Energy storage peaker plant replacement project

Technical and policy documentation

Background data analysis methods and state-level policy and regulatory considerations

Physicians Scientists and Engineers for Healthy Energy

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About

This document provides background, methods, data sources, and policy and regulatory background for the Energy Storage Peaker Plant Replacement Project. This document supports the state-level findings reported in individual state summaries and interactive data tools available at: www.psehealthyenergy.org/our-work/energy-storage-peaker-plant-replacement-project/.

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About PSE Healthy Energy

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Motivation

Grid-scale energy storage has arrived at a turning point: batteries and other storage systems are newly cost-competitive with oil- and gas-fired peaker power plants, many of which have high pollutant emission rates and are located in disadvantaged and vulnerable communities. Simultaneously, numerous states across the country are designing incentives and targets to support energy storage deployment. Together, these developments provide a unique opportunity to use energy storage to strategically displace some of the most polluting peaker power plants on the grid.

In this screening analysis, we identify peaker power plants across nine states that may be prime candidates for replacement based on operational and grid characteristics, and whose replacement may yield the greatest health, environment and equity co-benefits. This approach aligns state e orts to adopt energy storage with environmental and societal goals. We supplement our screening analysis with a discussion of how storage adoption and peaker plant replacement is a ected by the policy and regulatory environment in each state.

Contents

1. Overview

Peaker power plants run infrequently and are brought online to help deliver electricity during periods of high demand. They start up quickly, but are typically inefficient and expensive to operate and often have higher emission rates than power plants burning similar fuels to provide baseload electricity. Furthermore, many peaker plants are located in urban centers and often in low-income and minority communities [1]. The high cost of electricity generation and low number of operational hours of peaker plants mean that energy storage may present a cost-competitive alternative to meeting peak demand. Indeed, this prospect has become a reality in California and several other states, where energy storage is beginning to replace peaker plants [2]. Strategic deployment of energy storage has the potential to displace not only the most expensive facilities, but also those plants with the highest pollutant emissions, located in densely populated urban centers, and/or disadvantaged and vulnerable communities. Our approach in this study is to screen existing and proposed peaker power plants across nine states in order to help guide energy storage deployment and peaker power plant replacement. We examine the policy and regulatory environment in each state and identify plants that may be opportune targets based on operational and grid characteristics such as plant age, typical run times, and local capacity needs. We also consider environmental, health and equity metrics such as emission rates and the demographics of nearby residential communities.

In this study, we analyze plants across nine states: Arizona, California, Florida, Massachusetts, Nevada, New Jersey, New Mexico, New York, and Texas. These states were selected based on a variety of indicators, including existing state-level energy storage targets that suggest near-term opportunities for energy storage adoption to help meet peak demand. Certain states, such as California, New York, Massachusetts, and New Jersey, have already set ambitious energy storage targets for the coming decade. Others, such as Nevada, Texas, New Mexico, Arizona, and Florida, have begun to consider targets, have started to procure large-scale energy storage, or have electricity market structures that look favorable for energy storage adoption, such as high electric demand charges.[1] These incentives, markets and grid operational needs are discussed in Sections 4 and 5. Although our analysis covers only nine states, opportunities exist in other states and are likely to expand in the coming years.

This study presents a screening analysis across our nine target states to identify overarching trends in peaker characteristics, as well as potential peaker replacement opportunities. While we develop an initial framework here, we consider it a first step. The selection of actual replacement targets will require a deeper analysis of grid needs and plant operations, as well as consideration of local community objectives and state-level goals. Our approach includes three broad components: i) a review of state policy targets and regulatory environment; ii) an analysis of plant operational characteristics; and iii) an analysis of environmental, public health and nearby demographic indicators for each plant. We integrate these final indicators into an overarching environmental justice indicator, the Cumulative Vulnerability Index, to allow for comparison of peaker plants

[1] Electric demand charges are based on the maximum electric demand (in kW) that a customer uses during a billing period. Energy storage can be used to reduce this maximum demand and the associated charges.

across numerous metrics for each state. We finally rank the peakers across a mix of demographic and emission indicators to help prioritize replacement decisions. This technical report is coupled with both state-level summaries and interactive data visualizations, which allow users to compare peaker plants across specific metrics of concern or to look up data for individual plants. Together, the state summaries, data visualization tools and this technical report will provide the information for stakeholders in each state to begin to design strategic deployment of energy storage, solar and energy efficiency, and consider peaker power plant displacement and replacement opportunities. This approach also lays out the framework by which energy storage and other emerging resources can displace larger power plants and fossil fuel infrastructure in the coming decades.

This technical report is presented in the following sections. Section 2 provides background on grid energy storage, peaker power plant emissions and health impacts, and environmental justice screening. Section 3 presents our methodology for 1) the operational, 2) environmental health and equity and 3) integrated analyses. Sections 4 describes the energy and environmental policy a ecting renewable energy, storage, greenhouse gas and criteria pollutant emissions, and environmental justice in each state. Finally, Section 5 describes the regulatory environment and transmission markets implications for peaker replacement. The state-level findings for this analysis are reported in standalone state summaries and interactive data tools available at: www.psehealthyenergy.org/our-work/energy-storage-peaker-plant-replacement-project/.

2. Background

The power sector is undergoing an immense transition, shifting away from fossil-fuel power generation towards a mix of renewable energy resources such as wind and solar power. The transition to renewable energy, which is variable and intermittent, necessitates the adoption of flexible energy systems across the grid, including energy storage and demand response (which shifts electric demand to times when electricity supply is available). This transition has the potential to yield numerous co-benefits, including reductions in greenhouse gases and health-damaging co-pollutants, economic savings, energy equity, and grid resilience. However, the strategy guiding the adoption of energy storage, renewable energy, and other emerging resources will determine who benefits from these resources and how soon. In this study, we develop a framework for adopting storage and other resources that not only prioritizes achieving co-benefits but also ensures that many of these benefits accrue towards those communities that have historically been most burdened by pollution and by the costs of our extant fossil-based energy infrastructure. One of the most cost-competitive near-term opportunities for integrating energy storage and achieving local emission reductions is to displace peaker power plants, which are typically expensive, polluting, and frequently located in vulnerable and disadvantaged communities. In this section, we provide background on energy storage and its role in the electric grid, an overview of peaker power plants and their emissions and impacts, and an introduction to environmental justice screening methodology. Together, these descriptions frame how we might approach identifying grid, emission, and equity metrics to help prioritize energy storage adoption.

2.1 Energy storage and grid applications

Energy storage technologies store energy, produced at one point in time, for use at a later time. Perhaps the most familiar technology used to store electricity is the lithium-ion battery, which we use every day in our cellular phones and computers. However, numerous other technologies can provide energy storage. The most common type of energy storage currently on the grid—accounting for more than 95% of current storage capacity [3]—is pumped hydropower, where water is pumped up a hill and stored in a reservoir during times of electricity surplus, and then released downhill through a turbine to generate electricity when demand increases. The second most common type of energy storage is thermal storage. An example of thermal storage is the use of inexpensive nighttime electricity to make ice, and then utilizing this ice to provide cooling during the daytime. Finally, the third most common technology used for grid storage is battery storage.[1] Batteries e ectively store energy using an electrochemical reaction. When batteries are charged, electricity drives the chemical reaction in one direction and stores electrons. When discharged, the chemical reaction is reversed, electrons released, and electricity flows from the battery. Many di erent electrochemical reactions can store energy, which leads to the di erent types of batteries

Many additional energy storage technologies exist as well, including ultracapacitors, flywheels and others. Some have been used in a limited capacity on the grid.

we see today: lead-acid batteries, lithium-ion batteries, and so on. The chemistry itself a ects how dense the battery is, how efficient it is, how many charge-discharge cycles it can go through before dying, how safe the battery is, and how quickly it can be charged or discharged. These properties also a ect what types of batteries are useful for di erent applications on the grid. Currently, pumped hydropower is a large source of energy storage but it is limited in terms of where it can be built geographically and is therefore difficult to expand. Thermal storage is useful but tends to be applied to specific needs, such as heating and cooling. Batteries, by contrast, are being deployed rapidly because they can meet a more diverse set of grid needs.

Battery storage can play many valuable roles on the electric grid. These include, but are not limited to:

- **Renewable energy integration:** smoothing out the variability and intermittency of resources such as wind and solar power;
- **Peak demand reduction:** supplying electricity when the electric demand peaks, typically on hot summer days when air conditioning use is highest;
- **Resilience and back-up power:** providing electricity in the case of grid outages and other emergencies;
- **Grid services:** providing frequency, voltage and ancillary services to the grid;
- **Customer-side savings:** shifting electricity use to optimize time-of-use charges or reduce electric demand charges;[2]
- **Deferral of transmission and distribution investments:** reducing the need to expand electric transmission or distribution infrastructure to address local demand growth.

These applications can be "stacked"—that is, a battery can provide multiple services at once. For example, a large battery at a commercial building can help reduce electric demand charges for that customer, integrate solar on the rooftop of the building, provide back-up power if the grid goes down, and be aggregated with batteries across the region to help reduce grid-wide peak demand.

Overall, battery costs have been plummeting dramatically. The cost of batteries fell an estimated 76% from 2012 to 2018 [4], and these costs continue to fall. However, the cost of a battery, and how it is compensated, depends widely on the structure of the electric markets in a given region. In some cases, utilities can own batteries directly and connect them to their transmission and distribution infrastructure—these are referred to as in-front-of-the-meter batteries. Other times a private entity will own the battery and sell grid services. And some batteries are located behind-the-meter at residential, commercial, or industrial facilities, where they may be used only for customer needs (bill management, back-up power) or they may be aggregated to provide grid services as described above. Some regions only permit storage to participate in certain markets—such as the electric capacity market, if they have one—if the storage meets certain requirements. Policies a ecting energy storage are described in each of our key states in Section 4.

Energy storage size is typically given in terms of both *power* and *energy*. Power, measured in megawatts (MW) or kilowatts (kW), is a *rate* measure reflecting how much energy can be provided in a second. Power plant capacity is typically given in MW: a small peaker plant might be 25 MW while a large nuclear power plant could be 1,000 MW. The *energy* stored reflects how much time a battery could continue to discharge at the rated power, and is often given in megawatt-

[2]Time-of-use charges set di erent electricity prices at di erent times of day, so storage can allow a customer to shift electricity use to cheaper times; demand charges are fees paid by commercial and industrial customers to reflect the maximum amount of electricity (in kilowatts) used at any given time, and storage can be used to reduce this maximum demand and the consequent charges.

hours (MWh) or kilowatt-hours (kWh). A one-MW battery that can discharge for four hours stores four MWh of electricity. The battery could also be discharged at a lower power to last for longer than four hours. The requirements for batteries on the grid are often given in terms of capacity and discharge time. For example, a battery may be allowed to participate in a capacity market if it can provide four hours of power in one region or if it can provide ten hours elsewhere (e.g. in the mid-Atlantic market, PJM). The capacities of batteries currently on the grid vary widely. A residential energy storage system, such as the Tesla Powerwall, is on the order of 5 kW/14kWh [5]. Meanwhile in California, a 300 MW/1,200 MWh battery is being built at Moss Landing [6].

Energy storage has the potential to exacerbate or increase certain environmental impacts while mitigating others. In the first case, certain energy storage materials are toxic, and the conditions in which they are mined or produced can have negative impacts. For example, the cobalt used in certain lithium-ion batteries (such as lithium cobalt oxide batteries) is often sourced from mines using child labor in the Congo, leading certain manufacturers to try to phase out the use of cobalt. The end-of-life of batteries is important too, and there is a need for increased research on battery recycling, reuse, and material disposal to ensure that the component materials do not expose workers or communities to environmental health hazards. The operation of the batteries matters as well. If batteries are used to help store surplus solar electricity, and discharged to displace an oil-fired peaker power plant, they will reduce overall emissions. However, if the battery is charged with the generation from a coal plant, and discharged to displace generation from a hydropower system, overall grid emissions will increase. Therefore, managing the timing and fuel-sourcing of battery charging and discharging is important to ensure overall emission benefits.

Energy storage is still a relatively new resource on the electric grid, and adoption rates are expected to increase in coming years as costs continue to fall. Energy storage is also only one of a suite of technologies that provide increasing flexibility to the grid. Other technologies include demand response (e.g. reducing peak demand by lowering air conditioning use in response to a signal) or demand management—shifting electric user loads to other times of day (e.g. cooling a building early in the day). Together, storage, demand management, renewables, and energy efficiency can all play roles in creating a clean, flexible electric grid and displace or replace polluting energy resources.

2.2 Peaker power plants

One of the current most cost-e ective applications for grid energy storage is to meet peak electric demand, and in doing so displace the peaker power plants that typically meet this peak demand. These peaks often occur on hot summer afternoons when everyone turns on their air conditioning, although the timing of peak electric demand depends on the region and the weather. Peak demand may actually be met by a range of power plant types, but the most common technology are gas- or oil-fired combustion turbines that can be rapidly ramped up and down to meet the peak demand. Typically, they are only used for a few hours at a time. In some cases, small internal combustion engines may be used. Since the phrase *peaker power plant*, frequently shortened to *peaker*, is typically used to refer to any plant that is run less than 10-15% of the time, a number of aging steam engine power plants meet this classification as well. They were not designed as peakers, but are operated that way today. There are also many cases where a larger power plant will have multiple units, some of which are steam turbines used frequently and some of which may be combustion turbine units used infrequently only for peak demand. Here we will analyze both full power plants used as peakers and peaking units at larger plants.

Peaker power plant generation is often more expensive than other resources, making it one of the first plant types for which energy storage is cost-competitive. A peaker plant could be replaced by one large energy storage unit, or by distributed energy storage throughout a region that, aggregated, helps to meet peak demand. Peaker power plants may be used to meet peak demand across a large area of the grid, or may help provide electricity in transmission-constrained load pockets (see Section 5). In areas with limited electric transmission, the peaker power plants are serving *local* needs—and replacing them would require local deployment of energy storage and other resources. In cases where peaker power plants are meeting grid-wide needs, energy storage deployment could be distributed over a larger region.

Peaker plants are designed to be fast-ramping, which makes them less efficient than baseload power plants like natural gas combined cycle plants. Consequently, they use more fuel and produce more greenhouse gas and criteria air pollutant emissions for every unit of electricity generated. Plant start-up, ramping, and shutdown is associated with more emissions than continuous operation at full power, [7] meaning that turning the plants on and o increases emissions. As more renewable resources are integrated onto the grid, there is also some concern that peakers will be ramped more to help integrate variable wind and solar power, and thus increase emissions as compared to a continuously operational plant. The specific emissions of peakers depend on the fuel used (typically natural gas or oil) and the combustion technology and efficiency, but include greenhouse gases like carbon dioxide (CO_2), criteria air pollutants such as nitrogen oxides (NO_x) and sulfur oxides (SO_x), which contribute to the secondary formation of ozone and fine particulate matter ($PM_{2\ 5}$), as well as hazardous air pollutants. Acute and chronic exposure to $PM_{2\ 5}$ is associated with acute cardiovascular events, respiratory ailments (particularly among vulnerable populations such as children and the elderly), and premature mortality [8, 9]. Ozone is associated with respiratory and cardiovascular health impacts, including premature mortality and impacts on vulnerable populations such as increased asthma visits among children [10]. NO_x reacts in the atmosphere to form tropospheric ozone and particulate matter, but can also cause negative health impacts by itself, including increased asthma-related hospital visits in children and the elderly. Hazardous air pollutants can cause cancer, birth defects and other serious health e ects. Oil combustion is typically associated with higher criteria air pollutant emissions than natural gas combustion, although the rates are also a ected by the combustion and air pollution control technologies at each facility. It is therefore possible to target energy storage to replace peaker plants with the highest rates of emissions per MWh and have an outsized emission benefit.

Living next to oil- and gas-fired power plants is associated with negative health outcomes. For example, residential proximity to oil- and gas-fired power plants is associated with preterm (32-36 weeks) and very preterm (less than 32 weeks) birth, [11] and living near power plants has been associated with an increase in estimated rates of hospitalization for asthma, acute respiratory infections, and chronic obstructive pulmonary disease [12].

2.3 Environmental justice screening

In many areas, peaker plants and power plants in general are located in low-income, minority and otherwise environmentally overburdened and socioeconomically vulnerable communities. In California, for example, 50% of peaker plants are located in the top 30% of California's most disadvantaged communities [1], as measured using the state's environmental justice screening tool CalEnviroScreen [13]. Across the country, power plants tend to be located in low-income or minority communities [14, 15]. This distribution of plants could be the result of plants being sited in these communities in the first place, or in the growth of such communities in environmentally overburdened locations due to discriminatory housing policies, lack of or concealment of environmental burden knowledge, and lack of alternative, a ordable living options.

Historically, environmental health burdens from polluting facilities have fallen disproportionately on low-income and/or racial minority communities. Across the United States, these communities are more likely than more affluent and whiter communities to experience a cumulative burden of numerous exposures to pollutants, such as air pollution or groundwater contamination, and more likely to live in proximity to potential hazardous sites and facilities such as Superfund sites. Furthermore, communities experiencing the cumulative burden of numerous environmental health and socioeconomic stressors are also more likely to experience negative health outcomes because they are more vulnerable to these very same environmental health burdens [16].

There have been a number of cumulative impact methodologies proposed to identify overburdened, vulnerable and otherwise disadvantaged communities. Sadd *et al* [17] proposed an environmental justice screening method to evaluate cumulative impact and social vulnerability by creating census tract-level scores incorporating socioeconomic and environmental factors. Specifically, these scores include 1) proximity of sensitive receptors, like schools and senior care facilities, to hazardous facilities and stationary emission sources, 2) health risks and exposures such as air pollutant concentrations, and 3) social and health vulnerability indicators such as race/ethnicity, poverty rates and educational attainment. Each census tract was ranked statewide on each metric and given a score of 1-5 in each category based on the quintile of its ranking, and then averaged to create a score in each category. These were then summed to create a Total Cumulative Impact score, allowing for comparison of census tracts statewide.

Building on this approach, the California EPA's Office of Environmental Health Hazard Assessment created CalEnviroScreen, an environmental justice screening tool which ranks census tracts based on 1) exposure indicators such as air pollution, 2) environmental e ect indicators such as proximity to chemical facilities, 3) sensitive population indicators such as asthma prevalence rates and 4) socioeconomic indicators such as poverty level [18]. CalEnviroScreen integrates the first two categories to create a pollution burden score, the second two categories to create a population characteristics score, and then multiplies these scores to create a total score, which is then ranked to identify the percentile of each census tract across the state. This scoring directly a ects policy in California: for example, a portion of greenhouse gas cap-and-trade funds are directly set aside for investments in *disadvantaged communities*, defined as the 25% highest ranking census tracts in the state.

The U.S. EPA's Office of Environmental Justice has created a tool called EJSCREEN, which provides census tract values and rankings for certain population indicators (e.g. poverty, minority, linguistic isolation) and pollution burden indicators (e.g. traffic proximity) [19]. However, while EJSCREEN has a demographic index (average of the percent of low-income and percent minority populations) and environmental justice indices; this latter category is calculated by combining the demographic index with a single environmental burden at a time. Moreover, EJSCREEN does not provide a net score which integrates all environmental burden indicators. Unlike CalEnviroScreen, EJSCREEN does not include health indicators.

While these screening tools allow for the identification of potentially overburdened communities where pollution mitigation may be particularly valuable, they are also limited. They are based on the available data, which are sometimes estimated on the census tract level and therefore do not allow for analysis of granular variations on a block-to-block basis. Certain types of data may be omitted because they are not available at all (such as some health indicators). These tools tend to weigh many indicators equally, but certain populations may be more vulnerable to certain types of pollution or environmental exposures than others, and not all environmental exposures themselves have the same magnitude of health impacts. Most importantly, each individual community has numerous unique characteristics, including environmental burdens, sensitive receptors and so on, that cannot be reflected in such a scoring system. As such, these tools are useful for screening—

identifying overarching trends, identifying potential locations for support or interventions—but any findings must subsequently be ground-truthed through direct community engagement that is accessible, economically just (e.g. sponsored), and transparent in process and outcome.

3. Methodology

In order to help prioritize where energy storage might be a viable replacement technology for a peaker power plant and where it may yield the greatest health and equity benefits, we analyzed the typical operating patterns of each plant, their emissions, local grid requirements, and demographics of nearby communities. We subsequently integrated these measures into a cumulative Index to help prioritize sites for storage (or storage+solar) deployment. This section presents our data sources and methodology for i) analysis of power plant operational characteristics, emissions, and grid needs, ii) development of an environmental justice screen which incorporates demographic and environmental health burden indicators, and iii) integration of power plant screening results across metrics.

3.1 Power plants

3.1.1 Power plant selection

The phrase *peaker plant* commonly refers to fossil fuel-burning power generation used to meet peak demand on the electric grid, but the term itself does not have a precise definition. To identify peaker plants across our nine target states, we began with a list of power plants from the S&P Global Database [20], which we cross-checked with the U.S. Energy Information Administration (EIA) Schedule 923 [21]. We considered two categories of peaker plants: 1) entire power plants being utilized as peaker plants, and 2) individual units at larger plants being dispatched as peaking units. In some of our analysis, we address entire plants and peaking units separately. We identified peaker plants from this list using the criteria in Table 3.1.

We cross-checked and updated the location of all of the power plants with visual verification on Google Maps [22]. We also aggregated data on power plant ownership and utility from this S&P dataset. Power plant status was determined using a mix of data from EIA Schedule 860 [23] and requests for plant construction, expansion or retirement at each grid operator.

3.1.2 Operational data

We aggregated power plant operational data on a unit basis from EIA and U.S. Environmental Protection Agency (EPA) datasets. We obtained hourly, daily, and annual data on generation (MWh), emissions (CO_2, NO_x and SO_2), and fuel consumption (MMBtu) for the years 2014-2018 from the EPA's Air Markets Program Database (AMPD) [24]. Although these emissions data are available at greater temporal resolution than from EIA, data are not available for all plants, so we back-filled our emissions data using reported EIA annual data for the years 2014-2017 [25].

Table 3.1: Peaker plant selection criteria.

Characteristic	Included	Excluded
Fuel type	Oil, natural gas	Coal, nuclear, solar, wind, hydro, geothermal, land ll gas, other biogenic
Capacity	$\geq$ 5 MW	5 MW
Capacity factor	15% (3-yr. avg.)	> 15% (3-yr. avg.)
Unit technology type	Simple cycle combustion turbine, steam turbine, internal combustion	Combined cycle,[b] combined heat and power, and units designated as cogeneration on EIA Form 923
Application	Entire peaker plants; peaking units at larger plants	Units sited at schools, hospitals, industrial sites, or providing non-peaking services (e.g. emergency backup at medical sites)
Status	Existing and proposed units	Retired, postponed planned, or terminated units

Aging steam units were frequently originally constructed to operate at higher capacity factors but in many cases today are dispatched infrequently as peaking units.

[b]With the exception of two plants in California dispatched as peaking units: Harbor and Haynes.

We calculated plant heat rates (MMBtu/MWh), emission rates (tons CO_2/MWh, g NO_x/MWh, g SO_2/MWh) and capacity factors using either the AMPD or EIA data. For those units reporting data, we used the AMPD dataset to calculate the number of power plant starts per year, the average run hours per start, and the average generation from the plant for each hour of the day.

We next calculated the percent of electricity generation (from those units reporting daily electricity generation data to AMPD) occurring on days exceeding federal ozone or particulate matter standards. We first filtered EPA's list of air monitors [26] for those collecting data on ozone concentrations, $PM_{2\,5}$ concentrations, and active within the last five years. Next, we calculated the percent of electricity generation (in MWh) on days when ozone or $PM_{2\,5}$ concentrations exceeded federal air quality standards at one or more of the three air monitors closest to each of our power plant sites. The most recent National Ambient Air Quality Standard for ozone is set at 70 ppb averaged over an eight-hour time frame, and the $PM_{2\,5}$ standard is set at 150 g/m^3 over a 24-hour time frame. A single exceedance of these standards does not necessarily mean that a region is out of attainment—nonattainment is determined by the three-year average of the fourth-highest annual ozone concentration and the three-year average of the 98th percentile of the $PM_{2\,5}$ concentration—but the exceedance value is useful for determining if a plant frequently operates when the EPA deems the local air quality to be unhealthy. We also determined which plants are located in ozone or particulate matter nonattainment areas according to the EPA Greenbook [27] and other federal, state, or local regulatory bodies.

3.1.3 Transmission electricity market grid data

The electric grid in the nine states in our study are regulated by regional or multi-state grid operators or entities which manage transmission electricity markets. These markets help determine the compensation available to both peaker plants and energy storage on a regional and local basis. While analysis of the transmission grid is tailored to each state, we apply an overarching framework including the review of public data provided by regional, state, and federal agencies for several primary categories in each state's market, including but not limited to:

- Identification of grid operator and their key stakeholders;
- Identification of market divisions by zones, nodes, or other load and/or capacity grouping;
- Identification of transmission-constrained areas, as applicable;
- Identification of capacity and load requirements as related to grid reliability standards;
- Identification of load, capacity, and other trading market costs;
- Identification of capacity factors of plants in each zone.

Together, these data allow us to both understand the potential market for energy storage and more specifically to identify transmission constraints and local capacity needs that renewable and energy storage deployment could help meet. Each state's transmission market and underlying electrical grid data are unique. Specific market and grid details as well as additional data sources for each targeted state are provided in Section 5.

3.2 Environmental justice screen

In order to identify potentially overburdened and vulnerable populations near each power plant, we aggregated data on a) demographics, b) environmental burdens, and c) health vulnerability indicators for populations living within a one- and three-mile radius of each site. We primarily used data from EPA's EJSCREEN [19] for demographic and environmental indicators and added additional health vulnerability indicators based on the available data for each state. We ranked indicators in each category against the indicator values for census tracts across each state to find their percentile ranking. We integrated these percentiles to create a Cumulative Vulnerability Index to compare plants across each state, following methods originally developed in Krieger *et al* (2016) [1] and when available reflecting indicators used in CalEnviroScreen 3.0, California's environmental justice screening tool [18]. EJSCREEN provides numerous environmental justice indicators, but unlike CalEnviroScreen, EJSCREEN does not integrate them all into a cumulative score. For the state of California, we used CalEnviroScreen itself, and thus did not re-create a cumulative score. Below, we describe the indicators evaluated in each category and our methods for calculating the Cumulative Vulnerability Index.

3.2.1 Demographic indicators

We calculated the values for four demographic indicators for populations within a one- and three-mile radius of each plant using EJSCREEN. Underlying data for EJSCREEN come from the U.S. Census American Community Survey (ACS) for the years 2011-2015.[1] The following indicators were considered:

- **Low-income:** Households with income less than twice the federal poverty level;
- **Population of color:** Populations which identify as racially non-white alone, or ethnically as Hispanic or Latinx;
- **Less than high school education:** Population over age 25 without a high school diploma, General Education Degree or equivalent;
- **Linguistic isolation:** Households where those over 14 speak a non-English language and speak English less than "very well."

[1] Full technical documentation for EJSCREEN is available at [19].

While not included in our Index score, we independently calculated the racial and ethnic breakdown for populations living within our bu er regions using data and categories from ACS.

3.2.2 Environmental burden indicators

We calculated the values for eleven environmental burden indicators for populations in a one- and three-mile bu er for each plant using EJSCREEN. These indicators include a mix of environmental exposures, such as air pollution measures, and proximity to hazardous facilities, such as Superfund sites. Proximities are usually determined in relation to a give census block. Underlying data were retrieved from the National Air Toxics Assessment (NATA); the EPA ozone and $PM_{2\,5}$ indicators; EPA databases for Resource Conservation and Recovery Act sites for solid and hazardous waste; Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) for National Priorities List sites; and Risk Management Plan for chemical risk sites; ACS data on building age; Department of Transportation data on traffic proximity; and the Risk-Screening Environmental Indicators (RSEI) model for water discharge sites. Indicators are as follows (as described in EJSCREEN technical documentation [19]):

- **NATA air toxics cancer risk:** Lifetime cancer risk from hazardous air pollutants such as benzene or formaldehyde.
- **NATA respiratory hazard index:** Ratio of exposure concentration to standard index (RfC) for hazardous air pollutants.
- **NATA diesel PM:** Annual average diesel particulate matter concentration (g/m^3), which can contribute to respiratory health impacts.
- **Particulate matter**: Annual average particulate matter ($PM_{2\,5}$) concentration(g/m^3), which can contribute to cardiovascular and respiratory health impacts.
- **Ozone:** Summer average maximum eight-hour ozone concentration; ozone contributes to cardiovascular and respiratory health impacts, particularly in vulnerable populations such as children and the elderly.
- **Traffic proximity and volume:** Count of vehicles per day within 500 meters, reflecting potential air pollutant exposures.
- **Lead paint indicator:** Potential exposure is measured as the percent of housing built before lead paint was banned in 1960. Lead poisoning can damage the brain and nervous systems. Children in houses with lead paint are at particular risk for accidental consumption.
- **Proximity to Risk Management Plan sites:** Count of facilities within 5km that have a risk management plan (RMP) for potential chemical accidents, divided by distance.
- **Proximity to Treatment, Storage and Disposal sites:** Count of facilities within 5km that are treatment, storage and disposal facilities (TSDFs) for hazardous wastes, divided by distance.
- **Proximity to National Priorities List sites:** Count of facilities within 5km that are proposed or listed National Priorities List (NPL) sites, or Superfund sites, divided by distance.
- **Wastewater discharge:** Toxicity-weighted stream concentrations for streams within 500m, divided by distance.

Table 3.2: Acute Myocardial Infarction Health Data Inputs. Age 35+, per 10,000 population, age-adjusted.

State	Health endpoint	Data years	Geographic resolution	Sources
Arizona	Hospitalization	2015-2017	AZ primary care areas	Arizona Environmental Public Health Tracking Program, gis.azdhs.gov/ephtexplorer/
Florida	Emergency department visits	2015-2017	Zip code	Florida Environmental Public Health Tracking, www.floridatracking.com/healthtracking/mapview.htm
Massachusetts	Hospitalization	2013-2015	Sub-county township	Massachusetts Environmental Public Health Tracking, matracking.ehs.state.ma.us/
Nevada	Emergency department visits	2015-2017	County	Nevada Hospital Emergency Department Billing and Nevada Population Data; provided by Jie Zhang on 5/14/19
New Jersey	Emergency department visits	2016	Zip code	Healthcare Cost and Utilization Project, www.hcup-us.ahrq.gov/
New Mexico	Hospitalization	2012-2015	NM small area	New Mexico Department of Health, Indicator-Based Information System for Public Health Web site: ibis.health.state.nm.us ; retrieved 5/16/19
New York	Hospitalization	2010-2014	Zip code	Office of Public Health Practice, New York State Department of Health; provided on 3/1/19
Texas	Emergency department visits	2012	Zip code	Texas Department of State Health Services, Center for Health Statistics - Texas Hospital Inpatient Discharge, Public Use Data File (PUDF), www.dshs.texas.gov/thcic/hospitals/Inpatientpudf.shtm

3.2.3 Health vulnerability indicators

To develop a measure to reflect health vulnerability, we evaluated three health indicators for populations living within a one- or three-mile bu er zone for each plant:

- **Acute Myocardial Infarction (AMI):** Known as a heart attack, AMI is a cardiovascular event that has been linked with air pollution in scientific studies. We considered emergency department (ED) visits (or hospital admissions if ED visit data were not available) that were age-adjusted for populations 35 years and over.
- **Asthma:** Characterized by coughing, wheezing, shortness of breath, and chest tightness, asthma is a chronic lung condition. Asthma attacks or episodes are caused by triggers such as air pollution [28]. For all states, we evaluated age-adjusted ED visits (or hospital admissions if ED visit data were not available).
- **Premature births:** Births occurring prior to 37 weeks gestation. Studies have found premature birth to be associated with air pollution exposure [29].

3.2.4 Data inputs

The health data used in our analysis are provided for each state in Tables 3.2, 3.3 and 3.4.

Table 3.3: Asthma health data inputs. Per 10,000 population, age-adjusted.

State	Health endpoint	Data years	Geographic resolution	Sources
Arizona	Emergency department visits	2015-2017	AZ primary care areas	Arizona Environmental Public Health Tracking Program, gis.azdhs.gov/ephtexplorer/
Florida	Emergency department visits	2015-2017	Zip code	Florida Environmental Public Health Tracking, www.floridatracking.com/healthtracking/mapview.htm
Massachusetts	Emergency department visits	2013-2015	Sub-county township	Massachusetts Environmental Public Health Tracking, matracking.ehs.state.ma.us/
Nevada	Emergency department visits	2015-2017	County	Nevada Hospital Emergency Department Billing and Nevada Population Data; provided by Jie Zhang on 5/14/19
New Jersey	Emergency department visits	2016	Zip code	Healthcare Cost and Utilization Project, www.hcup-us.ahrq.gov/
New Mexico	Emergency department visits	2012-2015	NM small area	New Mexico Department of Health, Indicator-Based Information System for Public Health Web site: ibis.health.state.nm.us ; retrieved 5/16/19
New York	Emergency department visits	2010-2014	Zip code	Office of Public Health Practice, New York State Department of Health; provided on 3/1/19
Texas	Emergency department visits	2012	Zip code	Texas Department of State Health Services, Center for Health Statistics - Texas Hospital Inpatient Discharge, Public Use Data File (PUDF), www.dshs.texas.gov/thcic/hospitals/Inpatientpudf.shtm

3.2.5 Population-adjusted health rates

State health values are represented as spatial outcomes of residents. As presented in Tables 3.2, 3.3 and 3.4, the available geography varies by state and indicator (AMI, asthma, or premature births). Where health data is not already represented at the census tract scale, we assigned values to the census tracts nested within the boundaries of the provided spatial scale (e.g. ZIP codes, sub-county townships, primary care areas, etc.).

Census tract health rates were estimated by calculating the population-weighted average of the health rates within each census tract. We applied the population-weighting method used in EJSCREEN, described in Equation 3.1 (based on EJSCREEN technical documentation [19, 30]).[2]

$$Value(A) = \sum_{Blk, Blk \cap A} \frac{\frac{BlockPop1}{CTPop1} \; CTACSPop \quad CT_{RawValue}}{\sum_{Blk, Blk \cap A} \frac{BlockPop1}{CTPop1} \quad CTACSPop} \tag{3.1}$$

[2]Note: “BlockPop10” refers to the Census 2010 block level population total (used here because the ACS does not provide block resolution), and “CT” indicates census tract. “CTACSPop” is the census tract estimated population count from the ACS, which is often di erent than the Census 2010 total for all blocks in the census tract, because the ACS data used here is a composite estimate based on survey samples spanning five years, while the Census is a full count at one point in time.

Table 3.4: Premature births health data inputs. <37 weeks gestation, percent.

State	Data years	Geographic resolution	Sources
Arizona	2013-2015	County	Arizona Environmental Public Health Tracking Program, gis.azdhs.gov/ephtexplorer/
Florida	2015-2017	Census tract	Florida Environmental Public Health Tracking, www.floridatracking.com/healthtracking/mapview.htm
Massachusetts	2014-2016	Zip code	Registry of Vital Records and Statistics, Massachusetts Department of Public Health; provided on 4/23/2019
Nevada	2015-2017	County	Nevada Electronic Birth Registry and Nevada Population Data; provided by Jie Zhang on 5/14/2019
New Jersey	2015-2017	Sub-county township	Department of Health, New Jersey State Health Assessment Data Web site: https://nj.gov/health/shad ; retrieved 3/12/19
New Mexico	2012-2016	NM small area	New Mexico EPHT Tracking Public Web site: https://nmtracking.org/ ; retrieved 5/29/19
New York	2014-2016	Zip code	Office of Public Health Practice, New York State Department of Health; provided on 3/1/19
Texas	2013-2015	County	Texas Health Data, Center for Health Statistics

For each health indicator and state, census tracts were ordered by population-weighted rates and assigned percentiles based on the statewide distribution of values, creating an index.

To estimate the health data within 1- and 3-mile bu ers around each peaker power plant, health rates were population-weighted by the fraction of the census tracts that reside within the area captured by the bu er. To determine which blocks are contained by a bu er, we applied the protocol used for EJSCREEN, which relies on the designation of census block internal points. We compared the population-weighted bu er value to the state indicator index and assigned the percentile. The percentile represents the state population associated with an equal or lower population-weighted health rate.

3.2.6 Bu ers across borders

In New York and New Jersey, several peaker power plants are located near state borders, causing the bu ers of those plants to include bordering state territory. In order to determine health rates in bu ers across borders, we considered both states' health data within the bu er, where available, and population data. The indicator indexing method does not change, and is still based on the population-weighted health values in the state for which the index is being calculated.

3.2.7 Aggregation and age adjustments: New Jersey and Texas

Health data for New Jersey and Texas was only available as unaggregated, patient-level values. These data required 1) aggregation to determine health rates by ZIP code, 2) age-adjustment of rates, and 3) suppression of small cell values to prevent patient identity disclosure.

For Texas, we retrieved hospitalization data from the Texas Department of State Health Services through the Texas Inpatient Public Use Data File [31]. The most recent year available without purchase at the time we accessed the website was 2012 hospitalization data. We aggregated data for all four quarters in 2012, then extracted incidents for AMI and asthma based on ICD-10-CM codes [32].

New Jersey ED data on AMI and asthma is from the 2016 State Emergency Department Database (SEDD) and the State Inpatient Databases (SID) managed by and purchased from the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality (AHRQ). Duplicate patient records were removed, and SID data were combined with the SEDD database where patients were admitted to the hospital but initially seen in the ED. AMI and asthma incidents data were extracted using the ICD-10-CM codes [32].

3.2.8 Aggregation and age adjustments: finding the AMI and asthma rates at the ZIP code level

When extracting emergency department data, patient incidents of AMI and asthma were aggregated by ZIP code and age category. For AMI, five-year age categories start at 35 years and above, since incidents of AMI below the age of 35 are significantly less likely than incidents above the age of 35. For asthma, five-year age categories start at birth.

From the total patient ED visits for each ZIP code and age category, we calculated the crude rate of AMI and asthma by dividing the total ED incidents per ZIP code by the age-specific population. We used 2016 population data for New Jersey, and 2012 population data for Texas, with both sets derived from the US Census using ZIP code tabulation areas. We multiplied the crude rate by 10,000 in order to present a value per a population of 10,000, which is consistent with other health rate data in our study.

To find the age-adjusted health rates for Texas and New Jersey, we multiplied the crude prevalence rate by the age-adjustment weights, derived from the US projected population for 2000 [33]. Following adjustment, we combined age bin values for each ZIP code.

In some cases it is necessary to suppress health rates due to privacy concerns. We followed protective parameters for suppression—for demographic and geographic subgroups where there are fewer than or equal to 20 emergency department visits or a population less than 5000, ED rates are not presented [34].

3.3 Cumulative vulnerability index

In order to compare populations living near power plants across multiple metrics, we developed a Cumulative Vulnerability Index (following Krieger *et al* [35]) to combine demographic, environmental and health indicators. We calculated this Index for both 1- and 3-mile bu er regions around each plant. We first found the percentile ranking for each indicator value within the bu er zone as ranked against census tracts statewide. We next averaged these percentiles for each indicator i within each category j: demographic, environmental and health. Finally, we summed these average indicator percentiles to create a Cumulative Vulnerability Index, as given in Equation 3.2:

$$Cumulative\ vulnerability\ index = \sum_j \sum_i \frac{(Percentile)_{i,j}}{(Number\ of\ indicators)_j} \quad (3.2)$$

The maximum possible Index score accordingly to this methodology would be 300. If a census tract scored at the median percentile in every category it would have an Index of 150, which we use as our Reference Index value. However, we note that 150 is not necessarily the median Index value; to find the median index value we would have to create a statewide Cumulative Vulnerability Index for every census tract in each state, which is beyond our current scope.

4. State policy overview

Peaker power plant replacement and renewable energy and storage adoption will be shaped by the suite of policy and regulatory targets, incentives, and structures a ecting each state's electric grid operations. Relevant state-level measures typically include renewable energy incentives such as renewable portfolio standards (RPS), energy storage targets, and greenhouse gas and criteria pollutant emission reduction targets, among others. On a regional basis, New York, New Jersey and Massachusetts all belong to the ten-state Regional Greenhouse Gas Initiative (RGGI), a mandatory cap-and-trade market to reduce CO_2 emissions from the power sector [36].[1] Additional key state-specific policies are described below, addressing i) renewable energy, ii) energy storage, iii) air pollutant emissions, and iv) environmental justice in each state.

4.1 Arizona

Arizona has significant solar potential, but relatively low renewable energy targets. It considered but did not finalize a Clean Peak Standard, which would have supported energy storage.

Electricity: 15% renewable by 2025.

Arizona's Renewable Energy Standard and Tari (REST), implemented by the Arizona Corporation Commission (ACC) in 2006, requires utilities and cooperatives to secure at least 15% of generation by 2025 from renewable sources, with 30% of renewable generation from distributed energy resources (DERs) using a renewable energy credit program [37]. The REST includes DER credits for utilities when they provide financial incentives to customers who utilize or install solar. There is room for significant growth in solar in Arizona: it has the third highest nationwide urban utility-scale and fourth highest rural utility-scale technical potential for photovoltaic installations [38]. A recent ballot measure to increase the amount of renewables in Arizona's energy portfolio failed, due in part to heavy campaign spending by the utilities. In 2018, Commissioner Andy Tobin proposed the Arizona Energy Standard Modernization Plan, which would update the REST to a Clean Resource Energy Standard and Tari (CREST), expand the definition of renewable energy, require an increasing percentage of peak energy load to be met by clean generation, and set a target of 80% renewables by 2050 [39]. CREST has not been formally ratified as of 2019, but is still ongoing. In February 2019, the new ACC Commissioner, Sandra D. Kennedy proposed to update the REST to 50% renewables by 2028, including higher utilization of DERs, with additional incentives for solar and energy storage [40].

As of 2019, RGGI states include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. After the last comprehensive program review in 2012, which set the 2014 and beyond emission caps, the 2014 total emission of greenhouse gas CO_2 was set at 91 million short tons, with annual declines of 2.5% from 2015 through 2020.

Energy storage: No target.

Arizona has not successfully passed an energy storage target, in spite of a 2018 proposal from Commissioner Tobin for a 3 GW energy storage target and the implementation of a Clean Peak Standard. A March 2018 ACC restriction on the expansion of natural gas electricity [41] spurred increased utility interest in energy, particularly in areas with high levels of rooftop solar adoption. However, lithium-ion battery fires at the Arizona Public Service Company (APS) Elden Substation in 2012 and the APS McMicken Substation in 2019 prompted the ACC to withhold endorsement of large-scale lithium-ion battery installations and recommend other options for large-scale deployment [42]. APS is still promoting batteries to meet its deployment goal of 100 MW solar and 850 MW storage by 2025; other major energy storage companies are also targeting to increase energy storage by 2025, and have signed on the Energy Storage Industry Corporate Responsibility Pledge in 2019, to indicate corporate commitment to safely implement at least 35 GW while also considering employee and customer safety and risk concerns [43].

Emissions: 50% below 2000 greenhouse gas levels by 2040.

The Arizona Department of Environmental Quality (ADEQ) has adopted greenhouse gas (GHG) targets to reduce emissions to 2000 levels by 2020 and 50% below 2000 levels by 2040 [44]. In addition, individual cities have set GHG goals: for example, Phoenix met its 2015 goal of reducing city emissions to 5% below 2005 levels, and in 2018 set a target of 30% reductions below 2012 levels by 2025 and 80% GHG reductions by 2050 [45].

Environmental justice: Not defined by policy.

The Arizona Department of Transportation and the ADEQ directly address federal civil rights non-discrimination statutes within their agencies, and the ADEQ has a Civil Rights division with an Environmental Justice/Title VI Nondiscrimation Program Coordinator who oversees the Civil Rights division. The ADEQ commits to "ensuring that no person is excluded from participation in, denied the benefits of, or subjected to discrimination under any program, activity or service that it provides on the basis of race, color, national origin, or on the basis of gender or disability, or on the basis of age"' while complying with the Civil Rights Act, Rehabilitation Act, Age Discrimination Act, and other federal statutes related to anti-discriminatory policy [46, 47]. While ADEQ has taken some steps to avoid furthering environmental unjust treatment of individuals and communities, there is nothing in policy put forth by ADEQ that actually addresses the unfair treatment of communities, disproportionate contamination, and lack of remediation e orts for historical and legacy environmental injustices. Further, while ADEQ has an Environmental Justice coordinator and policy, the term Environmental Justice is not defined, and there is no mention of how to atone or remunerate for past injustices to historically discriminated-against communities. The University of Arizona and Arizona State University, non-Arizona Universities, as well as smaller local colleges, have studied environmental justice issues in Arizona and the surrounding regions, finding that environmental justice is not being applied equally among populations, with little or no historical reconciliation for previous environmental injustices [48, 49, 50]. Numerous local Arizona governments, nonprofits, native, and tribal communities also have organized to combat historic and current environmental injustices within Arizona.

4.2 California

California has numerous policies and incentives supporting the deployment of renewable resources and energy storage, including specific carve-outs for disadvantaged communities. Alignment of these many policies and incentives can help support the replacement of peaker plants with storage, particularly in vulnerable and environmentally overburdened communities.

Electricity: 60% renewable by 2030 and 100% carbon-free by 2045.

California has continuously updated its renewable portfolio standard (RPS) since its first introduction in 2002 [51], which required 20% renewables by 2017 from retail electricity sales from investor-owned utilities (IOU), publicly owned utilities, community choice aggregation programs, and electric service providers. Senate Bill 100 (2018) most recently updated the RPS to a 2030 target of 60% of electricity retail sales by 2030, and requires that all of California's electricity come from renewable, carbon-free sources by 2045 [52]. Implementation of the RPS is overseen by the California Energy Commission, which verifies eligibility, compliance, and certification [53].

Energy storage: 1,325 MW by 2020; recommended 12 GW by 2030.

Under legislative direction [54], the California Public Utilities Commission (CPUC) set the state's first energy storage target: 1,325 MW by 2020 to be installed before 2025 by the state's three investor-owned utilities—Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). These targets included utility-scale, distribution-connected and behind-the-meter allocations. Under AB2868, additional energy storage targets were added for up to 500 MW of behind-the-meter storage among the three largest IOUs [55]. The state's Self Generation Incentive Program supports behind-the-meter energy storage deployment and includes an underutilized 25% carve-out for storage projects in disadvantaged and low-income communities [56]. The CPUC recently recommended procurement of more than 12 GW of battery storage and additional pumped hydropower by 2030 to help integrate renewables and replace retiring capacity on the grid [57].

Emissions: 40% below 1990 greenhouse gas emissions by 2030; carbon-neutral by 2045; majority of state is in federal non-attainment for ozone and fine particulate matter concentrations.

California's 2006 California Global Warming Solutions Act (AB32) limits GHG emissions to 1990 levels by 2020, which the state has implemented through a cap-and-trade system [58]. In 2016, the legislature extended this target to require a 40% reduction in GHG emissions below 1990 levels by 2030 [59]. In 2017, SB398 extended the cap-and-trade market mechanism for GHGs reduction through 2030 [60]. In 2018, Governor Jerry Brown signed an executive order for the state to reach carbon neutrality by 2045 [61]. Both cap-and-trade and the carbon neutrality targets, which may allow for carbon o sets, do not ensure that emission reductions occur in the communities where emitting facilities are currently located.

Both the federal government and State of California set air quality standards, which are currently aligned for certain pollutants. Large portions of California are designated as in non-attainment for three of the National Ambient Air Quality Standards: eight-hour ozone concentrations, at 70 parts per billion (ppb); 24-hour fine particulate matter ($PM_{2\ 5}$) concentrations, at 35 g/m^3; and 24-hour PM_{1} , at 150 g/m^3 [27]. The California Air Resources Board (CARB), working with local air pollution control districts, is responsible for ensuring regional air quality monitoring, permitting, and planning are implemented for businesses and stationary emission sources, including power plants [62].

Environmental justice: Targeted clean energy funding for environmental justice communities defined by cumulative health, environment and socioeconomic burdens in CalEnviroScreen.

California's broad environmental justice community was organized by indigenous populations, nonprofits, and grassroots organizations, making it one of the first states in the nation to define and address environmental justice. The first codification of environmental justice in California was through the Office of Planning and Research in 1970, which defined environmental justice as "...fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies" [63]. The definition of environmental justice has expanded overtime, and has been addressed by numerous agencies within the California government.

The California Environmental Protection Agency (CalEPA) defines environmental justice as "...fairness, regardless of race, color, national origin or income, in the development of laws and regulations that a ect every community's natural surroundings, and the places people live, work, play and learn." Building on work including [64, 65], CalEPA's office of Environmental Health Hazard Assessment (OEHHA) worked with community members, scientists and stakeholders across California to develop CalEnviroScreen, an environmental justice screening tool to identify disadvantaged communities based on demographic and health characteristics and exposure to pollution and environmental hazards [18]. Other California agencies, such as the CEC and CARB, also define environmental justice, and have committees, grants or other programming to help implement the purpose of environmental justice [66, 67]. CalEnviroScreen is employed to allocate moneys from the cap-and-trade-funded GHG Reduction Fund: under SB535 and AB1550, 25% of these funds are set aside to invest in disadvantaged communities, 5% are designated for projects that benefit low-income households, and another 5% directed towards projects benefiting low-income households within proximity to disadvantaged communities [68, 69]. As noted earlier, 25% of SGIP funding also supports and Equity Budget for energy storage owned by and located within environmental justice communities [56]. In response to underutilization of the equity budget and the recent spate of wildfires and power cut-o s meant to prevent these fires, the legislature allocated another $100 million for an Equity Resilience Budget within SGIP to provide energy storage backup power for vulnerable populations at high risk for electricity shut-o s [70].

4.3 Florida

Florida has significant solar resources, but a lack of support policies has limited deployment from reaching its potential. The state has no explicit renewable energy or storage targets, although some large projects are being built due to the high resource potential in the region.

Electricity: No renewable targets.

Florida does not currently have a renewable portfolio standard or any targets [71], although limited renewable energy incentives are in place, including net metering. Tallahassee and other individual cities are taking a more progressive stance towards renewables by committing to 100% renewable-sourced energy by 2050 [72]. A number of recent state bills supporting renewable energy portfolio standards and targets have not left committee. Certain policies have also limited solar deployment, such as a ban on power purchase agreements between non-utility providers and consumers, but numerous solar and solar+storage systems have been built or announced, including Florida Power and Light's proposed plan for a 409 MW solar and storage project [73].

Energy storage: No target.

Florida has no energy storage targets, although some incentives are in place: balancing authority JEA provides rebates behind-the-meter residential rooftop solar customers to add battery storage [74], and Florida Power and Light o ers an installation rebate for thermal energy storage [75]. However, distributed storage and solar+storage systems can be a crucial resiliency approach to combating ever-growing natural disasters, which disrupt and damage the electrical grid. Duke

Energy Florida aims to install at least 50 MW of battery storage by 2022, with three projects in Trenton, Cape San Blas, and Jennings underway to improve reliability and add capacity to constrained areas [76]. While able to provide resiliency, particularly during natural disasters, solar and storage solutions still face political opposition in Florida, demonstrated by the failure of House Bill 1133 (2018) [77], which proposed a pilot program for onsite solar+storage at critical disaster resilience facilities.

Emissions: 80% below 1990 GHG levels by 2050 (unsupported).

In 2007, Governor Charlie Christ's executive order 07-127 established targets to reduce GHG emissions to year 2000 levels by 2017, 1990 levels by 2025, and 80% of 1990 levels by 2050 [78]. That same year, executive order 07-128 initiated the Energy and Climate Change Action Team to direct and implement the GHG targets [79]. However, Governor Rick Scott put all climate-related efforts on hold after taking office in 2011. On a regional level, Broward, Miami-Dade, Monroe, and Palm Beach counties formed the Southeast Florida Regional Climate Change Compact in 2010 to address regional climate impact through mitigation and adaptation strategies [80].

Environmental justice: Not defined by policy.

Florida does not have a state-wide environmental justice mandate, nor an official stance on environmental justice considerations for industrial or commercial projects. The state does consider environmental justice in brownfield redevelopment, and defines it as "...the fair treatment of all people of all races, cultures, and incomes with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" [81]. Additionally, under the Office of Resilience and Coastal Protection, planning grants that include environmental justice considerations can be used for preparing Florida's coastal communities for climate change impacts such as coastal erosion, flooding, and ecosystem changes [82]. Multiple universities, advocacy nonprofits, and community groups also push for environmental justice to be at the forefront of the sunshine state's redevelopment and remediation efforts for historically vulnerable communities.

4.4 Massachusetts

Massachusetts has a number of policies and incentives to increase renewable energy and storage on the grid and decrease emissions, specifically during peak demand hours.

Electricity: 35% renewable by 2030 and 80% renewable by 2050.

In 2017, Massachusetts set a Clean Energy Standard (CES) targeting 35% of electricity from clean resources in 2030 and 80% in 2050. This standard expands upon the state's 2002 Renewable Portfolio Standard (RPS), which had required 15% renewable electricity by 2020 from new resources (Class I) and 5.5% from existing resources, including 3.5% waste-to-energy (Class II). The RPS included an additional solar carve-out of 1,600 MW by 2020, which was achieved early. In response, the 2017 Solar Massachusetts Renewable Target increased support for an additional 1,600 MW of solar through a declining block tariff program. The CES requires electricity to be obtained from energy generation sources that have a net lifecycle greenhouse gas emission rate at or below 50%, as compared to efficient natural gas sources [83].

Energy storage: 1000 MW by 2025.

The Massachusetts 2015 Energy Storage Initiative set a 2020 energy storage target of 200 MWh. This initiative was established to encourage the expansion and deployment of commercial storage technology to support grid reliability, system efficiency, and peak demand reduction [84]. In 2018, the legislature increased this target to 1,000 MWh of energy storage by 2025 under An Act to Increase Clean Energy. In addition, this Act introduced a Clean Peak Energy Standard, still under development, which will require a percentage of peak demand to be met with clean resources. The state's Community Clean Energy Resiliency Initiative may also provide support for storage in certain cases, particularly in the form of backup energy storage and microgrids [85]. Initiatives to further expand the state's energy storage targets are under consideration.

Emissions: 80% below 1990 GHG emission levels by 2050.

Massachusetts power sector greenhouse gas emissions are governed in part by RGGI, as described above. In addition, the state has an in-state CO_2 cap-and-trade program limiting emissions from its power sector. Massachusetts currently has a 2050 target of 80% GHG emission reductions below 1990 levels [86, 87].

Environmental justice: Defined based on minority, low-income and linguistically isolated populations.

Massachusetts first defined Environmental Justice in 2002, under the former Executive Office of Environmental A airs, as a right of the people to be protected from environmental pollution and to make that protection equal, and for the people to have meaningful involvement of the equitable distribution of environmental benefits. Executive Order 552 in 2014 promoted environmental justice in laws and regulations, but fell short of providing sufficient enforcement mechanisms. In 2017, the environmental justice definition was updated by the Executive Office of Energy and Environmental A airs to specifically address historically disadvantaged communities, specifically including communities of color (25% or more residents identifying as non-white), low-income communities (median household income equal or less than 65% of statewide median), and English-limited communities (adults in 25% or more households speak English less than very well) [88].

However, implementation of environmental justice-based decision-making was difficult to enforce at the regulatory level without enforcement and deterrence for non-compliance. Therefore, House Bill 761/Senate 464 and House Bill 826/Senate 453 were introduced in June 2019 as the Environmental Justice Act (EJA), creating an advisory council comprised of environmental justice community representatives, university and research institutions, health board representatives, and other pertinent stakeholders in community health and welfare [89]. Additionally, the EJA enables public participation, establishes an environmental justice working group, and requires environmental impact reporting. Current projects under the environmental justice policy include revitalizing brownfields, investing in clean energy technology, and developing greenspaces within highly urbanized areas [90].

4.5 Nevada

Nevada has significant solar potential and ambitious renewable energy targets and numerous proposed solar and storage projects.

Electricity: 50% renewable by 2030 and 100% carbon-free by 2050.

Nevada's Renewable Portfolio Standard, first initiated in 1997, is currently set at a goal of 50% renewable energy by 2030 and 100% renewable by 2050 [91]. A proposal for solar capacity to double in 2018 was approved by the PUCN. Over the last two years, construction permits for new renewable or transmission facilities were higher than for general electric, water or natural gas facilities. Proposed new generation facilities in Nevada are overwhelmingly renewable and/or energy storage, which includes over 1,000 MW of solar photovoltaic and 1,600 MW of solar thermal capacity for 2019 and after [92].

Energy storage: 1,000 MW by 2030 under consideration by the Public Utilities Commission of Nevada.

Nevada does not yet have an energy storage target, but the Public Utilities Commission of Nevada has drafted a proposed goal of 1,000 MW of storage by 2030 [93]. Distributed battery energy storage is projected to increase across Nevada, particularly in combined with solar+storage systems. This deployment includes 101 MW of storage for 2019 and beyond [92].

Emissions: 45% below 2005 GHG levels by 2030 and zero or near-zero emissions by 2050.

Nevada has a goal to have net-zero greenhouse gas emissions by 2050, and in the interim, to reduce greenhouse gas emissions to 28% below 2005 emission levels by 2025 and 45% below 2005 emission levels by 2030 [94].

Environmental justice: Not defined by policy.

Nevada does not have a state-wide environmental justice mandate, nor official stance on environmental justice considerations for industrial or commercial projects. The only state department that addresses environmental justice from an official policy stance is the Department of Transportation [95].

4.6 New Jersey

Under Governor Phil Murphy, New Jersey has rejoined the Regional Greenhouse Gas Initiative and set numerous renewable energy and storage targets.

Electricity: 50% renewable by 2030, including solar carve-outs and 3,500 MW o shore wind.

Under the 2018 Clean Energy Act, New Jersey set a Renewable Portfolio Standard which requires at least 35% of electricity be sources from renewables by 2025 and 50% by 2030, including 3,500 MW of o shore wind and a solar carve-out ramping down from 5.1% in 2021 to 2.21% in 2030 [96]. The Solar Renewable Energy Credit program will be closed to new registrants once the 5.1% target is met.

Energy storage: 2,000 MW by 2030.

The Clean Energy Act also set an energy storage target of 600 MW by 2021 and 2,000 MW by 2030 [96], among the most ambitious storage goals in the country.

Emissions: 80% below 2006 GHG emissions below by 2050.

New Jersey set a goal of 80% greenhouse gas (GHG) emission reductions below 2006 levels by 2050 under the 2007 Global Warming Response Act [97].

Parts of New Jersey are designated as marginal to moderate nonattainment for National Ambient Air Quality 8-hour ozone standards (70ppb) [27]. New Jersey submitted a request for ozone standard revisions in 2016 that would account for upwind state's contributions to New Jersey's nonattainment, but has not been granted an exemption from current standards [98]. The New Jersey Bureau of Evaluation and Planning submits State Implementation Plans to the EPA outlining an approach to reduce criteria pollutant emissions, including ozone concentrations [99].

New Jersey's power sector emits NO_x, a precursor to ozone. On warm summer days, ozone concentrations can be very high. To address this, New Jersey implemented a High Electric Demand Day protocol in 2009, which restricts certain power plants with high NO_x emission rates from running when PJM forecasts load (demand) to be high, thereby limiting emissions on days likely to have high ozone concentrations [100].

Environmental justice: Limited policy.

New Jersey's Department of Environmental Protection's Environmental Justice Advisory Council (EJAC) was first created in 1998 as the "Environmental Equity Task Force." One of the original EJAC tasks was to include and prioritize environmental justice considerations in New Jersey's permitting processes [101].

The EJAC was renewed by Executive Order 23 in 2018. Governor Murphy's Executive Order 23 defined environmental justice being inclusive of "...at a minimum, ensuring that residents of all communities receive fair and equitable treatment in decision-making that a ects their environment, communities, homes, and health;..." [102]. The New Jersey Department of Environmental Protection uses the EPA's definition of environmental justice, and uses EPA's EJSCREEN tool and other local or community sourced data for determining an environmental justice area [103].

4.7 New Mexico

While coal- and natural gas-fired generation has dominated electricity generation in New Mexico, wind and solar energy have been growing and the state has set ambitious renewable energy targets.

Electricity: 50% renewable by 2030 and 100% zero carbon sources by 2045.

New Mexico's renewable portfolio standard began as the Renewable Energy Act of 1978, and has been updated to a current goal of 100% renewable by 2045 [104]. IOUs and rural cooperatives will have to meet intermediary goals of 50% renewables by 2030 and 80% by 2040. Renewable energy sources include solar, hydropower, geothermal, and wind energy as major sources with or without energy storage accompanying the renewable source.

Energy storage: No targets.

Energy storage was added to the allowable technologies available to utilities in their integrated resources plans in 2017 [105], but no specific carve-outs from the renewable portfolio standards are granted for energy storage currently.

Emissions: 45% of 2005 GHG levels by 2030.

By Executive Order, Governor Michelle Grisham joined the U.S. Climate Alliance in January 2019, which supports the 2015 Paris Agreement for reducing greenhouse gas emissions by at least 45% of 2005 levels by the year 2030 [106].

Environmental justice: Limited policy.

New Mexico adopted an environmental justice mandate in 2005, creating a task-force led by the New Mexico Environment Department, with participating agencies including the State Engineer's Office, and the Departments of Agriculture, Health, Transportation, the Energy, Minerals, and Natural Resources, Public Safety, Labor, and of Public Education [107].

4.8 New York

New York has numerous renewable and clean energy targets including a renewable portfolio standard, solar initiative, clean energy standard, and energy storage initiative. The state participates in the multi-state RGGI cap-and-trade program.

Electricity: 70% renewable by 2030, 100% carbon-free by 2040.

New York first adopted a Renewable Portfolio Standard in 2004, with the goal to increase renewables to 25% by the end of 2013, later extended to 30% by 2015—although the state fell short of that goal [108]. The RPS was replaced by the Clean Energy Standard (CES) after 2015 in order to meet Governor Andrew Cuomo's Reforming the Energy Vision projections set forth in the NY State Energy Plan [109]. Additionally, $1 Billion was allocated through the NY Sun Initiative to scale the solar industry via education and training, installations, technical assistance, solar energy and tax incentives, and net metering [110]. Under his Green New Deal, Governor Cuomo expanded the CES to achieve 70% renewable energy generation by 2030. The CES is divided into two mandates: the zero-emission credit (ZEC) requirement and the renewable energy standard (RES). The RES focuses on requiring Load Serving Entities (LSE) to procure renewable energy credits for energy, whereas the ZEC requires LSEs to obtain ZECs, depending on the load for a given year [111] The 2019 Climate Leadership and Community Protection Act (CCPA) set an additional target of 100% carbon-free electricity by 2040 [112].

Energy storage: 1,500 MW by 2025 and 3,000 MW by 2030.

In 2018 New York set energy storage targets of 1,500 MW by 2025 and 3,000 MW by 2030 and developed an Energy Storage Roadmap to inform deployment strategy recommendations. The energy storage target is meant, in particular, to help alleviate peak demand in New York City-Westchester-Long Island areas [113].

Emissions: 85% below 1990 GHG levels and full carbon neutrality by 2050; peaker plant-specific NO_x reduction targets; in non-attainment for ozone.

In addition to energy targets, the CLCPA set an economy-wide greenhouse gas emission target of 85% below 1990 levels by 2050 and the remaining 15% o set to achieve net-zero emissions state-wide [112].

The New York City-Long Island area is considered in serious nonattainment for National Ambient Air Quality eight-hour ozone standards of 70 ppb [27]. The Department of Environmental Conservation (DEC) recently set regulations for emission rates of NO_x, an ozone precursor, from peaker power plants by 2023-2025, which may force many existing peakers to either retire or retrofit their existing emission control systems [114].

Environmental justice: Defined by the state based on minority and low-income populations and incorporated into permitting processes.

The DEC defines Potential Environmental Justice Areas as those with minority populations above 51.1% in urban areas (33.8% in rural areas) or 23.59% of households with incomes below the federal poverty level. The DEC Office of Environmental focuses on implementation through regulatory enforcement, public participation in review and permitting processes, promoting green infrastructure, and through grant opportunities [115]. Environmental justice analyses are also required under Article 10 in power plant siting considerations. The New York State Assembly passed Assembly 01779 (Senate 00181) in April 2019 to specifically strengthen the DEC's identification of existing highly polluted areas, which often coincide with environmental justice communities. This law will publicly publish the listing every two years by zip code or census block and the environmental hazards that caused the area to rank as a high local environmental impact zone [116]. Additionally, under the 2019 CPPA, a minimum of 35% of the state's clean energy and energy efficiency program funds are required to benefit disadvantaged communities [112].

The OneNYC program, implemented by New York City Mayor's Office of Sustainability, recognizes environmental justice, and supports policy to address health and environmental source disparities and promote economic growth within environmental justice communities, including brownfield redevelopment with community participation, collaborating with NYC Housing Authority for clean indoor air, and using green and grey infrastructure to mitigate flooding and promote water management in highly dense environmental justice areas with impermeable surfaces [117]. The New York City Council passed two laws in 2017: Introduction 0886-2015 (Law 2017/064) requires city agencies to address environmental justice concerns directly with the communities by establishing an environmental justice Interagency Working Group (IWG) to make an environmental justice community plan, identify citywide environmental justice initiatives, and provide recommendations to incorporate environmental justice concerns into city operational and policy programs [118]. Introduction 0359-2014 (Law 2017/060) requires a comprehensive environmental justice study to identify environmental justice communities and areas within NYC, recommendations for addressing environmental justice issues identified in the study, and to make the study results available to the general public [119]. Various non-profit and advocacy organizations for environmental justice also exist in New York, and often work with government entities to create and enforce environmental justice laws.

4.9 Texas

Energy in Texas is unique among states: it is the only state in the contiguous U.S. with its own transmission grid, ERCOT, and is also the electricity production capital of the country. Texas has a complex and dense history when it comes to energy production, distribution, and the encompassing political climate. This history permeates the current regulatory climate, shaping how much of Texas approaches energy generation and solutions for environmental and social challenges.

Electricity: 10,000 MW of renewable capacity by 2025, achieved in 2009.

Texas easily achieved its initial RPS of 5,000 MW of new renewable capacity by 2009, and by that year had already passed its expanded target of 10,000 MW of new capacity by 2025. Under the renewables mandate, the Public Utilities Commission developed a renewable credits trading program [71]. The state has deployed more than double the capacity of its renewable energy mandate, almost exclusively with wind energy [120]. Solar provides less than 1% of Texas's electricity, although it has significant resource potential. The City of Austin, the capital of Texas, aims to have solar comprise half of its energy capacity by 2020 [121]. Other Texas cities are also adding renewable generation through multi-year contracts with utilities for solar and wind farms. Georgetown produces more renewable energy than it consumes, allowing ERCOT to designate it as 100% renewable [122].

Energy storage: No target.

Energy storage is considered a generation asset under Texas regulation [123], and has the same interconnection privileges as other generation assets in terms of electricity market participation, transmission access, and other transactions on the wholesale market. However, investor-owned utilities in Texas are prohibited from owning generation assets (and therefore storage) if they own transmission, which has presented limitations on energy storage growth and curtailed the ability of storage to provide multiple "stacked" grid services which allow it to be competitive in other markets. In September 2019, the enactment of Texas Senate Bill 1012 partially lowered this barrier by allowing municipally owned utilities and electric cooperatives to own storage systems without registering them as generating units [124]. Texas frequently has a surplus of wind power, which is either curtailed or sold at negative prices onto the grid, suggesting that energy storage would be particularly useful in this region if market barriers were removed.

Emissions: No target; out of attainment for ozone.

Texas has the largest greenhouse gas emissions in the nation, but has no greenhouse gas emission targets and its annual emissions are on the rise [125]. While public opinion to address climate change is growing in Texas, state legislation is slow to directly address carbon-based fuels or greenhouse gases. Local governments are acting more aggressively on climate goals.

Regions of Texas are also designated out of attainment with the National Ambient Air Quality eight-hour ozone concentration standard (70 ppb) [27].

Environmental justice: Limited policy.

The Texas Commission on Environmental Quality (TCEQ) is the primary agency in Texas for air, water, and waste regulatory compliance and monitoring [126]. The TCEQ has developed an official stance and program on environmental equity (used interchangeably by the agency with environmental justice), adopted from multiple federal nondiscrimination laws, and focuses on:

- Participation by residents and fairness in regulatory processes, and
- Promoting an equal benefit from environmental protections, while addressing environmental justice concerns.

Other regional Texas agencies also address civil rights issues through environmental justice, such as the Capital Area Metropolitan Planning Organization (CAMPO) in Austin, which is a multi-county transportation planning organization [127].

Texas was one of the first states to have an environmental justice lawsuit filed with the US Commission on Civil Rights, regarding the racially discriminatory siting of a landfill, and has historically utilized the courts and legal system to defend racially motivated injustices [128]. Numerous TCEQ environmental equity applied principles have helped to shape regulatory process and compliance, but local environmental justice organizations within Texas have much work left to ensure equity and justice is applied fairly to historically disadvantaged social, political, and economic populations.

5. Grid requirements: transmission constraints and capacity needs

While our overall analysis focuses primarily on individual states, most states are interconnected with larger regional grids and therefore their power sectors may be subject to regional grid management structures and decision-making. These regional transmission markets a ect where solar and storage can cost-competitively meet grid needs. Here, we assess transmission markets constraints by state to determine where solar and storage could play a role in meeting peak capacity requirements.

The Federal Energy Regulatory Commission (FERC) regulates most interstate energy transmission, particularly electricity, including the country's seven Regional Transmission Operators (RTOs) and Independent System Operators (ISOs): CAISO, ERCOT, SPP, MISO, PJM, NYISO, and ISO-NE. These ISOs and RTOs manage regional electricity markets, but not all states are covered by an ISO or RTO, in which case decisions are made on a more local level. RTOs and ISOs ensure that electricity needs across each region meet reliability standards. These requirements can be more challenging to meet in areas with transmission constraints, where there are grid limitations to importing electricity into a given zone. These transmission constraints impact the value of local energy storage and solar: local deployments may be more valuable in locations where transmission is limited. Clean energy deployments in these local areas may also be able to displace the nearby fossil generation currently meeting local loads; building solar and storage near a power plant in an area without local constraints could displace that fossil generation, but that plant could also go on to supply electricity elsewhere across the larger grid.

We evaluate transmission constraints by examining ISO reliability requirements to determine where deployment of local resources, such as solar and storage, may be required to displace a peaker power plant that meets local resource needs. The North American Electric Reliability Corporation (NERC) uses a 1 in 10 physical reliability standard which is calculated as the probability-weighted average of loss-of-load (LOL) per year, and can be reported as 1 day in 10 years equaling 0.1 LOL Events (LOLE) [129]. The 1 in 10 standard is directly reflective of a state's power capacity reserve margin, because higher reserve margins can decrease the LOL events and hours. ISOs adjust zonal loads and excess capacity such that the total LOLE will be equal to or less than 0.1. All states in this study either adhere to NERC's 1 in 10 physical reliability standard or are more restrictive.

Within the transmission electricity market structure for each state, we develop a framework to prioritize candidate peaker power plants for replacement with storage or solar+storage based on electricity capacity markets (to determine where storage might be well-compensated) and plant utilization rates (to identify plants which are infrequently used and therefore potentially vulnerable to replacement). We review the state's market as a whole and how electricity pricing is structured; examine ISO reliability requirements, transmission constraints, and subsequent congestion; review load pricing; and compare power plant capacity factors. We omit Texas, Florida, and New Mexico due to limited information about load zones and transmission constraints in these states.

5.1 Arizona

Arizona is not a part of an ISO, but instead operates within the Western Interconnection (WECC) which is regulated by both FERC and NERC, and has eight balancing authorities: Arizona Public Service Company (AZPS), Arlington Valley LLC (DEAA), Gila River Power LP (GRMA), Griffith Energy LLC (GRIF), New Harquahala Generating Company LLC (HGMA), Salt River Project (SRP), Tucson Electric Power Company (TEPC), and Western Area Power Administration: lower Colorado region (WALC) [130], as well as several electric cooperatives. Arizona Corporation Commission (ACC) agency, is Arizona's constitutionally-created public utility commission, and is one of thirteen states where the general public elects the commissioners as opposed to the state's governing body. The transmission electric market is currently a regulated market and the state allows public utilities to act as monopolies. Rate increases are debated in public hearings [131].

The transmission and distribution electric market in Arizona is overseen by ACC's Utilities Division. The ACC complies, or partners, with NERC, FERC, the National Association of Regulatory Utility Commissioners (NARUC), and the WECC. Additionally, Arizona may source or sell power through the transmission system of two of Western Area Power Administration's four regions: Desert Southwest or Colorado River Storage Project Management Center.

5.1.1 Transmission constraints

The ACC ensures compliance with NERC Reliability Standards and WECC rules [132]. The Biennial Transmission Assessment (BTA), last performed in 2018, evaluates the reliability of Arizona's transmission from a reliability stance for adequacy in meeting local load, including contingency studies and recommendations, and provides due diligence for transmission planning. ACC oversees the administrative, regulatory, and compliance for all utilities within Arizona that are not cooperatives, and other special cases. In this limited representation, the wholesale market operates with transmission inter- and intrastate, allowing for competition, and when needed, additional capability.

Arizona's first Biennial Transmssion Assessment, from 2000, showed potential and real import-constrained load pockets in Phoenix, Tucson, and Yuma. Four other regions were added in subsequent BTAs: Mohave County, Santa Cruz County, Pinal County, and Cochise County. Due to low population density and high transmission expansion costs, Cochise and Santa Cruz Counties are no longer receiving reliability upgrade analysis recommendations from the ACC [132]. For these two counties, since further development costs are suspended for reliability, they may be good area options for replacement of local peaker plants with renewable energy generation and storage (including distributed storage), as a replacement option would provide additional reliability to the pocket without necessarily increasing transmission upgrade expenses. Impact, however, would be limited to those service areas with low population density. Siting storage in the consistently import-constrained areas of Phoenix, Tucson, and Yuma would provide a benefit to a larger population density area, as this storage capacity would replace reliability-must-run generation that is likely more expensive.

5.1.2 Peaker replacement opportunities

The majority of Arizona's peakers are located within the state's load pockets, including six units at four plants in Maricopa County (in or near Phoenix), three each in Pima County (in or near

Tucson) and in Pinal County, two in Cochise County and one each in Yuma, Mohave, and Santa Cruz Counties. Replacing peakers in each of these counties would likely require local resources to ensure that reliability is met within each load pocket. Within these pockets, the plants with lowest capacity factors may provide opportunities for replacement. In Maricopa, the four gas turbine units (Agua Fria, West Phoenix, Ocotillo, and Kyrene, all of which are located at larger plants) have capacity factors under 2% (2016-2018 average), but the Kyrene gas turbine unit notably reports negative generation due to more on-site consumption of electricity than provision of electricity to the grid. DeMoss Petrie and North Loop, in Pima County, both report capacity factors of 1% or less. The oil-burning Douglas plant in Cochise has a capacity factor of 0.1%, and Valencia in Santa Cruz County has a capacity factor of 0.2%. Coolidge Generating Station and Saguaro in Pinal County both operate at capacity factors under 3%.

5.2 California

Eighty percent of the California electric grid is balanced by the California Independent System Operator (CAISO), although the grid in some sub-regions is balanced by other authorities, including the Los Angeles Department of Water & Power (LADWP), the Balancing Authority of Northern California (BANC), Imperial Irrigation District (IID), PacificCorp West, NV Energy, Turlock Irrigation District (TID), and Western Area Lower Colorado (WALC) [133]. While CAISO is regulated by FERC, it also complies with the North American Energy Standards Board, the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), and NERC. Like the wholesale (auction) electricity markets available in other ISO regions, the CAISO market ensures same day and day-ahead pricing and market services for the bulk transmission system on competitive terms, and also manages ancillary services. This includes the use of congestion revenue rights (CRRs) and convergence bidding, both instruments used to financially incentivize the free movement of electricity in the near term [134].

The CPUC is California's constitutionally-created public utility commission, and regulates the investor-owned electric utilities with operations in California's currently regulated electricity market. The CPUC oversees how electricity is generated within the state, near and long term procurement procedures, ensures reliability in meeting loads for local (load pocket) and broader regions, and ensures resource adequacy [135].

The CEC manages siting decisions for thermal power plants and certifies renewable energy generation, in addition to work developing energy policy, supporting energy research, and setting energy efficiency standards [136].

5.2.1 Local reliability areas and transmission constraints

Ten local capacity areas and additional sub-areas are identified and tracked by CAISO to establish local reliability requirements [137]. CAISO defines the local resource capacity required to meet local peak load given the risk of various contingencies and existing transmission constraints. For 2018, there were ten local capacity areas that were or had the potential to be import-constrained via local reliability requirements: Big Creek/Ventura, Greater Bay Area, Greater Fresno, Humboldt, Kern, LA Basin, North Coast/North Bay, San Diego, Sierra, and Stockton. The local capacity areas with the highest import-constraint potential (percent of local capacity requirement divided by the dependable generation) were the LA Basin (Southern California Edison territory) and the Greater Bay Area (PG&E territory). This is partially due to being located in highly populated, urban high load areas under 1 in 10 year reliability standard projections [137]. LADWP faces additional transmission constraints, but is a vertically integrated municipal utility operating outside of CAISO and manages these constraints internally.

When a generator may be needed to satisfy local load, and that is out of sequential merit order of the market, a reliability-must-run study may be performed to determine reliability conditions and may result in a reliability-must-run contract. The CPUC's resource adequacy program has largely supplanted these contracts, although a few were granted in 2018 and 2019 [137]. Plants receiving contracts are potentially economically vulnerable for replacement.

5.2.2 Peaker replacement opportunities

We considered three approaches to identify potential plants for energy storage replacement in California. In the first category are peaker plants which have recently received reliability-must-run contracts, which may be economically vulnerable. The second category includes California's once-through-cooling plants, which are required to retire by 2030 but many of which are slated to come offline before then. These plants were typically not designed as peakers, but many are now used in this capacity. Finally, within six of our largest local reliability areas, we identify the plants with the lowest capacity factor, which may be the most likely candidates for replacement in each region. All plants which received reliability must-run contracts were also among the plants with the three lowest capacity factors in their local reliability areas. In Table 5.1, we list the once-through-cooling plants and the plants with the lowest capacity factors in each reliability area. Plants with reliability-must-run contracts, which had all proposed retirement, are marked with a *.

5.3 Massachusetts

Massachusetts is a part of ISO New England (ISO-NE), the Regional Transmission Organization which covers Maine, Massachusetts, Rhode Island and Connecticut [138]; ISO-NE identifies the grid needs that determine the capacity value of peaker power plants or energy storage on the grid. ISO-NE, under FERC, is governed by the ISO Tari ,[1] which establishes roles for market participants, manages schedules and operations, and outlines services, rates, terms, and transmission conditions [139]. Massachusetts falls within the Northeast Power Coordinating Council (NPCC) under NERC for reliability standards.

ISO-NE operates as a hybrid zonal and nodal market, combining geographic districts with individual generating units. Nodes are located within, or in some cases across, di erent load zones. Multiple types of zones are used by ISO-NE, including load, capacity, reserve, dispatch, and key study areas. Three of ISO-NE's eight load zones are located in Massachusetts. These zones aggregate 900+ individual nodes for the wholesale market. Capacity zones combine several load zones together to establish the amount of capacity needed. These values are updated annually to determine the Forward Capacity Auction and other reconfigurations. ISO-NE is divided into four Reserve zones which are used to predict future capacity. ISO-NE also has 19 dispatch zones (seven in Massachusetts) used to ensure local system reliability using demand resources. ISO-NE uses Key Study Areas, including five in Massachusetts, to study, evaluate, and conduct assessments of related geographical regions to determine future loads, capacity, or other needs [140].

ISO New England Inc. Transmission, Markets, and Services Tari

Table 5.1: California replacement opportunities: a) Once-through cooling plants operated as peakers and required to retire, and b) the peaker plants with the lowest capacity factor in each if six of the local reliability areas 2016-2018 average). *Indicates plants recently proposing retirement and receiving reliability-must-run contracts.

Plant name	**EIA ID**	**Local reliability area** Sub-area)	**Capacity factor**
a. Once-through cooling plants retirement required for all)			
Alamitos	315	LA Basin Western LA Basin)	5.5%
Harbor	399	LADWP territory	2.1%
Huntington Beach	335	LA Basin Western LA Basin)	10.6%
Ormond Beach Generating Station*	8076	Big Creek/Ventura Ventura, Moorpark)	1.3%
Redondo Beach	356	LA Basin Western LA Basin)	3.3%
b. Low capacity factor by local reliability area			
Delano Energy Center	350	Big Creek/Ventura Big Creek, Vestal)	2.8%
Ellwood Generating Station*	8076	Big Creek/Ventura Ventura, Santa Clara, Moorpark)	1.3%
Ormond Beach Generating Station*	8076	Big Creek/Ventura Ventura, Moorpark)	1.3%
Alameda	7450	Greater Bay Area Pittsburgh/Oakland/Ames)	2.0%
Gianera	7231	Greater Bay Area San Jose, Moss Landing)	0.8%
Oakland*[b]	6211	Greater Bay Area Pittsburgh/Oakland/Ames)	0.2%
Hanford Energy Park Peaker	55698	Greater Fresno Wilson, Herndon, Hanford)	2.6%
Malaga Peaking Plant	56239	Greater Fresno Wilson, Herndon)	3.1%
Wellhead Power Panoche	55874	Greater Fresno Wilson)	2.5%
Century (Aliiance)	55934	LA Basin Eastern LA Basin, Eastern Metro)	0.4%
Drews-Agua Mansa	55935	LA Basin Eastern LA Basin, Eastern Metro)	0.3%
Springs Generation Project	56144	LA Basin Eastern LA Basin, Eastern Metro)	0.2%
CalPeak Power-Border	55510	San Diego/ IV Area San Diego, Border)	2.8%
Chula Vista Energy Center	55540	San Diego/ IV Area San Diego, Border)	0.8%
Cuyamaca Peak Energy	55512	San Diego/ IV Area San Diego, El Cajon)	2.7%
Feather River Energy Center*	55847	Sierra Bogue, Drum-Rio Oso, South of Table Mtn)	7.0%
Lodi CC (NCPA STIG)	7449	Sierra South of Rio Oso, South of Palermo, South of Table Mtn)	2.0%
Yuba City Energy Center*	55813	Sierra Pease, Drum-Rio Oso, South of Table Mtn)	7.9%

The once-through cooling plants Haynes (capacity factor 20.9%), Moss Landing (25.4%) and Scattergood (19.%) are also required to retire.

[b]Replacement with battery planned.

5.3.1 Capacity zones and transmission constraints

To ensure reliability and overcome transmission constraints, ISO-NE forecasts the locational capacity available over a Capacity Commitment Period within regional dispatch zones, which group together individual load zones [141]. ISO-NE identifies the capacity and load zones with a transmission interface (connection exchange) that may be import-constrained, signaling the zonal need for local resource adequacy requirements. For zones that are not import-constrained, load can be met by resources within the zone, in an adjacent zone, or from a further source including importing from a non-ISO-NE balancing authority [142]. To meet NERC's reliability standard of 0.1 LOLE, ISO-NE sets an Installed Capacity Requirement (ICR) which adjusts zonal loads and excess capacity such that the total LOLE will equal 0.1, on average [142]. The ICR measures the installed resources, subject to requirements from ISO-NE and NPCC, to satisfy peak load forecasted for the New England Balancing Authority area, accounting for required reserves.

Massachusetts has an import-constrained region, consisting of one capacity zone (Southeast New England, SENE), and three load zones: Northeast Massachusetts/Boston (NEMA/Boston), Southeastern Massachusetts (SEMA) and Rhode Island (RI). In unconstrained regions, the local capacity zone can meet its load with local resources while also satisfying the transmission security analysis (TSA) requirement. The TSA calculates the most reasonably anticipated events within the zone, typically utilizing first contingency (N-1) and second contingency (N-2) conditions [141]. In an import-constrained region, only a portion of the local TSA resource adequacy requirement can be met within the region, leading to a potential shortfall of capacity. The opposite is true of export-constrained regions, where there is too much capacity within a zone to be adequately exported outside of that zone due to zonal transmission constraints [142, 143]. The 2020 TSA requirement in SENE is 9,810 MW.

5.3.2 Peaker replacement opportunities

We identified peaker plants that may be candidates for replacement with energy storage based on i) capacity prices, ii) transmission constraints, and iii) plant capacity factors. Underutilized plants with low capacity factors may be easiest to retire or replace, while capacity prices indicate that meeting peak needs with current resources may be expensive. We identified the load and capacity zones for each peaker plant by comparing EIA site codes to the 2018 CELT (Capacity, Energy, Loads, and Transmission) forecast report, including capacity supply obligations and pricing by zones [144]. These load zones, particularly those with transmission constraints, indicate where local deployment of clean resources may be needed to displace a specific plant.

Capacity supply obligations (CSO) are contracts to sell capacity from a resource. We compare CSOs by load zone to identify peaker plants located in high CSO-contracted areas [144]. We also use wholesale hourly pricing of load, by zone, to identify peaker plants located in zones with higher pricing. This higher pricing indicates higher costs to deliver the capacity needed in a zone, and therefore where an alternative to peaking generation may be most valuable. Additional pricing and other technical reports available include Energy, Load, and Demand for each load zone [145].

Of the three MA load zones, SEMA consistently has the largest summer and winter CSOs during the capacity commitment periods, followed by WCMA, and finally NEMA. The wholesale hourly load cost comparison we calculated for the three load zones for June 2018 through December 2018 show that SEMA and NEMA have very similar costs, $57.11 and $57.17, respectively, while the average for WCMA is slightly lower at $54.49. The higher costs and import-constrained nature of SEMA and NEMA zones suggest that underutilized plants in these areas might present opportunities for replacement with local solar and storage deployment. The three plants with the lowest capacity factors in each zone are given in Table 5.2. All of the listed plants, with the exception of Nantucket, are over forty years old, also suggesting they might be ready for retirement.

Table 5.2: Massachusetts replacement opportunities: Lowest capacity factor plants in each load zone 2016-2018 average).

Load zone	Plant name	EIA ID	Capacity factor
NEMA	Framingham	1586	0.1%
	High St Station	1670	0.2%
	Wilkins Station	6586	0.1%
SEMA	Cleary Flood Steam	1682	0.7%
	Nantucket	1615	0.3%
	West Tisbury Generating Facility	6049	0.8%
WCMA	Doreen	1631	0.1%
	Shrewsbury	6125	0.2%
	Woodland Road	1643	0.1%

In certain years, Shrewsbury consumed more electricity onsite than it generated and reported negative generation.

5.4 New Jersey

New Jersey is a part of the PJM ISO, historically known as the Pennsylvania-New Jersey-Maryland Interconnection. PJM now partially or wholly encompasses 14 mid-Atlantic states.[2] While PJM is regulated by FERC, it also complies with NERC. NERC's ReliabilityFirst region (RFC) overlaps with the FERC PJM region for reliability standards in New Jersey. The ReliabilityFirst region also overlaps with FERC's MISO, and other small territorial regions.

PJM operates as a hybrid zonal and nodal market. Zones are established as Locational Deliverability Areas (LDAs), of which there are 27. According to the Regional Transmission Expansion Plan (RTEP) Baseline Assessment [146], LDAs need to import power under the Capacity Emergency Transfer Objective (CETO) in order to meet thermal and voltage testing cases for adherence to reliability standards. Nodes are established within, and in cases across, LDA zones. The 2018 RTEP Baseline Assessment clarifies that the LDAs must meet the CETO minimally, otherwise system reinforcements, including emergency scheduling as a penalty for inadequate local generation, are calculated to import enough capacity [147].

This current system, considered a nested LDA structure for the capacity market, does not allow for instantaneous and unrestricted movement of electricity throughout the PJM region. Instead, the pricing structure follows a locational market with mandatory participation by load. However, load can be met within the zone, in an adjacent zone, or from a further source including importing from a non-PJM balancing authority. The Marketing Monitoring Unit (MMU), created under the PJM Market Monitoring Plan, recommends that to improve reliability and efficiency, the market becomes a nodal capacity market that realizes capacity transfers between LDAs. Local capacity requirements for each LDA would be met by local resources, and then from exchanges with adjacent LDAs, until transmission constraints are alleviated. This approach would lower costs and increase reliability [148].

PJM has three major regions containing sub control zones: PJM Mid-Atlantic (11 control zones), PJM West Region (9 control zones) and PJM South (1 control zone). New Jersey includes the PJM Mid-Atlantic LDA control zones JCPL (Jersey Central Power and Light), PSEG N (PSEG North), PSEG (Public Service Electric and Gas), RECO (Rockland Electric Company), and AECO

[2] States include Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

(Atlantic City Electric) [148].

5.4.1 Transmission constraints and load zones

Real-time and day ahead market load and generation data shows that imports for the PJM region are relatively low compared to the exports for the full region [148]. The net generation, calculated as the real-time generation and real-time load for each zone, may also be evaluated at the nodal level. For New Jersey specifically, the JCPL and AECO have a net negative generation and are thus reliant on imports, whereas PSEG has a net positive generation. While it is currently not a requirement, the MMU does recommend that local capacity requirements be met with local resources, incentivizing those zones with negative net generation to invest in peaking generation locally, reducing load congestion and transmission constraints.

5.4.2 Peaker replacement opportunities

For this study, we identify the assigned LDAs for each peaker plant. The LDAs present in our study include AECO, PSEG, JCPL, and RECO. New Jersey has three import-constrained LDAs: JCPL, AECO, and RECO. We first identify import-constrained regions that cannot meet local demand via generation capability within that LDA, then evaluate capacity prices within each LDA. Within each LDA, the peaker plants with lowest capacity factors are likely the most vulnerable for replacement.

Further comparisons between LDAs can provide additional information to prioritize peaker units through zonal pricing. Two clearing prices were reviewed for each LDA, the zonal capacity price and the zonal net load price. Zonal capacity price is the “clearing price required in each Zone to meet the demand for Unforced Capacity and satisfy Locational Deliverability Requirements for the LDA [149] . Zonal net load price is the di erence between the Zonal capacity price less the Capacity Transfer Right (CTR) Credit Rate, where the CTR is the capacity transfer rights an owner can accumulate based on the number of CTRs owned and the settlement rate [150]. Higher clearing prices indicate higher costs to deliver the capacity needed in a zone, therefore zones with a higher pricing calculation would be prioritized for potential peaker replacement. However, for the three primary zones in NJ, all have the same final capacity price. Therefore, to prioritize zones based on capacity criteria, a review of the zonal unforced capacity (UCAP) obligations is useful.

PJM operates under load and capacity obligations. Load obligations either reduce or serve load during the Delivery year, as UCAP. Unforced capacity is capacity that is not scheduled or experiencing a forced outage or de-rating, and is based on summer conditions of installed capacity [150]. Each LDA zone has its own UCAP capacity obligation: 451.1 MW for RECO, 2,798.4 for AECO and 6,753.3 for JCPL. With a low capacity obligation, priority could be given to the peaker plants located within those LDAs: JCPL has four peaker plants, RECO has no peaker plants in this study, and AECO has five peaker plants. The AECO and JCPL lowest capacity factor plants are shown in Table 5.3, and could be the most suited peaker plants for renewable and storage replacement based on low capacity obligated to PJM. The PSEG territory is included here as well for reference; while it has a surplus of generation, it is New Jersey’s largest utility and therefore may also be one of the largest potential energy storage adopters.

Table 5.3: New Jersey replacement opportunities: Lowest capacity factor plants in each load zone 2016-2018 average).

Load zone	Plant name	EIA ID	Capacity factor
JCPL	Forked River	7138	1.4%
	Gilbert	2393	0.4%
	Sayreville	2390	0.2%
PSEG	Essex	2401	1.2%
	Linden (gas turbine)	2406	1.5%
	Salem	2410	0.02%
AECO	Carll's Corner	2379	1.8%
	Mickleton	8008	1.0%
	Sherman Avenue	7228	4.7%

5.5 Nevada

The peaker plant units in Nevada serve load centers in Reno and Las Vegas, respectively, and any replacement would likely require deployment near these load centers. The unit with the lowest capacity factor in the Las Vegas region is Sun Peak Generating Station (1.3%).

5.6 New York

The New York electric grid is operated by the New York Independent System Operator (NYISO) and governed by the NYISO Services Tari NYISO Services Tari and the New York State Reliability Council (NYSRC) Agreement; these entities identify the grid needs that determine the capacity value of peaker power plants or energy storage on the grid. NYISO establishes roles for market participants via the market participant user guide, establishes schedules and operations for profit, and outlines the transmission market including services, rates, terms, and transmission conditions [151]. NYISO is regulated by FERC, and the Northeast Power Coordinating Council (NPCC), the New York State Reliability Council (NYSRC), and the New York State Public Service Commission (PSC).

NYISO operates as a hybrid zonal and nodal market across the New York Control Area. Nodes are established within, or in some between, di erent load zones. There are 11 Load Zones that cover the state, labeled A (Frontier), B (Genesee), C (Syracuse), D (Adirondack), E (Utica), F (Capital), G (Mid Hudson), H (Millwood), I (Sprainbrook/Dunwoodie), J (New York City), and K (Long Island) [152]. These zones are used to quantify load and capacity, by geographical location, throughout the state. In 2017, the Downstate zones F-K, which include New York City, Long Island, and the Hudson Valley, consumed two-thirds of the state's electricity, while the Upstate zones A-E produced half of the electricity [153].

NYISO publishes a bi-annual Reliability Needs Assessment which focuses on finding vulnerabilities in market reliability and determining if each zone has sufficient capacity. This Assessment includes a ten-year Zonal Capacity at Risk assessment which identifies maximum zonal capacity that could be lost without risking a violation of reliability standards. The risk assessment results are highly dependent on location and used to identify potential transmission needs [154].

5.6.1 Capacity zones and transmission constraints

New York's downstate electricity load zones—covering the lower Hudson Valley, New York City, and Long Island—are an import-constrained region. In an import-constrained zone region, transmission constraints limit the amount of power that can be imported into these zones from the non-constrained, upstate zones. NYISO uses Locational Capacity Requirements (LCRs) to designate the amount of power generating capacity that must be located within the import-constrained region to reliably meet the normal load plus reserve margin. The 2018-2019 LCR for Zone J (New York City) is 80%, Zone K (Long Island) is 103.5%, and Zones G-J (Hudson Valley, lower portion) is 94.5% [153].

5.6.2 Peaker replacement opportunities

We evaluated reliability needs and peaker plant operations across New York's 11 load zones to identify plants with low capacity factors and where local deployment of solar and storage might be needed to replace a peaker plant due to transmission constraints. We compared zones using the 2018 Reliability Needs Assessment forecast report and the 2019 Load and Capacity report including zonal capacity at risk, load, and pricing by zones [155]. We further compared these plants to NYISO's prioritized deactivations and new generation.

Zone Capacity At Risk shows the relative amount of electricity that can be removed from a zone without causing reliability disruptions to that zone. However, the impacts of removing capacity is highly location dependent, "lower amounts of capacity removal are likely to result in reliability issues at specific transmission locations" and NYISO did not "attempt to assess a comprehensive set of potential scenarios that might arise from specific unit retirements" [154]. Therefore, when prioritizing zones for peaker plant deactivation, it is preferable to target those located in load zones that have little capacity to spare, with low to no (EZR) zone capacity at risk, coupled with the highest load requirements (i.e. downstate zones such as New York City and Long Island where load pockets exist due to transmission import-constraints) [153].

Therefore, the focus zones are H and I (due to no excess capacity) and J and K (for the highest load). Our study did not have any peaker plants located in the H and I load zones. We include six plants in J and five in K due to the large total number of facilities in this region, which covers New York City and Long Island; the facilities may provide potential opportunities for renewable and storage displacement. The peaker plants with lowest capacity factors within J and K load zones are shown below in Table 5.4.

Table 5.4: New York replacement opportunities: Lowest capacity factor plants in each load zone 2016-2018 average).

Load zone	Plant name	EIA ID	Capacity factor
J: New York	59th Street	2503	0.0%
	74th Street	2504	0.1%
	Arthur Kill	2490	0.3%
	Gowanus Gas Turbines	2494	0.2%
	Hudson Avenue	2496	0.3%
	Ravenswood (gas turbine unit)	2500	0.3%
K: Long Island	Charles P. Keller	2695	0.1%
	Freeport No 1	2678	0.1%
	Glenwood	2514	0.3%
	Greenport	2681	0.0%
	Northport	2516	0.1%

6. State findings

For overarching state-level findings, please see state summaries posted at: www.psehealthyenergy.org/our-work/energy-storage-peaker-plant-replacement-project/.

Bibliography

[1] E. M. Krieger, J. A. Casey, and S. B. Shonko , "A framework for siting and dispatch of emerging energy resources to realize environmental and health benefits: Case study on peaker power plant displacement," *Energy Policy*, vol. 96, pp. 302–313, 2016.

[2] J. Spector, *The Biggest Batteries Coming Soon to a Grid Near You*, Greentech Media, 019. [Online]. Available: www.greentechmedia.com/articles/read/the-biggest-batteries-coming-soon-to-a-grid-near-you

[3] U.S. Department of Energy, *DOE Global Energy Storage Database*, 2019. [Online]. Available: www.energystorageexchange.org

[4] Bloomberg New Energy Finance, *Battery Power's Latest Plunge in Costs Threatens Coal, Gas*, 2019. [Online]. Available: about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/

[5] Tesla, *Tesla Powerwall 2 Datasheet*, 2019. [Online]. Available: www.tesla.com/sites/default/files/pdfs/powerwall/Powerwall%202_AC_Datasheet_en_northamerica.pdf

[6] Luminant, *Vistra Energy to Develop 300-Megawatt Battery Storage Project in California*, 2018. [Online]. Available: www.luminant.com/vistra-energy-to-develop-300-megawatt-battery-storage-project-in-california/

[7] W. Katzenstein and J. Apt, "Air emissions due to wind and solar power," *Environ. Sci. Technol.*, vol. 43, no. 2, pp. 253–258, 2008.

[8] C. A. Pope III, R. T. Burnett, M. J. Thun, E. E. Calle, D. Krewski, K. Ito, and G. D. Thurston, "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution," *JAMA*, vol. 287, no. 9, pp. 1132–1141, 2002.

[9] B. Ostro, M. Lipsett, P. Reynolds, D. Goldberg, A. Hertz, C. Garcia, K. D. Henderson, and L. Bernstein, "Long-term exposure to constituents of fine particulate air pollution and mortality: results from the California teachers study," *Environmental Health Perspectives*, vol. 118, no. 3, pp. 363–369, 2009.

[10] M. Jerrett, R. T. Burnett, C. A. Pope III, K. Ito, G. Thurston, D. Krewski, Y. Shi, E. Calle, and M. Thun, "Long-term ozone exposure and mortality," *New England Journal of Medicine*, vol. 360, no. 11, pp. 1085–1095, 2009.

[11] S. Ha, H. Hu, J. Roth, H. Kan, and X. Xu, "Associations between residential proximity to power plants and adverse birth outcomes," *American Journal of Epidemiology*, vol. 182, no. 3, pp. 215–224, 2015.

[12] X. Liu, L. Lessner, and D. O. Carpenter, "Association between residential proximity to fuel-fired power plants and hospitalization rate for respiratory diseases," *Environmental Health Perspectives*, vol. 120, no. 6, p. 807, 2012.

[13] Office of Environmental Health Hazard Assessment and California Enviornmental Protection Agency. (2014, November) California communities environmental health screening tool, version 2 (CalEnviroScreen 2.0). Guidance and screening tool. [Online]. Available: http://oehha.ca.gov/ej/ces2.html

[14] J. K. Boyce and M. Pastor, "Clearing the air: incorporating air quality and environmental justice into climate policy," *Climatic Change*, vol. 120, no. 4, pp. 801–814, 2013.

[15] D. R. Faber and E. J. Krieg, "Unequal exposure to ecological hazards: environmental injustices in the Commonwealth of Massachusetts." *Environmental Health Perspectives*, vol. 110, no. Suppl 2, p. 277, 2002.

[16] R. Morello-Frosch, M. Zuk, M. Jerrett, B. Shamasunder, and A. D. Kyle, "Understanding the cumulative impacts of inequalities in environmental health: implications for policy," *Health A airs*, vol. 30, no. 5, pp. 879–887, 2011.

[17] J. L. Sadd, M. Pastor, R. Morello-Frosch, J. Scoggins, and B. Jesdale, "Playing it safe: Assessing cumulative impact and social vulnerability through an environmental justice screening method in the south coast air basin, California," *International Journal of Environmental Research and Public Health*, vol. 8, no. 5, pp. 1441–1459, 2011.

[18] Office of Environmental Health Hazard Assessment and California Enviornmental Protection Agency, *California Communities Environmental Health Screening Tool, Version 3 (CalEnviroScreen 3.0). California Communities Environmental Health Screening Tool*, 2018. [Online]. Available: oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

[19] U.S. Environmental Protection Agency, *EJSCREEN: Environmental justice screening and mapping tool share*, 2015. [Online]. Available: www2.epa.gov/ejscreen

[20] S&P Global, *Power plant database*, 2019.

[21] U.S. Energy Information Administration, *Form EIA-923: Annual electric utility data*, 2018. [Online]. Available: www.eia.gov/electricity/data/eia923/

[22] Google, *Google Maps*, March 2019. [Online]. Available: www.google.com/maps/

[23] U.S. Energy Information Administration, *Form EIA-860: Annual electric generator data*, 2018. [Online]. Available: www.eia.gov/electricity/data/eia860/

[24] U.S. Environmental Protection Agency, *Air Markets Program Data*, 2019. [Online]. Available: ampd.epa.gov/ampd/

[25] U.S. Energy Information Administration, *Emissions by plant and by region*, 2018. [Online]. Available: www.eia.gov/electricity/data/emissions/

[26] U.S. Environmental Protection Agency, *Monitor Listing*, 2019. [Online]. Available: aqs.epa.gov/aqsweb/airdata/download_files.html#Meta

[27] U.S. Environmental Protection Agency, *Nonattainment Areas for Criteria Pollutants (Green Book)*, 2019. [Online]. Available: www.epa.gov/green-book

[28] CA Department of Public Health, *Asthma*, 2019. [Online]. Available: www.cdph.ca.gov/Programs/CCDPHP/DEODC/EHIB/CPE/Pages/Asthma.aspx

[29] O. Laurent, J. Hu, L. Li, M. J. Kleeman, S. M. Bartell, M. Cockburn, L. Escobedo, and J. Wu, "A statewide nested case–control study of preterm birth and air pollution by source and composition: California, 2001–2008," *Environmental Health Perspectives*, vol. 124, no. 9, pp. 1479–1486, 2016.

[30] U.S. Census Bureau, *Decennial Census of Population and Housing: Population and Housing Unit Counts 2010*, 2019. [Online]. Available: www.census.gov/programs-surveys/decennial-census/decade/decennial-publications.2010.html

[31] C. f. H. S. Texas Department of State Health Services, *exas Inpatient Public Use Data File (PUDF/0*, 2019. [Online]. Available: www.dshs.texas.gov/thcic/hospitals/Inpatientpudf.shtm

[32] Healthcare Cost and Utilization Project, *Beta Clinical Classifications Software (CCS) for ICD-10-CM/PCS*, version 2019.1 ed., 2019. [Online]. Available: hcup-us.ahrq.gov/toolssoftware/ccs10/ccs10.jsp#download

[33] S. C. Klein, RJ, *Age adjustment using the 2000 projected US population*, National Center for Health Statistics, January 2001. [Online]. Available: www.cdc.gov/nchs/data/statnt/statnt20.pdf

[34] Asthma Initiative of Michigan, *Asthma methods*, 2019. [Online]. Available: getasthmahelp.org/michigan-asthma-statistics-methods.aspx

[35] Elena Krieger et al., *The Clean Power Plan in Pennsylvania: Analyzing power generation for health and equity*, 2016. [Online]. Available: www.psehealthyenergy.org/our-work/publications/archive/our-air-health-and-equity-impacts-of-pennsylvanias-power-plants/

[36] RGGI, *The Regional Greenhouse Gas Initiative*, 2019. [Online]. Available: www.rggi.org

[37] Arizona Corporation Commission, *Renewable Energy Standard & Tari* , 2019. [Online]. Available: www.azcc.gov/utilities/electric/renewable-energy-standard-and-tari

[38] A. Lopez, B. Roberts, D. Heimiller, N. Blair, and G. Porro, *U.S. renewable energy technical potentials: a GIS-based analysis*, U.S. National Renewable Energy Laboratory, NREL/TP-6A20-51946, 2012. [Online]. Available: www.nrel.gov/docs/fy12osti/51946.pdf

[39] Arizona Corporation Commission, *Review, Modernization and Expansion of the Arizona Energy Standards and Tari Rules and Associated Rules*, 2018. [Online]. Available: docket.images.azcc.gov/0000189786.pdf

[40] Arizona Corporation Commission, *In the matter of possible modifications to the Arizona Corporation Commission's energy rules*, 2019. [Online]. Available: docket.images.azcc.gov/0000195951.pdf

[41] Arizona Corporation Commission, *Tobin's proposed ammendment no. 4*, 2018. [Online]. Available: images.edocket.azcc.gov/docketpdf/0000186484.pdf

[42] Arizona Corporation Commission, *Letter from Commisioner Sandra Kennedy*, 2019. [Online]. Available: assets.documentcloud.org/documents/6240841/ACC-August-2-Kennedy-Letter-E000002248.pdf

[43] I. Gheorghui, *Arizona commissioner cites 'unacceptable risks' from lithium-ion batteries for large-scale projects*, 2018. [Online]. Available: www.utilitydive.com/news/arizona-commissioner-cites-unacceptable-risks-from-lithium-ion-batteries/560300/

[44] Trinity Consultants and City of Flagsta , *Greenhouse Gas Emissions Management program, City of Flagsta , Arizona*, 2008. [Online]. Available: www.flagsta .az.gov/DocumentCenter/View/8630/City-of-Flagsta -GHG-Report--2008-07-31?bidId=

[45] City of Phoenix, *Phoenix Sets New Goal to Reduce Greenhouse Gas Emissions by 30 Percent*, 2018. [Online]. Available: www.phoenix.gov/news/archive-mayor/1928

[46] Arizona Department of Environmental Quality, *Civil Rights Program Policty*, 2019. [Online]. Available: static.azdeq.gov/legal/VI_policy.pdf

[47] Arizona Department of Transportation, *Title VI and Environmental Justice*, 2019. [Online]. Available: azdot.gov/business/environmental-planning/guidance-federal-aid-projects/title-vi-and-environmental-justice

[48] D. C. C. Satheesh Aradhyula, Melissa A. Burns, "On notions of fairness in environmental justice," *Cardon Research Papers*, 2006.

[49] B. Bolin, S. Grineski, and T. Collins, "The geography of despair: Environmental racism and the making of South Phoenix, Arizona, USA," *Human Ecology Review*, pp. 156–168, 2005.

[50] S. Grineski, B. Bolin, and C. Boone, "Criteria air pollution and marginalized populations: environmental inequity in metropolitan Phoenix, Arizona," *Social Science Quarterly*, vol. 88, no. 2, pp. 535–554, 2007.

[51] CA State Senate, *SB 1078: Renewable energy: California Renewables Portfolio Standard Program*, 2002. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200120020SB1078

[52] CA State Senate, *SB 100: California Renewables Portfolio Standard Program: emissions of greenhouse gases*, 2018. [Online]. Available: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100

[53] CA Energy Comission. Renewables Portfolio Standard. [Online]. Available: www.energy.ca.gov/programs-and-topics/programs/renewables-portfolio-standard

[54] CA State Assembly, *AB 2514. Energy storage systems.*, 2010. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920100AB2514

[55] CA State Assembly, *AB 2868: Energy storage*, 2016. [Online]. Available: leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB2868

[56] CA Public Utilities Commission, *Self-Generation Incentive Program*, 2019. [Online]. Available: www.cpuc.ca.gov/sgip/

[57] CA Public Utilities Commission, *Rulemaking 16-02-007: 2019-2020 ELECTRIC RESOURCE PORTFOLIOSTO INFORM INTEGRATED RESOURCE PLANS AND TRANSMISSION PLANNING*, 2020. [Online]. Available: docs.cpuc.ca.gov/PublishedDocs/Published/G000/M330/K357/330357384.PDF

[58] CA State Assembly, *AB 32. Air pollution: greenhouse gases: California Global Warming Solutions Act of 2006*, 2006. [Online]. Available: leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB32

[59] CA State Senate, *SB 32: California Global Warming Solutions Act of 2006: emissions limit*, 2016. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32

[60] CA State Assembly, *AB 398: California Global Warming Solutions Act of 2006: market-based compliance mechanisms: fire prevention fees: sales and use tax manufacturing exemption*, 2017. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB398

[61] Governor Edmund G. Brown Jr., *Executive Order B-55-18: To achieve carbon neutrality*, 2018. [Online]. Available: www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

[62] CA Air Resources Board, *Air Pollution Control Districts*, 2019. [Online]. Available: www2.arb.ca.gov/air-pollution-control-districts

[63] State of California, *Title 7: Planning and land use. Article 4: Powers and Duties*, 22974. [Online]. Available: leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=GOV&sectionNum=65040.12.

[64] R. Morello-Frosch, M. Pastor, and J. Sadd, "Environmental justice and Southern California's "riskscape" the distribution of air toxics exposures and health risks among diverse communities," *Urban A airs Review*, vol. 36, no. 4, pp. 551–578, 2001.

[65] M. Pastor, R. Morello-Frosch, and J. Sadd, *Air pollution and environmental justice: integrating indicators of cumulative impact and socio-economic vulnerability into regulatory decision-making:*, CA Environmental Protection Agency, 2010.

[66] CA Air Resources Board, *Environmental Justice*, 2019. [Online]. Available: ww2.arb.ca.gov/our-work/topics/environmental-justice

[67] CA Energy Comission, *Environmental Justice*, 2019. [Online]. Available: ww2.energy.ca.gov/public_advisor/environmental_justice_faq.html

[68] CA State Senate, *SB 535: California Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund*, 2012. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB535

[69] CA State Assembly, *AB 1550: Greenhouse gases: investment plan: disadvantaged communities*, 2016. [Online]. Available: leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB1550

[70] CA State Assembly, *AB 1144: Self-generation incentive program: community energy storage systems: high fire threat districts*, 2019. [Online]. Available: leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB1144

[71] NC Clean Energy Technology Center, *DSIRE: Database of State Incentives for Renewables & Efficiency*, 2019. [Online]. Available: www.dsireusa.org

[72] City Commission of the City of Tallahassee, *A resolution of the city commissin of the City of Tallahassee, Florida, supporting 100% clean renewable energy for our community*, 2019. [Online]. Available: www.boarddocs.com/fla/talgov/Board.nsf/files/B9KTU963E005/$file/Clean%20Energy%20Resolution.pdf

[73] Florida Power & Light, *FPL announces plan to build the world's largest solar-powered battery and drive accelerated retirement of fossil fuel generation*, 2019. [Online]. Available: newsroom.fpl.com/2019-03-28-FPL-announces-plan-to-build-the-worlds-largest-solar-powered-battery-and-drive-accelerated-retirement-of-fossil

[74] JEA, *Battery Incentive Program*, 2019. [Online]. Available: www.jea.com/Residential_Customers/Residential_Rebates/Solar_Battery_Incentive_Program/

[75] Florida Power & Light, *Thermal Energy Storage*, 2019. [Online]. Available: www.fpl.com/business/save/programs/thermal-storage.html

[76] Duke Energy, *Duke Energy Florida to build its largest battery storage projects yet*, 2019. [Online]. Available: news.duke-energy.com/releases/duke-energy-florida-to-build-its-largest-battery-storage-projects-yet

[77] FL State Senate, *Track This Bill Glossary of Legislative Terms HB 1133: Energy Security and Disaster Resilience Pilot Program*, 2018. [Online]. Available: www.flsenate.gov/Session/Bill/2018/1133

[78] Governor Charles Christ Jr., *Executive Order Number 07-127: Establishing Immediate Actions to Reduce Greenhouse Gas Emissions within Florida*, 2007. [Online]. Available: www.fsec.ucf.edu/en/media/enews/2007/pdf/07-127-emissions.pdf

[79] Governor Charles Christ Jr., *Executive Order Number 07-128: Establishing the Florida Governor's Action Team on Energy and Climate Change*, 2007. [Online]. Available: www.fsec.ucf.edu/en/media/enews/2007/pdf/07-128-actionteam.pdf

[80] Southeast Florida Regional Climate Compact, *Regional Climate Action Plan*, 2019. [Online]. Available: southeastfloridaclimatecompact.org/regional-climate-action-plan/

[81] State of Florida, *The 2019 Florida Statutes*, 2019. [Online]. Available: www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&URL=0300-0399/0376/0376.html

[82] FL Department of Environmental Protection, *Resilience Planning Grants (RPG)*, 2019. [Online]. Available: floridadep.gov/rcp/florida-resilient-coastlines-program/content/resilience-planning-grants-rpg

[83] State of Massachusetts, *Program Summaries: Summaries of all the Renewable and Alternative Energy Portfolio Standard programs.*, 2019. [Online]. Available: www.mass.gov/service-details/program-summaries

[84] State of Massachusetts, *Energy Storage Initiative*, 2019. [Online]. Available: www.mass.gov/energy-storage-initiative

[85] MA Department of Energy Resources, *Massachusetts Comprehensive Energy Plan*, 2018. [Online]. Available: www.mass.gov/files/documents/2019/01/10/CEP%20Report-%20Final%2001102019.pdf

[86] MA Department of Environmental Protection, *310 CMR 7.75: Clean Energy Standard*, 2018. [Online]. Available: www.mass.gov/files/documents/2018/09/26/3dfs-electricity.pdf

[87] M. A. Beaton, *Massachusetts Clean Energy and Climate Plan for 2020: 2015 Update*, Executive Office of Energy and Environmental A airs, 2015. [Online]. Available: www.mass.gov/files/documents/2017/01/uo/cecp-for-2020.pdf

[88] MA Department of Environmental Protection, *Environmental Justice Policy*, 2019. [Online]. Available: www.mass.gov/service-details/environmental-justice-policy

[89] MA State Legislature, *Bill H.761: An act relative to environmental justice and toxics reduction in the Commonwealth*, 2019. [Online]. Available: malegislature.gov/Bills/191/H761/BillHistory

[90] MA Department of Environmental Protection, *Objectives of Environmental Justice*, 2019. [Online]. Available: www.mass.gov/service-details/objectives-of-environmental-justice

[91] NV State Senate, *SB 358: An act relating to renewable energy*, 2019. [Online]. Available: www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6651/Text

[92] Public Utilities Commission OF Nevada, *2019 Biennial Report*, 2019. [Online]. Available: puc.nv.gov/uploadedFiles/pucnvgov/Content/About/BiennialReport.pdf

[93] Public Utilities Commission of Nevada, *Dockket No. 17-17014: Proposed Regulation of the Public Utilities Commission of Nevada*, November 2019. [Online]. Available: pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-7/43083.pdf

[94] NV State Senate, *SB 254: An act related to greenhouse gas emissions*, 2019. [Online]. Available: www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6431/Text

[95] NV Department of Transportation, *Environmental Justice*, 2019. [Online]. Available: www.nevadadot.com/doing-business/external-civil-rights/civil-rights-title-vi/environmental-justice-902

[96] NJ Assembly, *Clean Energy Act*, 2018. [Online]. Available: www.njleg.state.nj.us/2018/Bills/A4000/3723_I1.HTM

[97] State of New Jersey, *Global Warming Response Act*, N.J.S.A 26:2C-37, June 14, 2007. [Online]. Available: www.njleg.state.nj.us/2006/Bills/A3500/3301_R2.HTM

[98] NJ Department of Environmental Protection, *Letter: Ozone designation recommendation*, 2016. [Online]. Available: www.nj.gov/dep/baqp/Ozone%20Designation%20Recommendation%209-29-16.pdf

[99] NJ Department of Environmental Protection, *Bureau of Evaluation and Planning*, 2019. [Online]. Available: www.nj.gov/dep/baqp/

[100] NJ Administrative Code, *7:27-19.29 2009 HEDD Emission Reduction Compliance Demonstration Protocol*, 2005.

[101] NJ Environmental Justice Advisory Council, *Annual Report*, 2005. [Online]. Available: www.nj.gov/dep/ej/docs/ejacannualreport20042005.pdf

[102] Governor Philip D. Murphy, *EXECUTIVE ORDER NO. 23*, 2018. [Online]. Available: nj.gov/infobank/eo/056murphy/pdf/EO-23.pdf

[103] Governor Philip D. Murphy, *Environmental Justice Executive OrderNo. 23 Guidance*, 2018. [Online]. Available: www.nj.gov/dep/ej/eo23/docs/eo23-draft-guidance.pdf

[104] NM State Senate, *SB 489: Energy Transition Act*, 2019. [Online]. Available: www.nmlegis.gov/Sessions/19%20Regular/bills/senate/SB0489.pdf

[105] New Mexico Public Regulation Commission, *Final Order Amending Integrated Resource Planning Rules 17.7.3 NMAC to include energy storage resources*, 2017. [Online]. Available: 164.64.85.108/infodocs/2017/8/PRS20243548DOC.PDF

[106] Governor Michelle L. Grisham, *Executive Order on addressing climate change and energy waste prevention*, 2019. [Online]. Available: blogs.edf.org/energyexchange/files/2019/01/EXECUTIVE-ORDER_003.pdf

[107] Governor Bill Richardson, *Executive Order 2005-056: environmental justice executive order*, 2005. [Online]. Available: www.env.nm.gov/wp-content/uploads/sites/10/2019/10/EO_2005_056.pdf

[108] U.S. Energy Information Administration, *Electricity data browser*, 2019. [Online]. Available: www.eia.gov/electricity/data/browser/

[109] NYSERDA, *Renewable Portfolio Standard*, 2019. [Online]. Available: www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard/Renewable-Portfolio-Standard

[110] NYSERDA, *NY-Sun*, 2019. [Online]. Available: www.nyserda.ny.gov/All-Programs/Programs/NY-Sun

[111] New York State Public Service Commission, *Order adopting a clean energy standard*, 2016. [Online]. Available: documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={44C5D5B8-14C3-4F32-8399-F5487D6D8FE8}

[112] NY State Senate, *Climate Leadership and Community Protection Act*, 2019. [Online]. Available: www.nysenate.gov/legislation/bills/2019/s6599

[113] NYSERDA. (2018) New York State energy storage roadmap. [Online]. Available: www.ethree.com/wp-content/uploads/2018/06/NYS-Energy-Storage-Roadmap-6.21.2018.pdf

[114] NY Department of Environmental Conservation, *Adopted Subpart 227-3 Express Terms*, 2019. [Online]. Available: www.dec.ny.gov/regulations/116185.html

[115] NY Department of Environmental Conservation, *Environmental Justice*, 2019. [Online]. Available: www.dec.ny.gov/public/333.html

[116] NY State Assembly, *A01779: An act to amend the environmental conservation law, in relation to high local environmental impact communities*, 2019. [Online]. Available: www.nysenate.gov/legislation/bills/2019/s6599

[117] NYC Mayor's Office of Sustainability, *Environmental Justice*, 2019. [Online]. Available: www1.nyc.gov/site/sustainability/onenyc/environmental-justice.page

[118] NY City Council, *0886-2015: A Local Law to amend the administrative code of the city of New York, in relation to identifying and addressing environmental justice issues*, 2017.

[119] NY City Council, *Int 0359-2014: A Local Law to amend the administrative code of the city of New York, in relation to requiring a study of environmental justice areas and the establishment of an environmental justice portal*, 2017.

[120] U.S.Department of Energy, *Wind Energy in Texas*, 2019. [Online]. Available: windexchange.energy.gov/states/tx

[121] City of Austin, *"Resolution No. 20150604-048"*, 2015. [Online]. Available: www.austintexas.gov/edims/document.cfm?id=234102

[122] City of Georgetown Texas, *Why Georgetown is 100 percent renewable*, 2019. [Online]. Available: georgetown.org/2019/02/22/why-georgetown-is-100-percent-renewable/

[123] State of Texas, *Texas Utilities Code Sec. 35.152. Generation Assets*, 2019. [Online]. Available: statutes.capitol.texas.gov/Docs/UT/htm/UT.35.htm#35.152

[124] TX State Legislature, *S.B. No. 1012*, 2019. [Online]. Available: capitol.texas.gov/tlodocs/86R/billtext/pdf/SB01012F.pdf#navpanes=0

[125] U.S. Energy Information Administration, *Energy-Related Carbon Dioxide Emissions by State, 2005-2016*, 2019. [Online]. Available: www.eia.gov/environment/emissions/state/analysis/

[126] Texas Commission on Environmental Quality, *Environmental Equity: Nondiscrimination in TCEQ Processes*, 2019. [Online]. Available: www.tceq.texas.gov/agency/decisions/hearings/envequ.html

[127] CAMPO, *Environmental Justice and Civil Rights*, 2019. [Online]. Available: www.campotexas.org/environmental-justice-civil-rights/

[128] U.S. Commission on Civil Rights, *Not in My Backyard: Executive Order 12,898 and Title VI as Tools for Achieving Environmental Justice*, 2012. [Online]. Available: www.usccr.gov/pubs/envjust/ch2.htm

[129] ISO-NE, *Market Rule 1: Standard Market Design*, 2014. [Online]. Available: www.iso-ne.com/static-assets/documents/2014/12/mr1_sec_1_12.pdf

[130] Western Electricity Coordinating Council, *Western Interconnection Balancing Authorities*, 2017. [Online]. Available: www.wecc.org/Administrative/Balancing_Authorities_JAN17.pdf

[131] Arizona Corporation Commission, *ACC Mission and Background*, 2020. [Online]. Available: www.azcc.gov/divisions

[132] Arizona Corporation Commission, *Tenth Biennial Transmission Assessment 2018-2027*, 2018. [Online]. Available: www.azcc.gov/docs/default-source/utilities-files/electric/biennial-transmission-assessment/10th-bta-report-final.pdf?sfvrsn=ad8209aa_4

[133] TANC, *A Matter of Balance*, 2020. [Online]. Available: https://www.tanc.us/understanding-transmission/a-matter-of-balance/

[134] CAISO, *Market processes and products*, CA Independent System Operator, 2020. [Online]. Available: http://www.caiso.com/market/Pages/MarketProcesses.aspx

[135] CA Public Utilities Commission, *Electric Power Procurement and Generation*, 2020. [Online]. Available: https://www.cpuc.ca.gov/procurement/

[136] CA Energy Comission, *Core responsibility fact sheets*, 2020. [Online]. Available: https://www.energy.ca.gov/about/core-responsibility-fact-sheets-0

[137] CAISO, *Annual Report on market issues and performance*, 2018. [Online]. Available: http://www.caiso.com/Documents/2018AnnualReportonMarketIssuesandPerformance.pdf

[138] U.S. Federal Energy Regulatory Commission, *Regional Transmission Organizations (RTO)/Independent System Operators (ISO)*, 2019. [Online]. Available: www.ferc.gov/industries/electric/indus-act/rto.asp

[139] ISO-NE, *Section II: ISO New England open access transmission tari* , 2019. [Online]. Available: www.iso-ne.com/static-assets/documents/regulatory/tari /sect_2/oatt/sect_ii.pdf

[140] ISO-NE, *Maps and Diagrams*, 2019. [Online]. Available: www.iso-ne.com/about/key-stats/maps-and-diagrams#isos-rtos

[141] ISO-NE, *Section III: Market Rule 1: Standard Markket Design*, 2014. [Online]. Available: www.iso-ne.com/static-assets/documents/2014/12/mr1_sec_1_12.pdf

[142] ISO-NE, *ISO New England Installed Capacity Requirement, Local Sourcing Requirements and Capacity Requirement Values for the System-Wide Capacity Demand Curve for the 2019/20 Capacity Commitment Period*, 2016. [Online]. Available: www.iso-ne.com/static-assets/documents/2016/01/icr_values_2019_2020_report_final.pdf

[143] ISO-NE, *Capacity Zone Development*, 2019. [Online]. Available: www.iso-ne.com/markets-operations/markets/forward-capacity-market/fcm-participation-guide/capacity-zone-development

[144] ISO-NE, *CELT Report*, 2018. [Online]. Available: www.iso-ne.com/system-planning/system-plans-studies/celt

[145] ISO-NE, *Markets and Operations ISO Express Energy, Load, and Demand Reports*, 2019. [Online]. Available: www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/hourly-wholesale-load-cost-report

[146] PJM, *Regional Transmission Expansion Plan*, 2019. [Online]. Available: www.pjm.com/planning/rtep-development/baseline-reports.aspx

[147] PJM, *PJM Market Efficiency Modeling Practices*, 2017. [Online]. Available: www.pjm.com/ /media/planning/rtep-dev/market-efficiency/pjm-market-efficiency-modeling-practices.ashx

[148] Monitoring Analytics, *State of the market report for PJM: 2018*, March 2019. [Online]. Available: www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2018/2018-som-pjm-volume2.pdf

[149] PJM, *Revisions to Governing Documents*, 2015. [Online]. Available: www.pjm.com/ /media/committees-groups/subcommittees/gdecs/20150529/20150529-item-04-definitions-governing-documents.ashx

[150] PJM, *PJM Manual 18: PJM Capacity Market*, 2019. [Online]. Available: www.pjm.com/ /media/training/nerc-certifications/gen-exam-materials-feb-18-2019/manuals/pjm-capacity-mkt.ashx

[151] NYISO, *Market Participants User's Guide*, 2018. [Online]. Available: www.nyiso.com/documents/20142/3625950/mpug.pdf/c6ca83ca-ee6b-e507-4580-0bf76cd1da1b

[152] NYISO, *Sub-zone boundaries*, 2019. [Online]. Available: www.nyiso.com/documents/20142/2923161/tablea1_subzone_boundaries.pdf/8be4d7b7-7c51-76cf-a125-c3b2525d0e8a

[153] NYISO, *2018 Power Trends*, 2018. [Online]. Available: www.nyiso.com/documents/20142/2223020/2018-Power-Trends.pdf/4cd3a2a6-838a-bb54-f631-8982a7bdfa7a

[154] NYISO, *2018 RNA report*, 2018. [Online]. Available: www.nyiso.com/documents/20142/2248793/2018-Reliability-Needs-Assessment.pdf/c17f6a4a-6d22-26ee-9e28-4715af52d3c7

[155] NYISO, *2019 Load & Capacity Data*, 2019. [Online]. Available: www.nyiso.com/documents/20142/2226333/2019-Gold-Book-Final-Public.pdf/a3e8d99f-7164-2b24-e81d-b2c245f67904?t=1556215322968