| DOCKETED | |
|---|---|
| **Docket Number:** | 19-SB-100 |
| **Project Title:** | SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future |
| **TN #:** | 230948 |
| **Document Title:** | Range Energy Storage System SB 100 Technical Workshop Comments |
| **Description:** | N/A |
| **Filer:** | System |
| **Organization:** | Range Energy Storage Systems |
| **Submitter Role:** | Public |
| **Submission Date:** | 12/2/2019 12:32:02 PM |
| **Docketed Date:** | 12/2/2019 |

*Comment Received From: Range Energy Storage Systems*
*Submitted On: 12/2/2019*
*Docket Number: 19-SB-100*

## Range Energy Storage System SB 100 Technical Workshop Comments

*Additional submitted attachment is included below.*

December 2, 2019

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RANGE ENERGY STORAGE SYSTEMS

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Docket # 19-SB-100

**RE: Technical Workshop on SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future**

Range is grateful for the leadership of the joint agencies in planning today to achieve SB 100 goals in 2045. We appreciate the opportunity to comment in this docket.

Range is developing a compressed air energy storage ("CAES") system for the Los Angeles Department of Water and Power ("LADWP") and other publicly owned utilities through a solicitation by the Southern California Public Power Authority ("SCPPA"). This 160 MW long-duration energy storage project will help LADWP transition off coal power from the Intermountain Power Project ("IPP") and integrate renewables through the Southern Transmission System. CAES will also help LADWP minimize the inefficient dispatch of the new combined cycle power plant planned for IPP by providing an alternative firm, flexible capacity resource. Hydrogen or natural gas supplements compressed air in the generation phase of a CAES system. Range's technology partner is developing options for utilizing hydrogen as a substitute to help California Load Serving Entities ("LSEs") meet their stated goals regarding the use of hydrogen in the power sector.

In these comments, Range discusses the importance of long-duration energy storage in the transition from conventional generation sources. These comments also provide information regarding the role of "green hydrogen" and hydrogen-fueled CAES in a zero-carbon electric system. In preparing the SB 100 report, the Commission should evaluate the need for a more holistic planning approach that accounts for a broader range of clean capacity resources than RESOLVE has been able to study to date. Pumped hydro storage is the only long-duration storage "candidate resource" currently studied in RESOLVE, even though CAES has a lower cost profile. As the State endeavors to build the next generation of clean capacity resources, and emphasizes the GHG accounting in resource planning proceedings, the state must ensure that it is planning for a broad list of clean capacity resources. CAES should be included as a candidate resource in any 2045 GHG modeling for the SB 100 report.

## Discussion

### I. The Joint Agencies should not confine the SB 100 vision and planning process to the limits of RESOLVE and recent IRP findings.

In conducting planning to achieve SB 100 targets, Range recommends that the Joint Agencies consider all required and desirable attributes of a 2045 electric system rather than focusing primarily on least-cost portfolio planning, as has been the focus in Integrated Resource Planning (IRP) to date.

RESOLVE, the capacity expansion model used in the IRP proceeding, selects least-cost resources from a limited set of candidate resources in the smallest increment needed to solve for a demand profile during certain representative days of the year, as well as a 2030 GHG target. While RESOLVE is a very robust model that accounts for some of the complexities in the electricity sector, (like all models) it is limited by the inputs and assumptions. RESOLVE does not account for certain supply-side resources outside the predefined list of "candidate resources." These limitations fall into three areas of the model:

- *Value of storage duration:* RESOLVE is unable to solve for resource optimization over periods longer than a day and will therefore miss the need to provide long-duration and multi-day storage during especially cloudy or low-solar events.
- *Candidate resource list:* The model only allows lithium-ion batteries, flow batteries, and pumped hydro storage to compete as candidate resources, thereby excluding existing and available technologies like CAES, which has its own unique cost and operating profile.
- *Baseline resources:* The value of bulk storage hinges on potentially flawed assumptions about other resources in the 2030 portfolio, including the ongoing retention of the thermal fleet, as well as assumptions about curtailment.

As a result, the reference system portfolios coming out of the IRP process have provided a limited view of what the 2030 resource mix could be. These limitations were evident in the 2017-18 IRP cycle, which only saw a need for 1,200 MW or more of bulk storage (pumped hydro storage in the model) under the most aggressive GHG target (30 MMT by 2030). It is important to note that the most recent release of the IRP RSP modeling data represents considerable refinements to both RESOLVE and the companion model, SERVM. The draft 2019-20 Reference System Plan calls for the addition of 11 GW of batteries by 2030, but still no bulk storage. The one bulk storage candidate resource, pumped hydro storage, was not selected in the 46 MMT "default" scenario. This begs the question, could fewer gas resources be retained if there were other resources available in the model that could provide local reliability and flexible capacity? Are we missing affordable options to invest in long-duration storage resources in the near-term by considering only pumped hydro storage? Both the RSP and the SB 100 modeling should be further improved to address these questions.

The Joint Agencies should acknowledge that the 2030 RESOLVE modeling is limited in its ability to solve for all portfolio attributes we desire – such as resource diversity, risk reduction, or energy security. The model may not address challenges of implementation too. For example, the 2019-2020 RSP calls for a quantity of lithium-ion batteries that is roughly 100 times the quantity of batteries currently installed in the California Independent System Operator ("CAISO") system. The CPUC acknowledges, "Such a large buildout of these resources is unprecedented at this magnitude, and the practical challenges associated with it in reality cannot be effectively estimated using only a model."[1] It is not clear if it will be possible to site this many batteries, and whether the lithium-ion supply chain will support this scale of development based on the cost projections used in RESOLVE. While lithium-ion will certainly be a key part of state's resource build out, the aforementioned questions underscore the need to diversify the list of clean firm capacity resources available in the system.

As a longer-term study, it is critical that the SB 100 modeling enables the state to plan for a diverse set of resources, thus minimizing the effect of risks in development, technology change, and other uncertainties inherent in a longer-term study. Planning for a future that is almost exclusively solar and lithium-ion batteries would fail to account for these uncertainties. The SB 100 planning process could establish a mechanism to develop pathways for procurement of large-scale, long-lead time resources. This planning should inform the IRP planning and provide an alternate data source that breaks the cycle of simply assuming smaller increments of solar and batteries will always be available and affordable when the need is closer. Without this longer-range planning input, the Commission and CPUC jurisdictional LSEs will end up repeatedly directing near-term incremental procurement, which excludes longer-lead time resources.

While IRP portfolios are certainly instructive, Range encourages the Joint Agencies to consider what is missing from IRP planning and how we can assess the potential for a broad set of resources to contribute to a resource portfolio which has all attributes we seek from a 2045 electric system. The Energy Commission's addition of "Resource Diversity and Flexibility" and "Innovation and Emerging Technologies" into its key considerations for SB 100 planning is a good first step in that direction. The Joint Agencies should ensure that the modeling conventions follow suit.

## II. Long-duration energy storage will be an essential component of the future clean energy portfolio.

Utility resource planners and the CAISO seem to inherently recognize that we will need longer-duration and bulk-scale energy storage resources at some point in the future as variable resources increase, flexible thermal resources are taken offline, and the scale and duration of the required time-shifting grows beyond tens of megawatts and four-hour increments.[2] However, state planning models have failed to adequately identify this need or provide clarity on how much bulk storage will be cost-effective, and when utilities should procure it.

[1] RSP Ruling p 21
[2] CEC bulk storage report.

Even still, there is some evidence of the need for bulk storage. The IRP studies to 2030 and CEC's Deep Decarbonization Study to 2045 have both identified that a huge increase in energy storage capacity will be needed in the future. The CEC's Deep Decarbonization Study saw a need for up to 84 GW of storage by 2050, and close to 4 GW of bulk storage to achieve RPS goals above 60%.[3] In addition, CPUC modeling has found that while in the near-term, four-hour duration energy storage is generally sufficient, under a longer-term high-electrification scenario, six and eight-hour duration batteries are selected after 2030.[4] Pumped Hydro Storage (PHS) also appears in the selected resource portfolio under a more stringent GHG scenario if battery costs are higher than expected and in the high-electrification 2045 scenario.[5] E3's study for Calpine showed that "cold, dark weeks" will be perhaps the biggest reliability constraint to the system in 2050, requiring a firm resource which can start up when needed and run for multiple days. It also demonstrated a need for long-duration storage in the absence of gas resources.[6] The California Energy Storage Alliance (CESA) pointed out in its presentation at the Technical Workshop that batteries are primarily relied upon for regulation service today, whereas in the future, energy storage will be called on for a significant quantity of energy arbitrage, a service which may be provided more affordably by bulk storage resources.[7]

Range recommends that the Joint Agencies incorporate bulk storage into the SB 100 planning process by 1) assessing the flexible resource services and operating characteristics required to manage a 2050 electric system with varying amounts of new renewable generation capacity online in 2050[8], and 2) studying bulk storage resources at the scale and location they have been proposed at by developers. There are no "generic" bulk storage resources, as different technologies have different scales, development timeframes, and geographic requirements. By focusing on how, where, and what kind of bulk storage resources California might acquire and how these would match system needs, rather than seeking to identify a precise "right" quantity which should show up at a specific point in time, the Joint Agencies will be much better equipped to assess the value of these resources in meeting long-term GHG targets.

## III. CAES provides a number of unique and valuable attributes and services that have not been considered in the past.

CAES is a mechanical form of energy storage in which electricity drives compressors that store air at high pressure in a storage vessel. When released, compressed air expands, combines with fuel to fire a turbine, and generates electricity.

[3] https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf
[4] CPUC, 2019-2020 Proposed Reference System Plan Presentation, November 6, 2019, slide 156
[5] CPUC, 2019-2020 Proposed Reference System Plan Presentation, November 6, 2019, RSP slides
[6] E3, "Long-Run Resource Adequacy under Deep Decarbonization Pathways for California" Presentation at Technical Workshop on SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future, November 18, 2019
[7] Alex Morris, California Energy Storage Alliance, Presentation at Technical Workshop on SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future, November 18, 2019
[8] https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

CAES can be configured to meet a variety of different portfolio needs. It can be co-located with solar and/or wind resources or used as a system resource. CAES can provide long-duration storage of regional wind and solar resources and maximize the utility of regional transmission assets.

SCPPA issued a competitive solicitation for a CAES facility at the site of the IPP in November 2017. In May 2019, Range was selected to proceed with negotiations for the project. Range will construct and operate a 160 MW CAES facility which will provide energy storage and flexible capacity at the terminus of the Southern Transmission System, which LADWP will use in part to import new renewables from the west.

CAES has a number of attributes that LADWP and other SCPPA members desire:

- Provides dispatchable/flexible load
- Performs long-duration time-shifting to supply evening load (typically with eight-hour per day dispatch cycles)
- Serves as a renewable integration multiplier: maximizes utilization of fixed transmission capacity
- Provides ancillary services typically supplied by conventional flexible resources, including: ramping, regulation, spinning and non-spinning reserves, load following, black start and resource adequacy capacity

If the SB 100 modeling includes diverse and flexible energy storage resources, it will account for key benefits of CAES. As noted above, RESOLVE only includes PHS as the bulk storage candidate resource. There are a few key differences between PHS and CAES, which would require substantially different input values, and which may result in different modeling results:

- **Size:** There are technological and geological/hydrological limits to the capacity at which a developer can build a bulk storage project. However, different technologies have different size limits. CAES can be built as small as 160 MW. By comparison, the PHS projects proposed for California range from 500 MW to 1,200+ MW. RESOLVE allowed 2,000 MW of PHS to be selected for the 2017-2018 IRP. Thus, for "lumpy" technologies, diversity significantly increases the model's optionality.

- **Duration**: The Commission proposes to set the minimum duration for PHS at 12 hours. CAES has a different operating profile from PHS which means this minimum duration would be inappropriate. CAES can perform an approximately 52-hour "deep discharge" cycle for emergency situations, but we expect that a system operator would more likely run CAES on daily eight-hour cycles to absorb midday solar overgeneration and meet the evening and morning ramps. Range has performed cavern modeling which demonstrates the potential for CAES to consistently discharge eight hours daily. This eight-hour duration may prove highly valuable: recent research from Woods Mackenzie found that eight-hour energy storage could meet 90%

of the peaks supplied by four gas combustion turbines over a year.[9] Applying a higher minimum duration of 12 hours may prevent the model from optimizing a bulk storage resource for its highest value.

- **Cost**: As shown in Table 1, below, the US Department of Energy found CAES to be cost-effective compared to other energy storage resources.

[9] https://www.greentechmedia.com/articles/read/just-how-much-business-can-batteries-take-from-gas-peakers#gs.0viF28Fk

**Cost of Storage Comparison**[10]

| | CAES | Pumped Hydro | Li-Ion Batteries (four hour) |
|---|---|---|---|
| Total Project Cost ($/kW) | | | |
| 2018 | $1,050 – $2,544 | $1,700- $3,200 | $1,876 |
| 2025 Predictions | $1,669 | $2,638 | $1,446 |
| Levelized Energy Cost ($/kWh) | | | |
| 2018 | $94 – $229 | $106 – $200 | $469 |
| 2025 Predictions | $105 | $165 | $362 |

## IV. Green hydrogen will help decarbonize conventional fossil-fueled turbines

The Green Hydrogen Council described the potential for "green hydrogen" to play a critical role in the low carbon future, in part by providing energy storage through electrolysis production of hydrogen from renewable sources and in part by providing a replacement fuel for conventional combustion turbines.[11] Hydrogen is typically produced through a steam reformation process and uses natural gas as the feedstock. This process results in some GHG emissions. Green hydrogen is hydrogen produced from a zero-carbon feedstock (e.g., electrolysis and zero carbon electricity).

Range anticipates that its CAES facility(ies) will be partially hydrogen-fueled from day one of operation (~2026) and will transition to 100% hydrogen-fueled in the near future. Siemens has been developing CAES generators capable of hydrogen co-firing with natural gas and could offer a CAES system fueled by 50% hydrogen and 50% natural gas today. A 50% hydrogen CAES system would have ~26% lower GHG emissions compared to conventional CAES (and 56% lower emissions compared to a combined cycle gas turbine) on a per-kWh basis. Siemens further expects 100% hydrogen-fueled CAES will be available by 2025, which will make CAES a zero-emissions resource. Combining on-site hydrogen production via electrolyzers with CAES will enable a highly flexible, zero-emission, bulk-scale, long-duration energy

[10] US DOE, Energy Storage Technology and Cost Characterization Report, July 2019 https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

[11] Janice Lin, Green Hydrogen Council, Presentation at Technical Workshop on SB 100 Joint Agency Report, November 18, 2019

storage system at locations suitable for salt-cavern construction. The fact that CAES is long-duration, cost-effective,[12] and will be capable of exclusive hydrogen-fueling within the next several years makes this technology an essential component of California's long-term clean energy portfolio.

In addition, as the Green Hydrogen Council presented, LADWP is working with technology developers to enable hydrogen fueling at the new combined-cycle facilities which will be built to replace coal power at the IPP. The combined-cycle facility will be capable of hydrogen co-fueling from day one, with a plan to reduce the natural gas component of the fueling to zero by 2045.

By combining on-site hydrogen production and storage with hydrogen-fueled CAES and combined-cycle facilities, LADWP and SCPPA members will create a highly flexible renewable integration hub, capable of seasonal energy storage (via hydrogen storage), multi-day energy storage (via hydrogen storage or CAES), fast ramping generation (from CAES), and rotating inertia to support the Southern Transmission System.

There are clear synergies between the Range project and LADWP's plans for hydrogen-fueled, combined-cycle facilities. If LADWP ramps up hydrogen fueling in the CAES facility first, it will provide a lower-risk opportunity to test and grow familiar with both hydrogen-fueled turbines and hydrogen production from electrolysis. Range, Siemens, and LADWP could also partner on the development of hydrogen production facilities and hydrogen storage facilities to achieve economies of scale and resource efficiencies.

The Joint Agencies should incorporate green hydrogen and CAES technologies into its SB 100 planning processes by including green hydrogen and CAES as candidate resources and by making other modeling improvements discussed above.

## V. Include all planned and available resources in a California-wide portfolio

Range appreciates that the agencies are looking to extend SB 100 analysis to include representation of Balancing Authority Areas ("BAAs") outside the CAISO (Imperial Irrigation District, LADWP, Balancing Authority of Northern California, and Turlock Irrigation District). Indeed, given that SB 100 applies to all LSEs, it is logical for SB 100 analysis to look across balancing areas.

With this expanded scope, it will be even more important that the models utilized are inclusive of diverse technologies, especially as progressive public utilities, like LADWP, invest in resources which the LSEs in the CAISO system have not to date.

At a minimum, the Joint Agencies should add CAES and hydrogen fuel production into SB 100 modeling, given LADWP's explicit plans to develop those resources. These additions will provide utilities and LSEs an opportunity to learn about new technologies and may also facilitate joint procurement between public utilities and CAISO LSEs in the future.

[12] NREL Study: Energy Storage Technology and Cost Characterization Report, July 2019: https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf.

## VI. The state should transition from a REC-based to a GHG-based electric resource accounting system.

The Air Resources Board ("ARB") staff's presentation at the Technical Workshop highlighted the differences and, in some cases, incompatibility between electric resource planning and accounting driven by Renewable Portfolio Standards (RPS) regulations versus the planning needed to achieve long-term GHG standards.[13]

Range notes that energy storage has never fit well within an RPS-driven system. Storage devices cannot be certified as RPS-eligible independently; they can only be certified together with a renewable facility. Specifically, "an energy storage device may be considered an addition or enhancement to an eligible renewable facility" if the device is integrated into the renewable facility, or capable of being physically isolated from other sources of energy, through direct connection between the renewable facility and storage device, behind-the-meter. Electricity generated from the renewable source must be delivered to the storage device before entering the electric grid, or it must be properly metered to accurately track the electricity delivered to the storage device to prevent double counting.[14]

Therefore, a resource like CAES could only help a utility earn RPS credit if it is paired with and metered to a specific renewable energy resource. For bulk storage resources, the best use and value will often be as a system resource, storing energy from multiple sources (i.e., in order to manage over-generation and to provide load following and ramping services). In this case, renewable energy from the grid (which does not satisfy the CEC's current metering and co-certification requirements) which delivers to and later from the CAES facility would not qualify as RPS-eligible. The result is that utilities will lose RPS credit for the renewable MWhs which are generated and delivered into an energy storage "system" resource, rather than delivered to serve load. To compensate, utilities would have to overbuild the renewable system so that they can generate and surrender sufficient Renewable Energy Credits ("RECs) despite the loss of some RECs to bulk storage that also stores grid energy. At an RPS level of 30-40%, this may be a minor issue, but at 60% RPS and higher, the portion of variable resources online will require greater quantities of storage, while the loss of REC value could deter a resource planner from investing in bulk storage.

Range understands that the Energy Commission developed RPS guidelines without system-level bulk energy storage resources in mind. One solution to the problem described above would be to qualify delivery of renewables into energy storage as equal to delivery to serve load (with some adjustments to account for losses and subtract for non-renewable energy input) while prohibiting the generation of RECs from storage.

Alternatively, and as Range recommends, the Joint Agencies and state legislature could elect to transition from an RPS-based accounting standard to a GHG-based accounting standard. To accommodate this shift, the California Air Resources Board ("CARB") would need to develop a process

[13] ARB Staff, Ryan Shauland, California Air Resources Board (CARB), Presentation - Options for Defining Eligible Electricity Resources under SB 100, SB 100 Technical Workshop, November 18, 2019.

[14] Chapter 3, Section F of the CEC Guidebook, 9th Edition

for: 1) assigning emissions factors for facilities outside California – rather than assigning a generic "import" value; and 2) assigning an emissions factor for "charging energy" delivered to this energy storage, which may include a mix of carbon-free and fossil fuel sources. As the developer of an out-of-state energy storage resource which may use some quantity of fossil fuel, Range would require resolution on both of these issues.

While the ARB's process for assigning emissions factors to "facilities" is relatively well established based on past practice of collecting facility-level data, CARB does not have a process or provisions in the Mandatory Reporting of Greenhouse Gas Emissions ("MRR") that govern the reporting of charging energy or the establishment of an emissions factor for a resource like Range CAES. The current California Electronic Greenhouse Gas Reporting Tool ("Cal e-GGRT") reporting template used to report imports to the ARB does not account for storage resources, and in particular, charging energy that is scheduled to a storage resource and then later discharged as part of a scheduled import into California. In developing a system for accounting for charging energy, CARB will need to be able to differentiate between charging energy generated in-state, and thus already accounted for, and charging energy generated out-of-state. It will also need to differentiate between carbon-free and carbon-emitting generation sources scheduled into the storage facility.

Thus, as we shift from a 60% RPS standard to a 100% carbon-free standard, retaining a REC-based accounting system could overly complicate the regulatory system and limit the types of resources and renewable integration strategies available to utilities.

**Conclusion**

Range appreciates the opportunity to comment on this workshop.

Sincerely,

Molly Croll