On-Site Renewable Energy Storage at San Diego Gas & Electric's Century Park Campus

Sandy M. Shamblin
School of Sustainability, Arizona State University
EMS 588: MSL Capstone
Prof. Jay Beeks
April 12, 2020

Executive Summary

This document contains a feasibility study that explores the necessity, collaborations, and possible methods of installing a 1 megawatt lithium-ion battery storage facility at San Diego Gas & Electric's Century Park campus located in the Kearny Mesa neighborhood in central San Diego, California. The battery will serve purposes of adding renewable energy to the energy mix, reducing operations costs via peak shaving, an educational component for the region, and meeting stringent State of California and California Public Utilities Commission mandates for both renewable energy and battery storage capacity.

On-Site Renewable Energy Storage at San Diego Gas & Electric's Century Park Campus

In a hotter, scarcer, and more open world, the dramatic need for clean and renewable energy is coming ever more in to focus. If the average layperson was doubtful, the State of California has set a series of goals to meet 60% renewable energy by 2030, and 100% renewable energy by 2045 (Domonoske, 2018). Opponents to renewables ask what happens to solar at night or wind on a still day and point out that "power from these renewable generation sources is produced at different times of the day, and often does not align with the instantaneous demand for electricity" (CAISO, 2014). However, the technology to store renewables in a battery storage facility for use at a later time exists, such as at high demand and peak pricing, and will be essential to California's meeting renewable energy goals in a robust, resilient, and efficient manner.

Battery technology, while not yet commonplace, is quickly becoming more attainable, as the technology advances and costs continue to go down. So much so that the State of California passed Assembly Bill 2514 and the California Public Utilities Commission (CPUC) has set battery targets for each of the investor-owned utilities (IOUs) in the State. These goals have set the IOUs on a quest to store 1,325 megawatts (MW) of energy in batteries by 2024. Further, research has estimated that by 2050 California will require 22 gigawatts (GW) of energy storage to successfully power the State (Shi, Wang, Xu, & Zhang, 2018).

In San Diego, California, the local IOU, San Diego Gas & Electric (SDG&E), is no stranger to renewables or battery storage. The utility is currently providing approximately 45% renewable energy every day (SDG&E, n.d.). It also has its hands in a variety of battery projects ranging from the Borrego Springs, California microgrid battery and what once was the largest lithium-ion battery storage facility in the world in Escondido, California (Weaver, 2018). Building a battery facility at SDG&E's central Century Park (CP) campus will enable the utility to gain further experience in the battery field, add to their required battery capacity, increase the number of renewables in the energy mix, and lower operations cost of the campus by providing their own peak-shaving via stored solar energy from the existing solar panels installed around the campus.

Previous Iterations

This project went through many iterations to reach its final form. Initially, this project focused on reducing building emissions via a remodel of CP buildings following LEED building

guidelines. Two factors came in to play that brought that original version of this project to a halt – the first being details of CP Renew being made public in late October 2019, which included minimally certifying all CP buildings with LEED. The other being the discovery of vehicle-to-grid (V2G) and bi-directional charging technology for electric vehicles (EVs).

As happens in life, when resistance is met, this project quickly shifted. With building emissions reduction already in place, SDG&E still needed to "make significant transformations in the way they produce and consume energy" (Meltzer & Sierra, 2011). Re-framing CP Renew to incorporate V2G quickly evolved into a new project. Preliminary research regarding V2G came back with an abundance of overwhelmingly interesting, relevant, credible, and salient information and examples that left researchers and initial audiences wondering why SDG&E was not actively pursuing light-duty V2G when others, locally in San Diego and across the world, were.

Unfortunately, reaching out to industry experts revealed that while V2G technology is here, battery longevity is not yet ready to support bi-directional charging, as V2G would require. Continuing to complicate matters is the lack of industry standards, which is making developers hesitant to develop V2G further. With deadlines looming, this project once again shifted focus into installing more EV charging at CP, building canopies over the uncovered EV charging spaces, and installing PV solar panels on the canopies. However, almost ironically, and to this study's chagrin, this project yet again shifted. Initial research into PV solar panels powering EV chargers led again and again to the need for on-site batteries. This need coming up at every turn delved this project down a rabbit hole of understanding how large-scale commercial energy batteries work and their role and importance in the energy landscape of the future.

With every season of this project, the study recognized the importance of being flexible and ready to adapt. After all, the basis of sustainability is to "meet the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations Environment Programme. n.d.). This entails creative problem solving, collaboration, effective communication, leadership, having a global context, and being able to adapt. Having battery facilities to store renewable energy certainly seems to fit this definition of meeting needs now and in the future.

Fate Intervening

As mentioned, in one of this study's previous forms, when the focus was on EVs and PV solar panels, conservations with industry experts and research kept turning to the issue of storing solar energy. A major turning point in this study was a conversation with Arizona State University's Electrical Energy Specialist, Emily Campion. A video tour utilizing FaceTime of an existing solar panel canopy on ASU's campus quickly turned into a video tour of the battery facility and the larger question of how to store the solar energy. While this brought the project to a standstill, it also brought this study to the more important question – how does one store solar energy? Or any renewable for that matter as "electricity generation from this source is limited to daytimes, depends on local weather conditions and fluctuates strongly over the year" (Hoppmann, Volland, Schmidt, & Hoffmann, 2014).

While the conversation with Ms. Campion certainly steered this study in the right direction, it was a fluke that ultimately turned this study on to the importance of battery storage facilities. A targeted ad one day on social media alerted this study to an upcoming webinar between the San Diego Zoo, EDF Renewables, and Cubic Corporation on the topic of the San Diego Zoo's brand new 1 MW battery storage facility located at the world-famous San Diego Zoo in central San Diego. It was as a result of this webinar that this study completely shifted gears into focusing on the necessity of SDG&E installing their own 1 MW lithium-ion battery storage facility at the CP campus.

Batteries as a Necessity

California is quickly adding more renewables to its energy mix. A sense of urgency has been created for all of the California IOUs to meet several goals by 2045 including ensuring that greenhouse gas emissions are 40% below 1990s levels, having the infrastructure in place for 1 million EVs to be on the roads, and that the utilities can reliably provide 100% renewable energy. These three main goals are a result of various legislation including Assembly Bill 32, Senate Bill 1275, and Senate Bill 100 (California Energy Commission, n.d.). In September 2019, California Governor Newsom allotted $700 million in funds to climate goals, including ramping up renewables and having sufficient infrastructure for EVs – which the charging infrastructure and energy demand related to their charging falls to the utilities to handle (Mulkern, 2019).

After the many false starts this study began with, it is clear that battery storage is desperately needed. "Battery energy storage systems are becoming increasingly important in power system operations. As the penetration of uncertain and intermittent renewable resources

increase, storage systems are critical to the robustness, resiliency, and efficiency of energy systems" (Shi et al., 2018). Even further underscoring the time crunch for functional batteries to come online is the 2013 CPUC decision that "energy storage procurement targets for each of the investor owned utilities totaling 1,325 MW [are] to be completed by the end of 2020 and implemented by 2024" (CAISO, 2014). That leaves precious little time for SDG&E to bulk up their battery inventory. This study was unable to procure the total amount of MW batteries SDG&E currently has deployed throughout the service territory. However, in 2018 SDG&E received CPUC approval for five separate battery facility projects totaling 83.5 MW throughout the service territory, including locations in central San Diego, Poway, Escondido, Fallbrook, and San Juan Capistrano in Orange County (Weaver, 2018).

Furthering the urgency for battery storage and adding a pull to the CPUC's push is California Assembly Bill 2868, which demands that California's IOUs open up battery storage projects to third-party bidders. While this is a bill designed to spur industry, collaboration, and to prevent IOUs from monopolizing batteries, it does slow down the design, construction, and implementation process for all IOUs, not just SDG&E. However, this leads to the opportunity for new collaborations. (St. John, 2019)

Mandatory Collaboration

With SDG&E being pushed to allow third-party bidders to be involved in rapidly adding battery storage capacity, it comes as a benefit that the IOU already has collaborated with other companies in some of their current battery projects. First is the remote town of Borrego Springs in eastern San Diego County. The town is set up as a microgrid – powered by a 4.5 MW lithium-ion battery owned by SDG&E. This project was completed to help the town stay powered during public safety power shutoffs resulting from high winds or wildfire threats and is the first of its kind. For this battery to work, SDG&E partnered with a Colorado-based software program, Spirae, to develop software to control the grid remotely from SDG&E's mission control in central San Diego and uses Smart Grid technology to control generation, storage, and switching remotely. This project should be an encouragement to other battery storage facility projects as its success can be replicated wherever SDG&E chooses. (Roth, 2019)

In February 2017, SDG&E briefly held the title as the owner of the largest lithium-ion battery storage facility at 30 MW in the north of their service territory in Escondido and unveiled a smaller 7.5 MW battery storage facility in the eastern service territory in El Cajon. These

batteries were built in partnership with AES Energy Storage, showing yet again that the IOU is no stranger to collaborating with third parties to complete state of the art battery storage facility projects. The Escondido battery facility is the reason why this study suggests SDG&E installs another lithium-ion battery at CP. Past experience and past success should be able to be replicated at SDG&E's main campus and what better project to mimic than a previous recording holding battery.

Existing Research

There is a wealth of battery storage facility research available, the majority of which is from very recent years due to the decline in costs and the advances in battery technology making battery projects all the more common. The majority of studies agreed that "the need for renewable energy storage is important due to the continual climate change and the fickle nature of the weather upon which renewable energy sources depend" (Ogunniyi, Emmanuel, & Pienaar, 2017). In 2018, 34% of California's power came from solar, of which that energy had to be used immediately unless it was able to be stored in batteries (Roth, 2019). SDG&E alone provides about 45% renewable energy, from sources including solar, on any given day to its consumers (SDG&E, n.d.). Still, as previously noted, the company needs to add to its battery storage capacity. The challenge of getting to 100% renewable energy, and the task of increasing battery capacity appears to be a perfect match. Both issues can successfully rely upon the other to reach their respective State and CPUC goals. Research ranging from across the globe all positively affirmed this study's hypothesis that batteries are a successful tool for harnessing renewable energy and adding more renewable energy to the current energy mix.

Why Century Park

With nearly 2,000 employees working out of CP and as it is the central hub for SDG&E, it makes business sense for SDG&E to have an example of a functioning battery storage facility closer to the main campus, ideally, located at CP East. Residents of the service territory frequently pass CP on their commutes along the busy State Route 163 freeway, and many businesses have equally large campuses in the Kearny Mesa neighborhood where CP resides. Additionally, meetings with legislators, regulators, other IOUs, community partners, and even local news frequently happen at CP once again, showing the benefits of having a physical and visible sign of SDG&E's growing commitment to a greener and more renewable future.

An informal survey of CP employees found that most did not know about SDG&E's work on batteries, let alone the CPUC decision to mandate all IOUs develop and construct battery storage. This shows the need for transparency in SDG&E's projects and communication to employees regarding CPUC decisions and how they affect employees for topics other than customer privacy or electric vehicles, of which employees seemed quite knowledgeable. Engaged employees are more productive and come up with better ideas (Winston, 2014). By merely keeping the workforce in the loop, potential solutions to renewables and battery storage could come faster than SDG&E realizes. Nonetheless, as CPUC Commissioner Michael Picker said at the unveiling of the Escondido battery facility, "we are far in advance of where we expected to be" (Guess, 2017). With more employee engagement and involvement, the utility could further surpass not only expectations but also goals. Figure 1 details a brief SWOT analysis of strengths, weaknesses, opportunities, and threats to installing a battery storage facility at CP. However, this study believes that the strengths and opportunities vastly outweigh the weaknesses and threats.

Figure 1

This graphic details strengths, weaknesses, opportunities, and threats to installing a battery storage facility at the CP campus.

Business Case for Batteries

In commercial spaces such as CP, batteries can be used to smooth load and provide backup services (Shi, et al., 2018). The two key functions this study found of importance that battery storage facilities provide are the ability to store renewables and the ability to peak shave.

"By its nature, electricity must be used the instant it is generated, which makes solar and wind resources challenging to manage on the power grid. Power from these renewable generation sources is produced at different times of the day, and often does not align with the instantaneous demand for electricity" (CAISO, 2014). Batteries provide a way to capture renewables and use them later when renewables are low in the energy mix, such as when wind power is low because there is no wind or at night when the sun is not out providing solar energy. By storing up enough renewables when they are readily available, one could potentially get the energy mix to 100% renewable faster. Having renewable energy stored also prevents the use of fossil fuels from power plants that are used to increase energy production at times of peak demand quickly. Further, installing a battery storage facility at CP gives SDG&E the ability to install more solar panels around campus as they will be able to capture and store the energy.

The second key service battery storage facilities provide is the service of peak shaving. "Peak shaving is not a new concept; industrial users with high peak demand already have been using diesel and gas generators to reduce electricity costs for a long time. Still, those conventional generation methods are expected to be replaced by 'green' technologies, among which energy storage and in particular batteries are the primary candidate" (Papadopoulos, Knockaert, Develder, & Desmet, 2020). When peak demand is high, energy can be used from the battery facility to consume the stored renewables collected at an earlier time. This prevents the company from using energy at a peak rate, thereby saving the company money in its operations. While those in the know have been practicing peak shaving for years, such as transport warehouses using diesel generators at peak hours, the lowering cost of large-scale batteries is making peak shaving and the utilization of renewables more enticing and more attainable. If advances in battery technology and the lowering of prices continue, it is not farfetched to image the near future when warehouses replace their diesel generators with batteries. It could very quickly be a common sight to see batteries attached to solar panels or wind turbines to supplement warehouse energy usage, reduce operations costs, and add renewables to the energy mix.

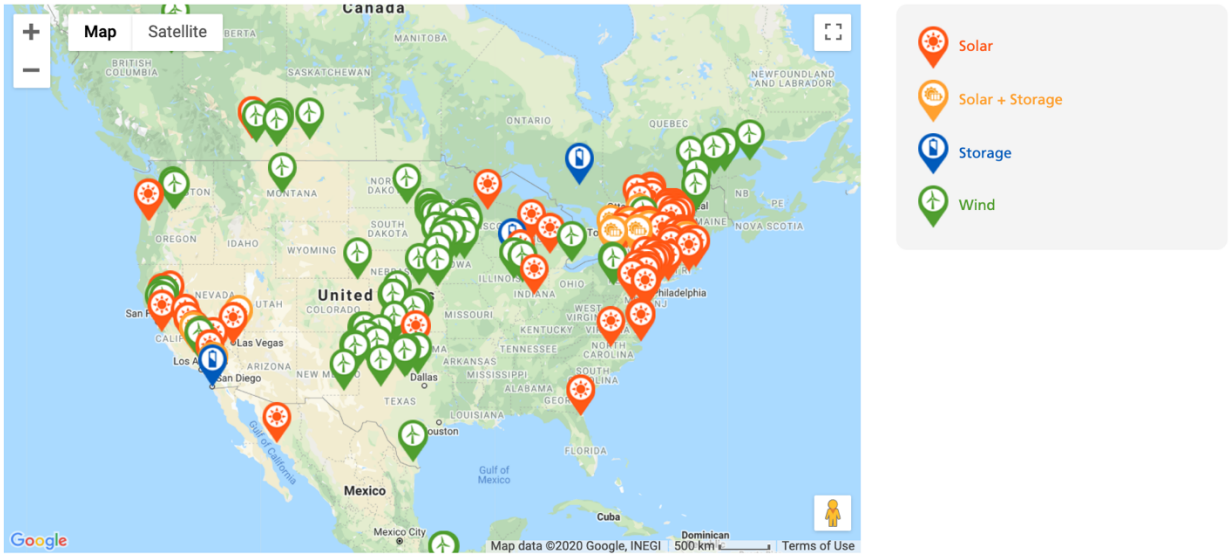
Meet Your Partner

This study has chosen EDF Renewables to assist SDG&E with the installation of a battery storage facility on campus. This choice was made based on 1) their previous experience in building a battery storage facility in central San Diego, and 2) their North American headquarters' location in San Diego. This study gives preferential treatment to local organizations and aims to build the local economy by recommending local organizations take on local projects. Aside from the local economy, this also reduces greenhouse gas emissions from commuting via plane, train, or automobile. Ideally, there are already supply chains in place to get materials from point A or their source, to point B, San Diego.

EDF Renewables not only has completed a 1 MW lithium-ion battery facility at the San Diego Zoo, but their experience extends to a 20 MW battery facility north of Chicago, Illinois, and a 4 MW battery in Ontario, Canada. Figure 2 shows a map of some of EDF Renewables' portfolio of work showing the location of their three battery facilities in blue (labeled "storage") and displaying their experience across North America and across renewables.

Figure 2

Map image taken from EDF Renewables "Projects" webpage. Online viewers can filter by technology, type, year, and country, and drill down to find out more information about individual projects.



While preliminary research did not show an existing partnership between EDF Renewables and SDG&E regarding storage, research did find that EnXco, a subsidiary of EDF Renewables, owns and operates a photovoltaic solar power station near Bakersfield, California

roughly 230 miles from San Diego. EnXco owns and operates the photovoltaic solar power station and sells the renewable energy to SDG&E, thereby making SDG&E a partner. SDG&E approaching EDF Renewables with the opportunity to bid on a battery storage facility project in San Diego would not be a longshot given both companies' track records. (EDF Renewables, 2011)

Pricing, Costs, & Estimated Savings

Batteries are a large monetary investment, as well as a significant real estate investment. This study suggests a battery can be installed in the CP East parking lot where it will have easy access for construction, contractors, tours, and it will be out of the way of most foot traffic, and not impede the flow of the parking lots or parking structures.

This study was surprised to learn that there are several low-cost pricing options for batteries. A company, such as SDG&E, does not have to purchase a battery outright. Potential purchase options include purchasing a battery outright, a Power Purchase Agreement (PPA), Shared Savings, or a PPA and Shared Savings combined plan. Figure 3 illustrates a "Business Solution Comparison" complied by EDF Renewables. Based on input from EDF Renewables, this study suggests SDG&E pursue a Shared Savings solution. Reasons for this choice include the zero upfront cost of purchasing a battery, the lack of technology or maintenance for SDG&E, EDF Renewables being responsible for all operations and support, and EDF Renewables being compensated based on the "Share of Saving generated by the battery's performance" (EDF Renewables, n.d.). With no upfront cost, it seems like an easy lower risk option for choosing to commit to a battery storage facility.

Figure 3

A "Business Solution Comparison" provided by EDF Renewables featuring four main paths a company can pursue when choosing to purchase a battery for on-site energy storage.

	Purchase	Power Purchase Agreement (PPA)	Shared Savings	PPA & Shared Savings
Facility Responsibility	High	Low	Low	Low
Facility Reward	High	Less	Shared	Shared
Upfront Cost	Facility responsible	No upfront cost for facility; EDF is responsible	No upfront cost for facility; EDF is responsible	No upfront cost for facility; EDF is responsible
Technology Performance	Facility responsible	EDF is responsible	EDF is responsible	EDF is responsible
Savings	Customer captures 100% savings	Difference in fixed PPA rate and rising utility rate	Defined Share of Savings generated by battery's performance	100% based on solar and storage performance
Annual Payments	Customer is responsible; fixed annual O&M payments	Based on solar generation performance	Based on Share of Savings generated by battery's performance	Based on battery and solar performance
Guarantees	Mechanical, equipment, and installation quality guarantees and warranties	Production guarantees	Guarantee that storage will not increase bill	Production guarantee; storage payment 100% performance based

Based on preliminary research, a 1MW lithium-ion battery storage facility, which this study proposes installing at CP, could reach over $40,000 in first-year savings. If SDG&E were to enter a 12-year contract with EDF Renewables, SDG&E could expect over $1,200,000 in cumulative savings (EDF Renewables, 2020). Again, with no upfront costs, this appears to be a low-risk way to save money and live up to the SDG&E mission to be the cleanest, safest, and most reliable energy infrastructure company in America (SDG&E, n.d.).

Work Breakout

This study has mocked up a work breakout structure for installing a battery storage facility at CP based on other battery facility projects' best practices. Figure 4 illustrates five phases of this project, starting with initial research, leadership approval/building a coalition, external parties, construction, and project closeout. This study was surprised at the speed with which battery storage facility projects can be completed. Figure 4 shows phases 3 through 5 lasting approximately seven months. While this does seem fast, based on previously completed battery projects in Southern California, that appears to be a standard timeline.

Phase 1 is mostly complete, as this proposal encompasses the majority of the initial research. Due to the global pandemic of COVID-19, this study is unable to meet with SDG&E CP facilities to discuss the potential for on-site batteries at this time. However, the study finds it

ironic that it is reverting to the main takeaway of this entire project – that of being flexible and ready to adapt. As shown below, the work break out structure continues past Phase 1.

Figure 4

A work breakout structure with suggested future start dates for phases 2-5.

TASK NAME	START DATE	END DATE	DURATION (WORK DAYS)	% COMPLETE
Phase 1: Initial research				
Research other similar projects country-wide	03/24/2020	03/30/2020	6	100%
Create feasibility study	03/30/2020	03/31/2020	2	100%
Research CP needs	09/01/2018	03/30/2020	576	100%
Discuss similar projects/best practices with facilities	05/01/2020			
Phase 2: Leadership approval/building a coalition				
Meet with teams working on batteries off-campus	06/01/2020			
Meet with SDG&E Sustainability Specialist MacKenna Kull	05/01/2020			
Meet with SDG&E Vice President, Clean Transportation, Sustainability, Chief Environmental Officer Estela de Llanos	05/012020			
Meet with SDG&E CEO Kevin Sagara	05/01/2020			
Meet with SDG&E President Scott Drury	05/01/2020			
Phase 3: External parties				
Open project for construction bidding	07/01/2020			
Select partner	08/25/2020			
Contract execution	09/01/2020			
Interconnect application submittal	04/01/2021			
Building permit submittal	05/01/2021			
Phase 4: Construction				
Construction starts	07/01/2021			
Battery delivery	09/01/2021			
Interconnection permission to operate	10/01/2021			
Site acceptance testing	11/01/2021			
Commercial operation	12/01/2121			
Phase 5: Project closeout				
Check in with vendors/contractors/ construction	01/01/2022			
Best practices learned	01/01/2022			
Press release/media segment	01/01/2022			

Phase 2 constitutes gaining leadership approval and building a coalition of those who can support and carry this project to completion. At the time of publication, this study was not in contact with teams in charge of SDG&E's battery projects, and again, due to COVID-19, the usual pathways to find such teams were not available to this study. Nevertheless, SDG&E Sustainability Specialist MacKenna Kull has been identified as a key stakeholder for this project as an on-site battery storage facility would fall under her realm and the realm of the Environmental department. With her support, this project could be introduced to SDG&E's Vice President of Clean Transportation, Sustainability, and Chief Environmental Officer Estela de

Llanos. With Ms. de Llanos' support, this project has instant credibility and the ability to be brought up to other members of the executive leadership board – those who will need to sign off on a battery storage facility being constructed and installed at CP.

Phase 3 sees a battery storage facility project turn into any other major project SDG&E may pursue. Usual channels would be followed for permitting, construction, and the bidding process would open up, allowing SDG&E to choose a partner. As this study has repeatedly suggested, EDF Renewables would be a strong candidate for this project. This study recommends SDG&E meeting with EDF Renewables before the bidding process begins to get their input and ensure that EDF Renewables is interested and available to help bring this project to life.

Phase 4 is the actual construction of the battery at CP. SDG&E facilities and security would need to be alerted and brought on as part of the project team for this phase. If SDG&E were to pursue a Shared Savings plan with EDF Renewables, it is this study's understanding that SDG&E would not be responsible for the majority of this phase and could act as project supervisor to EDF Renewables' teams.

The project closeout, phase 5, would result in some fanfare as this major project would be completed, and as SDG&E would have successfully enabled itself to provide cleaner, safer, and more reliable electricity to CP and the SDG&E service territory. Typical major projects, especially at CP, involve some amount of fanfare and media, sometimes external and always internal. SDG&E's media teams could promote the project across their social media platforms and send press releases to local news resulting in news cameras at the CP security gate. This study also recommends meeting with all involved parties from EDF Renewables, including construction, those in charge of maintenance, and the internal groups who worked on the permitting process. All groups could discuss lessons learned, best practices, and how to make this project scalable and potentially a smoother process next time a battery storage facility is installed.

Conclusion

This study believes that while batteries are not a silver bullet for California's energy needs, it is a powerful tool that will be needed in the coming years. The collaboration between SDG&E and any bidder who aims to install a battery storage facility at CP will make headway on securing clean, safe, and reliable energy not just for the San Diego region, but also North

America. Any battery project completed at CP can be easily scaled. A successful and public battery storage facility at CP will spur others in the Kearny Mesa neighborhood to pursue energy cost savings via peak shaving, clean energy, and energy resilience through battery storage facilities of their own. As the need for greener, cleaner, and reliable energy increases, batteries, appear to this study, to be the way forward.

References

California Energy Commission. (n.d.). California climate change legislation. Retrieved from https://www.climatechange.ca.gov/state/legislation.html.

CAISO, "Advancing and maximizing the value of energy storage tech- nology," California Ind. Syst. Operator, Folsom, CA, USA, Tech. Rep. 217998, 2014.

Domonoske, C. (2018, September 10). California sets goal of 100 percent clean electric power by 2045. Retrieved from https://www.npr.org/2018/09/10/646373423/california-sets-goal-of-100-percent-renewable-electric-power-by-2045.

EDF Renewables. (n.d.). Projects. Retrieved from https://www.edf-re.com/projects.

EDF Renewables. (2011, June 16). enxco and san diego gas & electric sign ppa for 130 mwp catalina solar. Retrieved from https://www.edf-re.com/enxco-san-diego-gas-electric-sign-power-purchase-agreement-130-mwp-catalina-solar-project.

EDF Renewables. (2020, March). San Diego.

Geuss, M. (2017, February 24). Largest grid-tied lithium ion battery system deployed today in san diego. Retrieved from https://arstechnica.com/science/2017/02/as-ca-bill-aims-for-100-renewable-by-2050-utility-starts-30mw-battery-system.

Hoppmann, J., Volland, J., Schmidt, T. S., & Hoffmann. (2014). The economic viability of battery storage for residential solar photovoltaic systems – A review and a simulation model. *Renewable & Sustainable Energy Reviews*, *39*, 1101–1118. https://doi-org.ezproxy1.lib.asu.edu/10.1016/j.rser.2014.07.068.

Meltzer, J., & Sierra, K. (2011). Trade and climate change. *Harvard International Review*, *33*(3), 64. Retrieved from https://asu.instructure.com/courses/24068/pages/module-2-readings?module_item_id=2094947.

Mulkern, A. C. (2019, September 23). Governor directs $700B pension funds toward climate goals. Retrieved from: https://governorswindenergycoalition.org/governor-directs-700b-pension-funds-toward-climate-goals.

Ogunniyi, Emmanuel, & Pienaar. (2017). Overview of Battery Energy Storage System Advancement for Renewable (Photovoltaic) Energy Applications. 10.23919/DUE.2017.7931849.

Papadopoulos, V., Knockaert, J., Develder, C., & Desmet, J. (2020). Peak Shaving through Battery Storage for Low-Voltage Enterprises with Peak Demand Pricing. *Energies (19961073)*, *13*(5), 1183. https://doi-org.ezproxy1.lib.asu.edu/10.3390/en13051183.

Roth, S. (2019, March 14). California's wildfire threat could be an opportunity for clean-energy microgrids. Retrieved from https://www.latimes.com/business/la-fi-microgrids-wildfires-power-shutoffs-20190314-story.html.

Roth, S. (2019, June 5). California has too much solar power. that might be good for ratepayers. Retrieved from https://www.latimes.com/business/la-fi-solar-batteries-renewable-energy-california-20190605-story.html.

Shi, Y., Wang, D., Xu, B., & Zhang, B. (2018). Using Battery Storage for Peak Shaving and Frequency Regulation: Joint Optimization for Superlinear Gains. *IEEE Transactions on Power Systems*, *33*(3), 2882–2894. https://doi-org.ezproxy1.lib.asu.edu/10.1109/TPWRS.2017.2749512.

St. John, J. (2019, May 23). San diego gas & electric hits snag in california microgrids rollout. Retrieved from https://www.greentechmedia.com/articles/read/san-diego-gas-electric-faces-challenge-to-microgrid-rollout.

San Diego Gas & Electric. (n.d.). Committed to becoming America's best energy company. Retrieved from https://www.sdge.com/more-information/environment/americas-best-energy-company.

United Nations Environment Programme. (n.d.). How "Net Zero" Buildings Can Help Us Tackle Climate Change. Retrieved from https://www.unenvironment.org/news-and-stories/story/how-net-zero-buildings-can-help-us-tackle-climate-change.

Weaver, J. (2018, June 6). SDG&E to build 334 mwh of energy storage to support renewables. Retrieved from https://pv-magazine-usa.com/2018/06/06/sdges-333-mwh-of-energy-storage-supporting-renewables-approved.

Winston, A. S. (2014). *The big pivot: radically practical strategies for a hotter, scarcer, and more open world*. Boston, MA: Harvard Business Review Press.