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Gigawatt-Scale Customer-Sited Potential

Achieving California Energy Policy Goals, Grid Reliability and Local Resilience

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California has chosen the groundbreaking path of achieving 100% clean energy by 2045,[1] driving transformation in how the grid will be powered and managed. Simultaneously, California must tackle the challenge of adapting the grid for a changing climate, fire risk and increasing need for resilience. Even as a transformation unfolds, the grid must remain stable and reliable. To achieve this will require innovation that draws on all of the solutions that the state can bring to bear.

Station A, a software company whose platform allows users to explore the feasibility of customer-sited clean energy on a building-by-building basis,[2] has worked with **Sunrun** and **Stem**, as market leaders in the deployment of distributed energy resources in California, to quantify the potential for customer-sited solar and battery storage to provide grid reliability capacity in key geographies across the state. This includes areas where local grid reliability has been or may become a concern in relation to the retirement of existing generation resources. By quantifying the aggregate potential, our goal is to bring focus to the enormous resource that California has across cities, suburbs and even rural areas to bolster grid reliability while driving clean energy uptake and increasing grid resilience.

This analysis identifies techno-economic potential for 48 gigawatts of rooftop solar and 42 gigawatt-hours of battery storage which together would provide approximately **9 gigawatts** of Resource Adequacy (RA) across the Investor-Owned Utility (IOU) service territories. Key geographies have Local RA potential of hundreds to thousands of megawatts. This potential was evaluated without grid reliability revenue; the addition of this revenue could increase scale potential even further.

1. California State Legislature. *"SB100 California Renewables Portfolio Standard Program: Emissions of Greenhouse Gases". https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.* September 2018
2. The Station A platform is accessible at *https://app.stationa.com*

As the CPUC, CAISO, and utilities identify approaches to maintain reliability while increasing resilience and clean energy, and the CEC identifies paths to achieve California's energy policy goals, customer-sited solar and battery storage resource potential can be a key pillar and should be at the forefront for consideration. The results of our analysis show that the scale of customer-sited potential is far greater, relative to the scale of local reliability needs, than has been observed in recent relevant procurements. The scale of resource potential should inform existing and future procurement and sourcing approaches from IOUs and CCAs that will more successfully drive the maximum deployment of customer-sited solar and battery storage to be cost-effectively drawn on for local and flexible capacity needs.

Specifically, current RA frameworks undervalue the capability of behind the meter resources to deliver cost-effective capacity, especially at the local level. Our analysis illustrates that fully 2.5 GW of aggregate RA potential would be "stranded," even after being developed, based on current rules limiting batteries participating as Proxy Demand Resources (PDR).

Customer-Sited Resources are Inherently Well-Suited for Local Reliability and Resilience

Enabling a transition to a cleaner energy mix includes ensuring reliability in local and sub-local areas, meaning clean resources must be found in every local area or there is a risk that reliability-based revenue streams will run counter to California policy goals, if they have the effect of delaying the retirement of thermal generation. Load is driven by businesses and homes, which are also the sites for customer-sited solutions. This means that, as our analysis shows, there is substantial potential for customer-sited solutions in every local area that makes major demands on the grid.

Importantly, customer-sited solar and battery storage not only supports local reliability, it is inherently aligned with increasing resilience. The more resources that exist within communities on a customer-sited basis - *especially solar-paired storage resources that can operate indefinitely regardless of grid availability* - the lower the impact or risk posed by de-energization, transmission contingencies, or other disruptions to the grid. Finally, resources that are sited on the distribution grid are inherently situated to provide distribution deferral value related to reliability.

Nature and Purpose of this Analysis

To inform the processes driving California's approach to reliability, resilience and clean energy, Station A, Sunrun and Stem have sought to highlight on a broad basis the clean energy grid reliability potential that exists in California's single-family home, and Commercial & Industrial (C&I) segments specifically. As leading developers of such resources, Sunrun and Stem operate competitively but see on a daily basis potential that may be opaque to observers outside of industry. Working with the aid of Station A's independent analysis, we have sought to illuminate this potential in a format that can inform all interested parties.

Our estimates for customer-sited solar and battery storage potential in local areas should be considered **techno-economic potential**, relating to the expected viability of solar and battery storage to create positive economics for customers based on factors such as building stock, energy usage expectations, and current costs for solar, storage and retail electricity in today's underlying tariff environment.

The potential for RA value from these resources is estimated based on the expected usage of this storage to deliver RA via PDR in CAISO, as described below, and takes into account seasonal variation due to variation in solar production. Estimates reflect the annual average of RA capacity across the year, with potential for higher values in summer when California's peak demand and thus maximum need for RA actually occurs.

It should be noted that this techno-economic potential does not factor in capacity revenue of any kind. This underscores two facts: first, that customer-sited resources will emerge independently of capacity revenue and second, that the cost to utilize these assets for grid reliability can be cost effective because customer value covers a portion of the cost of deployment. By adding potential revenue from services that enhance grid reliability, deployment can be accelerated, the overall market opportunity expanded, and these resources will be fully utilized for reliability value above and beyond their use for customer value.

Estimates represent the potential if all customers that are prime candidates for solar and battery storage today were to adopt this technology instantaneously. This analysis does not suggest the rate at which such adoption can be expected to occur. Rather, these numbers are intended to spur discussion of the approaches that will maximize the realization of this potential. Such approaches should include eliminating regulatory impediments to market potential that exist today and structuring procurement approaches to incorporate a resource type that is deployed in a modular form over years based on customer demand rather than in “lumpy” large-scale investments solely based on utility contracts.

If the potential exists and customer-sited resources have unique and inherent value towards multiple key policy goals while delivering grid reliability on a cost-effective basis, then approaches to local reliability should begin with this question. A criterion for procurement processes, as well as planning, tariffs and programmatic initiatives, should be their success against this potential. The objective should be speeding the achievement of California policy goals, including clean energy and resilience, in ways that bring the maximum benefits to all of California’s citizens.

Representing Customer-Sited Resources in Key Grid Modeling Efforts

Station A, Sunrun and Stem are forthright in acknowledging that this analysis is indicative as compared to the highly sophisticated models that inform California grid and resource planning. We challenge those determining the modeling approaches for such processes to improve on these numbers through approaches with greater economic sophistication that will yield greater detail, and then to consider how the load flexibility and reliability resources they create can interact with local reliability requirements in nuanced ways. Relevant processes include Integrated Resource Planning (IRP), the CAISO Transmission Planning Process (TPP), and potentially others including the Integrated Energy Policy Report (IEPR). The general methodologies we use can be translated to other datasets to enable such approaches.

It should be noted that this analysis reflects today's techno-economic viability. Given decreasing solar and battery storage costs, our estimates should be considered floors that will increase over time as more homes and businesses become prime candidates for adopting these technologies. This lends further importance to creating nuanced models that are integrated into California's planning processes and update over time to reflect increasing potential.

Using Customer-Sited Solar and Battery Storage for Local Resource Adequacy and Flexible Resource Adequacy

Customer-sited solar and battery storage are able to deliver grid reliability via existing mechanisms in CAISO to provide RA alongside traditional resources. The primary mechanism for this is participation as a PDR. In the context of PDR, solar and battery storage are joined by other load flexibility technologies, the potential for which should not be minimized. However, solar and battery storage are well suited to provide long-duration capacity that has particular salience for Local RA requirements that may extend beyond the requirements of System RA. In addition, solar and battery storage can provide Flexible RA, a growing need as renewable energy penetration creates variability in supply and new ramping requirements.

To focus attention on the specific value of customer-sited solar and battery storage, we have expressed potential in megawatts of RA from solar and battery storage organized as PDR. While Local RA requirements will vary in terms of duration and timing, we have used System RA as a generic starting point and proxy. In general, the amount of Local RA available for a given need should relate to System RA potential according to the ratio of the duration of Local RA need to the 4-hour duration of System RA. This is to say, 150 MW of System RA potential at 4-hour duration could be expected to translate to roughly 100 MW of Local RA potential of 6-hour duration. This could vary based on the time of day of this need in relation to solar production.

Key Issues and Considerations for Local Resource Adequacy
from Customer-Sited Solar and Battery Storage

Significant barriers still exist to fully realizing the value of solar and battery storage as PDR. Specifically, the RA that customer-sited storage can provide is limited to the coincident load on the associated customer meter in a given hour. While a customer-sited energy storage system may have additional capacity available at times of system or local need above the load on a given customer's meter, any injections back onto the grid are valued at zero and therefore would not be provided. To highlight the impact that this has on aggregate potential, which is dramatic, we identify two different sets of RA potential: one under current RA accounting, and one that allows the system to benefit from batteries discharging fully during hours of need. If this issue is not addressed, no matter how much of the techno-economic potential is realized, a material portion of the RA potential from customer-sited solar and battery storage will be unutilized.

Second, we necessarily worked from today's identified Local Areas and Sub-Local Areas and the mapping resources available publicly for the selected areas. As grid conditions evolve, Local Area definitions will change. This underscores further the need for the sophisticated modeling efforts that drive grid and resource planning to incorporate customer-sited resource potential from the bottom up, so that for any given geographic boundary an updated view of potential can be identified and incorporated at the very front end of conceptualization of options for addressing local needs.

Customer-Sited Solar and Battery Storage Capacity
in Select Local Areas and Sub-Local Areas

The results of Sunrun and Stem's analysis can be seen below, for a selection of Local and Sub-Local Areas. These have been chosen to represent a cross-section of geographies across California with widely varying building stock and climate characteristics, demonstrating that customer-sited solar and battery storage can serve as a key resource across the entirety of California's grid. For reference, we identify the aggregate solar techno-economic potential identified across the CA IOU's as being 47.8 GW.

Notably, researchers at NREL have estimated purely technical rooftop solar potential in California at 128.9 GW[3]. Against this total potential, the techno-economic potential for the residential and C&I segments in the IOU territories is broadly reasonable. Our approach for determining solar techno-economic viability and then building on this to identify storage sizing and RA potential is described in the Methodology section.

Local Resource Adequacy Potential: Selected Local & Sub-Local Areas

Local Area	**Solar Potential** MWdc	**Energy Storage Potential** MWh	**Resource Adequacy Potential** MW @ 4 hour duration, limited by load	**Resource Adequacy Potential** MW @ 4 hour duration, full ESS utilization
LA Basin	14,391	12,886	2,149	2,723
San Diego	4,455	5,570	928	1,194
Greater Bay Area	10,476	8,169	1,294	1,855
San Jose / Moss Landing Sub-Local Area	3,607	2,176	338	498
Pittsburg Sub-Local Area	1,343	1,132	175	261
Oakland Sub-Local Area	348	336	56	67
Greater Fresno	1,687	1,384	241	333
Stockton	1,694	1,357	224	300
Kern	977	754	129	168

3. Pieter Gagnon, Robert Margolis, Jennifer Melius, Caleb Phillips, Ryan Elmore. *"Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment".* National Renewable Energy Laboratory. January 2016

Because the boundaries of local areas change over time, we include for reference the overall resource potential we find in each of the IOUs, indicating the full scale of additional potential that exists should new local reliability needs be identified. A comprehensive modeling approach used for grid planning would incorporate underlying potential across all IOU territory to be used in analysis of evolving local reliability needs.

Customer-Sited Potential by Utility Service Territory[4]

Utility Service Territory	**Solar Potential** MWdc	**Energy Storage Potential** MWh	**Resource Adequacy Potential** MW @ 4 hour duration, limited by load	**Resource Adequacy Potential** MW @ 4 hour duration, full ESS utilization
IOU Territories	47,781	42,392	6,730	9,245
PG&E	23,347	19,039	2,870	4,086
SDG&E	4,455	5,570	928	1,194
SCE	19,979	17,782	2,931	3,965

4. The San Diego Local Area coincides with SDG&E Service Territory and is reflected in both tables

Conclusion

Gigawatt Potential to Support Policy and Grid Planning Goals

Customer-sited solar and battery storage across residential and C&I segments can provide upwards of **9,200 MW** of RA across California, including **2,515 MW** that are enabled by improvements to the CAISO PDR structure to enable RA value for the full capacity of customer-sited batteries. This includes hundreds of megawatts in areas where recent procurements have or are expected to focus on front-of-meter solutions with more limited resilience and customer benefits and that do not necessarily increase the clean energy mix on California's grid.

The mix of resources that will provide reliability on California's grid is too important to ignore a key potential clean resource that can be found at scale in every part of the state. This is especially the case when the status quo trajectory suggests that, even as solar and battery storage deployments grow day-by-day through autonomous customer adoption, only a fraction of this potential will be utilized as local reliability through LSE procurement.

Customer-sited resource potential should be evaluated on its ability to serve **identified grid needs** and should not be discounted in the ability to fully serve local reliability because these resources take a different form than traditional resources.

Customer-sited resources and resulting load flexibility must be fully reflected in grid reliability modeling in order to accurately identify the best path towards a clean, reliable grid for California. Equally importantly, procurement approaches must continually be evaluated on their success in sourcing from the broadest pool of resources to deliver grid reliability in a manner that most cost-effectively supports California's broader policy goals.

If these steps are taken, the continued growth of customer-sited resources will be properly valued and prioritized, and the role that they can play to support an energy transformation will be more fully realized.

Methodology

To identify techno-economic potential for customer-sited solar and storage, we sought to identify from building stock databases the sites likely to have energy usage and related characteristics enabling customers to realize savings on their energy costs relative to retail electricity rates given current tariffs and current solar and storage costs.

The potential for C&I solar and storage was based on a bottom-up analysis of individual buildings in the Station A platform, and the potential for residential solar and storage was evaluated based on a methodology informed by Station A and applied to a residential building stock and demographic datasets provided by Sunrun.

Given trends towards lower solar and storage costs, it can be assumed that techno-economic potential will increase. In the future, a greater number of the sites that can physically accommodate solar and storage will also see an economic benefit from adopting them.

Identifying the Building Stock

We started by identifying building stock with the physical characteristics to support solar and storage.

For the C&I segment, we built our analysis on Station A's geospatial dataset, which includes all buildings with a footprint over 10,000 ft^2 in California, as well as all land parcels in the state.

For the residential segment, we identified building stock potential based on home size by square footage, which was used to estimate energy usage. A minimum square footage threshold was used as a cutoff, below which it was estimated that attractive year one savings from solar and/or solar paired with storage could not generally be achieved. This is based on comparing the levelized cost of solar and storage to the utility retail rates, accounting for minimum bill charges.

Computing Solar Potential per Building

Based on the selected building stock, we applied further restrictions based on the amount of solar that could be installed as well as the potential that physical characteristics would prevent successful solar installation.

At each C&I site, we estimated the maximum technical potential for rooftop solar using industry-standard metrics for perimeter setbacks, roof coverage, and PV energy density. We disallowed solar on sites over 6 stories. We applied a limit to the solar potential based on net energy metering rules, disallowing system sizes that would generate more than 100% of the building's estimated energy usage in a typical year.

We then applied an economic filter. First, we estimated a Power Purchase Agreement (PPA) price for the system based on its estimated cost to build, accounting for policy incentives including the Investment Tax Credit (ITC), its expected annual production, and a rate of return required by the project developer. We then used the building's likely tariff and estimated energy usage to calculate the avoided cost of energy for the building. We only included sites at which the avoided cost of energy was greater than the estimated PPA price for the solar array.

For the residential segment, economic viability of roofs for solar depends on factors such as:
a. angling of roof planes for sufficient insolation, primarily based on azimuth
b. roof materials and quality
c. shading from trees or other structures

Estimates for the percentage of homes of sufficient square footage that meet these criteria of roof suitability were derived for each local area from data in Sunrun's prior evaluation of tens of thousands of homes across California for solar. Sizing for solar was based on observed average solar installations in California of approximately 6.5 kW per home.

Computing Energy Storage Potential per Building

We evaluated energy storage based on the expected electricity bill savings it could provide to customers. This ignores the resilience value of energy storage, which may lead customers to adopt energy storage even when it is not economically optimal or to adopt larger energy storage systems than are justified on a pure cost basis. Our energy storage sizing is therefore conservative, especially in the residential segment. Differences in sizing between residential and C&I segments results from the differing tariff structures (Time of Use versus Demand Charges) under which each segment generally receives electricity service.

To calculate energy storage potential in the C&I segment, we assumed that Energy Storage Systems (ESS) could be installed indoors or outdoors. We calculated the technical potential for energy storage indoors and outdoors using industry-standard metrics for ESS energy density, minimum and maximum size limitations, and property line and building setbacks. At each site, we chose either indoor or outdoor installation for energy storage based on potential system size and cost to build.

From the maximum technical potential, we limited the ESS power capacity to 100% of the customer's peak load when paired with solar, and 50% of the customer's peak load when not paired with solar. We assumed all ESS to have a 2:1 ratio of MWh to MW.

We filtered potential ESS sites based on economic criteria. We determined the likely tariff at each building and used it to estimate the electricity bill savings provided by an ESS, modeling savings due to reduced demand charges and due to "energy arbitrage," the process of shifting energy consumption from more expensive time of use periods to cheaper ones. We calculated system cost to build based on system size and whether it was located indoors or outdoors, accounting for policy incentives including the Self-Generation Incentive Program (SGIP). We filtered out systems that didn't provided sufficient bill savings to meet an ESS developer's required internal rate of return.

Every C&I property was modeled with stand-alone solar, stand-alone storage, and solar paired with storage, and we selected the product combination with the highest savings for the customer. Where solar and storage were sited together, we modeled cost savings from both the ITC and SGIP.

For the residential segment, storage capacity was modeled based on an assumed single ESS size for each home set at 8.8 kWh usable ESS capacity, in line with existing product availability for the residential market. The added levelized cost of an ESS was incorporated into estimates of customer savings, which is diminished in certain cases and leads to storage attachment of less than 100%.

The vast majority of solar systems sized to annual energy usage in California, averaging approximately 6.5 kW, can utilize an ESS of larger size and can be expected to do so in the future. Customers adopting batteries for resilience value might also choose to adopt large batteries. This would have the effect of increasing the RA potential, potentially dramatically so under rules enabling the full capacity of the battery to provide RA value.

Computing Resource Adequacy Potential

RA potential was estimated by modeling a 4-hour discharge of the ESS during CAISO's current Must Offer Obligation period. Local RA will vary, but this measure is used as a starting point.

For the C&I segment, RA capacity was de-rated relative to a 4-hour discharge from installed ESS capacity to account for the expected state-of-charge of the ESS given multiple operating parameters, including demand charge mitigation, energy arbitrage, and solar charging constraints.

For the residential segment, RA potential was estimated by modeling daily discharging of the ESS for 4 hour duration during CAISO's current Must Offer Obligation period, and subsequent recharging of the ESS on the subsequent day via solar. 100% of ESS charging is assumed to come from the paired solar system. Solar insolation was modeled for each hour of the year based on TMY3 data, varying by region of California. The result is a seasonal variation in RA per unit per month that is lowest in winter and highest in summer. The estimate shared reflects the average of all months of the year, underestimating the RA available during California's annual peak in summer. For estimates of RA based on current PDR rules that limit utilization of storage for RA purposes to coincident hourly load, household load was estimated based on climate zone and the approximate portion of a given Local Area or Sub-Local Area falling into each climate zone.

About the Authors

Station A

Station A is a software company offering a platform that provides the insights needed to take any building to zero carbon emissions. The platform connects clean energy developers with building owners and enables them to plan and execute projects. Station A's mission is to enable a carbon-neutral future by scaling and automating the clean energy development process. Station A's customers include the country's leading clean energy developers and technology providers. Join the Station A platform today at ***www.stationa.com***.

Sunrun

Sunrun is the nation's largest residential solar, battery storage and energy services company. With a mission to create a planet run by the sun, Sunrun has led the industry since 2007 with its solar-as-a-service model, which provides clean energy to households with little to no upfront cost and at a saving compared to traditional electricity. Sunrun offers a home solar battery service, Sunrun Brightbox, that manages household solar energy, storage and utility power with smart inverter technology. For more information, please visit ***www.sunrun.com***.

Stem

Stem creates innovative technology services that transform the way energy is distributed and consumed. Athena™ by Stem is the first AI for energy storage and virtual power plants. It optimizes the timing of energy use and facilitates consumers' participation in energy markets, yielding economic and societal benefits while decarbonizing the grid. The company's mission is to build and operate the smartest and largest digitally-connected energy storage network for our customers. For more information, please visit ***www.stem.com***.