Attachment A

Development of an Optimized Strategic Plan for Pasadena Water and Power

Proposal to Pasadena Water & Power and the City Manager's Office

March 19, 2024

Energy+Environmental Economics

Table of Contents

Introduction

E3 appreciates the opportunity to submit this proposal to assist Pasadena Water and Power (PWP) in the development of its upcoming Optimized Strategic Plan. E3 has worked extensively with utilities throughout North America to develop high-quality, robust plans to address future challenges, providing direct analytical support, strategic advice, and critical input to utilities seeking to decarbonize their generation portfolios while maintaining reliable electricity service. In multiple instances, E3 has provided rigorous technical analyses to inform visionary future plans. Notable examples of initiatives that are similar to the efforts being undertaken by PWP include:

- SMUD's **2030 Clean Energy Vision**, an ambitious and visionary plan detailing how SMUD can progress towards a goal of achieving a 2030 goal of providing carbon-free electricity to its customers. E3 provided technical analysis and strategic support to the development of this plan.
- SRP's **Integrated System Plan**, a first-of-its-kind effort to develop a plan for how all elements of the electric system – including generation, transmission, distribution, and customer programs – could together support achievement of SRP's objectives of affordability, reliability, and sustainability. Over the course of the three-year period during which this plan was developed, E3 was a partner to SRP and supported the scoping, technical analysis, and synthesis of the plan.
- PNM's **2020** and **2023 Integrated Resource Plans**, each of which focused on identifying viable pathways for PNM to achieve its 2040 goal to achieve a carbon-free system. In both cases, E3's team members were embedded within the resource planning team to provide strategic advice, technical review, and narrative development support of the plans.
- City of Glendale's **Solar & Energy Storage Plan**, in which E3 is currently working with the city to develop an equitable plan to meet its rooftop solar goal (10% of customers) and maximize use of renewable energy in its system *(this work is currently ongoing)*.

In this proposal, E3 describes a scope of work to provide technical analysis and strategic support to PWP and the City Manager's Office in their efforts to develop an optimized plan that meets the city's goals of sourcing all electricity from carbon-free sources by the end of 2030 while maintaining reliability, equity, and affordability.

Project Context

In January 2023, the City Council of Pasadena adopted Resolution 9977, declaring a climate emergency and setting an ambitious target for the city to source its electricity exclusively from carbon-free resources by the end of 2030:

> *Section 3: The City Council hereby sets a policy goal to source 100% of Pasadena's electricity from carbon free sources by the end of* 2030.

> *Section 4: The City Council hereby directs the City Manager to utilize the 2023 IRP process to plan multiple approaches to transition to the goal described in Section 3 and to optimize affordability, rate equity, stability, and reliability of electricity while achieving this goal.*

Following the passage of this resolution, PWP refocused its 2023 IRP on scenarios intended to explore options to achieve the goal to decarbonize the power sector established in Resolution 9977. The 2023 IRP was approved for submission to the California Energy Commission (CEC) by City Council in December 2023. Upon approval of the 2023 IRP, Pasadena City Council also issued guidance that the City Manager's Office should subsequently develop an optimized plan to meet its 2030 objectives:

> *"City Manager's Office to engage 3rd party consultant with expertise in green energy to advise in development of optimized plan. Optimized plan development to be completed within six months and presented to the Municipal Services Committee."*

On February 26, the Municipal Services Committee provided additional guidance that the development of the optimized plan should include a number of new technical studies that would enable the optimized plan to consider demand-side resource potential, the role of emerging technologies, and impacts on the transmission and distribution system. The specific studies proposed by PWP and endorsed by the MSC are summarized in Figure 1.

Figure 1. Studies recommended by PWP to support development of the city's optimized plan

The remainder of this document summarizes a study plan jointly developed by PWP, the City Manager's Office, and E3 to allow PWP to identify an Optimized Strategic Plan pursuant to the guidance provided by City Council and the Municipal Services Committee.

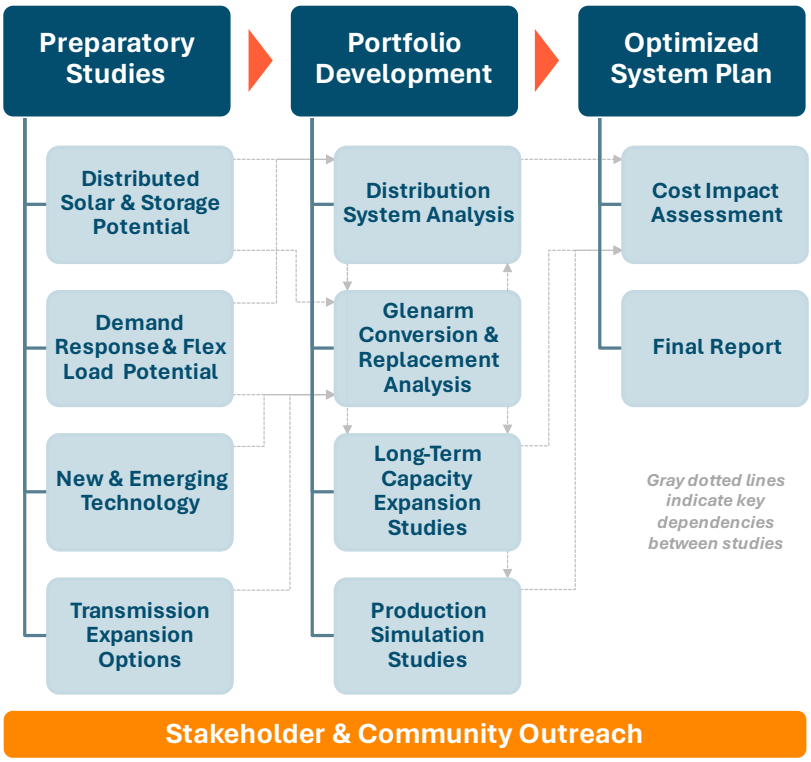
Scope of Work

Under this scope of work, E3 proposes to support PWP staff and the City Manager's Office in the development of an optimized plan to meet the objectives of Resolution 9977. E3's support will include original technical analysis that builds upon the foundations established by the Power Delivery Master Plan (PDMP) and Integrated Resource Plan (IRP) as well as support in the process of synthesizing the findings and developing a coherent narrative to support the plan. The general steps included in this proposal, shown in Figure 2, include:

- A number of **"Preparatory Studies"** needed to develop key inputs to the study process that are incremental to the 2023 IRP;
- A **"Portfolio Development"** phase, in which a variety of power system planning models will be used to develop potential plans that minimize cost, ensure reliability, and meet the objectives of Resolution 9977 to source all electricity from carbon-free sources;
- The identification of an **"Optimized Strategic Plan"** that best meets the objectives of Resolution 9977 based on the results of the technical analysis and a final assessment of cost, to be described in a final report jointly authored by PWP and E3.
- An extensive effort to **engage stakeholders** through bimonthly workshops, soliciting feedback and keeping them apprised of progress throughout the project.

Each of the specific studies recommended as part of this process is described in further detail below.

Figure 2. Overview of study process to develop Pasadena's optimized plan



Several additional general notes on this proposed study plan:

- While Figure 2 presents this study plan as relatively linear, many of these workstreams will be undertaken concurrently such that results from one may be incorporated in a more iterative process. For instance, the distribution system analysis may provide an indication of parts of the system that are suitable for deployment of virtual power plants to mitigate the impacts of growing loads and electrification, which may subsequently be considered in the bulk system planning studies (Glenarm Conversion & Replacement and Long-Term Capacity Expansion)
- Subsequent study descriptions provide E3's current expectations for the technical analysis needed to inform an optimized plan, but the specific technical analysis undertaken may be further refined based on additional input from PWP, the City Manager's Office, and stakeholders.
- Preceding each task in this proposal, E3 and Pasadena shall collaboratively review the scope of each assessment, study, and/or modeling approach and collectively agree on any needed updates, changes, or enhancements.
- While major changes to this proposed scope may require utilization of a contingency budget or a formal change order, E3 will do its best to accommodate minor refinements and adjustments within the current proposed budget.
- E3 shall provide all new or updated modeling inputs developed and utilized by E3 under this Scope of Work that vary from the 2023 Integrated Resource Plan modeling inputs in order to easily update the Encompass modeling software utilized by Pasadena.

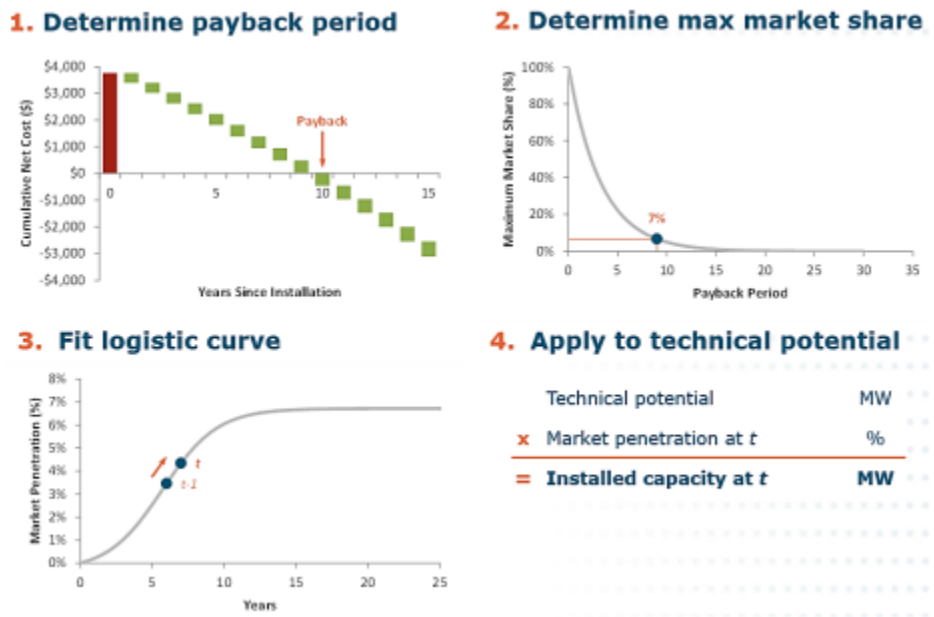
Distributed Solar & Storage Study

Objective: assess technical potential and cost for distributed solar and storage resources in the Pasadena system using detailed building data; develop multiple plausible projections for market potential based on low, medium, and high adoption rates; quantify additional potential for solar in PWP service territory for ground-mounted and parking canopy applications

Rooftop Solar & Storage

In this study, E3 will quantify the technical potential of rooftop solar and storage and develop a range of adoption scenarios reflecting different levels of customer uptake. To do so, E3 will develop a Bass diffusion model of rooftop solar adoption calibrated to historical uptake and use the parameters of this model to develop multiple projections of the rate of future adoption (an approach illustrated in Figure 3).

Figure 3. Basic approach used to develop future projections of customer-sited solar and storage



E3 has used the approach proposed herein in a number of different studies to quantify future adoption of rooftop solar and believes this approach will meet the objectives of this effort. Key steps involved in this process are described below:

1) **Quantify total technical potential:** E3 will first develop estimates of the technical potential for rooftop solar in the PWP service territory drawing upon multiple available public data sources. These include NREL's Rooftop Energy Potential of Low Income Communities in America (REPLICA) data set, Google Sunroof, and other relevant datasets as identified by E3.
2) **Determine customer segmentation of technical potential:** residential and commercial customers (and different subsegments within these groups) have shown significant differences in propensity to adopt rooftop solar; using building data and other public resources, E3 work closely with PWP to divide the technical potential into customer segments so that each can be treated independently in adoption and resource modeling.
3) **Analyze historical adoption data to calibrate adoption parameters:** E3 will apply a Bass diffusion model to determine future adoption trajectories; before this model is used to look forward, it must be carefully calibrated to yield results consistent with historical results.
4) **Project future adoption under a range of payback assumptions:** the rate of adoption in the Bass diffusion model is directly tied to the payback period of the investment; E3 will vary the payback period between levels consistent with today's compensation under net energy metering and lower/higher payback periods to develop a range of potential trajectories.

This approach will be applied to both standalone rooftop solar systems and systems paired with energy storage resources.

Non-Rooftop Solar & Storage

The Distributed Solar & Storage Study will also include an assessment of the potential for new ground-mounted and parking canopy solar resources that could interconnect directly to the PWP subtransmission system. This evaluation will be completed using a GIS-based modeling approach and leveraging mapping layers developed in the process of creating inputs for the CPUC IRP proceeding. Because of the scarcity of land within the PWP system, ground-mounted resource potential is not expected to be large; however, potential for parking canopy solar may be more significant: NREL's LA100 study found that "parking canopy solar makes up the majority…of the city's local solar potential."[1] These potential figures will provide useful information to downstream studies regarding the limits on how much solar can be deployed internal to the PWP system.

Demand Response and Flexible Load Potential Study

Objective: assess cost and potential for future demand response within PWP's service territory

The most detailed relevant study of demand response potential to date is Lawrence Berkeley National Laboratory's (LBNL) California Demand Response Potential Study.[2] A prior version of this study established the now common lexicon of "shed" and "shift" used to describe different types of demand response programs:

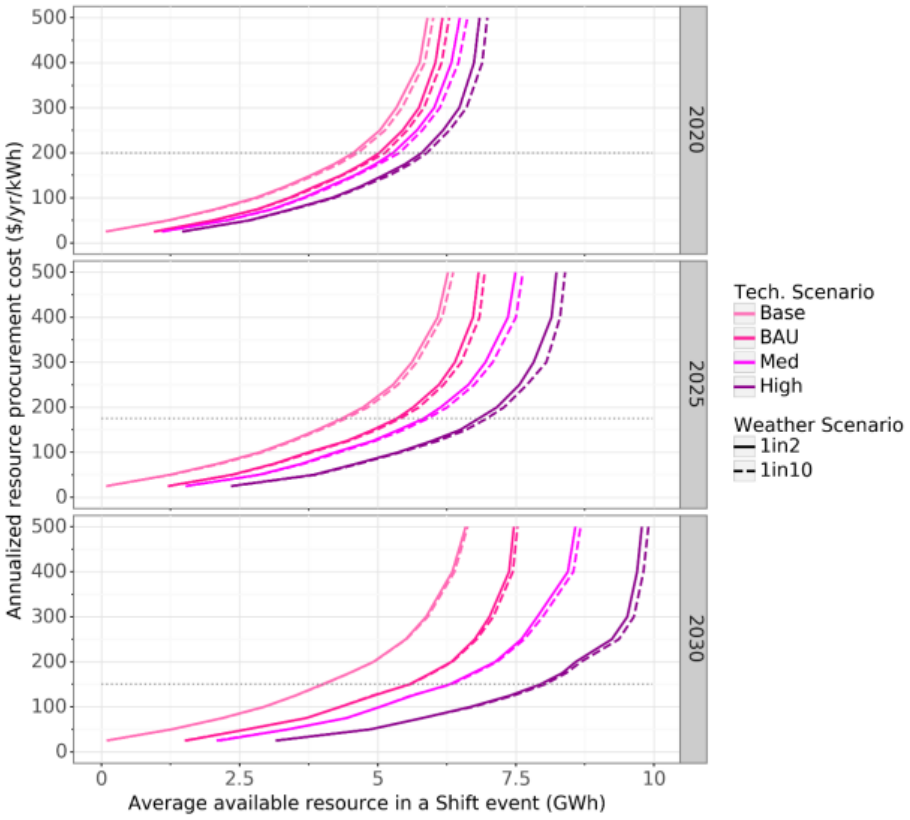
> ***Shed*** *describes loads that can be curtailed to provide peak capacity reduction and support the system in emergency or contingency events with a range in dispatch advance notice times.*

> ***Shift*** *represents DR that encourages the movement of energy consumption from times of high demand to times of day when there is a surplus of variable renewable energy (VRE) generation. Shift could smooth net load ramps associated with daily patterns of solar energy generation.*

LBNL's studies provide an unparalleled level of detail in their characterization of demand response potential, developing supply curves for shed and shift DR programs based on detailed end use data across multiple customer segments (an example is shown in Figure 4).

[1] https://www.nrel.gov/docs/fy21osti/79444-5.pdf
[2] https://eta-publications.lbl.gov/sites/default/files/ca_dr_potential_study_-_phase_3_-_shift_-_final_report.pdf

Figure 4. Example supply curves developed in LBNL's California Demand Response Potential study



To quantify demand response potential for the City of Pasadena, E3 will leverage this prior work, developing estimated supply curves by downscaling the supply curves developed by LBNL so that they can be applied to PWP's service territory. LBNL's analysis focuses upon the service territories of the three California investor-owned utilities; to adapt these curves for use in this study, E3 will downscale the curves developed for the SCE service territory based on relative customer counts, building stocks, and/or electric loads in the PWP service area.

Additionally, this study will examine the potential for electric vehicle loads to act as a source of flexibility to support both renewable integration and local reliability. E3 will develop EV profiles consistent with the levels of EV adoption anticipated by PWP that reflect various combinations of home vs. workplace/charging plaza and managed vs. unmanaged charging.

New & Emerging Technology Assessment

Objective: survey current landscape of new & emerging generation technologies to identify potential options that could contribute to meeting the goals of Resolution 9977 (with particular focus on resources that could be sited locally in the PWP service area); characterize performance assumptions and potential cost ranges to use in development of optimized plan

Error! Reference source not found. includes a representative list of potential technologies that may be evaluated; this list will be finalized in consultation with PWP, the City Manager's Office, and stakeholders through the stakeholder engagement process.

Table 1. Illustrative list of potential candidate technologies for consideration

Technology *(Illustrative List)*	
Solar PV – Utility Scale, Community, Rooftop	Iron-Air Energy Storage
Wind – On shore, Offshore, Out-of-State	Thermal Air Energy Storage
Geothermal (Traditional)	Lithium-Ion Battery Storage
Geothermal (Enhanced)	Flow Battery Storage
Hydrogen Fuel Cells	Compressed Air Energy Storage
Hydrogen Combustion Turbines	Pumped Hydro Storage
Renewable Natural Gas	Others…

New technologies that would not meet the requirements of Resolution 9977 (e.g. fossil fueled resources) or are in conflict with current California law (e.g. new nuclear) will not be considered.

Key Outputs: For each technology included, E3's review will include assessments and/or descriptions of:

- Technology readiness and description of commercialization;
- Performance characteristics;
- Plausible cost ranges (capital and O&M)
- Land use requirements and constraints on location;
- Technology-specific risk factors

The quantitative data gathered in this assessment will inform downstream analyses; the qualitative information may be used to inform decision-making regarding the optimized plan.

Transmission Expansion Options Assessment

Objective: characterize options to expand intertie capability with neighboring systems that are possible within the next decade

In 2022, PWP published the Power Delivery Master Plan (PDMP), which enumerates the utility's future plans to replace, reinforce, and upgrade assets in the aging subtransmission system over which power is delivered to customers. One of the key strategies described in this plan is the expansion of intertie capabilities between the PWP system and its neighbors, including an upgrade of transformers at the Goodrich receiving station that would allow it to be operated at 336 MW (vs. 280 MW today).

In this study – defined with a relatively narrow scope – E3 will coordinate with PWP's planners to (1) understand how these upgrades would impact PWP's ability to import power from its neighboring utilities; (2) characterize assumptions about the cost and performance of those upgrades for modeling consistent with those impacts, and (3) explore whether additional expansion of intertie capability with neighboring systems is feasible and merits consideration in this study.

To the extent this effort identifies opportunities for additional expansion of the interties, E3 may recommend an expansion of this specific study's scope to explore the cost, feasibility, and timing of those options.

Distribution System Analysis

Objective: use geospatial analysis to identify localized impacts of changes in electric loads (including electric vehicles) and DERs, providing an indication of where distribution system may be constrained relative to thermal ratings of substations and identifying areas of the system that may be suitable for deployment of virtual power plants

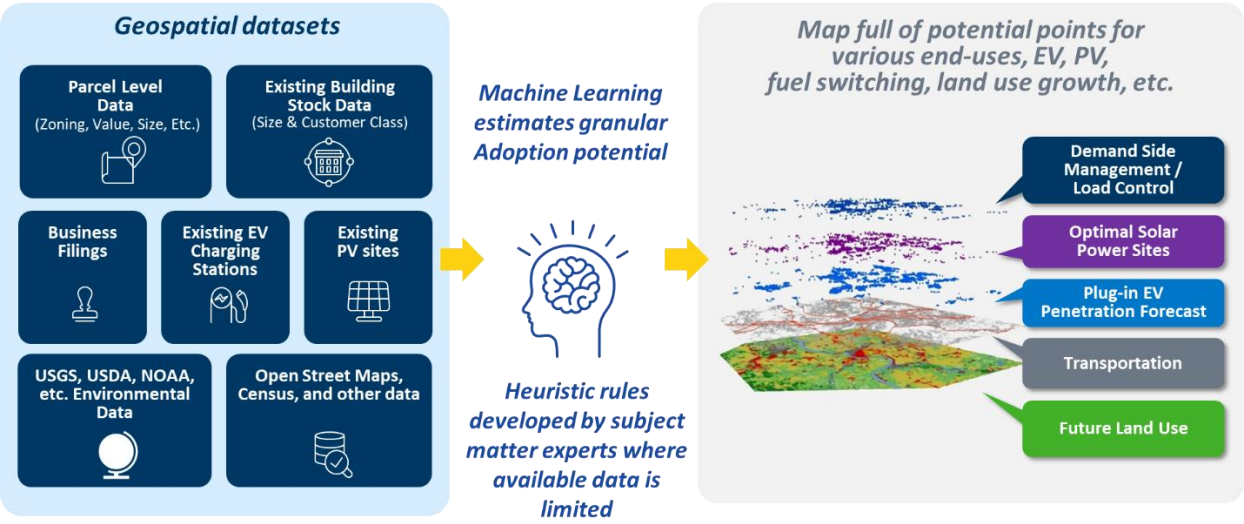
Additional Note: the proposed analysis will not include power flow modeling of the distribution system; this type of analysis will ultimately be necessary to determine specific infrastructure needs as system evolves but would be considerably more time- and budget-intensive than the other efforts included in this scope of work. E3 considers this a possible area for additional research following the development of the Optimized Strategic Plan.

E3, in partnership with our sister company Integral Analytics (IA), has developed Forecasting Anywhere, an approach to advanced geospatial forecasting of DER and electrification loads and their effects on the transmission and distribution system. IA provides the LoadSEER software, a leading distribution planning and load forecasting tool implemented at over 15 large utilities in North America, including PG&E, SDG&E, HECO and Xcel. Whereas LoadSEER performs detailed planning with proprietary utility distribution data, Forecasting Anywhere uses a variety of publicly sharable datasets to perform robust scenario analysis for policy and planning. The Forecasting Anywhere tool can also take in utility and city specific data sets to enhance forecasting for local areas. E3 uses Forecasting Anywhere to develop and provide multiple holistic distribution planning scenarios that are consistent with the utility IRP and with state and local policy goals.

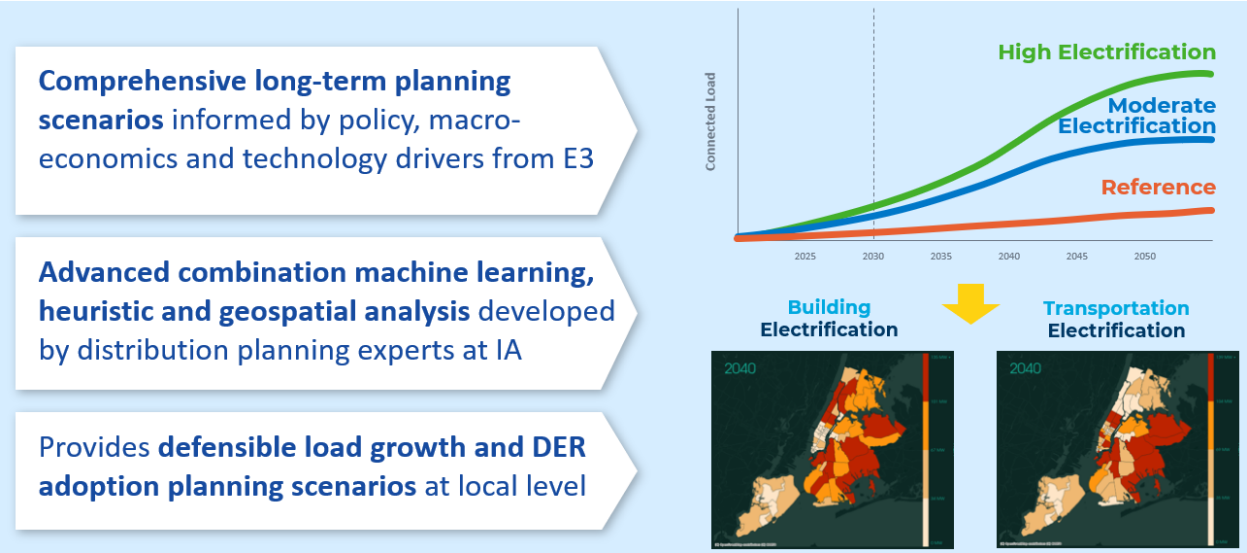
E3 will work with Pasadena to start with several of the portfolios developed in the above tasks and translate them into geospatially granular impacts for quantifying distribution system impacts. E3 will develop these portfolios for use in distribution system planning by detailing the magnitude and location of DER and load growth including PV, Storage, DR, EVs and building electrification. High

resolution geospatial forecasting supports distribution planning that achieves state, city and utility clean energy goals, optimizes infrastructure investments, and increases overall distribution system utilization and reliability. A summary of the data sets used for geospatially granular DER adoption and load growth projections is shown below.

Overview of Datasets Used



High Electrification Distribution Planning Scenarios



Forecasting Anywhere provides a nimble and data-driven approach to evaluate geospatially-specific distribution and transmission investment needs and costs across a wide range of planning scenarios out to 2050. This will provide useful insights for planners, council members and stakeholders in considering alternative electrification scenarios. Evaluating multiple scenarios for distribution impacts is essential to understand the uncertainties, risks, and opportunities posed by rapid growth

in transportation and building electrification, rooftop solar, and energy efficiency and to advocate for city and stakeholder approval of a preferred integrated plan for the utility.

The deliverable for this task will be an aggregation of DER adoption and peak load growth for each substation and substation bank/feeder in Pasadena (assuming Pasadena can provide GIS boundaries or line diagrams to facilitate matching of loads to feeders). E3 will work with Pasadena distribution planners and engineers to make a high level but robust assessment of the types and costs of upgrades that will be required for each planning scenario. Illustrative results for such an analysis are shown below.

Illustrative Distribution Cost Impacts by Distribution Planning Area (DPA)

			Local Capacity Zone (Transmission)		
	2030		DPA 1	DPA 2	DPA 3
	Incremental Load Growth				
	Diversified coincident peak (Primary)	MW	10	12	10
	sum of FLT non-coincident peak (Secondary)	MW	16	17	19
	Annual energy	MWh	52,560	57,816	56,940
	Diversity factor		63%	71%	53%
	Utilization Factor		60%	55%	65%
	Capital Investment				
Primary	New Substations	#	1	2	0
	New Banks (at existing substations)	#	2	0	4
	New Feeders	#	6	8	11
	Bank/Feeder Upgrades	#	4	2	6
	Total Cost				
	Incremental Capital	$1,000	$12,555	$21,800	$4,075
	$/kW Capital Cost	$/kW	$1.26	$1.82	$0.41
	Incremental Annualized cost	$1,000	$1,004	$1,744	$326

To the extent certain scenarios analyzed in the distribution system analysis present greater challenges or imply more costly upgrades to existing substations, this information may be used to inform what specific scenarios/portfolios are explored in subsequent phases of the analysis.

Glenarm Conversion & Replacement Study

Objective: identify options to either (a) convert Glenarm to a carbon-free fuel or (b) replace Glenarm with a portfolio of local carbon-free resources in a manner that preserves reliability within the Pasadena load pocket.

PWP's ability to meet customer electricity demands reliably during peak load conditions is heavily dependent upon two things: (1) its ability to import electricity from CAISO through the Goodrich receiving station (up to 280 MW), and (2) the Glenarm generating station, a 200 MW natural gas generator located within the PWP system. Both of these sources are critical to meeting customer

loads today, as PWP's current peak demand (330 MW) exceeds the maximum capability of either one individually.

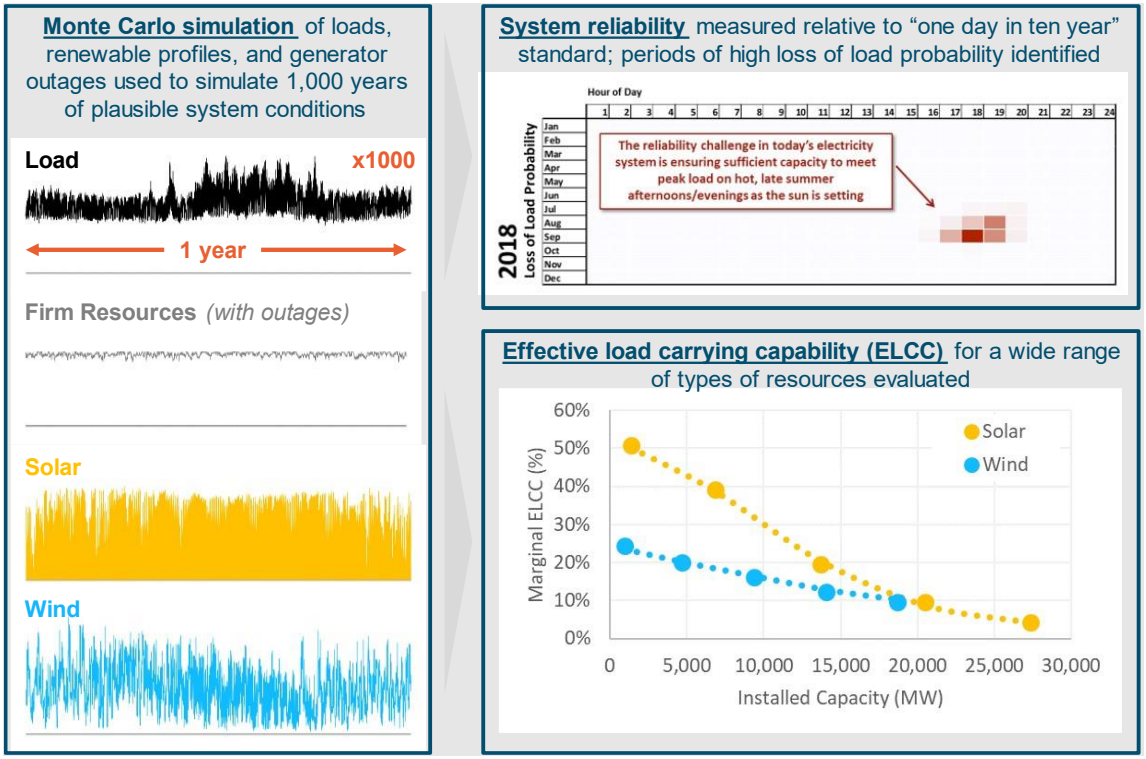
In the context of developing a plan that sources all electricity from carbon-free resources, Pasadena City Council has directed PWP to evaluate options to convert or replace Glenarm with carbon-free resources. This study will identify options for conversion and replacement, highlighting the attendant risks associated with each and examining their impacts to reliability. Conversion options examined will include the potential to purchase renewable natural gas and/or green hydrogen to fuel the plant's operations (along with any associated equipment upgrades necessary to make that transition). Replacement portfolios will consider a wide range of potential solutions to the Glenarm retirement, including:

- Transmission expansion (e.g. Goodrich expansion)
- Incremental demand response and load flexibility (as identified in **Demand Response and Flexible Load Potential Study**)
- Local distributed solar and battery storage (based on results of **Distributed Solar & Storage Study**)
- Additional emerging technologies (e.g. long duration storage) (based on results of **New & Emerging Technology Assessment**)

Recognizing the current importance of Glenarm in meeting the city's reliability needs, the principal question this provokes is what combination of local resources (and/or transmission solutions) would be needed to maintain reliability. To answer this question, replacement options will be studied by applying loss-of-load-probability (LOLP) modeling techniques commonly used in resource adequacy studies to the PWP local system. Specifically, this analysis will be completed using E3's Renewable Energy Capacity (RECAP) model, a Monte Carlo LOLP model designed to evaluate the reliability of electricity systems under high penetrations of renewable and storage resources. Each replacement portfolio – which may comprise generation and/or transmission solutions – will be designed to provide the same level of reliability to PWP customers as if Glenarm remained in service;[3] this will ensure no degradation of local reliability due to a generation inadequacy. Each conforming replacement portfolio will be carried forward into subsequent stages of analysis.

[3] The level of reliability may be measured using Loss of Load Expectation, Expected Unserved Energy, and/or a deterministic analysis of a peak summer week.

Figure 5. Summary of RECAP modeling methodology and key outputs



A robust study of reliability requires extensive efforts to characterize the load and resource conditions at the "tails of the distribution", i.e., during unusual combinations of extreme weather and facility outages, that could result in insufficient generation resources to serve loads. To represent these tails, E3 will develop a library of electricity demand profiles representative of a long-term record of historical weather data by using a neural network regression model. Rather than analyzing system performance under a single deterministic weather condition, this analysis will reflect the plausible outcomes under rare but extreme weather events that tend to drive the most challenging electric demands (for instance, the 1-in-35 weather event that contributed to load shedding across CAISO in August 2020). Similarly, E3 will utilize National Renewable Energy Laboratory's (NREL) National Solar Radiation Database (NSRDB) and System Advisor Model to simulate hourly solar production profiles in the PWP service territory across a similarly wide range of weather years. Finally, this analysis will incorporate the risk of planned and unplanned outages of equipment at the Goodrich receiving station, which can directly restrict PWP's ability to import electricity from CAISO, requiring generation capability within the service territory to maintain reliability.

Key Outputs: This study will produce a range of options for replacement or conversion of Glenarm that provide for a comparable level of local generation adequacy. Those options will be incorporated directly into the subsequent long-term capacity expansion (LTCE) modeling.

Long-Term Capacity Expansion Modeling

Objective: use optimal LTCE modeling to develop multiple possible portfolios consistent with the objectives of Resolution 9977 that incorporate the results of the **Distributed Solar & Storage Study**, the **Demand Response and Flexible Load Potential Study**, findings from the **Distribution System Analysis**, and results of the **Glenarm Conversion & Replacement Study**

E3 will develop a LTCE model of the PWP system that builds upon the foundation established in the IRP, which will be used to develop a "Reference Case" (for comparative cost analysis) and multiple portfolios designed to achieve the objectives set forth by Resolution 9977. The LTCE model will leverage information and data sources developed for the 2023 IRP (as well as comparable information developed by E3 for the CPUC's IRP proceeding) but will update this information where necessary to reflect the best available market intelligence. Proposed assumptions include:

- A demand forecast for PWP consistent with the assumptions used in the 2023 IRP;
- Updated resource costs for commercially available resources (wind, solar, geothermal, energy storage) based on more recently available market intelligence and public data sources;
- Potentials for new resource development external to the PWP system informed by assumptions developed in the CPUC IRP process; and
- Updated forecasts to commodity pricing (include wholesale electricity prices).

Further, each portfolio developed will include:

- The resources currently owned by and under contract to PWP (including future additions); with the recent approval of the Bonanza Solar & Storage project, this portfolio of resources is currently projected to achieve a 95% RPS by 2028
- Adoption projections for distributed solar & storage resources developed the **Distributed Solar & Storage Study**
- One of the options for Glenarm conversion & replacement identified in the **Glenarm Conversation & Replacement Study**
- to ensure that the resulting portfolio includes sufficient import capability & local generation to meet reliability needs within the PWP system

In each portfolio, the LTCE model will be allowed to select additional resources beyond these three categories to the extent they are needed to meet reliability or clean energy constraints.

The specific modeling platform used in this analysis will be determined through further conversations with PWP and the City Manager's Office. E3 currently uses both RESOLVE, an in-house capacity expansion model developed and maintained by E3 and currently used by the CPUC in its Integrated Resource Planning proceeding; and PLEXOS LT, a commercial capacity expansion model commonly used by utilities throughout the country to develop robust IRPs. E3 is confident that both approaches would yield consistent results, having benchmarked the two models closely against one another in parallel modeling efforts on several occasions.

Production Cost Modeling

Objective: calculate operational costs and validate operational reliability by simulating the electric system across all (8760) hours of the year

Portfolios developed by the LTCE model will subsequently be evaluated using production cost modeling to simulate their operations over the course of the entire year. This will provide enhanced resolution of the energy costs associated with operating PWP's generating resources and any costs/revenues associated with market transactions with CAISO.

Cost Impacts Assessment

Objective: calculate the energy supply costs associated with each scenario, including ranges to account for future technology and fuel price uncertainties; translate total cost metrics into projections of average system rate

In its 2023 IRP, PWP produced final cost metrics and retail rate projections based on the results of the scenario analysis. E3 will use these cost and rate projections as a starting point, updating the information relevant to the modeling outputs from the portfolio optimization process. These include costs associated with maintaining and operating existing generation resources (including contracts), costs associated with new resources identified in each scenario, and wholesale transaction costs. Additionally, to the extent the transmission review and distribution system analysis provides an indication that scenarios would have differential impacts on the distribution system, E3 will work with PWP to develop informed estimates of those costs.

Optimized Plan Identification

E3 believes that the study plan described above will provide enough information to define an Optimized Strategic Plan to meet the objectives of Resolution 9977; however, the selection of an optimized plan will require consideration of the cost, reliability, emissions, and equity impacts of various options – and may require consideration of tradeoffs among those objectives that reflect policy judgements – as well as tolerance for various risks and uncertainties. Therefore, the final decision making around what plan to bring forward to City Council as the Optimized Strategic Plan should be determined by PWP with due consideration of input from the City Manager's Office, stakeholders, and City Council. E3 will support and advise PWP in evaluating those tradeoffs and considerations throughout the project.

Final Report

Objective: support PWP in synthesizing analytical results to identify an optimized plan that best meets the objectives of Resolution 9977 and in developing a written narrative describing the elements of that plan (targeting a main report of 30-50 pages in length, plus additional appendices for each of the technical studies completed by E3)

The final report will provide a narrative description of the optimized plan, synthesizing the results of the technical analysis conducted herein and contextualizing it against the backdrop of other planning processes (the PDMP, IRP, and upcoming cost of service study). The report will describe the optimized plan and articulate a clear set of actionable next steps that will allow the utility to progress towards its goal to source all electricity from carbon-free sources. Because 2030 is rapidly approaching, and many of the contemplated changes to the system either require long lead times or are dependent upon other planned changes (e.g. advanced DR programs would require deployment of AMI; upgrades to Goodrich transformers require completion of upgrades to internal distribution lines), a major focus of the development of this plan will be upon sequencing and timing of key steps needed to advance towards the goal of Resolution 9977.

While E3 anticipates the final document will be published under PWP's name with E3 credited for our technical contributions and general support, we anticipate working collaboratively with PWP in the drafting and revision process. Further, E3 will directly contribute technical appendices with the results of each of the preparatory studies.

Stakeholder & Community Engagement

Objective: provide updates to and solicit input from local stakeholders and community members to ensure the optimized plan is developed in a manner that is transparent and incorporates input directly from those who it will impact most directly

E3 has significant experience in developing, facilitating, and participating in stakeholder engagement processes on behalf of our clients, particularly in the electric system planning space. We believe our experience make us well qualified to support PWP in developing the optimized plan. We have worked across departments in utilities to implement far reaching initiatives and believe our ability to navigate utility organizations while facilitating constructive dialogue to ensure perspectives are heard and addressed will be key to this engagement.

In this project, E3 will work closely with PWP and the City Manager's Office to plan and lead a series of six stakeholder workshops over the 12-month study process (a cadence of roughly one meeting every two months). These workshops – which will include a combination of in-person and remote sessions – will include presentations from the study team regarding the study plan, progress updates, and results; as well as opportunities for questions and answers and general feedback on the analysis as it takes shape.

Further, E3 will provide periodic updates to the Municipal Services Committee on progress throughout the study.

Project Timeline & Budget

This project will be completed over the course of a twelve-month period, a time span intended to allow for some iteration and incorporation of feedback from PWP, the City Manager's Office, and stakeholders. Assuming a project kickoff at the beginning of May 2024, the project would conclude in April 2025. The sequence of tasks is shown in the figure below.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Distributed Solar & Storage				●								
DR/Flex Loads Potential				●								
Emerging Technology				●								
Tx Expansion Options				●								
Glenarm Conv/Replacement						●						
Distribution System							●					
LT Capacity Expansion									●			
Production Cost										●		
Cost Impacts										●		
Final Report												●
Stakeholder Engagement		●		●		●		●		●		●

E3 will complete this work on a Time and Materials basis with a budget of $1,100,000; $850,000 of the budget is allocated to technical analysis, and the remaining $250,000 is reserved for stakeholder engagement and the final report. E3 is pleased to offer our discounted rates for this work (15% below standard rates) to PWP as a public power entity. The rough breakdown of hours by task are shown in the table below. Discounted billing rates by title are included in the subsequent table.

Table 2. Proposed budget associated with the study plan

Task	Estimated Hours	Budget
Distributed Solar & Storage Study	450	$150,000
Demand Response & Flex Loads Potential Study	225	$75,000
Emerging Technology Assessment	150	$50,000
Transmission Expansion Options Assessment	75	$25,000
Distribution System Analysis	450	$150,000
Glenarm Conversion & Replacement Study	300	$100,000
Long-Term Capacity Expansion Modeling	600	$200,000
Production Cost Modeling	150	$50,000
Cost Impacts Analysis	150	$50,000
Total Analysis Budget	**2,550**	**$850,000**
Final Report	300	$100,000
Stakeholder & Community Engagement	450	$150,000
Total Project Budget	**3,300**	**$1,100,000**

Figure 6. E3's discounted rates

Title	Hourly Rate
Managing Partner	$555
Senior Partner	$555
Partner	$510
Senior Director	$465
Director	$445
Associate Director	$420
Senior Managing Consultant	$390
Managing Consultant	$355
Senior Consultant	$320
Consultant	$270
Associate	$225

Project Team

This effort will be led by Nick Schlag, a partner at E3 with fourteen years of industry experience and a long history of working with utilities to support integrated resource planning. The project will be managed by Dr. Nathan Lee, Senior Managing Consultant, who previously oversaw E3's independent review of the IRP and brings broad expertise in power system planning. Mr. Schlag and Dr. Lee will be further supported by a team of senior subject matter experts with extensive expertise in planning various aspects of low-carbon electricity systems. Additional E3 subject matter experts and analysts will support this leadership team to execute upon the study plan.

Nick Schlag, Partner Mr. Schlag's principal area of expertise is electric integrated resource planning, with an emphasis on renewable integration, system flexibility needs, and resource adequacy. He also has extensive experience in distributed resource cost effectiveness, market analysis, and gas-electric coordination. Recent projects include engagements with Arizona Public Service, NV Energy, the Sacramento Municipal Utilities District (SMUD) and Xcel Energy to support their recent respective integrated resource plans. He has been the lead author on several high-profile planning studies of electric infrastructure in the Western Interconnection, including *Pacific Northwest Low Carbon Scenario Analysis* and the *Western Interconnection Flexibility Assessment*. Prior clients include the Balancing Authority of Northern California, Bonneville Power Administration, the California Public Utilities Commission, the California Independent System Operator, Los Angeles Department of Water and Power, the New York State Energy Research & Development Authority, Portland General Electric, the Western Electricity Coordinating Council, and the Western Interstate Energy Board. Mr. Schlag holds a Master of Science in Civil and Environmental Engineering (Atmosphere and Energy) and a Bachelor of Science in Earth Systems, both from Stanford University.

Dr. Nathan Lee, Senior Managing Consultant Dr. Nathan Lee supports E3's work in integrated system planning. He spent six years at the National Renewable Energy Laboratory (NREL) where he supported multiple power system planning and grid integration efforts around the globe. Additionally, he led NREL research on decision science for energy transitions. Nathan's doctoral research focused on decision support methodologies for national energy planning in emerging economies. He completed his Ph.D. and Masters in Sustainable Energy Systems with the MIT Portugal Program at the University of Porto. He also earned a B.S. in Engineering Physics from Miami University of Ohio.

Arne Olson, Senior Partner Mr. Olson leads E3's resource planning practice. Since joining E3 in 2002, he has led numerous analyses of how renewable energy and greenhouse gas policy goals could impact system operations, transmission, and energy markets. In 2013, he led the technical analysis and drafting of the landmark report *Investigating a Higher Renewable Portfolio Standard for California*, prepared for the five largest utilities in California. Since that time, he has overseen numerous studies of deeply decarbonized and highly renewable power systems in California, Hawaii, the Pacific Northwest, the Desert Southwest, New York, South Africa, and many other regions. Mr. Olson's clients have included most of the major utilities and market participants in the West, including the California Independent System Operator, Pacific Gas & Electric, Southern California Edison, Puget Sound Energy, PacifiCorp, Arizona Public Service, Sacramento Municipal Utilities District, Los Angeles Department of Water and Power, the Bonneville Power Administration, Calpine, NextEra, NRG, TransAlta and many others. He also works extensively with government agencies and industry organizations such as the California Public Utilities Commission, California Energy Commission, Oregon Public Utilities Commission, the Western Electric Coordinating Council, and the Western Interstate Energy Board. Mr. Olson earned an M.S. in International Energy Management and Policy from the University of Pennsylvania and the Institut Français du Pétrole, and bachelor's degrees in Statistics and Mathematical Sciences from the University of Washington.

Eric Cutter, Partner Mr. Cutter leads E3's practice area enabling distributed resources and electric vehicles to serve as valuable resources for the electric grid. He manages E3's team working on vehicle grid integration with utilities, regulators, automakers and electric vehicle service providers to develop strategic roadmaps, perform cost-benefit analysis and develop business strategies. He is co-leading the team developing the Forecasting Anywhere tool, using advanced machine learning and heuristic approaches to provide granular geospatial DER and load forecasts for distribution planning. Building on decades of experience in distributed resources, Mr. Cutter is also leading work on valuation of energy storage and flexible loads, with an emphasis on distribution planning. Prior to joining E3, he worked as an independent consultant in water resources for seven years, and at PG&E for ten years. Mr. Cutter graduated with an M.B.A. and M.S. in Energy and Resources from U.C. Berkeley, and bachelor's degrees in Economics and German from Tufts University.

Aaron Burdick, Director Mr. Burdick joined E3's planning group in 2019, where he helps utilities, system operators, and state agencies prepare for a high renewables future. He leads projects forming long term planning and reliability analyses for the electric system. His work includes working on electric planning in California, the Pacific Northwest, Hawaii, and the Midwest with expertise in utility procurement, commercial strategy, and electricity market design. He joined E3 from utility Pacific Gas & Electric, where he led the

development of PG&E's 2018 Integrated Resource Plan and provided leadership on decarbonization efforts and renewable energy strategy. Before attending graduate school, Mr. Burdick spent two and a half years at energy consultancy ICF International. Mr. Burdick holds an M.S. in Civil and Environmental Engineering (Atmosphere/Energy) from Stanford University and a B.S. in Environmental Studies from the University of California, Santa Barbara.

Michael Sontag, Associate Director Mr. Sontag's work focuses on the interactions between building loads, the electric grid, and greenhouse gas emissions, as well as leveraging distributed energy resources to support and enhance a clean energy future. Since joining E3 in 2016, he has led the development of E3's building decarbonization analysis toolkit, including models that calculate upfront consumer costs, ongoing utility bills, grid impacts, avoided utility costs, and attributable emissions for a variety of space heating and water heating technologies in a variety of building types. In addition to this, he has developed avoided cost models that leverage knowledge of wholesale energy markets and utility regulations to calculate the hourly avoided utility costs and emissions impacts of demand side programs and building standards. He has also worked extensively in the area of flexible loads, both in terms of modeling their impact on building decarbonization efforts and understanding the emerging regulatory and wholesale market opportunities for DER technology providers and aggregators. As part of his work, Mr. Sontag has created many intuitive, user-focused Excel tools to help public stakeholders and private developers make informed, data-driven decisions based on E3's research. He received his M.S. in Civil and Environmental Engineering (Atmosphere and Energy) from Stanford University, and a B.S. in Mechanical Engineering from the University of California, Berkeley. He earned his Professional Engineer license in California in 2014.

Michaela Levine, Managing Consultant Ms. Levine's work focuses on analyzing opportunities to leverage distributed energy resources to support the clean energy transition and supporting clients' transportation and building electrification efforts. She specializes in analysis of electrification and flexible loads, modeling building electrification and transportation electrification at scale. She is also an experienced modeler in Forecasting Anywhere, applying the tool to provide a distribution planning understanding of the impact of distributed energy resources on the grid. Several of her recent projects have examined grid impacts and opportunities associated with electrification including microgrid and V2X use cases, geospatial forecasts and allocation of electric vehicles and chargers in both New York City and California, and vehicle-grid-integration. Ms. Levine joined E3 in 2020 after completing her master's degree in Civil and Environmental Engineering in the Atmosphere/Energy program at Stanford University. In addition to her M.S., Ms. Levine has a B.A. in Geoscience with a concentration in Environmental Studies from Williams College.

Qualifications

E3's project experience relevant to this study is extensive. This section includes a selection of a number of the projects most relevant to the current proposed effort for PWP.

Resource Adequacy & Reliability

Los Angeles Department of Water and Power Once-Through Cooling Study (2017-2018). E3 completed a study for the Los Angeles Department of Water and Power, the nation's largest municipal utility, to evaluate the retirement of dispatchable once-through cooling (OTC) power plants that served the transmission-constrained load pocket of the Los Angeles basin but were mandated to retire due to California environmental regulations. Using our in-house RECAP model, E3 evaluated the reliability contribution of alternative preferred resources including utility-scale wind and solar, energy efficiency, distributed solar, storage, demand response, flexible loads, and T&D upgrades. Through this project, we showed that energy-limited resources such as battery storage, flexible loads, or demand response have some ability to replace traditional generating units but have stark diminishing returns beyond limited penetrations such as 5%-10% of peak load capacity. This project was executed with a large team consisting of five different consulting firms in addition to LADWP subject matter experts.

New York Energy Storage Peaker Replacement Study (2019). After developing the New York State Energy Storage Roadmap (2018) with a senior-level team at the New York State Energy Research and Development Authority (NYSERDA) and Department of Public Service (DPS), E3 was retained to evaluate the potential for energy storage to replace fossil-fuel peaking units across the state. To do this, E3 performed a statewide, unit-by-unit analysis of all simple-cycle and regenerative combustion turbine (SCCT) units to identify potential candidates for repowering or replacement with energy storage and/or clean resources. E3's methodology involved developing hourly historical operations and emissions profiles for all peaker units and then feeding this data into RESTORE, E3's energy storage dispatch tool, which simulates optimal storage dispatch (either on a standalone or paired basis) in response to different price signals and constraints. The resulting storage operational profiles were then compared to historical peaker operations to determine whether storage can fully displace a unit's generation or bring it into compliance with local air pollution limits. Overall, E3 found that at least 275 MW of peaking units, or about 6% of total fleetwide rated capacity, could be replaced by six-hour energy storage, and that over 500 MW of peaking units could be replaced by eight-hour storage. The study also found that pairing six-hour storage with solar could enable the replacement of 1,804 MW of peaking units that would not comply with new NOx emissions regulations proposed by the New York Dept. of Environmental Conservation (DEC). The findings were published in the report "The Potential for Energy Storage to Repower or Replace Peaking Units in New York State," filed at the Public Service Commission in July 2019.

Results/Deliverables:

https://www.ethree.com/wp-content/uploads/2019/08/E3_The_Potential_for_Energy_Storage_to_Repower_or_Replace_Peaking_Units_in_New_York_State_July_2019.pdf

New York Power Authority, Peaker Adaptation Analysis (2021-2022). E3 led an engagement in collaboration with GEEC to provide the New York Power Authority (NYPA) with an assessment of adaptation strategies at its SCPP sites in New York City. This analysis included production cost modeling using GE MAPS as well as a detailed evaluation of multiple hybridization and replacement strategies using E3's storage dispatch tool, RESTORE. The project involved an examination of site economics including remaining book value and the installation costs of each adaptation strategy. E3 also met regularly with New York City environmental justice stakeholders (the PEAK coalition) to understand the community impacts of various strategies and to ensure that NYPA's planning efforts are fully taking into account stakeholder input and feedback. E3 worked closely with NYPA to develop an action plan grounded in analysis to directly inform NYPA's near-term decision-making and implementation.

Puget Sound Energy, PRM and ELCC Study (2022-2023). In 2022, E3 supported Puget Sound Energy (PSE) by quantifying the planning reserve margin (PRM) and effective load carrying capability (ELCC) values for PSE's system using E3's proprietary RECAP model. E3 quantified these values for two seasons (winter, summer) and three climate models, which reflect varying degrees of climate change impacts in Western Washington. PSE used these values to perform long-term planning for its 2023 Electric Progress Report. E3 also quantified the ELCC for more than 100 bids that PSE received through its All-Source RFP, which will support PSE's selection of cost-effective bids. In 2023, E3 is continuing to support PSE by modeling a range of options for PSE's future resource procurement.

Confidential Utility, Coal Replacement Study (2022-2023). E3 is supporting a utility in selecting request for proposal (RFP) bids that would replace a large retiring coal plant. E3 is evaluating hundreds of different combinations of bids—including wind, pumped hydro storage, battery storage, and solar projects—to determine which options are most economical. In the first phase of analysis, E3 is quantifying the reliability contribution of each combination of bids using the effective load carrying capability (ELCC) framework, which is one of the key inputs in selecting between the bids. These bids would utilize the transmission that becomes available following the retirement of the coal plant. Because of resource diversity between different wind and solar projects, as well as the ability for energy storage to shift generation to later times, the least-cost selection my involve adding much more nameplate capacity across bids than there is transmission capacity. E3 is evaluating a range of options to determine how the utility can utilize the limited transmission capacity in the most cost-effective manner.

CAISO Demand Response ELCC (2020). E3 investigated the effective load carrying capability (ELCC) of demand response in the California Independent System Operator (CAISO) system. Using E3's RECAP model, the project showed that the ELCC value of demand response was approximately 30% - 40% lower than the capacity credit attributed to them through the Load Impact Protocol (LIP) process administered by the California Public Utility Commission (CPUC). Additionally, E3 investigated attributes of demand response, such as maximum number of calls and call duration,

that could improve the ELCC of demand response as the electricity system evolves with more solar and storage. E3 presented these results in a public workshop with the CAISO, including a proposal for how demand response ELCC could be incorporated into the existing Resource Adequacy framework administered by the CPUC.

Integrated Resource Planning

Silicon Valley Power (SVP) Integrated Resource Plan Support (2023). Silicon Valley Power (SVP), the vertically integrated, municipally owned utility of the City of Santa Clara (Santa Clara) faced unique challenges in the latest 2023 integrated resource plan (IRP) cycle. These included stringent greenhouse regulations and aggressive clean energy targets in California increasing pressure for SVP, and other load serving entities, to accelerate the pace of renewable and clean energy additions, while the City of Santa Clara is investigating potentially even more accelerated carbon-free resource procurement targets. Additionally, migration of industrial customers continues to drive load growth within the utilities territory, and potential growth in transportation and building electrification will could further add pressure to the existing system. SVP has traditionally relied on short-term capacity market purchases to meet its reliability need, however, changing market dynamics and regulatory requirements have driven increased uncertainties in this strategy. It is in this context that SVP contracted Energy and Environmental Economics (E3) to support their 2023 IRP development as an important platform to carefully analyze the changing planning environment and develop plans to reach their near- and long-term goals. E3 worked closely with SVP to update their load forecast for the 2024 – 2035 planning horizon, craft plausible planning scenarios, and update generation resource options. The IRP details three potential resource portfolios developed using least-cost optimization, all of which meet or exceed the California's emission and reliability requirements. The base portfolio meets the California Air Resources Board's base targets for Silicon Valley Power and Senate Bill 100 target of 60% renewable energy in 2030, with mature renewable technologies (those commercially available today). A second portfolio accelerates Senate Bill 100 renewable energy and zero-carbon generation targets for 2045 to 2035, requires a minimum of 70% carbon-free energy (60% renewable) in 2030. The third portfolio achieves a zero-carbon emissions portfolio across all hours of the year and explores the use of emerging technologies (such as biogas, hydrogen, and natural gas with carbon capture and storage).

California Public Utilities Commission Integrated Resource Plan (2016 - ongoing). E3 has been assisting the California PUC in its administration of the state's IRP program, mandated by the passage of SB 350 in 2016. E3 worked with CPUC staff to develop the structure of the IRP program including a three-year modeling cycle in which Staff prepares a system-wide plan that informs the California Independent System Operator (CAISO)'s annual Transmission Planning Process (TPP) and informs Load-Serving Entities integrated resource plans in alternate years. E3 helped the CPUC design an optimal "Preferred System Plan" for the combined utilities that incorporates the resource procurement plans of the LSEs and complies with policy requirements. The policy requirements considered include a 60% RPS by 2030 and SB 100 by 2045, 38 million metric tons (MMT) of greenhouse gas emissions by 2030 statewide emissions target, a reliability order requiring the procurement of up to 11.5 GW of capacity by 2026, while capturing the operational and reliability challenges encountered at high penetrations of variable renewable generation. As part of this

process, E3 evaluated dozens of scenarios reflecting alternative assumptions about load forecasts and electrification, resource costs, the availability of offshore wind and out-of-state wind, the ability of end-use loads to operate flexibly, and a variety of other input parameters. The CPUC adopted the Preferred System Plan, which presents a long-term vision for the California electric system under current state policy, in February 2022.

Salt River Project, Integrated System Plan Development (2019-Present). E3 was retained by SRP to develop the company's first public facing Integrated System Plan (ISP). The objective of the ISP is to bring currently disparate planning processes across supply-side resource planning, transmission planning, distribution planning and customer programs into a single process with comprehensive stakeholder engagement to develop an optimized pathway to achieve SRP corporate objectives related to reliability, affordability, and sustainability. ISP is largely an uncharted frontier and an aspirational goal for utilities today as they begin to prepare for a decarbonized future with increasing levels of renewable supply, distributed resources and electrification of transportation and buildings. E3 has supported SRP in several areas. E3 has worked closely with an internal team at SRP to engage SRP's leadership team and planning functions through a series of interviews and workshops to develop an ISP roadmap, analytical framework, and stakeholder engagement approach. E3 has supported several components of the analysis, including performing a detailed review of SRP's modeling approach, performing long-term capacity expansion modeling in PLEXOS, and developing a financial model to project total system costs.

SMUD 2030 Zero Carbon Plan, 2020-2021. E3 worked with SMUD to study electric sector pathways to carbon neutrality by 2030, as required by SMUD's Climate Emergency Resolution. The results of the study were synthesized in a public-facing report and presented to SMUD's Board in March 2021. The study detailed key aspects of the 2030 target including: how carbon neutrality should be defined, which accounting methodology should be used to set the targets, whether existing or proven cleantech can accomplish the 2030 goal within reasonable costs and resource build rates, how emerging technologies like DERs, long-duration storage, and hydrogen can and aide in reaching the goal or reducing costs, and most importantly, how to achieve SMUD's goals while maintaining strict reliability. E3 found that as the strictness of the 2030 target definition was increased to achieve absolute zero emissions on an hourly accounting basis, maintaining reliability became challenging and resulted in relatively high costs. Emerging technologies, at the cost trajectories modeled, could substantially mitigate those cost increases, especially in the long-term.

Public Service Company of New Mexico (PNM) 2020 Integrated Resource Plan Support, 2019-2021. Prior to developing its 2020 IRP, PNM had established a corporate goal to achieve a carbon-free electricity portfolio by 2040. E3 provided technical and strategic support to PNM's planning team to create a plan that fulfills that commitment. E3's primary role in the IRP process was as lead author of the IRP document – including the writing of the IRP narrative, creation of supporting figures and graphics, and compilation of detailed technical appendices. Throughout the process, E3 also provided guidance to PNM during scenario development, reviewed and validated inputs and outputs from the Encompass and SERVM models, and supported stakeholder outreach efforts. PNM's 2020 IRP, released to the public in January 2021, provides one of the first roadmaps for a utility to achieve a transition to a carbon-free generation portfolio, along with a detailed action plan set against the context of that transition.

California Energy Commission (CEC) lead Joint Agency SB100 Analysis 2019-2020. E3 performed a RESOLVE analysis to determine the least-cost portfolio of resources required to meet different definitions of SB100. This work is intended to support the first SB100 Joint Agency Report which is required by law and will be released January 2021. The 2019 IRP RESOLVE model was scaled-up to reflect a statewide representation and three different interpretations of California's policy future were modeled. Additionally, over thirty sensitivities were performed to study various aspects of the potential portfolio including varying costs and resource eligibility. Load data was leveraged from PATHWAYS scenarios which represented an IEPR-informed reference case, high electrification, high hydrogen, and high biofuels for the economy outside of the electric sector.

Xcel Energy Upper Midwest Integrated Resource Plan Support (2019). As part of its 2019 Integrated Resource Plan, Xcel Energy retained E3 to conduct two independent analyses to support its IRP: (1) an economy-wide study for the state of Minnesota examining what would be needed to meet deep decarbonization goals throughout the economy (e.g. 80% reductions by 2050); and (2) a portfolio optimization and reliability analysis for Xcel's portfolio to examine the costs of meeting the utility's carbon reduction goals (80% reductions by 2030; 100% carbon-free by 2050). E3's statewide pathways study provided Xcel with a novel perspective on future electricity loads in the context of an economy-wide carbon reduction effort, showing how decarbonization measures such as building and transportation electrification could lead to significant long-term increases in load. These findings were used to inform a sensitivity analysis conducted within Xcel's internal IRP modeling. E3's portfolio and reliability analyses were conducted in parallel with Xcel's internal work to develop a forward-looking resource plan, testing the notion that an independent expert using advanced industry-standard methods would come to similar conclusions. E3 used RECAP for sophisticated loss-of-load-probability analysis and RESOLVE for optimal capacity expansion to design reliable, least-cost portfolios to meet carbon reduction goals, ultimately corroborating the findings in Xcel's plan.

Nova Scotia Power Incorporated (NSPI) Integrated Resource Plan (2018-2021). NSPI retained E3 to assist in developing its Integrated Resource Plan, which considered alternative resource options to meet provincial and federal greenhouse gas goals while maintaining reliable and affordable electricity service. E3's support included: (1) Developing a Resource Options study to characterize the cost, performance and resource potential for a variety of resource options available to Nova Scotia Power including solar, wind, hydro, thermal, and energy storage resources; (2) Preparing a Planning Reserve Margin (PRM) study to identify the capacity needed for NSP to meet long-run electric reliability requirements as well as the Effective Load-Carrying Capability (ELCC) of each candidate resource, using E3's RECAP model; (3) Developing a Portfolio study that identifies optimal portfolios of demand-side and supply-side resources, including remote resources paired with new high-voltage transmission lines, to meet year-by-year GHG targets while meeting the PRM requirement, using E3's RESOLVE model in conjunction with NSP's PLEXOS LT; and (4) stakeholder and regulatory support throughout the process including in-person presentations to stakeholder workshops and expert witness in front of the Nova Scotia Utility and Review Board as needed.

Calpine Corporation, Electric Reliability Under Deep Decarbonization in New England (2020). The Calpine Corporation engaged E3 to study electricity sector resource adequacy requirements under long-term economy-wide decarbonization in the New England states (MA, CT, RI, NH, VT, ME).

E3 completed this work in conjunction with Ernest Moniz's Energy Futures Initiative (EFI) and a regional stakeholder advisory group. Using our economy-wide decarbonization scenario model (PATHWAYS), E3 studied economy-wide decarbonization up to net zero carbon which resulted in a significant quantity of building, vehicle, and industrial electrification as well as 95% direct emission reductions in the electricity sector. Using our in-house electricity capacity expansion model (RESOLVE) and reliability model (RECAP), E3 determined that achieving electricity sector decarbonization while meeting additional load growth from electrification requires a significant build-out of solar, wind (onshore and offshore), battery storage, and additional firm generating capacity to maintain acceptable reliability during periods of low wind and solar generation.

Pacific Northwest Low Carbon Scenarios Study (2017). On behalf of the Public Generating Pool (PGP), a group of hydro-owning public power entities in Washington and Oregon, E3 examined the effectiveness of a range of policy mechanisms to decarbonize the electric sector. Using its RESOLVE model, E3 evaluated the cost and emissions impacts of a variety of policy mechanisms, including: (1) regional carbon cap & trade; (2) regional carbon tax; (3) increased regional Renewables Portfolio Standard; and (4) a prohibition of new gas generation. The study results indicate that decarbonizing the electric sector in the Northwest can be achieved at relatively low cost with a policy that focuses directly on carbon reductions, whereas policies with an indirect focus on emissions reductions such as a higher Renewables Portfolio Standard generally achieve less reduction, result in higher costs to ratepayers, and can introduce distortions into electricity markets with unintended consequences. The study results and key findings have been broadly shared with key stakeholders and government officials in the electricity sector, including investor-owned utilities, public power agencies, and environmental groups.

Distributed Energy Resource Valuation & Adoptions

Glendale Water and Power Solar and DER Strategy (2024). Glendale Water and Power (GWP) selected the team lead by E3, including Willdan Energy Services and Dakota Communications, to develop strategies for an equitable and cost-effective distributed solar and DER program that maximizes customer adoption and peak load reductions. The Glendale City Council adopted resolutions setting forth goals of achieving 10% customer adoption of solar and DER by 2027 with a 100 MW load reduction. E3 and Willdan are evaluating the feasibility of achieving these goals and making specific program and incentive recommendations to maximize cost-effective customer adoption and peak load reductions given the mix of building and customer types in the city. E3 will also perform a cost-benefit analysis showing how distributed solar and DER compare to supply side alternatives in GWP's IRP for providing clean energy and reliable peak capacity for the city. Dakota Communications is leading a community engagement effort including text messaging, mailers and a combination of five in-person and remote community meetings that kicked off in February 2024.

SMUD Value of Solar and Solar+Storage Study (2020). Sacramento Municipal Utility District (SMUD) selected E3 in 2020 to prepare a study of the value of customer solar and solar plus storage facilities in scenarios that are consistent with SMUD's long-term carbon goals. E3 subsequently worked with SMUD to quantify the impacts of a variety of rate design options on the economics of customer solar adoption

as well as their ability to ameliorate the cost shifting associated with SMUD's current Net Energy Metering program.

Sacramento Municipal Utility District (SMUD) Virtual Power Plant Cost Effectiveness & Resource Planning (2020-2021). E3 worked with SMUD to understand the adoption potential of DERs and use cases, including electric vehicles (V1G and V2G), behind-the-meter solar and storage, and building demand response from water heaters and AC. We then used these adoption rates, SMUD's specific avoided costs, and SMUD's bulk grid resource plan to: 1) determine the cost effectiveness of different DER configurations from multiple perspectives (utility and customer) specific to SMUD's territory (using E3 developed avoided cost streams) 2) model the 8760-hr economic operation of different VPP configurations and 3) determine the grid benefits of those different VPP configurations within the context of SMUD's 2030 Zero Carbon Plan.

Portland General Electric (PGE), DER Cost-Effectiveness Framework (2022). E3 is supporting PGE to advance cost-benefit analysis for DERs, improve valuation of DERs, and support key strategic decision making at the company regarding impacts on rates, competitiveness, and electrification policy. E3 will help PGE align DER cost-benefit evaluation with Integrated Resource Planning, expand and improve the range of grid, host and societal benefits considered, balance environmental justice objectives with goals for energy affordability and competitive rates and to advance electrification policy.

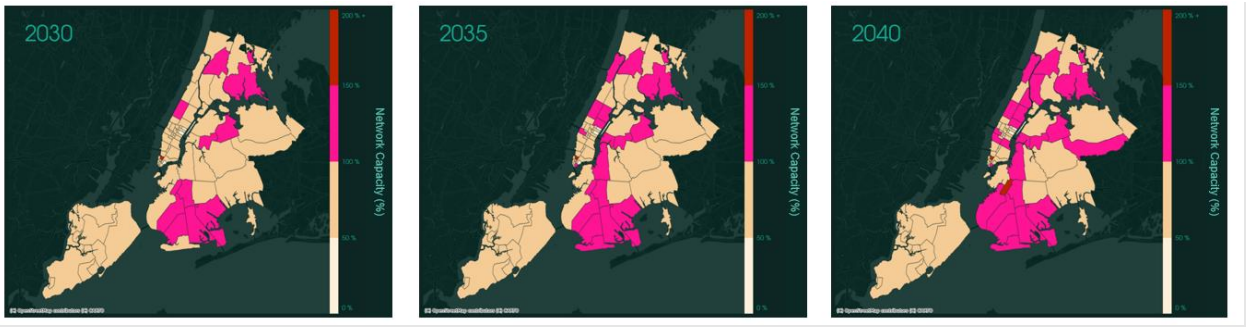
NV Energy Advanced DER and Load Forecasting (2023 - Present). E3, Integral Analytics (IA), and Tierra are combining forces to implement advanced distributed energy resource (DER) and load forecasting for NV Energy (NVE) as it plans to achieve to achieve corporate and state climate goals, including economy-wide net zero emissions by 2050. The work will leverage energy system models to evaluate emissions reduction opportunities and identify optimal technology pathways for decarbonization. A key output will be actionable scenarios that outline the technology investments needed in the power sector, buildings, industry and transportation needed to achieve both state and corporate climate goals.

E3 developed multiple long-term decarbonization scenarios as well as a DER market potential study to support NV Energy's 2024 Integrated Resource Plan. E3 quantified technical, economic and achievable adoption for several categories of DER, including energy efficiency, distributed PV, vehicle electrification and building electrification. Using the Forecasting Anywhere tool developed by E3 and IA, E3 performed high resolution geospatial forecasting of DER adoption and load shapes to evaluate local impacts across NV Energy's service territory. E3 and IA will also deploy IA's LoadSEER distribution planning tool and the DSMore DER Cost-benefit Analysis tool for NV Energy. Together these tools will support distribution planning that incorporates DER, optimizes infrastructure investments, and increases overall distribution system utilization while maintaining reliability. The end result will be internally consistent generation, transmission and distribution plans that fully account for the utility's net zero strategy, ensure grid reliability and maximize value for customers.

New York City PowerUp NYC Grid Readiness Research (2022 - Present). E3 is working for New York City to support implementation of the city's Long Term Energy Plan. One of several workstreams includes grid readiness research required by Local Law 154 to evaluate the reliability and resiliency of the city's grid under electrification scenarios. E3 is evaluating the combined

electric loads of building and transportation scenarios and their impact on the distribution system. This includes evaluating the impact of building and transportation electrification on peak demand at the Con Edison network level and identifying the extent to which electrification will exceed available capacity at the network level. E3 is using advanced geospatial tools and machine learning map adoption of both transportation and building electrification with the necessary granularity to calculate peak load impacts over time at the Con Edison network level. E3 will provide actionable recommendations for how to best prepare the City's grid for electrification and support grid reliability and resiliency in NYC's Disadvantaged Communities (DACs) and Environmental Justice (EJ) Areas.

Analysis of Distribution Network Capacity With Transportation and Building Electrification in New York City



Results: Grid Readiness – Research and Findings Memo: https://climate.cityofnewyork.us/wp-content/uploads/2023/09/PowerUp_ResearchandFindings-Memo_Grid-Readiness.pdf

Nashville Electric Service (NES) EV Forecast and Distribution Grid Impacts Analysis (2024). E3 is employing the Forecasting Anywhere tool jointly developed with Integral Analytics (IA) to complete a thorough analysis of the distributional impacts of electric vehicle charging in the NES service territory. E3 will develop economywide annual and hourly outputs for Tennessee and NES on energy demand, GHG emissions, fuel usage, and number of devices adopted for sectors and subsectors of the economy. E3 will use this analysis to give NES a better understanding of where infrastructure is needed in the short and the long-term to support vehicle electrification on the NES system. Sensitivities will be designed to understand the impacts of load management and flexibility on the grid as well as the impacts of different scenarios and interventions on low-income and disadvantaged communities. The study is focused on vehicle electrification, but will also include building electrification within the analysis to appropriately capture the additional load associated with this market transformation. E3 is providing geospatially granular forecasts that can be directly incorporated in the IA LoadSEER software tool that NES uses for distribution planning.

Wilcox CEC Zero Net Energy. E3 calculated the cost-effectiveness of several technologies related to ZNE residential homes in 2020 including solar PV, smart thermostats, flexible heat pump water heaters, and battery storage. E3 found that solar PV under a variety of potential future NEM policy scenarios was cost-effective, even without federal subsidy support. Using this information, E3 created a new measure

proposal that was the basis for the CEC inclusion of a prescriptive solar requirement in the 2019 building standards for new residential homes.

City of Culver City, Microgrid Feasibility Analysis. Willdan developed a feasibility analysis combining two Red Cross emergency sites into a single, sustainable microgrid arrangement. The microgrid solution included enough energy efficiency, solar PV, battery storage and microgrid controllers to supply continuous power to emergency sites for temporary community disaster recovery shelter needs. Willdan also conducted a feasibility study of converting Culver City's transit fleet from renewable natural gas buses to a zero emissions fleet by 2028, in line with the City's sustainability plan. Analysis included assessment of zero emission bus options, infrastructure and EV charging needs, as well as necessary facility improvements to support fleet electrification needs.

Confidential California School District, Microgrid Design and Implementation. Willdan helped configure existing systems at a High School gymnasium into a fully islanding microgrid that uses clean energy and can safely disconnect and operate independently during situations such as wildfires or public safety power shutoff event. Willdan managed the system design and project management, coordinating subcontractors through construction, controls integration, commissioning, testing, and district training. The designed microgrid generates enough power to run critical life safety systems for Red Cross (lighting, HVAC, sprinkler systems) for days to weeks at a time. Willdan also provided District preparation for the system including clear signage, islanding/grid reconnection procedures, and annual drills for emergency events.

Emerging Technologies

Massachusetts Clean Energy Center, Energy Storage Market Update and Long Duration Storage Study (2023). E3 conducted a project for the State of Massachusetts to assess the current deployment of short-duration storage and to evaluate the future role of long-duration storage in providing effective capacity to the region. The study included several modeling and stakeholder engagement elements. Leveraging E3's pro forma financial model of storage technology costs and a custom-built storage dispatch model, the project team analyzed several storage use cases to help the state understand impacts of current incentive programs and what reforms to them would be most effective for developers, ratepayers, and the state. Assessment of future storage value involved loss-of-load probability modeling of the entire ISO-NE footprint to predict the reliability value of long-duration storage to the system and how this value will depend on the rest of the generation portfolio, particularly the quantity of offshore wind. The study also contained robust stakeholder engagement, including interviews with more than 50 key stakeholders and two public stakeholder workshops. In addition to writing a report providing study findings, the team worked with Massachusetts Clean Energy Center and Department of Energy Resources to translate findings into policy recommendations put forth by the client in an accompanying report. The final study deliverables included a written report, an Excel-based storage use case cost/benefit model, and Excel-files that document key modeling inputs and outputs.

California Public Utilities Commission, Zero Carbon Technology Assessment (2022). E3 prepared a report that explores zero-carbon firm capacity generation technologies that could support California's efforts to decarbonize its electricity grid but have not yet reached full commercialization. The report characterizes emerging zero-carbon firm capacity technology options

(long-duration ion air batteries, adiabatic compressed air energy storage, carbon capture and sequestration, enhanced geothermal, small modular light water nuclear reactors, etc.) for the purpose of informing capacity expansion modeling to support long-term resource planning. The report finds that while almost all technologies surveyed show promise as zero-carbon firm capacity and all exhibit high technical potentials on total resource deployment, most require significant levels of research and development to reach maturity and significant legal and operational hurdles to deployment.

California Energy Commission, EPC-19-056, Assessing the Value of Long Duration Storage (2020-present). E3 was awarded an EPIC grant by the California Energy Commission (CEC) to investigate the role of long duration energy storage in achieving California's energy and climate goals. This study (1) developed a clearer understanding of the tradeoffs between energy storage duration, performance, and cost against a range of other emerging energy technologies (including but not limited to carbon capture & storage, low-carbon fuels, and advanced nuclear); (2) developed an updated, publicly available dataset to characterize potential futures for California's grid; and (3) developed a new modeling toolkit to extend California's capabilities to plan for a deeply decarbonization electricity sector that appropriately values emerging technologies like long duration storage.

ACES, a joint development project between Mitsubishi Hitachi Power Systems Americas, Inc. and Magnum Development, LLC; Hydrogen Opportunities in a Low-Carbon Future: An Assessment of Long-term Market Potential for Hydrogen in the Western United States (2019-2020). ACES, a joint development project between Mitsubishi Hitachi Power Systems Americas, Inc. and Magnum Development, LLC enlisted E3 to evaluate the potential for zero-carbon hydrogen in a low-carbon future in the Western U.S. This study performed a broad assessment of the market for renewable hydrogen, focusing on the Western Interconnect through 2045. As a first task, E3 evaluated the existing and potential future hydrogen production pathways in the West. Informed by the hydrogen production cost estimates, E3 developed a market outlook for hydrogen across four key sectors: power, transportation, buildings and industry. This work included a deep dive assessment into the potential for hydrogen as long-duration power storage in the West. Finally, the study evaluated the current and potential future hydrogen supply chain. E3 found that hydrogen could decarbonize certain applications in critical sectors, particularly heavy-duty ground transportation, however, E3 found that the most promising opportunity for carbon-neutral hydrogen is as long-duration energy storage for the electricity sector. More details of this study can be found in the full report.

2025 California Advanced Demand Response Potential Study (2017). E3 teamed with the Lawrence Berkeley National Laboratory and Nexant to study the potential for Advanced Demand Response resources to contribute to meeting California's energy policy goals through renewable integration and provision of zero-carbon peaking capability. E3 used the RESOLVE model to quantify the grid value of four types of Advanced DR: "Shed", "Shape", "Shift" and "Shimmy". Based on supply curves for DR developed by LNBL and demand curves developed by E3 using RESOLVE, E3 determined the market size and market clearing prices for each service in 2017, 2020, 2025 and 2030 under different planning scenarios. Shift DR, a flexible load service, is projected to clear the market at 10 to 20 GWh of load shifted per day (with an annual value of ~$200 million) in 2025; Shimmy DR –

fast-response Regulation and Load Following services – showed a market-clearing quantity of 100 to 500 MW ($5-7 million) and 100 to 1,000 MW ($9-16 million), respectively. E3's analysis provides critical insight about the value proposition of ADR services in meeting the planning and grid integration challenges before the California electricity grid.