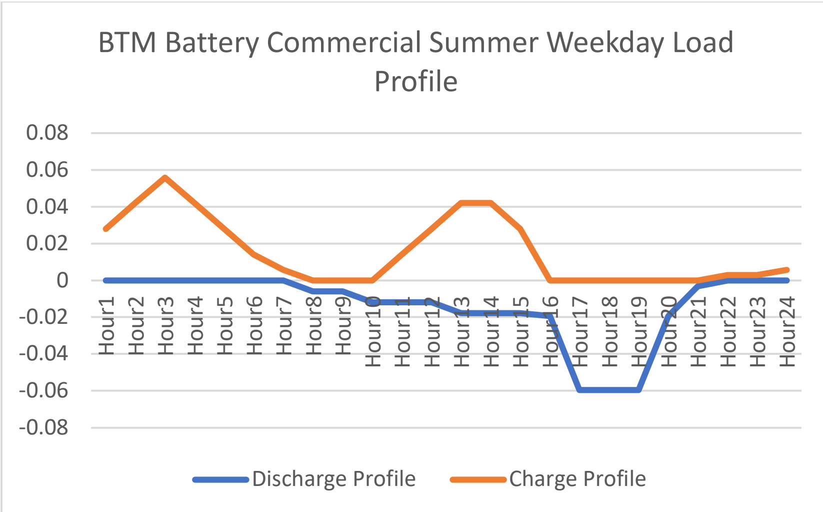

Figure 41.Commercial Battery Storage Load Shapes by Discharge and Charge Profile for a Summer Weekday

Residential Time-of-Day

Residential TOD was rolled out from Fall 2018 through Spring 2019. The 2020 Load Forecast included an adjustment to shift load as well as an overall reduction of load. In the 2021 Load Forecast, the after RTOD system load was considered the base case. A set of special regression equations were used to treat the load data before RTOD and thus combined all hourly load data together. As a result, the new RTOD rate is correctly reflecting in the models going forward and no RTOD adjustment was needed since the 2021 Load Forecast.

Gross to Net Adjustment

The common measure of SMUD system load is the gross EMS load. The Gross to Net Adjustment is the station service and large customer owed generation that is included in SMUD's EMS. It is the system generation plus net import reported by SMUD EMS system. Part of the EMS generation does not directly go into customer sales. This is the difference between gross EMS and net EMS load. The main elements of generation that are not includes in customer sales include the:

1. Station service load for SMUD thermal generation plants - It is also known as "parasitic load," which is the part of power consumed inside the power plant.

2. Large customer Combined Heat and Power (CHP) - This part of generation is produced by the customer and consumed by the customer, which is not part of SMUD sales. The main components in this category are the UC Davis CHP and Elk Grove Mill CHP.

3. Other Large Private Generation - This category includes all large PVs (>500kw) and Fuel Cells.

The forecast of each of the items above are based on research of recent metered data of the relevant generation or station service load. The adjustment is calculated from historical actuals and no growth is forecasted. The table below shows the data used to calculate the adjustment.

Net Load Adjustment Item	Data Source	Notes
Station service load	Partial hourly metered data calibrated to the monthly net system generation report	Hourly metered data from PI and monthly report in recent years. Regression analysis and monthly average by weekday and weekend.
Large customer CHP	Hourly metered data from EDGE.	Forecast uses monthly average by weekday and weekend.
Private Generation	Hourly metered data reported by EDGE for large PV systems and Fuel cells.	Hourly shape developed based on PV data for existing PV system with at least 12 month of data. Forecast project the energy based on the latest installations of PV systems. LT model combined the hourly shape with the projected annual generation.

Figure 42. Gross to Net Adjustment Data Sources

Gross EMS Load = Net EMS Load + Gross to Net Adjustment. Net EMS load represents the energy provided to customers at the system level.

System Losses

System Losses is calculated as the ratio of annual net system energy to annual retail sales. It represents the difference of net system energy and final sales to retail customers. It reflects the distribution losses, unaccounted for energy and some billing adjustments. Net system energy is the total energy generation minus the house load at SMUD thermal power plants, and the generation from large private generation resources (which include large CHPs, large PV's and Fuel cells).

The loss factor fluctuates from year to year. Load Forecast uses the average loss factor of the recent years. For the 2022 forecast (produced in Sept 2021), we used the average loss factor of the most recent five years and the value is 4.6%.

Annual Sales vs Energy and Loss Factor	Last updated 6/7/2021				
kWh Sales from Annual Report	(Adjusted for Calendar Year)				
KWH Sales (thousands)					
Sales to customers -	**2020**	**2019**	**2018**	**2017**	**2016**
Residential		4,493,548	4,515,031	4,957,240	4,670,304
Commercial, Industrial and other		5,672,690	5,718,480	5,819,110	5,750,831
Subtotal	**10,415,277**	**10,166,238**	**10,233,511**	**10,776,350**	**10,421,135**
Annual System Load (EMS_EDGE) (MWh)	11,199,450	10,966,092	11,007,446	11,598,647	11,215,146
Gross Energy to Sales	1.075	1.079	1.076	1.076	1.076
HouseLoads at Thermal power plants	150,090	126,303	150,008	131,842	155,626
CHP	87,387	88,885	90,914	93,023	93,972
Fuel Cell	5,450	5,746	5,865	5,971	6,197
Large PV	89,819	94,799	85,533	54,411	41,806
Total Adjustment	332,746	315,733	332,320	285,247	297,601
Annual Net System Load (EMS - Net Adjustment) (MWh)	**10,866,704**	**10,650,359**	**10,675,126**	**11,313,400**	**10,917,545**
Net Energy to Sales ratio	104.3%	104.8%	104.3%	105.0%	104.8%
Notes: Losses (Transmission and distribution losses plus unaccounted for energy) is calculated as the ratio of Net EMS energy to Sales.	**104.6%**	104.7%	104.7%	104.7%	
	2021 assumption Average of 2016 to 2020 (recent 5 years)	2020 assumption Average of 2015 to 2019 (recent 5 years)	2019 assumption Average of 2014 to 2018 (Recent 5 years)	2018 assumption avg of 2016 and 2015. (left out 2017, an outlier)	

Figure 43. System Losses Calculation

Error

There are two types of forecast error – model error and input error. Model error comes from the data used to create the models. Input error comes from the subjective data used in the forecast. Input error is hard to quantify but model error can be calculated and is best measured by Mean Absolute Percentage Error (MAPE). The unmanaged energy sales forecast is made up of multiple models so to get a single model error value, each individual models' MAPE is weighted to get Weighted Mean Absolute Percentage Error (WMAPE). To weight the MAPE, calendar year 2019 sales energy was used (because of the disproportionate impact of Covid on rate classes in 2020, 2019 was used). The WMAPE for the energy sales models is 2.35%.

Rate Class	MAPE	2019 Energy Sales (MWh)	Class Weight
Residential	2.92%	4,476,434	43.75%
Small Non-Demand	1.98%	745,543	7.29%
Small Demand	1.50%	1,808,159	17.67%
GS-TOU3	1.68%	535,831	5.24%
GS-TOU2	1.82%	568,265	5.55%
GS-TOU1	2.00%	1,973,342	19.29%
Agriculture	12.30%	69,630	0.68%
Streetlight	1.59%	51,582	0.50%
Nightlight	0.20%	3,485	0.03%
Total	**2.35%**	**10,232,271**	

Figure 44. Energy Sales Model Error

The following tables show the individual rate class energy sales model statistics for each model.

Model Statistics (Daily)	Residential	Small Commercial Sales (<20 kW)	Small Commercial Sales (21-299 kW)	Small Commercial Sales (300-499 kW)	Medium Commercial Sales (500-999 kW)	Large Commercial Sales (>1000 kW)	Agricultural Sales	Streetlight Sales	Nightlight Sales
Iterations	1	1	1	1	1	1	1	1	1
Adjusted Observations	1365	1365	1365	1365	1365	1365	1365	1426	1369
Deg. of Freedom for Error	1332	1327	1326	1334	1333	1336	1343	1412	1355
R-Squared	0.981	0.97	0.984	0.977	0.979	0.906	0.958	0.848	1
Adjusted R-Squared	0.981	0.969	0.984	0.977	0.978	0.904	0.958	0.847	1
AIC	-0.061	-0.036	5.082	8.557	9.991	13.525	4.867	-0.106	-10.519
BIC	0.065	0.109	5.231	8.675	10.114	13.635	4.951	-0.054	-10.466
F-Statistic	2175.342	1169.583	2200.433	1930.369	1984.035	459.969	1469.651	607.038	582705.828
Prob (F-Statistic)	0.0000	0	0	0	0	0	0	0	0
Log-Likelihood	-1,861.95	-1,874.03	-5,366.50	-7,745.96	-8,723.98	-11,138.37	-5,236.60	-1,933.83	5,271.93
Model Sum of Squares	63,920.90	40,599.49	13,099,754.15	294,606,546.02	1,312,378,566.75	9,427,725,030.12	3,946,538.37	7,028.85	202.54
Sum of Squared Errors	1,223.12	1,244.97	207,737.52	6,786,356.98	28,443,189.96	977,972,921.05	171,735.00	1,257.65	0.04
Mean Squared Error	0.92	0.94	156.66	5,087.22	21,337.73	732,015.66	127.87	0.89	0.00
Std. Error of Regression	0.96	0.97	12.52	71.32	146.07	855.58	11.31	0.94	0.01
Mean Abs. Dev. (MAD)	0.68	0.72	9.26	53.29	109.01	664.59	8.13	0.74	0.00
Mean Abs. % Err. (MAPE)	2.92%	1.98%	1.50%	1.68%	1.82%	2.00%	12.30%	1.59%	0.20%
Durbin-Watson Statistic	1.093	1.059	1.111	1.029	1.172	0.771	0.577	0.364	0.015
Durbin-H Statistic	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
Ljung-Box Statistic	395.05	768.75	587.94	724.62	535.35	847.67	1831.47	7029.81	25191.84
Prob (Ljung-Box)	0.0000	0	0	0	0	0	0	0	0
Skewness	-0.457	0.049	-0.082	0.151	-0.29	-0.281	-0.227	0.358	0.205
Kurtosis	6.362	4.386	4.503	4.191	4.693	3.93	4.912	3.206	2.621
Jarque-Bera	690.360	109.77	129.932	85.904	182.026	67.112	219.614	33.021	17.788
Prob (Jarque-Bera)	0.0000	0	0	0	0	0	0	0	0.0001

Figure 45. Daily Energy Sales Models' Statistics

Peaks are forecasted at a system level, and the peak model's MAPE is 2.75%. The following table shows the system peak load model statistics. This is the model statistics for the HE17 model discussed earlier in the section of hourly system load models.

Model Statistics	
Iterations	12
Adjusted Observations	628
Deg. of Freedom for Error	608
R-Squared	0.969
Adjusted R-Squared	0.968
AIC	-4.190
BIC	-4.048
F-Statistic	994.290
Prob (F-Statistic)	0.0000
Log-Likelihood	444.48
Model Sum of Squares	277.39
Sum of Squared Errors	8.93
Mean Squared Error	0.01
Std. Error of Regression	0.12
Mean Abs. Dev. (MAD)	0.09
Mean Abs. % Err. (MAPE)	2.75%
Durbin-Watson Statistic	1.543
Durbin-H Statistic	#NA
Ljung-Box Statistic	21.49
Prob (Ljung-Box)	0.6094
Skewness	-0.540
Kurtosis	4.568
Jarque-Bera	94.842
Prob (Jarque-Bera)	0.0000

Figure 46. System Models' Statistics

The following table shows the actual error of prior load forecasts.

	Energy Sales (MWh)			System Peak (MW)			Customer Count		
Year	Actual	Forecast	% Error	Actual	Forecast	% Error	Actual	Forecast	% Error
2007	10,913,372	10,940,472	0.2%	3,099	3,124	0.8%	572,107	595,130	4.0%
2008	10,959,168	11,238,188	2.5%	3,086	3,062	-0.8%	590,607	598,717	1.4%
2009	10,757,807	10,358,626	-3.7%	2,848	3,038	6.7%	593,971	594,838	0.1%
2010	10,389,858	10,560,255	1.6%	2,990	2,976	-0.5%	596,367	593,975	-0.4%
2011	10,459,022	10,527,298	0.7%	2,840	2,979	4.9%	598,730	599,098	0.1%
2012	10,519,497	10,513,856	-0.1%	2,953	2,974	0.7%	602,141	600,904	-0.2%
2013	10,480,762	10,432,362	-0.5%	3,014	2,946	-2.3%	607,997	605,887	-0.3%
2014	10,585,750	10,572,551	-0.1%	3,003	2,987	-0.5%	612,592	614,694	0.3%
2015	10,523,765	10,548,236	0.2%	2,956	3,008	1.8%	615,930	618,560	0.4%
2016	10,477,398	10,546,872	0.7%	2,972	3,030	1.9%	619,934	620,974	0.2%
2017	10,929,610	10,414,914	-4.7%	3,157	2,970	-5.9%	623,119	623,277	0.0%
2018	10,297,311	10,472,133	1.7%	2,944	2,942	-0.1%	628,354	628,481	0.0%
2019	10,232,271	10,348,458	1.1%	2,927	2,915	-0.4%	634,203	634,024	0.0%
2020	10,442,864	10,257,621	-1.8%	3,057	2,919	-4.5%	642,098	641,033	-0.2%

Figure 47. Actual Forecast Error