

Battery Energy Storage in Florida

Value, Challenges, and Opportunities



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About This Report

This report examines the economics of battery energy storage in Florida, including analysis of the return on investment in customer-sited battery systems and the outlook for procurement of larger (grid-scale) battery systems in the state in coming years. It also identifies barriers to storage deployment in Florida and makes recommendations for mitigating these barriers. The report does not compare the economics of battery storage to other technologies, but does point to research underway in Florida and the Southeast region that will do so. The authors are graduate students at the School of Global Policy and Strategy and the Jacobs School of Engineering at the University of California San Diego. The report is released as part of an ongoing series of papers by School of Global Policy and Strategy faculty and students on the crucial challenges of the 21st century.

This report is available online at http://gps.ucsd.edu/_files/research/battery_energy_storage_in_florida.pdf.

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1 Executive Summary

This report analyzes the potential value of battery energy storage in Florida's electric power sector. Key conclusions are that "behind the meter" batteries located on the premises of electricity consumers can be profitable today under certain conditions and that momentum toward deployment of "front of the meter" batteries on the Florida grid has grown over the last year. Momentum in the front of the meter market has been driven by the inclusion of battery investments in rate case settlements between important utilities, regulators, and other stakeholders as well as by the launch of a robust modeling process involving key municipal utilities and Department of Energy laboratories. Based on announced procurement plans from its largest two utilities, Florida could see \$230 million of investment in utility-owned battery systems from 2017 through 2021.

Behind the Meter Methodology and Findings

The report uses load data from Florida buildings, utility tariffs from the state's largest investor-owned and municipal utilities, and a peer-reviewed scheduling algorithm¹ to model stand-alone storage installations optimized for demand charge management. This enables calculation of the economic value of batteries optimized to capture a single value stream at four commercial and industrial buildings chosen to represent common load profiles. Battery system costs are taken from a survey of cost projections published by the National Renewable Energy Laboratory in August 2016.²

The analysis considers a range of battery system sizes, load profiles, load forecast accuracies, battery cost projections, and other variables. For each scenario, net present value (NPV) and internal rate of return (IRR) are calculated to identify the returns a Florida Power & Light (FPL) or Jacksonville Electric Authority (JEA) customer can earn by investing in battery storage. The analysis concludes that positive investment cases for behind the meter storage already exist for a set of typical Florida demand profiles under certain storage cost assumptions. For the purposes of this analysis, which focuses on demand charge management, the investment case is driven in large part by the shape of a building's load profile. However, it is likely that the set of conditions in which positive investment cases exist could be expanded beyond those identified in this report through integration of control systems that allow batteries to capture multiple revenue streams³ and through pairing batteries with distributed solar generation in order to make the storage eligible for the federal Investment Tax Credit (ITC).⁴

¹ R. Hanna et al., "Energy dispatch schedule optimization for demand charge reduction using a photovoltaic-battery storage system with solar forecasting," *Solar Energy* 103 (May 2014): 269-287.

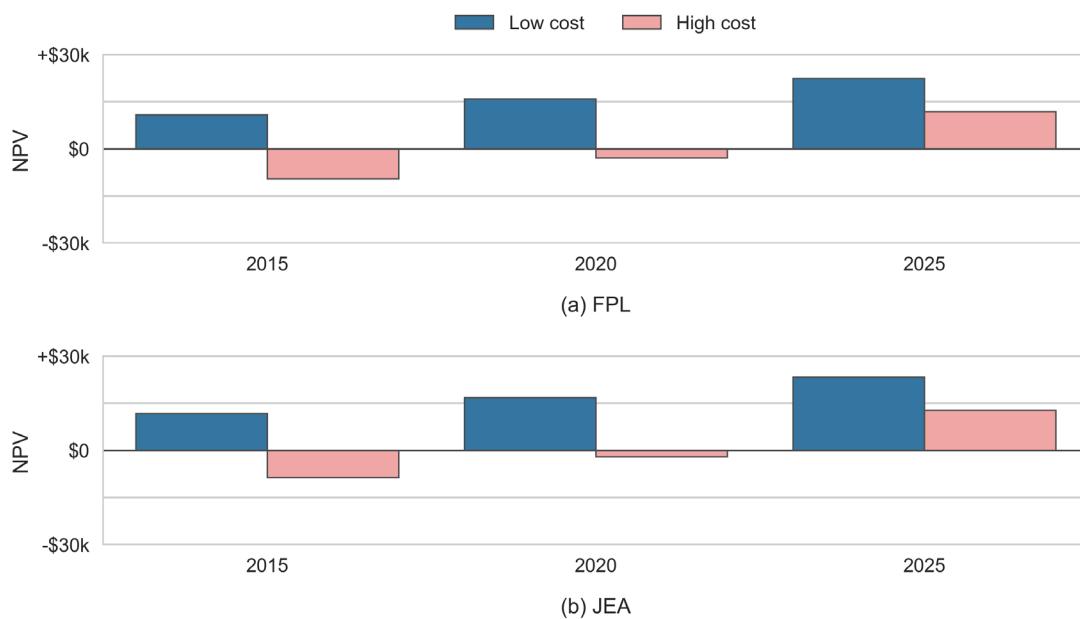
² David Feldman et al., *Exploring the Potential Competitiveness of Utility-Scale Photovoltaics plus Batteries with Concentrating Solar Power, 2015-2030*, National Renewable Energy Laboratory, August 2016, <https://www.nrel.gov/docs/fy16osti/66592.pdf>.

³ Garrett Fitzgerald et al., *The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid*, Rocky Mountain Institute, September 2015, <https://rmi.org/insights/reports/economics-battery-energy-storage/>.

⁴ Stand-alone storage is eligible for a 7-year MACRS accelerated depreciation schedule, but storage charged by renewable generation can be eligible for the ITC. See National Renewable Energy Laboratory, "Federal Tax Incentives for Battery Storage Systems," January 2017, <https://www.nrel.gov/docs/fy17osti/67558.pdf>.

Executive Summary Figure 1 presents the net present value of batteries deployed at a warehouse with a 26% load factor (the most “peaky” building modeled in this analysis) under high and low cost scenarios in FPL and JEA service territories. The figure indicates two key findings. First, battery systems are already “in the money” under a variety of scenarios at the low end of today’s cost estimates. Second, as lithium-ion battery prices fall, the set of scenarios with positive NPV will expand in coming years to encompass even cases representing the high end of battery cost projections.

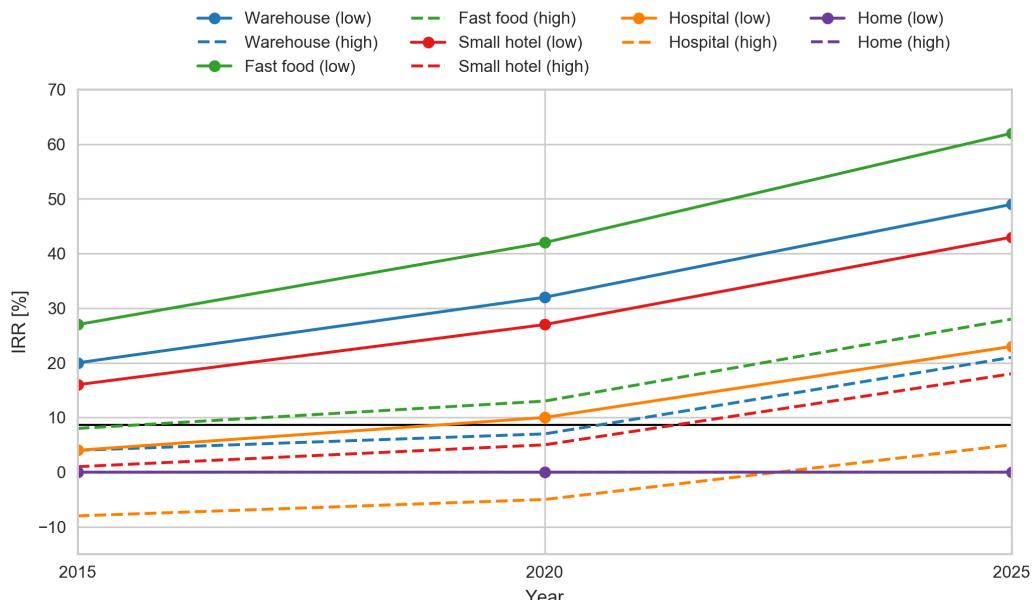
Executive Summary Figure 1: NPV of Battery System Deployed at Warehouse (Low Load Factor) in FPL and JEA Service Territories



Results of net present value (NPV) analysis for a battery system deployed to optimize demand charge management at a Florida warehouse with 26% load factor. Blue bars represent a model using the low end of a range of battery system installed costs (Feldman et al., 2016). Red bars represent the high end of the range. Analysis was conducted using Florida Power & Light (FPL) and Jacksonville Electric Authority (JEA) tariffs. The system modeled in this figure is sized to shave a maximum of 5% of peak demand for two hours. System life is assumed to be ten years. The model does not include financial incentives other than a 7-year MACRS accelerated depreciation schedule and does not consider more than one revenue stream. See Tables 2 and 3 for other details of the model.

Executive Summary Figure 2 displays the internal rate of return for the modeled battery storage systems for the warehouse and three other property classes under two future cost assumptions. This figure underscores the same key findings, showing that IRR already exceeds 15% for three buildings at the low end of the cost range and will do so even at the high end of the cost range sometime between 2020 and 2025.

Executive Summary Figure 2: IRR of Battery System Deployed at Representative Florida Buildings in JEA Service Territory



Results of internal rate of return (IRR) analysis for a battery system deployed to optimize demand charge management at Florida properties with load factors ranging from 26% to 69%. Solid lines represent the low end of a range of battery system installed costs (Feldman et al., 2016). Dashed lines represent the high end of the range. This figure assumes a Jacksonville Electric Authority (JEA) tariff. The system modeled in the figure is sized to shave a maximum of 5% of peak demand for two hours. System life is assumed to be ten years. The model does not include financial incentives other than a 7-year MACRS accelerated depreciation schedule. An 8.6% cost of capital assumption, calculated from Lazard's Levelized Cost of Storage 2.0 report, is represented by the solid black line. However, behind the meter batteries represent a new asset class that may require a higher cost of capital. See Tables 2 and 3 for other details of the model.

This analysis suggests that batteries already offer significant opportunity for business owners in Florida to cut operating costs by reducing electricity bills. With IRR over 40% for the fast food restaurant at the low end of the 2020 cost projections, the battery system modeled here could be a compelling investment. However, this analysis does not compare battery storage to other alternatives for reducing peak demand, such as demand response, other storage technologies, or customer-sited natural gas or diesel generation.

Front of the Meter (Grid-Scale) Methodology and Findings

Other types of storage deployments, which in Florida would usually be owned by utility companies and sited at utility-scale power plants or on the transmission or distribution system, are much more difficult to model. Detailed state-level system studies require significant investments in data collection and analytics that are beyond the scope of this work. Instead, the report outlines the conclusion of grid-scale storage reports done in other states where state agencies or utility companies have invested in public analysis of the potential value of this market. The most notable efforts on this front have been from Texas, Oregon, Massachusetts, California, and Minnesota (see Section 3).

This research also included interviews with 25 key stakeholders, primarily those with experience in Florida's regulatory agencies, investor-owned and municipal utilities, state and local energy policy, research institutions, and storage project developers. Based on these interviews, the report identifies significant advances over the last 12 months in the state's grid-scale battery storage landscape. These include:

- **Proposals from the state's two largest investor-owned utilities** (IOUs), FPL and Duke Energy Florida, to build 50 megawatts (MW) each of battery projects by the end of 2021 – and Florida regulators' decision to allow utility ownership and cost recovery for these initiatives. Taken together, the proposals amount to nearly one-sixth of the 622 MW of total battery storage installed in the US through 2016.⁵ If these investments materialize, the state could go from having essentially no meaningful storage projects today to dozens within five years.
- **The July 2017 launch of the Florida Alliance for Accelerating Solar and Storage Technology Readiness** (FAASSTeR), a Department of Energy (DOE)-funded initiative through which six of the state's most important municipal utilities will work with DOE laboratories to identify pathways for successful expansion of grid-integrated solar, energy storage, and other distributed energy resources in Florida. The FAASSTeR program's conclusions, which are scheduled to be released in 2020, may become the most important public resource for planners seeking to understand where grid-scale storage can provide cost-effective benefits to Florida's grid.
- **Formation of working groups within the state's IOUs dedicated to building the companies' understanding of battery storage.** In most cases, these are initially focused on determining the benefits batteries can offer to the IOUs' systems. This generally includes reviews of literature and implementation of small-scale pilot programs, though the parent companies of Florida IOUs – NextEra, Duke, Emera, Southern Company, and Chesapeake Utilities Corporation – include unregulated businesses with significant battery storage experience outside of Florida.

Outlook

This report suggests that value already exists in Florida's behind the meter market and that IOUs and the Florida Public Service Commission (PSC) are beginning to see value in front of the meter deployments as well. Though early US battery storage markets were driven by short duration ancillary services markets in the PJM Interconnection and by incentives and mandates in California, this research suggests that different factors will drive Florida's market. But significant barriers remain in the state. The report identifies these barriers and offers recommendations for mitigating them that are rooted in interviews with Florida stakeholders and tailored for compatibility with the state's energy landscape.

These recommendations generally rely on boosting access to information, improving knowledge-sharing, updating resource planning methodology, and implementing limited market design changes that expand the range of benefits battery owners are able to capture in exchange for investing in systems that may offer diffuse benefits to the grid. These approaches include:

- **Ensure utilities evaluate storage:** The PSC should seek disclosure from Florida IOUs regarding their efforts to incorporate the costs and benefits of storage in the utilities' integrated resource planning (IRP) methods. Legacy utility planning processes generally

⁵ Nick Esch et al., 2017 Utility Energy Storage Market Snapshot, Smart Electric Power Alliance, September 2017, <https://sepapower.org/resource/2017-utility-energy-storage-market-snapshot/>.

struggle to account for the unique characteristics of battery storage. Washington state regulators have started to address this challenge by issuing guidance outlining their expectations for treatment of energy storage in resource planning.⁶

- **Foster knowledge networks:** Business models and policy options are proliferating in the battery storage space. Stakeholders should ensure that lessons are shared across municipalities, service territories, and other jurisdictions. More broadly, these knowledge efforts should include consideration of other resources, including demand response, alternative storage technologies, and distributed generation, with the goal of determining an optimal technology mix. Initiatives are underway throughout the Southeast that focus on opportunities and challenges associated with new power sector technologies in the region's vertically-integrated power sector. Institutions and programs sponsoring these initiatives include Alabama's Southern Research, Georgia Tech's Energy Policy and Innovation Center, North Carolina's Clean Energy Technology Center, and Florida's FAASSTeR.
- **Educate lawmakers and city officials:** Florida lawmakers and officials have generally not been exposed to data on the falling cost of batteries and the growing set of stationary storage installations around the US. When faced with decisions on the state's power sector, they should be aware of the trajectory of batteries and other emerging technologies. City officials responsible for implementing municipal renewable portfolio standards, who often lack realistic options for influencing the resource mix of large utilities, should be aware of opportunities to use batteries to boost the amount of renewable power capable of serving local load pockets.
- **Facilitate data access:** Unlike some other states, Florida has not adopted policies to facilitate third-party access to load data from utility companies. This data is crucial to enabling markets in which storage developers can identify and develop promising projects. It would also benefit developers of demand response and distributed solar projects.
- **Consider tax incentives:** The recent success of Florida's SB 90 legislation, which provides a property tax exemption for 80% of the value of installed renewable energy devices, provides an example of Florida advocates, voters, and legislators using tax policy to facilitate adoption of new power sector technologies. SB 90 applies to batteries charged by renewable resources, but Maryland's recently-passed SB 758 provides a first-in-the-nation example of a dedicated energy storage tax credit which does not require systems to be charged by renewable energy.
- **Consider targeted financial incentives:** Limited financial incentives for batteries offer opportunities to encourage storage deployments in support of policy goals. Section 6.3 and Appendix C of this report find that incentive levels significantly lower than the \$500 per kilowatt-hour (kWh) level offered through California's Self-Generation Incentive Program (SGIP) could expand the number of Florida properties for which behind the meter batteries optimized for demand charge management could make economic sense. In one of the first programs of its kind in the US, Jacksonville Electric Authority recently announced a rebate for 30% of the cost of behind the meter batteries up to a cap of \$2,000 per system. JEA's program uses a very different approach to incentives and battery revenue than the one modeled in this report, underscoring the range of possible approaches to deploying and incentivizing the technology.
- **Identify value stacking opportunities:** Value stacking is easier in restructured states with organized capacity and ancillary services markets, but projects in Arizona suggest that vertically-integrated utilities can use this strategy to improve the benefit-cost ratio of battery systems as well (see Case Study 4).

⁶ Washington Utilities and Transportation Commission, *Report and Policy Statement on Treatment of Energy Storage Technologies in Integrated Resource Planning and Resource Acquisition*, 11 October 2017.

2 The Florida Power Sector

The value of a new technology like energy storage can vary widely across the US power sector due to starkly different regional policies and regulations, market designs, and electricity rates. Understanding how a technology fits into a specific state or region is key to determining the value of the technology in that market. This section outlines Florida's power sector, lithium-ion battery storage as an emerging power sector technology, and the state of play of this technology in Florida today. Four brief case studies are included in this report that detail battery installations in other states in order to illustrate the range of applications for which battery storage is already being deployed.

2.1 Regulation

Florida's investor-owned utilities (IOUs), like those in other Southeastern states, remain traditionally regulated and vertically integrated. The state long relied on what local experts call "the three-legged stool" of nuclear, coal, and natural gas in its generation mix, but recent shifts toward natural gas have increased the fuel's share of the state's generation to roughly two-thirds, more than almost any other state in the country.¹ Utility companies and regulators have discussed concerns that this poses risks related to price volatility and reliability of supply. After a hurricane season threatened both major natural gas pipelines leading into the state, a third was quickly planned and constructed to improve reliability. Price risks are harder to mitigate. Utility companies are actively thinking about how to manage the risk, but so far this has not included significant steps toward decreasing the role of natural gas in their resource mix.

Florida's utilities are regulated by the Florida Public Service Commission (PSC), and grid reliability is coordinated by the Florida Reliability Coordinating Council (FRCC). Unlike the Regional Transmission Organizations or Independent System Operators established in some other states, the FRCC is largely a convening body. It offers a venue in which the state's utilities can coordinate their operations but does not exercise significant control over their decision-making. Like in most states, Florida's governor selects PSC commissioners and the state Senate confirms them. Unlike in most other states, however, the governor's choices are constrained to a list of candidates nominated by a council controlled by leaders of the state legislature.² Sitting commissioners must apply to the council in order to be nominated for reappointment. Critics of this arrangement argue that it gives Florida legislators much more influence over the state's utility regulators than is the norm in other states,³ though regulators nonetheless regularly rule against proposals from utility companies.

Florida utilities have used natural gas-fired generation to deliver relatively cheap, clean, and reliable electricity to their customers. Accordingly, Florida legislators and regulators have been content to allow the investor-owned utilities great latitude to plan and manage the state's power sector. This positions Florida's utilities as key decision-makers who play a central role in determining which technologies the state adopts and how fast they are deployed. While other states have set legislative or regulatory mandates to drive adoption of new renewable

¹ US Energy Information Administration, "Electric Power Monthly with Data for July 2017," September 2017, Tables 1.3.B, 1.7.B, <https://www.eia.gov/electricity/monthly/archive/september2017.pdf>.

² The 2017 Florida Statutes, Title XXVII, Chapter 350, http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&URL=0300-0399/0350/0350.html.

³ Alan Stonecipher, Brad Ashwell and Ben Wilcox, *Florida's "Public Service" Commission? A Captured Regulatory Agency*, Integrity Florida, October 2017.

generation and electricity storage technologies, experts in Florida generally believe it is unlikely that the state will impose this type of mandate on its utilities. A renewable portfolio standard (RPS) mandating a minimum amount of renewable generation was authorized by the state legislature in 2008, but it was quickly repealed by lawmakers.

2.2 Florida Utilities

Floridians are served by 57 electric utilities.⁴ Five are investor-owned, but just two of these – Florida Power & Light (FPL) and Duke Energy Florida – dominate the state’s power sector. FPL, which is owned by NextEra Energy and accounts for about half of the state’s electricity sales, is by far the largest. Duke Energy Florida was known as Progress Energy Florida before a recent rebranding. It serves about one-third as many meters as FPL.

The state also has 34 publicly-owned municipal electric utilities and 18 rural electric cooperatives. Municipal utilities – commonly known as “munis” – are non-profit public bodies with rates set primarily by city governments. The PSC retains some jurisdiction over municipal utilities’ rate structures, boundaries, and operations. One example is that the PSC does not allow utilities to mandate time-of-use (TOU) rates for their customers, a prohibition that applies to municipal utilities as well as IOUs. The municipal utilities serve about 15% of Floridians and the utility cooperatives serve about 10%.⁵ The average bill for Florida residential customers served by municipal utilities is slightly lower than for those who buy electricity from IOUs, while commercial and industrial customers’ bills are slightly higher.⁶ Jacksonville’s municipal utility, JEA, is the largest muni in the state and among the ten largest in the US.

2.3 Solar Generation

Despite its nickname, the “Sunshine State” has lagged in deployment of solar generation. Even with its very high potential for solar power – Florida has the third-highest solar potential in the country and the highest east of the Mississippi River, according to the Solar Energy Industries Association – the state got under half a percent of its electricity from the sun in 2016.⁷ A large number of states, including many with much lower irradiance, exceed this low level of solar penetration. Florida’s low solar penetration is likely due to a combination of cheap natural gas, the lack of a renewable portfolio standard, and an adverse policy environment for distributed generation.

Restrictions on distributed generation mean that Florida’s rooftop solar market is far smaller than its sunny weather would suggest. These restrictions may have the additional effect of reducing demand for behind the meter battery storage, which in many cases is most valuable when paired with solar generation. The most important restriction is a state law requiring any organization that sells electricity to be capable of providing power 24 hours a day. Florida

⁴ Florida Public Service Commission, *Facts and Figures of the Florida Utility Industry: 2016*, March 2016, <http://www.psc.state.fl.us/Files/PDF/Publications/Reports/General/Factsandfigures/March%202016.pdf>.

⁵ Florida Municipal Electric Association, “Fact sheet,” January 2017, http://publicpower.com/wp-content/uploads/2017/01/FMEAFact-Sheet_0117.pdf.

⁶ Florida Department of Agriculture and Consumer Services, Office of Energy, *2016 Annual Report*, http://www.freshfromflorida.com/content/download/75674/2205501/Final_2016_Annual_Report.pdf.

⁷ US Energy Information Administration, “Electric Power Monthly with Data for July 2017,” September 2017, Tables 1.3.B., 1.17.B., <https://www.eia.gov/electricity/monthly/archive/september2017.pdf>.

is one of a small number of states with such a law.⁸ In practice, the requirement means that only utility companies can sell electricity. This amounts to a prohibition of the third-party solar ownership models common in other states, though it does not prohibit homeowners from buying their own panels. Such an arrangement transfers risks to homeowners, who generally cannot invest in multiple systems like third-party companies can to mitigate the risk of any single system underperforming. It also restricts financing options.

Florida's distributed solar market has also been restricted by opposition from investor-owned utilities. In 2016, Florida IOUs backed a referendum on Amendment 1, a constitutional amendment worded to appear pro-solar that in reality would have further restricted the state's rooftop solar market. The amendment failed to achieve the 60% threshold needed to pass. After the failure of Amendment 1 – and the passage of Amendment 4 in the same year, which directed the legislature to provide tax exemptions for property used for solar generation – residential solar installers have ramped up their activity in Florida.

The rapidly falling costs of solar generation have also driven new utility-scale projects. FPL plans to add 600 megawatt (MW) or more of new solar by 2018,⁹ Jacksonville municipal utility JEA has signed several large solar power purchase agreements, and Tallahassee's municipal utility has recently approached meeting 10% of load with solar generation. These procurements could lead to solar penetration approaching 2% statewide in coming years. Florida has the advantage of learning from the experience of states with much higher solar penetration like California, Hawaii, North Carolina, and others, which may allow it to manage increasing solar penetration more efficiently than other states have. Some of the most important municipal utilities in Florida plan to use a DOE-funded initiative known as the Florida Alliance for Accelerating Solar and Storage Technology Readiness (FAASSTeR) to model the system-level effects of increasing solar penetration and identify ways that storage and other solutions can optimize the process of increasing solar generation on the state's grid.

In 2015, the PSC concluded that, if current trends continue, "cost-effective forms of renewable generation will continue to improve the state's fuel diversity and reduce dependence on fossil fuels."¹⁰ However, conversations with Florida regulatory experts undertaken during this research suggest that the Commission's primary goal for integrating new technologies is "getting it right" rather than "doing it fast." From this perspective, it is reasonable to expect that issues like ramping challenges and cross-subsidization will cause regulators to move more cautiously in Florida than they have in other states.

⁸ North Carolina Clean Energy Technology Center and Meister Consultants Group, *The 50 States of Solar: 2015 Policy Review Q4 Quarterly Report*, February 2016, <https://nccleantech.ncsu.edu/wp-content/uploads/50sosQ4-FINAL.pdf>.

⁹ Robert Walton, "Florida Power & Light plans to build 596 MW of solar farms by 2018," Utility Dive, February 22, 2017, <http://www.utilitydive.com/news/florida-power-light-plans-to-build-596-mw-of-solar-farms-by-2018/436634>.

¹⁰ Florida Public Service Commission, *Review of the 2015 Ten-year Site Plans of Florida's Electric Utilities*, November 2015, <http://www.psc.state.fl.us/Files/PDF/Utilities/Electricgas/TenYearSitePlans/2015/Review.pdf>.

Case Study 1: Connexus seeking 20 MW (40 Megawatt-hours) of battery storage to mitigate coincident peak demand and on-peak energy charges and meet customer demand for renewable electricity

Minnesota's largest distribution cooperative released a request for proposal in March 2017 for 20 MW of battery storage paired with 10 MW of solar generation. Connexus expects to pay up to about \$1,150 per kilowatt-hour for the storage element of the system and will charge the battery with solar PV energy in order to secure the 30% federal Investment Tax Credit. The procurement will allow Connexus to avoid a share of the coincident peak demand charges and on-peak energy charges it currently pays to its generation and transmission provider, Great River Energy. It will also allow Connexus to provide a greater share of renewable energy to their customers, for which a 2016 survey found they were willing to pay 5% higher prices.¹ The project expects to tap into additional revenue streams in the future, including distribution deferral and the Midcontinent Independent System Operator's ancillary services market.

¹ University of Minnesota Energy Transition Lab, Strategen Consulting, and Vibrant Clean Energy, *Modernizing Minnesota's Grid: An Economic Analysis of Energy Storage Opportunities*, July 11, 2017, <http://energytransition.umn.edu/wp-content/uploads/2017/07/Workshop-Report-Final.pdf>.

2.4 Primer on Battery Storage

Historically, the electric power sector has had very limited ability to deploy storage technology that was both economically viable and technologically scalable. Grid operators instead faced the challenge of on-the-spot matching of aggregate electricity supply to aggregate demand. Recently, the price of lithium-ion batteries has fallen rapidly at rates similar to those seen earlier in the market for solar modules. As prices decline, increasing demand for batteries has motivated technological improvement and investments in mass production, which further decrease prices and increase demand. Analysts at Lazard, a financial advisory firm,¹¹ and Bloomberg New Energy Finance¹² expect lithium-ion battery prices to continue to fall, though specific projections vary.

Estimating the trajectory of installed battery system costs, however, is difficult. Battery prices in some cases represent less than half the total cost of a storage system, which also includes battery racks and cooling systems, operations and maintenance, installation service, customer acquisition, and taxes.¹³ The costs of storage also vary widely depending on the size and application of the system. Smaller residential systems cost more per kilowatt-hour (kWh) than larger transmission grid systems, which can spread their non-battery costs over greater capacity. Some applications, such as frequency regulation, require short duration batteries, while others require more expensive batteries able to discharge for longer periods.

¹¹ Lazard, *Lazard's Levelized Cost of Storage—Version 2.0*, December 2016, <https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf>.

¹² Claire Curry, "Lithium-ion Battery Costs and Market," Bloomberg New Energy Finance, July 2017, <https://about.bnef.com/blog/lithium-ion-battery-costs-squeezed-margins-new-business-models/>.

¹³ Lazard's Levelized Cost of Storage.

If battery prices continue to decline as expected, affordable battery storage has the potential to make the electricity system more reliable, clean, and cost-effective.¹⁴ Large-scale battery deployment could allow electric utilities, independent power producers, and grid operators to store the excess electricity generated by solar and wind generation for discharge during periods of high demand, mitigating the intermittency problem that has plagued these renewable resources and reducing the need for expensive, rarely run fossil fuel “peaker” power plants. Storing electricity in batteries located physically close to consumers can also reduce peak congestion in the transmission and distribution system and help avoid costly upgrades to the grid.

Case Study 2: Convergent Energy + Power deployment of 3 MWh of battery storage as non-wires alternative to relieve overloaded transmission system

In 2015, Convergent deployed storage to relieve an overloaded area of the transmission system near Boothbay, Maine. Costs of the project were not released, but costs in the middle of the 2015 range used in this analysis (\$820 per kilowatt-hour) would result in a total project cost of about \$2.5 million. Actual costs may have been higher, as the company has suggested that the storage ultimately cost about 20% of the \$18 million cost associated with building new transmission wires in the region.¹ The project also showcased the ability to deploy storage much more rapidly than traditional pole and wire assets due to the lower lead times for permitting and development.

¹ “Convergent Energy + Power Commissions Innovative Energy Storage System in Maine,” Convergent Energy + Power press release, May 5, 2015, <http://www.convergentep.com/52/>.

Customer-sited “behind the meter” storage can provide additional benefits. Unlike “front of the meter” storage, which is located further upstream in the electricity transmission and distribution system, behind the meter battery storage can provide localized backup power during blackouts.¹⁵ This backup capability is vital for hospitals, universities, police stations, and potentially military bases¹⁶ that desire the ability to “island” themselves from a damaged grid and supply their own power in an emergency. Storage can also prove valuable to manufacturers and industrial facilities that suffer costly production shutdowns when electricity fails. Today backup power for these facilities is typically provided by diesel generators or gas-fired co-generation that provides both electricity and heating, but battery storage can be lower maintenance and easier to site. Battery storage can also provide emergency power for buildings that are unsuited for diesel generators – which are noisy, polluting, and must be sited away from buildings – and homes and apartment buildings that, like many homes on the Florida coast, are not connected to the gas lines necessary to supply gas-fired backup generators.

¹⁴ Garrett Fitzgerald et al., *The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid*, Rocky Mountain Institute, September 2015, <https://rmi.org/insights/reports/economics-battery-energy-storage/>.

¹⁵ National Academies of Sciences, Engineering, and Medicine, *Enhancing the Resilience of the Nation’s Electricity System* (Washington, DC: The National Academies Press), <https://doi.org/10.17226/24836>.

¹⁶ Elisa Wood, “The Life and Death Value of Energy Storage in Military Microgrids,” Microgrid Knowledge, January 10, 2017, <https://microgridknowledge.com/military-microgrids-ess/>.

Behind the meter storage may also offer the possibility of significant economic benefits. Utilities' commercial and industrial rates often include demand charges, which are based on a consumer's peak demand for electricity during a given billing period. If consumers can reduce their peak demand by charging onsite storage during periods of low demand and "shaving" their peak by drawing on stored electricity when their electricity usage is highest, they can reduce these charges. Since demand charges are often a significant share of commercial customers' bills, peak-shaving can lead to important reductions in total electricity costs. This is especially the case for consumers with the "peaky" load profiles characteristic of low load factors.¹⁷ On-site generators can also be used to reduce peak demand and lower demand charges, but they can be unsuitable for some properties. Batteries can also benefit customers who are charged time-of-use rates that rise during high-demand periods of the day by allowing customers to charge batteries when prices are low – typically late at night – and draw from them during peak periods in the morning, afternoon, or evening. Where net metering for rooftop solar generators is not available or offers unfavorable rates, behind the meter storage also offers the additional benefit of allowing owners to store their over-generation to consume later.

In many cases, behind the meter storage also offers diffuse benefits to the grid. In some states, Regional Transmission Organizations or Independent System Operators run competitive markets that allow behind the meter batteries to earn additional compensation for providing grid services. However, these revenue streams are not accessible in vertically integrated states like Florida - yet the commercial viability of energy storage rests on market design that allows storage owners to earn compensation for the diffuse value their assets offer to the grid. While the costs of batteries are falling, they remain substantial, and many electricity customers cannot justify the large upfront capital costs unless they are able to tap into multiple sources of compensation. The Rocky Mountain Institute released an influential report in 2015 that demonstrated batteries are more valuable when they can "stack" revenue from multiple different value streams.¹⁸ These could include demand charge management, time-of-use rate arbitrage, the value of backup power supplies, and provision of ancillary services like frequency regulation and spinning and non-spinning reserves to the grid. Companies interested in storage see great value in developing software that increases their ability to optimize battery systems across multiple sources of revenue and in advocating for market design changes to allow batteries to participate in a greater number of markets and value streams.

2.5 State of Play: Battery Storage in Florida Today

There is essentially no battery storage deployed in Florida on a commercial basis today. But some pilot projects are operating, conversations with stakeholders in the state indicate significant interest in learning about the technology, and IOUs and public utilities are making efforts to understand the benefits batteries could offer to their grids.

Battery deployment in Florida today includes the following:

- A Collaboration between Siemens and FPL in Miami-Dade and Monroe counties (1.5 MW in each county) for backup power and voltage support.¹⁹

¹⁷ A customer has a low load factor when their peak demand is much higher than average demand.

¹⁸ Fitzgerald et al., *The Economics of Battery Energy Storage*.

¹⁹ "FPL launches innovative energy storage project in conjunction with White House summit on scaling renewable energy and storage," Florida Power & Light press release, June 16, 2016, <http://newsroom.fpl.com/2016-06-16-FPL-launches-innovative-energy-storage-project-in-conjunction-with-White-House-summit-on-scaling-renewable-energy-and-storage>.

- The SunSmart Schools and Emergency Shelters program, launched by the Florida Department of Agriculture and Consumer Services in 2009 to provide power at critical facilities during power outages, which has installed solar PV systems with battery storage in 115 emergency shelters (often schools).²⁰
- A Department of Energy-funded collaboration with the Electric Power Research Institute (EPRI), part of a program known as Sustainable and Holistic Integration of Energy Storage and Solar Photovoltaic (SHINES), in which two homes in the Beulah area – outside Pensacola – are testing how batteries and automation can interact with home systems to deliver cost savings.²¹
- A test project in which Southern Company's Florida subsidiary, Gulf Power, is using a 250 kilowatt (kW), 1 MW-hour battery storage system to build the utility's capacity to install and operate commercial and industrial storage projects.²²
- A Duke Energy Florida-funded battery system at the University of South Florida St. Petersburg.²³

However, the landscape may be set to change significantly. In October 2017, JEA announced a rebate to offset 30% of the costs of behind the meter batteries up to a cap of \$2,000 per system. JEA plans to spend up to \$1 million per year on the rebate program. To JEA's knowledge, this is the first financial incentive for batteries in Florida and one of the first in the US. At the state level, the PSC has demonstrated its willingness to allow the state's IOUs to pursue cost recovery for relatively large battery investments. FPL has secured approval to procure 50 MW of storage through 2020,²⁴ while Duke Energy has proposed its own 50 MW in a rate case settlement set for final approval in December 2017.²⁵ These are often referred to as pilot programs, but industry sources suggest they are substantially larger than would be expected from programs designed purely for technical learning. The PSC may expect them to operate somewhat cost-effectively.

Despite these projects, some analysts say there is significant distance between the actions of Florida's large IOUs and their corporate parent companies. NextEra and Duke Energy, which own FPL and Duke Energy Florida, have shown more interest in storage than most other US energy companies, but Florida IOUs "play in their own sandbox," in the words of one Florida stakeholder. For example, in 2016 FPL proposed a new fast-ramping natural gas peaker plant to meet demand spikes – at a cost of \$800 million to Florida ratepayers – even as the Miami

²⁰ Florida Solar Energy Center, "SunSmart E-Shelter Program," <http://www.fsec.ucf.edu/en/education/sunsmart/index.html>.

²¹ Joseph Baicum, "Escambia County takes part in new solar program," Pensacola News Journal, May 5 2017, <http://www.pnj.com/story/money/business/2017/05/05/beulah-gulf-power-epri-doe-solar-energy/101159094/>.

²² "Southern Company building the future of energy with new battery storage research demonstration," Southern Company press release, July 12, 2017, <https://www.southerncompany.com/newsroom/2017/july-2017/0712-mccrary-battery-demonstration.html>.

²³ "USF St. Petersburg, Duke Energy Unveil Solar Battery Project," University of Florida St. Petersburg press release, May 22, 2015, <http://www.usfsp.edu/home/2015/05/22/usf-st-petersburg-duke-energy-unveil-solar-battery-project/>.

²⁴ Order Approving Settlement Agreement, Order No. PSC-16-0560-AS-EI, (December 15, 2016), <http://www.floridapsc.com/library/filings/2016/09338-2016/09338-2016.pdf>.

²⁵ "Duke Energy Florida files settlement agreement for building a smarter energy future," Duke Energy press release, August 29, 2017, <https://news.duke-energy.com/releases/duke-energy-florida-files-settlement-agreement-for-building-a-smarter-energy-future>.

Herald reported that NextEra's CEO said to a conference in September 2015 that after 2020 "there may never be another peaker built in the United States – very likely you'll be just building energy storage instead."²⁶ The Sierra Club used this statement in its filings opposing FPL's investment,²⁷ but it should be noted that the power sector's experience with using storage to replace peaker plants is very limited. Yet the dynamic may be changing as falling storage prices push Duke and NextEra toward greater interest in transferring battery expertise from their unregulated divisions to the regulated utilities. Duke Energy recently proposed the first large battery storage projects – 13 MW in North Carolina to come online in 2019 – to be built by one of the company's regulated utility subsidiaries. However, the firewall between regulated and unregulated divisions may limit the possibilities for IOUs to leverage the expertise of their unregulated sister companies.

In the behind the meter market, industry leaders suggest that Florida homeowners may be much more interested in battery storage than homeowners in other states. Sonnen, an important battery manufacturer, opened an Innovation Hub in Atlanta to provide easy access to East Coast markets like Florida. Blake Richetta, the company's vice president of sales, said in early 2017 that "we actually do significant business in Florida, because the small solar industry that is emerging in Florida is very excited about the idea of solar-plus-storage and energy security. They can sell that a lot easier than can a Californian solar installer."²⁸ This interest may be due to concerns about backup power during extreme weather events, though most residential battery systems today are not designed to provide backup power for more than a few hours. That Florida consumers seem interested anyway may represent lack of familiarity with product offerings – or an opportunity for new products tailored to the unique weather concerns of Florida building owners. When paired with on-site solar generation in the service territory of a utility that allows distributed solar to continue generating when the grid goes down, battery systems are better positioned to provide meaningful back-up power.

For larger systems, storage developers report that bidding is underway for utility-scale microgrid projects that are scheduled to come online in Florida by the end of 2018. These tend to be driven by IOUs in collaboration with large customers with extreme reliability needs. Developers also report "huge" interest in hardening Florida's grid infrastructure for resiliency, but they say storage is not necessarily a central part of these conversations yet because it is perceived to be too expensive and unable to compete with natural gas-fired backup generation. Recent solar projects on military bases in Florida, for example, have not included serious discussion of battery storage.

In the front of the meter market, Florida municipal utilities are interested in a variety of storage applications, but most of these remain theoretical. They report that frequency regulation applications are most likely to be deployed first due to the lower cost of very short duration battery systems used in frequency regulation. Some municipal utilities have also been leaders in solar deployments, so they are interested in managing intermittency as well. A third application that officials from multiple Florida munis identified during this research is

²⁶ Mary Ellen Klas, "Regulators must decide: Is FPL rate increase a customer investment or a tax?," Miami Herald, August 30, 2016, <http://www.miamiherald.com/news/business/article98893112.html>.

²⁷ *In re: Florida law precludes FPL's petition in Docket No. 170122*, Docket No. 170122 (July 11, 2017), <http://www.psc.state.fl.us/library/filings/2017/05807-2017/05807-2017.pdf>.

²⁸ Julia Pyper "Sonnen Expands US Presence With Battery Manufacturing Hub in Atlanta" Greentech Media, February 15, 2017, <https://www.greentechmedia.com/articles/read/Sonnen-Expands-US-Battery-Factory-and-Innovation-Hub-Atlanta-manufacturing>.

adding batteries to natural gas turbines in order to make them “instant on” resources able to immediately discharge stored electricity. GE and other vendors say this type of “gas+storage” system can reduce fuel and maintenance costs by allowing turbines to be run at more constant power outputs.

Similarities between Florida and other vertically integrated markets in Southeast states like Georgia and Alabama mean that it can be instructive to consider developments outside Florida as well. Georgia Tech’s recently inaugurated Energy Policy and Innovation Center is conducting a pilot study of the technical potential of storage in the Southeast, including policy considerations. Southern Research in Birmingham, Alabama is also conducting a technical study of storage applications. Both studies will likely include results relevant to Florida.

3 Valuing Battery Storage in Selected States

Relatively few reports exist on the value of battery storage in specific states, but those that do generally find significant potential value. In many areas, there are positive investment cases for behind the meter storage systems that are relatively easy to partially monetize through time-of-use arbitrage, demand charge management, and self-consumption of on-site generation. There are also opportunities to deploy larger storage installations in organized energy markets where rules allow storage to bid to provide capacity or ancillary grid services in competition with other resources. Yet these reports often note important challenges related to the ability to monetize benefits from storage technology.

Many studies find that the benefits of storage to the entire grid are larger than the sum of the income earned by individual battery owners. These grid benefits are diffused over a very large number of customers and are much harder to monetize, unless a public utility commission decides to include the cost of the storage in utilities' ratebase or legislators, regulators, or other officials decide to create policies to compensate storage owners. Failing to allow storage owners to earn a return on the full value they provide to the grid restricts storage deployment, possibly even to the extent of making storage uncompetitive with higher cost solutions that provide more monetizable value as revenue to their owners.

Multiple and often overlapping value streams with widely varying scope for monetization create significant barriers to understanding the quantity of storage that maximizes overall value. There are two key problems. First is that even full deployment of all customer- and merchant-owned systems with positive investment cases would likely leave deployment levels below the optimal level that would be identified through a system-wide analysis accounting for diffuse, but non-monetizable, benefits. Brattle Group estimates that 30% to 40% of the value of storage deployments comes from reliability, transmission, and distribution benefits that cannot be monetized by owners of battery systems (unless the batteries are owned by utilities, which may have greater scope to capture benefits accruing to the grids they own).²⁹ The second problem is that simply determining optimal deployment levels requires costly analytical work. Several states have attempted to study the issue, leading to the following set of influential reports.

3.1 California

California was one of the earliest states to undertake extensive consideration of battery storage. In 2012, the California Public Utilities Commission asked EPRI to study the cost effectiveness of battery storage in the state. The resulting report analyzed dozens of use cases, including bulk storage, distribution support, and ancillary services.³⁰ Most cases analyzed found social benefit-to-cost ratios of greater than one, indicating those deployments would improve net social welfare. The study found that many systems could break even with capital costs of \$1,000 to \$4,000 per kW installed.

However, EPRI's evaluation of investment cases was based on direct, quantifiable – but not necessarily monetizable – benefits. This means that many of the benefits would accrue to

²⁹ Judy Chang et al., *The Value of Distributed Electricity Storage in Texas: Proposed Policy for Enabling Grid-Integrated Storage Investments*, Brattle Group, November 2014, http://www.brattle.com/system/news/pdfs/000/000/749/original/The_Value_of_Distributed_Electricity_Storage_in_Texas.pdf.

³⁰ Electric Power Research Institute, *Cost-Effectiveness of Energy Storage in California: Application of the Energy Storage Valuation Tool to Inform the California Public Utility Commission Proceeding R. 10-12-007* (Palo Alto, CA: 2013), 3002001162, <http://large.stanford.edu/courses/2013/ph240/cabrera1/docs/3002001162.pdf>.

stakeholders who do not own the batteries. The EPRI study thus fails to address either of the two problems identified here. It provides no estimate of the market size for monetizable customer or merchant-owned systems and no estimate of optimal deployment levels from a societal perspective. But it does suggest that social benefits achievable through battery deployment may be large. Five years of technological progress since the EPRI report was conducted have driven prices down to often less than half of the breakeven costs identified in the study.

3.2 Texas

In 2014, Brattle Group produced a report for Oncor Electric, Texas' largest transmission and distribution utility, that estimated system-wide benefits of storage would be maximized with about 5,000 MW of deployments in the state.³¹ The report concluded that this level of deployment would be economical with installed battery system prices of \$350 per kWh, which roughly corresponds to the low end of forecasted price ranges for systems installed in 2020 according to the projections used in this analysis (see Table 3). At these deployment levels, Brattle estimates system-wide net benefits would be about \$300 million annually. Oncor told state regulators that it believed customers could realize \$625 million in savings on electricity bills if 5,000 MW of batteries were deployed. Yet many of the benefits Brattle identified are impossible to realize under current Texas market design, which limits battery owners' ability to benefit from the full value they provide to the grid.

3.3 Massachusetts

More recently, Massachusetts also commissioned an important analytical report that sought to determine optimal levels and locations for battery storage on the state's grid. The report found that 1,766 MW of new storage would maximize system-level benefits.³² These would include \$2.3 billion in savings to Massachusetts ratepayers, \$250 million in savings for other states in the New England power market, and \$1.1 billion in monetizable market revenue for owners of storage resources. At assumed costs of \$970 million to \$1.35 billion, this represents a benefit-cost ratio of 2.7 to 3.76. When benefits are limited to only the \$2.3 billion realizable as savings for Massachusetts ratepayers, the ratio falls to 1.7 to 2.4. The battery costs used in this study are higher than those used in the Brattle study, so comparing the two requires adjusting cost assumptions.

Massachusetts state agencies commissioned this report to inform the state's development of pro-storage policies. It has since become the third state after California and Oregon to adopt storage procurement mandates. In Texas, on the other hand, Oncor and Brattle proposed rule changes that would allow Oncor and other transmission and distribution companies to plug batteries into a wider set of overlapping revenue streams.³³ These rule changes have not been adopted. The two states' varying experiences with these studies illustrate the importance of understanding the nuances of storage markets on a state-by-state basis.

3.4 Oregon

After passage of legislation that required Oregon utilities to submit proposals for energy storage projects, the state's Public Utility Commission ordered Pacific Power (a division of PacifiCorp)

³¹ Chang et al., *The Value of Distributed Electricity Storage in Texas*.

³² *State of Charge: Massachusetts Energy Storage Initiative*, September 2016, <http://www.mass.gov/eea/docs/doer/state-of-charge-report.pdf>.

³³ Gavin Bade, "Whatever happened to Oncor's big energy storage plans?," Utility Dive, September 1, 2015, <http://www.utilitydive.com/news/whatever-happened-to-oncors-big-energy-storage-plans/404949/>.

and Portland General Electric (PGE) to commission studies of the value of energy storage in their service territories. Unlike the Texas and Massachusetts studies, these reports did not estimate the optimal level of storage across the state but instead evaluated the benefits of specific storage use cases. They are intended to guide the utilities toward proposing storage projects to meet mandates that call for operational batteries by 2020. These reports, which were completed by DNV GL for Pacific Power³⁴ and Navigant for PGE,³⁵ were submitted to the Oregon PUC in July 2017.

DNV GL assessed various behind the meter and front of the meter storage use cases and identified locations in Pacific Power's service territory where the potential value of storage is highest. Navigant's study used three models to evaluate storage across PGE's grid and in a number of specific behind and front of the meter use cases. Two of these models were previously used by PGE for non-storage modeling. The other was Navigant's Valuation of Energy Storage Tool. Both reports identify substantial opportunities for battery storage in numerous use cases in Oregon. The study of PGE service territory estimates the net present value of demand charge reduction and reliability benefits to commercial and industrial owners of behind the meter storage systems at up to \$2,400 per kW, though the report notes that reductions to utility demand charge revenue could impact other customers.³⁶

3.5 Minnesota

In late 2016 and early 2017, a group of Minnesota power sector stakeholders met to discuss the potential of storage in the state and in the wider Midcontinent Independent System Operator (MISO) RTO. Based on these workshops, the University of Minnesota's Energy Transition Lab, Strategen Consulting, and Vibrant Clean Energy produced a report modeling the cost-effectiveness of lithium-ion battery storage in specific use cases in Minnesota and across the MISO grid.³⁷

Primarily modeling investments in four-hour duration lithium-ion battery projects, the study finds that storage can reduce needed investments in transmission upgrades and assist the integration of higher penetrations of low-cost variable wind and solar generation in MISO. Additionally, the study finds that battery storage is more cost-effective than gas-fired combustion turbine peaker generation in Minnesota after 2022. When considering the Investment Tax Credit and environmental benefits, the date by which storage systems paired with solar generation become more cost-effective than a gas-fired combustion turbine peaker accelerates to 2018. The 2018 date may be more relevant, because accounting for environmental costs in Minnesota Public Utility Commission decisions is required by state law. The report also notes that storage investments could help Minnesota avoid overreliance on natural gas, a finding with relevance to Florida.

³⁴ DNV GL, *Energy Storage Potential Evaluation*, Oregon Public Utilities Commission Docket – UM 1751, July 14, 2017, <http://edocs.puc.state.or.us/efdocs/HAA/haa165931.pdf>.

³⁵ Navigant Consulting, Inc., *Energy Storage Potential Evaluation*, Oregon Public Utilities Commission Docket – UM 1751, July 14, 2017, <http://edocs.puc.state.or.us/efdocs/HAA/haa115310.pdf>.

³⁶ Note that battery costs can be represented in terms of kilowatts or megawatts, which are power ratings that indicate how much electricity can be discharged from a battery at one time, or in terms of kilowatt-hours (kWh) or megawatt-hours (MWh), which indicate the total capacity of a battery to store electricity and depend on the duration of the battery.

³⁷ University of Minnesota Energy Transition Lab, Strategen Consulting, and Vibrant Clean Energy, *Modernizing Minnesota's Grid: An Economic Analysis of Energy Storage Opportunities*, July 11, 2017, <http://energytransition.umn.edu/wp-content/uploads/2017/07/Workshop-Report-Final.pdf>.

4 Value of Battery Storage in Florida

This section outlines the potential value of battery storage in Florida. For behind the meter storage, the analysis identifies scenarios in which market forces could drive investment. It does not attempt to estimate a total market size. For front of the meter storage, the analysis identifies fundamental changes in the Florida market over the last 12 months and estimates investment based on currently announced procurement plans from Florida IOUs.

4.1 Behind the Meter Storage

Behind the meter storage is located at the end of the generation, transmission, and distribution chain. It is generally sited on property owned by a homeowner, business, industry or other utility customer. Applications of behind the meter systems can vary widely. On the small side, these can be 10 kWh systems installed in a homeowner's garage to provide limited backup power or store rooftop solar generation. Larger systems deploy significantly higher capacity to provide backup power for entire building complexes or shave peak demand for energy intensive commercial and industrial consumers.

4.1.1 Cost Savings

This analysis focuses on systems optimized to reduce demand charges, a use case that is easily modeled, provides transparent benefits with clear monetary values, and can be viewed as a conservative lower bound of the benefits of behind the meter storage. Most Florida IOUs impose demand charges to incentivize lowering peak demand and offer optional time-of-use rates that encourage load shifting during peak periods. The analysis also considers savings associated with shifting energy consumption from on-peak to off-peak hours, but this is a byproduct of batteries optimized for demand charge management. We estimate the potential value of storage for multiple Florida customer classes by combining representative customer load profiles with Florida utility tariff structures.

The US Department of Energy Office of Energy Efficiency and Renewable Energy TMY3 hourly load profile dataset includes energy usage from a set of representative commercial and residential buildings in Florida, ranging from fast food restaurants and small hotels to schools, hospitals, and office buildings.³⁸ These medium-to-large customers face demand charges based on their peak consumption in addition to volumetric electricity charges. Some of these customers can also choose to enroll in time-of-use rates that impose higher charges during peak hours.

Using these representative load profiles and rate structures, we model the cost savings from using battery storage to shave peak demand. The modeling is based on prior peer-reviewed battery schedule optimization methods developed at the University of California San Diego.³⁹ This model's battery is based on the SANYO DCB-102 battery arrays, which have a 2:1 energy storage capacity to maximum discharge ratio. Battery arrays are sized relative to the annual peak demand of each load profile. The analysis does not consider paired solar generation, but does consider results based on both a perfect load forecast and a day-ahead persistence

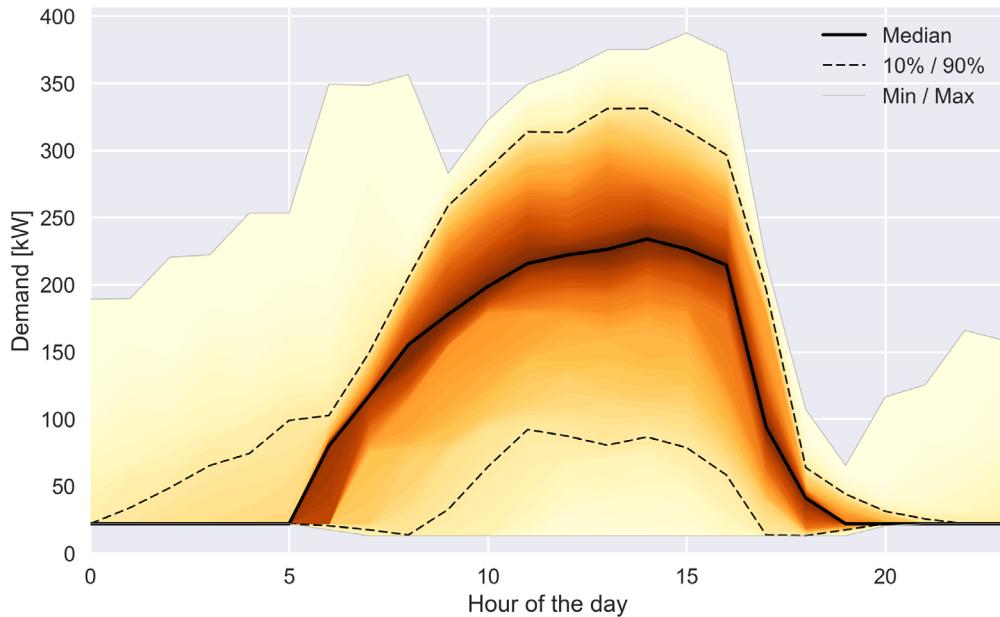
³⁸ Office of Energy Efficiency & Renewable Energy, "Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States," <https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>.

³⁹ R. Hanna et al., "Energy dispatch schedule optimization for demand charge reduction using a photovoltaic-battery storage system with solar forecasting," *Solar Energy* 103 (May 2014): 269-287.

forecast. The perfect forecast is assumed to predict the next day's load profile flawlessly, while the day-ahead persistence forecast assumes the load profile for the current day will be the same as the previous day. Because it is very unlikely for a battery system to perfectly predict the next day's demand, the perfect forecast provides an upper bound on cost savings. The day-ahead persistence forecast provides a lower bound. Both are extreme cases. While the perfect forecast is difficult to approximate in the real world – especially for peaky load profiles – proprietary forecasting methods used by energy companies today are generally more accurate than the naive persistence forecast used here. Cost savings are calculated by applying Florida utility rates to representative load profiles, applying these same rates to new load profiles created by using the battery scheduling algorithm to represent the addition of battery systems, and finding the difference between the electricity costs that would be incurred with and without battery systems.

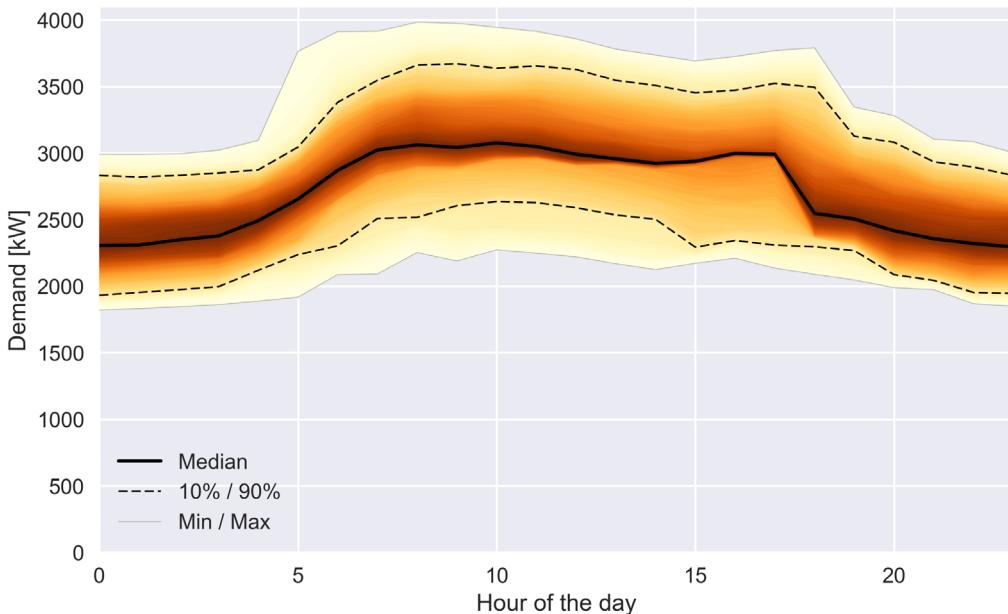
Results are presented for four commercial load profiles (warehouse, hospital, fast food restaurant, and small hotel) and one residential site in Miami (see Table 1). These profiles were selected to cover peaky, semi-peaky, and non-peaky load behavior as well as a wide range of peak demand behavior in which peaks range from 10 to 4,000 kW. However, the analysis can be easily extended to other commercial and residential load profiles, including the full set of 16 commercial and 42 residential Florida load profiles in the DOE EERE TMY3 data set. Figure 1 represents the peaky load profile, a warehouse with peak demand of 387 kW, which is almost four times as large as its average demand of 100 kW. Figure 2 shows the non-peaky hospital load profile, which – in contrast to the peaky warehouse – has an annual peak demand (3,983 kW) that is only approximately 1.5 times larger than its average demand (2,754 kW).

Figure 1: Visualization of Load Profile for Warehouse (Low Load Factor)



The colors indicate how often a particular demand occurs in the year-long data set (darker: more common, lighter: more rare). The black solid line shows the median demand, while the dashed black lines show the 10th and 90th percentiles. The 6am-8am peak of 350 kW is rare, but can have a significant impact on energy costs as it aligns with one of the TOU on-peak periods.

Figure 2: Visualization of Load Profile for Hospital (High Load Factor)



In comparison to the peaky warehouse profile, the hospital has a more constant level of demand throughout the day with an annual peak demand of 3,983 kW and annual average demand of 2,754 kW.

Table 1 outlines the demand behavior of these properties and Table 2 outlines the annual cost savings associated with a battery sized to shave 5% of peak demand for two hours. Savings are shown for various combinations of utility service territories and perfect and day-ahead persistence forecasts. The peaky warehouse profile has the largest relative cost savings, followed by the semi-peaky fast food restaurant and small hotel. The non-peaky hospital has the least relative cost savings due to its high load factor.

Table 1: Summary of Representative Florida Load Profiles Used in the Analysis

	Warehouse	Fast food	Small hotel	Hospital	Home
Load factor	25.8%	53.5%	59.9%	69.1%	40.3%
Peak demand (kW)	387	162	319	3,983	10
FPL rate schedule	GSLDT-1	GSDT-1	GSDT-1	GSLDT-2	RTR-1
FPL annual electricity cost	\$93,816	\$60,516	\$129,210	\$1,655,983	\$897
JEA rate schedule	GSD	GSLD	GSD	GSD	Residential
JEA annual electricity cost	\$112,377	\$77,856	\$163,739	\$2,255,076	NA

All four commercial load profiles are evaluated for both Florida Power & Light (FPL) and Jacksonville Electric Authority (JEA) rates, with the annual electricity cost without battery storage reported for reference. The residential property is not modeled in JEA service territory due to lack of residential TOU rates.

Table 2: Cost Savings Available Through Deployment of Modeled Battery Systems

	Warehouse	Fast food	Small hotel	Hospital	Home
Cost savings (%): FPL, perfect forecast	\$6,788 (7.2%)	\$2,236 (3.7%)	\$3,801 (2.9%)	\$26,852 (1.6%)	\$94 (10.5%)
Cost savings (%): FPL, persistence forecast	\$5,365 (5.7%)	\$2,103 (3.5%)	\$3,094 (2.4%)	\$22,520 (1.4%)	\$95 (10.6%)
Cost savings (%): JEA, perfect forecast	\$7,641 (6.8%)	\$3,042 (3.9%)	\$4,951 (3.0%)	\$39,561 (1.8%)	Not modeled
Cost savings (%): JEA, persistence forecast	\$5,511 (4.9%)	\$2,895 (3.7%)	\$4,061 (2.5%)	\$30,099 (1.3%)	Not modeled

Commercial load profiles are modeled under Florida Power & Light (FPL) and Jacksonville Electric Authority (JEA) rates, with a battery system sized to shave 5% of peak demand for two hours. Cost savings are presented annually. The residential property is not modeled in JEA service territory due to lack of residential TOU rates.

The cost savings are sensitive to forecast accuracy and utility service territory. Depending on the load profile and day-to-day demand variability, load forecast performance can have a significant impact on cost savings. Savings for a battery operating with a perfect demand forecast – unachievable in reality – are greater than with a day-ahead persistence forecast. This difference is particularly obvious for the peaky warehouse load profile, where cost savings as a percentage of total electricity bill in FPL service territory fall from 7.2% annually under perfect forecasting to 5.7% under persistence forecasting. The difference can be seen to a lesser extent in the other commercial load profiles as well. Utility rates also matter. For the properties modeled here, electricity costs in JEA service territory are 20% to 36% higher than in FPL service territory. With battery costs assumed to be constant across service territories, this leads to higher savings associated with battery deployment in JEA territory.

Table 3: Modeling Assumptions Used in Behind the Meter Analysis

Variable	Assumptions
Operations and maintenance costs	2% of capital expenditure per year (1%, 3%)
Discount rate	8.6% (6.6%, 10.6%)
Project life	10 years
Depreciation	MACRS 7-year depreciation with 35% tax rate (15%, 0%)
Battery system size	5% of peak demand for 2 hours (10% of peak demand for 2 hours)
Battery decline rate	2% per year (1%, 3%)
Demand forecasting	Perfect forecast, day-ahead persistence forecast
2015 battery cost estimate	\$620 / kWh (low), \$1,200 / kWh (high)
2020 battery cost estimate	\$380 / kWh (low), \$1,010 / kWh (high)
2025 battery cost estimate	\$300 / kWh (low), \$590 / kWh (high)

The values in parentheses are those used in sensitivity analyses. Costs are estimates of the per kWh cost of an installed battery storage system (Feldman et al., 2016).

4.1.2 Economic Analysis

While battery storage systems can reduce electricity bills, they are attractive investments only if these savings are greater than the comprehensive set of costs associated with deploying and operating the systems. To estimate the business case for storage, net present value (NPV) and internal rate of return (IRR) are calculated for various investment scenarios. NPV analysis indicates whether the savings from a battery investment exceed its costs – and by how much – and IRR analysis indicates the percentage return earned each year for each dollar invested in the system. In a later section of the report (Section 6.3), we also calculate the level of incentive that would be necessary to create positive NPV investments for scenarios in which non-subsidized systems have negative NPV. Table 3 lists the assumptions underlying the NPV, IRR, and incentive modeling. After a comprehensive review of existing literature, this analysis assumes the battery price ranges and projections compiled by the National Renewable Energy Laboratory (NREL) in August 2016.⁴⁰ The NREL numbers represent consideration of a wide range of projections and we have checked them with a number of industry insiders to verify that they are broadly legitimate in the eyes of corporate decision-makers, academic analysts, and other experts. NREL's assumed yearly operations and maintenance costs are also roughly equivalent to assumptions used in other leading studies, including the DNV GL study referenced in Section 3.4 of this report.

The models are most sensitive to forecast accuracy, battery cost, and system size. Following sections present results based on various values of these variables. For brevity, results of other sensitivity analyses are not presented. In order to estimate a baseline value of battery storage, this analysis does not incorporate incentives like the federal Investment Tax Credit, which can apply to storage systems charged primarily by renewable generation, or the newly-announced JEA incentives. It does include the 7-year MACRS depreciation schedule that applies to stand-alone battery storage.

4.1.3 Net Present Value

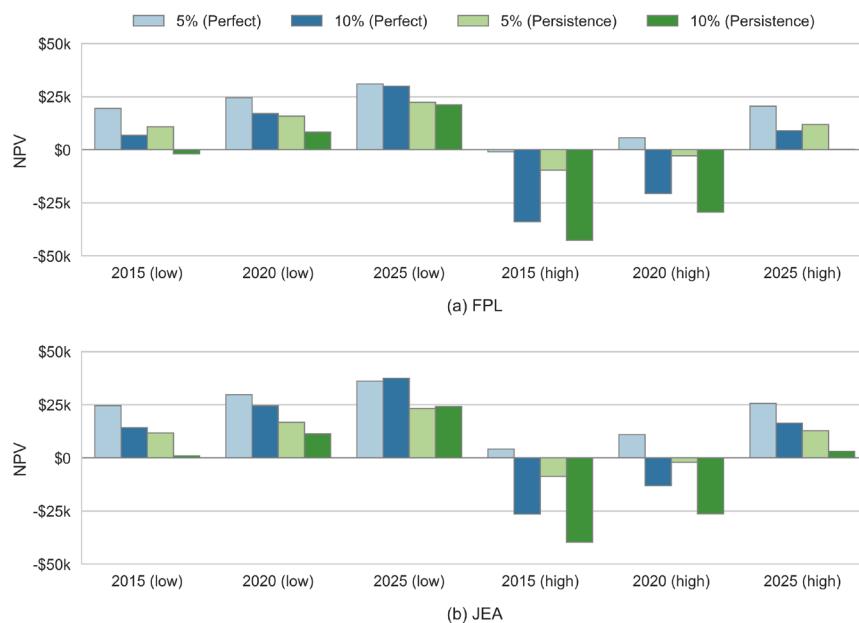
Appendix A presents the full set of NPVs for investments in small and large battery systems in FPL and JEA service territories at low and high price estimates for 2015 and low and high price forecasts for 2020 and 2025. Figure 3 presents a condensed set of NPV results for the peaky warehouse property. Six different price estimates are displayed for each of eight different scenarios. The scenarios include combinations of different rate structures, forecast accuracies, and battery system sizes. An important result is that due to higher JEA electricity bills, persistence forecast scenarios under JEA rates return NPVs that are quite close to those of perfect forecast scenarios under FPL rates. In practice – since a battery system with advanced forecasting capabilities would be more costly than a battery operating under a naive forecast – the value differential between JEA and FPL service territories may be even greater than indicated in this model.

NPV results vary by property and load profile. For semi-peaky or non-peaky properties where it is less crucial to perfectly predict high demand peaks, JEA's higher rates mean that JEA persistence forecast scenarios can result in equal or even greater NPVs than FPL perfect forecast scenarios. For three of the properties – the semi-peaky fast food restaurant, small hotel, and non-peaky hospital – NPVs are higher under a JEA persistence forecasting scenario

⁴⁰ David Feldman et al., *Exploring the Potential Competitiveness of Utility-Scale Photovoltaics plus Batteries with Concentrating Solar Power, 2015-2030*, National Renewable Energy Laboratory, August 2016, <https://www.nrel.gov/docs/fy16osti/66592.pdf>.

than under an FPL perfect forecasting scenario. The peaky nature of the warehouse load profile makes it more sensitive to forecasting error, so there are no cases in which a persistence forecast outperforms a perfect forecast (see Figure 3). The highest NPV investments for each property are in JEA territory, with the exception of the residential property because JEA residential rate structures do not include time-of-use rates. It is possible that some homeowners in JEA territory may find positive investment cases for other storage applications, especially pairing battery systems with rooftop solar to optimize self-consumption.

Figure 3: NPV of Battery System Deployed at Warehouse (Low Load Factor) by Scenario



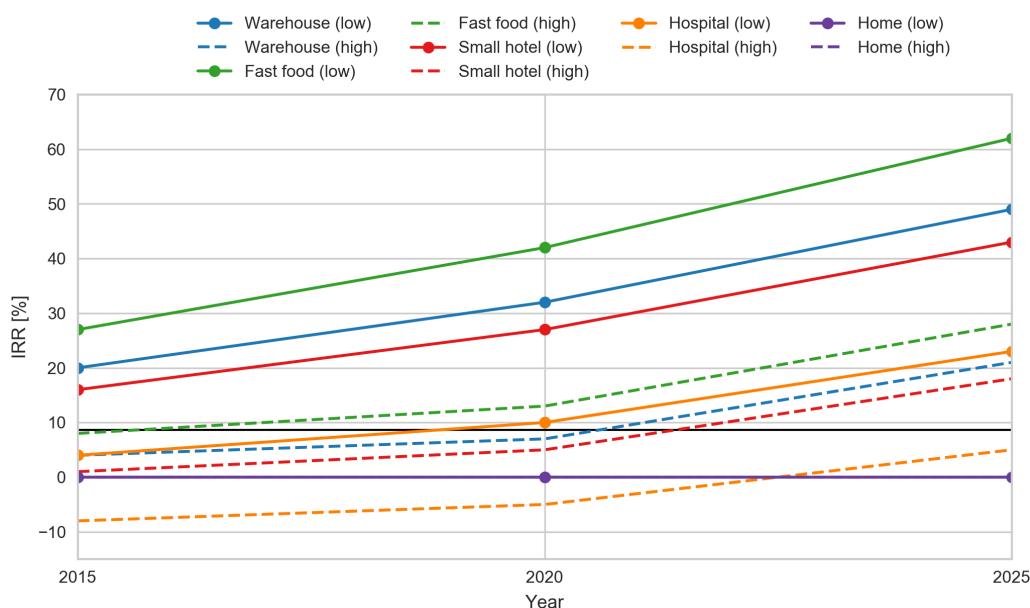
Blue bars represent perfect forecasts and green bars represent persistence forecasts. Florida Power & Light (FPL) service territory scenarios are represented on the top, and Jacksonville Electric Authority (JEA) service territory scenarios are represented on the bottom. Scenarios for the low end of price estimates are in the left half of the figure, and scenarios for the high end are in the right half. Scenarios are presented for batteries sized to shave 5% of peak demand for two hours (5%) and others sized to shave 10% of peak demand for two hours (10%). For modeling assumptions, see Table 3.

The analysis concludes that behind the meter battery storage is already a positive NPV investment for some Florida customers and that storage will become a better investment for more customers as costs fall in coming years. For customers with peaky and semi-peaky loads, positive investment cases already exist at the low end of the battery cost range and will begin to emerge by 2025 even for the high end of the cost range.

4.1.4 Internal Rate of Return

NPV analysis is a useful tool for understanding the value of a project, but it is not always the best tool for an organization looking for the most efficient way to deploy its capital. IRR analysis helps investors determine the most efficient way to produce investment returns. In the context of this analysis, it normalizes differences between property and system size by indicating the percent return that can be earned annually on every dollar invested in a battery system.

Figure 4: IRR of Battery System Deployed at Representative Florida Buildings in JEA Service Territory



Battery systems are sized to shave 5% of peak demand for two hours with day-ahead persistence forecasts. IRR values are reported based on both low (solid lines) and high (dashed lines) battery price estimates for 2015, 2020, and 2025. A hurdle rate of 8.6% is represented by the solid black line. System life is assumed to be 10 years.

Figure 4 presents the IRR values for a battery system sized to shave 5% of peak demand for two hours using a persistence forecast in JEA territory for each property under low and high battery cost assumptions. Using low cost estimates for 2015, the semi-peaky properties (fast food restaurant and hotel) and the peaky warehouse already have IRR greater than 15%. These appear to be attractive investments, but more information about other investment opportunities available to the owners of these properties would be necessary before determining if buying a battery system makes sense for them. The set of properties for which battery systems might make economic sense does not change significantly between 2015 and 2020, but the expected returns rise by ten or more percentage points for each property. The next five-year period sees a significant shift, with nearly all projects modeled in the figure earning expected returns of nearly 20% or more by 2025. Crucially, this is true for semi-peaky and peaky properties even at the high end of the cost range.

Full results of the IRR analysis are presented in Appendix B. These results generally support the conclusions of the NPV analysis, but they clarify that – despite large NPV in some scenarios – battery systems are generally a poor investment for the non-peaky hospital property except in 2025 low cost scenarios. In all cases, returns from battery systems in semi-peaky and non-peaky properties are more sensitive to service territory than to forecast accuracy.

4.1.5 Discussion

The NPV and IRR analyses indicate that property owners in Florida can make money on investments in battery systems under certain conditions. This is already true today under low battery cost assumptions and, according to this analysis, will become true even under high cost assumptions for other properties between 2020 and 2025. Yet this property-level view provides an incomplete analysis of Florida's potential market for behind the meter battery storage. Building a reliable estimate of the total number of properties for which battery systems might be positive investments is difficult because of severe challenges around collecting data for millions of customers – utility companies, however, would likely be able to do this.

A larger problem is that these NPV and IRR analyses only identify the cases in which the value a battery owner can monetize is larger than costs of deploying the battery. This does not account for diffuse, non-monetizable benefits and so does not allow estimation of the number of battery systems that should be deployed to maximize the level of overall benefit to the grid. The result is a classic market design problem in which, left to their own devices, customers will invest in fewer battery systems than they should from a system optimization perspective. Low cost public policies, including steps like providing easier access to load profile data, can mitigate the problem to some extent. But fully realizing the benefits of storage technology requires either new policies to compensate the owners of storage systems for the benefits their investments provide to the grid or deployment of larger front of the meter storage systems – or both. The Opportunities section (Section 6.3: Incentives) of this report provides initial analysis of incentive levels that would be required to expand the range of properties that could make money from behind the meter storage deployments. This could be a useful way to increase the amount of storage on the grid if legislators, regulators, or utilities decide more storage is a desirable goal. Florida's JEA has been a pioneer of this strategy, though the muni's decision to position batteries as alternatives to retail net metering has been a controversial one (see Section 6.2: Public Utilities).

There is significant scope for further research to build on these contributions by considering whether it would be more efficient to provide incentives to increase the size of battery systems for properties where positive investment cases already exist, to expand the number of properties with positive investment cases, to focus incentives on high-need areas of Florida's grid, or to focus on front of the meter storage. Further analysis should also consider pairing storage with behind the meter solar resources. Storage systems are eligible for the federal Investment Tax Credit if a large share of the energy used to charge them comes from solar or other qualifying generation. This can substantially improve the NPV and IRR of storage systems. Analysis of the investment cases for behind the meter solar plus storage would likely expand the set of attractive investment cases in Florida significantly, even though these systems would still be subject to the challenges and risks associated with Florida's prohibition on third-party ownership.

Finally, there is some risk to basing this economic modeling on NREL's 2016 battery cost forecasts. Battery prices have fallen rapidly, often outstripping even the most up-to-date forecasts. The complications of a market with rapidly changing costs are evident in the ongoing battle over whether storage could be a cost-effective alternative to NRG Energy's proposed Puente gas-fired

power plant in California. A recent study by the California Independent System Operator (CAISO) that estimated the cost of alternatives to the plant has been criticized for using storage cost estimates from 2014, which many observers claim are higher than costs seen in reality today.⁴¹ In October 2017, the CAISO recognized the legitimacy of the challenge by suggesting that a new request for offer may be necessary to let the market provide updated pricing.⁴² It may be the case that NREL's numbers could be subject to similar criticism in one or two years. However, the authors have spoken to multiple industry sources and determined that NREL's cost forecasts are broadly perceived to be reasonable. This dilemma reflects a wider problem in the battery storage industry - as even critics of the CAISO study admit, battery costs are usually proprietary and it is difficult for regulators to stay up-to-date on quickly changing prices.

4.2 Front of the Meter

Front of the meter battery systems require very different types of analysis than behind the meter systems. Though both provide benefits to the entire grid, behind the meter systems are generally deployed either to provide backup power for a specific property or to provide value for their owners through bill management or self-consumption. Front of the meter systems are used to provide more diffuse value at the generation, transmission, or distribution level. In organized markets, front of the meter systems can be commercially deployed by merchant operators. In vertically integrated states like Florida, these systems are more likely to be owned and operated by utility companies. From a technical perspective, front of the meter deployments can provide value through black start and spinning and non-spinning reserves services, provision of grid services like frequency regulation and voltage support, contributing to resource adequacy requirements, easing congestion on the transmission system, and allowing deferral of costly transmission and distribution upgrades.⁴³

4.2.1 Emergence of a Front of the Meter Market in Florida

Though Florida has essentially no battery storage installed today beyond small pilot projects, the last year has been marked by important steps toward front of the meter deployments in the state. In December 2016, an FPL rate case settlement was approved that authorizes the company to procure 50 MW of batteries through 2020 and seek cost recovery in the next rate case.⁴⁴ Regulators in other states have occasionally rejected IOU proposals to own batteries, but FPL appears to have convinced the PSC that it can deploy the storage to provide benefits to customers. Duke Energy Florida also proposed 50 MW of batteries in a rate settlement set to be approved in late 2017. The programs are referred to as pilots in the PSC proceedings, but the Commission's willingness to allow cost recovery for so many utility-owned megawatts suggests that it expects the installations to operate somewhat cost-effectively. Taken together, these proposals amount to nearly one-sixth of the 622 MW of total battery storage capacity installed in the US through 2016.⁴⁵ If these investments materialize, Florida could go from essentially no meaningful storage projects today to dozens within five years.

⁴¹ Julian Spector, "In Storage vs. Peaker Study, CAISO's Outdated Cost Estimates Produce Higher Price Tag for Storage," Greentech Media, August 31, 2017, <https://www.greentechmedia.com/articles/read/energy-storage-nrg-puente-gas-peaker-plant-cost>.

⁴² Julian Spector, "CAISO Suggests New RFO to Settle Question of Storage vs. Puente Gas Peaker," Greentech Media, October 3, 2017, <https://www.greentechmedia.com/articles/read/caiso-suggests-new-rfo-to-settle-question-of-storage-vs-puente-gas-plant>.

⁴³ Fitzgerald et al., *The Economics of Battery Energy Storage*.

⁴⁴ Order Approving Settlement Agreement, Order No. PSC-16-0560-AS-EI.

⁴⁵ Nick Esch et al., 2017 Utility Energy Storage Market Snapshot, Smart Electric Power Alliance, September 2017, <https://sepapower.org/362-thank-you-2017-utility-energy-storage-market-snapshot-aug17>.

Case Study 3: Southern California Edison combines natural gas turbine with 10 MW (4.3 MWh) of battery storage to meet resource adequacy requirements after gas storage leak

In 2015, a massive leak at the Aliso Canyon natural gas storage facility raised concerns about the security of California's gas supply and prompted state regulators to require utilities to add battery storage capacity to meet resource adequacy requirements. As part of its response to this mandate, Southern California Edison built the world's first gas-fired power plant to combine a 50 MW gas turbine with 10 MW / 4.3 MWh of battery storage, which entered service in 2016.¹ Because the battery can discharge more rapidly than even a modern gas turbine can ramp up, the combined system can serve as instantly-dispatchable spinning reserves without the turbine burning any fuel at idle, reducing maintenance and fuel costs. Given the increasing penetration of intermittent solar generation in the California grid, this flexibility is vital for increasing the value of load-following peaker plants. The Aliso Canyon leak also spurred the procurement of 83.5 MW of battery storage by southern California's other investor-owned utility, San Diego Gas & Electric.

¹ Robert Walton, "SoCal Edison, GE complete first hybrid gas-storage turbine," Utility Dive, April 18, 2017, <http://www.utilitydive.com/news/socal-edison-ge-complete-first-hybrid-gas-storage-turbine/440634/>.

Most large Florida utilities have also formed internal working groups dedicated to building their understanding of batteries. In most cases, these teams are initially focused on determining the benefits batteries can offer to the IOUs' systems. This generally happens through literature reviews, though some Florida IOUs have sister companies with significant battery storage experience outside of Florida. Individuals involved in these efforts indicate that, while they are committed to exploring the benefits of batteries, gathering reliable data is extremely challenging due to variation in market design between states, rapid changes in battery costs and capabilities, and other factors. The IOUs also participate in joint working groups focused on storage, but these forums may be limited by divergent business objectives.

Municipal utilities have not announced significant front of the meter storage procurements, but six of the most important munis in Florida have worked together to launch the Florida Alliance for Accelerating Solar and Storage Technology Readiness (FAASSTeR). Launched in July 2017, this DOE-funded initiative will pair the participating utilities with DOE laboratories to identify pathways for successful expansion of grid-integrated solar, energy storage, and other distributed energy resources in Florida. The FAASSTeR program's conclusions, which are scheduled to be released in 2020, may become the most important public resource for planners seeking to understand where grid-scale storage can provide cost-effective benefits to Florida's grid. This type of collective action is particularly important for municipal utilities, which often lack the internal capacity of large IOUs and on their own would likely be unable to tackle the costly technical challenge of understanding how to deploy storage. Another DOE-funded grant, the North Carolina Clean Energy Technology Center's Community Solar for the Southeast,⁴⁶ is focusing on helping public utilities around the Southeast implement community

⁴⁶ North Carolina Clean Energy Technology Center, "Community Solar," <https://nccleantech.ncsu.edu/community-solar/>.

solar programs and consider storage as an added value stream. The program plans to release a report in late 2017 that is likely to be an instructive resource for public utilities in Florida, including those not participating in FAASSTeR.

4.2.2 Value of Front of the Meter Storage Market in Florida

Analysis of the benefit-cost ratio of the FPL and Duke procurements is beyond the scope of this work. Regulators will determine the value the IOUs can monetize when they revisit cost recovery in base rate proceedings in 2020 and 2021. But it is straightforward to estimate the amount of investment that will go into Florida's front of the meter storage market from 2017 through 2021 based on the volume of planned procurements announced in the two rate proceeding settlements. FPL's approved settlement from December 2016 indicates that battery costs are not to exceed an average of \$2,300 per kilowatt.⁴⁷ The duration of the batteries is unknown, but two hour duration batteries would lead to a \$1,150 per kWh cost point. This at the high end of today's cost range, according to the NREL estimates assumed elsewhere in this report, and above the high end of the cost range for 2020. If the full 100 MW are installed and Duke procures at the same prices as FPL, the companies will spend up to \$230 million on these systems. TECO, Gulf Power, and various public utilities may also enter the market, driving this figure higher.

Case Study 4: Arizona Public Service deploys 2 MW (8 MWh) to defer transmission upgrades and 4 MW (4 MWh) for voltage control and power quality

Faced with the need to serve load peaks that occur on 20 to 30 days per year in the town of Punkin, Arizona Public Service (APS) chose to deploy 8 MWh of storage on land it already owns in the area. These will deliver power during peak load periods and will deliver other services during the rest of the year. APS has not disclosed costs, but says the battery storage costs less than the transmission upgrades that would otherwise be necessary.¹ This installation follows a pair of 2 MWh installations deployed to smooth solar integration and manage power quality at a distribution feeder in the area of Phoenix with the highest penetration of rooftop solar.²

¹ Gavin Bade, "APS to deploy 8 MWh of battery storage to defer transmission investment," Utility Dive, August 9, 2017, <http://www.utilitydive.com/news/aps-to-deploy-8-mwh-of-battery-storage-to-defer-transmission-investment/448965/>.

² Ryan Randazzo, "Utilities Experiment with Big Batteries in Phoenix to Tackle One of Solar's Major Problems," AZCentral.com, April 20, 2017, <http://www.azcentral.com/story/money/business/energy/2017/04/20/power-grid-utilities-big-batteries-metro-phoenix-solar-srp-aps/100349564/>.

⁴⁷ Order Approving Settlement Agreement, Order No. PSC-16-0560-AS-EI.

5 Barriers to Storage Deployment in Florida

While this report has identified value in Florida's storage market, the path to greater deployment faces serious obstacles. These are generally related to market design, economics, and state policy choices.

5.1 Resource Planning Process

In many states, regulated utilities are required by state laws, administrative codes, or public utility commission statutes to conduct integrated resource planning (IRP) to demonstrate that a mix of supply and demand side resources will be sufficient to meet forecasted energy demand, peak demand, and a reserve margin.⁴⁸ This is burdensome for companies, but is often seen as necessary to ensure the companies are doing as much as possible to determine how to serve load cost-effectively.⁴⁹ Florida is one of a group of states that do not have such requirements on the books.⁵⁰ Instead, Chapter 186 of the Florida Statutes requires that IOUs file Ten Year Site Plans (TYSP) with the PSC at least once every two years.

IOUs and regulators often claim that the requirement to propose TYSP is functionally equivalent to an IRP. To underscore this point, within their TYSP submissions IOUs generally describe their own internal planning as integrated resource planning. While it is true that these companies – which include some of the most sophisticated IOUs in the country – do engage in rigorous internal planning, there is nevertheless a fundamental difference between a voluntary IRP process and a mandatory IRP process imposed by state authorities. This difference may be particularly salient when it comes to the question of how to account for the unique characteristics of storage within resource planning processes. The locational and sub-hourly dimensions of battery storage add significant complexity to traditional resource planning, and it is not clear that IOUs have an incentive to shoulder this burden in the absence of mandates to do so. While the TYSP process does require the PSC to approve or reject utility site plan submissions based on a set of criteria (see Chapter 186 of 2017 Florida Statutes), it is not clear that these are detailed enough to provide guidance on how regulators should evaluate an IOU's consideration of storage within internal resource planning.

The lack of a formal integrated resource planning requirement gives Florida IOUs a relatively important role in deciding how rigorously the opportunity for storage deployment in the state is studied. Given the storage expertise of FPL and Duke's parent companies, it is possible that state-mandated IRP is not necessary to ensure full consideration of the value storage may offer to Florida's grid. Yet it is also possible that storage resources will be poorly accounted for in Florida resource planning because the regulated companies do not have clear incentives to take on the expense of equipping themselves to do this analysis. Determining which of these outcomes is more likely is beyond the scope of this analysis.

⁴⁸ Rachel Wilson and Bruce Biewald, *Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans* (Montpelier, VT: The Regulatory Assistance Project, June 2013), <http://www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf>.

⁴⁹ Jim Lazar, *Electricity Regulation In the US: A Guide, Second Edition* (Montpelier, VT: The Regulatory Assistance Project, June 2016), <http://www.raponline.org/wp-content/uploads/2016/07/rap-lazar-electricity-regulation-US-june-2016.pdf>.

⁵⁰ Wilson and Biewald, *Best Practices in Electric Utility Integrated Resource Planning*.

5.2 Low Electricity Costs

High electricity costs generally increase the value of battery storage deployments. This analysis demonstrates that this is true within Florida, where the value of behind the meter storage is higher in JEA service territory – where rates are steeper – than in FPL territory. However, on a statewide basis, Florida's average electricity rates are on par with the US average and far less than in states with higher levels of storage procurement such as Massachusetts, Hawaii, and California.⁵¹ This does not mean storage can never be economical, but it does mean that developers working in Florida face more challenging conditions than developers in states with higher electricity rates.

5.3 Rate Structures

Differentials between on-peak and off-peak time-of-use rates are key drivers of behind the meter storage markets. While Florida's major utilities offer opt-in residential and commercial time-of-use rates, the PSC does not allow utilities to make these rates mandatory. Among FPL and Duke's customers – which account for over half the state's electricity meters – those who choose time-of-use rates tend to be smaller commercial customers. Other large utilities, including Tampa Electric Company and Jacksonville Electric Authority, offer time-of-use rates for commercial but not residential customers. The limited reach of TOU rates in the state reduces the value of behind the meter storage revenue streams like peak-shaving and TOU arbitrage, making investing in battery storage less attractive for potential buyers. This is compounded by Florida's demand charges, which are lower than those in much of market-leader California.

5.4 Lack of Renewable Generation Mandates

While renewables are not necessary for economical energy storage deployments, greater penetration of variable renewables increases opportunities for energy storage to provide benefits to the grid. Renewable mandates can push states toward higher penetration levels more quickly than market force might. Florida flirted with an RPS a decade ago, but no such mandate exists in the state today. Most observers do not believe there is much state-level interest in revisiting the issue. However, the falling cost of solar generation is driving Florida utilities to procure increasing amounts of solar on economics alone. Multiple Florida sources indicated that they expect storage to be particularly valuable to munis like JEA that are approaching or plan to approach 10% solar penetration.

5.5 Restrictions on Behind the Meter Solar Market

Another barrier to widespread storage deployment in Florida is the state's relatively low rooftop solar penetration. Expansion of distributed solar has been a driver of behind the meter storage deployments in other states, because the value of behind the meter storage is often enhanced when it is paired with solar assets. Despite Florida's sunny climate, retail net metering policy, and property tax exemptions for home solar installation, rooftop solar is hampered by the limitations on third-party electricity sales. Some residential solar installers left the state in recent years due to the poor market outlook for rooftop systems, but important players have begun to return since voters rejected additional restrictions proposed during the November 2016 election.

⁵¹ US Energy Information Administration, "State Electricity Profiles," January 17, 2017, <https://www.eia.gov/electricity/state/>.

5.6 Data Access

Florida does not generally require utilities to share energy use data. Representative load data is sufficient for high-level analyses, but property owners interested in storage must estimate its cost-effectiveness based on their own building's actual electricity demand. Most building owners lack the sophistication to perform their own analysis, so they must either provide their load data to a third party for analysis or consent to third party data access on their behalf. In many areas of the US, utility companies have failed to create easy processes for customers or their designated third parties to access their own data. Some states have adopted policies requiring more cooperation, but Florida has not. This lack of data access allows inefficiencies to persist in markets for behind the meter storage and other customer-sited distributed energy resources.

5.7 High Customer Acquisition Costs

Successfully marketing storage projects requires considerable investments of time, funding, and other resources. For front of the meter projects, developers report pitching projects to dozens of utilities for each request for proposal (RFP) they ultimately secure. One developer cited marketing costs of \$5,000 to \$10,000 for each RFP they see issued. Yet, in this case, an RFP simply means a developer has convinced a utility that it is worthwhile to begin seeking more information about a project. There is no guarantee that the developer who spent the money convincing the customer to issue the RFP will be the one to win a bid and capture the value of the project. In fact, the same developer estimated their chances of winning a bid at less than 50% – and much lower if the bid is sized large enough to provide satisfactory compensation (in the form of a developer fee) for the demand generation activities that led to the opportunity. This is a significant disincentive to engage in the primary demand generation activities necessary to connect vendor supplies and customer demand.

6 Opportunities

Despite severe challenges, conversations with Florida stakeholders reveal significant opportunities in the storage market. Demand for battery storage will not be as high in Florida as in states with organized ancillary services markets, aggressive renewable energy mandates, high rooftop solar penetration, and extensive time-of-use rates. Nonetheless, the state's size, solar resources, reliability and resiliency concerns, and capable utilities position it to potentially become an important storage market. This section describes the most promising avenues for meaningful storage deployment in the near term.

6.1 Investor-Owned Utilities

Florida's un-restructured electricity sector and utility cost-of-service regulation can discourage investment in storage. Yet even under cost-of-service regulation, IOUs still face pressure to control costs. Batteries, especially as they become cheaper and quicker to deploy, represent an addition to the toolbox an IOU draws from as it seeks to serve load efficiently enough to earn attractive returns. If regulators allow the companies to own behind the meter storage, they also have an opportunity to offer a new technology to customers while exploring opportunities to cushion themselves against the threat of diminished demand charge revenue. The strong relationship that key Florida IOUs enjoy with the PSC and with parent companies that are accumulating significant experience with battery projects may position these companies well to capture value as storage costs decline.

6.2 Public Utilities

Twenty-five percent of Floridians obtain electricity through non-profit municipal utilities or rural electricity cooperatives. These organizations generally seek to deliver low-cost electricity to their customers – who in many cases are also their owners – rather than to earn returns on investments with which to reward shareholders. This means decisions about adopting new technologies can be driven by organizational capacity and consequences for customers without the additional level of consideration that IOUs must give to shareholder value. This incentive structure may prove important for battery storage, which in some cases can diminish opportunities for IOUs to earn regulated returns by offering a lower-cost alternative to traditional utility-sector investments.

Municipal utilities serve 15% of the state's customers and play an important role in Florida's electricity landscape. Florida munis are for the most part not directly regulated by the state Public Service Commission and can alter policies more quickly than the more heavily regulated IOUs. Jacksonville Electric Authority, one of the ten largest public utilities in the US by number of electric meters served, has taken advantage of this flexibility to announce wide-ranging changes to the way it compensates distributed energy resources, including solar and battery storage.

In October 2017, JEA announced a rebate program that will offset 30% of the cost of behind the meter battery systems up to a cap of \$2,000 per system. Due to JEA's status as a municipal utility, the rebate program was approved by JEA's Board of Directors rather than the Florida PSC. This was part of a larger policy shift that included reducing the net metering rate paid to new distributed solar installations by more than two-thirds and expanding procurement of

utility-scale solar.⁵² To the authors' knowledge, this is the first financial incentive program for customer-owned battery storage offered by a municipal utility in the US. JEA has budgeted up to \$1 million for the rebate program and has suggested it expects about 500 customers to take advantage of the rebate each year.

Nonprofit rural electric cooperatives (co-ops) serve 10% of Florida customers and face similar incentive and regulatory structures as municipal utilities. Florida has two generation and transmission (G&T) co-ops, PowerSouth Energy Cooperative and Seminole Electric Cooperative, and 16 distribution co-ops. Distribution co-ops buy power from wholesalers or procure it from the G&T co-ops. G&T co-ops are owned by distribution co-ops, which work together to set rate structures. In some cases, this can lead to frustration when customers of one distribution co-op feel their G&T co-op is serving the interests of other member distribution co-ops at their expense. Project developers report that storage can be particularly attractive for distribution co-ops in this situation who are seeking to change their load profile to adapt to rate structures imposed by their G&T. Connexus (see Case Study 1) is an example of a distribution co-op seeking to use storage to reduce exposure to coincident demand charges owed to its G&T. However, even though co-ops may have greater incentive to invest in storage than IOUs, one developer estimated that only about 1 in 20 co-ops have the capacity to make these investments. This demonstrates the challenge associated with deploying storage even when regulatory incentives do not work against the technology.

6.3 Incentives

Incentives can have a significant impact on the economics of battery storage and may be justified by inefficient market structures that do not allow storage owners to be fully rewarded for the benefits they provide to the grid. States with high levels of storage deployments have achieved this through a combination of market design, mandates, and incentives. Based on conversations with local stakeholders, increased incentives would likely find more political support than mandates or large market design changes in Florida. JEA's rebate program may provide an important test of this assertion.

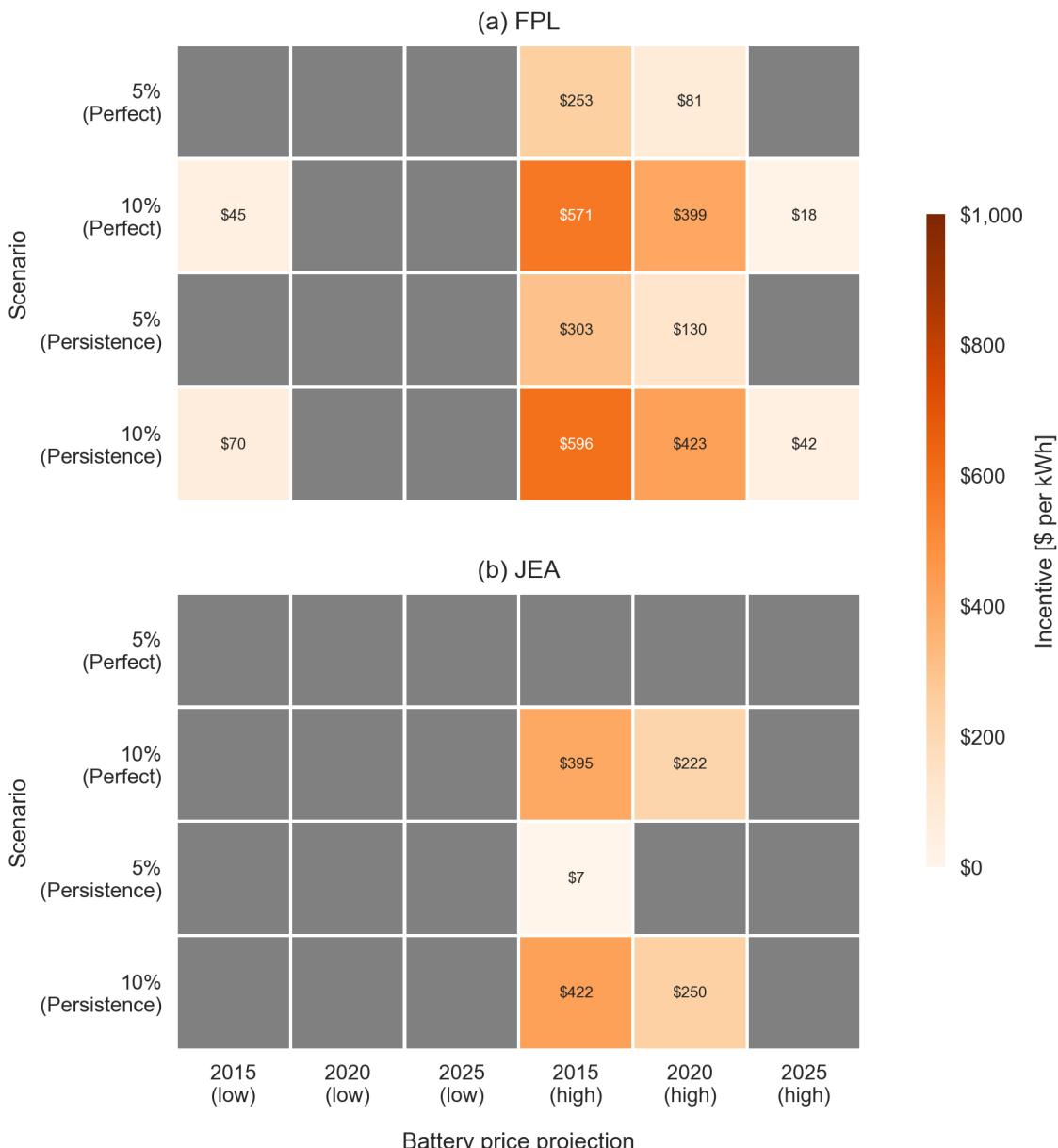
The most prominent incentive program in the US, California's Self-Generation Incentive Program (SGIP), peaks at \$500 per kilowatt-hour of storage deployed. A similar program in New Jersey, which excludes residential customers, offered \$300 per kWh before funding was exhausted. The NPV analysis presented in this report suggests that incentives sized closer to New Jersey's levels than to California's could create more nominally positive investment cases than would otherwise exist. However, uncertainty about the real cost of capital facing Florida storage developers and the risks of participating in the state's nascent storage market likely mean that a positive NPV alone is not enough to justify investment decisions. Nonetheless, this incentive analysis offers an outline of the magnitude of incentive necessary to make a difference for batteries deployed for demand charge management.

For storage projects sited at the fast food restaurant property with negative NPV in the initial analysis, Figure 5 shows how many dollars per kilowatt-hour are required to boost NPV to zero. An alternative description of this process is that, for all cases in which project IRR is lower than the assumed cost of capital without incentives, we calculate the per kilowatt-hour incentive levels required to produce IRR equal to the cost of capital. At these incentive levels, the

⁵² Robert Walton, "New Florida muni solar program cuts NEM rates, includes battery storage incentives," Utility Dive, October 23, 2017, <http://www.utilitydive.com/news/new-florida-muni-solar-program-cuts-nem-rates-includes-battery-storage-inc/507868/>.

projects would earn rates of return high enough to offset the cost of capital used to finance the battery systems. This means the incentive levels suggested in Figure 5 represent the minimum levels required to create profitable investments. Appendix C presents similar tables for the other properties analyzed in this report.

Figure 5: Incentive Levels (Dollars per Kilowatt-Hour) Required to Create Non-Negative NPV for Fast Food Restaurant (Intermediate Load Factor) by Scenario



The incentive levels (\$ per kWh) required to push negative NPV values to zero for the fast food restaurant load profile under Florida Power & Light (FPL) and Jacksonville Electric Authority (JEA) rates. Scenarios with positive NPV values before incentives are shown as empty grey cells.

6.4 Amendment 4

Florida voters have demonstrated interest in supporting the development of distributed solar. In 2016, 73% of voters approved Amendment 4, which directed legislators to expand property tax exemptions for solar installations. Implementing legislation was signed in June 2017. Florida already had a prohibition on including renewable energy devices installed in 2013 or later in taxable property values. Amendment 4 expands that prohibition to include renewable energy devices on any real property and expands the definition of renewable energy device.⁵³ Developers in the state say the measure provides significant cash flow benefits. The law applies to batteries used to store renewable generation and could be a template for expanding this type of exemption to stand-alone storage projects that offer benefits to the grid even when they are not charged by renewable resources, as Maryland's recently-passed SB 758 has done.

6.5 Municipal Renewable Energy Mandates

A new potential driver of storage demand is municipal renewable energy standards. A statewide renewable portfolio standard in Florida remains unlikely. However, the falling cost of renewables and grassroots pressure is driving more cities to enact increasingly ambitious clean energy mandates, and Florida cities, including Orlando, have adopted 100% clean energy targets.

However, while municipal clean energy mandates may become drivers of Florida storage deployment, these goals will require years of dedicated work, political will, and financial resources to become reality. Today's municipal clean energy pledges are aspirational goals that mark the start of a long-term process, not detailed planning frameworks. While dedicated program implementers and city sustainability managers are aware of the potential benefits of storage, other city officials often are not. Florida cities also have little ability to pressure the IOUs that serve their load to procure more renewable energy. The Orlando municipal utility's experience implementing the city's pledge could set an important precedent.

⁵³ Florida Senate Appropriations Subcommittee on Finance and Tax, Bill Analysis and Fiscal Impact Statement, CS/SB 90, April 12, 2017, <https://www.flsenate.gov/Session/Bill/2017/90/Analyses/2017s00090.pre.aft.PDF>.

7 Recommendations

Based on the growing number of studies that find significant value in battery storage across a range of US regulatory regions, Florida stakeholders may find it worthwhile to identify opportunities to increase the rate of deployment of these resources in their own state. While early US battery storage investments were driven by short duration ancillary services markets in the PJM Interconnection and by incentives and mandates in California, this research suggests that different factors will drive Florida's market. The following recommendations build on the market drivers and opportunities identified in this report and are tailored to fit Florida's energy and policy landscape:

- **Ensure utilities evaluate storage:** The PSC should seek disclosure from Florida IOUs regarding their efforts to incorporate storage in their integrated resource planning. Large utilities across the country have struggled to incorporate the unique characteristics of battery storage into their resource planning processes. Better methodologies are emerging as DOE laboratories create modeling tools and utilities such as Portland General Electric commit to clear processes for determining when storage may be a least-cost resource. The PSC should ask Florida IOUs to describe their efforts to understand costs of storage and other emerging resources and to incorporate these in their resource planning. The Washington State Utilities and Transportation Commission's recently issued statement on the treatment of energy storage in resource planning provides a good example of the next step in this process - which is to use knowledge gained about how utilities currently evaluate storage technologies as a basis for issuing guidelines on how to improve.⁵⁴
- **Foster knowledge networks:** Business models and policy options are proliferating in the battery storage space. Stakeholders should ensure that lessons are shared across municipalities, service territories, and other jurisdictions. More broadly, these knowledge efforts should include consideration of other resources, including demand response, alternative storage technologies, and distributed generation, with the goal of determining an optimal technology mix. Initiatives are underway throughout the Southeast that focus on opportunities and challenges associated with new power sector technologies and the region's vertically-integrated power sector. These include Alabama's Southern Research, Georgia Tech's Energy Policy and Innovation Center, North Carolina's Clean Energy Technology Center, and Florida's FAASSTeR.
- **Educate lawmakers and city officials:** Florida lawmakers and officials have generally not been exposed to data on the falling cost of batteries and the growing set of stationary storage installations around the US. When faced with decisions on the state's power sector, they should be aware of the trajectory of batteries and other emerging technologies. City officials responsible for implementing municipal renewable portfolio standards, who often lack realistic options for influencing the resource mix of a large utility, should be aware of opportunities to use batteries to boost the amount of renewable power capable of serving local load pockets.
- **Facilitate data access:** Unlike some other states, Florida has not adopted policies to facilitate third-party access to load data from utility companies. This data is crucial to enabling markets in which storage developers can identify and develop promising projects. It would also benefit developers of demand response and distributed solar projects.

⁵⁴ Washington Utilities and Transportation Commission, *Report and Policy Statement on Treatment of Energy Storage Technologies in Integrated Resource Planning and Resource Acquisition*, 11 October 2017.

- **Consider tax incentives:** The recent success of Florida's SB 90 legislation, which provides a property tax exemption for 80% of the value of installed renewable energy devices, provides an example of Florida advocates, voters, and legislators using tax policy to facilitate adoption of new power sector technologies. SB 90 applies to batteries charged by renewable resources, but Maryland's recently-passed SB 758 provides a first-in-the-nation example of a dedicated energy storage tax credit which does not require systems to be charged by renewable energy.
- **Consider targeted financial incentives:** Limited financial incentive programs could be used to encourage clusters of behind the meter battery deployments strategically located to support grid operations or policy goals. Section 6.3 and Appendix C of this report find that incentive levels significantly lower than the \$500 per kilowatt-hour level offered through California's Self-Generation Incentive Program (SGIP) could expand the number of properties for which behind the meter batteries could make economic sense. JEA's new rebate for batteries may offer important opportunities for learning how Florida customers respond to this approach.
- **Identify value stacking opportunities:** Value stacking is easier in restructured states with organized capacity and ancillary services markets, but projects in Arizona suggest that vertically-integrated utilities can use this strategy to improve the benefit-cost ratio of battery systems as well.

8 Conclusions

Battery storage plays almost no role in the Florida grid today, but the technology is poised to grow significantly in the state. Florida's largest investor-owned utilities appear enthusiastic about storage's potential, and their approved large-scale pilot projects are important opportunities to demonstrate the value of front of the meter batteries. Industry players are rapidly accumulating experience and understanding of the technology and where it can be deployed economically. Solar deployments, which have been limited by economics and restrictive regulation, also look set to grow rapidly with an assist from falling prices and voter preferences. This will feed demand for both grid-scale and behind the meter storage.

Florida could do much more to capture the potential value of storage in applications where this value has already been demonstrated. Behind the meter systems are already attractive investments for certain customer classes, though many of those customers may be unaware of the returns they could earn by investing in batteries. Restrictions on customer-sited solar installations and lack of access to energy data undercut some of the key drivers of behind the meter storage observed in other states, likely preventing building owners from accessing worthwhile investment opportunities that could also provide additional system-level benefits to the grid. Florida utilities are embarking on significant front of the meter storage projects, but the state's traditionally-structured power sector may limit these deployments. It also makes such deployments difficult for outside analysts to study.

There are a range of options the state could consider to boost storage deployment if legislators, regulators, or utility officials determine this to be a policy goal. These include facilitating data access, investing in robust system modeling to identify optimal storage deployment levels and locations, removing barriers to behind the meter solar deployment, urging utilities to provide more details about how they consider declining storage costs in their resource planning, and adopting mechanisms to help storage owners capture more of the value provided by their assets.

This report estimates an upper and lower bound on cost savings for behind the meter storage optimized for demand charge management. There is significant scope to expand on the analysis by modeling the economic value of behind the meter storage optimized for value-stacking and to use geographic information system methods to estimate how many properties in the state might face positive investment cases. This would provide important insights on market size. Further analysis could also examine the impact of JEA's rebate program and the Investment Tax Credit for storage systems paired with solar generation. It will also be critical to supplement research on the economics of battery storage with similar research around other emerging technologies and to undertake robust system modeling to determine where various technologies might be cost-effective on Florida's grid. The authors of this report look forward to forthcoming research from Florida and other Southeastern states on these topics. Alongside this report, such research will better assist policymakers, consumers, and industry in making effective and informed decisions about the future of Florida's power grid.

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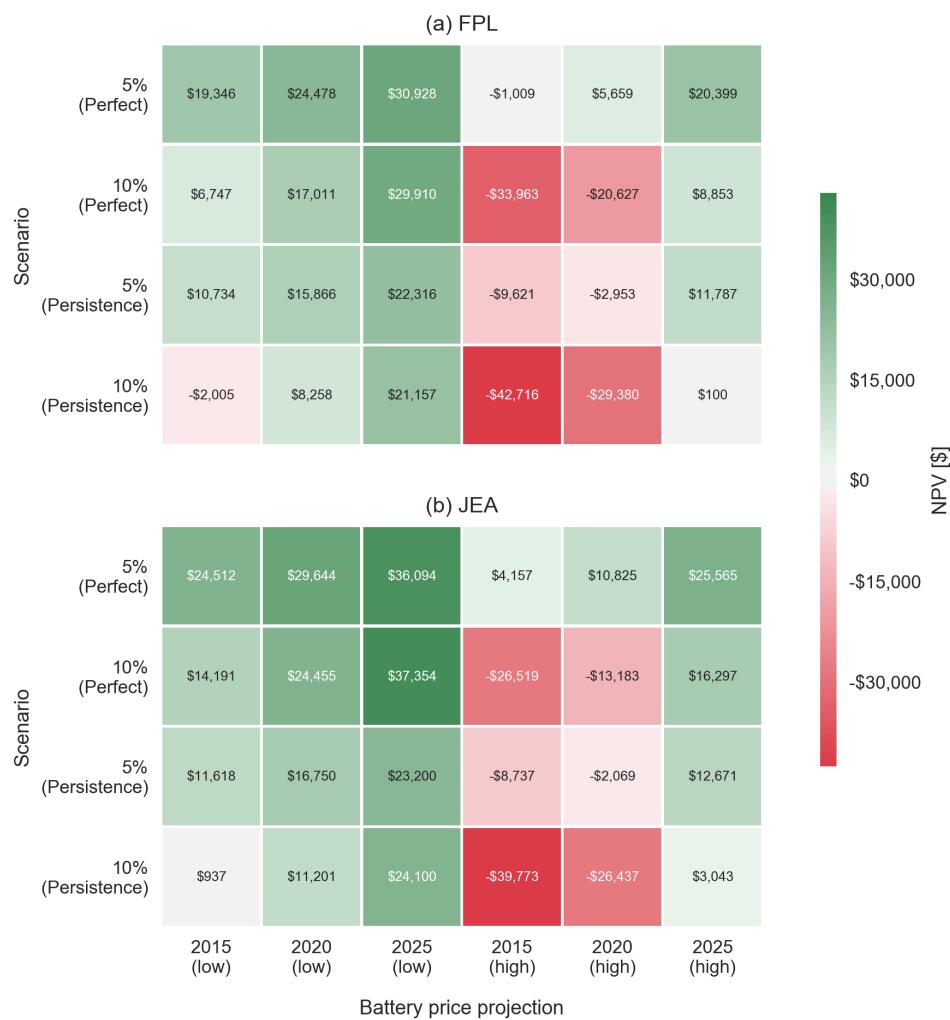
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Appendix

Appendix A: Net Present Value

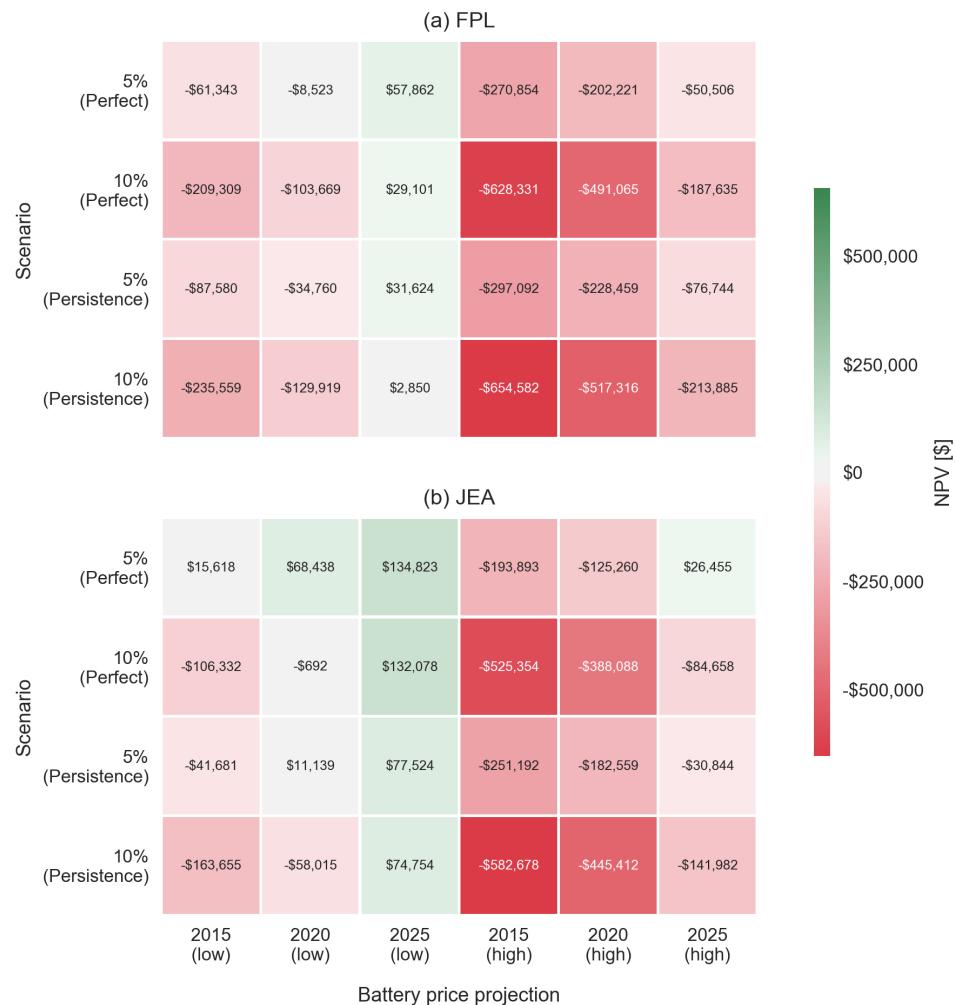
Cells in Figures 6 – 10 are color-coded for easy visual interpretation of scenarios with large positive and large negative NPVs, with darker red cells indicating large negative NPVs and darker green cells indicating large positive NPVs. See Section 4.1.3 for details of the NPV analysis.

Figure 6: NPV Values for Warehouse Load Profile (Low Load Factor)



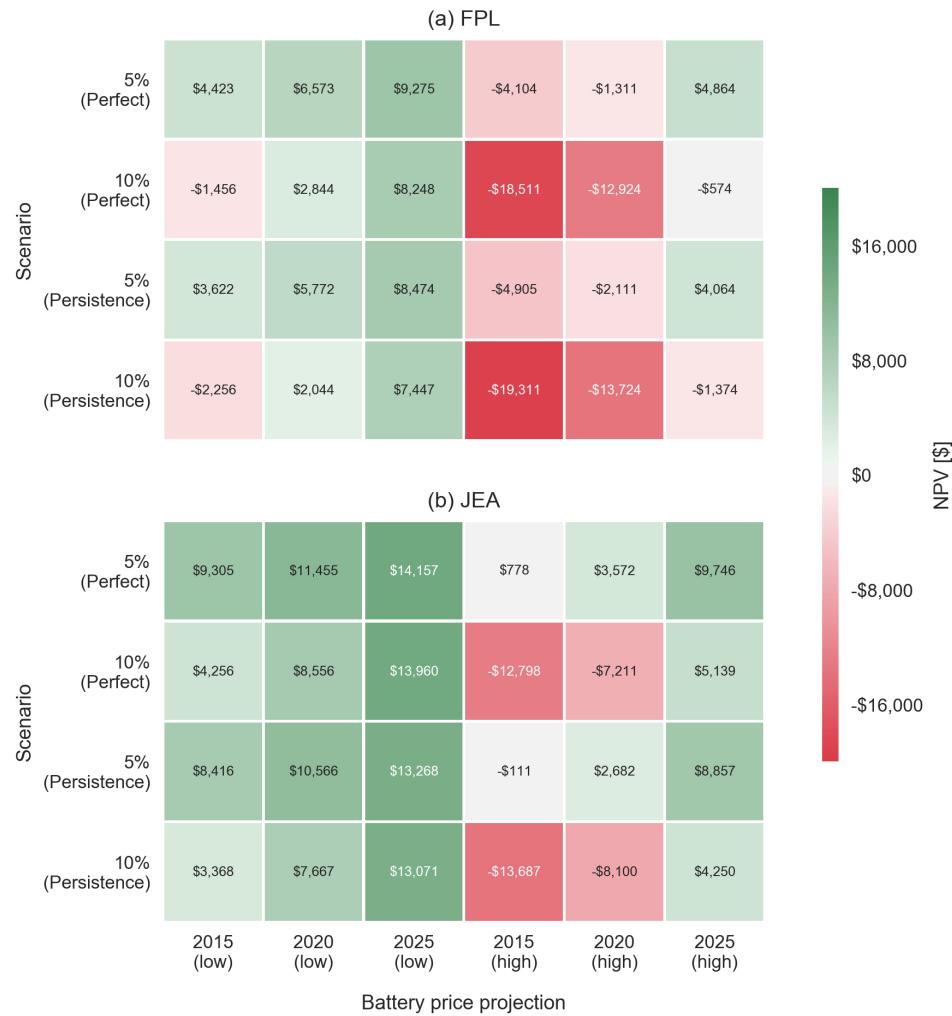
NPV values for the warehouse load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high 2015, 2020 and 2025 estimates). Annotated values are shown inside each cell, in addition to the color map of NPV.

**Figure 7: NPV Values for Hospital Load Profile
(High Load Factor)**



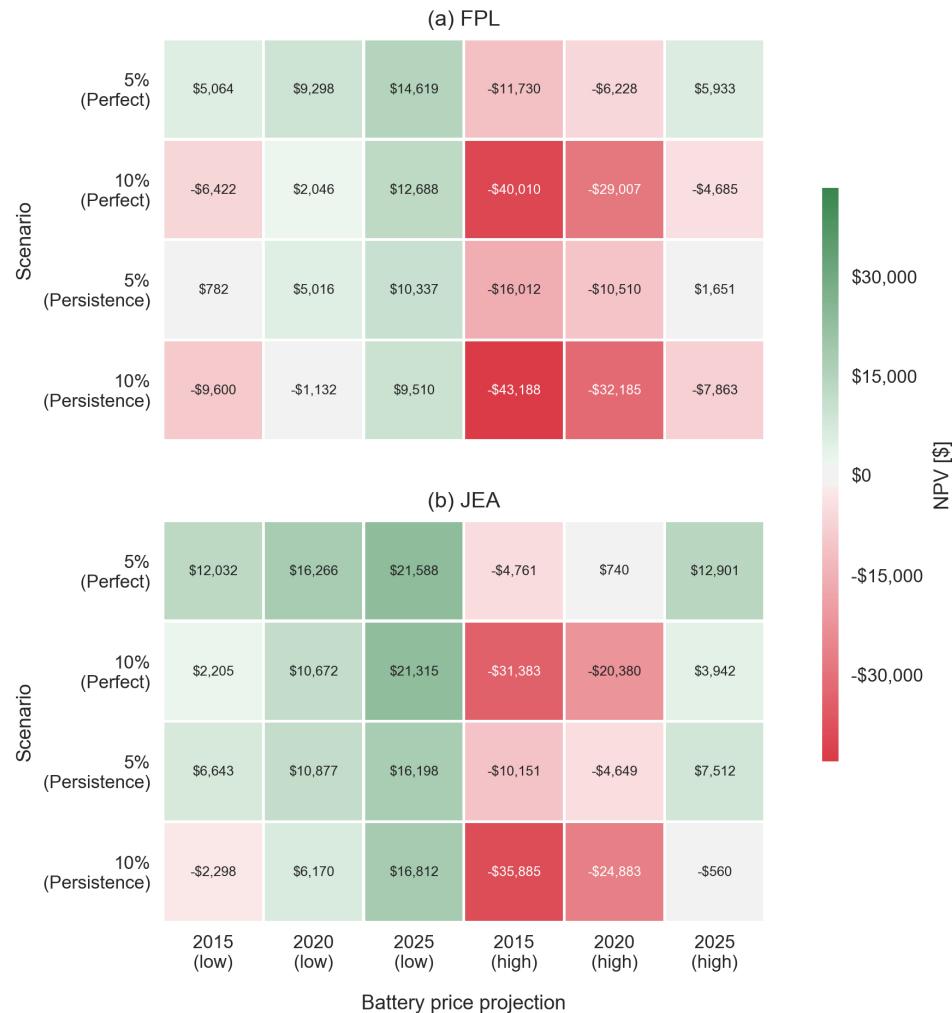
NPV values for the hospital load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the NPV of a single scenario.

**Figure 8: NPV Values for Fast Food Restaurant Load Profile
(Intermediate Load Factor)**



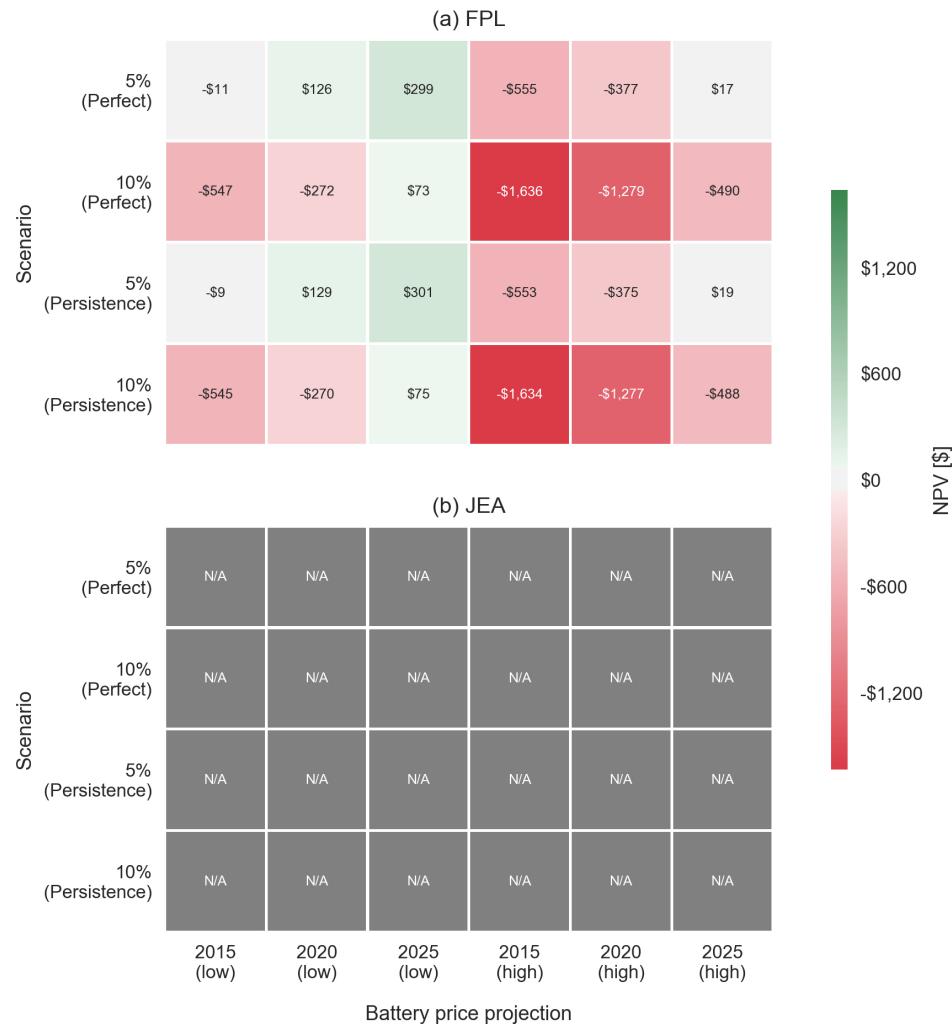
NPV values for the fast food load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the NPV of a single scenario.

**Figure 9: NPV Values for Small Hotel Load Profile
(Intermediate Load Factor)**



NPV values for the small hotel load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the NPV of a single scenario.

**Figure 10: NPV Values for Residential Load Profile
(Intermediate Load Factor)**

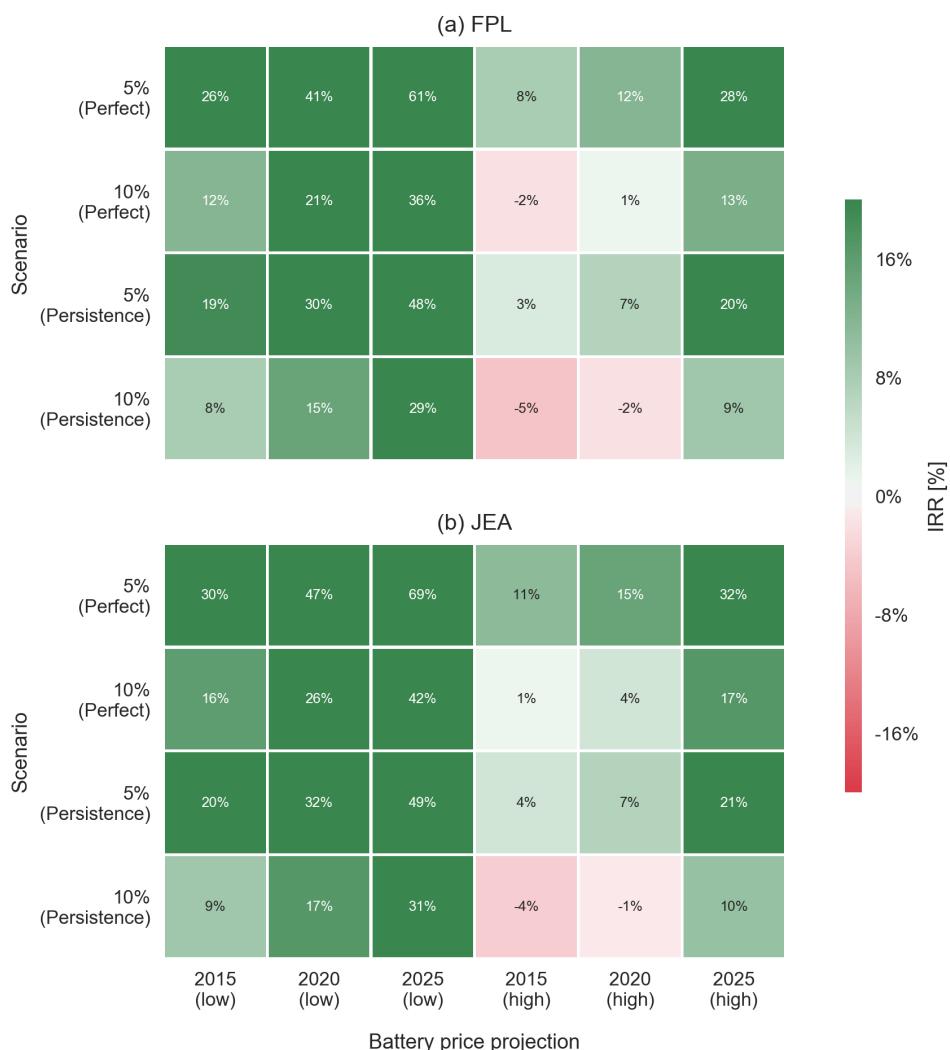


NPV values for the residential load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the NPV of a single scenario. Note that JEA does not offer residential time-of-use rates, so there are no opportunities for cost saving under this model.

Appendix B: Internal Rate of Return

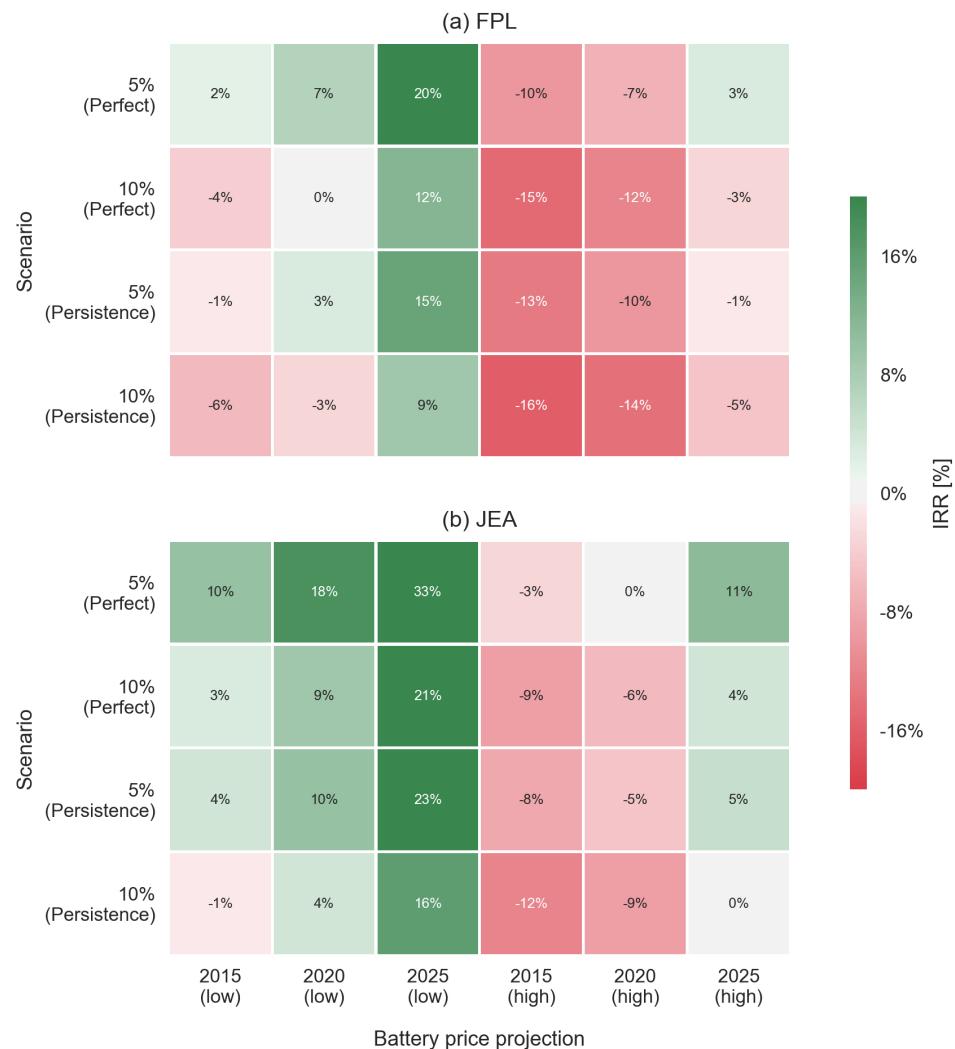
Internal rate of return (IRR) analysis, presented in this section, is a better metric than NPV for comparing investment cases across properties of varying size. Cells in Figures 11 – 15 are color-coded for easy visual interpretation of scenarios with large positive and large negative IRRs, with darker red cells indicating large negative IRRs and darker green cells indicating large positive IRRs. See Section 4.1.4 for details of the IRR analysis.

Figure 11: IRR Values for Warehouse Load Profile (Low Load Factor)



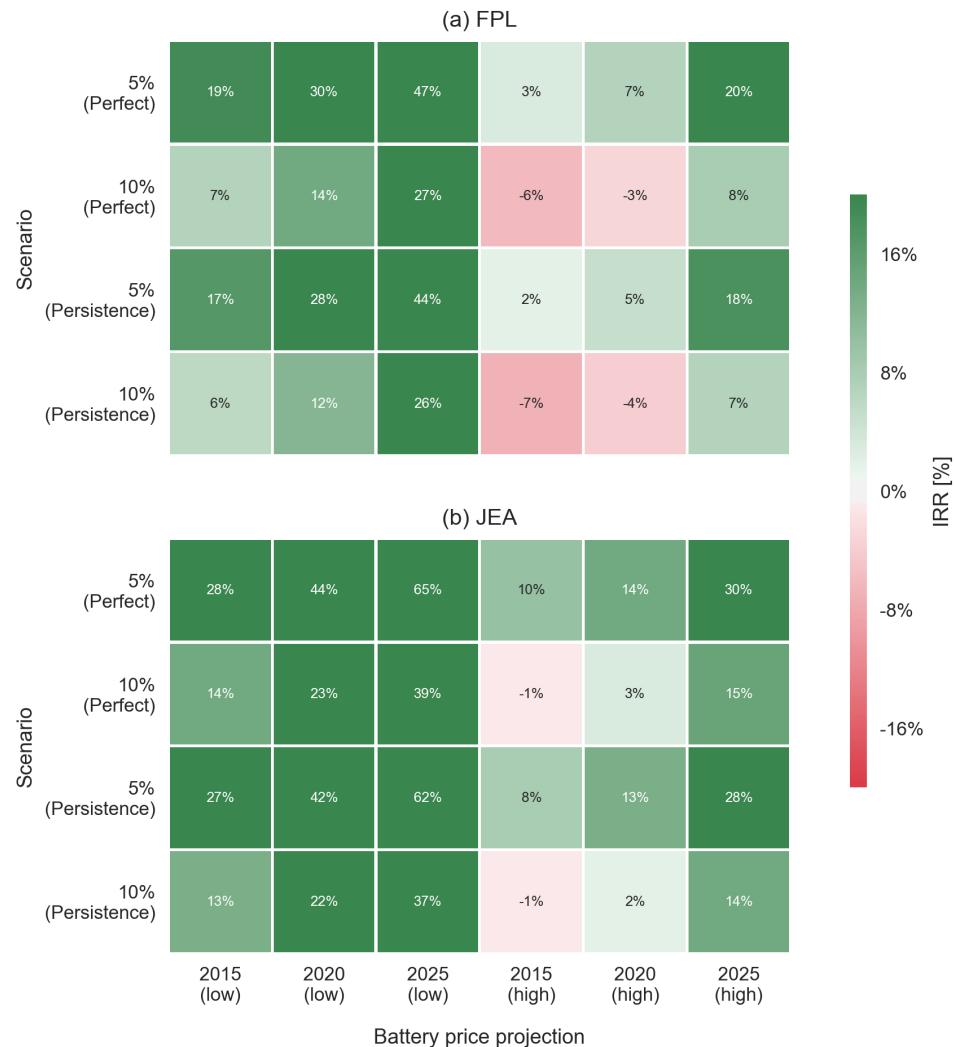
IRR values for the warehouse load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the IRR of a single scenario.

**Figure 12: IRR Values for Hospital Load Profile
(High Load Factor)**



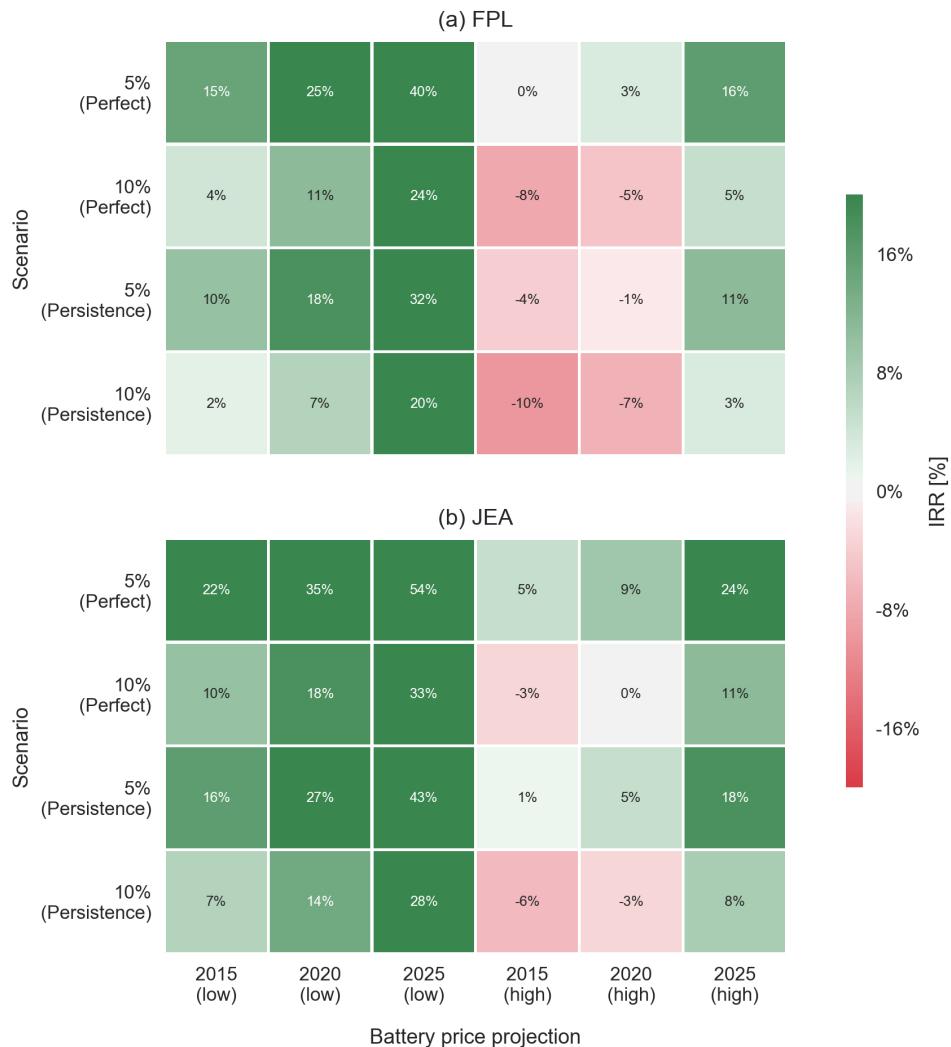
IRR values for the hospital load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the IRR of a single scenario.

**Figure 13: IRR Values for Fast Food Restaurant Load Profile
(Intermediate Load Factor)**



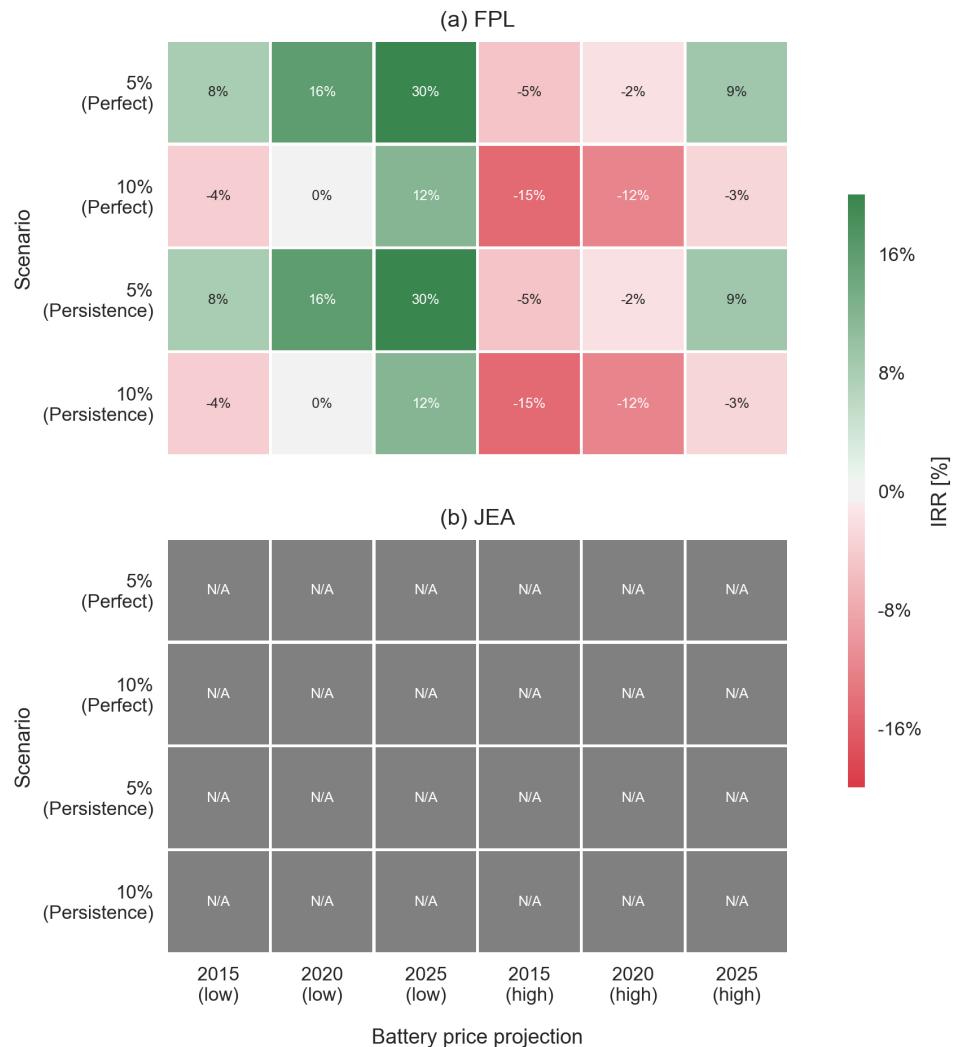
IRR values for the fast food load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the IRR of a single scenario.

**Figure 14: IRR Values for Small Hotel Load Profile
(Intermediate Load Factor)**



IRR values for the small hotel load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the IRR of a single scenario.

**Figure 15: IRR Values for Residential Load Profile
(Intermediate Load Factor)**

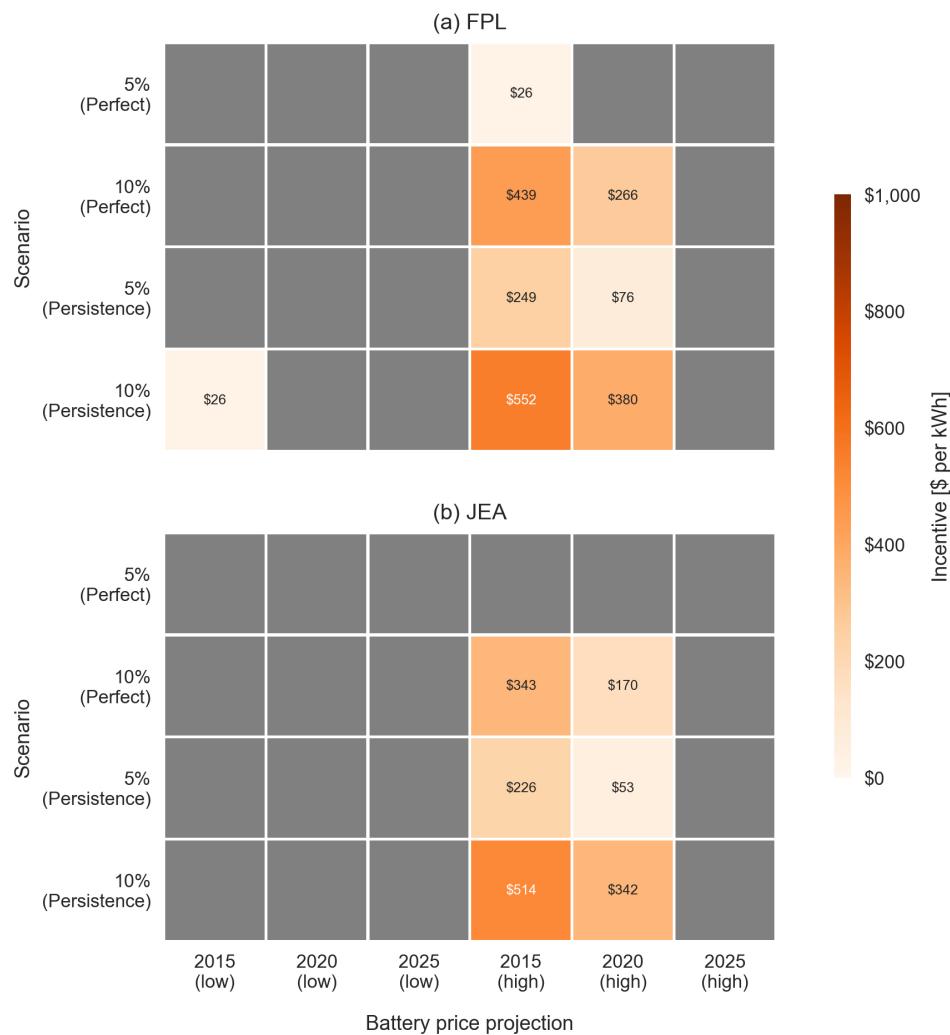


IRR values for the residential load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the IRR of a single scenario. Note that JEA does not offer residential time-of-use rates, so there are no opportunities for cost saving under this model.

Appendix C: Incentives

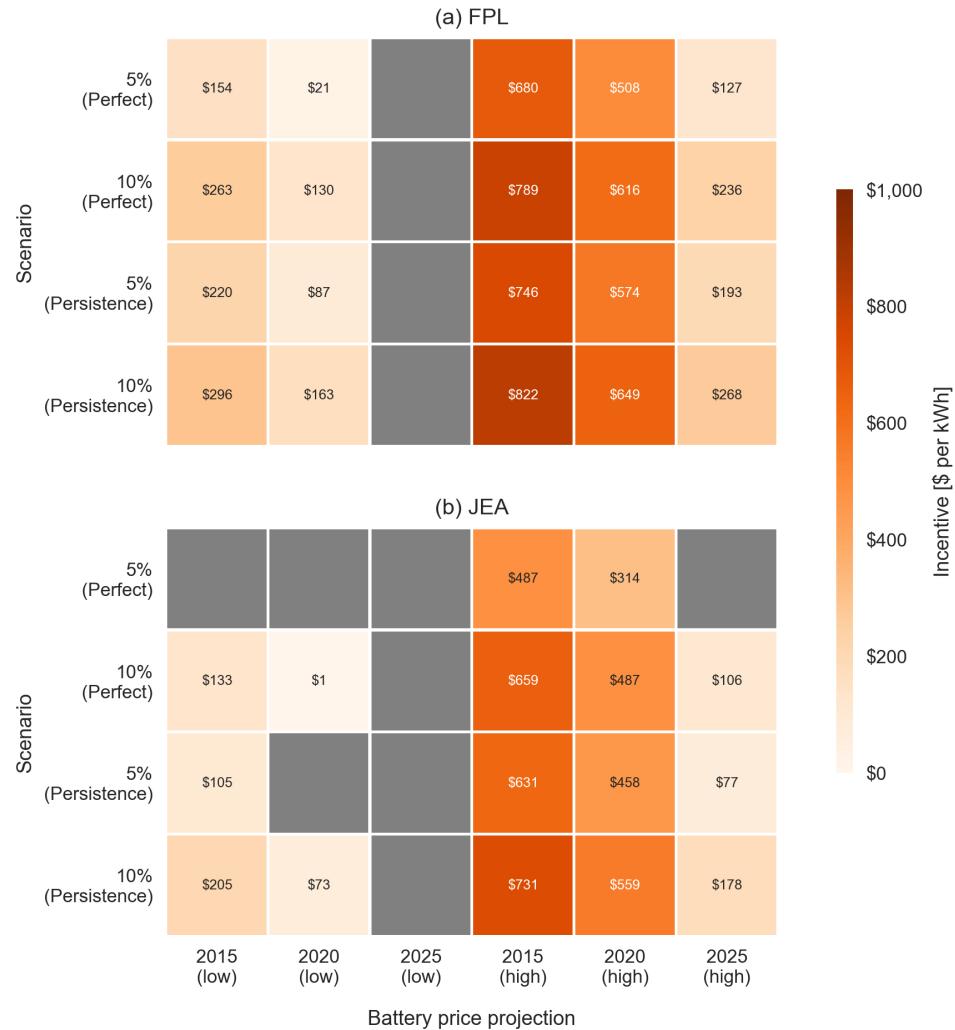
The complete breakdown of tax incentives (\$ per kWh) required to bring negative NPV scenarios up to zero NPV is presented in Figures 16 – 20. Cells in the following tables are color-coded to indicate the magnitude of incentives required for each scenario. Scenarios which have positive NPV without incentives are shown as blank grey cells. See Section 6.3 for details on incentives and Section 4.1.3 for details of the NPV analysis.

Figure 16: Incentive Levels Required to Produce Non-Negative NPV for Warehouse Load Profile (Low Load Factor)



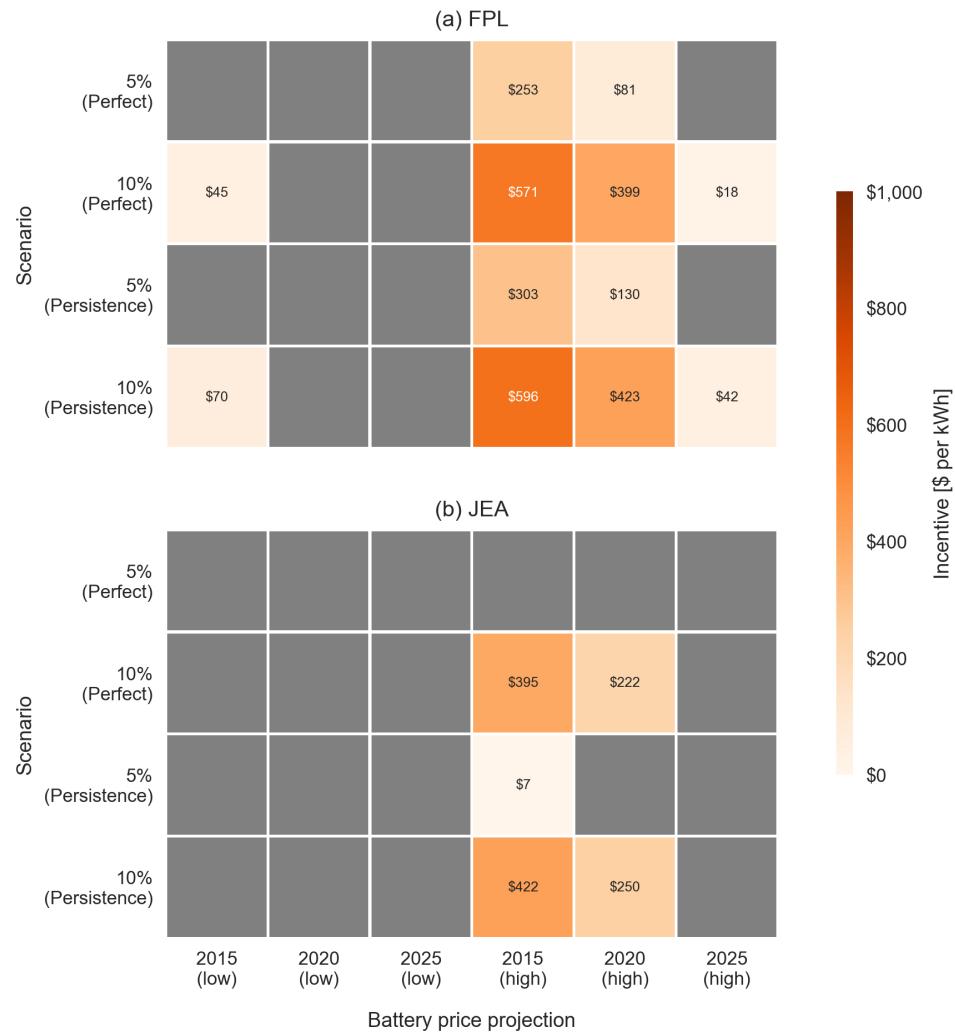
Incentives (\$ per kWh) required to reach zero NPV for the warehouse load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the incentive level required to produce a non-negative NPV in the scenario represented by that cell or indicates that NPV is already non-negative for that scenario.

Figure 17: Incentive Levels Required to Produce Non-Negative NPV for Hospital Load Profile (High Load Factor)



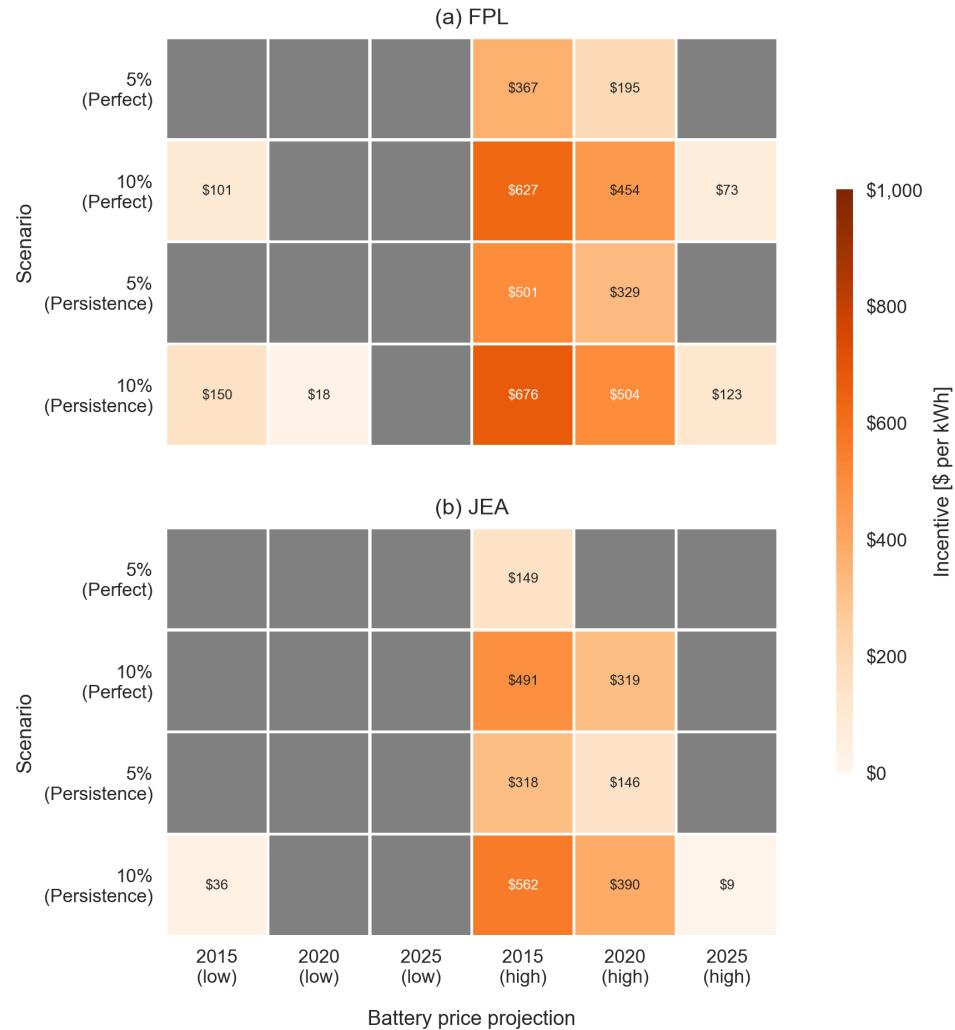
Incentives (\$ per kWh) required to reach zero NPV for the hospital load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the incentive level required to produce a non-negative NPV in the scenario represented by that cell or indicates that NPV is already non-negative for that scenario.

Figure 18: Incentive Levels Required to Produce Non-Negative NPV for Fast Food Restaurant Load Profile (Intermediate Load Factor)



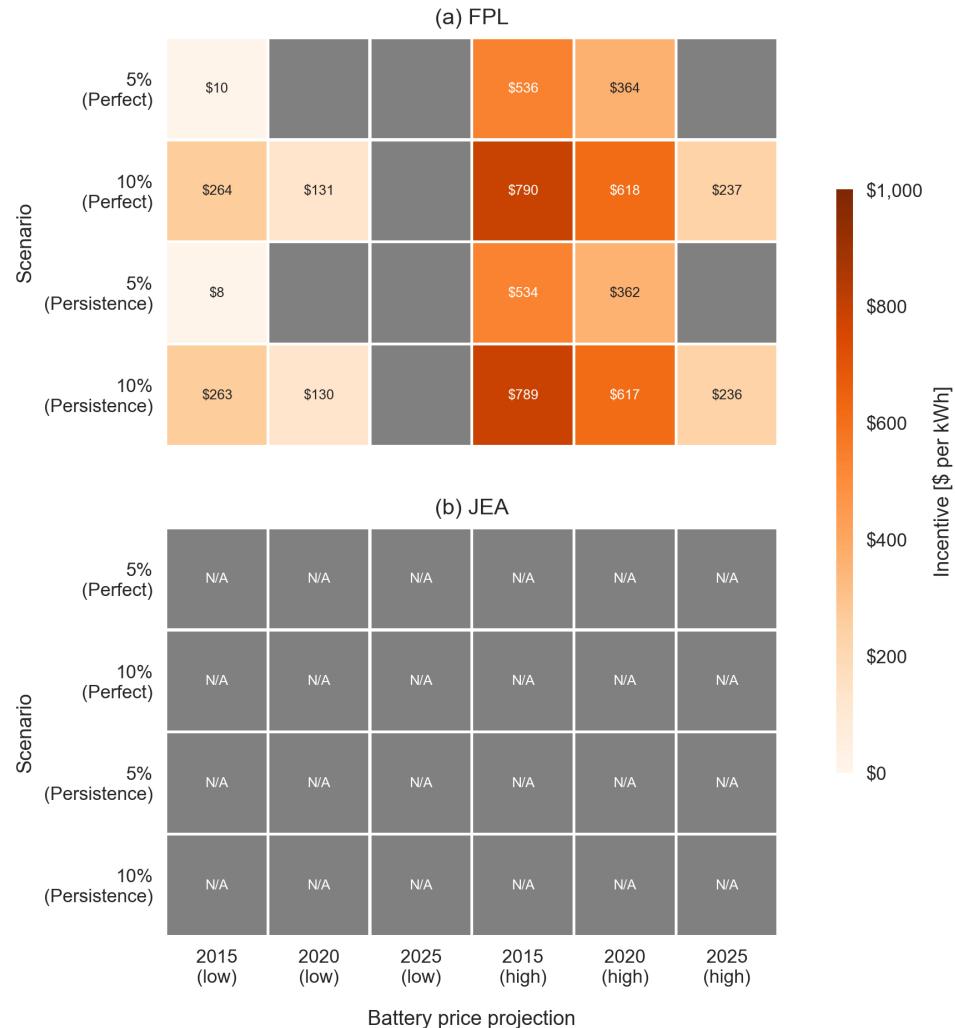
Incentives (\$ per kWh) required to reach zero NPV for the fast food load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates for a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the incentive level required to produce a non-negative NPV in the scenario represented by that cell or indicates that NPV is already non-negative for that scenario.

Figure 19: Incentive Levels Required to Produce Non-Negative NPV for Small Hotel Load Profile (Intermediate Load Factor)



Incentives (\$ per kWh) required to reach zero NPV for the small hotel load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the incentive level required to produce a non-negative NPV in the scenario represented by that cell or indicates that NPV is already non-negative for that scenario.

Figure 20: Incentive Levels Required to Produce Non-Negative NPV for Residential Load Profile (Intermediate Load Factor)



Incentives (\$ per kWh) required to reach zero NPV for the residential load profile under (a) Florida Power & Light (FPL) and (b) Jacksonville Electric Authority (JEA) rates a range of battery sizes (5% and 10% of peak demand), forecasts (perfect and persistence), and battery price projections (low and high estimates for 2015, 2020, and 2025). Each cell represents the incentive level required to produce a non-negative NPV in the scenario represented by that cell or indicates that NPV is already non-negative for that scenario. Note that JEA does not offer residential time-of-use rates, so there are no opportunities for cost saving under this model.