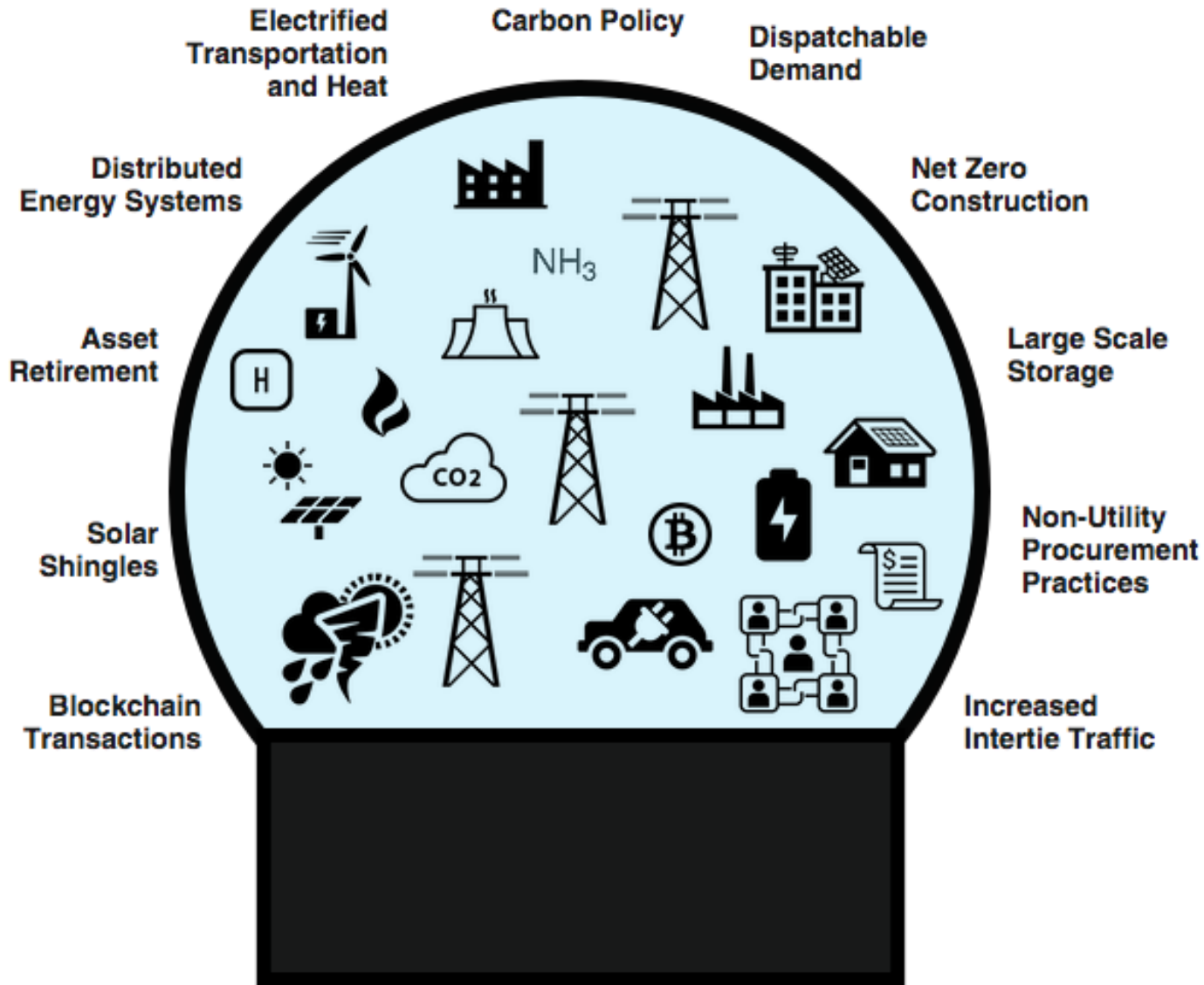


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Climate Led Energy Evolution Network 2040

Look Into The Future Of Energy Systems

Rupp Carriveau
Lindsay Miller
Nick MacMackin



Demand Curve Model Demonstration.

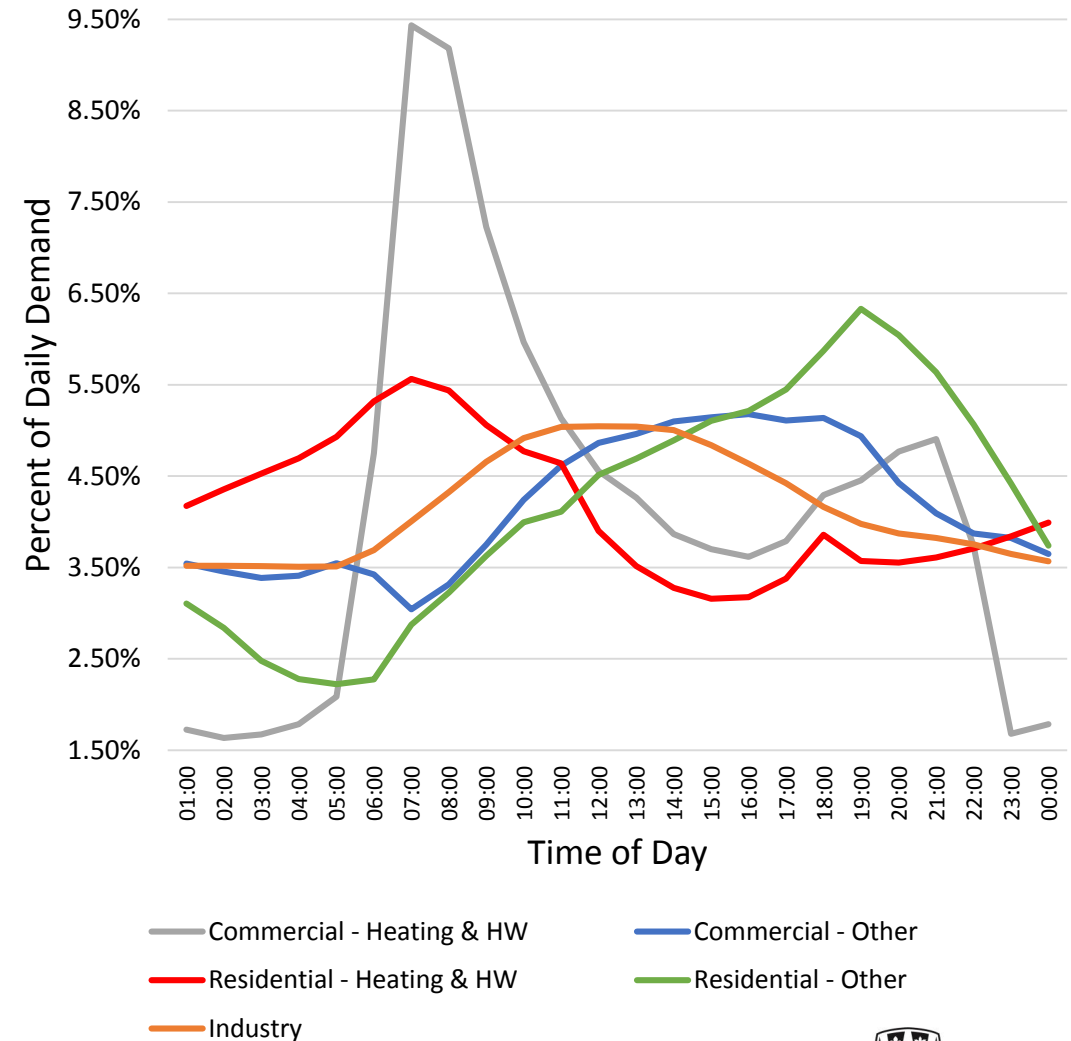
DEMAND CURVE MODELING

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BASIC METHODOLOGY

- Identify sectors with unique representative demand curves
- Identify modifying factors and resulting demand or supply curves
- Adjust the magnitude of curves based on various future technology and policy scenarios



DEMAND CURVE MODELING

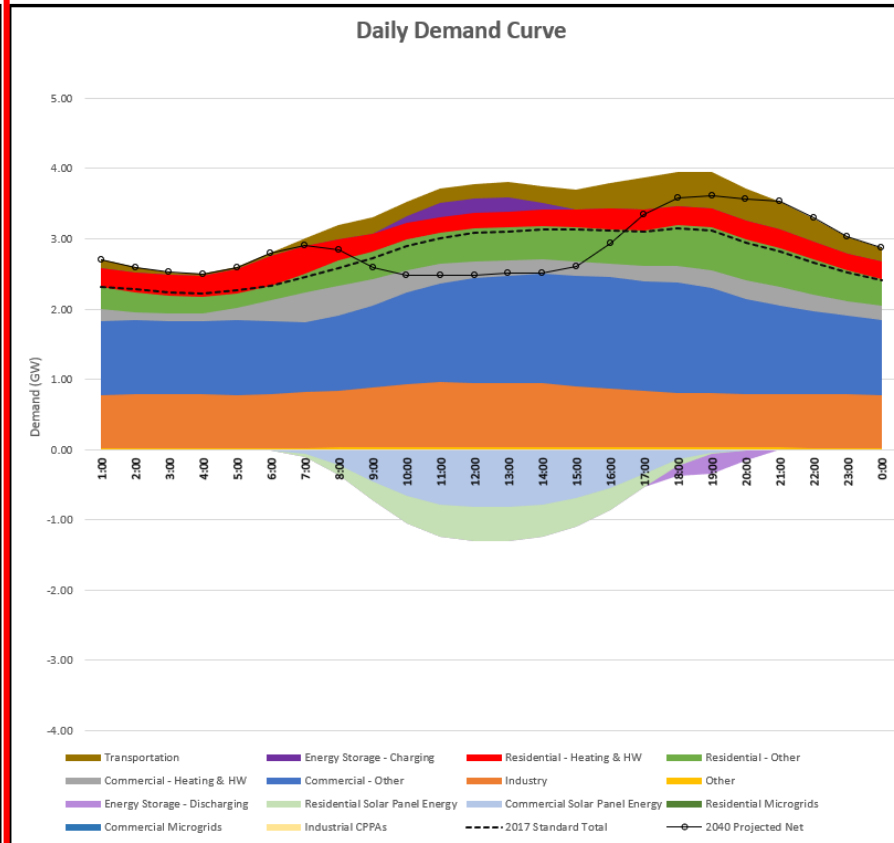
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MODEL INTERFACE

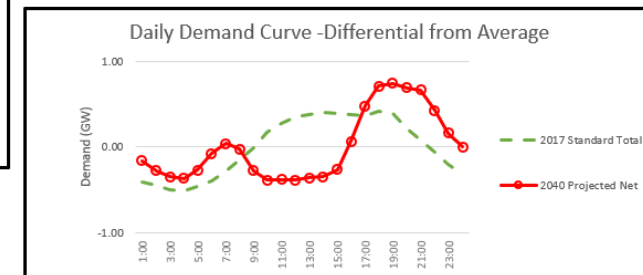
Dynamically Adjustable Parameters

EV Market Penetration (%)	50%	NREL
Evs with Charging Stations Available at Work (%)	70%	
PV Residential Market Penetration (% of Total Suitable Roof Area)	43%	
PV Commercial Market Penetration (% of Total Suitable Roof Area)	44%	
PV's allowed to feed excess energy into grid?	Yes	
PV's oriented West (as opposed to South) (%)	0%	
Energy Storage Capacity (GWh)	0.8	
Residential Electrified Heating Penetration (%)	38%	
Commercial Electrified Heating Penetration (%)	21%	
Value of Industrial CPPAs (GW)	0.0	
Value of Microgrid Communities (GW)	0.0	
Switch to Sector Growth Values		



Curve Score:	Peak Ramp		Utilization		CV		Cost		Total
	GW/h	Points	%	Points	%	Points	\$/B	Points	
	0.41	0.35	79.6	1.48	13.7	1.22	10.1	0.99	4.03

Financials	Daily Revenue			Total (\$M)
	GWh	\$/GWh	\$	
Off Peak	35.58	\$65,000	\$2,313,007	\$6.07
Mid Peak	16.63	\$94,000	\$1,563,114	
On Peak	16.63	\$132,000	\$2,195,011	
Capital Costs				Total (\$B)
		\$B/unit	\$B	
EV Infrastructure (10^6 EVs)	0.6	\$1.928	\$1.19	\$10.118
Solar Panels (GW)	2.5	\$2.671	\$6.77	
Energy Storage (GWh)	0.8	\$0.600	\$0.480	
Residential Electric Heating (GW)	0.2	\$0.708	\$0.16	
Commercial Electric Heating (GW)	0.2	\$0.270	\$0.056	
Added Capacity (GW)	0.5	\$3.189	\$1.464	
Stranded Assets (GW)	0.0	\$3.189	\$0.000	



DEMAND CURVE MODELING

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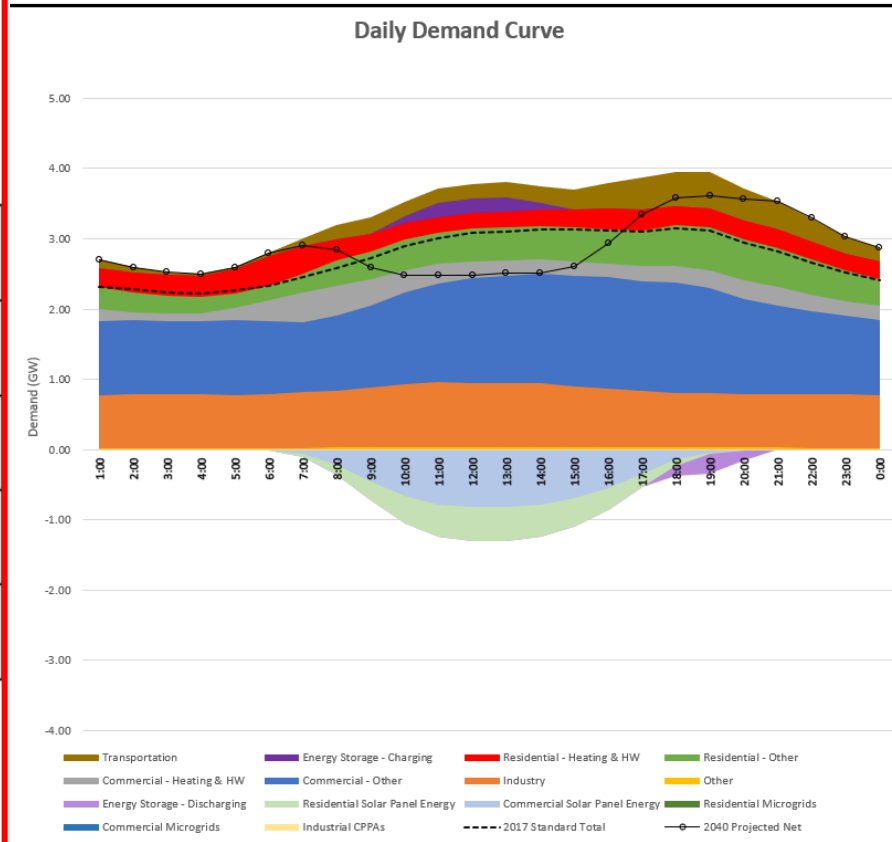
Climate Led Energy Evolution Network 2040

MODEL INTERFACE

Dynamically Adjustable Parameters

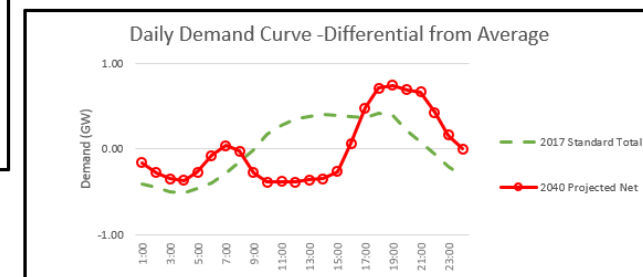
Industrial Annual Avg Growth Rate	0.04%
Commercial HHW Annual Avg Growth Rate	0.66%
Commercial Other Annual Avg Growth Rate	0.17%
Residential HHW Annual Avg Growth Rate	-0.20%
Residential Other	0.07%

Switch to Dynamic Parameters



Curve Score:	Peak Ramp		Utilization		CV		Cost		Total
	GW/h	Points	%	Points	%	Points	\$/B	Points	
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DEMAND CURVE MODELING

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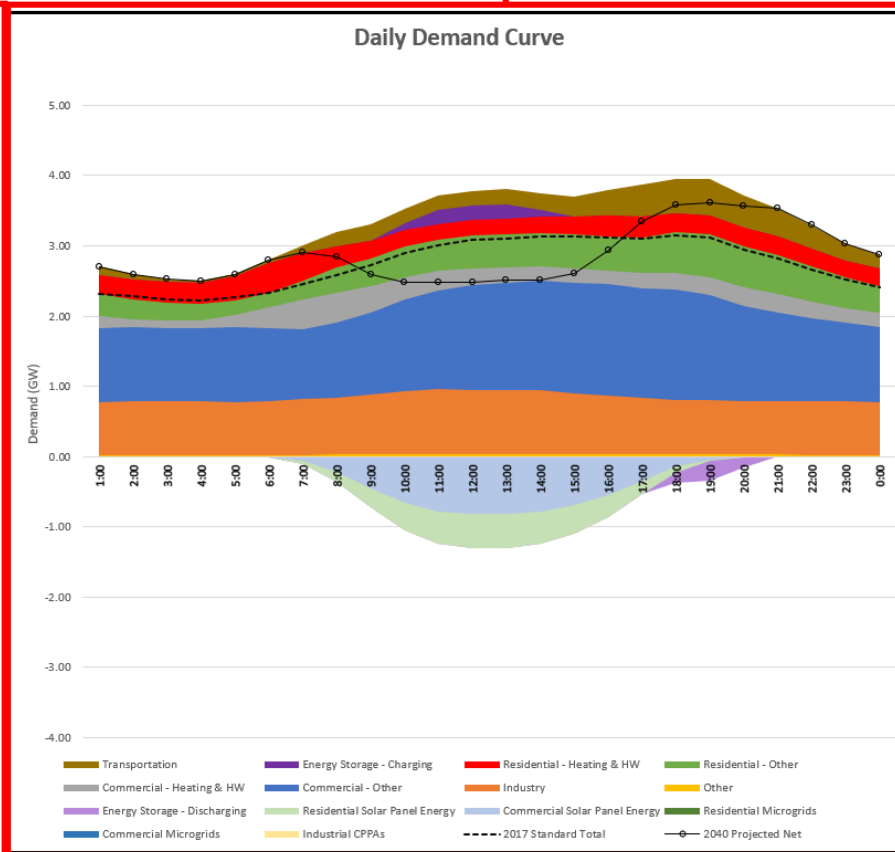
Climate Led Energy Evolution Network 2040

MODEL INTERFACE

Resulting Average Daily Demand Curve

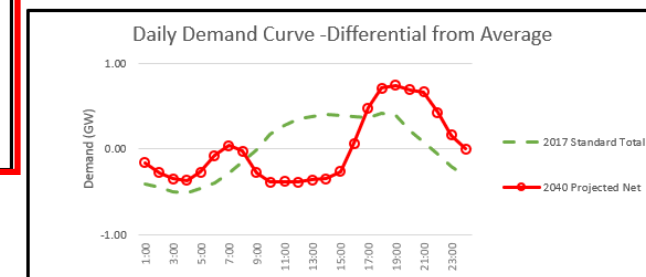
Dynamically Adjustable Parameters

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PV Residential Market Penetration (% of Total Suitable Roof Area)	43%	
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PV's allowed to feed excess energy into grid?	Yes	
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Switch to Sector Growth Values		



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	GW/h	Points	%	Points	%	Points	\$/B	Points	
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DEMAND CURVE MODELING

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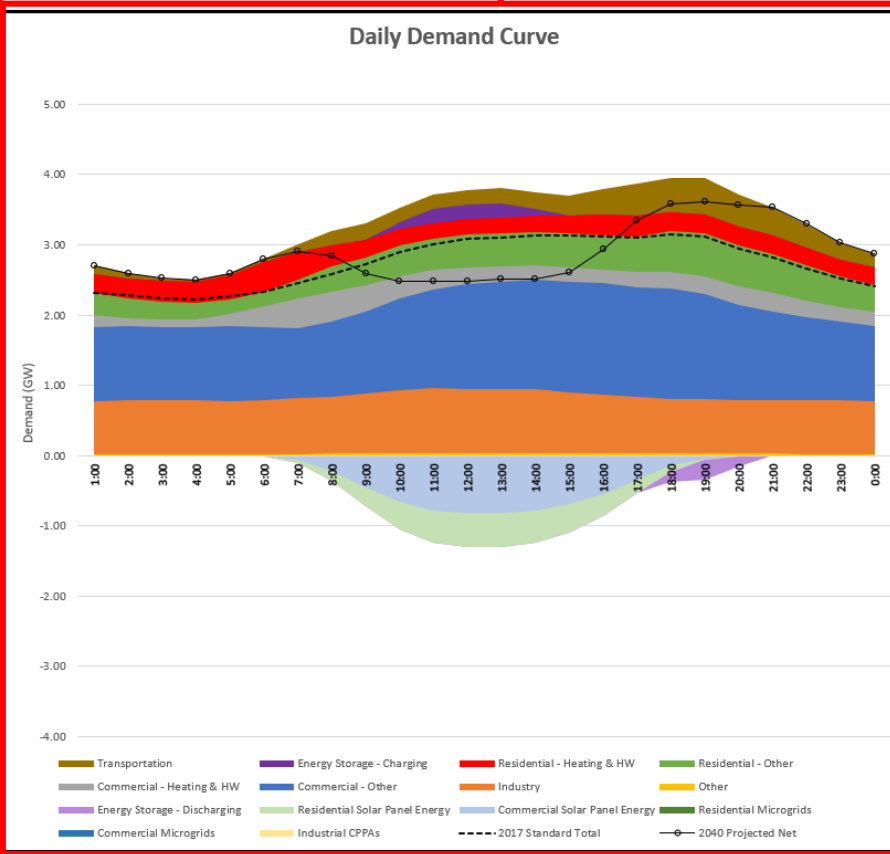
Climate Led Energy Evolution Network 2040

MODEL INTERFACE

Resulting Average Daily Demand Curve

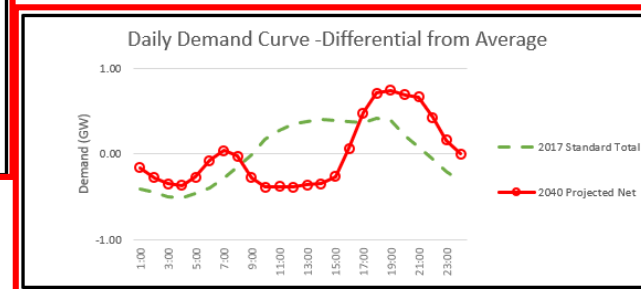
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Mean Centered Total Demand

DEMAND CURVE MODELING

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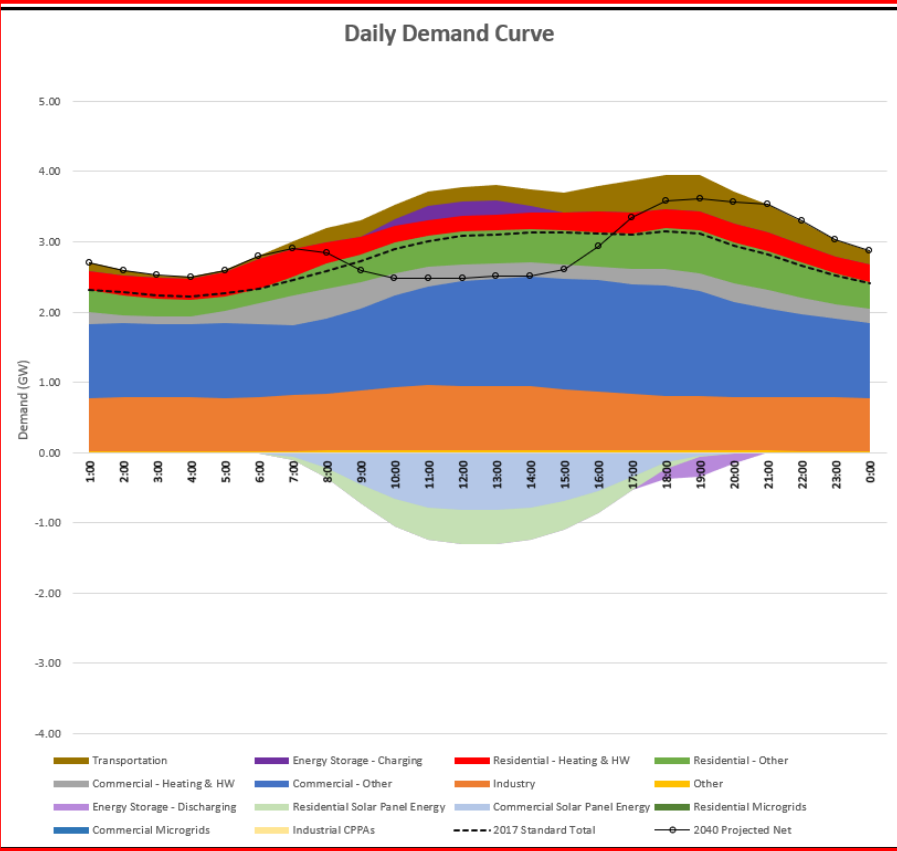
Climate Led Energy Evolution Network 2040

MODEL INTERFACE

Resulting Average Daily Demand Curve

Dynamically Adjustable Parameters

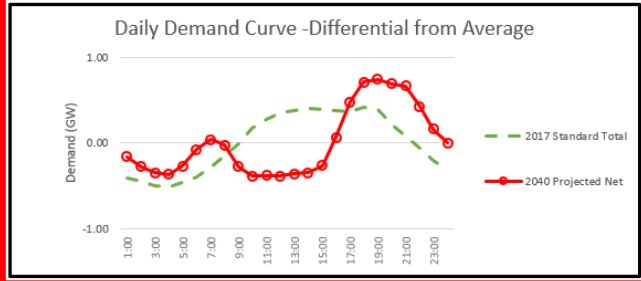
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Costs and Revenues



Mean Centered Total Demand

DEMAND CURVE MODELING

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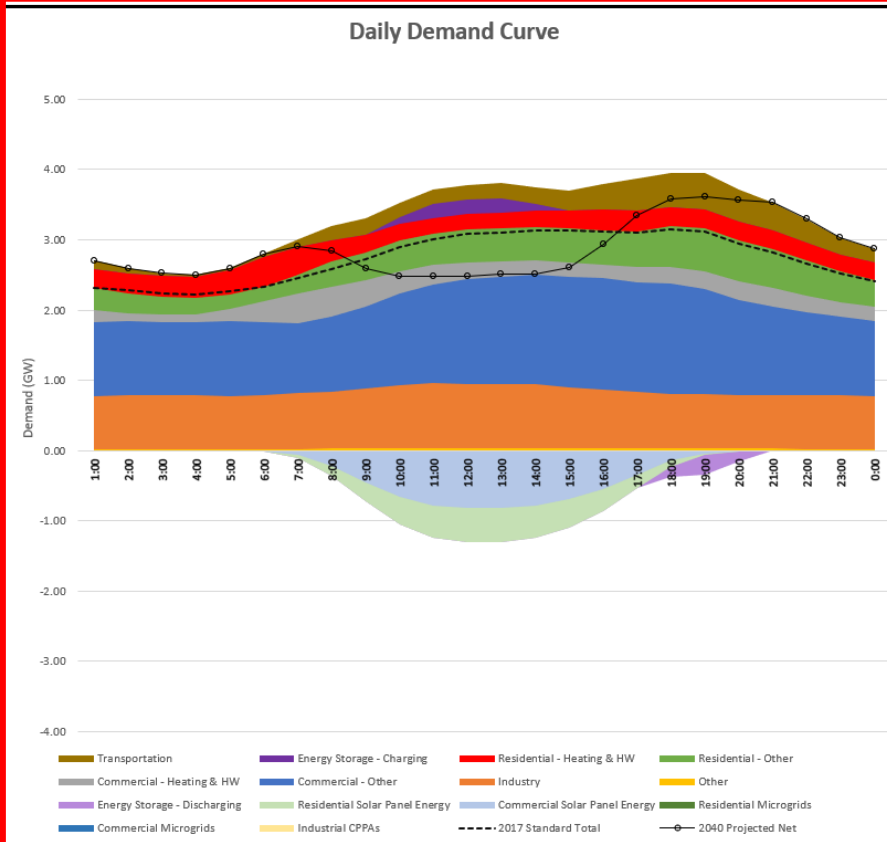
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MODEL INTERFACE

Resulting Average Daily Demand Curve

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< >	< >	
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Switch to Sector Growth Values		

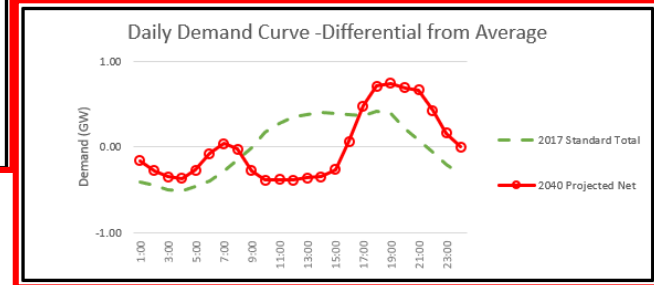


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	GW/h	Points	%	Points	%	Points	\$/B	Points	
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Curve Scoring Metric

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Costs and Revenues



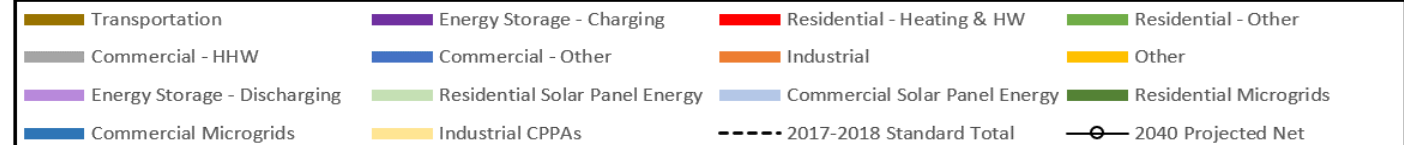
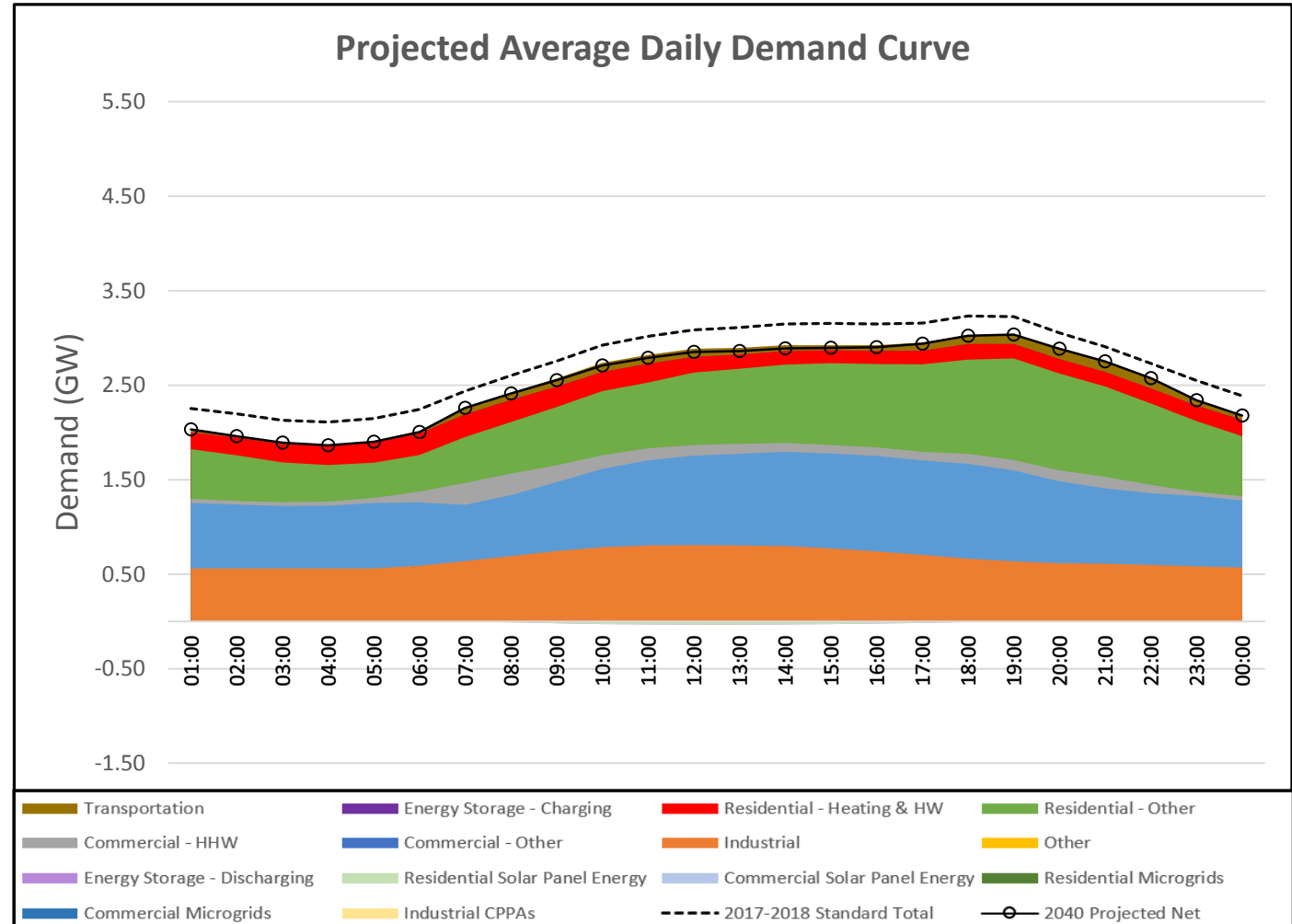
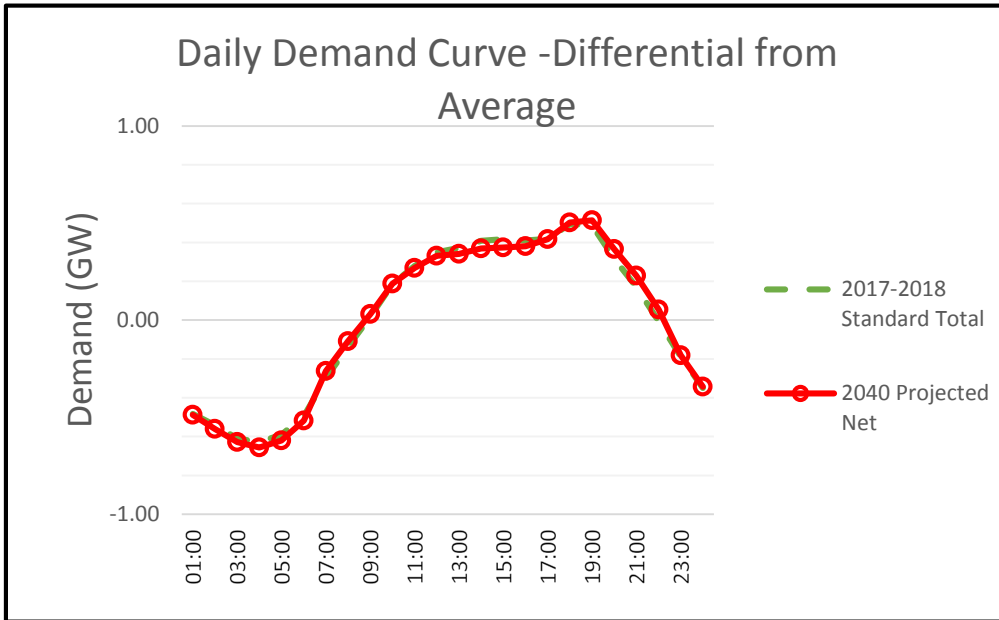
Mean Centered Total Demand

DEMAND CURVE MODELING

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Scenarios – IESO A

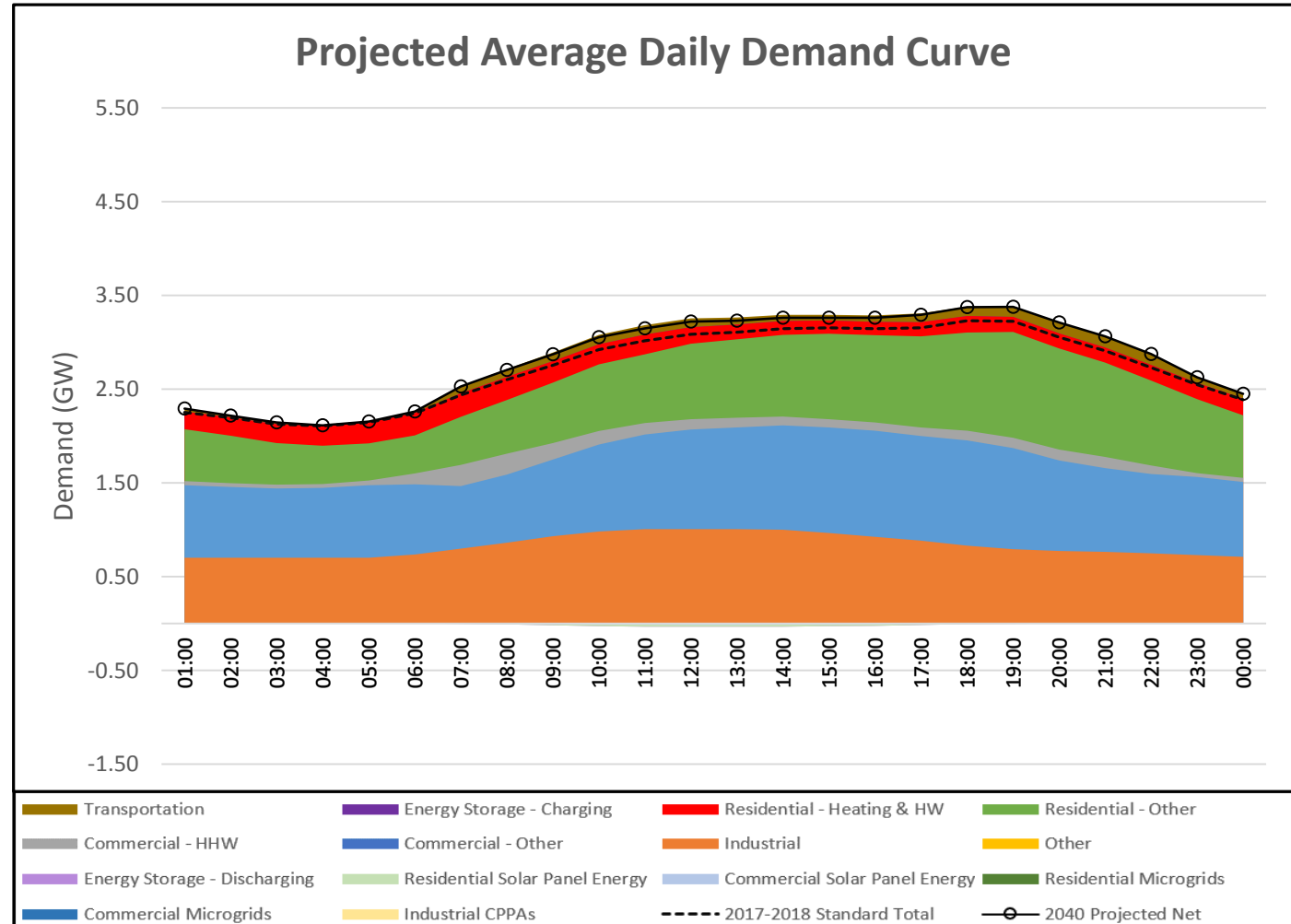
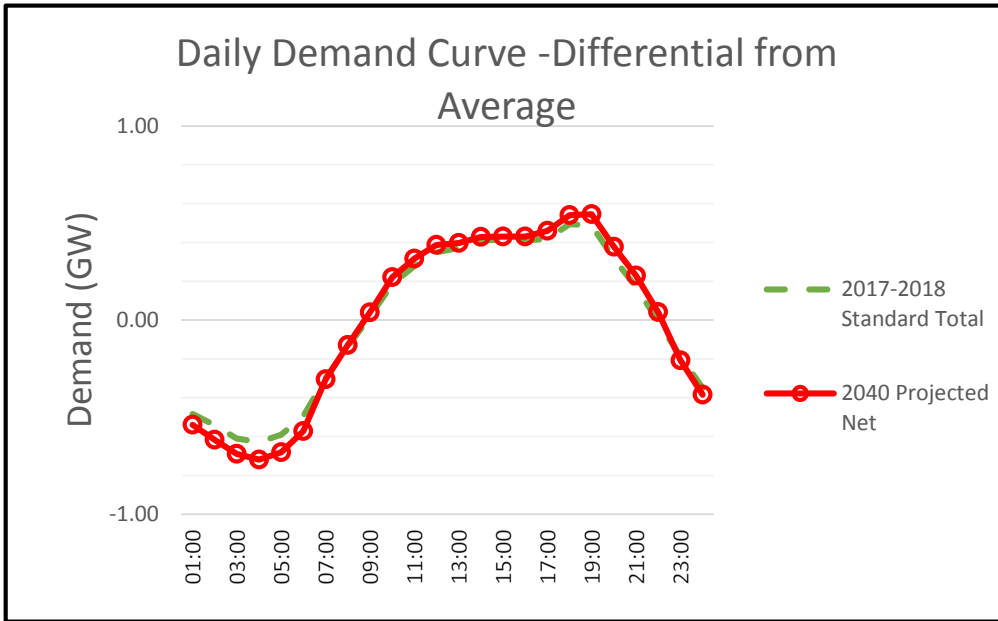


DEMAND CURVE MODELING

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Scenarios – IESO B

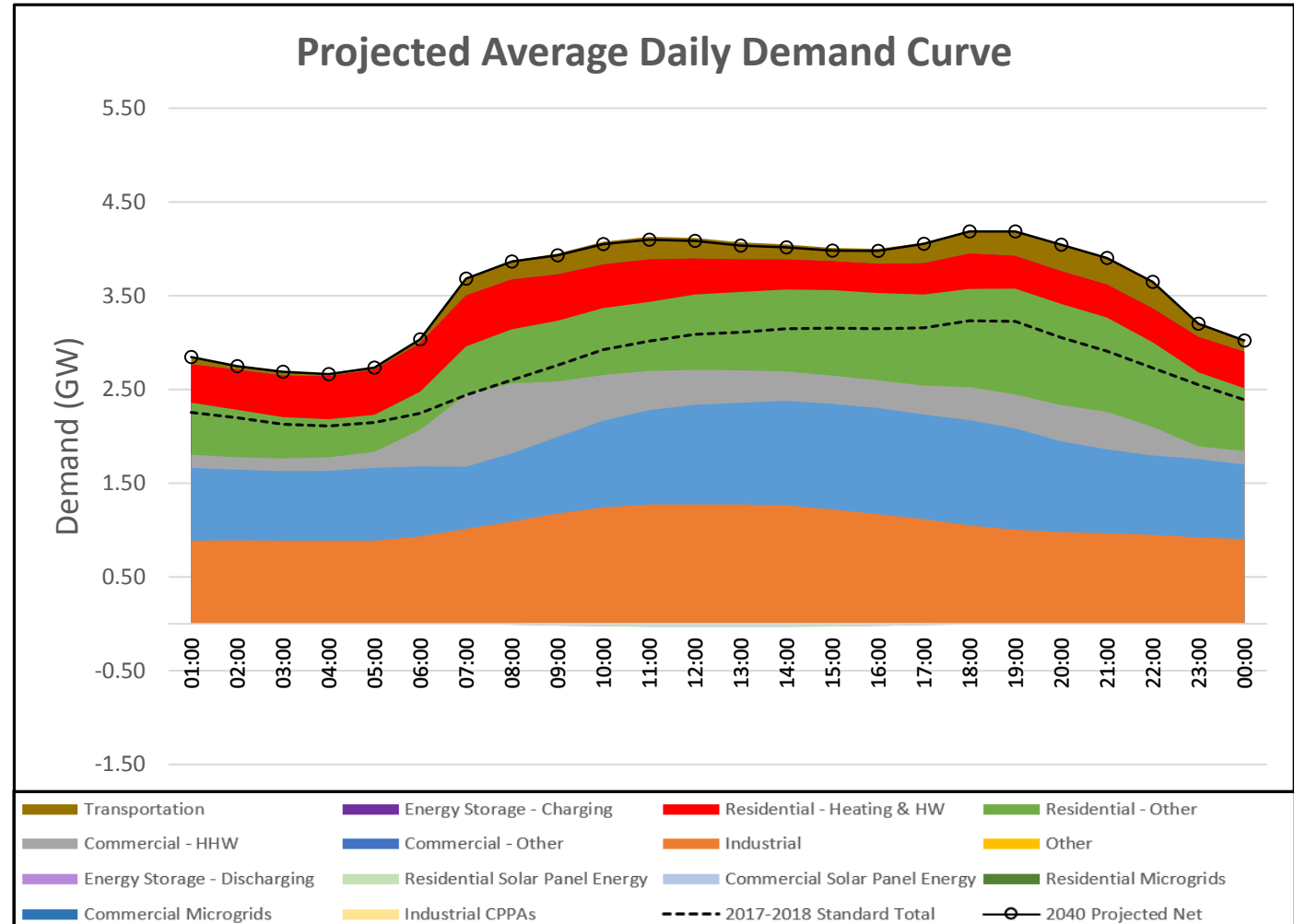
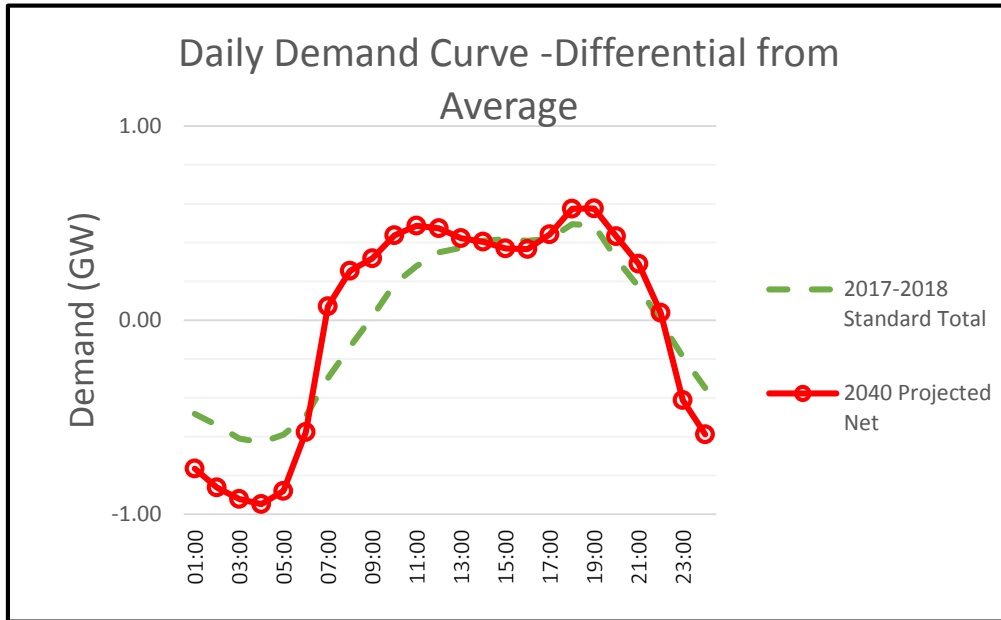


DEMAND CURVE MODELING

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Climate Led Energy Evolution Network 2040

Scenarios – IESO C

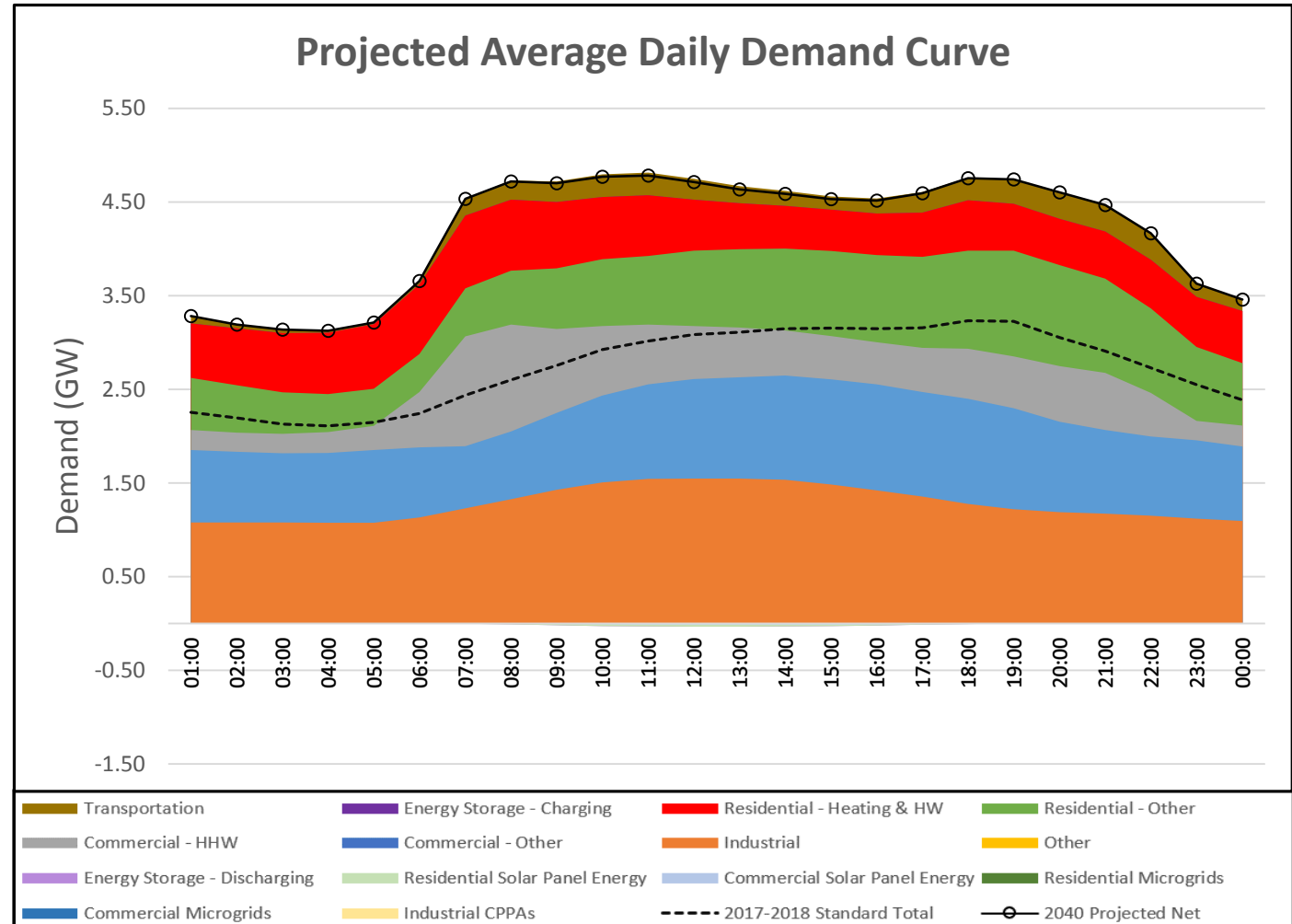
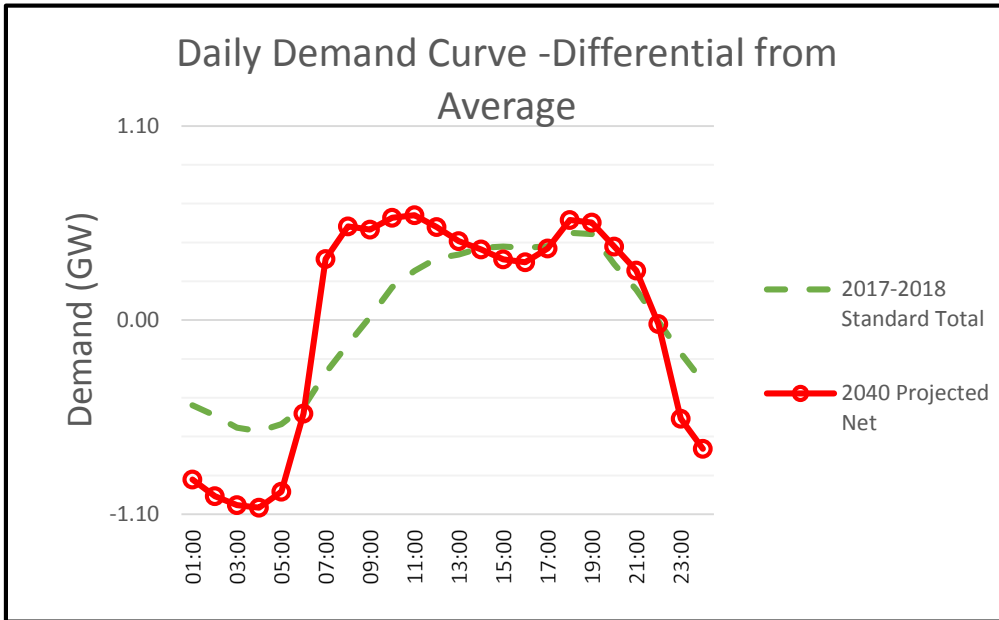


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Scenarios – IESO D



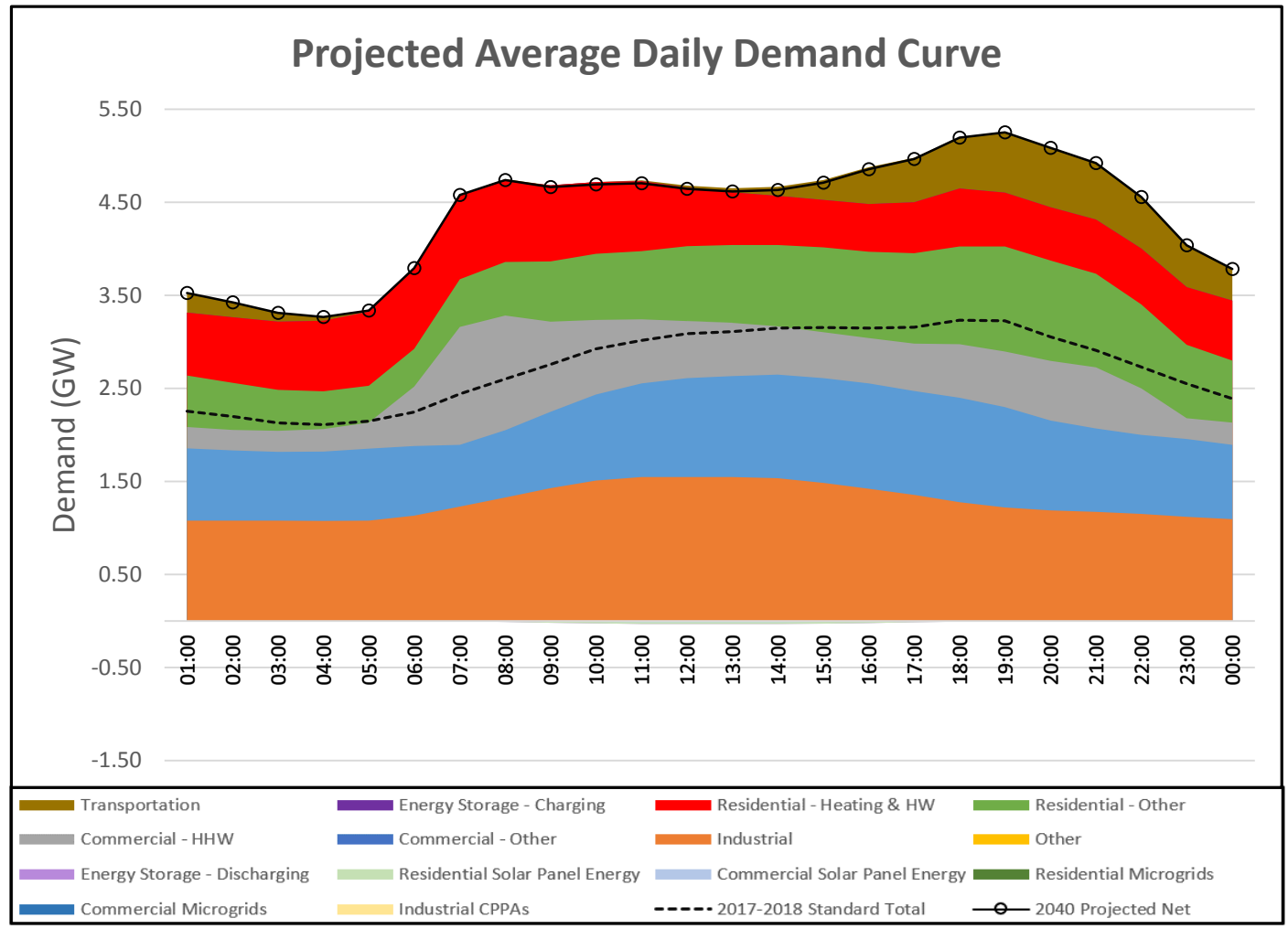
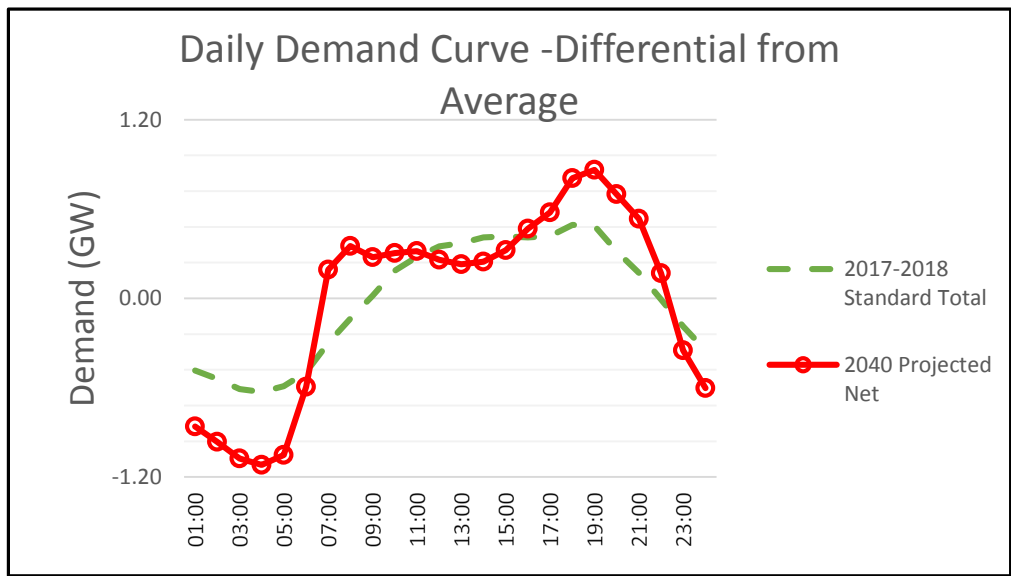
DEMAND CURVE MODELING

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Scenarios – High Demand

- Outlook D projected sector growth rates
- City concentrated EV penetration
- Quebec & Outlook D levels of electrical heating penetration
- National Renewable Energy Laboratory (NREL) projected 'Convenience' EV charging



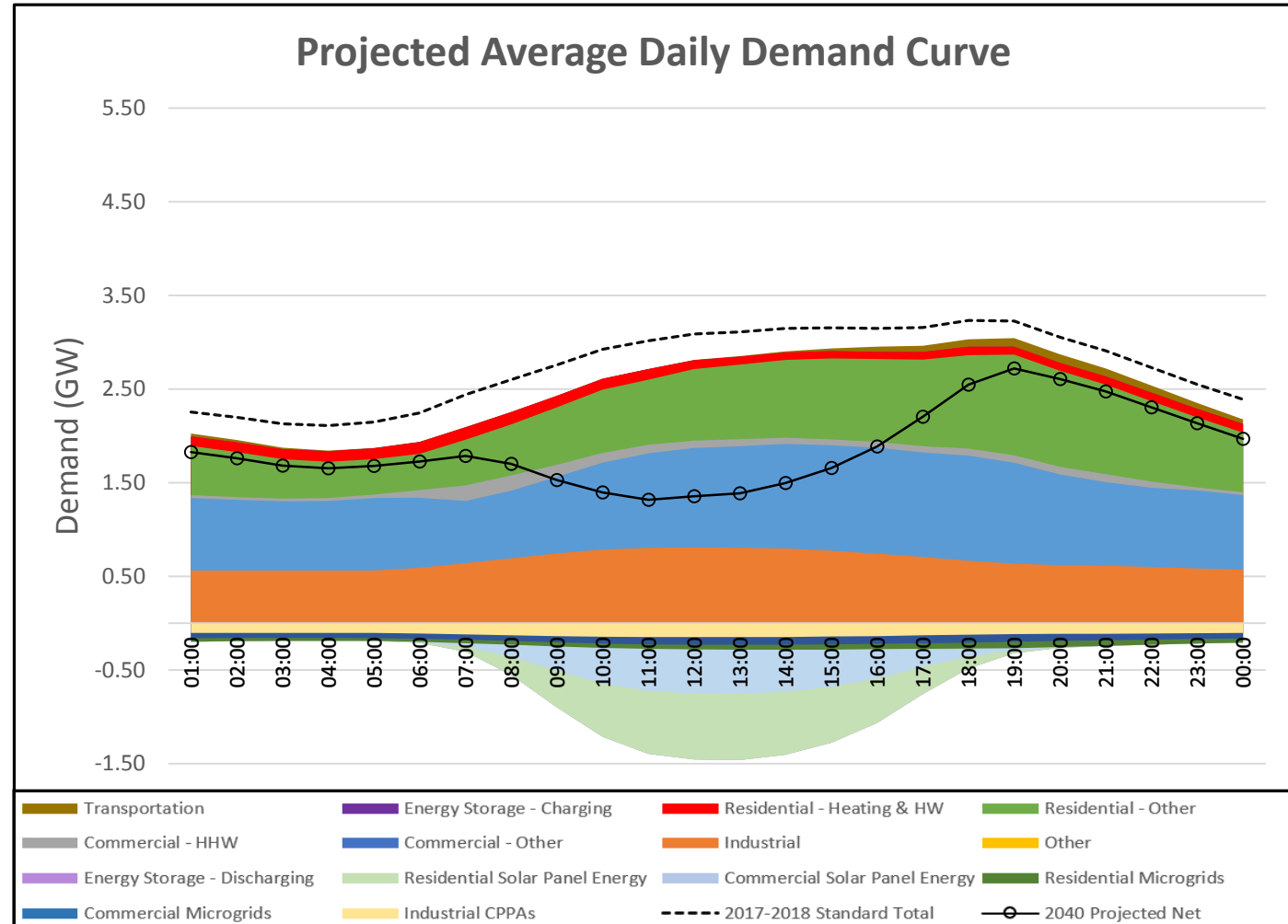
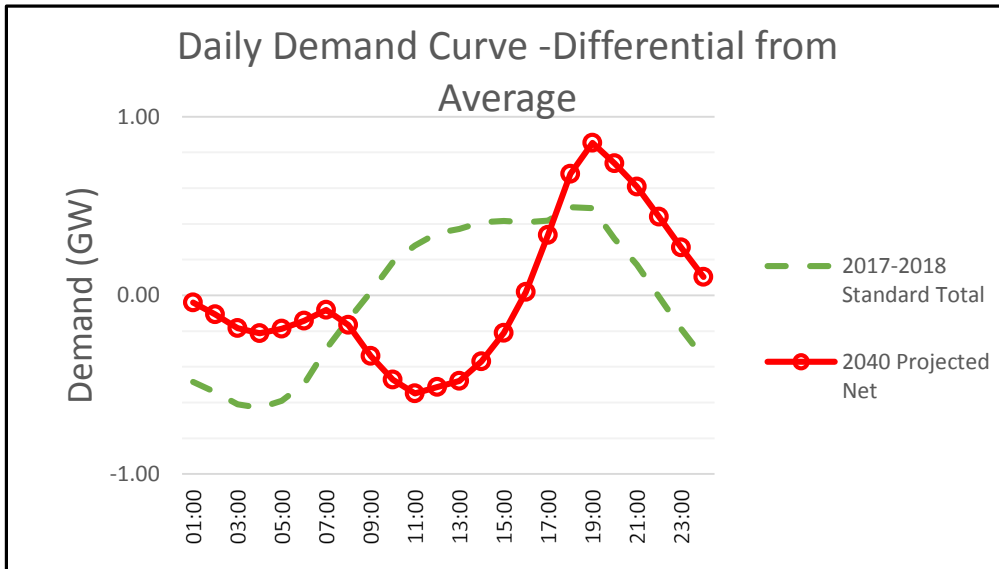
DEMAND CURVE MODELING

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Climate Led Energy Evolution Network 2040

Scenarios – Low Demand

- Outlook A projected sector growth rates and penetration of EVs without public transit
- Slight decline in electrical heating
- NEB 'Technology Case' projections for Embedded PV generation capacity
- 10% of demand to non-utility procurement



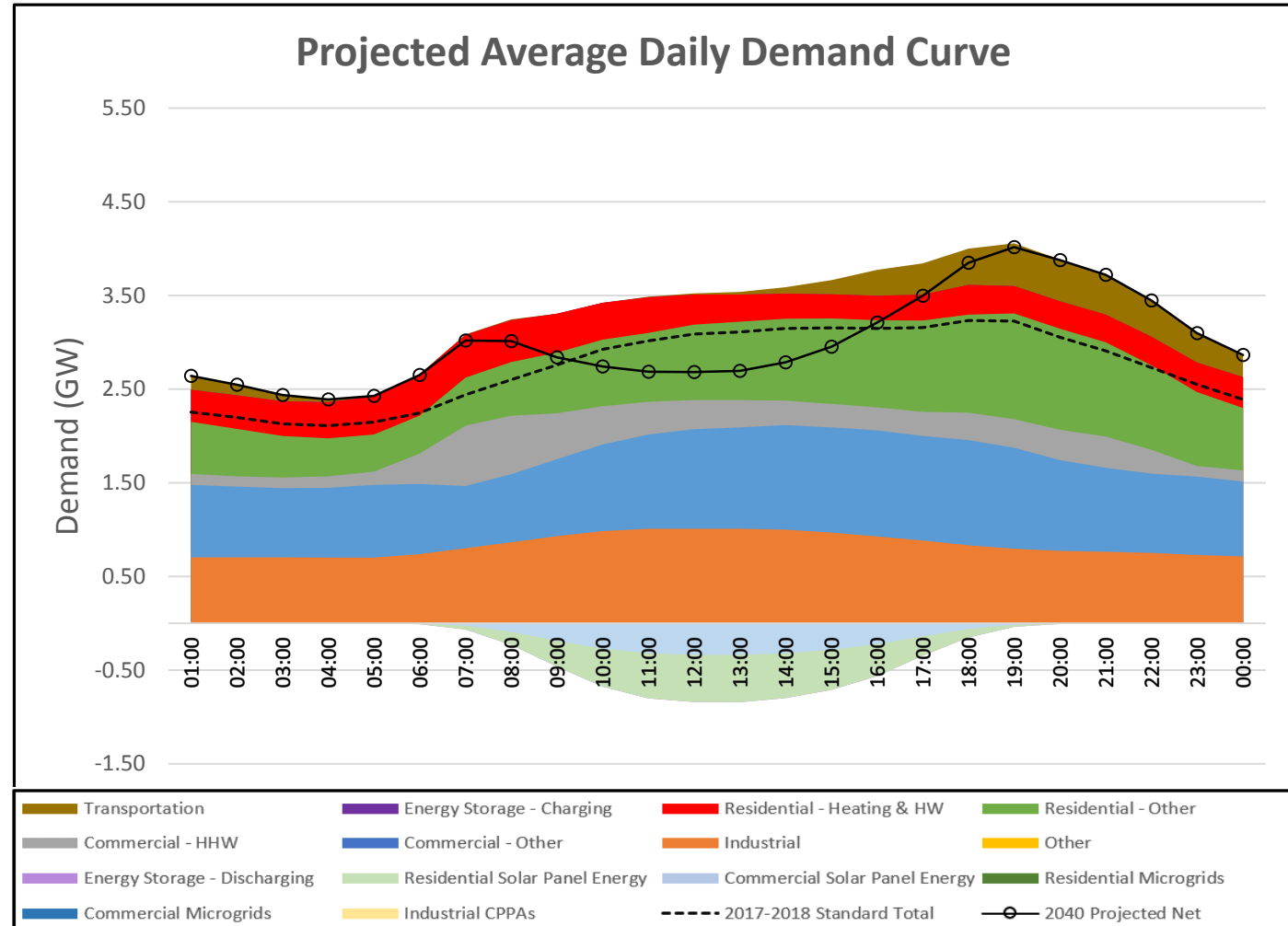
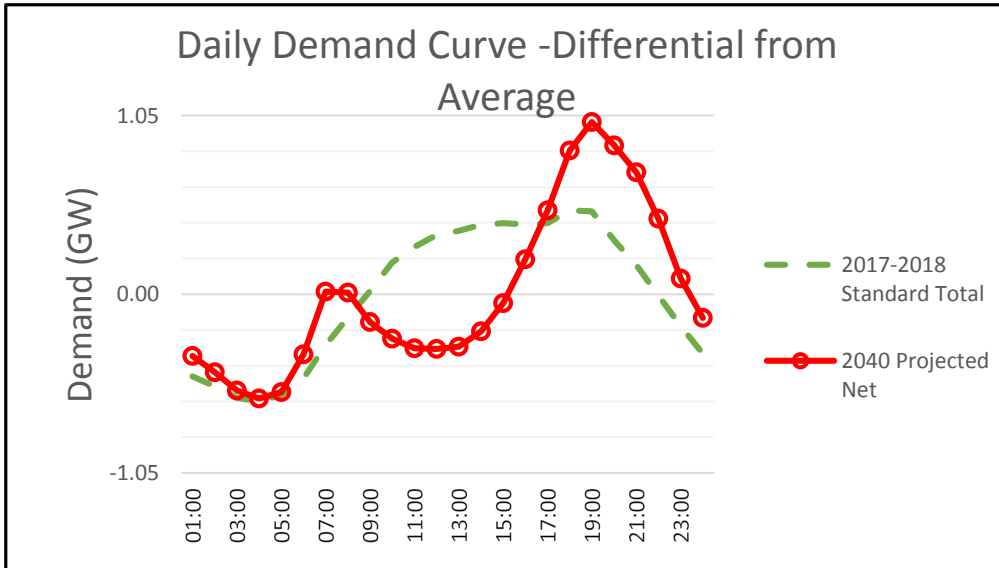
DEMAND CURVE MODELING

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Scenarios – Duck Curve

- Outlook B projected sector growth rates
- Average Outlook values for penetration rates of electrical heating
- Near Outlook C/D estimated EV penetration
- Midpoint of NEB 'Reference' & 'Technology' projections for Embedded PV



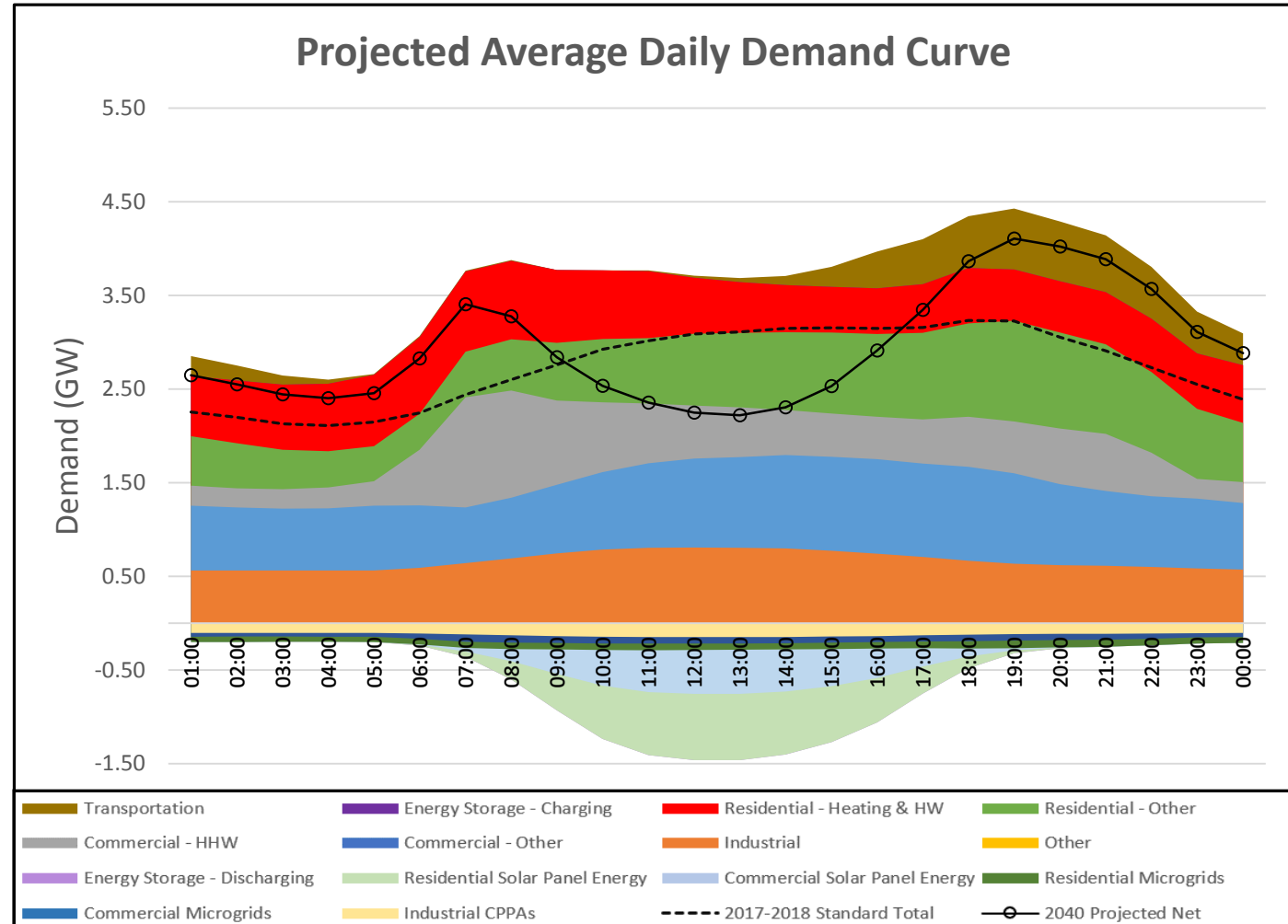
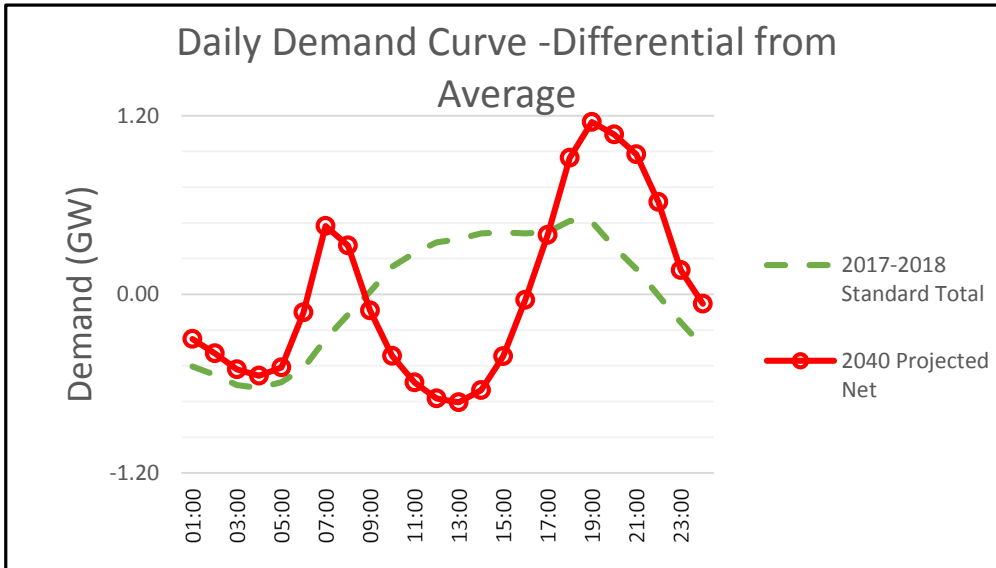
DEMAND CURVE MODELING

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Climate Led Energy Evolution Network 2040

Scenarios – Extreme Duck Curve

- Outlook A projected sector growth rates
- City concentrated EV penetration
- Quebec/Outlook D levels of electrical heating penetration
- NEB 'Technology Case' projections for Embedded PV generation capacity
- 10% of demand using non-utility procurement



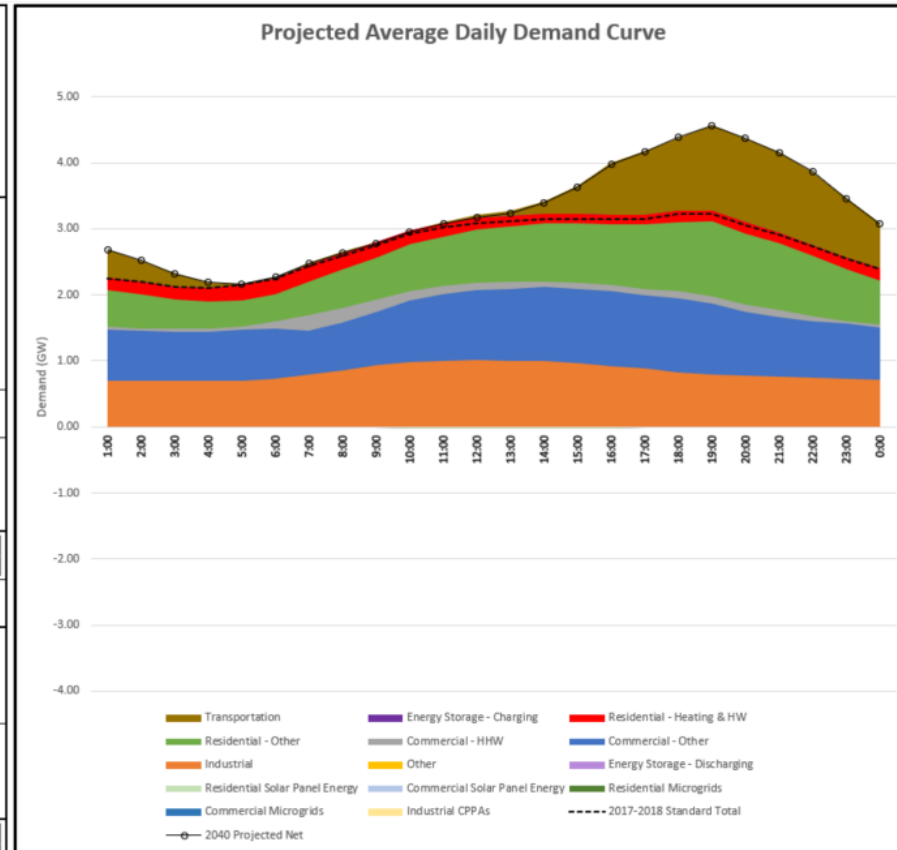
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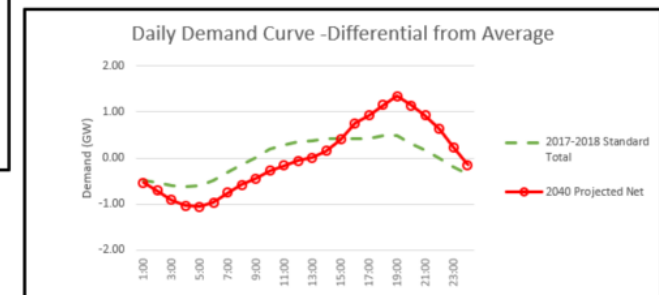
Activity Scenarios – EV Takeover

EV Market Penetration (%)	100%	NREL
< >		
Evs with Charging Stations Available at Work (%)	0%	1% of Peak Demand
< >		
PV Residential Market Penetration (% of Total Suitable Roof Area)	1%	Yes
< >		
PV Commercial Market Penetration (% of Total Suitable Roof Area)	1%	Grid
< >		
PV's allowed to feed excess energy into grid?	Yes	17%
PV's oriented West (as opposed to South) (%)	0%	
< >		11%
Energy Storage Capacity (GWH)	0.00	
Energy Storage Charging Source	Grid	0.0
Residential Electrified Heating Penetration (%)	17%	
< >		0.0
Commercial Electrified Heating Penetration (%)	11%	
< >		0.0
Value of Industrial CPPAs (GW)	0.0	
Value of Microgrid Communities (GW)	0.0	
Switch to Sector Growth Values		



Curve Score:	Peak Ramp		Utilization		CV		Cost		Total
	GW/h	Points	%	Points	%	Points	\$/B	Points	
	0.40	0.78	70.7	1.04	23.1	0.79	6.1	2.00	4.61

Financials	Revenue			Total (\$M)
	GWh	\$/GWh	\$	
Off Peak	37.66	\$65,000	\$2,447,935	\$6.95
Mid Peak	19.94	\$94,000	\$1,874,271	
On Peak	19.94	\$132,000	\$2,631,955	
Capital Costs				Total (\$B)
		\$/unit	\$B	
EV Infrastructure (10^6 EVs)	1.2	\$1.518	\$1.84	\$6.121
Solar Panels (GW)	0.0	\$2.671	\$0.00	
Energy Storage (GWh)	0.0	\$0.600	\$0.000	
Residential Electric Heating (GW)	0.0	\$0.708	\$0.000	
Commercial Electric Heating (GW)	0.0	\$0.270	\$0.009	
Added Capacity (GW)	1.3	\$3.189	\$4.267	
Stranded Assets (GW)	0.0	\$3.189	\$0.000	



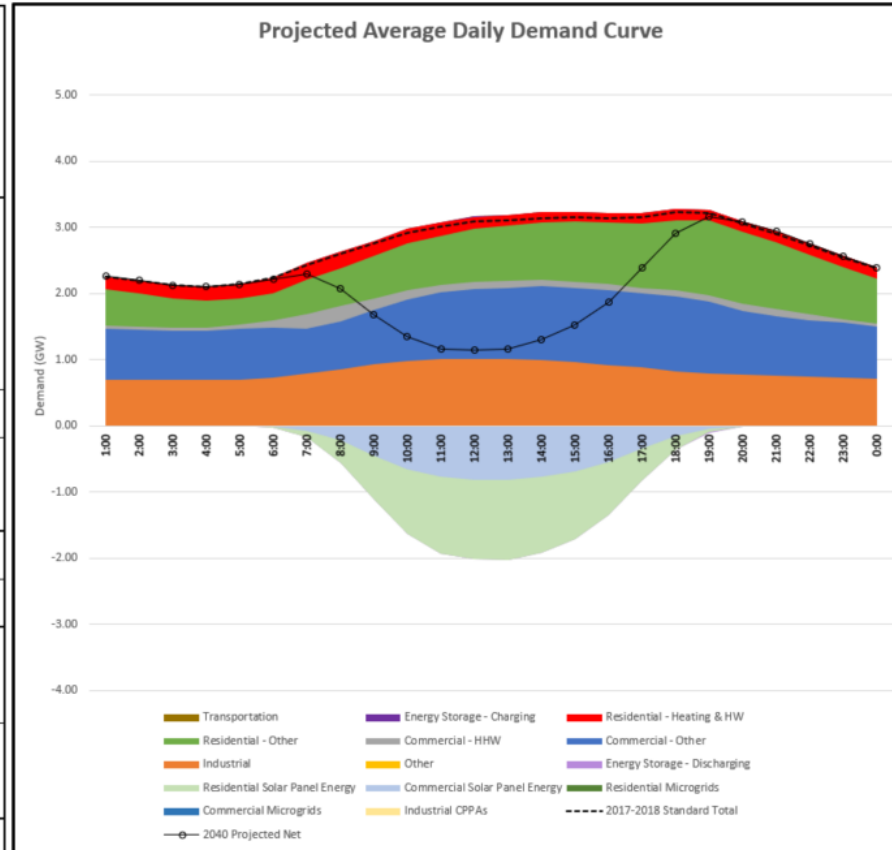
DEMAND CURVE MODELING

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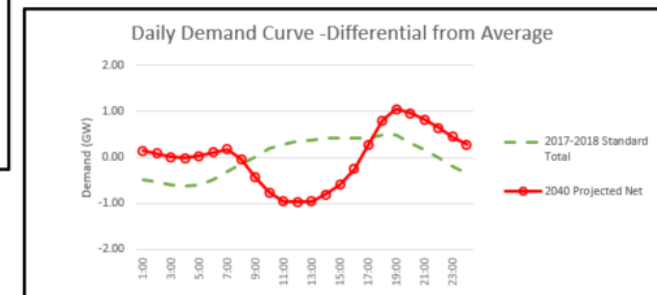
Activity Scenarios – PV Takeover

EV Market Penetration (%)	0%	IESO
< >		
Evs with Traditional Load Management (%)	0%	106% of Peak Demand
< >		
PV Residential Market Penetration (% of Total Suitable Roof Area)	60%	
< >		
PV Commercial Market Penetration (% of Total Suitable Roof Area)	60%	
< >		
PV's allowed to feed excess energy into grid?	Yes	
PV's oriented West (as opposed to South) (%)	0%	
< >		
Energy Storage Capacity (GWH)	0.00	
Energy Storage Charging Source	Grid	
Residential Electrified Heating Penetration (%)	17%	
< >		
Commercial Electrified Heating Penetration (%)	11%	
< >		
Value of Industrial CPPAs (GW)	0.0	
Value of Microgrid Communities (GW)	0.0	
Switch to Sector Growth Values		



Curve Score:	Peak Ramp		Utilization		CV		Cost		Total
	GW/h	Points	%	Points	%	Points	\$/B	Points	
	0.53	0.27	66.9	0.84	28.5	0.43	13.5	2.00	3.55

Financials	Revenue			Total (\$M)
	GWh	\$/GWh	\$	
Off Peak	29.98	\$65,000	\$1,948,884	\$4.31
Mid Peak	10.45	\$94,000	\$982,205	
On Peak	10.45	\$132,000	\$1,379,267	
Capital Costs				Total (\$B)
		\$/unit	\$B	
EV Infrastructure (10^6 EVs)	0.0	\$2.103	\$0.00	\$13.451
Solar Panels (GW)	5.0	\$2.671	\$13.25	
Energy Storage (GWh)	0.0	\$0.600	\$0.000	
Residential Electric Heating (GW)	0.0	\$0.708	\$0.00	
Commercial Electric Heating (GW)	0.0	\$0.270	\$0.009	
Added Capacity (GW)	0.0	\$3.189	\$0.000	
Stranded Assets (GW)	0.1	\$3.189	\$0.194	



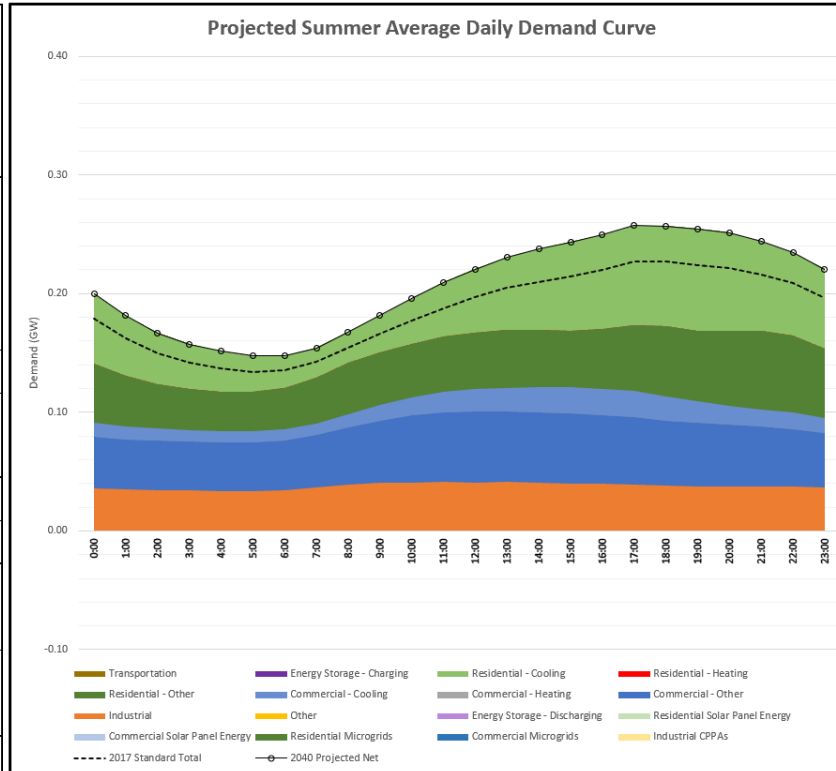
DEMAND CURVE MODELING

CLEEN2040

Climate Led Energy Evolution Network 2040

Temperature Dependence

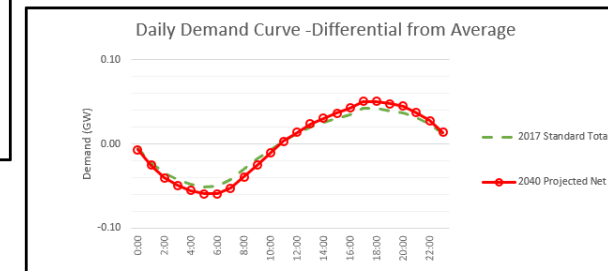
EV Market Penetration (%)	0%	NREL
< >		
Evs with Charging Stations Available at Work (%)	0%	0% of Peak Demand
< >		
PV Residential Market Penetration (% of Total Suitable Roof Area)	0%	0% of Peak Demand
< >		
PV Commercial Market Penetration (% of Total Suitable Roof Area)	0%	0% of Peak Demand
< >		
PV's allowed to feed excess energy into grid?	Yes	0% of Peak Demand
PV's oriented West (as opposed to South) (%)	0%	
< >		0% of Peak Demand
Energy Storage Capacity (GWH)	0.00	
Energy Storage Charging Source	Grid	0% of Peak Demand
Residential Electrified Heating Penetration (%)	20%	
< >		0% of Peak Demand
Commercial Electrified Heating Penetration (%)	11%	
< >		0% of Peak Demand
Value of Industrial CPPAs (GW)	0.00	
Value of Microgrid Communities (GW)	0.00	0% of Peak Demand
Climate Change - Increase in Average Temperature (°C)	2.00	
Switch to Sector Growth Values		



Curve Score:	Peak Ramp		Utilization		CV		Cost		Total
	GW/h	Points	%	Points	%	Points	\$/B	Points	
	0.02	2.00	80.3	1.51	18.9	1.08	0.1	2.00	6.59

Winter Curve

Financials	Revenue			Total (\$M)
	GWh	\$/GWh	\$	
Off Peak	2.47	\$65,000	\$160,295	\$0.44
Mid Peak	1.25	\$94,000	\$117,279	
On Peak	1.25	\$132,000	\$164,690	
Capital Costs				Total (\$B)
		\$/unit	\$B	
EV Infrastructure (10^6 EVs)	0.0	\$1.518	\$0.00	\$0.096
Solar Panels (GW)	0.0	\$2.671	\$0.00	
Energy Storage (GWh)	0.0	\$1.000	\$0.000	
Residential Electric Heating (GW)	0.0	\$0.708	\$0.000	
Commercial Electric Heating (GW)	0.0	\$0.270	\$0.000	
Added Capacity (GW)	0.0	\$3.189	\$0.096	
Stranded Assets (GW)	0.0	\$3.189	\$0.000	



New Adjustable Parameter

