

Economics of Solar with Storage for Municipal Buildings in the City of Orlando

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November 2019

NREL/PR-6A20-75271

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- This analysis relies on site information, provided to NREL by the Orlando SEIN team, that has not been independently validated by NREL.
- 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 of NREL or Orlando.

Background

- This analysis was conducted under the first round of the [Solar Energy Innovation Network](#) (SEIN), which is a program led by the [National Renewable Energy Laboratory](#) (NREL). The program assembles diverse teams of stakeholders to research solutions to real-world challenges associated with solar energy adoption.
- This analysis supported the efforts of the [Orlando: Renewable and Resilient](#) SEIN team, which consists of the City of Orlando, Orlando Utility Commission, University of Central Florida's Solar Energy Center, and the Greenlink Group.
- The City of Orlando aims to deploy solar and solar-plus-storage to support energy resiliency, environmental quality, and the continued affordability of the electricity supply. The team's efforts include identifying the total solar potential available city-wide, conducting more detailed analysis for municipal facilities and distribution grid modeling, and gathering insights on municipal-level solar policies and building guidelines to share with other municipalities.
- This analysis supports the team's work by analyzing the techno-economic potential of solar photovoltaics (PV) and lithium-ion battery energy storage at 14 municipal sites in the City of Orlando. The analysis was conducted for both direct purchase/ownership by the city and third-party financing, although third-party financing is not a structure available in the state of Florida.

Solar Energy Innovation Network: <https://www.nrel.gov/solar/solar-energy-innovation-network.html>

Orlando: Renewable and Resilient: https://www.nrel.gov/solar/solar-energy-innovation-network-round-1.html#panel10e186_1

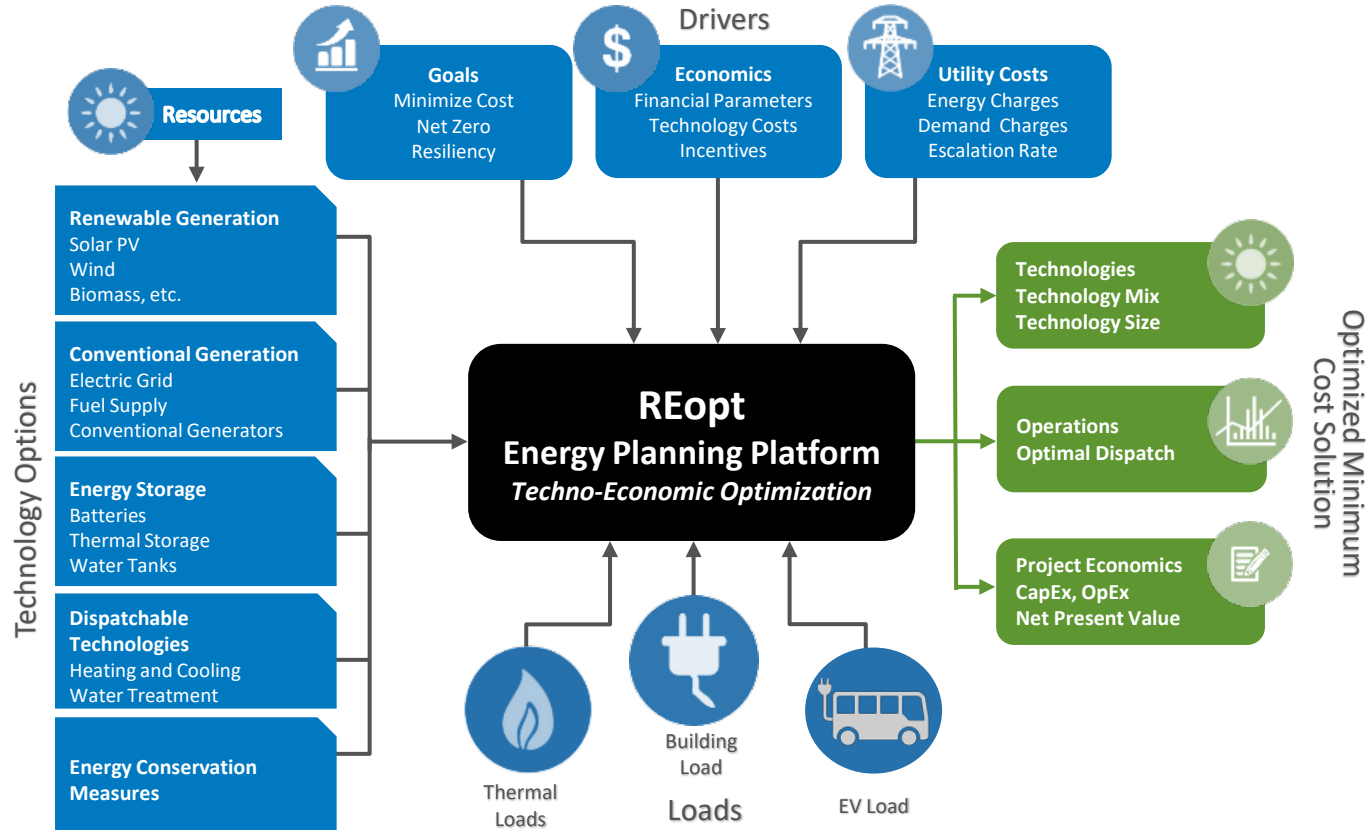
Analysis Overview

- As part of the Solar Energy Innovation Network, NREL is using a tool called REopt to evaluate the techno-economic potential of PV and storage at 14 buildings in the City of Orlando.
- This analysis considered the 15-minute electric load and complex utility rate structure of each site to recommend the size of PV and storage to minimize the cost of utility electric purchases to the site.
- This screening should be treated as an initial step to prioritize and focus additional, in-depth analysis of potential renewable energy projects.
- These results follow from a preliminary screening based on feedback on analysis assumptions from the City of Orlando.
- The assumptions and inputs for the analysis are covered first, before turning to the analysis results, which begin on slide 12 with the base case for the buildings.

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

Sites Evaluated

| Site # | Facility Name | Address | Roof Area Available (sq. ft) | Land Area Available (acres) | Max PV Size (kW-DC) | Annual Electric Consumption (kWh) | Utility Rate |
|--------|----------------------------------|----------------------------------|------------------------------|-----------------------------|---------------------|-----------------------------------|--------------------------------------------------|
| 1 | City Hall | 400 S. Orange Ave. | 9,312 | – | 93 | 4,321,525 | OUC GSD Secondary Demand TOU Rate |
| 2 | College Park Neighborhood Center | 2393 Elizabeth Ave. | 17,059 | – | 171 | 557,324 | OUC GSD Secondary Demand Rate* |
| 3 | Conserv I Facility | 11401 Boggy Creek Rd. | – | 10.0 | 2,180 | 7,601,439 | OUC GSD Secondary Demand TOU Rate |
| 4 | Conserv II Facility | 5420 L B McLeod Rd. | – | 6.2 | 1,339 | 20,174,280 | OUC GSD Primary Demand TOU Rate |
| 5 | Fire Station #07 | 601 South Goldwyn Ave. | 10,294 | – | 103 | 250,351 | OUC GSD Secondary Demand Rate + Community Solar* |
| 6 | Fire Station #08 | 6651 South Shoal creek Dr. | 9,406 | – | 94 | 168,128 | OUC GSD Secondary Demand Rate + Community Solar* |
| 7 | Fire Station #14 | 5450 South Econlockhatchee Trail | 9,780 | – | 98 | 145,760 | Duke Energy GSD Secondary Demand TOU Rate |
| 8 | Fire Station #15 | 10199 South Narcoossee Rd. | 10,281 | – | 103 | 129,052 | OUC GSD Secondary Demand Rate + Community Solar* |
| 9 | Fire Station #16 | 12375 Lake Nona Gateway | 10,048 | – | 100 | 140,387 | OUC GSD Secondary Demand Rate + Community Solar* |
| 10 | Fire Station #17 | 3691 Millenia Blvd. | 10,283 | – | 103 | 147,514 | OUC GSD Secondary Demand Rate + Community Solar* |
| 11 | Iron Bridge Facility | 601 Iron Bridge Cir. | – | 59.7 | 12,998 | 31,315,271 | Duke Energy GSD Primary Demand TOU Rate |
| 12 | Northwest Neighborhood Center | 3955 W D Judge Dr. | 24,099 | – | 241 | 678,380 | OUC GSD Secondary Demand Rate* |
| 13 | Orlando Operations Center | 110 George Desalvia Way | 29,984 | – | 300 | 1,601,012 | OUC GSD Secondary Demand Rate* |
| 14 | Wadeview Neighborhood Center | 2177 S Summerlin Ave. | 7,992 | – | 80 | 188,357 | OUC GSD Secondary Demand Rate* |
| | | | | | | 18,003 | 67,418,780 |

* Currently, Orlando Utilities Commission (OUC) GSD Secondary Demand Rate has an option for community solar, which has a higher energy charge than non-community solar rate (see next slide). The City of Orlando requested that analysis be performed on current rates, although this assumption incentivizes solar on sites currently on community solar rate more than it incentivizes solar on sites currently on non-community solar rate. Additionally, community solar rates are expected to decrease in coming years.

Electric Rates – Orlando Utilities Commission (OUC)

| Utility Rate | Season | Period | Hours | Energy Charges (\$/kWh) | TOU Demand Charges (\$/kW) | Monthly Non-Coincident Demand Charges (\$/kW) | Sites on this Rate |
|-------------------------------------------------|--------------------|--------------|----------------------------|-------------------------|----------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| OUC GSD Secondary Demand Rate | All year (Jan–Dec) | – | All hours | 0.06482 | – | 8.00 | College Park Neighborhood Center Northwest Neighborhood Center Orlando Operations Center Wadeview Neighborhood Center |
| OUC GSD Secondary Demand Rate + Community Solar | All year (Jan–Dec) | – | All hours | 0.08847 | – | 8.00 | Fire Station #07 Fire Station #08 Fire Station #15 Fire Station #16 Fire Station #17 |
| OUC GSD Primary Demand TOU Rate | Summer (Apr–Oct) | On Peak | Weekdays 1pm–6pm | 0.09510 | – | 7.50 | Conserv II Facility |
| | | Partial Peak | Weekdays 11am–1pm, 6pm–8pm | 0.07260 | – | | |
| | | Off Peak | All other hours | 0.06029 | – | | |
| | Winter (Nov–Mar) | On Peak | Weekdays 7am–10am, 6pm–9pm | 0.07131 | – | | |
| | | Partial Peak | Weekdays 10am–6pm | 0.06871 | – | | |
| Off Peak | All other hours | 0.04628 | – | | | | |
| OUC GSD Secondary Demand TOU Rate | Summer (Apr–Oct) | On Peak | Weekdays 1pm–6pm | 0.09606 | – | 8.00 | City Hall Conserv I Facility |
| | | Partial Peak | Weekdays 11am–1pm, 6pm–8pm | 0.07331 | – | | |
| | | Off Peak | All other hours | 0.06086 | – | | |
| | Winter (Nov–Mar) | On Peak | Weekdays 7am–10am, 6pm–9pm | 0.07201 | – | | |
| | | Partial Peak | Weekdays 10am–6pm | 0.06942 | – | | |
| Off Peak | All other hours | 0.04674 | – | | | | |

Electric Rates – Duke Energy

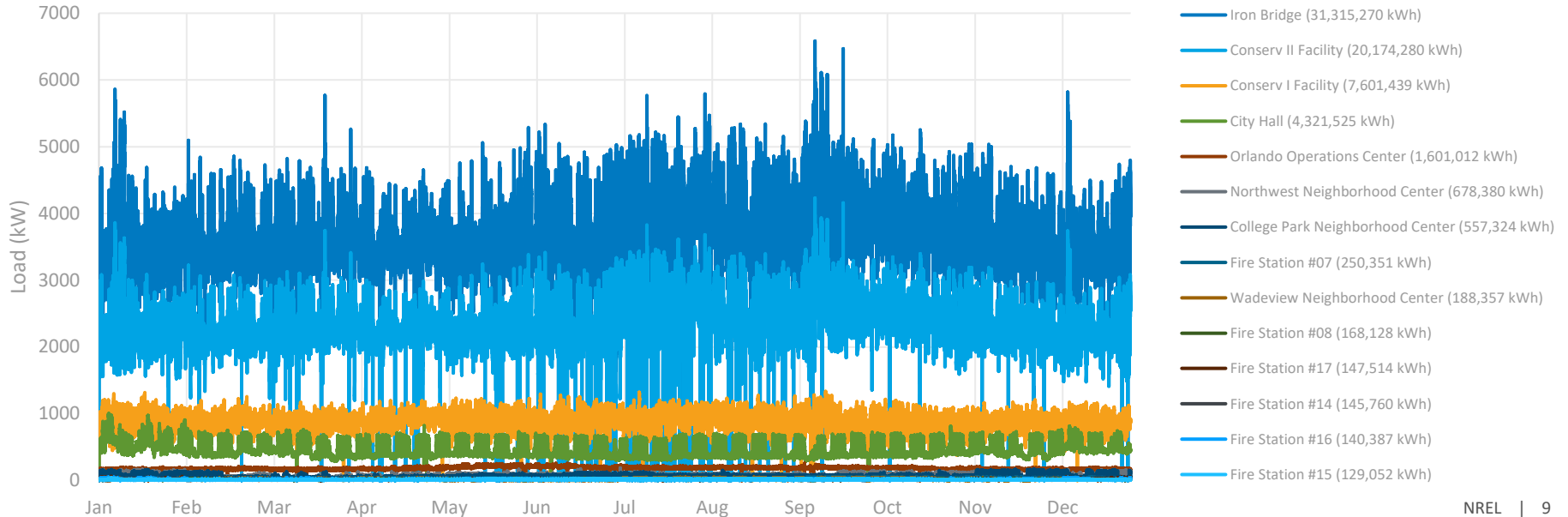
| Utility Rate | Season | Period | Hours | Energy Charges (\$/kWh) | TOU Demand Charges (\$/kW) | Monthly Non-Coincident Demand Charges (\$/kW) | Sites on this Rate |
|-------------------------------------------|------------------|----------|-----------------------------|-------------------------|----------------------------|-----------------------------------------------|----------------------|
| Duke Energy GSD Primary Demand TOU Rate | Summer (Apr–Oct) | On Peak | Weekdays 12pm–9pm | 0.10523 | 3.94 | 5.1282 | Iron Bridge Facility |
| | | Off Peak | All other hours | 0.04831 | – | | |
| | Winter (Nov–Mar) | On Peak | Weekdays 6am–10am, 6pm–10pm | 0.10523 | 3.94 | 5.1282 | |
| | | Off Peak | All other hours | 0.04831 | – | | |
| Duke Energy GSD Secondary Demand TOU Rate | Summer (Apr–Oct) | On Peak | Weekdays 12pm–9pm | 0.10586 | 3.94 | 6.37 | Fire Station #14 |
| | | Off Peak | All other hours | 0.04871 | – | | |
| | Winter (Nov–Mar) | On Peak | Weekdays 6am–10am, 6pm–10pm | 0.10586 | 3.94 | 6.37 | |
| | | Off Peak | All other hours | 0.04871 | – | | |

Reference: <https://www.duke-energy.com/ /media/pdfs/rates/peratespefcommercialrateinsert.pdf?la=en>

Load Data

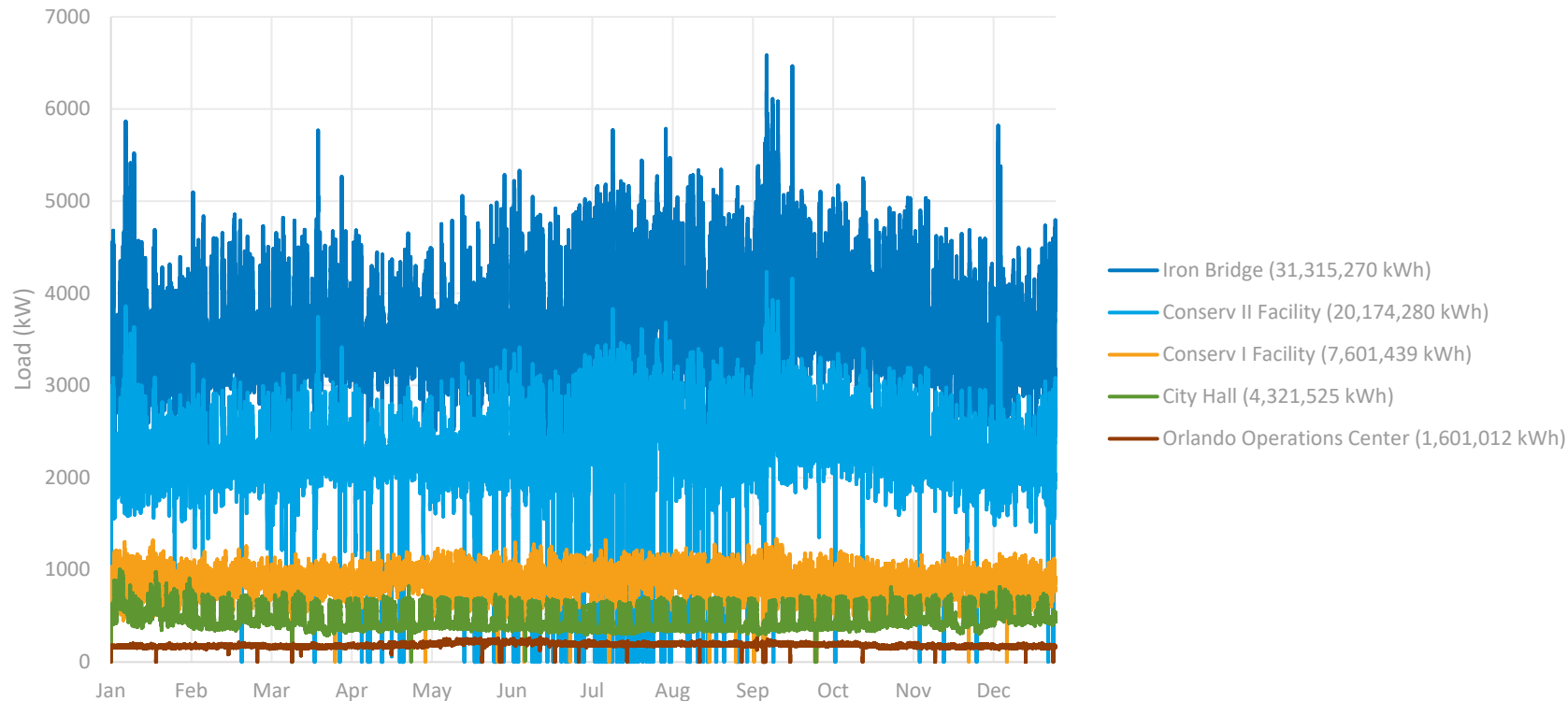
- OUC sites (12): 15-minute interval data from May 1, 2017 – May 1, 2018
- Duke Energy sites (2): NREL synthesized 15-minute load profiles by scaling reference load profiles to monthly consumption data
 - Fire Station #14: monthly totals scaled to shape of Fire Station #08 load profile (selected one fire-station load profile rather than average to consider full variation of load (spikes/troughs))
 - Iron Bridge Facility: monthly totals scaled to match shape of Conserv II Facility load profile (buildings have similar purposes)

15-Minute Load Interval Data (All Sites)



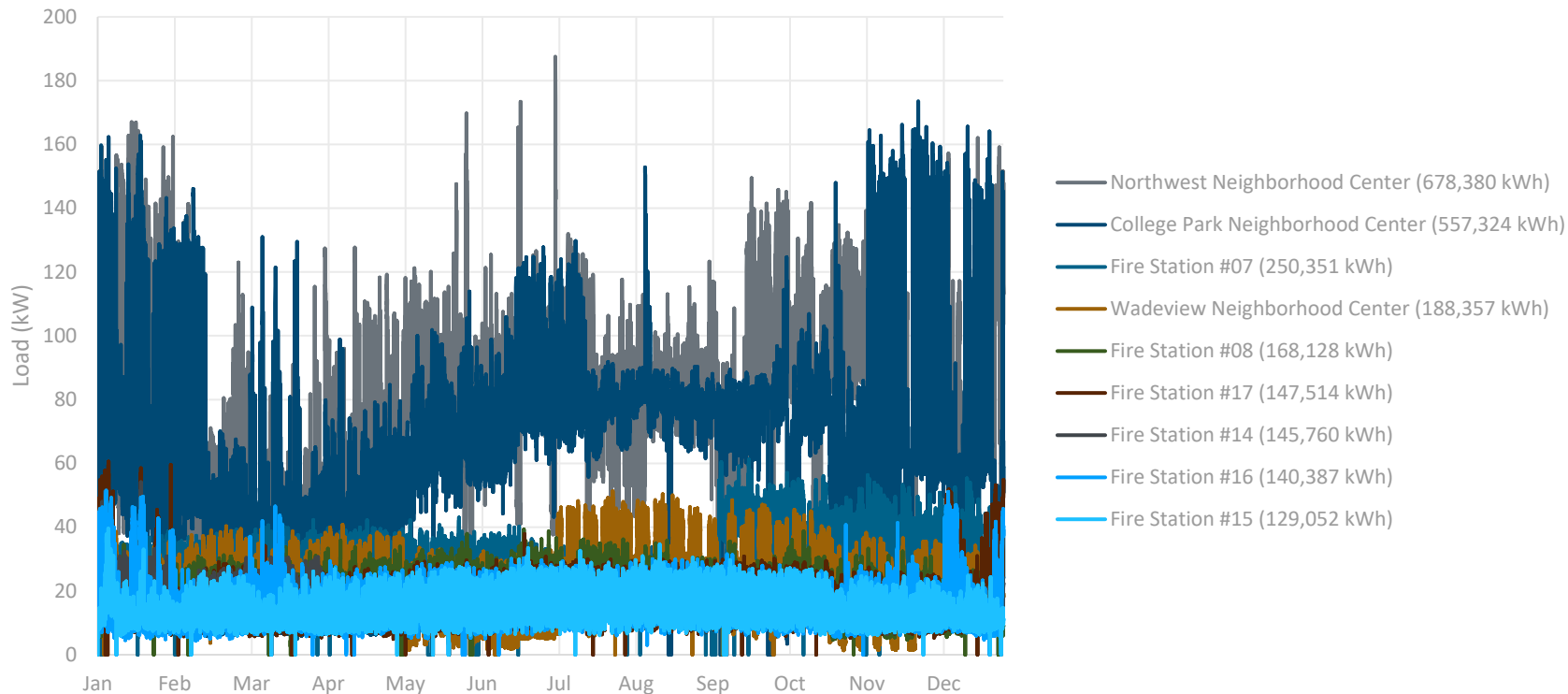
Load Data – Sites with Annual Load > 1,000,000 kWh

15-Minute Load Interval Data, Sites with Annual Load > 1,000,000 kWh



Load Data – Sites with Annual Load < 1,000,000 kWh

15-Minute Load Interval Data, Sites with Annual Load < 1,000,000 kWh



Economic Assumptions

| Input | Assumption |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Technologies | Solar PV and lithium-ion battery storage |
| Objective | Minimize lifecycle cost (cost-effective projects) |
| Ownership model | 1) Direct purchase 2) 3 rd -party financing (Florida does not currently allow power purchase agreements, but it was included to evaluate other potential 3 rd -party options such as leasing) |
| Analysis period | 20 years |
| Discount rate | 3% for site, 8.1% for developer (developer rate only included in 3 rd -party financing scenario) |
| Electricity cost escalation rate | 2.6% per EIA |
| Inflation rate | 2.5% per EIA |
| Interconnection limit | No limit |
| Net metering limit | Florida net metering limit is 2,000-kW system per DSIRE; but for this analysis, it was assumed that multiple meters could be installed at a site to avoid the net metering limit to assess a ceiling for potential. Cost of installing additional meters was not considered in this analysis. Net metering compensation was assumed to be provided for electricity exports up to annual site load. |

Technology Assumptions: Solar PV

| Input | Assumption |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| System type | Fixed-tilt systems, rooftop or ground-mount (site-specific) |
| Technology resource | TMY2 weather file for Tampa, FL (annual capacity factor = 16.9%) |
| Installed capacity density | Rooftop: 10 W/sq.ft.; Ground: 5 W/sq.ft. |
| Tilt | Rooftop: 10°; Ground: 28.55° (latitude) |
| Azimuth | 180° (south-facing) |
| Technology costs | Capital costs: 0–100 kW - \$2.03/W; 100–1000 kW - \$1.74/W; >1000 kW - \$1.12/W (per NREL Q1 2017 US PV Cost Benchmark) O&M: \$16/kW/yr per NREL ATB |
| Incentives | 1) Direct purchase: none 2) 3 rd -party financing: 30% ITC; 5-yr MACRS with no-bonus MACRS |

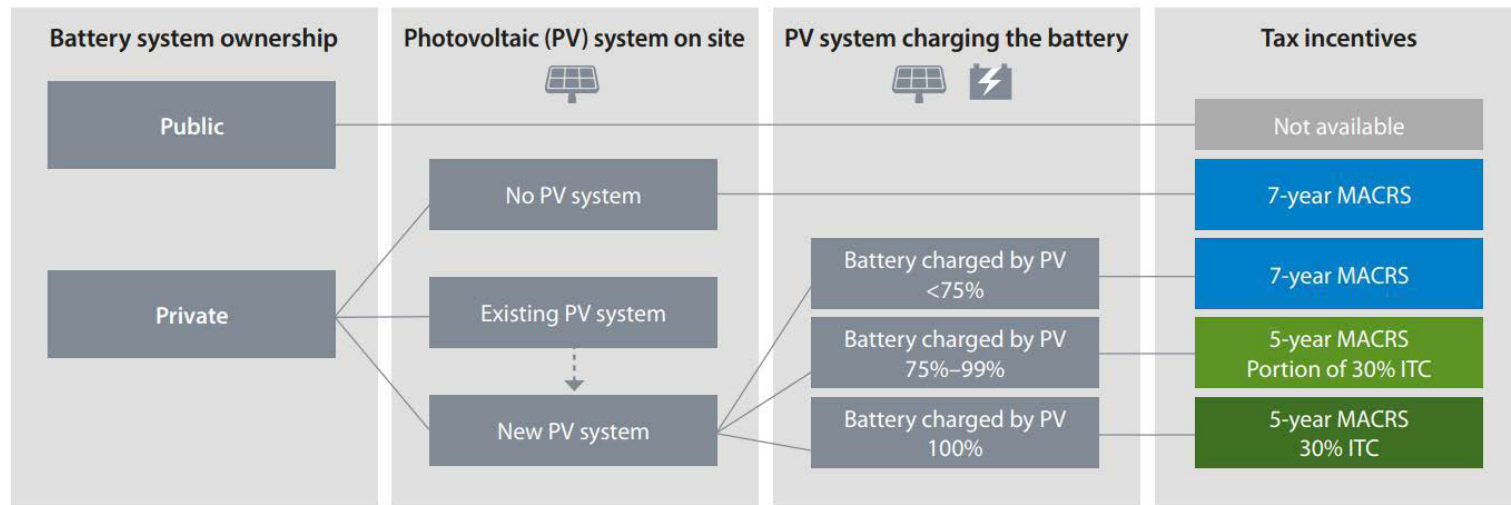
Technology Assumptions: Battery Storage

| Input | Assumption |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Battery type | Lithium-ion |
| AC-AC round trip efficiency | 89.9% |
| Minimum state of charge | 20% |
| Technology costs | Capital costs: \$500/kWh + \$1000/kW Replacement (yr 10): \$230/kWh + \$460/kW |
| Incentives | 1) Direct purchase: none 2) 3 rd -party financing: 30% ITC; 5-yr MACRS with no-bonus MACRS. <i>The model required battery to only charge from PV; if the battery were charged by PV and the grid, then incentives would reduce - see next slide</i> |

Federal Incentives for Batteries, Based on PV System

This REopt analysis required the battery to only charge by PV so as to take advantage of maximum incentives.

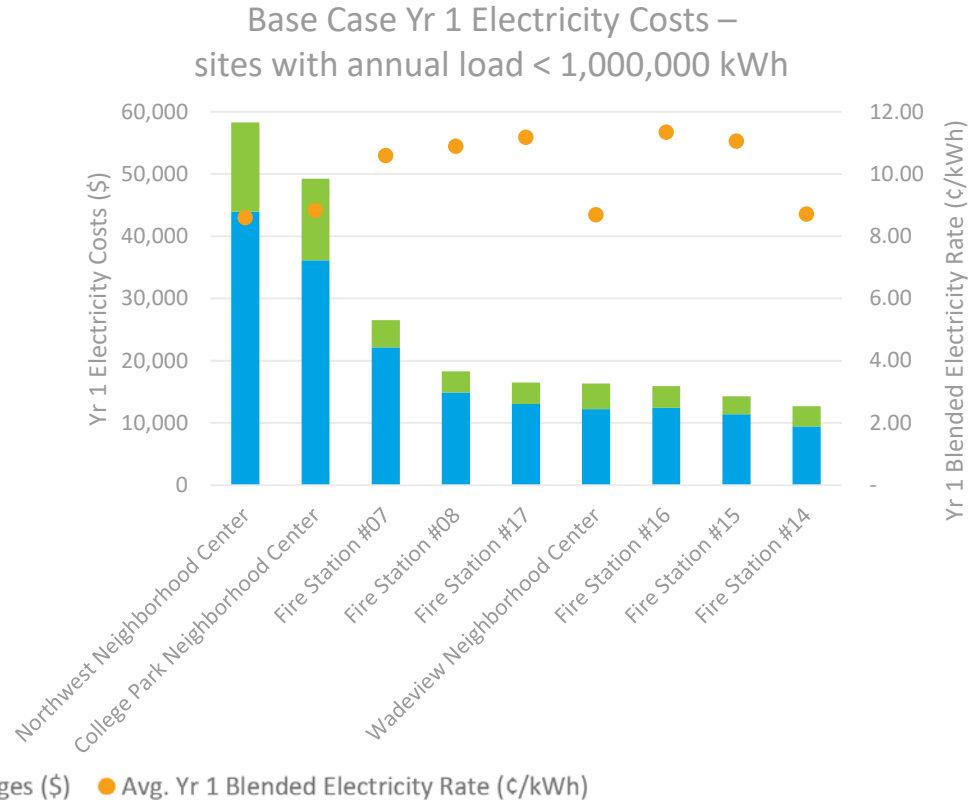
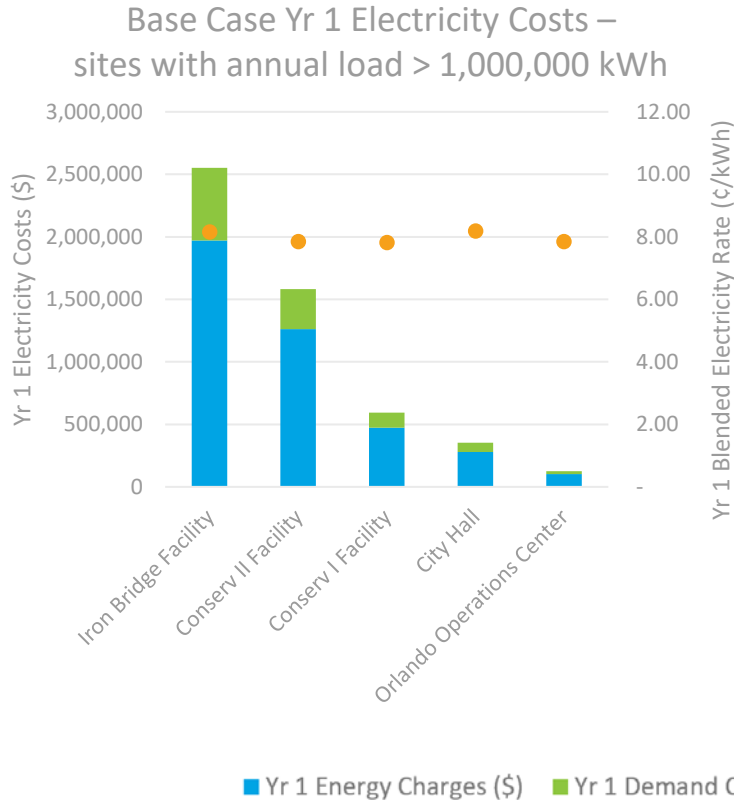
Federal Tax Incentives for Energy Storage Systems



For more on federal tax incentives for energy storage systems, see:
<https://www.nrel.gov/docs/fy18osti/70384.pdf>

Base Case Cost of Electricity (Calculated by REopt)

(ordered by decreasing annual site load)



* Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Base Case Cost of Electricity (Calculated by REopt)

| Site # | Facility Name | Electricity Use (kWh) | Annual Energy Charges (\$) | Annual Demand Charges (\$) | Total Annual Elec Costs (\$) | 20-Year Cost of Electricity (\$) |
|--------------|----------------------------------|-----------------------|----------------------------|----------------------------|------------------------------|----------------------------------|
| 1 | City Hall | 4,321,525 | 279,516 | 74,275 | 353,791 | 6,794,268 |
| 2 | College Park Neighborhood Center | 557,324 | 36,115 | 13,132 | 49,246 | 945,732 |
| 3 | Conserv I Facility | 7,601,439 | 473,601 | 120,033 | 593,634 | 11,400,245 |
| 4 | Conserv II Facility | 20,174,280 | 1,262,720 | 319,194 | 1,581,914 | 30,379,359 |
| 5 | Fire Station #07 | 250,351 | 22,156 | 4,365 | 26,521 | 509,311 |
| 6 | Fire Station #08 | 168,128 | 14,879 | 3,425 | 18,304 | 351,513 |
| 7 | Fire Station #14* | 145,760 | 9,424 | 3,264 | 12,688 | 243,656 |
| 8 | Fire Station #15 | 129,052 | 11,421 | 2,840 | 14,261 | 273,866 |
| 9 | Fire Station #16 | 140,387 | 12,424 | 3,500 | 15,924 | 305,813 |
| 10 | Fire Station #17 | 147,514 | 13,055 | 3,432 | 16,487 | 316,626 |
| 11 | Iron Bridge Facility* | 31,315,270 | 1,971,392 | 581,994 | 2,553,386 | 49,035,687 |
| 12 | Northwest Neighborhood Center | 678,380 | 43,959 | 14,370 | 58,329 | 1,120,169 |
| 13 | Orlando Operations Center | 1,601,012 | 103,746 | 21,797 | 125,543 | 2,410,945 |
| 14 | Wadeview Neighborhood Center | 188,357 | 12,206 | 4,154 | 16,359 | 314,169 |
| TOTAL | | 67,418,779 | 4,266,614 | 1,169,774 | 5,436,388 | 104,401,358 |

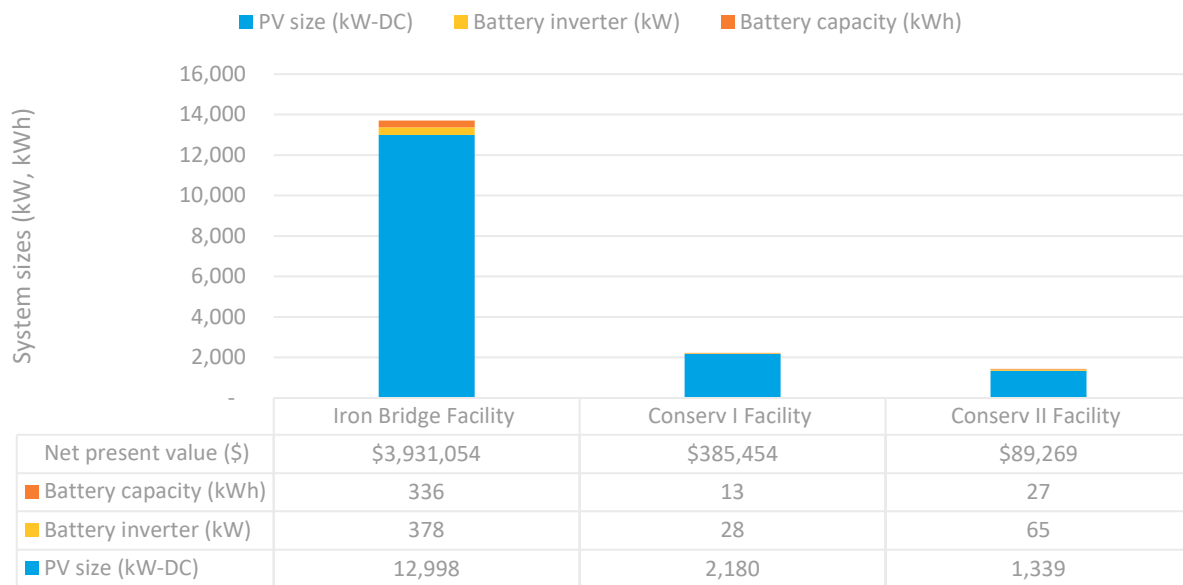
* Note: Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Results

Direct Purchase by City

Cost-Optimal System Sizes – Direct Purchase, Sites with Recommended PV > 1 MW; PV + Battery Storage

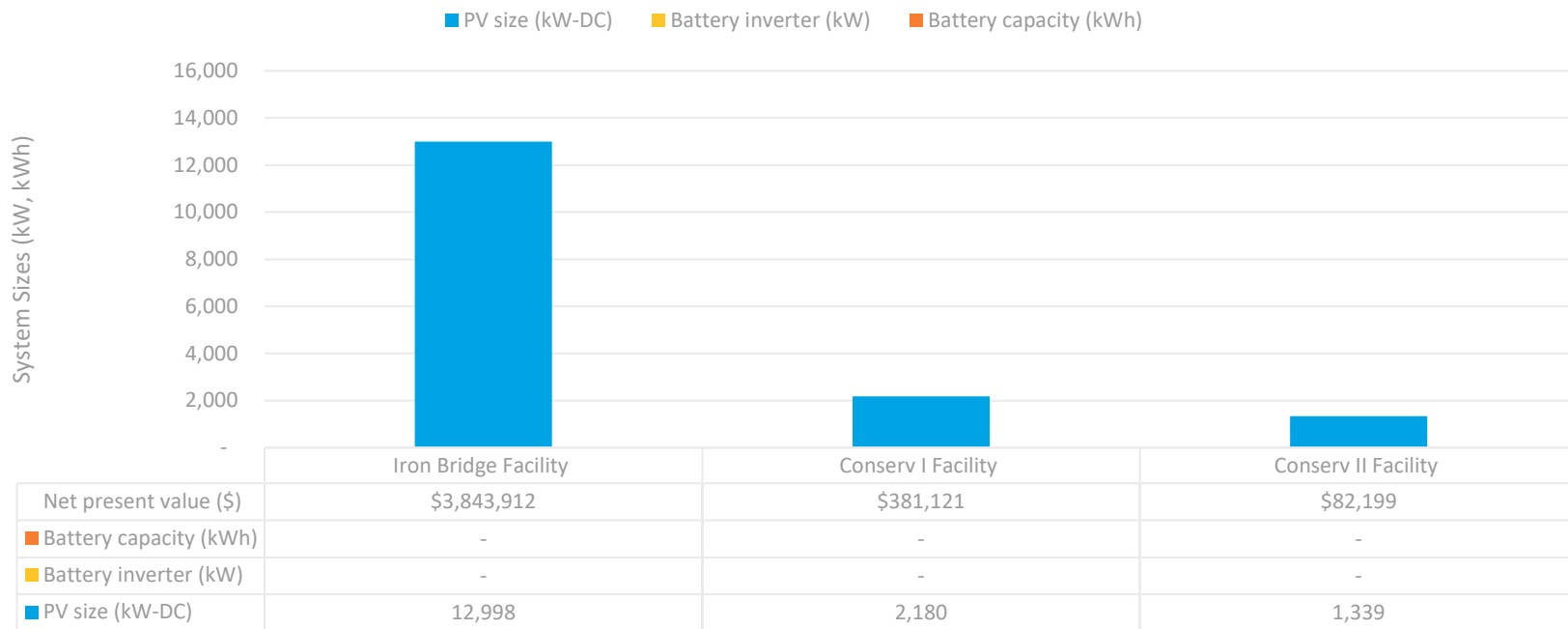
Sizing Recommendations - Direct Purchase, PV + BESS (systems > 1 MW)



- This slide shows the cost-optimal system sizes calculated by REopt for the three largest sites.
- These recommended batteries are small relative to the load, but they could provide lifecycle cost savings and resiliency to the site.
- See next slide for cost-optimal PV sizing without batteries.
- Sites with less than 1 MW are on slides 21 and 22.

Technology Sizing Recommendations – Direct Purchase, Sites with Recommended PV > 1 MW; PV Only

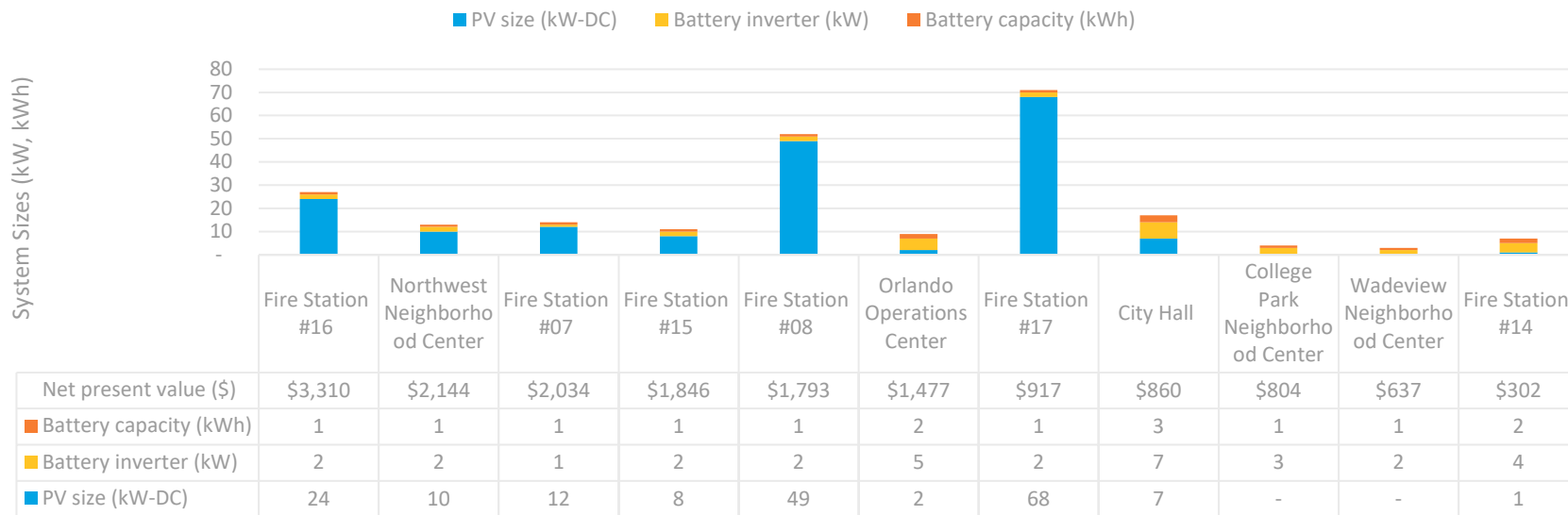
Sizing Recommendations - Direct Purchase, PV only (systems > 1 MW)



Note: Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Cost-Optimal System Sizes – Direct Purchase, Sites with Recommended PV < 1 MW; PV + Battery Storage

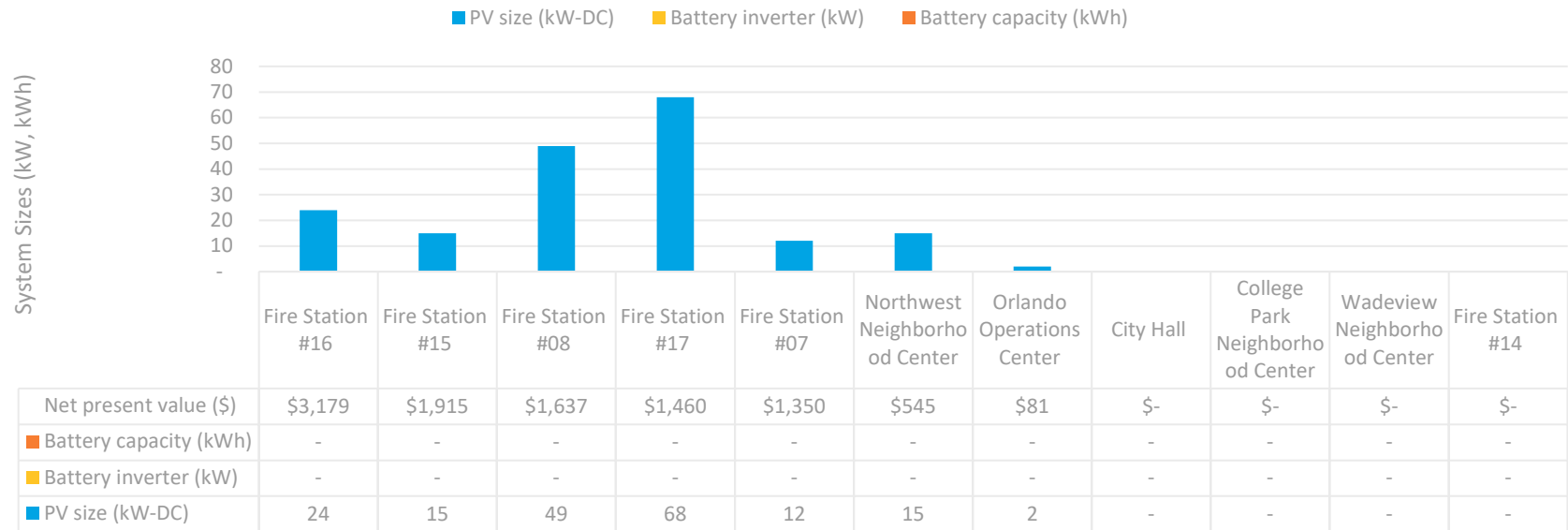
Sizing Recommendations - Direct Purchase, PV + BESS (systems < 1 MW)



Note: These REopt-recommended batteries are quite small (both in absolute and relative to the load), and although marginally cost-effective, they would likely be too small to be practical for facilities managers and other relevant decision makers. See next slide for cost-optimal PV sizing without batteries.

Cost-Optimal System Sizes – Direct Purchase, Sites with Recommended PV < 1 MW; PV Only (No Batteries)

Sizing Recommendations - Direct Purchase, PV only (systems < 1 MW)



* Cost-optimal PV size at Orlando Operations Center is extremely small; recommend no PV installed or more PV installed.

Cost-Optimal System Sizes – Direct Purchase, PV + Battery Storage (Ordered by NPV)

| Facility Name | Annual Electric Consumption (kWh) | Max PV size (kW) | PV size (kW) | Battery inverter (kW) | Battery capacity (kWh) | Capital costs without incentives (\$) | Annual PV production (kWh) | % Electricity from RE | Yr 1 Energy Charge Savings (\$) | Yr 1 Demand Charge Savings (\$) | Total Yr 1 Electricity Cost Savings (\$) | O&M (\$) | Simple Payback (yrs) | IRR (%) | NPV (\$) |
|----------------------------------|-----------------------------------|------------------|---------------|-----------------------|------------------------|---------------------------------------|----------------------------|-----------------------|---------------------------------|---------------------------------|------------------------------------------|----------------|----------------------|------------|------------------|
| Iron Bridge Facility | 31,315,270 | 12,998 | 12,998 | 378 | 336 | 15,753,392 | 18,494,050 | 59.1 | 1,180,312 | 50,575 | 1,230,887 | 207,968 | 15.40 | 5.7 | 3,931,054 |
| Conserv I Facility | 7,601,439 | 2,180 | 2,180 | 28 | 13 | 3,092,634 | 3,101,446 | 40.8 | 212,264 | 3,376 | 215,641 | 34,880 | 17.11 | 6.6 | 385,454 |
| Conserv II Facility | 20,174,280 | 1,339 | 1,339 | 65 | 27 | 2,219,977 | 1,905,180 | 9.4 | 129,635 | 11,821 | 141,456 | 21,424 | 18.49 | 7.0 | 89,269 |
| Fire Station #16 | 140,387 | 100 | 24 | 2 | 1 | 52,051 | 32,729 | 23.3 | 2,895 | 368 | 3,263 | 384 | 18.08 | 3.6 | 3,310 |
| Northwest Neighborhood Center | 678,380 | 241 | 10 | 2 | 1 | 23,631 | 14,158 | 2.1 | 917 | 583 | 1,501 | 160 | 17.63 | 3.9 | 2,144 |
| Fire Station #07 | 250,351 | 103 | 12 | 1 | 1 | 26,358 | 16,423 | 6.6 | 1,455 | 214 | 1,669 | 192 | 17.85 | 3.8 | 2,034 |
| Fire Station #15 | 129,052 | 103 | 8 | 2 | 1 | 19,571 | 11,147 | 8.6 | 987 | 255 | 1,242 | 128 | 17.57 | 3.9 | 1,846 |
| Fire Station #08 | 168,128 | 94 | 49 | 2 | 1 | 102,801 | 65,920 | 39.2 | 5,836 | 387 | 6,223 | 784 | 18.90 | 3.2 | 1,793 |
| Orlando Operations Center | 1,601,012 | 300 | 2 | 5 | 2 | 12,054 | 3,200 | 0.2 | 206 | 530 | 736 | 32 | 17.12 | 4.3 | 1,477 |
| Fire Station #17 | 147,514 | 103 | 68 | 2 | 1 | 141,371 | 92,078 | 62.4 | 8,147 | 339 | 8,486 | 1,088 | 19.11 | 3.1 | 917 |
| City Hall | 4,321,525 | 93 | 7 | 7 | 3 | 25,535 | 9,060 | 0.2 | 637 | 849 | 1,485 | 112 | 18.59 | 3.3 | 860 |
| College Park Neighborhood Center | 557,324 | 171 | – | 3 | 1 | 4,663 | – | – | 25 | 260 | 285 | – | 16.38 | 5.1 | 804 |
| Wadeview Neighborhood Center | 188,357 | 80 | – | 2 | 1 | 3,331 | – | – | 30 | 177 | 207 | – | 16.12 | 5.3 | 637 |
| Fire Station #14 | 145,760 | 98 | 1 | 4 | 2 | 8,692 | 893 | 0.6% | 78 | 406 | 484 | 16 | 18.57 | 3.3 | 302 |
| Overall | 67,418,779 | 18,003 | 16,698 | 503 | 391 | 21,486,060 | 23,746,285 | 35.2 | 1,543,424 | 70,140 | 1,613,563 | 267,168 | 15.96 | 6.0 | 4,421,900 |

Note: Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Cost-Optimal System Sizes– 3rd-Party Financing, PV Only (Ordered by NPV)

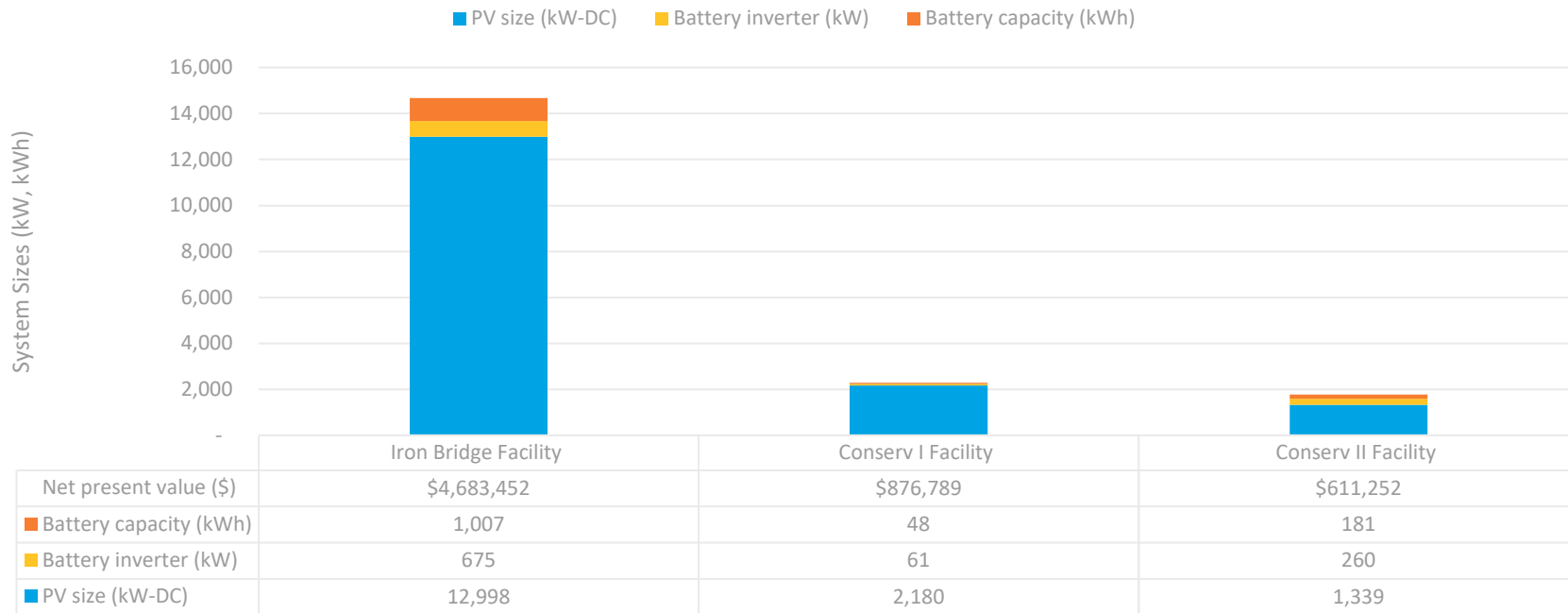
| Facility Name | Annual Electric Consumption (kWh) | Max PV size (kW) | PV size (kW) | Capital costs without incentives (\$) | Annual PV production (kWh) | % Electricity from RE | Yr 1 Energy Charge Savings (\$) | Yr 1 Demand Charge Savings (\$) | Total Yr 1 Electricity Cost Savings (\$) | O&M (\$) | Simple Payback (yrs) | IRR (%) | NPV (\$) |
|----------------------------------|-----------------------------------|------------------|---------------|---------------------------------------|----------------------------|-----------------------|---------------------------------|---------------------------------|------------------------------------------|----------------|----------------------|------------|------------------|
| Iron Bridge Facility | 31,315,270 | 12,998 | 12,998 | 15,025,949 | 18,494,050 | 59.1 | 1,176,704 | 11,766 | 1,188,470 | 207,968 | 15.32 | 5.7 | 3,843,912 |
| Conserv I Facility | 7,601,439 | 2,180 | 2,180 | 3,046,669 | 3,101,787 | 40.8 | 212,229 | 792 | 213,022 | 34,880 | 17.10 | 6.6 | 381,121 |
| Conserv II Facility | 20,174,280 | 1,339 | 1,339 | 2,115,391 | 1,905,180 | 9.4 | 129,518 | 6,123 | 135,642 | 21,424 | 18.52 | 7.1 | 82,199 |
| Fire Station #16 | 140,387 | 100 | 24 | 48,720 | 32,550 | 23.2 | 2,881 | 202 | 3,083 | 384 | 18.05 | 3.6 | 3,179 |
| Fire Station #15 | 129,052 | 103 | 15 | 30,450 | 20,344 | 15.8 | 1,800 | 122 | 1,923 | 240 | 18.09 | 3.6 | 1,915 |
| Fire Station #08 | 168,128 | 94 | 49 | 99,470 | 66,457 | 39.5 | 5,881 | 160 | 6,041 | 784 | 18.92 | 3.2 | 1,637 |
| Fire Station #17 | 147,514 | 103 | 68 | 138,040 | 92,226 | 62.5 | 8,162 | 179 | 8,341 | 1,088 | 19.03 | 3.1 | 1,460 |
| Fire Station #07 | 250,351 | 103 | 12 | 24,360 | 16,275 | 6.5 | 1,440 | 88 | 1,529 | 192 | 18.22 | 3.5 | 1,350 |
| Northwest Neighborhood Center | 678,380 | 241 | 15 | 30,450 | 20,344 | 3.0 | 1,318 | 533 | 1,852 | 240 | 18.89 | 3.2 | 545 |
| Orlando Operations Center | 1,601,012 | 300 | 2 | 4,060 | 2,713 | 0.2 | 176 | 72 | 247 | 32 | 18.86 | 3.2 | 81 |
| City Hall | 4,321,525 | 93 | - | - | - | - | - | - | - | - | - | - | - |
| College Park Neighborhood Center | 557,324 | 171 | - | - | - | - | - | - | - | - | - | - | - |
| Fire Station #14 | 145,760 | 98 | - | - | - | - | - | - | - | - | - | - | - |
| Wadeview Neighborhood Center | 188,357 | 80 | - | - | - | - | - | - | - | - | - | - | - |
| Overall | 67,418,779 | 18,003 | 16,702 | 20,563,559 | 23,751,927 | 35.2 | 1,540,111 | \$20,038 | 1,560,149 | 267,232 | 15.90 | 6.0 | 4,317,401 |

Results – 3rd-Party Financing

Note: Power purchase agreements are not currently an option in Florida; included per request from City of Orlando, especially considering 3rd-party leasing options

Cost-Optimal System Sizes – 3rd-Party Financing, Sites with Recommended PV Size > 1 MW; PV + Battery Storage

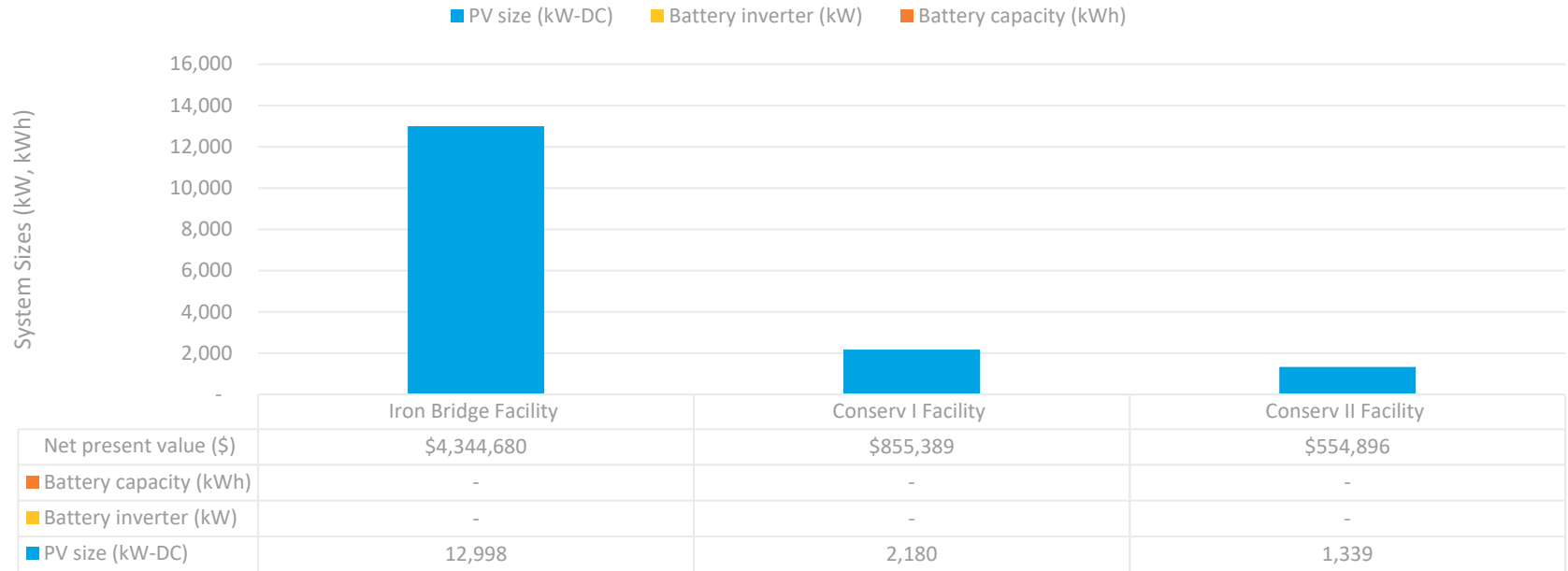
Sizing Recommendations - 3rd Party, PV + BESS (systems > 1 MW)



Note: These recommended batteries are small relative to the load, but they could provide lifecycle cost savings and resiliency to the site. See next slide for cost-optimal PV sizing without batteries.

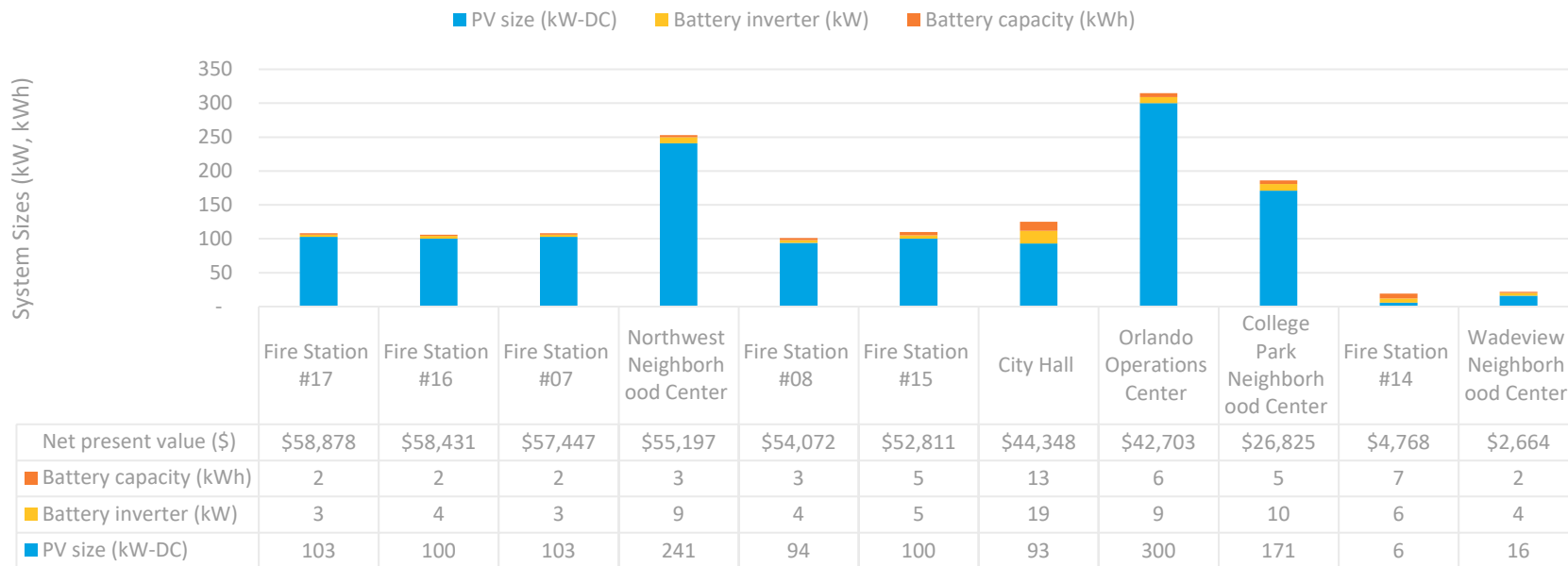
Cost-Optimal System Sizes – 3rd-Party Financing, Sites with Recommended PV Size > 1 MW; PV Only

Sizing Recommendations - 3rd Party, PV only (systems > 1 MW)



Cost-Optimal System Sizes – 3rd-Party Financing, Sites with Recommended PV Size < 1 MW; PV + Battery Storage

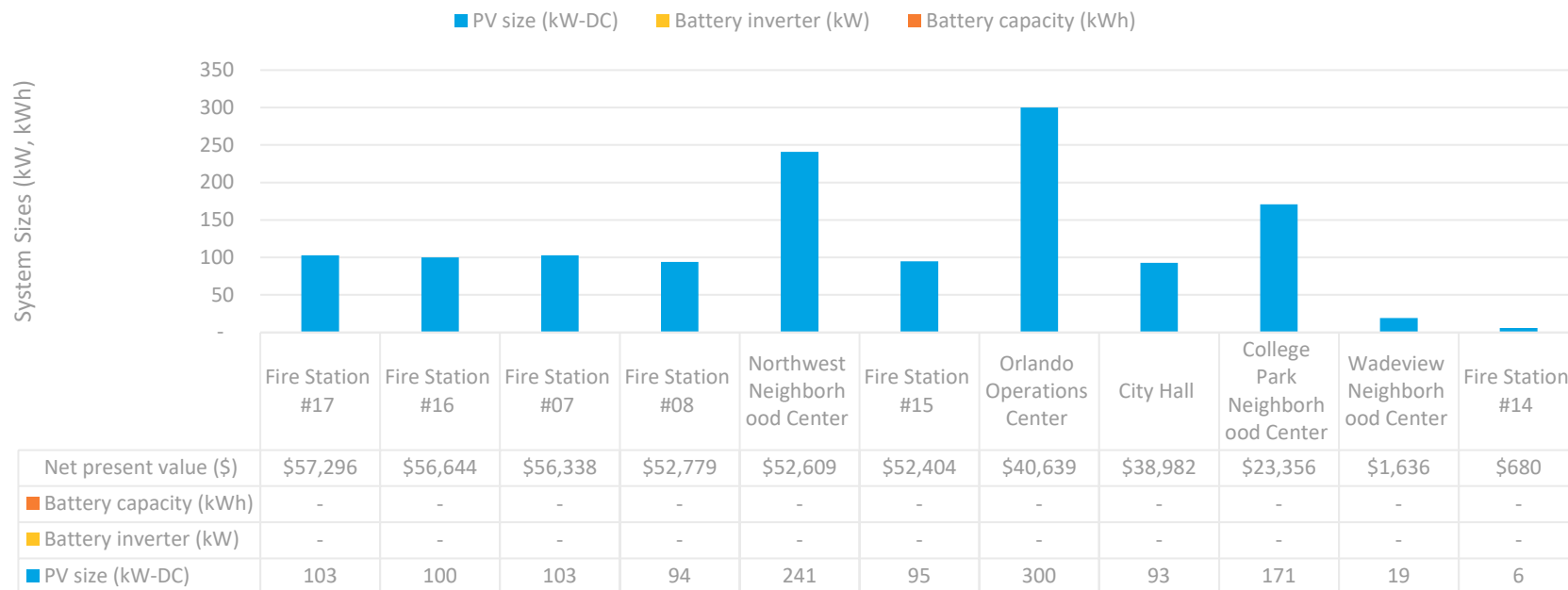
Sizing Recommendations - 3rd Party, PV + BESS (systems < 1 MW)



Note: These REopt-recommended batteries are quite small (both in absolute and relative to the load), and although marginally cost-effective, they would likely be too small to be practical for facilities managers and other relevant decision makers. See next slide for cost-optimal PV sizing without batteries. The only potential exception would be the City Hall proposed battery size of 19 kW/13 kWh.

Cost-Optimal System Sizes – 3rd-Party Financing, Sites with Recommended PV Size < 1 MW – PV Only (No Batteries)

Sizing Recommendations - 3rd Party, PV only (systems < 1 MW)



Cost-Optimal System Sizes – 3rd-Party Financing, PV + Battery Storage (Ordered by NPV)

| Facility Name | Annual Electric Consumption (kWh) | Max PV size (kW) | PV size (kW) | Battery inverter (kW) | Battery capacity (kWh) | Capital costs without incentives (\$) | Annual PV production (kWh) | % Electricity from RE | Yr 1 Energy Charge Savings (\$) | Yr 1 Demand Charge Savings (\$) | Total Yr 1 Electricity Cost Savings (\$) | O&M (\$) | Simple Payback (yrs) | NPV (\$) |
|----------------------------------|-----------------------------------|------------------|---------------|-----------------------|------------------------|---------------------------------------|----------------------------|-----------------------|---------------------------------|---------------------------------|------------------------------------------|----------------|----------------------|------------------|
| Iron Bridge Facility | 31,315,270 | 12,998 | 12,998 | 675 | 1,007 | 15,823,776 | 18,494,050 | 59.1 | 1,187,325 | 82,213 | 1,269,539 | 207,968 | 14.91 | 4,683,452 |
| Conserv I Facility | 7,601,439 | 2,180 | 2,180 | 61 | 48 | 3,104,213 | 3,101,446 | 40.8 | 212,407 | 6,281 | 218,688 | 34,880 | 16.89 | 876,789 |
| Conserv II Facility | 20,174,280 | 1,339 | 1,339 | 260 | 181 | 2,352,674 | 1,905,180 | 9.4 | 130,158 | 27,281 | 157,439 | 21,424 | 17.30 | 611,252 |
| Fire Station #17 | 147,514 | 103 | 103 | 3 | 2 | 210,831 | 139,483 | 94.6 | 12,342 | 478 | 12,821 | 1,648 | 18.87 | 58,878 |
| Fire Station #16 | 140,387 | 100 | 100 | 4 | 2 | 206,385 | 135,627 | 96.6 | 12,001 | 609 | 12,609 | 1,600 | 18.75 | 58,431 |
| Fire Station #07 | 250,351 | 103 | 103 | 3 | 2 | 210,831 | 139,632 | 55.8 | 12,359 | 388 | 12,746 | 1,648 | 19.00 | 57,447 |
| Northwest Neighborhood Center | 678,380 | 241 | 241 | 9 | 3 | 450,905 | 326,860 | 48.2 | 21,180 | 2,927 | 24,107 | 3,856 | 22.27 | 55,197 |
| Fire Station #08 | 168,128 | 94 | 94 | 4 | 3 | 194,543 | 127,489 | 75.8 | 11,284 | 567 | 11,852 | 1,504 | 18.80 | 54,072 |
| Fire Station #15 | 129,052 | 103 | 100 | 5 | 5 | 208,077 | 135,627 | 105.1 | 11,944 | 507 | 12,451 | 1,600 | 19.18 | 52,811 |
| City Hall | 4,321,525 | 93 | 93 | 19 | 13 | 206,053 | 126,133 | 2.9 | 8,726 | 3,602 | 12,329 | 1,488 | 19.01 | 44,348 |
| Orlando Operations Center | 1,601,012 | 300 | 300 | 9 | 6 | 552,679 | 406,716 | 25.4 | 26,355 | 1,940 | 28,295 | 4,800 | 23.52 | 42,703 |
| College Park Neighborhood Center | 557,324 | 171 | 171 | 10 | 5 | 332,715 | 231,396 | 41.5 | 14,997 | 2,096 | 17,093 | 2,736 | 23.17 | 26,825 |
| Fire Station #14 | 145,760 | 98 | 6 | 6 | 7 | 18,679 | 8,150 | 5.6 | 604 | 718 | 1,323 | 96 | 15.23 | 4,768 |
| Wadeview Neighborhood Center | 188,357 | 80 | 16 | 4 | 2 | 35,865 | 21,130 | 11.2 | 1,373 | 522 | 1,895 | 256 | 21.88 | 2,664 |
| Overall | 67,418,779 | 18,003 | 17,844 | 1,072 | 1,286 | 23,908,228 | 25,298,917 | 37.5 | 1,663,056 | 130,130 | 1,793,187 | 285,504 | 15.86 | 6,629,638 |

Note: Internal rate of return not provided for 3rd-party financing because it must be calculated from either perspective of the owner or offtaker, and without information about power purchase agreement price, it is not possible to calculate accurately.

Note: Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Cost-Optimal System Sizes – 3rd-Party Financing, PV Only (Ordered by NPV)

| Facility Name | Annual Electric Consumption (kWh) | Max PV size (kW) | PV size (kW) | Capital costs without incentives (\$) | Annual PV production (kWh) | % Electricity from RE | Yr 1 Energy Charge Savings (\$) | Yr 1 Demand Charge Savings (\$) | Total Yr 1 Electricity Cost Savings (\$) | O&M (\$) | Simple Payback (yrs) | NPV (\$) |
|----------------------------------|-----------------------------------|------------------|---------------|---------------------------------------|----------------------------|-----------------------|---------------------------------|---------------------------------|------------------------------------------|----------------|----------------------|------------------|
| Iron Bridge Facility | 31,315,270 | 12,998 | 12,998 | 15,025,949 | 18,494,050 | 59.1 | 1,176,705 | 11,772 | 1,188,477 | 207,968 | 15.32 | 4,344,680 |
| Conserv I Facility | 7,601,439 | 2,180 | 2,180 | 3,046,669 | 3,101,446 | 40.8 | 212,207 | 792 | 212,999 | 34,880 | 17.10 | 855,389 |
| Conserv II Facility | 20,174,280 | 1,339 | 1,339 | 2,115,391 | 1,905,180 | 9.4 | 129,518 | 6,124 | 135,642 | 21,424 | 18.52 | 554,896 |
| Fire Station #17 | 147,514 | 103 | 103 | 208,123 | 139,483 | 94.6 | 12,343 | 180 | 12,523 | 1,648 | 19.14 | 57,296 |
| Fire Station #16 | 140,387 | 100 | 100 | 203,000 | 135,627 | 96.6 | 12,002 | 246 | 12,247 | 1,600 | 19.07 | 56,644 |
| Fire Station #07 | 250,351 | 103 | 103 | 208,123 | 139,632 | 55.8 | 12,359 | 114 | 12,473 | 1,648 | 19.23 | 56,338 |
| Fire Station #08 | 168,128 | 94 | 94 | 190,820 | 127,489 | 75.8 | 11,285 | 203 | 11,488 | 1,504 | 19.11 | 52,779 |
| Northwest Neighborhood Center | 678,380 | 241 | 241 | 443,797 | 326,860 | 48.2 | 21,180 | 2,227 | 23,407 | 3,856 | 22.70 | 52,609 |
| Fire Station #15 | 129,052 | 103 | 95 | 192,850 | 129,052 | 100.0 | 11,422 | 140 | 11,562 | 1,520 | 19.20 | 52,404 |
| Orlando Operations Center | 1,601,012 | 300 | 300 | 544,556 | 406,716 | 25.4 | 26,355 | 1,186 | 27,542 | 4,800 | 23.95 | 40,639 |
| City Hall | 4,321,525 | 93 | 93 | 188,790 | 126,133 | 2.9 | 8,678 | 1,999 | 10,677 | 1,488 | 20.55 | 38,982 |
| College Park Neighborhood Center | 557,324 | 171 | 171 | 324,252 | 231,395 | 41.5 | 14,998 | 1,241 | 16,239 | 2,736 | 24.01 | 23,356 |
| Wadeview Neighborhood Center | 188,357 | 80 | 19 | 38,570 | 25,355 | 13.5 | 1,647 | 204 | 1,852 | 304 | 24.92 | 1,636 |
| Fire Station #14 | 145,760 | 98 | 6 | 12,180 | 8,138 | 5.6 | 525 | 69 | 593 | 96 | 24.49 | 680 |
| Overall | 67,418,779 | 18,003 | 17,842 | 22,743,070 | 25,296,555 | 37.5 | 1,651,224 | 26,498 | 1,677,722 | 285,472 | 16.34 | 6,188,327 |

Note: Internal rate of return not provided for 3rd-party financing because it must be calculated from either perspective of the owner or offtaker, and without information about power purchase agreement price, it is not possible to calculate accurately.

Note: Iron Bridge Facility and Fire Station #14 loads were synthesized by NREL; results for these sites are suggestive based on NREL load assumptions, but will likely vary based on actual load profile.

Results Summary

OVERALL

- Batteries were generally only viable (economically beneficial and large enough to contribute) at the three largest sites—Iron Bridge, Conserv I, and Conserv II—in this modeling.
- At smaller sites, the REopt model assessed PV-only systems to be the most cost-effective.

DIRECT PURCHASE

- Aggregate NPV of \$4.3–4.4M for the cost-optimal systems for all 14 buildings
- For the three largest sites (Iron Bridge Facility, Conserv I, Conserv II), REopt suggested cost-optimal solutions that max out the area available for PV and also include a battery
 - Iron Bridge Facility
 - Note that Iron Bridge Facility load profile was synthesized by NREL; results for this site is suggestive based on NREL load assumptions, but will likely vary based on actual load profile
 - Also note that about one-third of savings come from demand-charge savings, which are less reliable savings than energy-charge savings
 - Reminder that this analysis assumes the FL net metering limit of 2 MW can be avoided by installing additional meters, an option about which NREL is uncertain about the realistic feasibility - if site cannot do this, the electricity cost savings of the recommended system would be significantly reduced without net metering
 - Conserv I Facility
 - Cost-optimal PV of 2,180 kW-DC, which slightly exceeds net metering limit of 2,000 kW; so, it might make more sense to install only 2,000 kW rather than install a second meter
 - Conserv II Facility
 - Cost-optimal PV of 1,339 for this facility
- For the 11 smaller sites with suggested cost-optimal PV of less than 1 MW, there were two sub-categories that emerged:
 - Small PV (no battery) assessed as cost-optimal at six sites (Northwest Neighborhood Center and the five fire stations (#7, #8, #15, #16, #17) on OUC GSD Secondary Demand Rate with Community Solar)
 - Reminder that OUC community solar energy charges are greater than non-community solar energy charges, and community solar energy charges are expected to decrease in the coming years; so, the energy cost savings from PV at these five fire stations may be overestimated.
 - PV was not cost-effective on an NPV basis at five sites (Orlando Operations Center, City Hall, College Park Neighborhood Center, Fire Station #14, Wadeview Neighborhood Center)
 - Note that some of these sites are on OUC GSD Secondary Demand Rate *without* community solar; this difference in tariff appears to contribute to where PV is cost effective

3RD-PARTY FINANCING

- Aggregate NPV of \$6.2–6.6M for the cost-optimal systems for all 14 buildings
 - 3rd-party financing allows for larger systems and stronger economics due to incentives, despite higher rate of return required
- The cost-optimal sizes through 3rd-party financing would max out the area available for PV at 11 of 14 sites
 - Fire Station #15 is achieving 100% renewable electricity with recommended PV size, so it is not maxing out area available
- Batteries cost-optimal at three largest sites: Iron Bridge, Conserv I, Conserv II

Thank you

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

