Evaluating Utility Costs Savings for EV Charging Infrastructure

Emma Elgqvist & Josiah Pohl, NREL
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- This analysis was conducted as a part of the Solar Energy Innovation Network (SEIN) and relies on site information provided to NREL by the Minnesota SEIN Team that has not been independently validated by NREL. See https://www.nrel.gov/solar/solar-energy-innovation-network.html for more information about SEIN and the Minnesota-based team (the full team title is "Technological and Market Deployment Synergies between EVs and Solar DG Using EV Charging to Add Value to Distributed Solar.")

- The analysis results are not intended to be the sole basis of investment, policy, or regulatory decisions.

- This analysis was conducted using the NREL REopt Model (http://www.reopt.nrel.gov). REopt is a techno-economic decision support model that identifies the cost-optimal set of energy technologies and dispatch strategy to meet site energy requirements at minimum lifecycle cost, based on physical characteristics of the site and assumptions about energy technology costs and electricity and fuel prices.

- The data, results, conclusions, and interpretations presented in this document have not been reviewed by technical experts outside NREL *or* the Minnesota SEIN Team.

Analysis Overview

- As part of the Solar Energy Innovation Network, NREL used a tool called REopt to evaluate the impact on utility costs of light duty electric vehicle (EV) charging stations in Minnesota.

- Specifically, this analysis explores:
  - How can photovoltaics (PV) and stationary storage be co-deployed with EV charging infrastructure to lower the cost of purchasing grid electricity?
  - What are the potential savings of co-locating EV charging infrastructure with (behind the meter of) a commercial building?
  - What savings can be gained from optimizing the times at which the EVs are charged to decrease lifecycle costs?

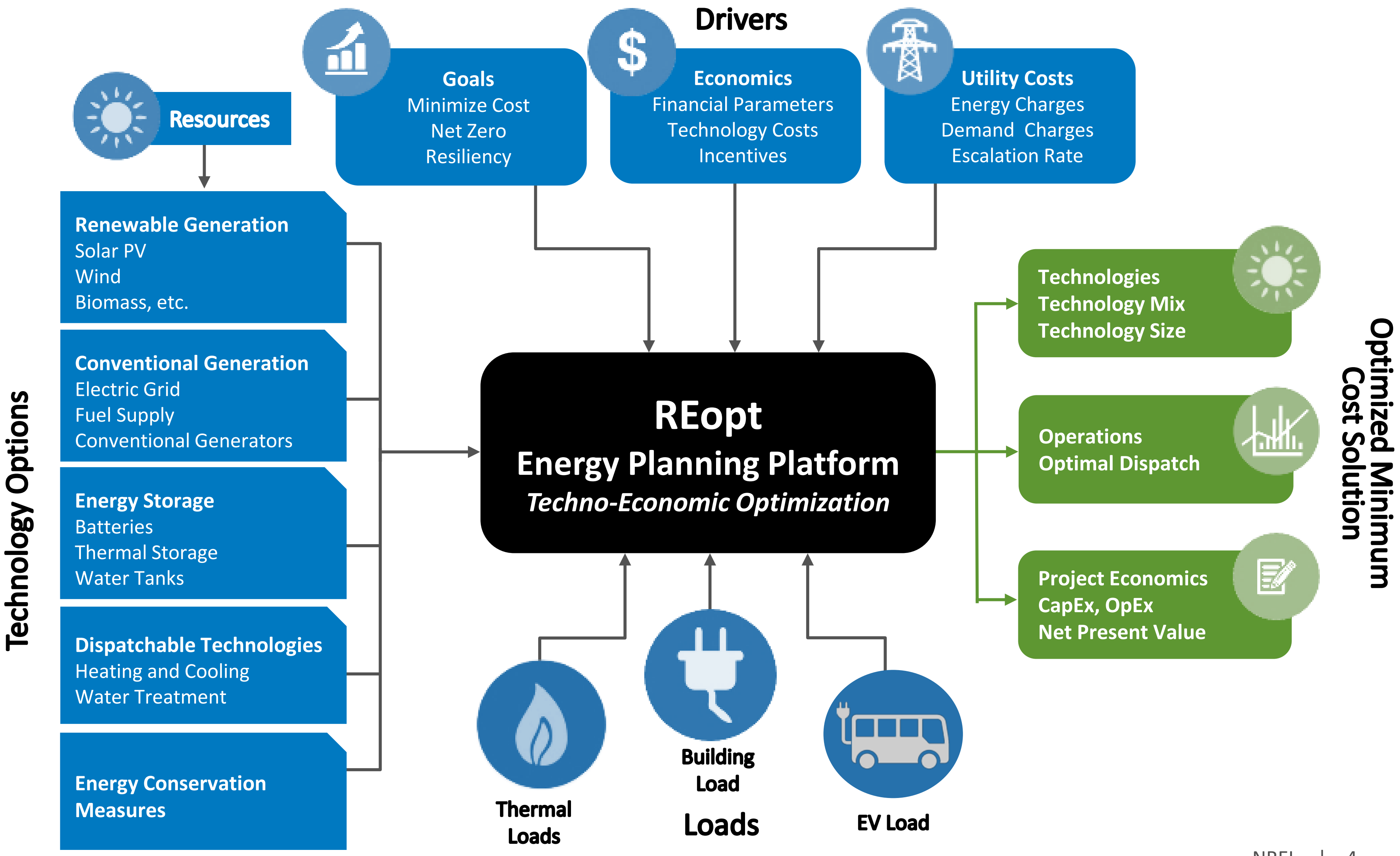
- The lifecycle costs evaluated in this analysis do not include the capital cost of purchasing the EV chargers.

Solar Energy Innovation Network: https://www.nrel.gov/solar/solar-energy-innovation-network.html
REopt Model: https://reopt.nrel.gov/

REopt Model Overview

Formulated as a mixed-integer linear program, the REopt model optimizes the integration and operation of behind-the-meter energy assets.

REopt solves a deterministic optimization problem to determine the optimal selection, sizing, and dispatch strategy of technologies chosen from a candidate pool such that loads are met at every time step at the minimum lifecycle cost.



Overview of inputs and outputs of the REopt model

Input Data and Analysis Assumptions

Input Data Overview

Data	Source	Options	Selection
Solar Resource	PVWatts	Location, configuration	Minneapolis, MN
Building Load Profile	DOE Commercial Reference Buildings	Building type	Medium office
Utility Rate	URDB	Utility and customer type	Xcel General Service (A14) Secondary Voltage
EV Load Profile	EVI-Pro	Number of charges/day; level of charging	Level 2 workplace charging

This analysis considers the economics of solar PV, battery storage, and electric vehicle loads for a representative office building in Minneapolis, MN, under Xcel General Service (A14) Secondary Service rate. **The results are not representative of other locations, building loads, or rate structures.**

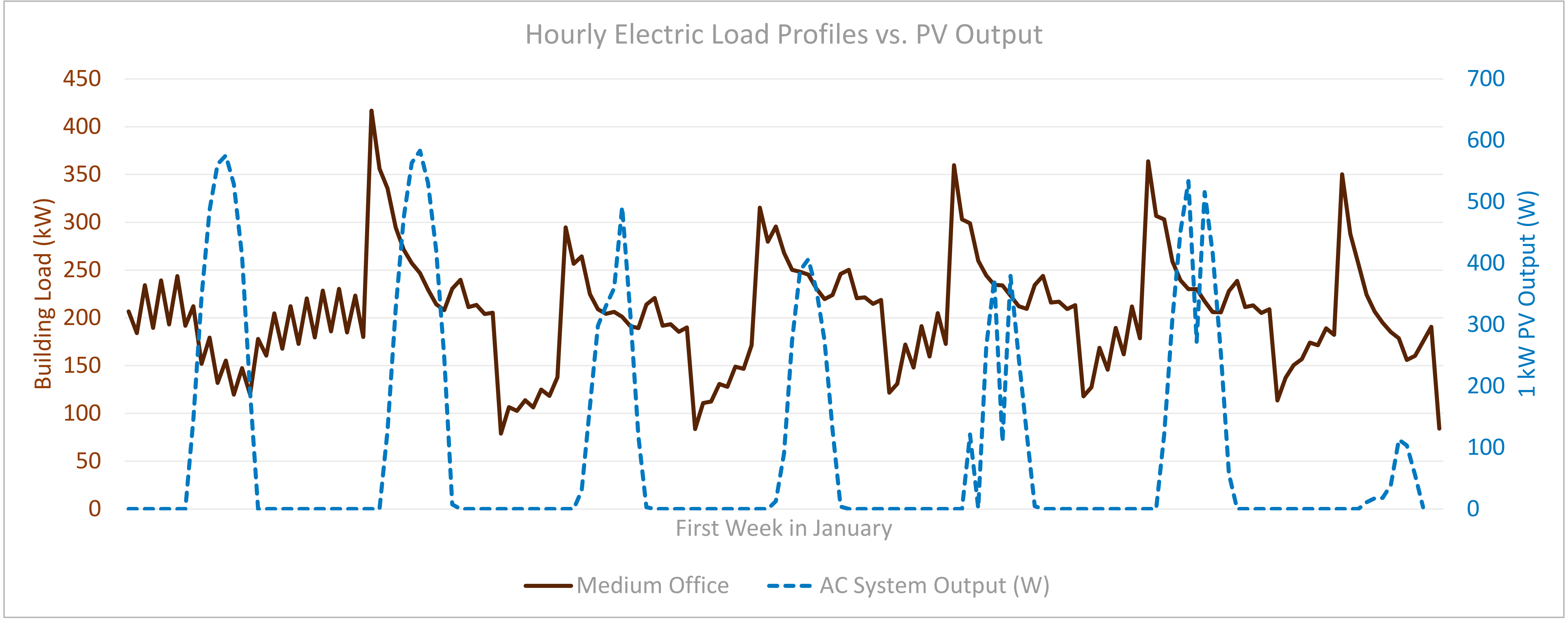
Xcel – General Service (A14) Secondary Voltage

	$/kWh	$/kW	$/month
Customer Charge			$25.64
Demand Charge		$10.71 Oct. – May $15.25 Jun. – Sep.	
Energy Charge	$0.03498		
Fuel Adjustment Factor	$0.02676		
Total	**$0.061740**	**$10.71 Oct. – May $15.25 Jun. – Sep.**	**$25.64**

Additional attributes of the selected rate include:

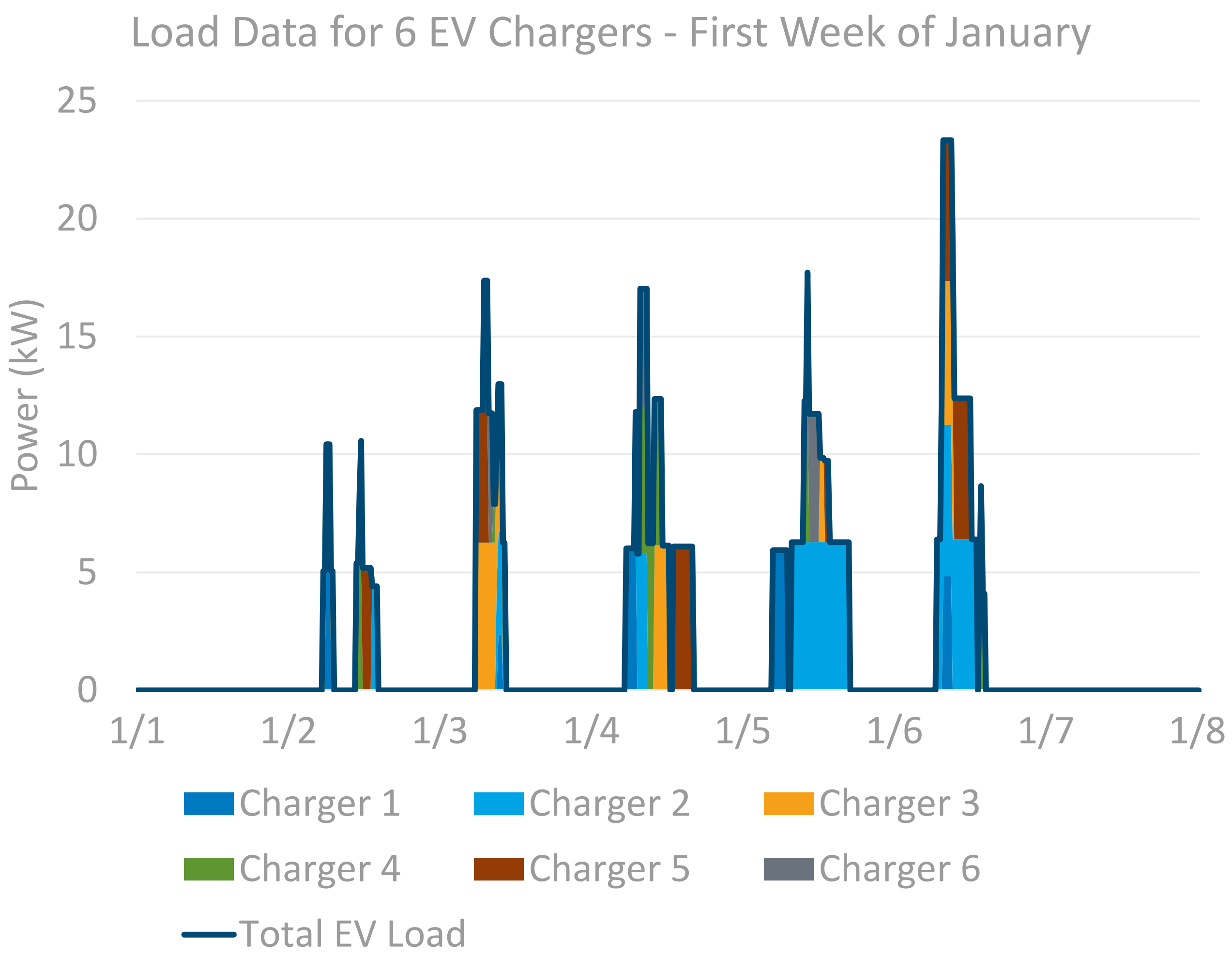
- In no month shall the demand to be billed be considered as less than current month's adjusted demand in kW or 50% of the greatest monthly adjusted demand in kW during the preceding 11 months
- Does not include environmental improvement rider or resource adjustment
- Fuel adjustment factor for C&I demand non-TOD
- For more information visit: https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/rates/MN/Me_Section_5.pdf

Building Load Profile vs. PV Output



This chart shows the load profile of a medium-sized office (based on DOE Commercial Reference Building database) and PV system output for an illustrative week in January.

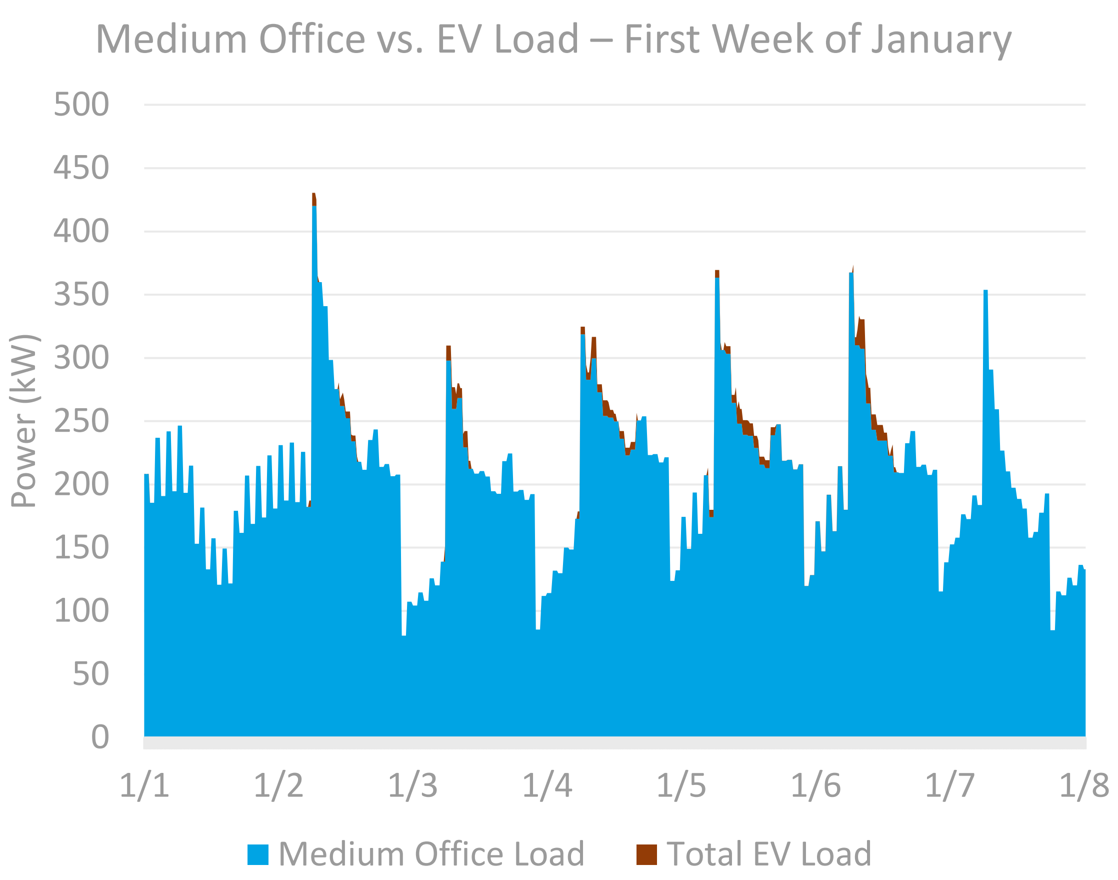
EV Load Input for Static Load Profile

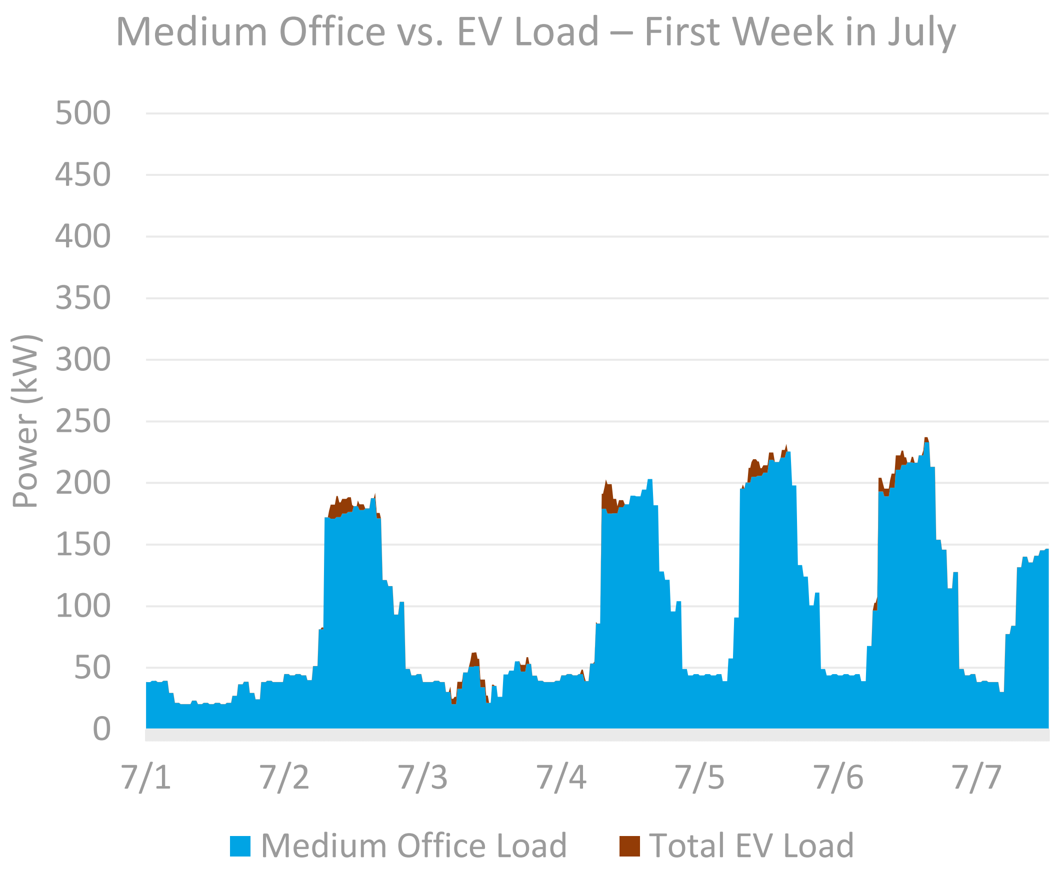


This chart shows the loads of the six chargers (each represented as its own color) over the course of a week in January. This evaluation of workplace charging assumed that charging only occurred on weekdays.

- NREL's EVI-Pro database was used to generate the EV load profiles; the EVI-pro database provides simulated vehicle arrival and departure times (at the EV charging station), and energy (kWh) requirements.
- This analysis considers (6) 6.6 kW EV chargers, located at an office building.
- For the static loads (i.e., without smart or managed charging), it was assumed that the EVs would start charging at the arrival time, and continue charging (6.6 kW) at the maximum rated power of the charge until the energy requirement was met.
- For the flexible (or smart/managed) charging loads, the daily arrival and departure time, and energy requirement were entered into REopt; the model determined at what level the EVs were charged (between 0 and 6.6 kW) throughout the day, such that the energy requirement was met by the departure time and lifecycle costs were minimized.

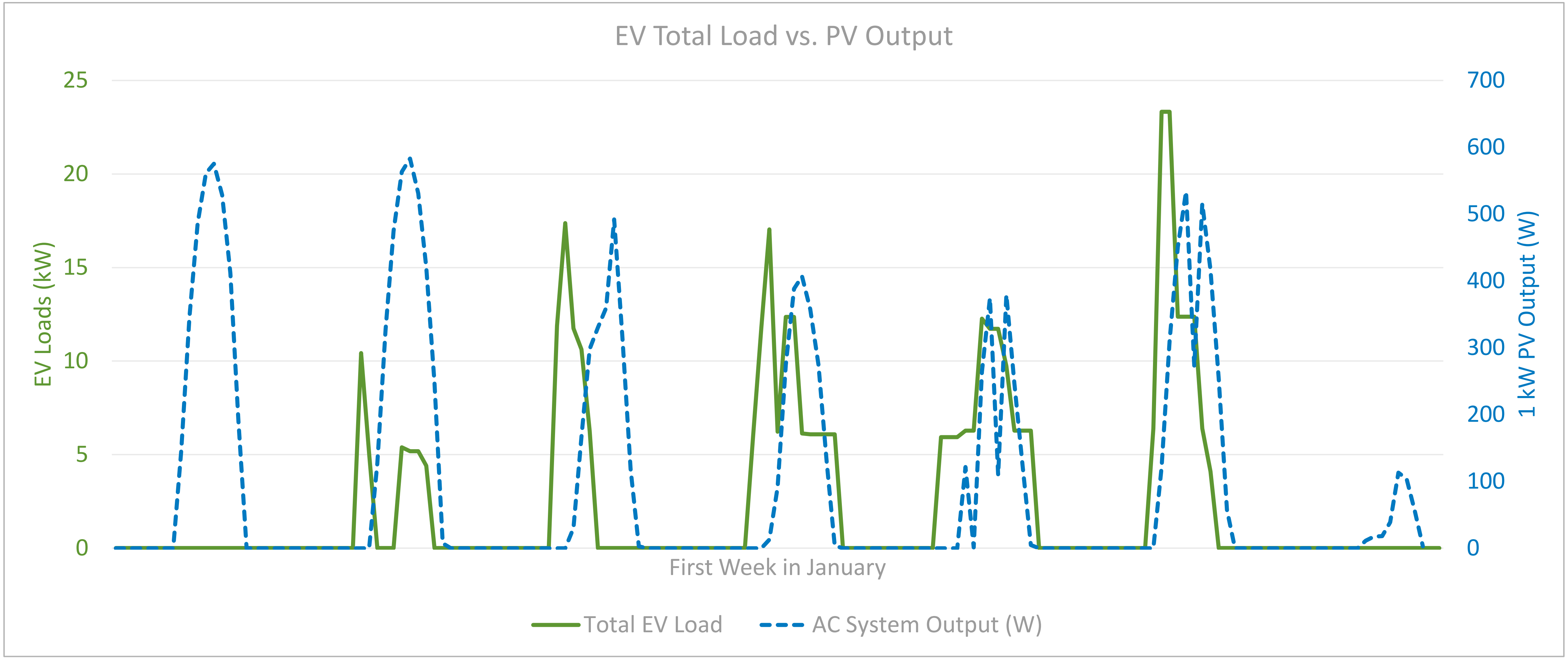
Building and EV Load





These charts show the static EV charging load (red) layered on top of the medium office load (in blue) for a week in January and a week in July.

EV Charging Profile vs. PV Output



These charts show the EV loads from the six chargers (shown aggregated as a single load) and the PV system output for a week in January.

Other Analysis Assumptions

Input	Assumption
Technologies	EV, solar PV, battery storage (depending on scenario)
Objective	Minimize lifecycle cost (cost-effective projects)
Ownership model	3rd party financed
Analysis period	25 years
Discount rate	3% for site/8.1% for developer
Escalation rate	2.60% per EIA utility cost escalation rates
Inflation rate	2.1% per EIA
Incentives	30% ITC; 5 year MACRS for PV & storage (storage not charging from grid)
Net metering	None
Electricity sellback rate	$0/kWh
Interconnection limit	None
Technology costs	PV: $2.00/W ground mount installed; $15.50/kW/yr. O&M Storage: $500/kWh and $1000/kW; replacement costs in year 10: $230/kWh and $460/kW
Technology resource	TMY3 Weather Data
Area for PV	Not constrained

Analysis Explored

- Specifically, this analysis will explore:
  1. How can PV and stationary storage be co-deployed with EV charging infrastructure to lower the cost of purchasing grid electricity?
  2. What are the potential savings of co-locating EV charging infrastructure with (behind the meter of) a commercial building?
  3. What savings can be gained from optimizing the times at which the EVs are charged?
  4. What savings can be gained from optimizing the times at which the EVs are charged when co-located with a commercial building?

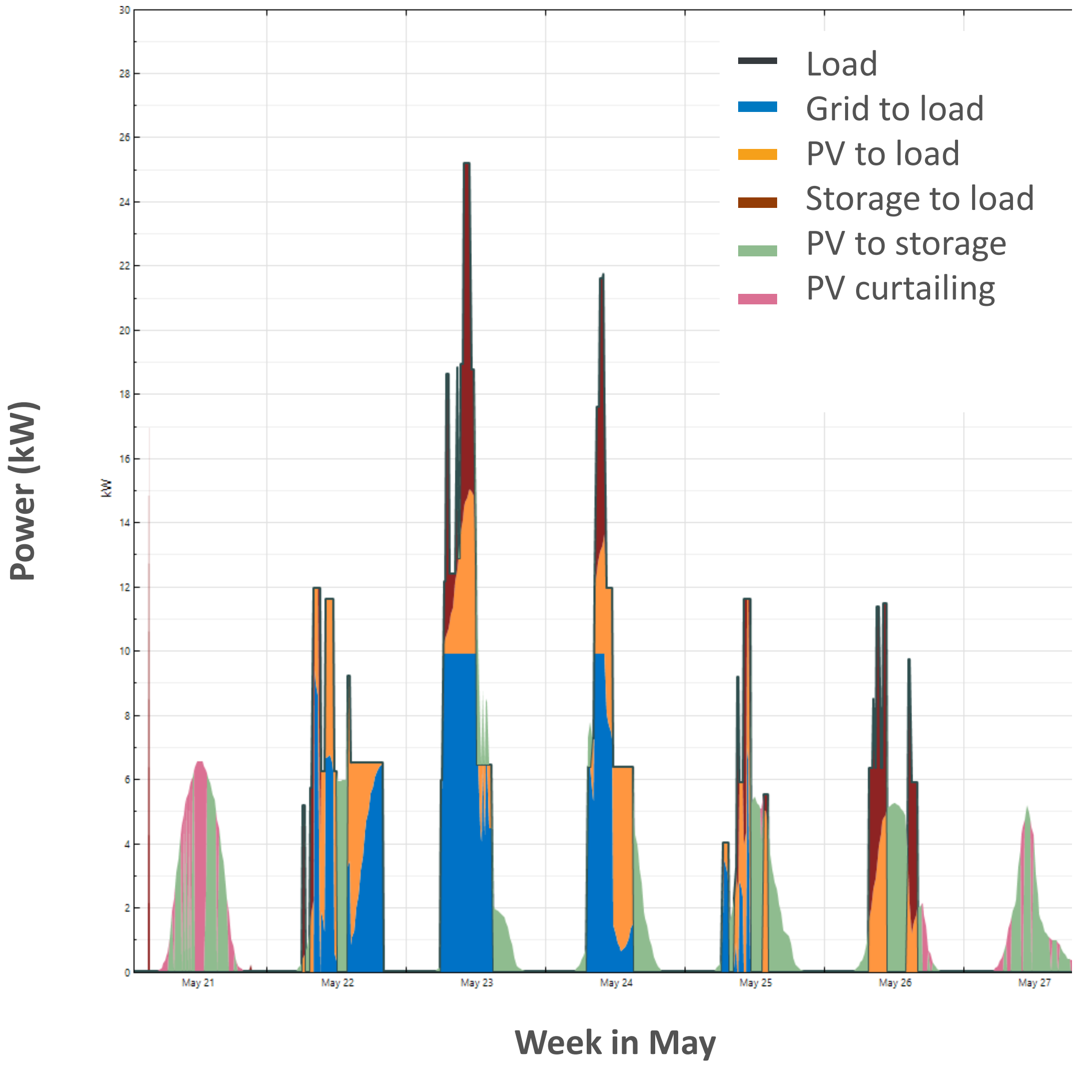
1. How can PV and stationary storage be co-deployed with EV charging infrastructure to lower the cost of purchasing grid electricity?

NREL evaluated the following scenarios:

- **EV charging load only**: The cost of electricity for the load of the six EV chargers, assuming all electricity is purchased from the utility
- **EV charging load with PV + storage**: The minimum lifecycle cost of electricity for the load of the EV chargers assuming electricity can be purchased from the utility, and that PV and stationary storage can be deployed to mitigate these costs if they are cost-effective
- **Sensitivity**: The following sensitivity analyses were conducted:
  - Impact of higher solar PV prices
  - Impact of a utility rate with lower demand charges
  - Impact of fewer EV chargers

1. Results

Scenario	EV Chargers Only	EV Chargers + PV and Storage
PV Size (kW)	0	9
Battery Size (kW)	0	17
Battery Size (kWh)	0	28
Total Capital Cost ($)	$0	$49,100
Electricity Purchases (kWh)	17,400	9,100
Percent RE (%)	0%	64%
Year 1 Energy Costs ($)	$1,100	$600
Year 1 Demand Costs ($)	$4,500	$2,000
Year 1 Fixed Costs ($)	$300	$300
Year 1 Total Electricity Cost ($)	$5,900	$2,800
25 Year Lifecycle Cost ($)	$140,000	$118,000
Net Present Value (NPV) ($)	**$0**	**$21,000**



Results show that under NM Xcel A14, PV and battery storage can be used to mitigate the cost of the electric load from charging the EVs by offsetting both energy and demand costs.

1. Results (continued)

Sensitivity Scenario	Base Case		Increase Solar Cost	Lower Demand Charge		Fewer EV Chargers	
Technology Options	Grid Only	Grid, PV, Storage	Grid, PV, Storage	Grid Only	Grid, PV, Storage	Grid Only	Grid, PV, Storage
PV Size (kW)	0	9	4	0	3	0	5
Battery Size (kW)	0	17	16	0	7	0	10
Battery Size (kWh)	0	28	26	0	7	0	17
Total Capital Cost ($)	$0	$49,100	$41,000	$0	$16,500	$0	$28,600
Electricity Purchases (kWh)	17,400	9,100	12,700	17,400	14,400	8,700	4,200
Percent RE (%)	0%	64%	31%	0%	24%	0%	76%
Year 1 Energy Costs ($)	$1,100	$600	$800	$1,300	$1,100	$500	$300
Year 1 Demand Costs ($)	$4,500	$2,000	$2,200	$2,400	$1,800	$2,700	$1,200
Year 1 Fixed Costs ($)	$300	$300	$300	$300	$300	$300	$300
Year 1 Total Electricity Cost ($)	$5,900	$2,800	$3,300	$4,000	$3,200	$3,600	$1,800
25 Year Lifecycle Cost ($)	$140,000	$118,000	$122,000	$96,000	$93,000	$85,000	$73,000
NPV ($)	**$0**	**$21,000**	**$18,000**	**$0**	**$2,000**	**$0**	**$11,000**

As in the prior slide, the size of PV and/storage system that the model suggests is based on seeking to minimize the 25-year lifecycle cost. The Increase Solar Cost NPV is relative to the Grid Only Base Case, all others are relative to the Grid Only option within their scenario.

- Sensitivity analysis shows that the recommended solar PV system size is decreased when the:
  - Installed cost of PV increases from $2/W to $3/W; the size of battery storage also decreases, but not as much
  - The rate has a demand charge of $6.50 instead of $10-15/kW; the size of battery decreases more so than the size of the PV system
  - The number of EV chargers is reduced from 6 to 3; the PV and storage size both decrease proportionally

2. What are the potential savings of co-locating EV charging infrastructure with (behind the meter of) a commercial building?

NREL evaluated the following scenarios:

- **Building + EV charging load**: The cost of electricity for the load of the commercial building and the EV chargers (when billed separately, behind two separate meters), assuming all electricity is purchased from the utility.
- **Building + EV charging combined load**: The cost of electricity for the load of the commercial building and the EV chargers (as one load, behind the same meter), assuming all electricity is purchased from the utility.
- **Building + EV charging load with PV + storage**: The minimum lifecycle cost of electricity for the load of the commercial building and the EV chargers (as one load, behind the same meter), assuming electricity can be purchased from the utility and that PV and stationary storage can be deployed to mitigate these costs if cost-effective.

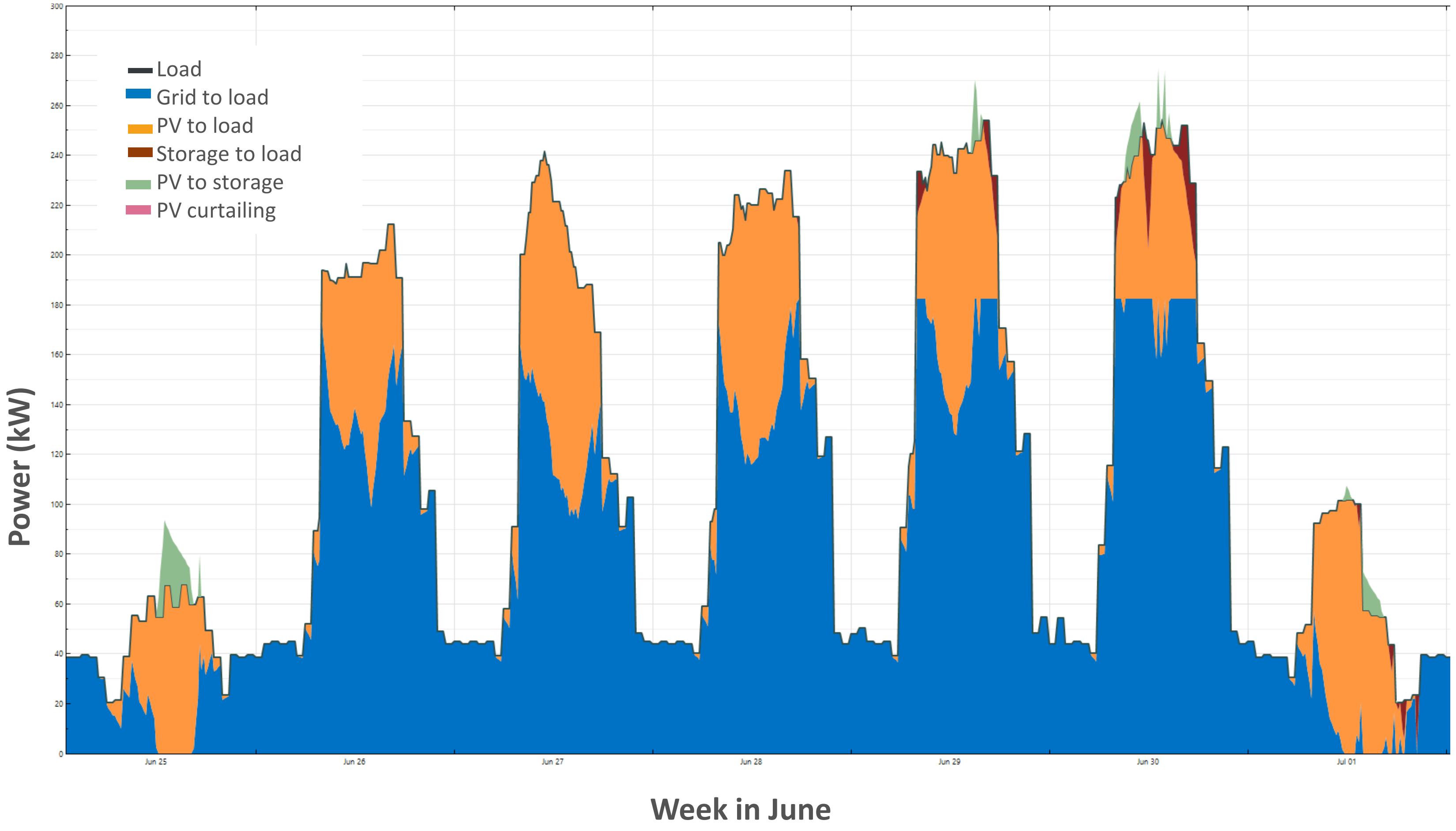
2. Results

Scenario	EV Chargers Only	Building Only	Building + EV Chargers (Separate Meters)	Building + EV Chargers (Combined Meter)	Building + EV Chargers (Combined Meter) Add PV + Storage
PV Size (kW)	0	0	0	0	155
Battery Size (kW)	0	0	0	0	66
Battery Size (kWh)	0	0	0	0	77
Total Capital Cost ($)	$0	$0	$0	$0	$416,100
Electricity Purchases (kWh)	17,400	1,022,700	1,040,100	1,040,100	852,100
Percent RE (%)	0%	0%	0%	0%	19%
Year 1 Energy Costs ($)	$1,100	$63,100	$64,200	$64,200	$52,600
Year 1 Demand Costs ($)	$4,500	$42,900	$47,400	$43,700	$35,100
Year 1 Fixed Costs ($)	$300	$300	$600	$300	$300
Year 1 Total Electricity Cost ($)	$5,900	$106,400	$112,200	$108,200	$88,000
25 Year Lifecycle Cost ($)	$140,000	$2,529,000	$2,669,000	$2,573,000	$2,494,000
NPV ($)	**-**	**-**	**$0**	**$96,000**	**$79,000**

The NPV for the Building + EV Chargers (Combined Meter) is relative to Building + EV Chargers (Separate Meters). The NPV for the Building + EV Chargers (Combined Meter) Add PV+Storage is relative to the Building + EV Chargers (Combined Meter).

- If the EV and building load were billed under the same meter, demand costs and fixed costs could be decreased (by ~$96,000)
  - The demand charges are reduced because the peak load of the building is not aligned with the peak load of the EV chargers
  - The fixed charges are reduced because they are billed per meter
- PV and storage can reduce the cost of the combined building and EV load

2. Results (continued)



- Dispatch shows the solar PV offsetting energy charges and demand.
- The relatively small storage system is dispatched to mitigate the variability of PV, especially during early morning/late evening.

3. What savings can be gained from optimizing the times at which the EVs are charged?

NREL evaluated the following scenarios:

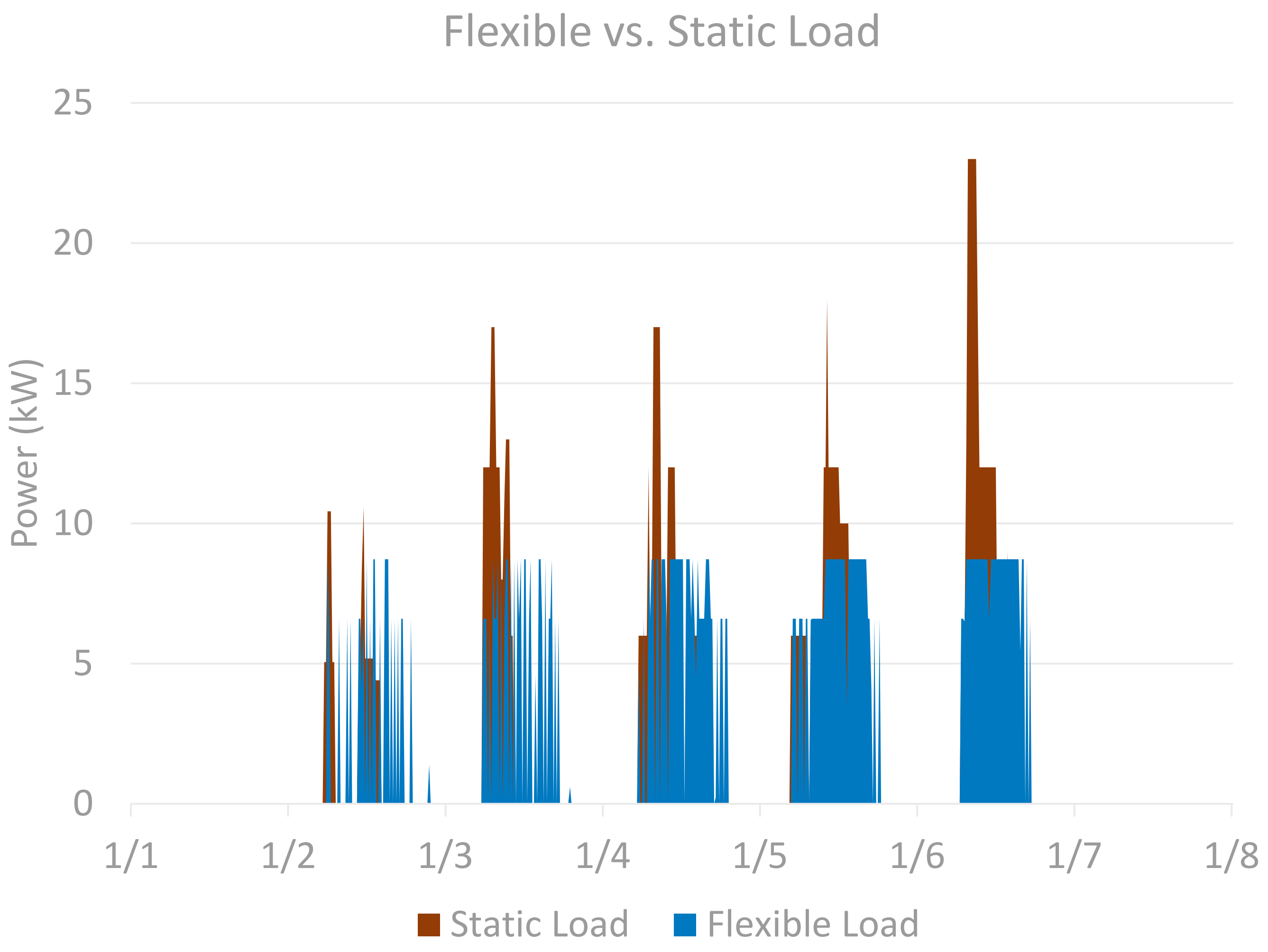
- **Static EV charging load only**: The cost of electricity is calculated for the load of the six EV chargers, assuming all electricity is purchased from the utility. Charging starts when vehicles arrive and continues at a constant rate until a vehicle's battery is full.
- **Flexible EV charging load only**: The cost of electricity is calculated for the load of the EV chargers, assuming all electricity is purchased from the utility. Charging of the EVs is flexible within specified parameters (e.g., the rating of the charger and the energy needs for the vehicles each day based on EVI-Pro modeling).
- **Flexible EV charging load with PV + storage**: The cost of electricity is calculated for the load of the EV chargers, assuming electricity can be purchased from the utility. PV and stationary storage can be deployed to mitigate these costs if cost-effective. Charging of the EVs is flexible within specified parameters and can be managed to decrease lifecycle cost taking all loads, generation, and storage sources into account.

3. Results

Scenario	EV Chargers Only (Static Load)	EV Chargers Only (Flexible Load)	EV Chargers Only (Flexible Load) Add PV + Storage	EV Chargers Only (Flexible Load) Add PV + Storage 50% Cost Reduction
PV Size (kW)	0	0	0	13
Battery Size (kW)	0	0	0	0
Battery Size (kWh)	0	0	0	0
Total Capital Cost ($)	$0	$0	$0	$15,000
Electricity Purchases (kWh)	17,400	17,400	17,400	6,600
Percent RE (%)	0%	0%	0%	62%
Year 1 Energy Costs ($)	$1,100	$1,100	$1,100	$400
Year 1 Demand Costs ($)	$4,500	$1,400	$1,400	$900
Year 1 Fixed Costs ($)	$300	$300	$300	$300
Year 1 Total Electricity Cost ($)	$5,900	$2,800	$2,800	$1,600
25 Year Lifecycle Cost ($)	$140,000	$67,000	$67,000	$57,000
NPV ($)	**$0**	**$73,000**	**$0**	**$10,000**

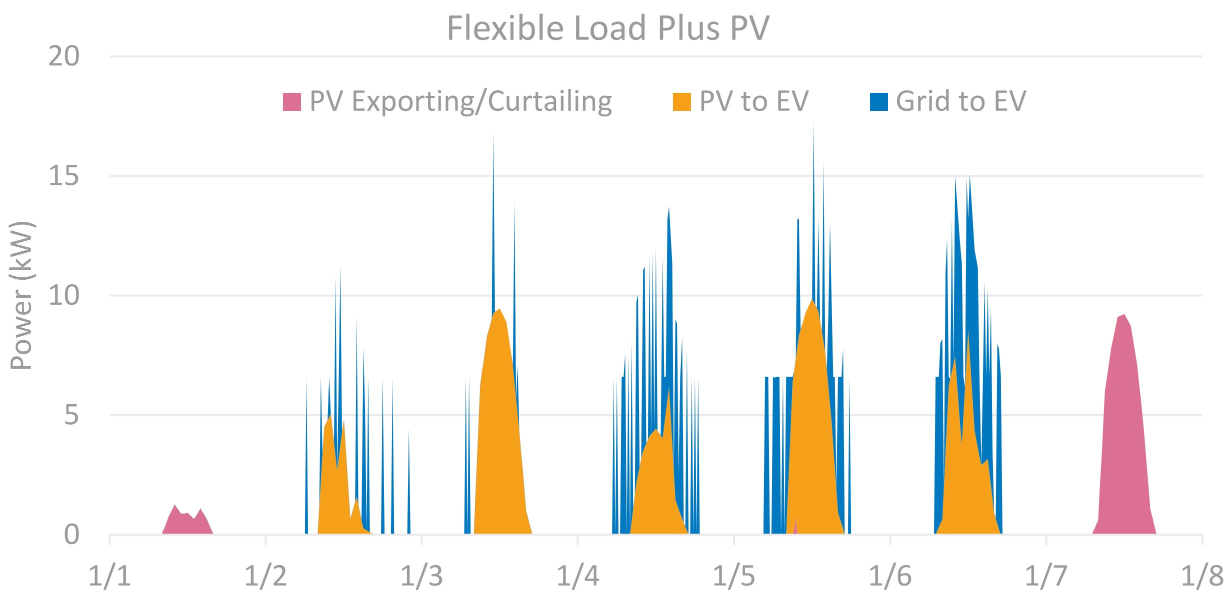
The NPV for EV Chargers Only (Flexible Load) is relative to EV Chargers Only (Static Load). The NPV for EV Chargers Only (Flexible Load) Add PV+ Storage 50% Cost Reduction is relative to EV Chargers Only (Flexible Load) Add PV + Storage and assumes 50% capital cost reduction for PV and Storage

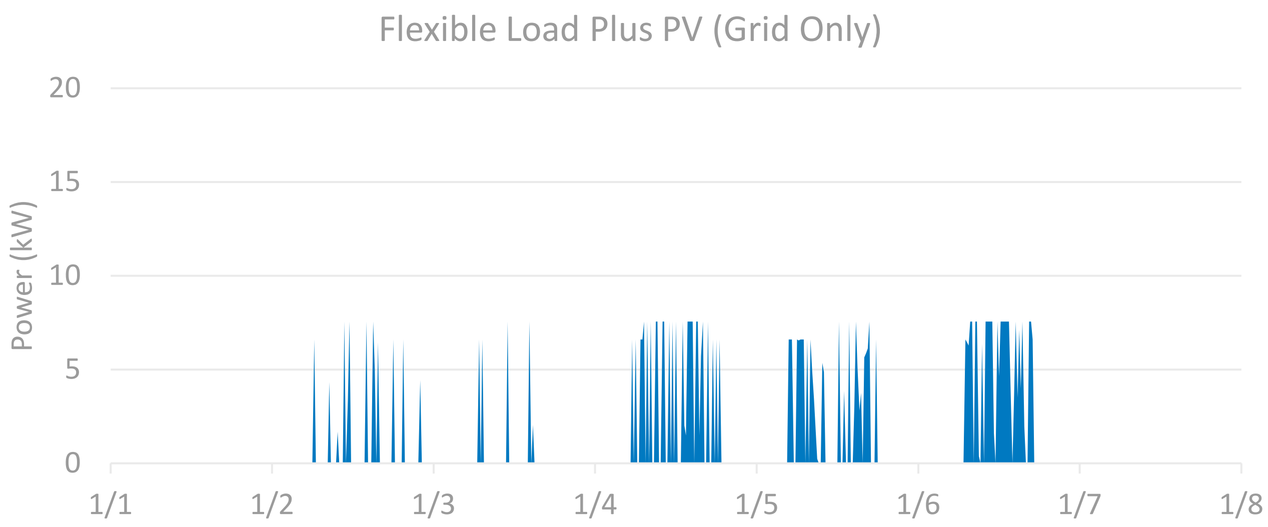
3. Results (continued)



- When the model is allowed to determine how the EVs should be charged (flexible EV load), the load is spread out throughout the day, lowering the peak demand.
- As a result, the demand charges are lowered from $4,500 to $1,400 in year 1 (energy and fixed charges are not impacted).
- Adding PV and/or storage (at current costs) to the flexible EV load only (no building load) does not appear cost effective, as the “peakiness” of the load has been mitigated, and a larger (longer duration), more expensive, battery would need to be installed to further reduce the demand and cost.

3. Results (continued)





- When battery storage and PV capital costs are reduced by 50%, a 13 kW PV system appears cost effective, lowering both energy and demand charges.
- In this scenario, the PV system is serving the EV load during the day, and the EV load is being shifted to fit under the PV generation.
- In this scenario, battery storage does not appear cost effective. The EV load flexibility is serving the same purpose as stationary storage, as the charging can be modified to mitigate demand charges.

4. What savings can be gained from optimizing the times at which the EVs are charged when co-located with a commercial building?

NREL evaluated the following scenarios:

- **Building + static EV charging load**: The cost of electricity is calculated for the load of the commercial building and the EV chargers (as one load, behind the same meter), assuming all electricity is purchased from the utility. Charging starts when the a vehicle arrives, and continues at a constant rate until the battery is full.
- **Building + flexible EV charging load**: The cost of electricity is calculated for the load of the commercial building and the EV chargers (as one load, behind the same meter), assuming all electricity is purchased from the utility. EV Charging is flexible within specified parameters.
- **Building + flexible EV charging load with PV + storage:** The cost of electricity is calculated for the load of the commercial building and the EV chargers, assuming electricity can be purchased from the utility. PV and stationary storage can be deployed to mitigate these costs if cost-effective. EV charging is flexible within specified parameters.

4. Results

Scenario	Building + EV Chargers (Combined Meter Static EV Load)	Building + EV Chargers (Combined Meter) Flexible EV Load	Building + EV Chargers (Combined Meter) Flexible EV Load Add PV + Storage
PV Size (kW)	0	0	211
Battery Size (kW)	0	0	60
Battery Size (kWh)	0	0	71
Total Capital Cost ($)	$0	$0	$521,000
Electricity Purchases (kWh)	1,040,100	1,040,100	791,692
Percent RE (%)	0%	0%	26%
Year 1 Energy Costs ($)	$64,200	$64,200	$48,900
Year 1 Demand Costs ($)	$43,700	$43,000	$33,400
Year 1 Fixed Costs ($)	$300	$300	$300
Year 1 Total Electricity Cost ($)	$108,200	$107,400	$82,500
25 Year Lifecycle Cost ($)	$2,573,000	$2,554,000	$2,458,000
NPV ($)	**$0**	**$19,000**	**$96,000**

The NPV for each scenario is relative to the preceding column.

- When PV and storage is evaluated at the office building along with the flexible EV load, the optimal size of PV is larger, and the optimal size of storage is smaller, compared to the same scenario with the static EV load.
- The EV load flexibility is serving the same purpose as stationary storage, as the charging can be modified to mitigate demand charges.
- Because of this, additional PV is cost effective, because the flexible EV load enables it to shave a wider part of the demand peak.

Conclusions

- Three different ways of mitigating the cost of EV charging stations were explored:
  - Adding PV + Storage
  - Co-locating with a commercial building
  - Optimizing the times at which the EVs were charged.
- Under the rate tariff, building and EV load, solar resource, and other assumptions specific to this analysis, all three mitigation options result in savings.
- When considering the load of the EV chargers only, optimizing the times at which the EVs were charged provided more potential savings than deploying PV + storage because the flexibility of EV charging serves the same function as adding battery storage, but at a lower (no) cost.
- Combining the load of the EV charges with a commercial building provided both demand and fixed cost savings.
  - In this scenario, the flexibility of EV charging had less of an impact, likely due to the demand of the EV chargers not coinciding with that of the building in the first place.
  - In either scenario (flexible or static load EV charging), PV and storage can mitigate the cost of the total electric load.

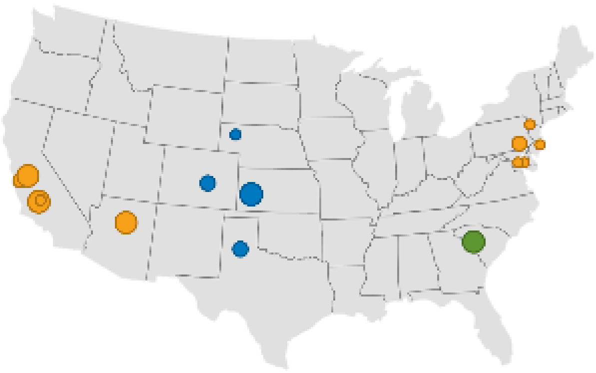
Appendix

REopt Platform: Decision Support through the Energy Planning Process

Optimization • Integration • Automation

Master Planning

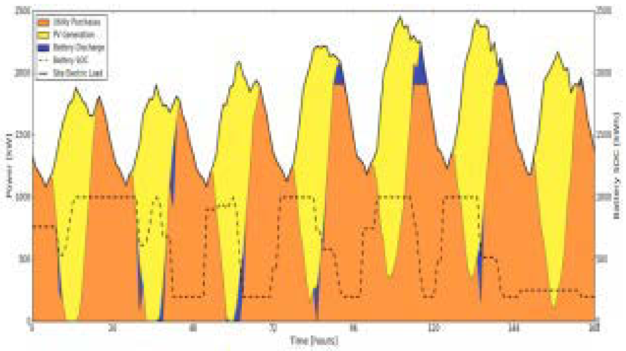
- Portfolio Prioritization
- Cost to Meet Goals



Cost-effective RE at Army bases

Economic Dispatch

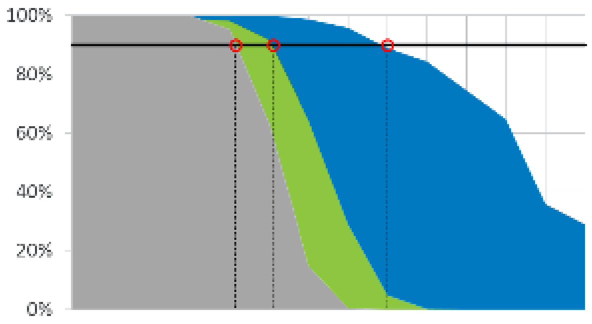
- Technology Types & Sizes
- Optimal Operating Strategies



Cost-Optimal Operating Strategy

Resiliency Analysis

- Microgrid Dispatch
- Energy Security Evaluation



Extending Resiliency with Renewable Energy

REopt PV and Battery Assumptions

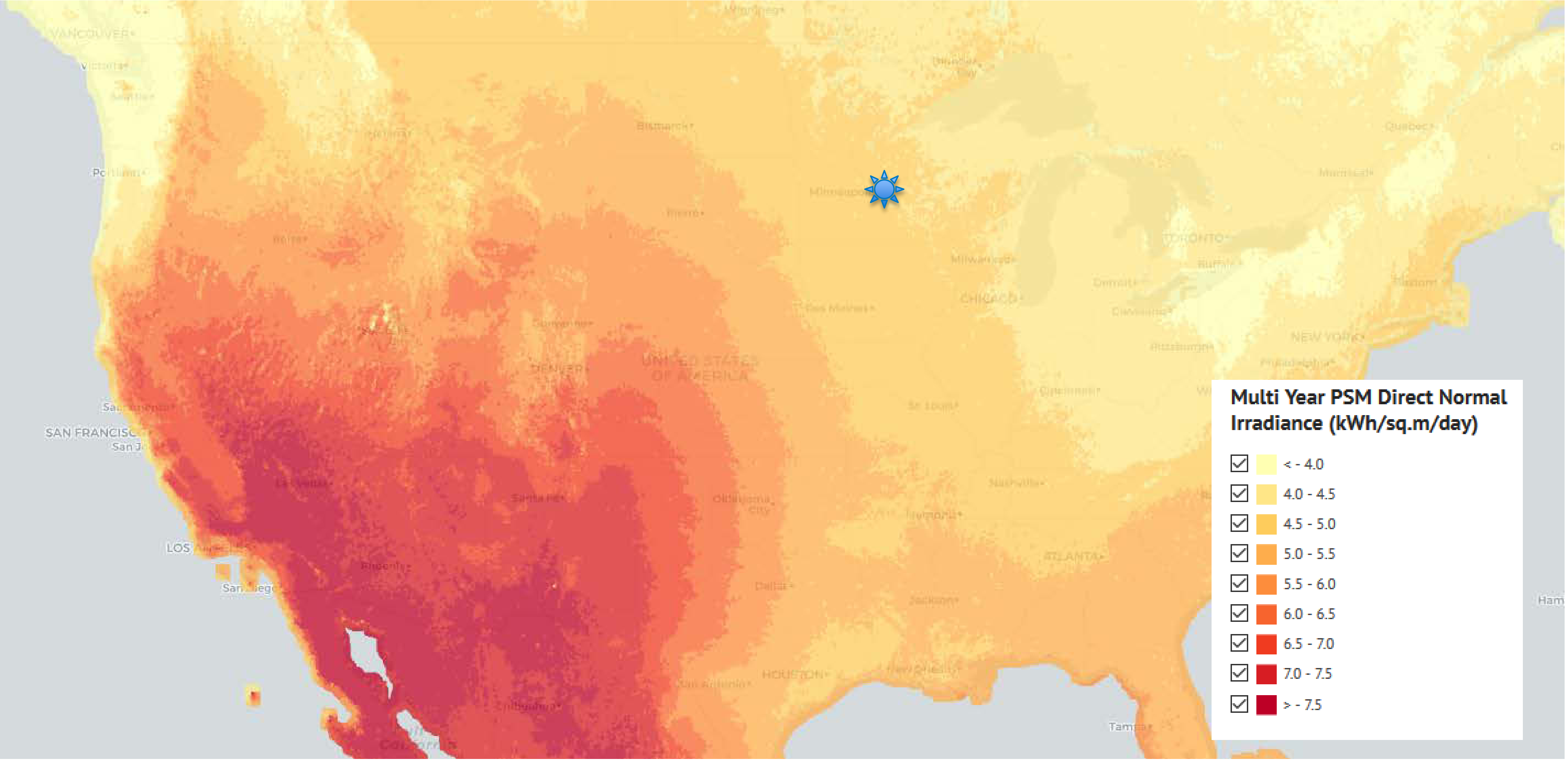
- Solar PV
- Fixed tilt; oriented due south with tilt = latitude
- Hourly solar radiation data from Typical Meteorological Year 3 (NREL 2008). Represents 1,020 locations in the US. Derived from 1991–2005 National Solar Radiation Data Base.

Solar PV Characteristics	
Annual Degradation (%)	-0.5%
Inverter Efficiency (%)	96%
BOS Efficiency	86%

- Li-Ion battery technology
- Bucket model moves energy from one time period to another
- Sizes energy capacity / power independently
- Tracks and costs battery degradation
  - Simple throughput
  - Cycles
  - Cycles / Depth of Discharge

Li Ion Battery Characteristics	
Total Round Trip Efficiency	89.9%
Battery Throughput	97.5%
Inverter Efficiency	96%
Rectifier Efficiency	96%
Minimum Charge	0%
Initial SOC	0%

Solar Resource

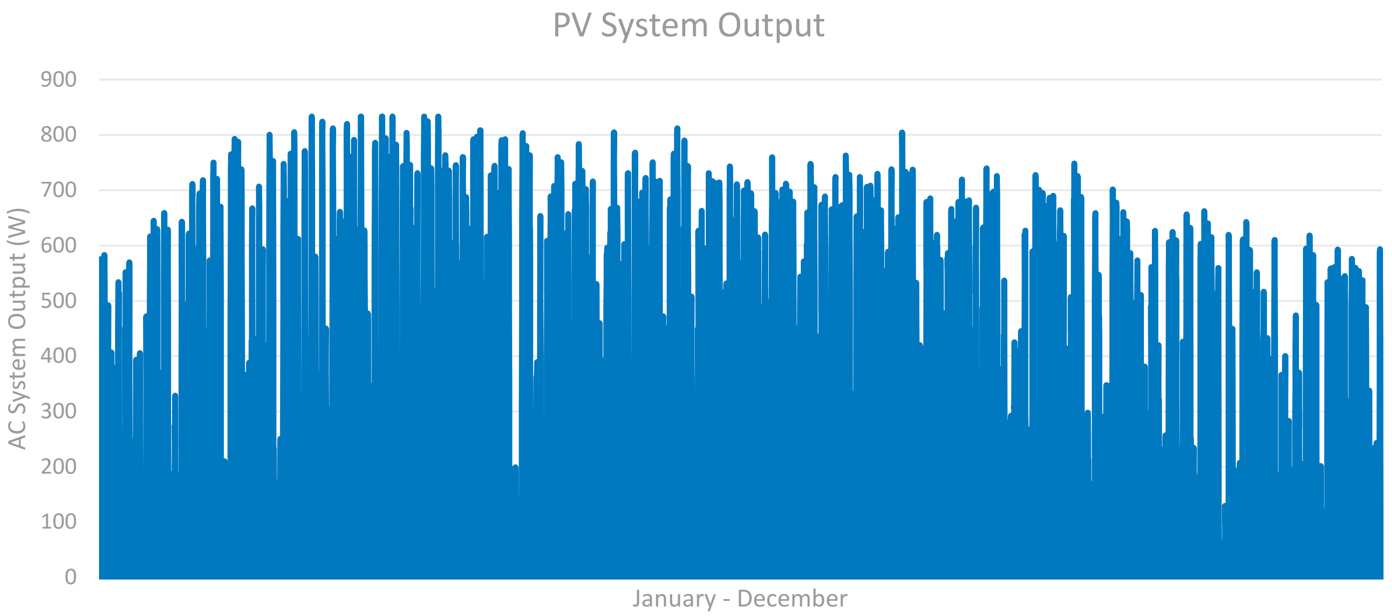


https://nsrdb.nrel.gov/nsrdb-viewer

Solar Resource Data for Minneapolis, MN

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)
January	2.89	78
February	3.76	92
March	4.99	130
April	5.57	131
May	5.93	141
June	6.22	141
July	6.73	151
August	6.08	140
September	5.09	116
October	3.60	90
November	2.85	72
December	2.32	62
Annual	**4.67**	**1,344**

Capacity Factor: 15.3%



Requested Location	Minneapolis, MN
Weather Data Source	Lat, Lon: 44.97, -93.26
DC System Size	1 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	20°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Electric Rate Tariffs for Xcel in Minneapolis

Rate Name	Sector	Service Type	Latest Update
General Service Time-of-Day Unmetered (A19) Transmission Voltage	Commercial	Bundled	2018-02-20 13:02:44
General Service Time-of-Day Unmetered (A19) Transmission Tranformed Voltage	Commercial	Bundled	2018-02-20 13:00:51
General Service Time-of-Day Unmetered (A19) Primary Voltage	Commercial	Bundled	2018-02-20 12:58:48
General Service Time-of-Day Unmetered (A19) Secondary Voltage	Commercial	Bundled	2018-02-20 12:56:23
General Service Time-of-Day kWh Metered (A17) Transmission Voltage	Commercial	Bundled	2018-02-20 12:54:21
General Service Time-of-Day kWh Metered (A17) Transmission Transformed Voltage	Commercial	Bundled	2018-02-20 12:52:25
General Service Time-of-Day kWh Metered (A17) Primary Voltage	Commercial	Bundled	2018-02-20 12:50:37
General Service Time-of-Day kWh Metered (A17) Secondary Voltage	Commercial	Bundled	2018-02-20 12:48:49
General Service Time-of-Day Metered (A15) Transmission Voltage	Commercial	Bundled	2018-02-20 12:46:08
General Service Time-of-Day Metered (A15) Transmission Transformed Voltage	Commercial	Bundled	2018-02-20 12:43:16
General Service Time-of-Day Metered (A15) Primary Voltage	Commercial	Bundled	2018-02-20 12:41:01
General Service Time-of-Day Metered (A15) Secondary Voltage	Commercial	Bundled	2018-02-20 12:38:45
General Service (A14) Transmission Voltage	Commercial	Bundled	2018-02-20 12:35:14
General Service (A14) Transmission Transformed Voltage	Commercial	Bundled	2018-02-20 12:32:30
General Service (A14) Primary Voltage	Commercial	Bundled	2018-02-20 12:29:56
General Service (A14) Secondary Voltage	Commercial	Bundled	2018-02-20 12:27:08
Small General Time-of-Day Unmetered Service (A18)	Commercial	Bundled	2018-02-20 12:23:34
Small General Time-of-Day kWh Metered Service (A16)	Commercial	Bundled	2018-02-20 12:21:57
Small General Time-of-Day Metered Service (A12)	Commercial	Bundled	2018-02-20 12:19:20
Small General Service Direct Current (A13)	Commercial	Bundled	2018-02-20 12:13:05
Small General Service Water Heating (A11)	Commercial	Bundled	2018-02-20 12:10:07
Small General Service Metered (A10)	Commercial	Bundled	2018-02-20 12:08:31
Small General Service Unmetered (A09)	Commercial	Bundled	2018-02-20 12:06:58

Utility Name: Northern States Power Co – Minnesota (Xcel); approved and bundled rates
Other rates to consider include RPU Medium General Service and Connexus General Commercial

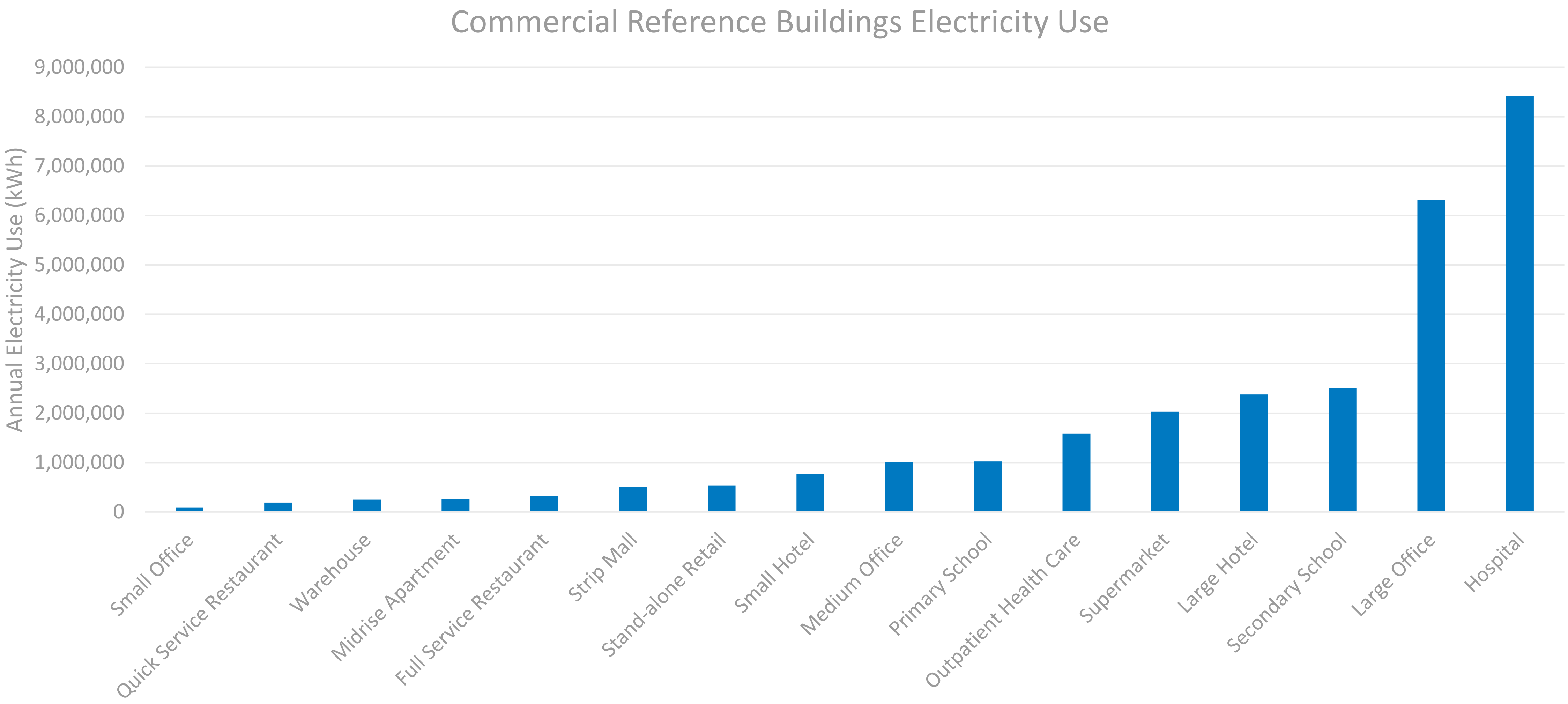
Building Load Profile
DOE Commercial Reference Buildings

Climate Zone	Representative City
1A	Miami, FloridaClimate Zone Table
2A	Houston, Texas
2B	Phoenix, Arizona
3A	Atlanta, Georgia
3B-Coast	Los Angeles, California
3B	Las Vegas, Nevada
3C	San Francisco, California
4A	Baltimore, Maryland
4B	Albuquerque, New Mexico
4C	Seattle, Washington
5A	Chicago, Illinois
5B	Boulder, Colorado
6A	Minneapolis, Minnesota
6B	Helena, Montana
7	Duluth, Minnesota
8	Fairbanks, Alaska

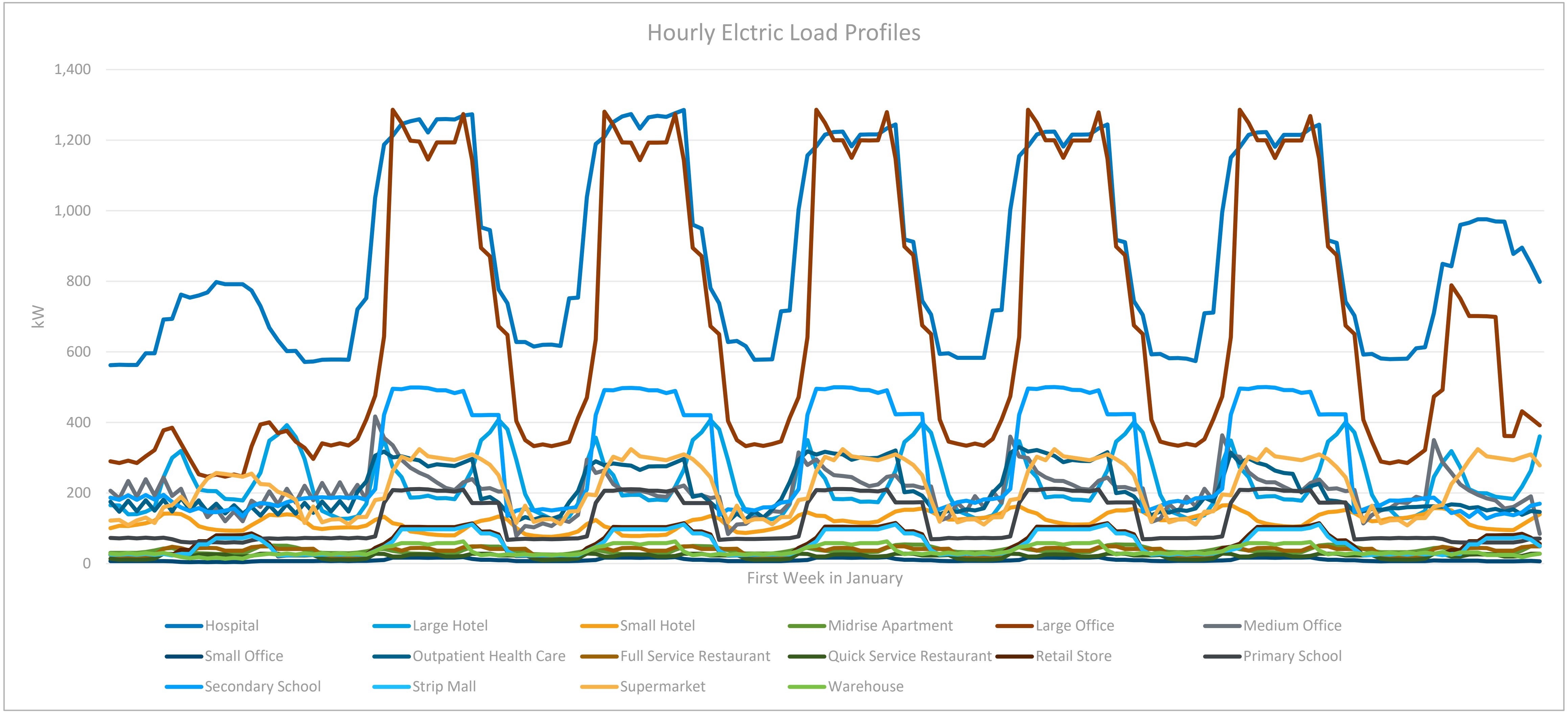
Building Type Name	Floor Area (ft^2)	Number of Floors	Electricity Use (kWh/yr)
Hospital	241,351	5	8,425,063
Large Office	498,588	12	6,306,693
Secondary School	210,887	2	2,498,647
Large Hotel	122,120	6	2,378,872
Supermarket	45,000	1	2,034,650
Outpatient Health Care	40,946	3	1,582,701
Primary School	73,960	1	1,022,667
Medium Office	53,628	3	1,005,875
Small Hotel	43,200	4	774,571
Stand-alone Retail	24,962	1	539,203
Strip Mall	22,500	1	511,567
Full Service Restaurant	5,500	1	330,920
Midrise Apartment	33,740	4	267,383
Warehouse	52,045	1	249,332
Quick Service Restaurant	2,500	1	188,368
Small Office	5,500	1	85,921

Electricity use for existing buildings constructed in or after 1980 ("post-1980") in climate zone 6A

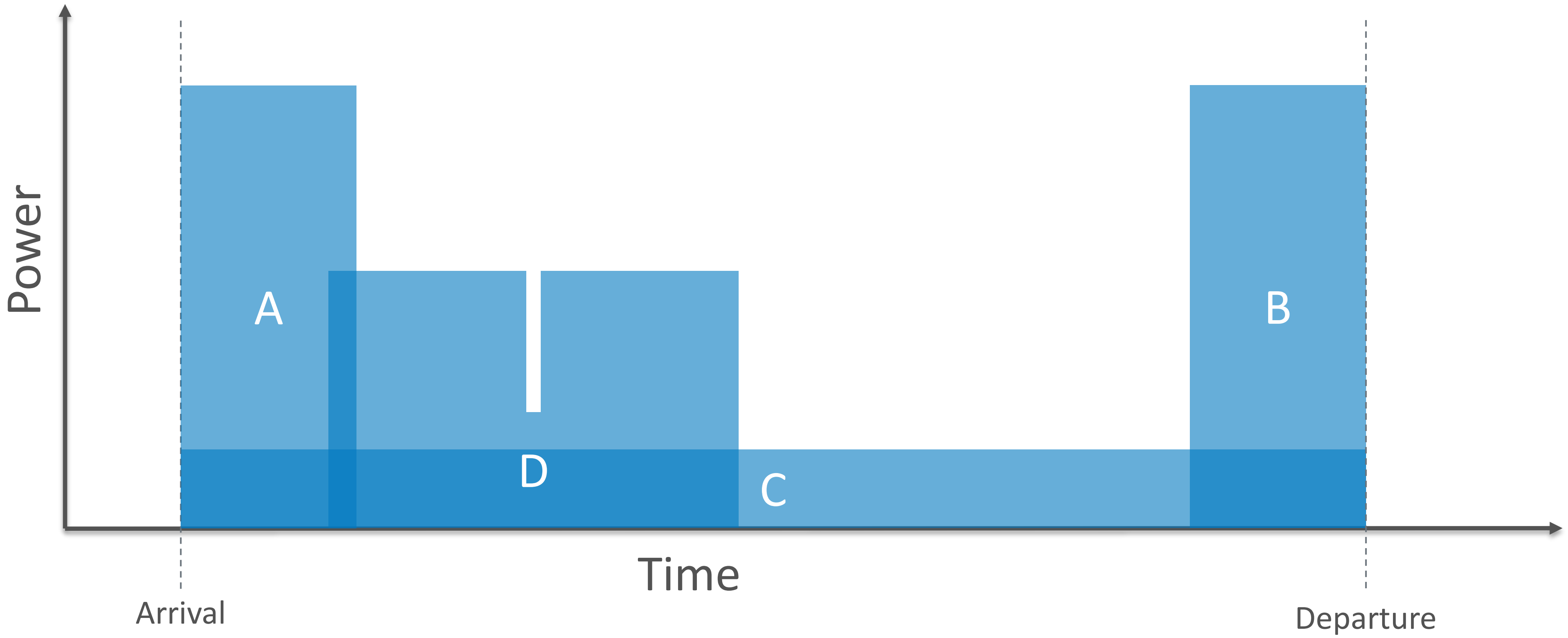
Annual Electricity Use



DOE Load Profiles



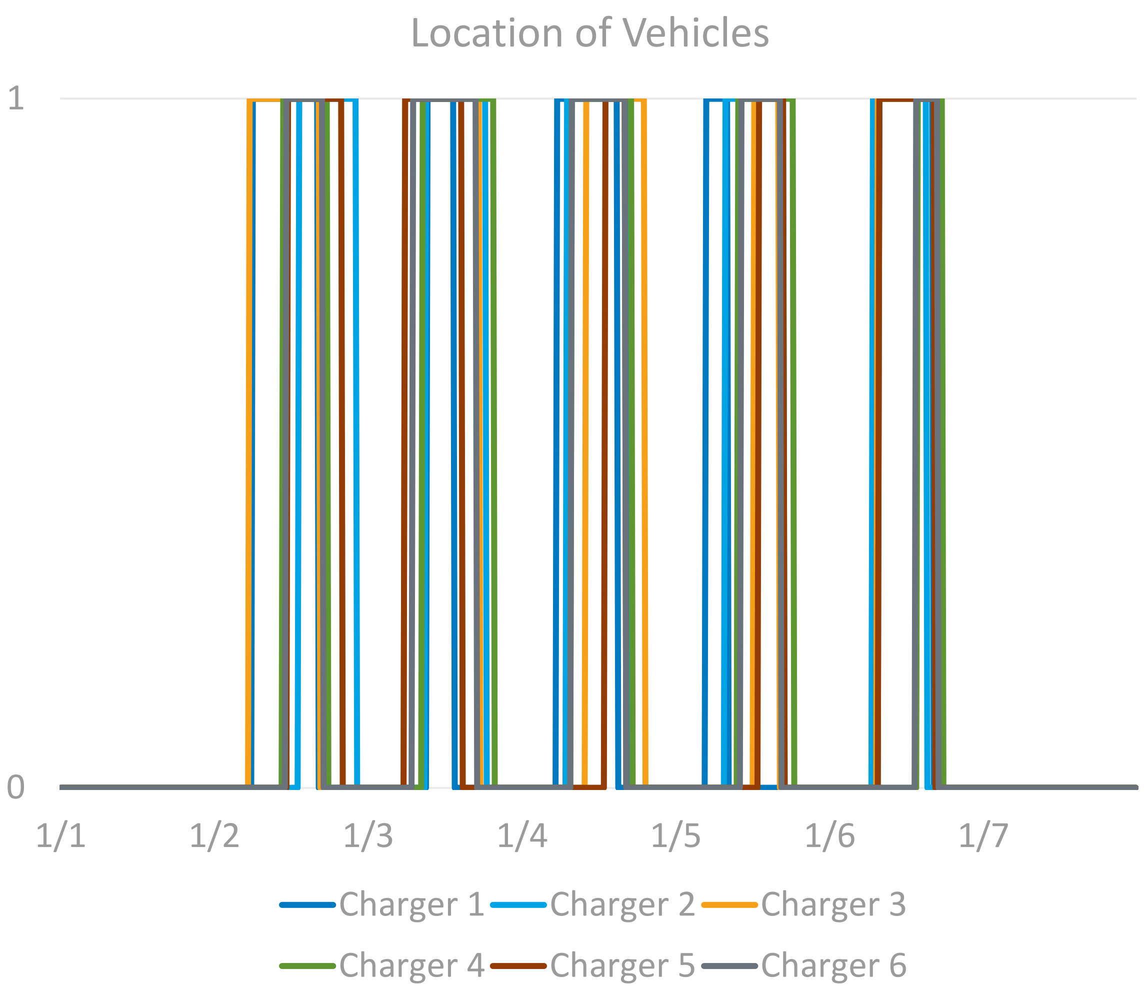
EV Load Profiles

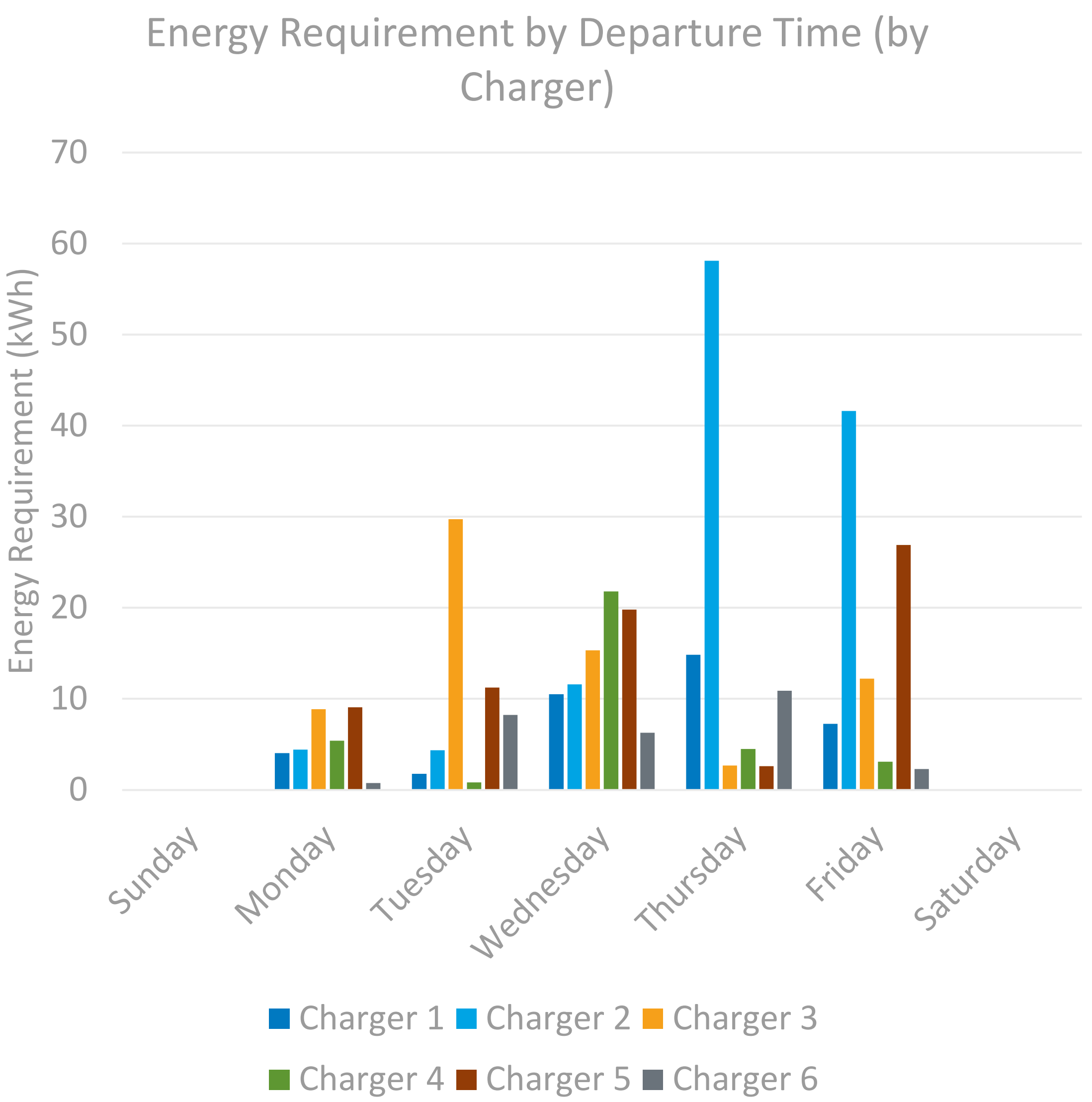


A: Start charging at max power as soon as vehicle arrives
B: Delays charging as long as possible at max power until departure
C: Charges with minimum power possible between arrival and departure
D: Optimal charging strategy to minimize lifecycle cost of electricity purchases (illustrative example)

This analysis compares the economics of options A and D

EV Load Input for Flexible Load Profile





Location of EV

1 – At workplace charger

0 – Not at workplace charger

Office and EV Load Profile – Full Year