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MEMO TO: Memphis Light, Gas and Water Team

FROM: Siemens IRP Team

DATE: January 13, 2020

SUBJECT: Load Forecast

Siemens developed a deterministic reference case load forecast for the Memphis Light, Gas and Water (MLGW) service territory. This memorandum presents a twenty-year net load forecast, followed by a forecast of electric vehicle (EV) penetration, and a brief summary of the net load forecast adjusted for projected electric vehicle loads. The net load forecast is the gross system load forecast adjusted for energy efficiency (EE), distributed solar generation (DS), and other known future commercial load centers under development.

Net Load Forecast

Exhibit 1 below states the historical average and peak load for Memphis and Compounded Annual Growth Rates (CAGR), as provided by MLGW.

Exhibit 1: Historical Average and Peak Load (MW)

	Avg. Load (MW)	Peak Load (MW)
1999	1,635	3,234
2000	1,696	3,334
2001	1,670	3,174
2002	1,704	3,211
2003	1,661	3,264
2004	1,693	3,269
2005	1,765	3,390
2006	1,757	3,466
2007	1,814	3,533
2008	1,727	3,336
2009	1,641	3,287
2010	1,763	3,444
2011	1,698	3,507
2012	1,670	3,256
2013	1,650	3,195
2014	1,633	3,062
2015	1,625	3,226
2016	1,640	3,155
2017	1,577	3,086
2018	1,647	3,097
	CAGR	CAGR
1999-2008	0.61%	0.35%
2008-2013	-0.91%	-0.86%
2014-2018	0.72%	0.29%
1999-2018	0.04%	-0.23%

Source: MLGW

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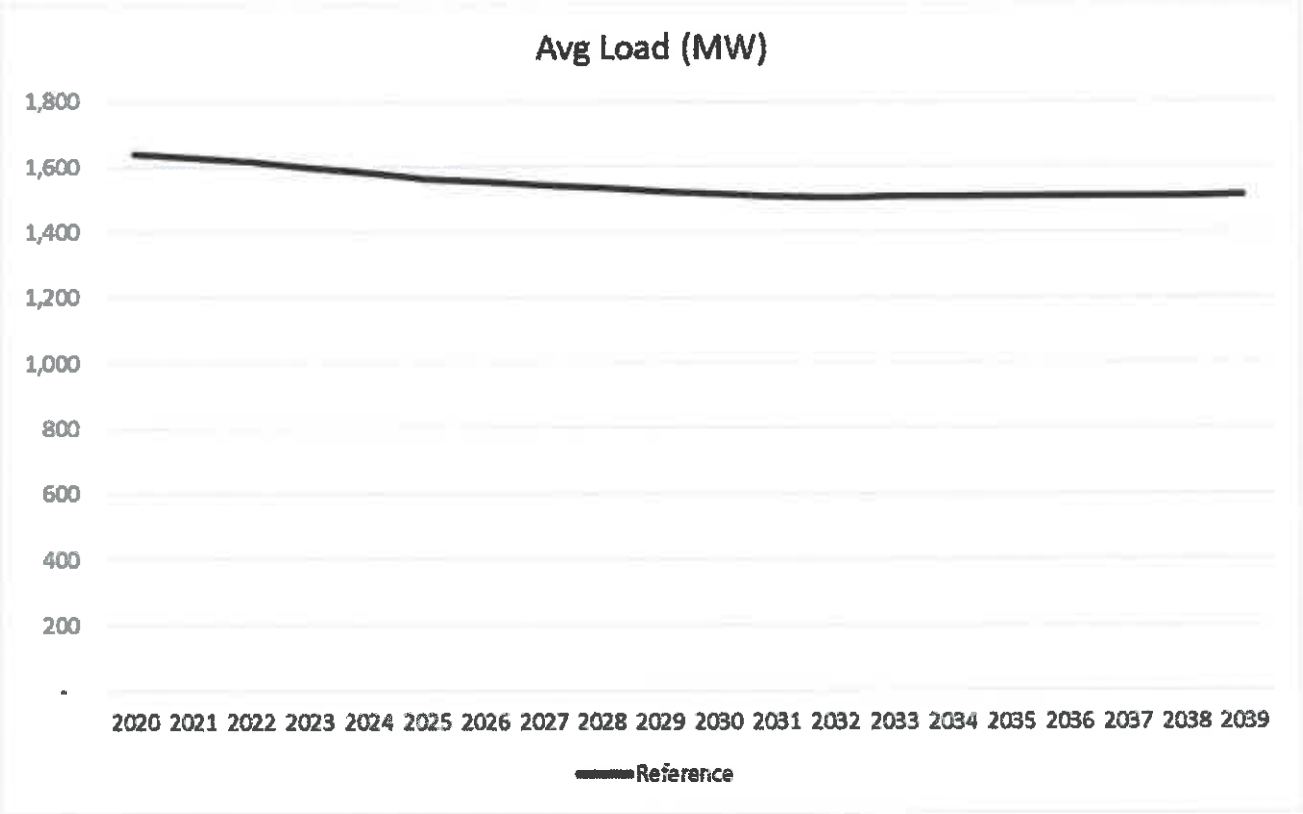
Exhibits 2-4 below display the net load from our reference case.

Exhibit 2: Forecasted Net Average Load (MW)



Source: Siemens

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Exhibit 3: Forecasted Net Average Load (MW)

	Reference
2020	1,642
2021	1,631
2022	1,616
2023	1,600
2024	1,582
2025	1,564
2026	1,554
2027	1,545
2028	1,535
2029	1,526
2030	1,517
2031	1,510
2032	1,507
2033	1,508
2034	1,508
2035	1,508
2036	1,509
2037	1,509
2038	1,510
2039	1,511
	CAGR
2020-2025	-0.97%
2026-2030	-0.61%
2031-2039	0.01%
2020-2039	-0.44%

Source: Siemens

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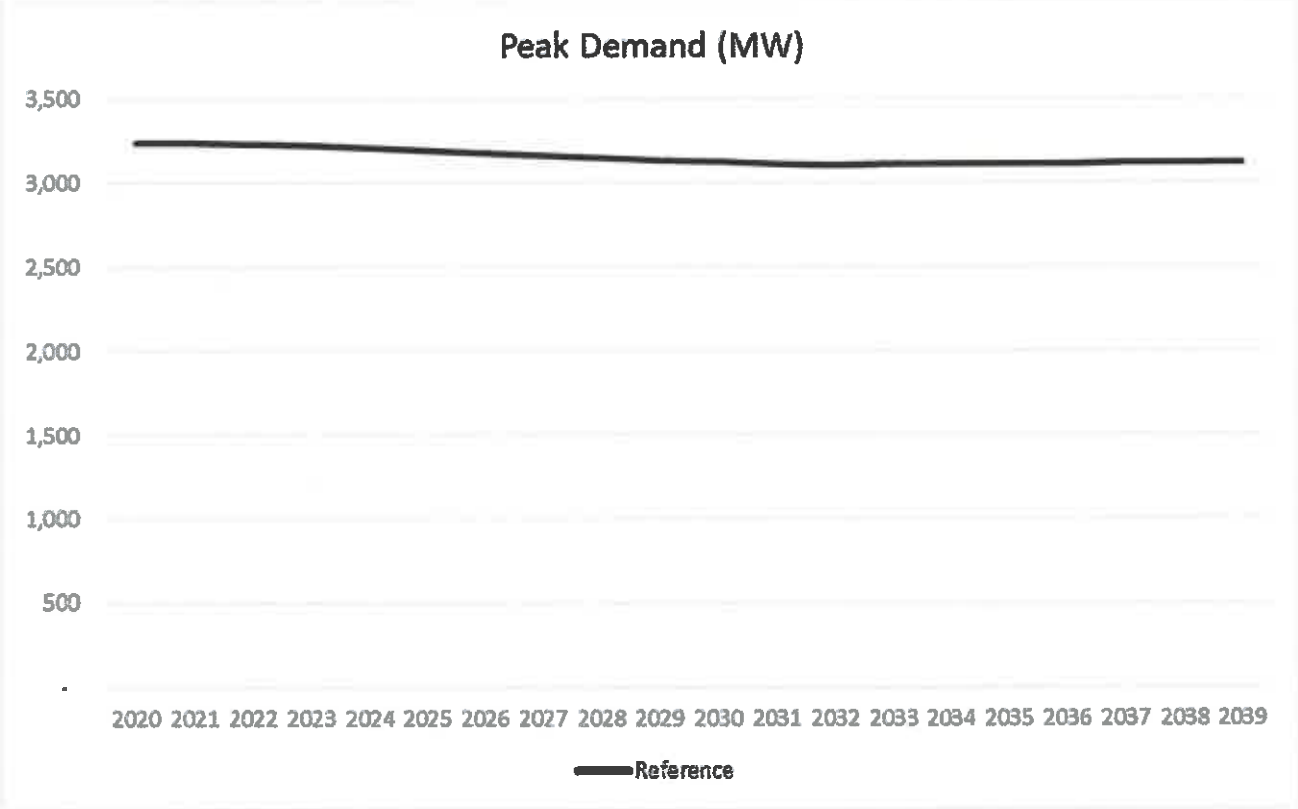
Exhibit 4: Forecasted Net Peak Load (MW)



Source: Siemens

Exhibit 5: Forecasted Net Peak Load (MW)

	Reference
2020	3,244
2021	3,244
2022	3,236
2023	3,224
2024	3,211
2025	3,197
2026	3,182
2027	3,168
2028	3,153
2029	3,139
2030	3,124
2031	3,113
2032	3,108
2033	3,110
2034	3,112
2035	3,114
2036	3,116
2037	3,118
2038	3,121
2039	3,123

Source: Siemens

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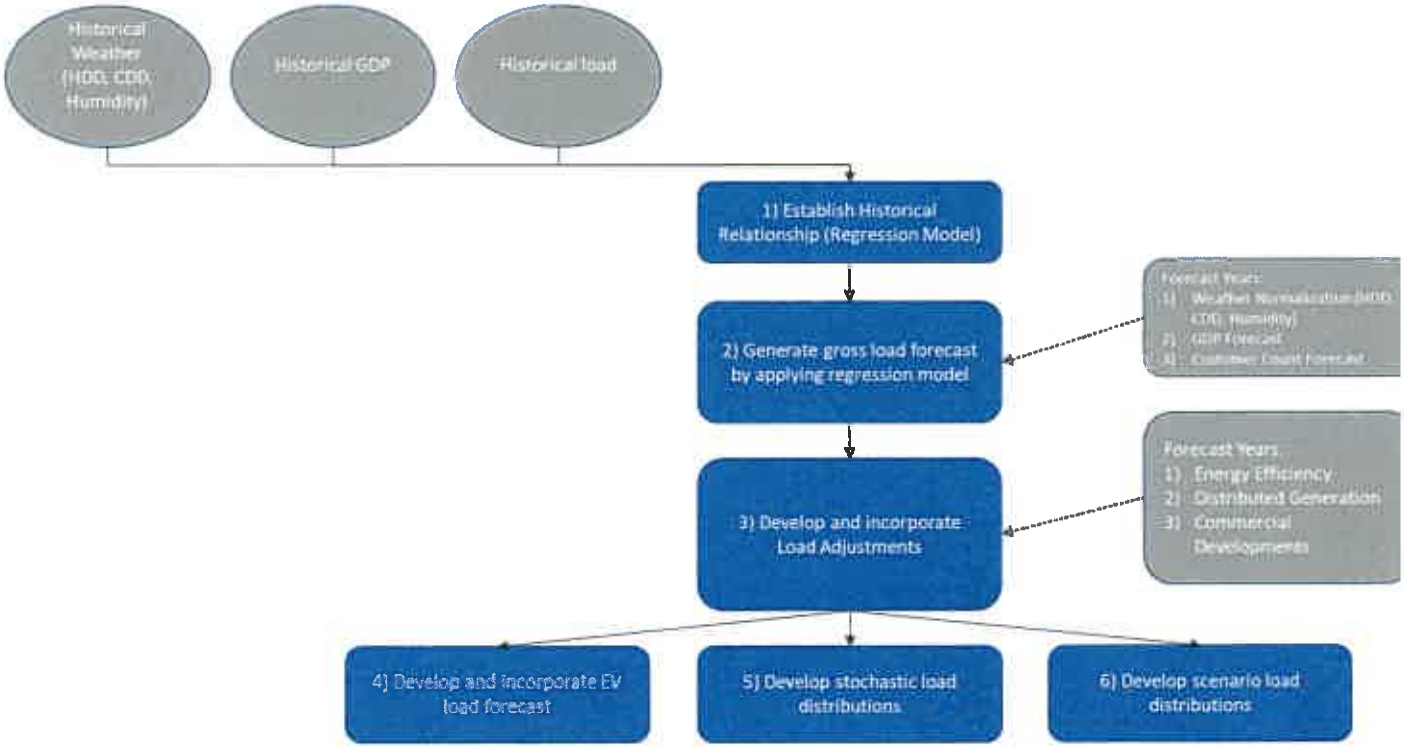
Load Forecasting Process

Siemens has developed a deterministic load forecasting process, described in the flow chart in Exhibit 6 shown below. The average and peak load were generated separately using the same process. The rest of this memorandum describes the deterministic and stochastic load process.

Exhibit 6: Deterministic Load Forecasting Process



Source: Siemens

1) Establish Historical Relationships (Regression Model)

Siemens used a stepwise regression model using MATLAB to discover the relationship between historical weather data, economic data, and historical load. All available data from 2014-2019 was used for the regression analysis. The following input data sets were used to create historically based relationship between weather, economic, and load data:

a) **Historical weather data** – Monthly Humidity data from Memphis International Airport, that MLGW provided. Monthly Heating Degree Days (HDD) and Cooling Degree Days (CDD) were sourced from Degreedays.net.

b) **Historical economic data** – Historical real per capita GDP for the Memphis metropolitan area was downloaded from The Federal Reserve Bank of St. Louis.[1]

[1] https://fred.stlouisfed.org/series/NGMP32820

c) **Historical load data** – Hourly load data for Memphis service territory.

Siemens found a positive relationship between HDD, CDD, and humidity with load, but found an inverse relationship between GDP and load. Historically, economic variables such as GDP or personal income would have a positive relationship to the load growth. This relationship, however, has not been holding for many regions throughout the United States—especially in the residential sector since 2010.[2] Considering that Memphis's average load was relatively flat to decreasing from 2014-2018 during a period of economic growth, Siemens expected an inverse relationship between GDP and weather normalized load in the analysis.

2) Generate Gross Load Forecast

Siemens formed a gross load forecast by applying the coefficients calculated in our regression model to their corresponding forecasted variables for the 2020-2025 period. Siemens used 10 years of available historical weather and customer count data to average out short term variability. The following input data sets were used to forecast the needed variables for gross load:

a) **Normal temperature data** – Siemens extrapolated weather data from 2009-2018 by averaging HDD, CDD, and humidity, all aggregated on a monthly basis. Humidity data was sourced from the Memphis International Airport, and HDD and CDD were sourced from Degreedays.net

b) **Customer count forecast data** – Siemens extrapolated customer counts by averaging data that MLGW provided from 2008-2017. Siemens used an estimated annual customer growth rate of 0.1%.

c) **Economic forecast data** – For the purposes of forecasting load, Siemens assumed an average 1% annual GDP growth rate through 2025 to emulate the economic growth in the historical data with consideration for long-term forecasts. Long-term national economic forecasts call for modest growth during this period[3], and historically Memphis has grown at a slower rate than the national average.

For the average load, the following relationship was constructed:

Avg_Load_per_Customer = f (HDD, CDD, Humidity, GDP, Calendar Variables)

For the peak load, the following relationship was constructed:

Peak_Load_per_Customer = f (HDD, CDD, Calendar Variables)

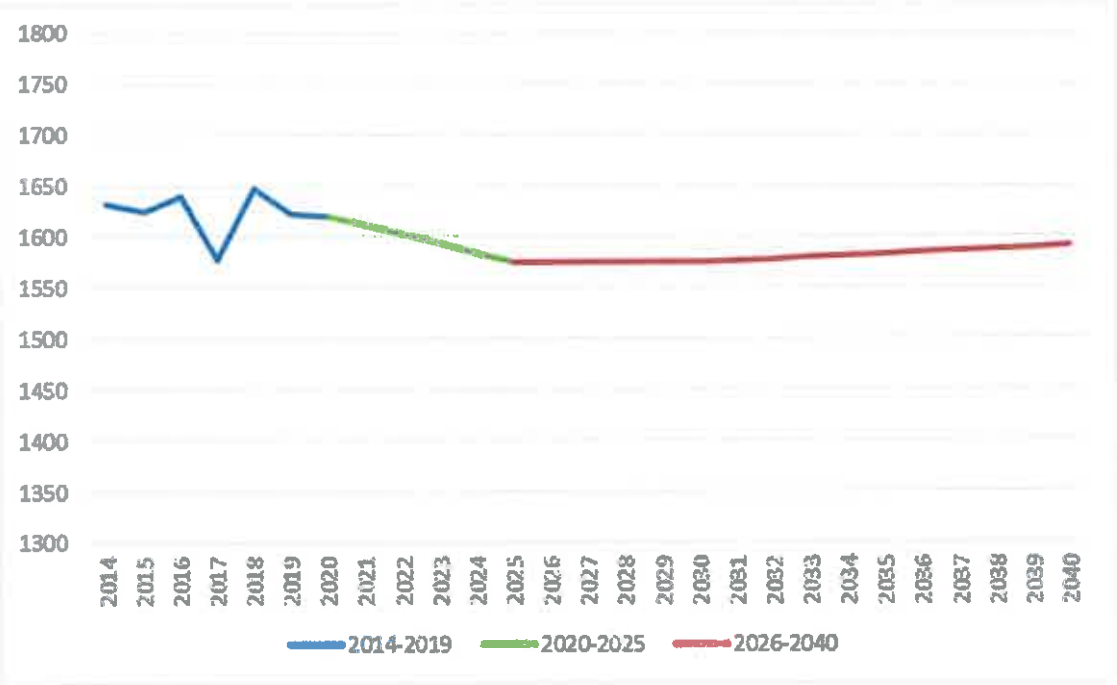
The adjusted R-squared values for each of the models exceeded .9.

Using the functions above, Siemens developed a forecast of average and peak load per customer for 2020 to 2025. Using the customer count forecast data, the MW per customer values are converted into the service area level average and peak load forecasts.

[2] https://www.eia.gov/todayinenergy/detail.php?id=14291
[3] https://www.cbo.gov/system/files/2019-03/54918-Outlook-3.pdf

Siemens views the reductions in average load to only be applicable in the short term returning to modest growth over time, as reflected in the long-term forecast in TVA's IRP[4]. Therefore, Siemens assumes average load to flatten in the medium term (2026-2030), followed by a period of load growth equal to projections in the TVA IRP (0.1%) for the long term (2031-2040).

Exhibit 7: Historical and Forecasted Annual Average Load (MW)

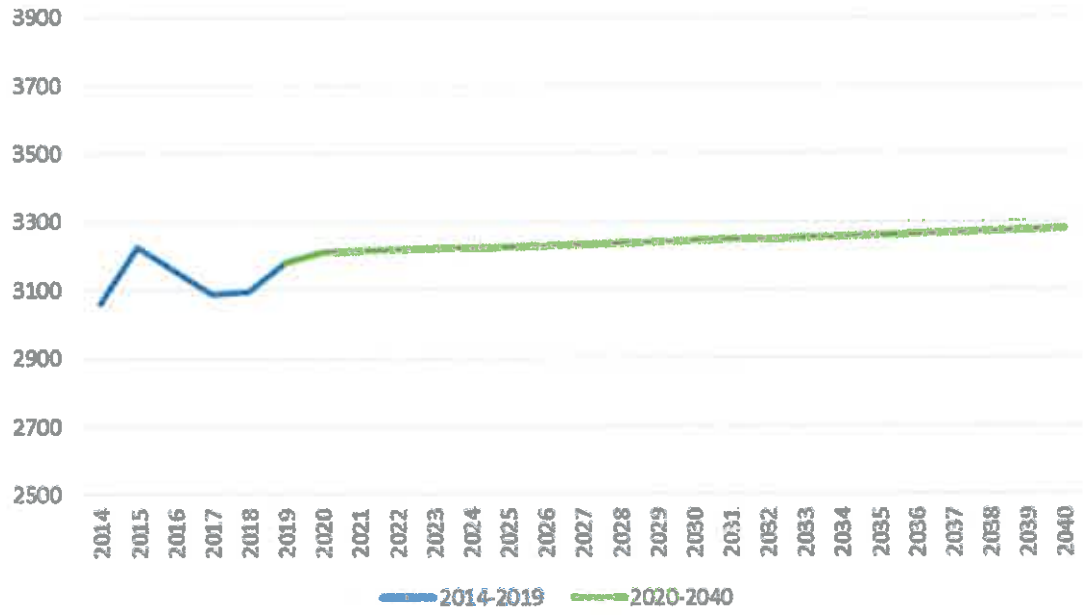


Source: Siemens

[4]https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/IRP/2019%20Documents/TVA%202019%20Integrated%20Resource%20Plan%20Volume%20I%20Final%20Resource%20Plan.pdf

Meanwhile, as shown in Exhibit 5, peak load has been increasing historically, and Siemens viewed it appropriate to extend the regression-based peak load forecast throughout the entire period of the study. The average growth rate for the 2020 to 2040 period is -1.81%.

Exhibit 8: Historical and Forecasted Annual Peak Load (MW)



Source: Siemens

Exhibit 9: Historical and Forecasted Gross Annual Average and Peak Load (MW)

	Avg Load (MW)	Peak (MW)
2014	1,633	3,062
2015	1,625	3,226
2016	1,640	3,155
2017	1,577	3,086
2018	1,647	3,097
2019	1,622	3,182
2020	1,620	3,211
2021	1,611	3,215
2022	1,602	3,218
2023	1,593	3,221
2024	1,584	3,224
2025	1,575	3,228
2026	1,575	3,231
2027	1,575	3,234
2028	1,575	3,238
2029	1,575	3,241
2030	1,575	3,244
2031	1,576	3,247
2032	1,578	3,251
2033	1,580	3,254
2034	1,581	3,257
2035	1,583	3,261
2036	1,584	3,264
2037	1,586	3,267
2038	1,587	3,271
2039	1,589	3,274
	CAGR	CAGR
2020-2025	-0.56%	0.10%
2026-2030	0.00%	0.10%
2031-2039	0.10%	0.10%
2020-2039	-0.10%	0.10%

Source: Siemens

3) Develop and Incorporate Load Adjustments

Adjustments to the gross load forecast are needed to incorporate the future effects of energy efficiency/demand side load management, distributed solar generation, and known future commercial developments. Siemens developed average and peak load forecasts for each of load variables and are explained below.

Energy Efficiency (EE)

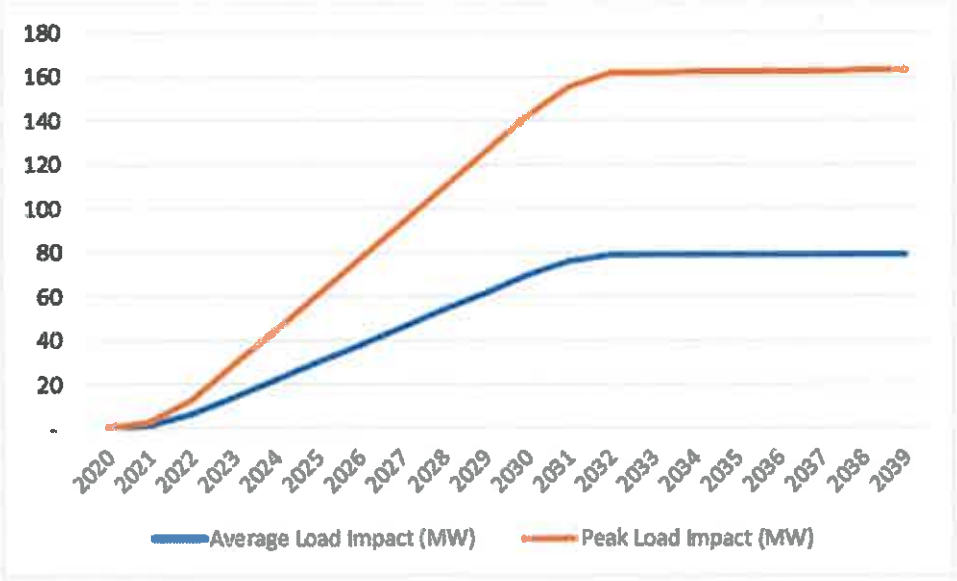
To forecast estimated impacts of EE and demand side management, Siemens used data from the U.S. Energy Information Administration (EIA) Form 861. To develop a comparison group, Siemens considered the system size, customer profile, and geographic location. Siemens used the following utilities for comparing annual energy savings and sales:

- Entergy Mississippi LLC
- KCP&L Greater Missouri Operations Co.
- Southwestern Electric Power Co
- Entergy New Orleans, LLC
- City Utilities of Springfield (MO)

Siemens determined that the average contribution from EE from those utilities as a percentage of annual sales was 0.50%. By multiplying the 0.50% average by Memphis's forecasted load, Siemens estimated the overall impact of EE on average load. For peak load impacts, Siemens assumed that such a small portfolio would be primarily composed of heating and cooling programs, and that all EE resources would be peak coincident.

Siemens assumes that Memphis will start funding EE projects by 2021 and that the useful life of the technology used in the programs will be 10 years. Therefore, the forecasted load reductions start to flatten out after 2031. After 2031, programs will continue to replace the older technology, but it will no longer result in net additional load reductions.

Exhibit 10: Annual Average and Peak Load Energy Efficiency Contribution (MW)



Source: Siemens

Exhibit 11: Annual Average and Peak Load Energy Efficiency Contribution (MW)

	Avg. Load Reduction (MW)	Peak Load Reduction (MW)
2020	0	0
2021	2	3
2022	6	13
2023	14	29
2024	22	45
2025	30	61
2026	38	77
2027	46	94
2028	54	110
2029	62	126
2030	70	142
2031	76	155
2032	79	162
2033	79	162
2034	79	162
2035	79	162
2036	79	162
2037	79	163
2038	79	163
2039	79	163

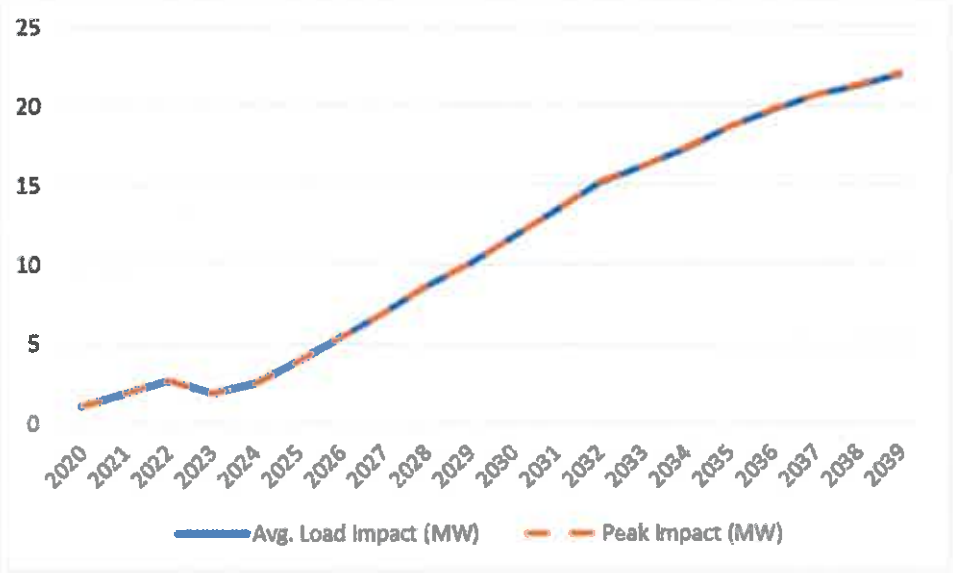
Source: Siemens

Distributed Solar Generation (DS)

To project the DS penetration, Siemens assumes that MLGW's DS penetration proportionally corresponds with TVA's projected DS penetration. MLGW's peak demand is roughly 10% of TVA's total peak demand, so Siemens assumes that MLGW's DS penetration is 10% of TVA's DS forecast. Siemens applied NREL's PV Watts[5] capacity factor for the Memphis geographic location to calculate an average load and peak load impact for MLGW.

[5] https://pvwatts.nrel.gov/

Exhibit 12: Annual Average and Peak Load Distributed Solar Generation (MW)



Source: Siemens

Exhibit 13: Annual Average and Peak Load Distributed Solar Generation (MW)

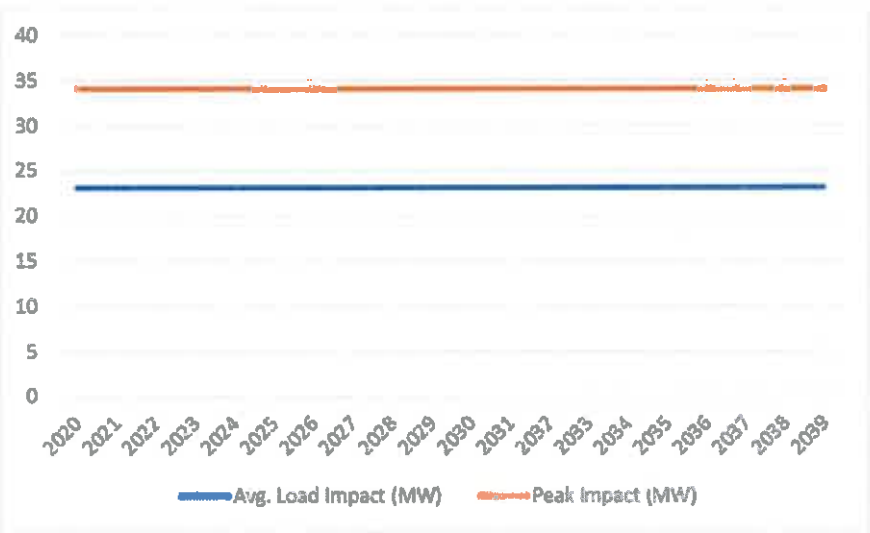
	Avg. Load Impact (MW)	Peak Impact (MW)
2020	1.1	1.1
2021	1.9	1.9
2022	2.7	2.7
2023	1.9	1.9
2024	2.5	2.5
2025	3.9	3.9
2026	5.4	5.5
2027	7.0	7.0
2028	8.7	8.7
2029	10.1	10.1
2030	11.7	11.8
2031	13.5	13.5
2032	15.2	15.2
2033	16.2	16.2
2034	17.4	17.4
2035	18.7	18.7
2036	19.7	19.8
2037	20.7	20.7
2038	21.3	21.4
2039	22.0	22.0

Source: Siemens

Known Commercial Developments

MLGW provided estimated peak load data for known future commercial developments that will impact Memphis's system load. MLGW reported increases in expected peak load from a FedEx Hub Expansion (25MW), Amazon (5MW), One Beal Project New Hotel (2.4MW), and One Beal Project Dr. MLK (1.7MW). Siemens applied an assumed base industrial load of 70% to apply to FedEx and Amazon and a commercial load factor of 50% for the One Beal Projects to calculate their contribution towards average load.

Exhibit 14: Annual Average and Peak Load Contribution from Future Known Commercial Developments (MW)



Source: Siemens

Exhibit 15: Annual Average and Peak Load Contribution from Future Known Commercial Developments– (MW)

	Avg. Load Impact (MW)	Peak Impact (MW)
2020	23	34
2021	23	34
2022	23	34
2023	23	34
2024	23	34
2025	23	34
2026	23	34
2027	23	34
2028	23	34
2029	23	34
2030	23	34
2031	23	34
2032	23	34
2033	23	34
2034	23	34
2035	23	34
2036	23	34
2037	23	34
2038	23	34
2039	23	34

Source: Siemens

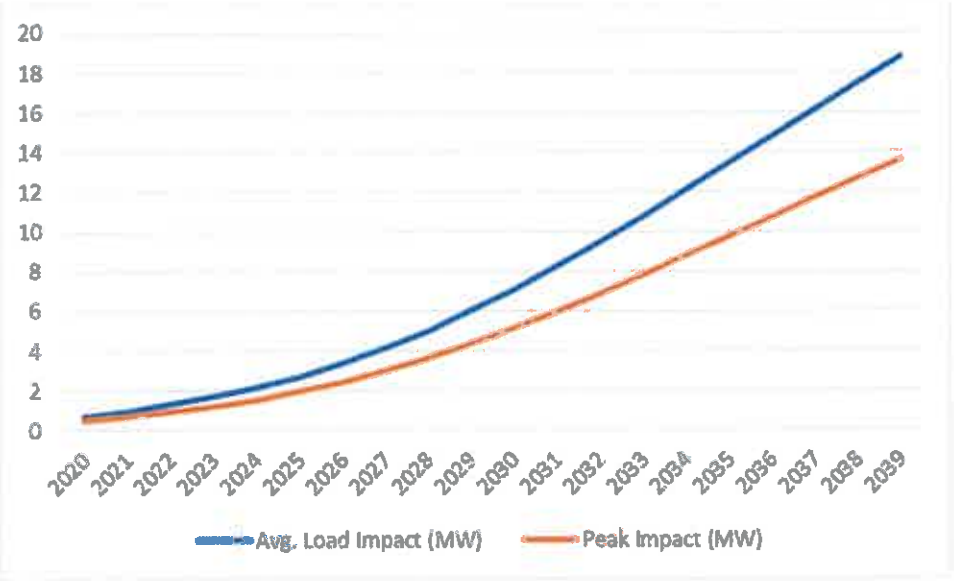
4)Electric Vehicle Forecast

Siemens forecasted the average and peak load impacts of increased electric vehicle adoption within the Memphis Light Gas and Water (MLGW) service territory through the forecast period. To estimate the potential for EV adoption in MLGW's territory, Siemens applied our proprietary electric vehicle forecasting approach, which employs our market view, a leading Light Duty Vehicle (LDV) adoption tool, and our proprietary analytical models to project commercial and bus adoption and load calculations. The Siemens' reference case LDV adoption forecast leverages proprietary inputs and adjustments to the latest version of the best-in-class customer choice model (MA^{3}T Model[1]) developed by Oak Ridge National Labs (ORNL). This model generates forecasts for both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) by state, and Siemens segmented the Tennessee forecast derived from this model into MLGW's portion using MLGW's residential customer count.

The reference case commercial vehicle forecast was derived from the Department of Energy's 2019 Annual Energy Outlook PEV adoption forecast, which we applied to the commercial vehicles operating in MLGW's service territory. As demonstrated in Exhibit 16, the peak impact is lower than the average impact because the peak most frequently occurs at 4-5 P.M, which is not when most customers are charging.

[1] https://www.ornl.gov/content/ma3t-model

Exhibit 16: Annual Average and Peak Load Electric Vehicle Contribution (MW)



Source: Siemens

Exhibit 17: Annual Average and Peak Load Electric Vehicle Contribution (MW)

	Avg. Load Impact (MW)	Peak Impact (MW)
2020	1	1
2021	1	1
2022	1	1
2023	2	1
2024	2	2
2025	3	2
2026	3	2
2027	4	3
2028	5	4
2029	6	4
2030	7	5
2031	8	6
2032	9	7
2033	11	8
2034	12	9
2035	13	10
2036	15	11
2037	16	12
2038	18	13
2039	19	14

Source: Siemens

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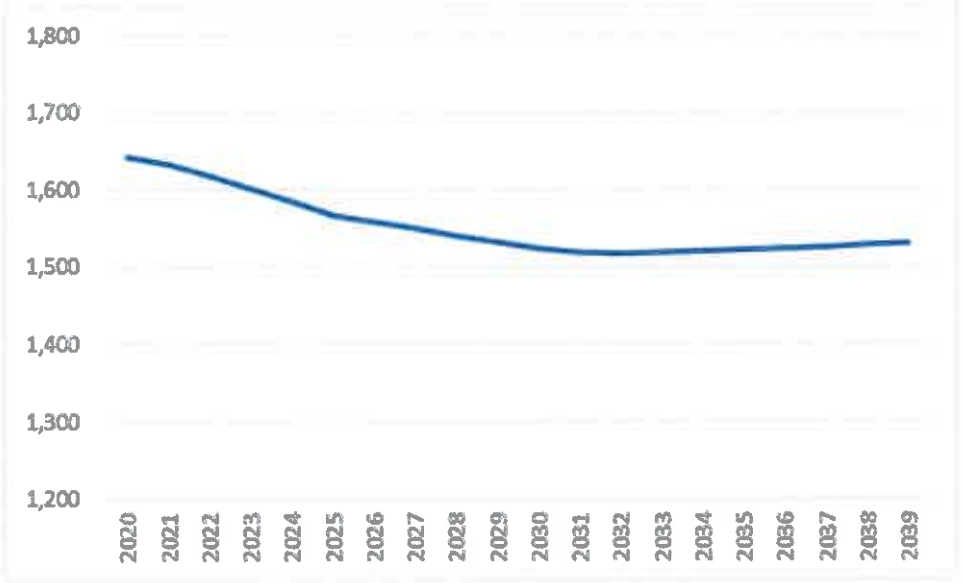
Net Load Adjusted for Electric Vehicle Impact

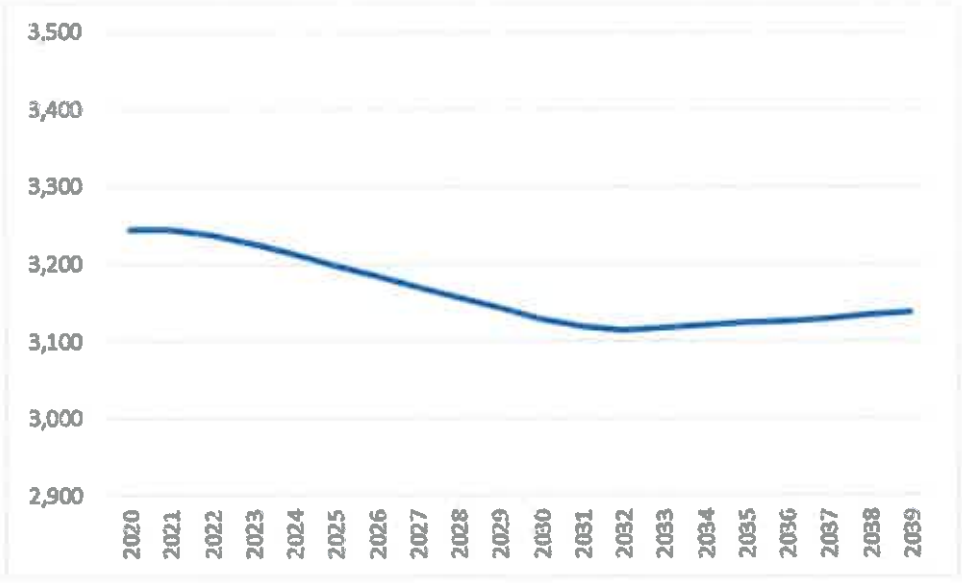
Siemens developed final average and peak forecasts of net loads inclusive of EVs, as presented in the following Exhibits 27-29.

Exhibit 18: Annual Net Average Load Including EV Impact (MW)



Source: Siemens

Exhibit 19: Annual Net peak Load Including EV Impact (MW)



Source: Siemens

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Exhibit 20: Annual Net Average and Peak Load Including EV Impact (MW)

	Avg. Load (MW)	Peak Load (MW)
2020	1,643	3,245
2021	1,632	3,244
2022	1,618	3,237
2023	1,602	3,226
2024	1,585	3,213
2025	1,567	3,199
2026	1,558	3,185
2027	1,549	3,171
2028	1,540	3,157
2029	1,532	3,143
2030	1,524	3,129
2031	1,518	3,119
2032	1,516	3,115
2033	1,518	3,118
2034	1,520	3,121
2035	1,522	3,123
2036	1,523	3,127
2037	1,525	3,130
2038	1,528	3,133
2039	1,530	3,137
	CAGR	CAGR
2020-2025	-0.94%	-0.29%
2026-2030	-0.55%	-0.44%
2031-2039	0.09%	0.07%
2020-2039	-0.37%	-0.18%

Source: Siemens

Nelson Bacalao, Senior Consulting Manager

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