You've got the power

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June 7, 2024

[redacted]
Executive Director – Energy & Utilities
Utility Regulation and Competition Office ("**OfReg**")
Grand Cayman
Cayman Islands

Certificate of Need

Dear [redacted],

We write regarding the need for more generating capacity.

Pursuant to Conditions 29.1 and 31.1 of CUC's Transmission and Distribution Licence dated 3 April 2008, we include *inter alia* a Certificate of Need ("**CON**") in ***Attachment A***; and a Near-Term Generation Adequacy Study in ***Attachment B***.

Over the past five years we have engaged in extensive and ongoing communications with OfReg, including but not limited to formal submissions, correspondence, provision of related documents, and discussions, each raising the need for additional generation resources while seeking to ensure alignment with the targets of the National Energy Policy ("**NEP**").

CUC has made multiple recommendations regarding approaches which could simultaneously achieve resource adequacy requirements while meeting policy objectives. [redacted]. As we explain herein, all projection scenarios for Grand Cayman show that it is faced with capacity shortfalls.

These capacity shortfalls will not be adequately addressed by the proposed Renewable Energy Auction Scheme ("**REAS**"), which has made insufficient progress since OfReg released the first formal consultation document on 23 September 2019. Similarly, while CUC recognizes that there has been recent progress with efforts to competitively procure a Dispatchable Photovoltaic ("**DPV**") project, the pace of these efforts raises the significant concern that any mechanism other than the CON process will lead to near-term capacity shortfalls and system unreliability.

Pursuant to NEP 2017-2037 targets, and the now-promulgated NEP 2024-2045 revisions, CUC, with the support of Energy and Environmental Economics, Inc. (**E3**), a leading industry consultant, has undertaken an evaluation to determine:

1. Identification of projected system load and existing resources in the near term, including:
    a. High load growth scenario considered, based on near-term historical growth trends.
    b. Behind-the-meter Distributed Generation ("**DG**") growth projected to 24 MW_{AC} capacity connected in 2027.
    c. Planned retirement for 37 MW of thermal generation resources.
    d. Fixed operating reserves of 30 MW to meet worst-case scenario for loss of largest unit in low-solar generation days.
    e. A sensitivity was evaluated to determine the impact if the planned procurement of the 22.5 MW DPV project is completed prior to 2027.
2. The quantity of new, "perfect capacity"[1] necessary to meet near-term system needs while achieving industry standards for system reliability[2]. This approach addresses gaps inherent in evaluating firm and non-firm resource nameplate capacity[3] contributions to meet planning reserve margin requirements by using the Effective Load Carrying Capability ("**ELCC**")[4] for all resources.
3. Resource scenarios[5] utilizing a potential mix of new firm (thermal) generation, standalone solar PV generation, standalone battery energy storage systems ("**BESS**"), as well as hybrid solar PV and coupled BESS generation that meet the determined capacity requirement to achieve reliability. These were evaluated based on the interactive ELCC curves for each generation technology and associated nameplate capacities.
4. A dispatch analysis on the relative operational cost savings to the "business as usual" scenario[6] for the alternative resource scenarios that meet the determined capacity requirement to achieve reliability.
5. Study sensitivities examining the relative change in total emissions and operational cost savings for resource scenarios, considering activities associated with a (1) fuel conversion of specific existing units and any potential new thermal units to LNG, or (2) an additional 20MW of connected DG solar resources by 2027.
6. The study did not perform detailed network stability studies to assess network stability or validate grid stability, including frequency response, voltage regulation, and short circuit strength to determine if transmission upgrades are required. These system impact assessment studies will be conducted once OfReg has announced proposed projects.

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[1] Perfect capacity accounts for annual peak load variation, operating reserve requirements, and forced outages in resource accreditation.
[2] Loss of Load Expectations (LOLE) of 0.1, which equates to 1 loss-of-load event-day every 10 years.
[3] Nameplate capacity, also known as rated capacity or nominal capacity, is the maximum output of electricity that a power generation facility, such as a power plant is designed to produce under specific conditions.
[4] For more information, see ***Attachment D*** – *Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capability in Resource Adequacy*
[5] Due to unrealistic permitting timelines, wind generation was excluded as a near-term potential resource.
[6] Business as usual scenario modeled as procurement of only thermal (LNG), firm capacity to meet system needs.

The study determined that, based on the high levels of load growth observed in recent years (exceeding previous high growth projections), and weather and economic growth trends, in order to meet a projected 2027 peak load of 143 MW while providing and maintaining a reliable service, at least **82 MW** of equivalent perfect capacity is required to be added to Grand Cayman's electricity system by summer 2027. In the absence of additional resources, the study model indicated a Loss of Load Expectation ("**LOLE"**) of **304.5 loss-of-load events per year**. As clarified in the study, the specific nameplate capacity of resources that might fulfil this requirement will vary depending on the specific mix of resource technologies and their interactive ELCCs.

On the basis of the work presented in ***Attachment B*** CUC has prepared a summary of the alternative scenarios explored to meet the identified capacity requirement. There are four primary resource scenarios. These have been considered in the context of techno-economic and socio-economic factors, NEP targets and objectives, and procurement, permitting and development risks, amongst other constraints. Each scenario, excepting the "business as usual," was explored with increased incremental units of renewable resources, which were modeled based on typical industry configurations and characteristics. These scenarios are provided below, with a summary of the primary pros and cons associated with each.

Scenario 1 – Business as Usual (Thermal)[7]

In this scenario, to provide the necessary perfect capacity requirement, and accounting for incremental, discrete generating unit sizing, 90.1 MW of new thermal, firm resources would be procured. The generating units could be run with either diesel or LNG, in the event of a fuel transition to LNG if supported by the viability study denoted in the revised NEP 2024-2045.

Pros	**Cons**
• Lowest procurement and development risk • Lowest upfront capital investment • Lowest interconnection risks and costs	• Highest emissions (though LNG switch would materially reduce emissions from 2019 levels) • Least renewable energy penetration and high likelihood of not meeting NEP goals • Highest projected operating costs

Scenario 2 – Thermal and Standalone Solar

In this scenario, capacity requirements are also met by the procurement of 90.1 MW of new thermal, firm resources as described in Scenario 1. However, incremental additions of standalone solar PV resources,[8] up to 100 MW_{AC},[9] were injected to identify the opportunities and impact of displacing thermal generation energy with increased renewables. Due to non-coincidence with typical system

[7] Thermal units considered for all scenarios were modeled with a 18V51/60 engine, which is dual-fuel capable to allow for the use of either diesel or LNG as a fuel source.

[8] Standalone solar was modelled with an Inverter Loading Ratio (ILR) of 1.3, in 25 MW_{AC} increments.

[9] Beyond 100 MW_{AC}, the beneficial marginal changes in emissions reductions and renewable energy penetration are outweighed by significantly increased curtailment losses, which cause increasing marginal costs.

peak load periods, the standalone solar would only provide a contribution to capacity requirements of the system in the range of 3-5 MW.

Pros	**Cons**
• Second lowest procurement and development risk (failure to procure/develop standalone solar will not impact capacity requirement) • Second lowest capital investment • Tied for lowest projected operating costs	• Highest curtailment of solar resources • Reduces commercial opportunities for smaller and distributed renewable generation • Lost opportunities for further renewable energy penetration* • Lost opportunities to further reduce emissions*

**Due to curtailment of solar overproduction periods without associated storage regime*

Scenario 3 – Thermal and Hybrid Solar + Storage

In this scenario, incremental additions of hybrid solar PV and BESS[10] resources are injected to reduce capacity from new thermal, firm resources while retaining system reliability.

Pros	**Cons**
• Second highest renewable energy penetration • Second lowest emissions portfolio • Second lowest projected operating costs • Lowest curtailment of solar resources • Preserves commercial opportunities for smaller and distributed generation renewable projects to provide energy to the grid system	• Mid-level procurement and development risk (failure to procure/develop *some* hybrid solar and storage may be bridged in short term) • Second highest upfront capital investment

Scenario 4 – Hybrid Solar + Storage (No New Thermal)

This scenario reviewed the addition of only hybrid solar PV and BESS resources, without any new thermal, firm resources. Variations of this scenario explored the use of 8-hour duration BESS; however, this approach modeled substantially increased investment costs but only very minimal operating benefits. The minimum nameplate capacity for this scenario to achieve reliability was identified as 175 MW_{AC} (350 MW_{DC} solar and 700 MWh of coupled storage). This magnitude of nameplate capacity would be expected to present significant development, permitting, and interconnection challenges in order to achieve commercial operations by 2027.

Pros	**Cons**
• Lowest emissions portfolio • Highest renewable energy penetration • Tied for lowest projected operating costs	• Highest procurement and development risk • Highest upfront capital investment • Highest interconnection risks and costs

[10] The hybrid resource was modeled as a DC-coupled, co-located solar and storage plant with an ILR of 2.0, in 25 MW_{AC} increments, with 4-hour duration storage.

Analysis of Alternatives & Recommendation

There are two key factors to consider in respect to the procurement of resources necessary to meet the capacity needs of Grand Cayman in 2027: risks impacting achievement of commercial operations in time to meet capacity needs, and benefits that can be delivered to stakeholders from the associated resources (e.g. resiliency of generating assets and overall electricity system, electricity cost reductions, net emissions reductions, increased renewable energy penetration, etc.).

While Scenarios 1 and 2 clearly present the least risks to achieving the capacity required on time (noting that any delays in Scenario 2 to deploy solar resources will not impact *capacity* provisions, but will reduce other benefits related to the displacement of thermally generated *energy*), Scenario 1 provides the least additional benefits to consumers and Scenario 2 sees significant missed benefit opportunities due to high levels of solar curtailments and risks of stranded or sub-optimal future resources. Similarly, Scenario 4 provides the greatest potential mix of environmental and cost benefits and meeting the NEP goals, but carries the highest risks associated with development and interconnection delays. Given the repercussions of failing to meet capacity requirements to consumers and the broader economy, in such instance, CUC would be compelled to seek short-term, firm capacity resources, which are typically more costly and provide less benefits than alternatives. This would diminish the relatively higher environmental and cost benefits of Scenario 4 and would risk the stability and reliability of electricity service provision in Grand Cayman.

Scenario 3, and specifically the generation resources identified in Scenario 3.4 described in ***Attachment B***, surpasses other alternatives, based on recognizing the imperative of achieving capacity requirements, while maximizing all other potential environmental and cost benefits. Scenario 3.4 recommends that OfReg procure a portfolio mix of **100 MW_{AC}[11] of hybrid solar PV with 100 MW_{AC} 4-hour duration BESS and 36.1 MW of new thermal, firm capacity**.

Scenario 3.4 presents the most flexibility in respect to absorbing risks associated with the development and interconnection of renewable resources, reduces costs to consumers, and meets - or exceeds – incremental NEP targets for emissions reductions and renewable energy penetration in 2027. Key benefits include:

- The portfolio of recommended resources, in conjunction with existing resources, achieves an effective perfect capacity of 210 MW in 2027. Based on the projected 2027 system peak load of 143 MW, this is sufficient to meet the required reserves margins as described in CUC's T&D Licence for 2027. These resources would achieve a target reserve margin of 47% perfect capacity, utilizing an ELCC analysis to accredit all system resources (new and existing). The application of ELCC to quantify capacity and planned reserve margins for resource adequacy evaluation and planning activities is described in detail in ***Attachments B & D***.
- The hybrid solar and storage resources (100 MW_{AC}), even if solely located on the Eastern side of Grand Cayman, are projected to be supportable by the existing transmission system while

[11] The 22.5 MW DPV project could form part of this set of resources, if procurement proceeds as planned, and its effect on the CON requirement is detailed in ***Attachment B***. CUC would recommend this DPV procurement proceeds separate to procurement activities associated with this CON, given the criticality to bring all potential contributory resources to operation in an expedited manner.

retaining N-1 redundancy standards[12] with only relatively minor upgrades, subject to additional study and analysis.

- The 36.1 MW of new thermal resources are less than the nameplate capacity of retiring assets (37 MW), leading to a reduction in the net thermal generation resources on the system.
- The total thermal capacity (existing and new) will exceed the projected 2027 system peak load of 143 MW, of which the majority is located on the Western transmission loop.
  - In the rare event of outage, in full or in large part, of the Eastern transmission loop, there is a high probability that sufficient capacity will be available to meet system load.
  - In the event of extreme adverse weather events, the resiliency of, or service restoration for, hardened engine room facilities is expected to be superior to lengthy transmission circuits serving Eastern solar and storage generation facilities to retain or return service to primary, and critical, loads on the Western side of Grand Cayman.
- This scenario provides the greatest flexibility to achieve contingencies retaining capacity reliability requirements in the event of delays or challenges associated with the procurement process, development, permitting or achievement of commercial operations by 2027 for the hybrid solar plus storage resources.
  - Where up to 50% of the hybrid solar plus storage resources are delayed or challenged, the system could be made reliable through only an additional 7.1 MW of "perfect capacity," which could be achieved through extending the life of one or two retiring units. However, increased utilization of thermal resources in such a scenario could cause carbon emissions reductions to fall behind schedule to National Energy Policy targets[13].
- Scenario 3.4 avoids calling for the procurement of 90.1 MW of new thermal resources, as described in the Business-as-Usual case (Scenario 1), which would otherwise present major challenges in achieving National Energy Policy targets or increasing risks of stranding generation assets at later stages of the National Energy Policy implementation.
- This Scenario exceeds the interim 2027 NEP targets for both carbon emissions reductions and renewable energy penetration and would exceed the 2030 NEP target for renewable energy penetration significantly ahead of schedule.

In accordance with sections 29.1 and 31.1 of CUC's T&D Licence dated April 3, 2008, CUC is required to submit a Certificate of Need for firm generating capacity three years in advance of the in-

[12] N-1 redundancy ensures system availability and resiliency through the event of component failure. In this instance, N-1 allows for the loss of one transmission circuit on the Eastern transmission loop without compromising system availability.

[13] In the event of a fuel switch to Liquified Natural Gas, use of these thermal resource contingencies would achieve the carbon emissions reduction target due to emissions improvements as compared to diesel combustion.

service date of the needed capacity. To date, an insufficiency of resources has been procured, or is in an advanced state of procurement, to meet the near-term capacity needs projected for 2027.

As a result of this, CUC is obligated to and hereby issues the Certificate of Need in ***Attachment A*** for OfReg's review and approval.

The criticality of successfully procuring these capacity resources for Grand Cayman by 1 May 2027 cannot be overstated. In the absence of bringing new resources online, Grand Cayman is modelled to face outage events due to insufficient supply at an average of 4 days out of every 5. This unreliability would be highly disruptive and detrimental to both the core drivers of Grand Cayman's economic activities and residential quality of life. Furthermore, it is unlikely that alternative short-term measures (e.g. current rental thermal generation, demand response initiatives and, where feasible, the extension of those thermal units slated for retirement) would be sufficient to mitigate the reliability challenges. Such measures also would not be ideal if goals associated with energy affordability, environmental impact, and other aspects of national interest are to be met. Coordination and planning of system upgrades will be a critical factor in successfully bringing the identified resources in Scenario 3 to commercial operation. Given these challenges, CUC is open to collaborate and discuss how best to mitigate risks and ensure that resources are procured in a competitive and expedited manner.

To ensure near-term generation adequacy requirements, CUC is exploring all possible supply and demand alternatives and has made multiple submissions and generation planning decisions to meet License Requirements. Already, as a result of the above-noted delays with ongoing generation procurements for projects that would both serve capacity purposes and advance clean energy targets of the NEP, CUC has been forced to rent thermal capacity resources to meet short-term capacity and reserve margin requirements. By 2026, rented thermal capacity requirements may increase to as much as 50MW. This is unsustainable and undesirable for all stakeholders. The duration for which such resources are needed to address capacity requirements should be minimized as much as possible.

CUC also recommends that procurement processes should include appropriate reward mechanisms to commercially incentivize the delivery of desired new capacity resources ahead of schedule.

With respect to OfReg's ongoing activities to procure a 22.5 MW DPV project, CUC strongly recommends that procurement proceed without delay. To avoid additional delays, however, that project should not be integrated with any procurement associated with the CON submitted herein.

We attach that CON in ***Attachment A***, with supporting documents in ***Attachments B, C, & D***. CUC representatives are available to discuss the above as needed and we look forward to OfReg's response.

Yours faithfully,

[redacted]

Director, Sustainable Finance

Attachments*:*

A: Certificate of Need

B: CUC Near-Term Generation Adequacy Study

C: [redacted]

D*:*

Caribbean Utilities Company, Ltd.
Certificate of Need
RESOURCE ADEQUACY REQUIREMENTS for 2027

1. Need for the CON

This document serves as a formal certificate of need for a lower-carbon energy generation and storage system portfolio, designed to meet varying electricity demands across different time periods in Grand Cayman. Based on our grid data analysis, load forecasts, operational and investment cost benchmarking, and study of portfolio and marginal Effective Load Carrying Capabilities ("**ELCC"**) for sets of low-carbon resources, we have identified a recommended quantum of firm and dispatchable resources necessary to meet the capacity reserves and energy requirements for summer of 2027 that also will make substantial progress toward key National Energy Policy ("**NEP"**) targets.

- In accordance with Conditions 29.1 and 31.1 of CUC's Transmission and Distribution Licence dated April 3, 2008. Caribbean Utilities Company, Ltd. ("**CUC"** or **the "Company"**) hereby files this Certificate of Need ("**CON"**) with the Utility Regulation & Competition Office ("**OfReg"**) to demonstrate the need for additional generating capacity on Grand Cayman.

- Attached to this CON Cover Letter, as Attachment B, is a resource adequacy projection for 2027 demonstrating that with load growth and contract expirations, CUC has a large capacity shortfall of 82 MW ("**ELCC"**) / 90.1MW incremental thermal ("**firm"**) capacity to fill to ensure adequate system reliability. This study also reviewed:
  - Projected growth in electric peak load (both low, mid and high growth scenarios) and energy requirements.
  - Availability of existing capacity, including any anticipated retirement and planned life extensions of generating units as proposed by the generation Licensee and approved by OfReg based on economics, reliability, obsolescence, safety and environmental requirements, Government and Regulatory policy and prudent utility practices.
  - Projected reserve capacity requirements – given that the recommended resources include intermittent and non-firm technologies, CUC has utilized a portfolio ELCC analysis to achieve an equivalent effective capacity to meet the reliability outcome of the previous peak reserve margin required band[1].

2. Evaluation of Alternatives

In 2017 CUC produced an Integrated Resource Plan (the "**IRP"**), which OfReg accepted in January 2019 as a roadmap for future generation resources on Grand Cayman. This plan includes recommendations for large amounts of renewable energy of approximately 25 megawatts ("**MW"**) per year for 5 years starting in 2021. The IRP also recommends the utilization of large amounts of energy storage to support the implementation of intermittent renewable energy storage systems. The NEP contains targets on carbon emission reduction goals and renewable energy penetration levels, revisions to which were approved by the Cabinet of the Cayman Islands Government in April 2024. The reduction targets called for a

[1] Peak Reserve Margin of a minimum of 35% and maximum of 55% over projected peak load in the target year.

downward trajectory in carbon emissions starting with a 30% reduction relative to 2019 actual emissions by 2030, and 100% reduction by 2045. In addition, the NEP targets a 30% renewable energy penetration by 2030, 70% by 2037, and 100% by 2045.

In the period since the 2017 IRP, Grand Cayman has experienced significantly accelerated load growth than was anticipated by the original study. This stems from a combination of increased economic activity and higher annual average temperatures, amongst other factors. Accordingly, the quantity and specific mix of resources identified within the IRP for 2027 would not have been sufficient to meet expected system needs. However, the IRP still provides reasonable directional information in respect to the relative set of resources that will make meaningful progress toward reliability, affordability, and environmental goals.

Informed by the IRP, which recognized previous NEP carbon reduction goals through select portfolios and analyzed the cost impact of meeting those carbon goals, CUC has studied a set of incremental resource portfolios that will achieve system capacity requirements under the lens of the revised NEP targets. This study commenced with a base case utilizing strictly firm, thermal capacity resources and then explored a set of alternative resource portfolios utilizing mature, viable technologies with clear development pathways to achieve commercial operations by 2027. These alternative resource portfolios were run through dispatch and cost modelling to identify their impact on carbon emissions reductions, renewable energy penetration, and relative change in operating costs (as compared to the base case portfolio). Further assessment considered risk factors regarding development, permitting, and interconnection activities and the potential impact on meeting capacity and reliability requirements by summer 2027. Sensitivities were also modelled to examine the impact of key input assumptions, such as changes in the fuel supply to Liquefied Natural Gas ("**LNG**"), the resource contribution of the Dispatchable Solar Photovoltaic ("**DPV**") project issued for RFQ by OfReg in April 2022, lower load growth projections, and a 20MW increase in Distributed Generation ("**DG**") interconnections from the 24MW modeled for 2027.

As part of this study, the viability of using a combination of solar photovoltaic generation with energy storage to create a dispatchable generation resource was examined in great depth. The Company has calculated that system resources that meet the technical criteria contained herein are capable of reducing the peak load that CUC's traditional firm capacity plant would have to serve and therefore effective capacity can be assigned to such renewable energy and energy storage systems for the purposes of Reserve Capacity planning.

Furthermore, CUC is nearing completion of a project to install (20 MW: 20 megawatt hours ("**MWh**")) of utility scale storage to provide spinning reserve to Grand Cayman's power system. This initiative will reduce the amount of fuel burned to generate the energy demanded by consumers. CUC's current and future demand side management programmes include the following:

- CUC continues to provide its customers with educational information in the area of energy efficiency in an effort to allow its customers to better manage their electricity consumption.
- CUC currently provides customers with detailed information on their usage in 15-minute increments so that they can self-analyse their energy usage and make changes to their behavior to reduce energy wastage.
- CUC has recently implemented the issuance of mid-month consumption notifications to its residential customers to assist in their awareness and management of ongoing electricity consumption.

- CUC supports the NEP strategy of encouraging energy efficiency and has trialed a smart thermostat program, behind the meter battery pilot projects and other energy efficiency initiatives for its customers.
- CUC has encouraged the development of rooftop solar generation through its CORE and DER programmes with associated tariffs that recognise power system reliability requirements and equitable customer costs.
- CUC has launched a special rate programme for customers who wish to charge Electric Vehicles at their premises and has launched a pilot project for public electric vehicle chargers located in strategic points across Grand Cayman.

3. Recommended Action

Based on the projected need for additional generating capacity, as demonstrated herein, CUC requests OfReg to approve the generating capacity according to the following criteria and process guidelines.

Criteria:

General:

- Technologies: Solar Photovoltaic with Energy Storage (co-located); thermal resources (procured portfolio must meet NEP & IRP emissions objectives).

- Total Capacity needed:

Project Specifications:

Resource Type	Capacity (MW)	Indicative Annual Energy Requirement (MWh)
Firm, thermal	36.1 MW_{AC}	
Hybrid Dispatchable Solar: • Solar Photovoltaic • Battery Energy Storage	100MW_{AC} • 200MW_{DC} minimum • 100$MW_{AC;}$ 400MWh energy capacity	

- (**MWac**) (Nominal Net Capacity).

- Maximum Output to Grid: the project(s) must be interconnected to the power system such that no single point failure of the facility or power system could lead to a loss of generating capacity greater than 20 MWac.

- Nominal shall be defined to allow an actual capacity to be within +/- 5% tolerance of the nominally listed value.

Timing:

- Commercial Operation Date shall be no later than **June 01, 2027**

- Minimum useful life**:** 20-25 years

Expected Operating Criteria: Solar Photovoltaic with Energy Storage (co-located):

- Integrated real time dispatch controlled directly by CUC's SCADA system (Operational Integration efforts including modifications to AGC programs and EMS upgrades will be required to connect to CUC's system).

- Operating range of dispatch in regular operation: 0 - Full Generating Facility's Storage Capacity Output (MW), as called for by CUC's Generation Management System. Net energy generated by the plant is to be sold into the grid subject to generation availability, the economical dispatch of all available generation licensed by OfReg, the overall system demand, and system security constraints that are required to keep power quality within levels defined by the T&D Code.

- Maximum ramp down rate: Lesser of 1 MW per minute or Maximum Output over 30 minutes.

- Minimum Available Ramp up/down rate of 100% of the plant's Nominal Net Capacity over 1 minute within its available dispatchable range at the time.

- Plant must be able to provide Instantaneous Reserve services for frequency regulation of 6% of Nominal Net Capacity when frequency falls outside of 60 Hz +/- 200 MHz. This capability must also be available at (100% + 6%) output for five (5) minutes.

- If an energy storage system is utilized, the charging of the energy storage system shall be from the renewable source, however, at the grid operator's option and control, charging from the grid shall be allowed.

- Expected unit annual operating availability factor: 90% (based on IEEE EAF equivalent availability factor – this does not include major scheduled maintenance as per manufacturers specification).

Expected Thermal Criteria Operating Characteristics & Fuel:

- Integrated real time dispatch controlled directly by CUC's SCADA system (Operational Integration efforts including modifications to AGC programs and EMS upgrades will be required to connect to CUC's system).

- Nominal level of dispatch in regular operation: 90% of rated capacity, subject to generation availability, the economical dispatch of all available generation licensed by OfReg, the overall system demand and system operational constraints as defined in CUC's T&D Code.

- Expected unit annual operating availability factor: 90% (based on IEEE EAF equivalent availability factor – this does not include major scheduled maintenance as per manufacturers specification).

- Expected annual operating availability factor during the year of major maintenance: 85%. (Based on major scheduled maintenance occurring approximately every 2 years).

- If a fuel source is required, a fuel source which leads to equal to or lower interpolated metric tons (t) CO_2-e per Megawatts than modelled in the IRP Portfolio 5 and updated NEP shall be used to generate the energy required.

- If a fuel source is required, there shall be a minimum fuel storage capacity of 25 days operation at Nominal Net Capacity.

Expected Commercial Terms:

- PPA to be negotiated with the winning bidder based on overall energy price, project capabilities and compliance with the technical criteria contained herein. PPA will be based on the proposed project and could be a (Blended PPA, Solar PPA + storage capacity payment or Renewable Dispatchable Generation ("**RDG"**) based on capability and performance).

- All PPA costs, if any, to CUC shall be passed on to electric consumers.

4. Certification

The Recommended Action set forth above in this CON is based on our understanding of CUC's obligations under its T&D Licence. The calculations, projections, assumptions and technical requirements used in developing this recommendation have been developed or based on our good faith efforts and sound engineering principles. CUC certifies that the next increment of capacity, as described in more detail along with related recommendations in the Recommended Action above, is necessary to meet the projected electric generation requirements as of the date recommended.

5. Approval

This CON complies with the requirements of CUC's T&D License and applicable law and represents a valid determination of needed generation capacity and related requirements as set forth in the Recommended Action herein and is hereby approved.

ON BEHALF OF
CARIBBEAN UTILITIES COMPANY, LTD.

June 7, 2024

______________________________ __________________
Date

ON BEHALF OF
UTILITY REGULATION AND COMPETITION OFFICE

______________________________ __________________
TITLE: Date

Generation Adequacy Study: Caribbean Utilities Company (CUC)

Final Report

May 29, 2024

Arne Olson, Sr. Partner
Aaron Burdick, Director
Nathan Lee PhD, Senior Managing Consultant
Adrian Au, Senior Managing Consultant
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Rene Cole, Consultant
Melissa Rodas, Associate

Energy+Environmental Economics

Contents

Executive Summary

Challenge: With increasing load and expected resource retirements by 2027, CUC faces the near-term challenge of ensuring a reliable system while also achieving clean energy and emissions goals. This study explores portfolio options to ensure reliability and achievement of policy goals, while also addressing local development risks.

+ By 2027 with load growth and contract expirations, CUC will have a capacity shortfall of 82 MW (ELCC) to fill to ensure adequate system reliability.
  - E3's loss of load probability analysis found an installed capacity (ICAP) based planning reserve margin need of 53% to meet a one-day in ten-year loss-of-load standard, at the high end of the 35-55% existing CUC reserve margin range.
+ The island's aggressive clean energy goals will require adjustments to CUC resource adequacy planning methods.
  - Increasing shares of non-firm resources (such as solar, battery storage, and wind) will impact the required ICAP reserve margin; a reserve margin based on equivalent perfect capacity (PCAP) provides a more durable, fair, and resource agnostic long-term approach to reliability planning and procurement.
  - Accrediting resources at their effective load carrying capability (ELCC) for a PCAP based need ensures a level playing field that considers the operational limitations of both non-firm clean energy and firm capacity resources.
+ Solar and storage can provide reliable capacity as well as clean energy, with hybrid solar and storage systems providing higher reliability value due to the "diversity benefits" provided.
  - However, the value of hybrids also saturates with increased penetrations, requiring the continued long-term use of firm capacity resources to maintain reliability. While firm resources (such as the current thermal resources, but potentially longer-duration storage or other technologies in the future) will be necessary as CUC's clean energy resource portfolio grows, these firm resources will be dispatched less frequently (lower operating costs and emissions).
+ The modeled 2027 clean energy targets are achievable with 25-200 MW of new clean energy capacity, while staying on track for the latest 2030 emissions targets is more challenging and requires at least 100 MW of new clean energy resources amidst forecasted load growth.
  - Distributed generation may help overcome development challenges of utility-scale solar deployment; however, relying on new battery storage requires significant charging energy from solar and feasible near-term growth of distributed resources may be insufficient to support concurrent reliance on new battery storage instead of new firm thermal capacity.
+ Increased reliance on renewables reduces system operating costs by offsetting diesel fuel costs. A switch to natural gas, as the primary fuel for select thermal units would help CUC to reduce both emissions and operating costs.

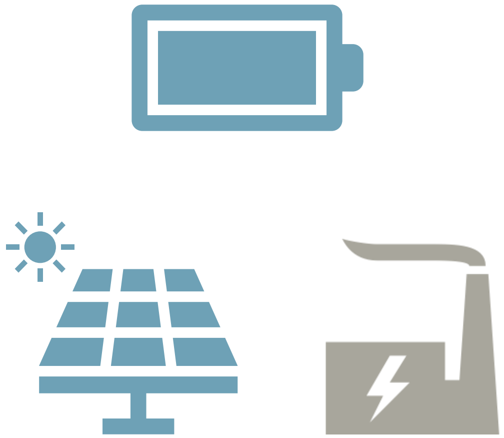
Study Background

Energy+Environmental Economics

Study Purpose and Scope

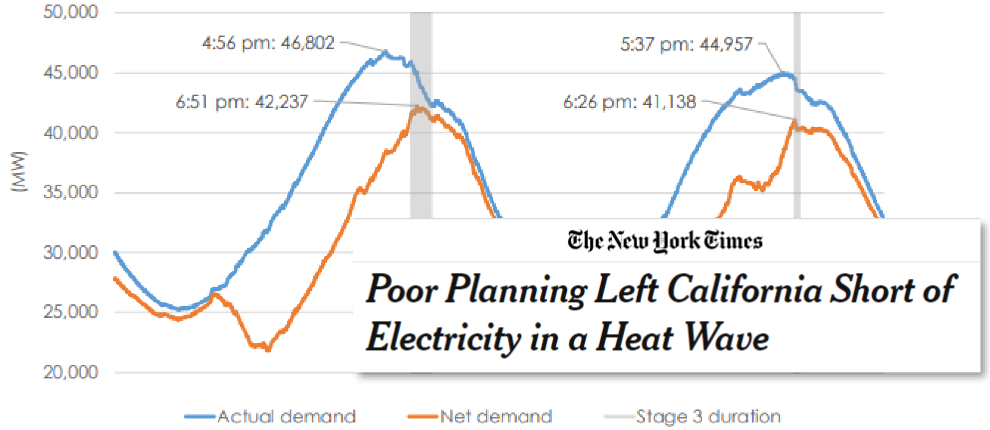
+ **In this study, CUC retained E3 to:**

1. **Calculate CUC Reliability Needs in 2027**
   Ensure system generation adequacy requirement of 1-day-in-10-years loss-of-load expectation
2. **Calculate Effective Load Carrying Capability of Resource Additions**
   Explore a range of new technologies that may be added to the grid by 2027
3. **Evaluate Operational Cost Savings of Resource Additions**
   Compare operational costs of various resource combinations that meet reliability requirements
4. **Produce Final Report and Recommendations**
   Summarize findings and recommendations to inform a new resource solicitation (certificate of need)

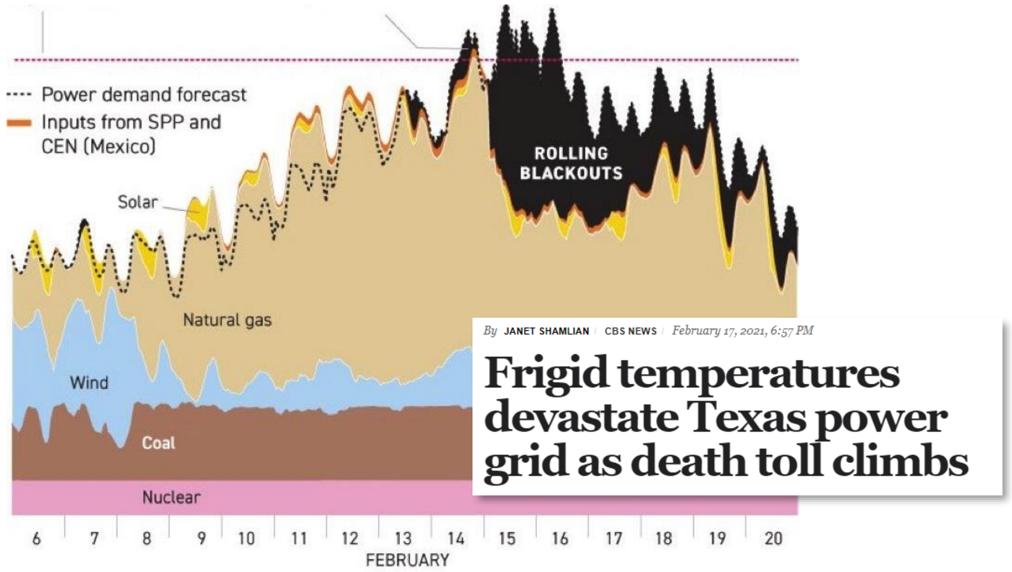


Increased Complexity and Importance of Resource Adequacy

- **Transition towards renewables and storage introduces new sources of complexity in resource adequacy planning**
  - Planning exclusively for “peak” demand is quickly becoming obsolete
  - Frameworks for resource adequacy must be modernized to consider conditions across all hours of the year – as underscored by the U.S. state of California’s rotating outages during August 2020 “net peak” period (top right figure)
- **Reliable electricity supply is becoming increasingly important to society**
  - Ability to supply cooling and heating electric demands in more frequent extreme weather events is increasingly a matter of life or death
  - Economy-wide decarbonization goals will drive electrification of transportation and buildings, making the electric industry the keystone of future energy economy



Graph source: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf

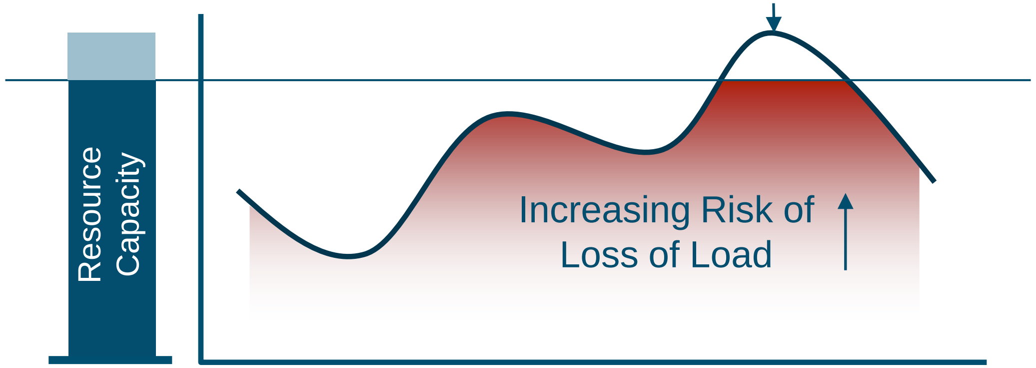


Graph source: https://twitter.com/bcshaffer/status/1364635609214586882

CUC Near-term Generation Adequacy Needs

- Due to growing loads and the retirement of existing generation resources, Caribbean Utilities Company (CUC) faces a near-term procurement need to ensure reliable electricity services in Grand Cayman
- With a national energy policy targeting 100% renewable energy by 2045, as well as aggressive clean energy and greenhouse gas reductions goals for 2030, maintaining reliability as the generation fleet evolves to a low carbon emitting fleet is of paramount importance

Loss of Load Example
Insufficient resource capacity to serve load



NERC Definition of Resource Adequacy:
"The ability of supply-side and demand-side resources to meet the aggregate electrical demand (including losses)"

Source: NERC Glossary of Terms

Clean Energy Policy and Emission Reduction Targets

+ **The Cayman Islands have set ambitious renewable energy and greenhouse gas reduction targets for 2030:**
  - **Reaching 30% renewable energy generation**
  - **30% GHG emissions reduction from electricity supply (relative to 2019 levels)**
    - This target particularly – set on an “absolute” or mass-based basis – will be challenging for the grid to meet amidst forecasted load growth

+ **This study focuses on 2027, to support CUC in filing a Certificate of Need (CoN) with the Utility Regulation and Competition Office**
  - A 2027 renewable energy target of **13%** and emissions reduction target of **25%** were interpolated based on the above targets

RENEWABLE ENERGY

30% Renewable energy penetration by 2030

70% Renewable energy penetration by 2037

100% Renewable energy penetration by 2045

This target is in line with targets of peer countries. Global trends in cost declines of renewable energy technologies, including solar and storage, point to the viability of meeting these goals.

ELECTRIC VEHICLES

Light-Duty
New Vehicle Sales & Imports
30% from EVs by 2030
100% by 2045

Heavy-Duty
New Vehicle Sales & Imports
30% from EVs by 2030
100% by 2045

Many US[1] states have made commitments to achieve a full transition to zero emissions vehicle sales in all categories by 2040. The NEP recommends a slightly longer timeframe to achieve 100% new EV sales to allow time to implementation policies to meet these targets. As such, all new vehicle sales will come from EVs by 2045.

GREENHOUSE GAS EMISSIONS

Electricity Supply
30% emissions reduction over 2019 levels by 2030

100% emissions reduction by 2045

Ground Transportation
35% reduction by 2030
90% reduction by 2045

The Five-Year Review revised the emissions target to be an absolute instead of per capita reduction, with the goal to eliminate all emissions from electricity supply by 2045. Overall economy-wide emissions targets, including those of the transportation sector, are included in the forthcoming Climate Change Policy.

Methodology

Energy+Environmental Economics

Develop Model Inputs and Assumptions

Loads and Resources

+ **E3 relied on inputs from CUC to characterize CUC loads and resources in 2027 as the primary study year for procurement needs**

Summary of RECAP Inputs

Category	Data
Weather conditions simulated	1998-2023
Loads	Historical hourly load shapes
	Annual energy and peak load forecasts
Thermal Units	Plant nameplate capacity
	Forced outage rate and maintenance schedule
Renewables (Utility + DG solar)	Plant capacity, location and hourly output profile
Storage	Plant capacity (MW) and duration (MWh)
	Round trip efficiency

Summary of PLEXOS Inputs

Category	Data
Loads	2027 forecasted hourly load (based on 2022 conditions)
Thermal Units	Plant nameplate capacity
	Operational characteristics and costs
	Forced outage derate and maintenance schedules
	Emission Rates
Renewables (Utility + DG solar)	Plant capacity
	Weather-matched hourly profile with Load
Storage	Plant capacity (MW) and duration (MWh)
	Operational characteristics

RECAP: CUC's Reliability Procurement Need Calculated with Loss-of-Load Probability Modeling

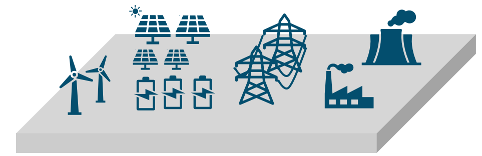
- **RECAP is a loss-of-load-probability model developed by E3 to study the reliability dynamics of high-renewable electricity systems**
- **RECAP simulates the operations of the electricity system under thousands of scenarios to capture different conditions**
  - Including load variability, weather variability, renewable output variable, forced outage events
- **Key RECAP outputs:**
  - System reliability
  - Target planning reserve margin
  - Capacity need shortfall
  - Capacity value of resources

Temperature and Load Artificial Neural Network Simulation

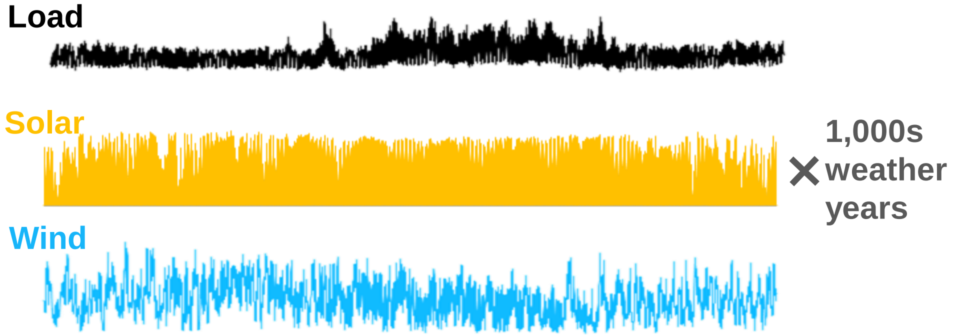
Capturing hourly load conditions under mild and extreme historical weather

Operational Module

Dispatching resources based on outage characteristics, weather dependency, state of charge availability, and demand-side management

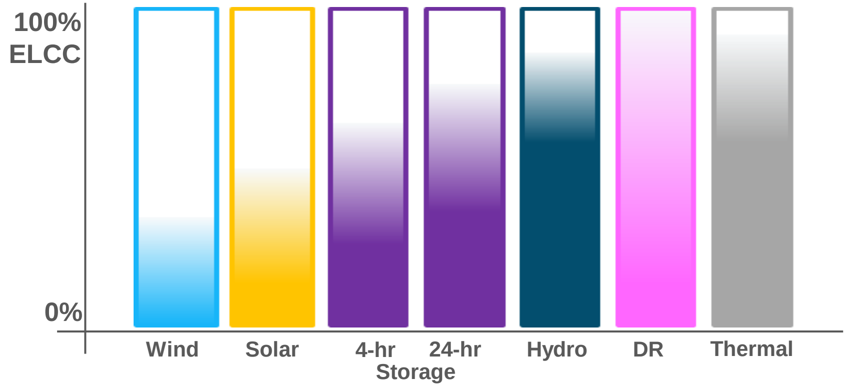


System Reliability: simulates the operations of the electricity system under thousands of scenarios to capture different conditions



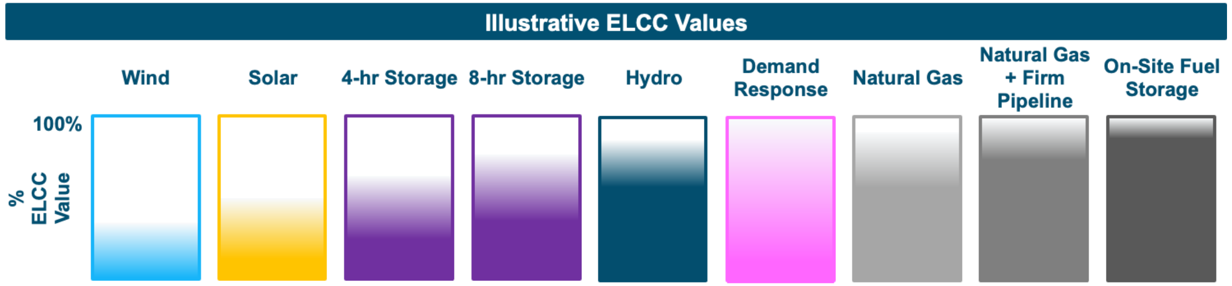
Resource Capacity Value: measures resource's ability to contribute to reliability under a marginal or average ELCC methodology

Illustrative ELCC Values Across Technologies

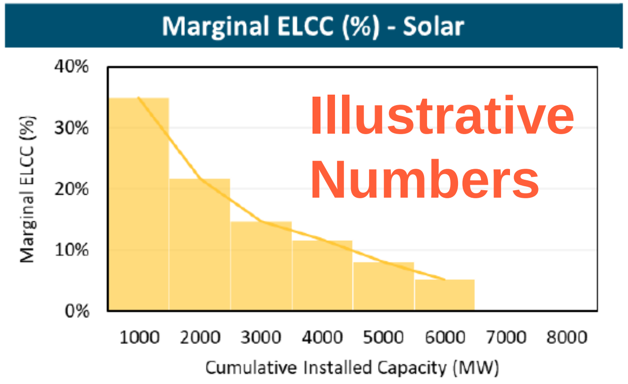


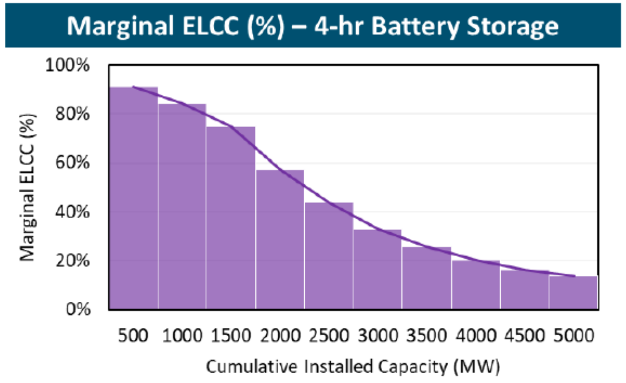
RECAP: Calculating Resource Reliability Value

- **Effective Load Carrying Capability (ELCC) represents the equivalent "perfect" capacity that a resource provides in helping to achieve the target reliability metric (0.1 day/year LOLE)**
  - **Derived from LOLP modeling in RECAP**, building on foundation for resource adequacy analysis
  - Captures **complex interactive effects**, e.g., saturation effects and diversity benefits
  - **Agnostic to technology** and can be applied to all resources
- **Marginal ELCC curve / surfaces can show the incremental ELCC of different resource technologies at increasing penetration in CUC grid:**
  - Standalone Solar
  - Standalone Storage
  - Hybrid Solar and Storage
  - Generic Thermal Plant



ELCC can be used to accredit all resource types on a level playing field, increasing fairness and economic efficiency



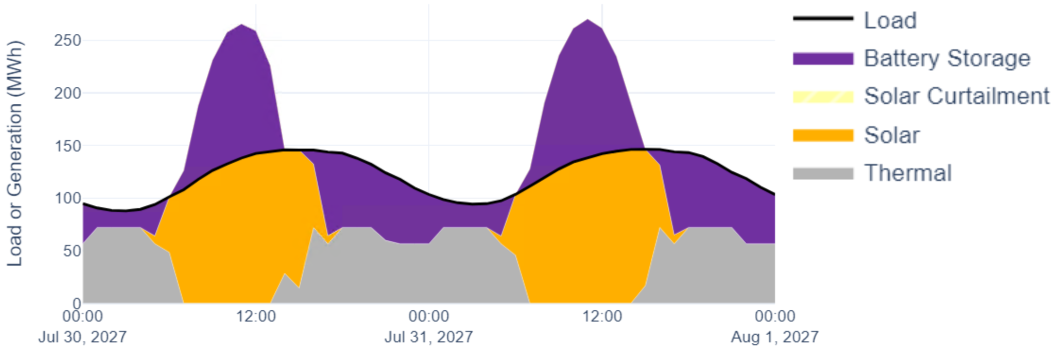


ELCC can be used to capture changing marginal values as a resource grows

PLEXOS: Evaluating Operational Cost Savings

- **PLEXOS-ST, a Production Cost Model tool is used to assess the operational value of various potential CUC resource portfolios**
  - PLEXOS is a mixed-integer programming based chronological optimization tool able to model each day of the model horizon in full, hourly resolution.
- **PLEXOS represents least-cost dispatch with functionality for unit commitment and constraint modeling (detailed operating reserves, etc.)**
- **The incremental operational cost of resource additions are calculated by running cases with and without the resources (“in/out” cases).**
  - Allows for identifying fuel cost and variable O&M cost impacts of changes to portfolio

Example 2027 CUC Hourly Dispatch Plot (MW)



- **Key Production Cost Model outputs include:**
  - Production Costs
    - Fuel costs, Variable O&M costs, etc.
  - Greenhouse gas emissions
  - Resource utilization and capacity factors
  - Renewable curtailment
  - Reliability challenges (loss of load, overgeneration, loss of reserves)

Inputs and Assumptions

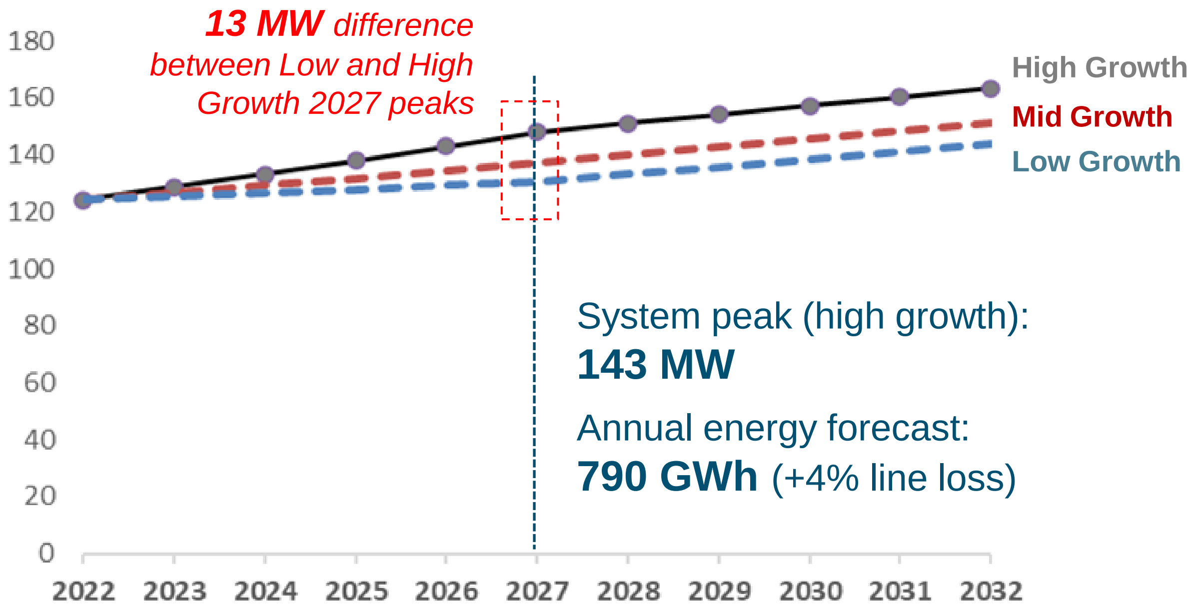
RECAP Model: Loss-of-Load Probability Modeling

Loads and Operating Reserves

+ **E3 modeling focused on CUC system needs in 2027, under a high load growth scenario**

+ **Grid needs to maintain a fixed amount of operating reserve requirements of 30 MW in all hours**
  - Driven by the contingency reserve need for the largest possible unit outage (reflects worst-case scenario when certain baseload thermal units are offline in low-solar generation days)
  - Changes to operating reserve needs from solar growth was not included in this study
  - Thermal and storage plants can provide operating reserves

<u>CUC Annual Peak Demand Forecast, 2022-2032</u>
(MW)



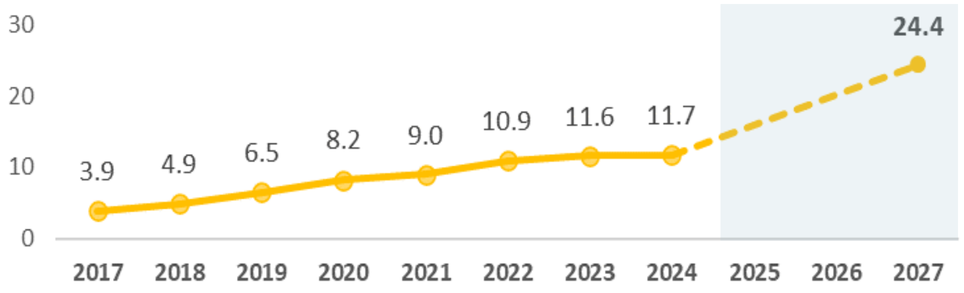
System peak (high growth):
143 MW

Annual energy forecast:
790 GWh (+4% line loss)

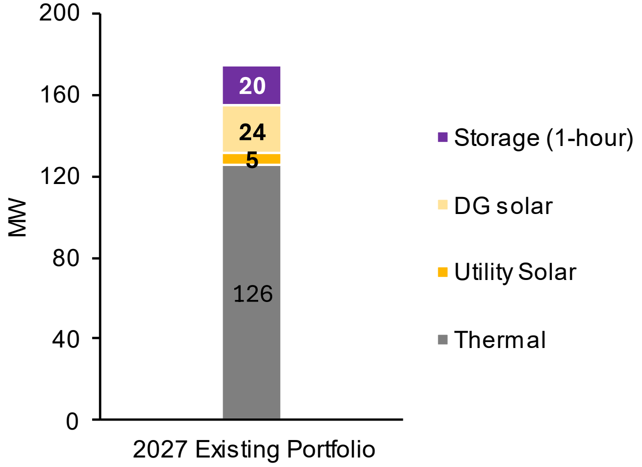
Resource Additions and Retirements

+ **Existing and planned resource additions in the next three years are reflected in modeling:**
  - Growth of interconnected distributed solar to reach 24 MW by 2027 (based on CUC estimation)
  - Two one-hour energy storage systems recently added on the island
+ **37 MW of thermal resources are scheduled to be retired by 2027***
+ **Hybrid system currently under consideration in an RFQ** (Utility scale PV coupled with 4-hour storage behind a same inverter) **is modeled in a sensitivity case to understand its impact on 2027 CUC procurement need**

DG PV Forecasts on Grand Cayman
(MW ac)



2027 Existing and Planned Resources
(MW)



*For modeling purposes, all resources scheduled for retirement before 2027 summer were made unavailable by end of December 2026.

Load and Renewable Datasets were Extended to Capture a Broad Range of Weather Conditions

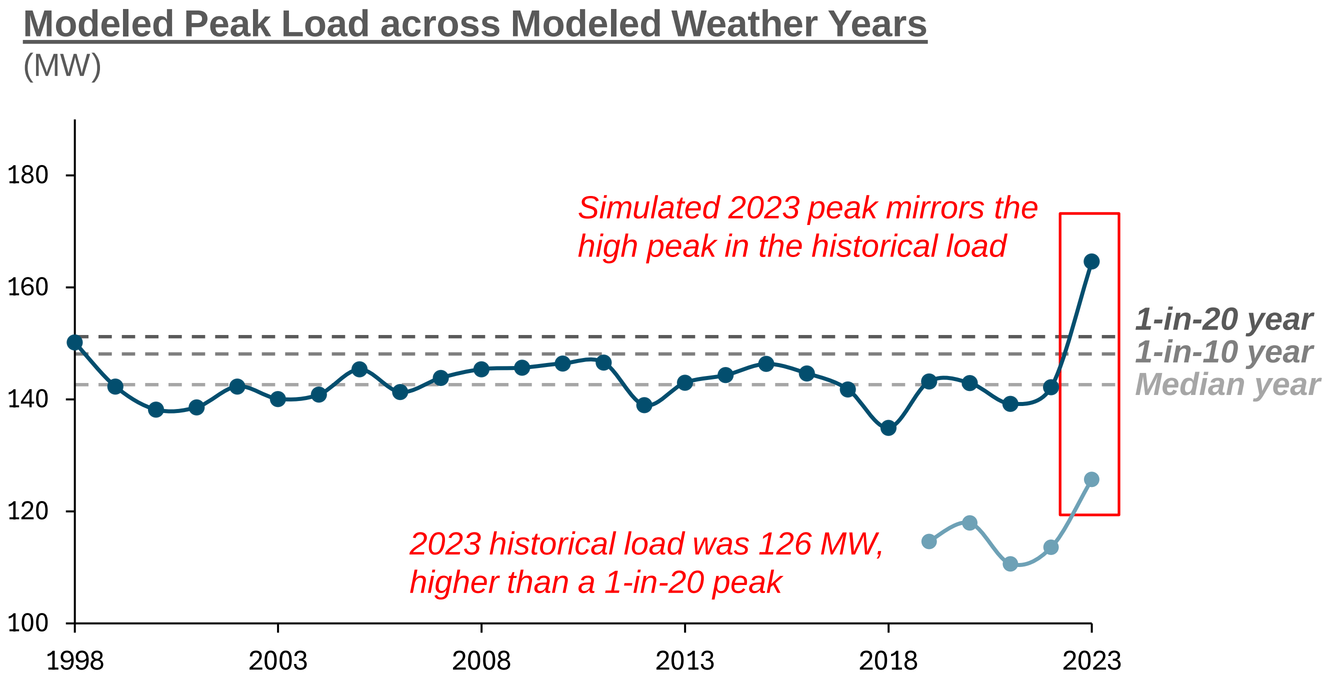
+ **Load shapes and solar profiles were simulated for extended weather years between 1998-2023 to capture the uncertainties in electric demand and the frequency of low solar output periods**

Profile	Primary Source(s)	Weather Conditions Captured	Approach
Loads	**CUC** Hourly Historical Load	2019 - 2023	• E3's neural network regression model was used to back-cast hourly load patterns under **broad range of weather conditions** using recent gross historical load data (2019-2023*, for model training) and long-term weather data (1998-2023) • Historical shape was scaled to match future forecasts of CUC energy demand
	NOAA Historical Weather Data	1998 - 2023	
Solar	**CUC** Historical Solar Production	2020 - 2023	• Profiles for **existing utility-scale solar and distributed resources** were simulated based on plant locations and characteristics (tilt, inverter loading ratio); output was scaled to match historical production • Profiles for **additional utility-scale solar resources** simulated based on expected project locations and technology characteristics, based on input from CUC
	NREL System Advisor Model	1998 - 2023	

**2020 was excluded from model training since load was abnormally low due to the COVID pandemic*

Hourly Loads Simulation

+ **To capture the uncertainties in electricity demands, E3 modeled a broad range of weather conditions observed across historical periods**
  - A neural network model is used to simulate hourly gross load profile for 1998-2023 based on historical temperature conditions
  - Simulated hourly loads are generally well-aligned with actual historical records (R2*: 89.1%)



Simulated annual peak
The simulated historical load profile is scaled to 2027 expected load (both peak and annual sales) to provide a set of potential realization of 2027 electric demands

Historical peak load
For benchmark in training of the neural network

* R2 (the coefficient of determination) is a measure that provides information about the goodness of fit of a model

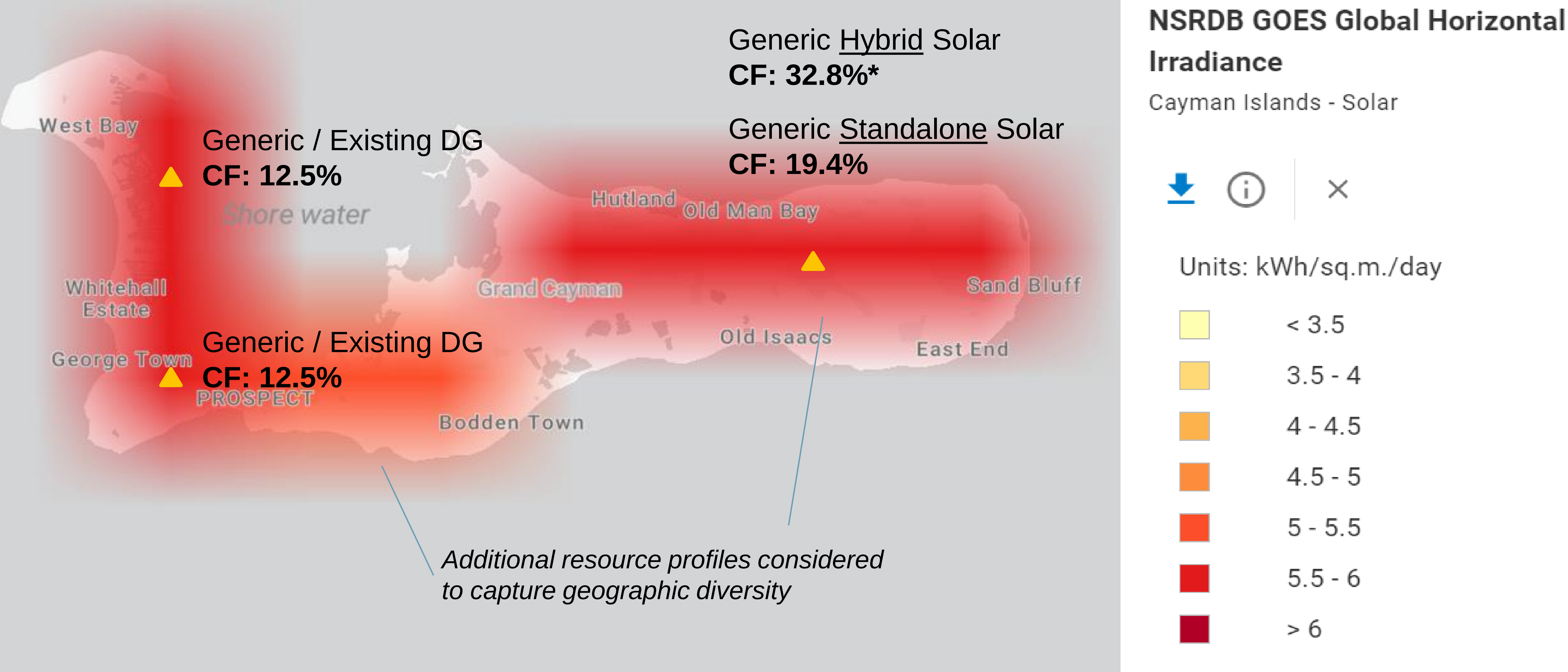
Renewable Profile Development

- For existing solar projects, a plant-level generation profile is simulated based on location and identified panel characteristics
- For new resource additions, simulated profiles reflect locations identified with CUC input

	Size (MW ac)	ILR	Tilt	Tracking Type	Azimuth
Utility-scale Solar					
Existing Bodden Town Solar	5	1.32	15	Fixed; No tracking	180
Planned RFQ Hybrid Solar	23	2	15	Fixed; No tracking	180
Generic Standalone Solar	-	1.32	15	Fixed; No tracking	180
Generic Hybrid Solar	-	2	15	Fixed; No tracking	180
Distributed Solar					
Residential (*Existing & Generic*)	7.1	1.25	20 (roof-mounting)	Fixed; No tracking	180
Commercial (*Existing & Generic*)	4.7	1.25	10 (roof-mounting)	Fixed; No tracking	180

Source: CUC and E3 assumption based on Berkeley Tracking the Sun report

Illustrative Location for Existing and Generic Solar Projects



Source: RE Data Explorer (re-explorer.org)

* Hybrid solar capacity factors are higher due to the higher inverter loading ratio (more DC solar energy behind the inverter).

Thermal Outages Modeling

- **For thermal generators, both Forced Outage Rate (FOR) and Maintenance Outage Schedule are modeled to capture the impact of thermal outages on its ability to serve loads**
- **Maintenance outages were provided by CUC based on planned schedules**
  - Note that planned outages scheduled to occur in summer peak load periods could have pronounced impact in small island grids like CUC
  - A sensitivity was also performed to investigate impacts of moving planned maintenances to off-peak periods
- **FOR was calculated based on historical forced outage records from 2021 to 2023**
  - Each unit was assigned an individual forced outage rate based on its historical performance

Modeled Maintenance Schedules for CUC Thermal Units

	Original Schedule (from 2022 LOLP study)	**Moved Maintenance** (Sensitivity)
Unit 20	Apr 2 – Jun 18	Jan 23 – Mar 18
Unit 31	Dec 24 – Dec 31	Dec 24 – Dec 31
Unit 36	May 28 – Jun 27	Mar 1 – Mar 31

Weighted FOR% for CUC Thermal Units

	2019-2021 (from 2022 LOLP study)	**2021-2023** (modeled in this study)
Fleet-wide	5.7%	6.6%
Baseload Units	3.6%	4.0%
Balancing Units	12.8%	14.8%

LOLP Modeling Analysis Summary

+ **This study evaluates CUC procurement needs in future years within a base case scenario and several sensitivity cases, with key varying factors be:**
  - Study year
  - Load growth scenario
  - Planned RFQ resource inclusion, and
  - Season of planned maintenances

Procurement Need Analysis Scenario	Modeling Year	Load Growth Scenario	Include RFQ hybrid storage?	Move Maintenance to off-peak months?
Base	2027	High	×	×
Sensitivities	**2027**	**High**	✓	**×**
	2027	**High**	**×**	✓
	2026	High	×	×
	2028	High	×	×
	2027	Medium	×	×
	2027	Low	×	×

Reliability Value Analysis on Base Case Scenario only

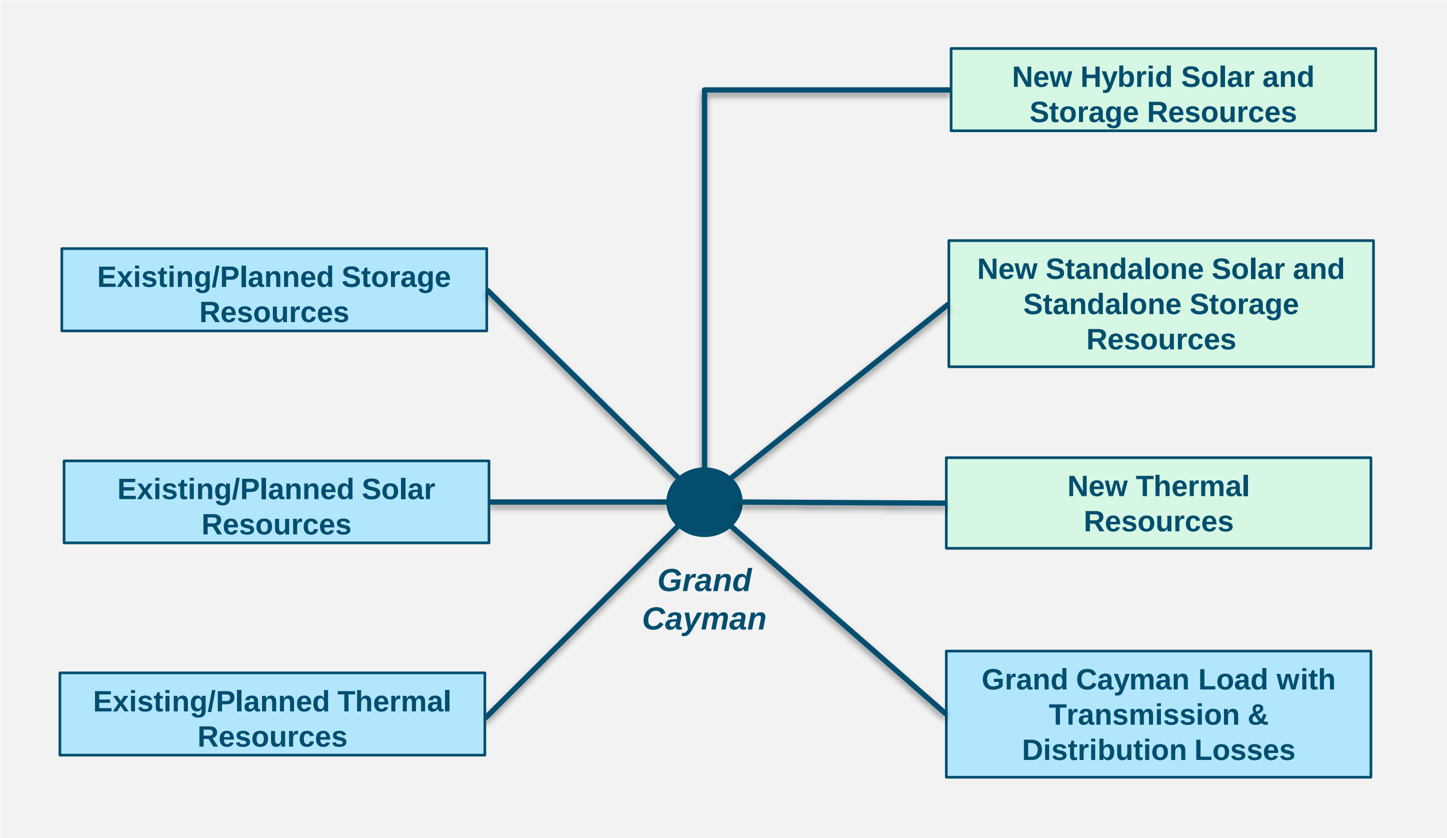
* See Appendix for procurement need results for sensitivity cases

Inputs and Assumptions

PLEXOS Model: Production Cost Modeling

PLEXOS Model Topology

+ **The Grand Cayman System is represented by a single Cayman node with Load and Generation**
    - Load reflects T&D losses of 4%

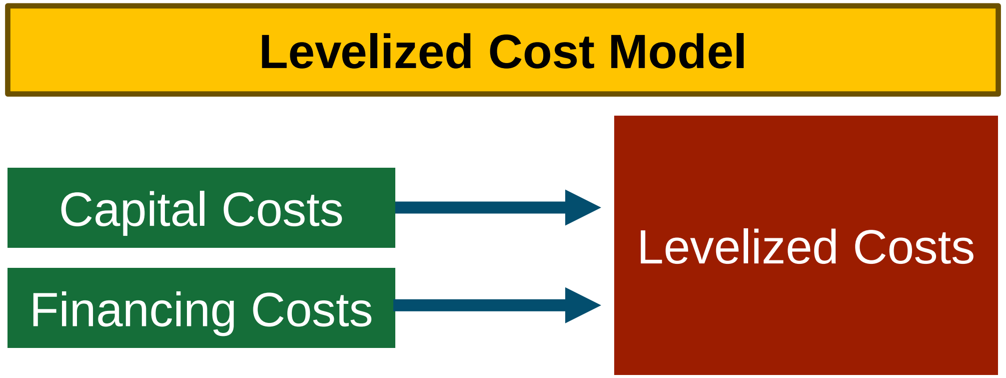


Key PLEXOS Inputs and Assumptions

Category	Unit	Assumptions	Reference
Fuel Costs	$/MMBtu	Diesel fuel costs used in the base case were projected to reach $23.53/MMBtu ($2027) based on West Texas Intermediate (WTI) hub prices. This final fuel cost includes a $5.28/MMBtu CUC delivery adder consisting of delivery + CI duty + fees, also escalated using the Consumer Price Index (CPI). A fuel switch sensitivity explored the impacts of natural gas availability for new thermal and certain existing units with a price varying from $7.33 to $8.67/MMBtu ($2027) depending on the unit, based on Henry Hub gas prices and escalated with CPI. The natural gas fuel costs also include a $5.28/MMBtu CUC delivery adder. For the base model, all existing and new thermal units are diesel-fired. The exception is Unit 28, a steam turbine, part of a combined cycle combustion turbine.	CUC
Variable Costs	$/MWh	Variable costs were projected to reach $6.5 ($2027) based on CPI	CUC
Heat Rates	Btu/kWh	Thermal resource-specific HHV heat rates curves were used for all thermal resources.	CUC
Emissions Rates	lb CO_2/MMBtu	For the base model, a fuel-based emission rate for diesel generation of 163.45 lb/MMBtu was applied to all thermal resources. For the fuel switch sensitivity, a fuel-based emission rate for natural gas generation of 110.95 lb/MMBtu was applied to the new thermal units and selected existing units switching fuels.	U.S. Energy Information Administration (EIA)

Indicative Portfolio Investment Costs

- Resource costs are typically quoted in either "upfront capital costs" ($/kW) or levelized energy ($/MWh) or fixed ($/kW-yr) costs that are indicative of likely PPA prices
- To compare resources across long periods of time, we need to account for all costs together, and E3 presents indicative investment costs with levelized fixed costs as Annual Resource Cost on a Levelized Basis
- Levelized fixed costs include several other project cost factors and assumptions beyond upfront capital cost



Inputs and Assumptions

Scenario Design

Additional Resource Technologies Evaluated in RECAP

- **In reliability value analysis, E3 evaluated a select set of thermal, solar and storage candidate resources identified by CUC**
- **Different penetrations of solar and storage additions are modeled to construct:**
  - Standalone ELCC curves; and
  - Full solar MW - storage MWh ELCC surface assuming a DC-coupled configuration

Resource Tiers Modeled

	Tier size (MW)	Maximum Cumulative Additions (MW)
Standalone Solar	25	200
Standalone Storage (4-hour)	25	200
Hybrid Solar + Storage (various duration)	25	200
New Thermal	18.025*	90.125

* Represent the size of single thermal unit based off 18V51/60 units shared by CUC

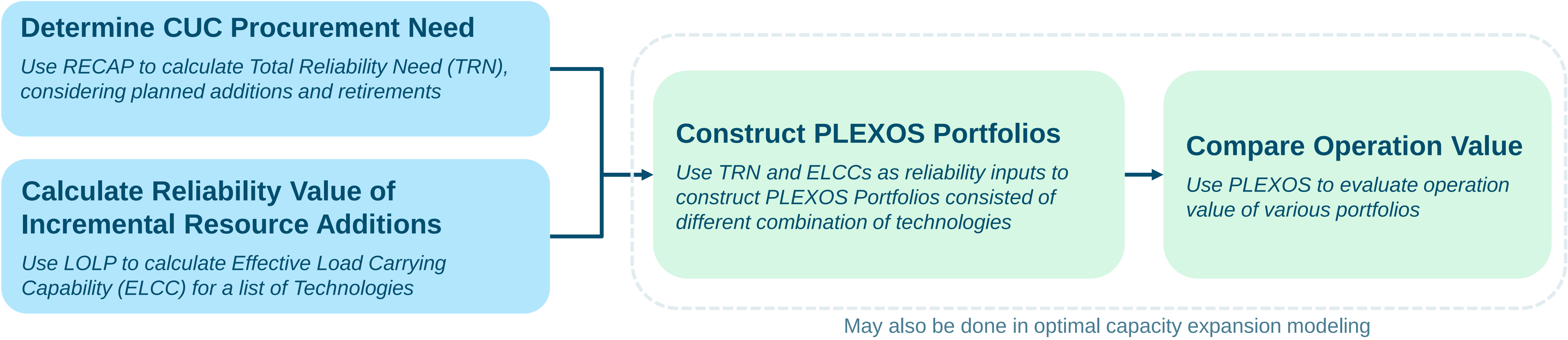
Illustrative Solar + Storage Configuration Settings

50 MW solar + 50 MW storage Example

	Standalone	DC-coupled
Utility-Solar Capacity (MWac)	50	50
Utility-Solar ILR	1.3	2
Storage Capacity (4-hr) (MW)	50	50
Storage Round Trip Efficiency	87%	85%
Storage Max Output	100%	100%
Grid-charging allowed	-	Yes
Inverter Limit (MW)	Solar + Storage Capacity	Storage Capacity

PLEXOS Model Portfolio Development

- **Multiple scenarios were developed to calculate the operational cost impacts of potential resource portfolios in 2027**
- **RECAP LOLP modeling informed the scenario design, to ensure that the resource portfolios studied met the reliability shortfall identified**



- **This approach differs from capacity expansion modeling, which identifies least-cost resource portfolios with consideration of future policies, technology availability, fuel prices, and demand forecasts, among other factors**
  - In this case, the resource cost data will come from the solicitation bids rather than model assumptions

PLEXOS Scenarios Based on Reliability Input

- **Four main scenarios were constructed around key CUC resource options**
  - Scenario 1 represents a business-as-usual (BAU) approach with thermal only additions.
  - Scenarios 2-4 present varying penetrations of standalone and hybrid solar + storage solutions.
- **All study scenarios bring the system to reliable (0.1 LOLE)**

New Thermal capacity reflects discrete unit size (18.025 MW/unit) and differs from the capacity necessary for grid reliability identified in LOLP modeling that could lead to fractional unit build decisions

- For example, Scenario 3.5 needs 5.2 MW firm capacity from thermal resources to meet the reliability target, and this is shown as one unit with 18.025 MW in the PLEXOS Scenarios table. *Please See Appendix for actual resource needs*.

Production Cost Model Scenarios: 2027 CUC Portfolio Incremental Capacity

		Thermal *(MW)*	Solar *(MW ac)*	Hybrid Storage *(MW)*	
				4 Hour	8 hour
Scenario 1: Thermal BAU	1.1	90.1	-		
Scenario 2*: Standalone Solar + Thermal	2.1	90.1	25	-	
	2.2	90.1	50		
	2.3	90.1	75		
	2.4	90.1	100		
	2.5	90.1	150		
	2.6	90.1	200		
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-
	3.2	52.1	50	50	
	3.3	36.1	75	75	
	3.4	36.1	100	100	
	3.5	18.0	150	150	
Scenario 4: Hybrid S+S	4.1	-	175	175	-
	4.2		200	200	
	4.3		150	-	150
	4.4		175	50	125
	4.5		175	100	75

* In Scenario 2, size of standalone solar additions are scaled up to get similar DC energy from 2 ILR hybrid solar

RECAP LOLP Modeling Results

Reliability Procurement Need and Value of Resource Additions

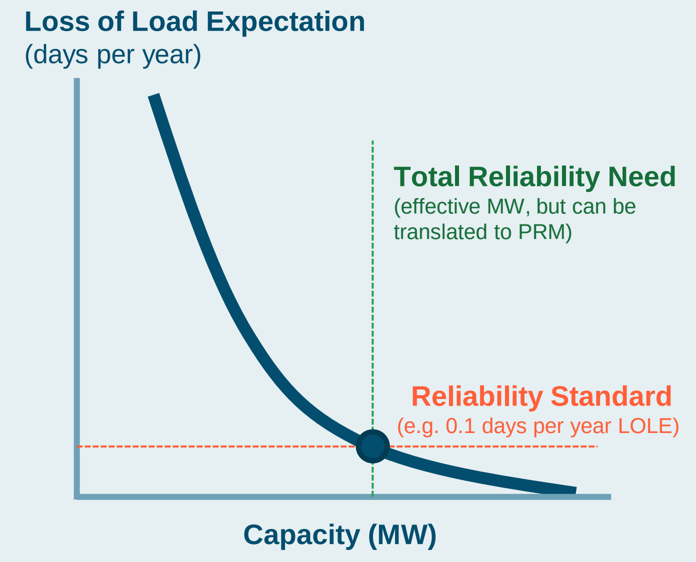
Energy+Environmental Economics

Use Total Resource Need to Derive Planning Reserve Margin

+ **Total Resource Need (TRN) is the quantity of effective capacity needed to meet a defined reliability standard**
  - "1 day in 10 years" or 0.1 LOLE in CUC grid

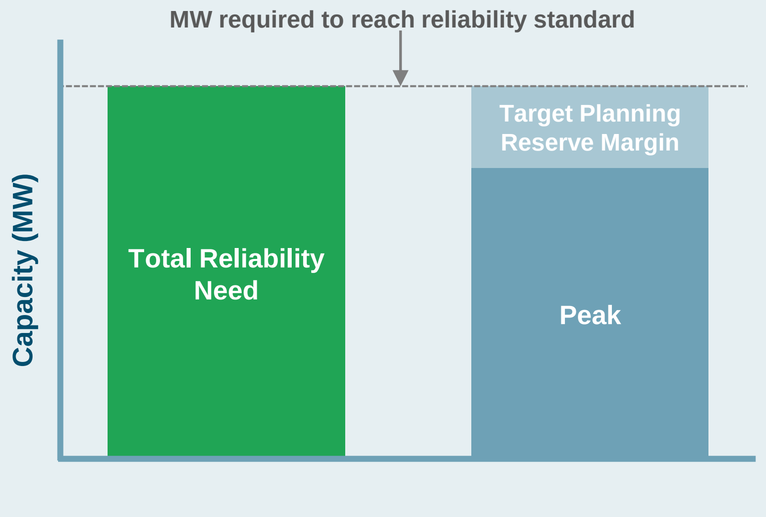
+ **Planning Reserve Margin (PRM) is measured as the quantity of capacity needed above the median year peak load to meet the LOLE standard**

Identify the Total Reliability Need



Total Reliability Need =
Total capacity MW necessary to maintain an adopted reliability standard (e.g. < 0.1 day/yr LOLE).

Translate to a PRM

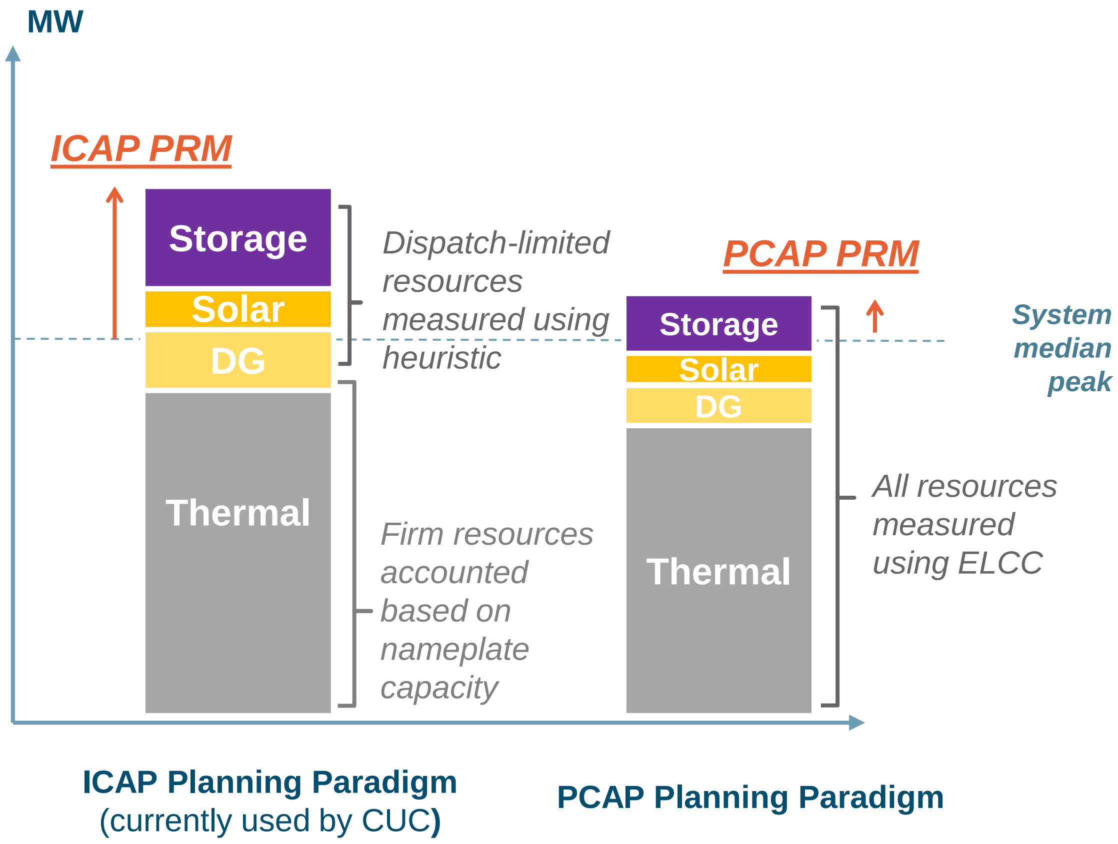


Planning Reserve Margin =
% margin above peak demand necessary to reach the TRN

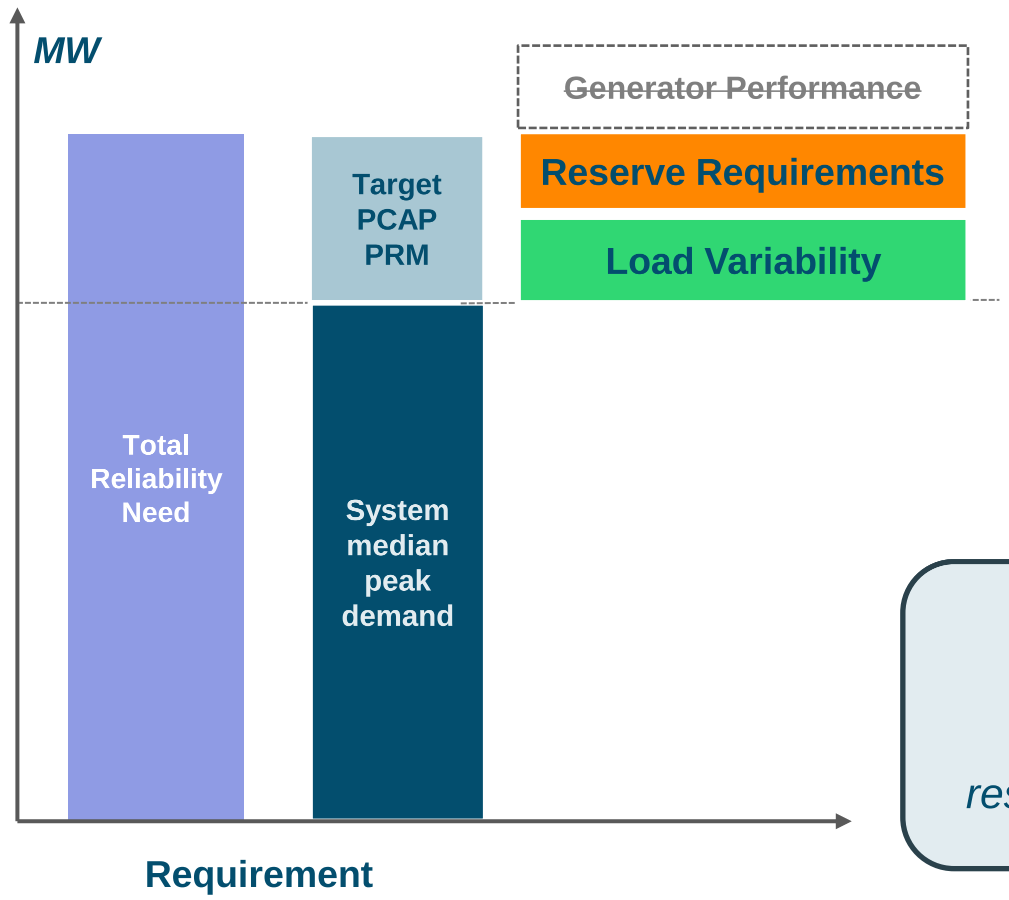
$$PRM\ \% = \left(\frac{TRN}{Peak\ Demand}\right) - 1$$

A PCAP PRM target for CUC was calculated using LOLP Modeling in this study

+ **In this study, E3 calculated a PRM requirement based on need for Equivalent Perfect Capacity (PCAP)**
  - All Resources' capacity contribution are measured using ELCC (perfect capacity)
+ **Historically, CUC retains a 35-55% planning reserve margin (PRM) to ensure reliable electricity supply**
  - This PRM was defined based on Installed Capacity (ICAP), and thermal resources are accredited based on nameplate capacities



Decomposing the contribution to PCAP PRM into parts



PCAP PRM covers **annual peak load variation** and **operating reserve requirements**, while addressing forced outage risks in resource accreditation

Reserve Requirements covers contingency reserves CUC needs to hold in case of the largest possible unit outage

Load Variability considers weather-driven baseline demands uncertainties

Note that:
Contingency reserves modeled in RECAP are currently a fixed amount (30 MW); this means the % of PRM requirement from reserve requirements would decrease as median peak load grows.

2027 CUC Capacity Position and Procurement Needs

Loads & Resources	2027		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Thermal	126	102	81%
Utility Solar	5	1	22%
DG	24	1	3%
Storage (1-hour)	20	8	42%
Total Supply	**175**	**112**	
Median Peak Demand		143*	
Total Resource Need		194	
Procurement Need		82	
Achieved ICAP Reserve Margin		-5%	
Target ICAP Reserve Margin		53%	
Achieved PCAP Reserve Margin		-21%	
Target PCAP Reserve Margin		36%	

* Note: Assume high load growth scenario

Thermal contribution in times of need could be lower than nameplate due to modeled outages

Dispatch-limited storage cannot act as perfect resource due to duration limits

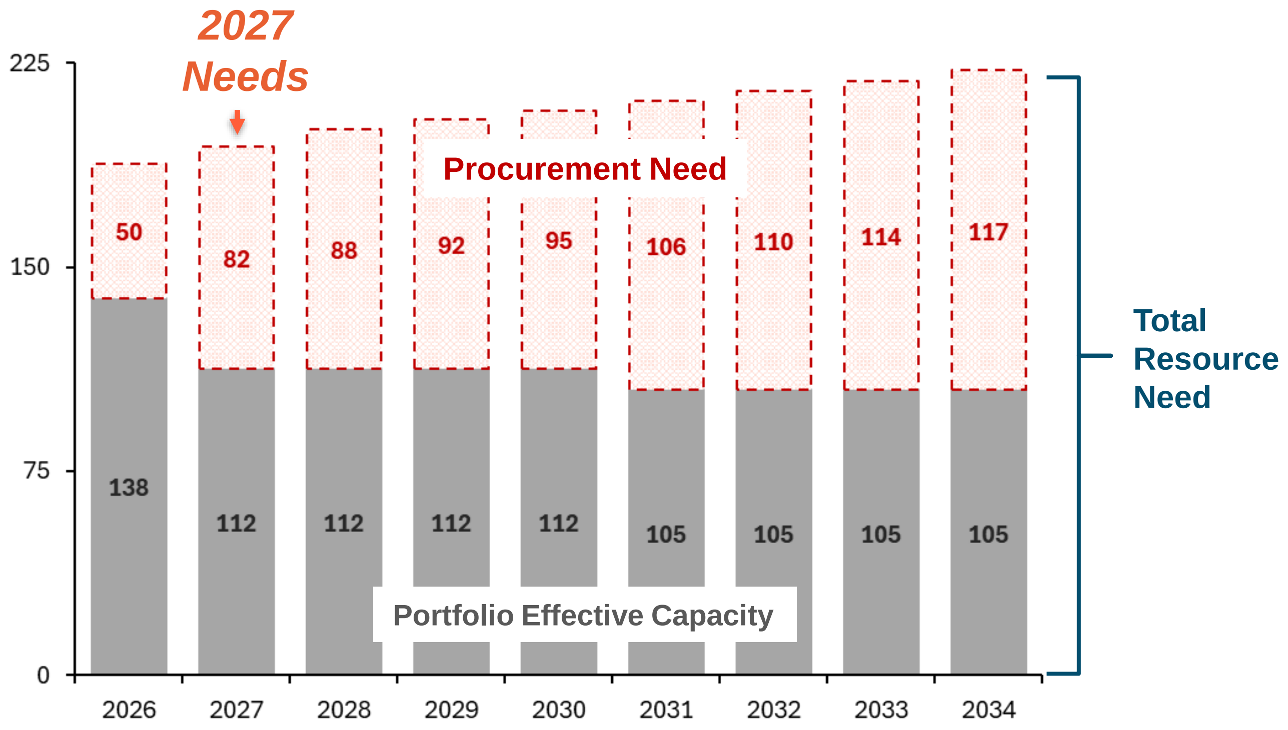
With existing portfolio and projected load growth, CUC needs to procure additional ~82 MW perfect capacity resources to meet reliability target in 2027

Target ICAP PRM (53%) is close to the upper bound of CUC's past reserve margin (55%);

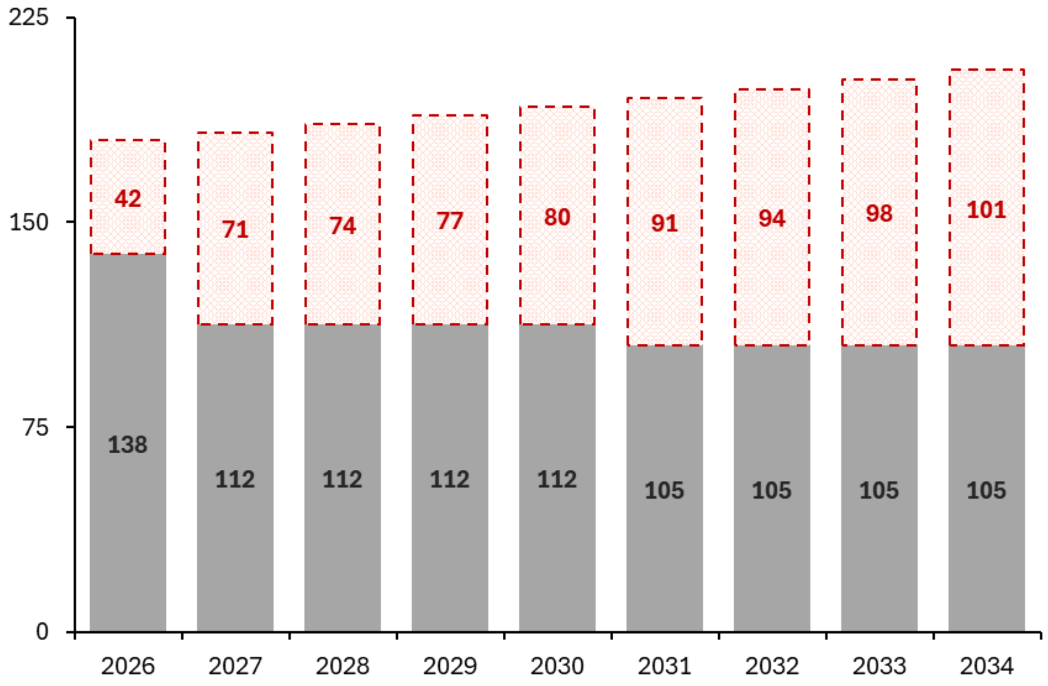
Target PCAP PRM (36%) reaches equivalent reliability as the 53% ICAP PRM but uses perfect capacity (ELCC) accounting, addressing thermal outage risks in ELCC accreditation

2026 - 2034 CUC Capacity Position Outlook

<u>Projected TRN and Procurement Need – *High Load Growth*</u> *(MW)*



<u>Projected TRN and Procurement Need – *Mid Load Growth*</u> *(MW)*



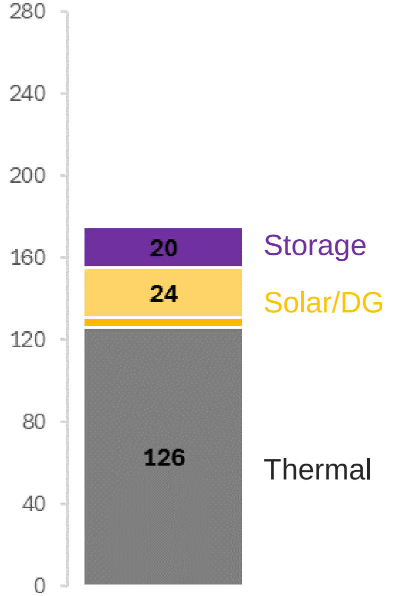
Increasing Total Resource Need due to growing energy demand in future years
+
Reducing Portfolio Effective Capacity due to retirement of existing thermal fleet

→ **Growing Procurement Need**

Evaluate size and timing of most critical resource needs in a calibrated system

+ **With existing resource portfolios, the CUC system would not have sufficient generation to meet 2027 load requirements in much of the year**
+ **To pinpoint the riskiest periods of the time for the grid, perfect capacity is added to calibrate the system to 0.1 days/yr LOLE in 2027**
  - Observed reliability risk in this at-criteria system is similar to when new firm thermal capacity (with a low forced outage rate) is procured and added to the grid

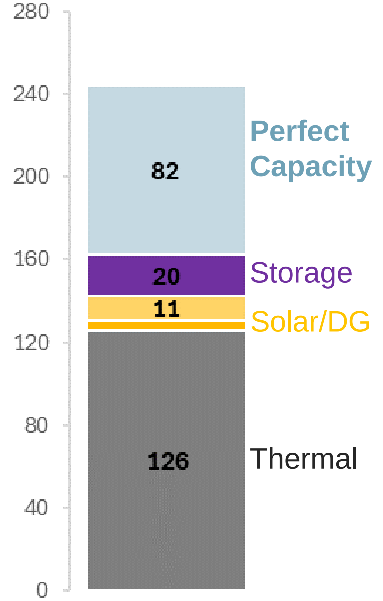
Installed Capacity (MW)



Existing System

- **304 days/year LOLE**
- Need additional capacity resources (~82 ELCC MW) to satisfy reliability requirement
- Hard to demonstrate when the riskiest time is in the system

Installed Capacity (MW)



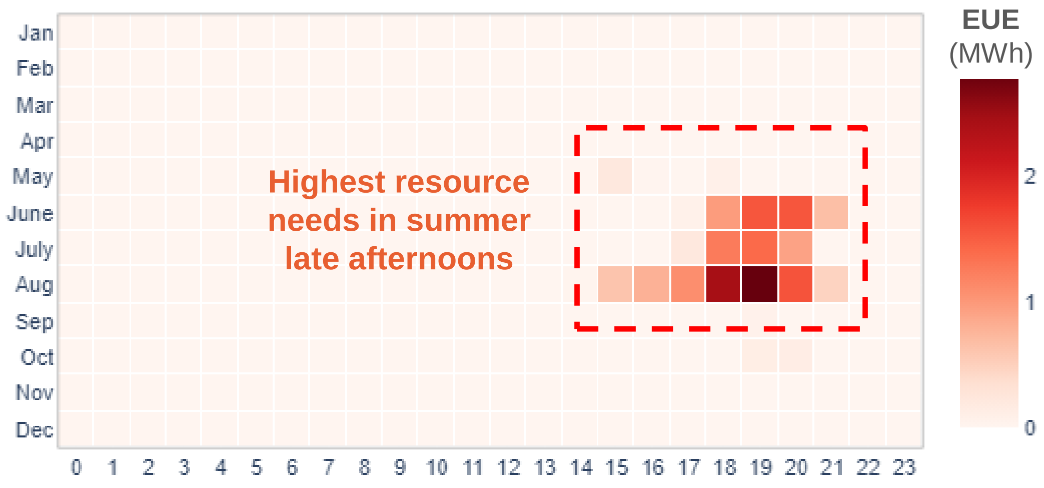
Calibrated System

- 0.1 days/year LOLE
- Assume 82 MW of perfect capacity is added to the system to achieve reliability standard
- Zoom into the time when the system is in the most need when already meets reliability target

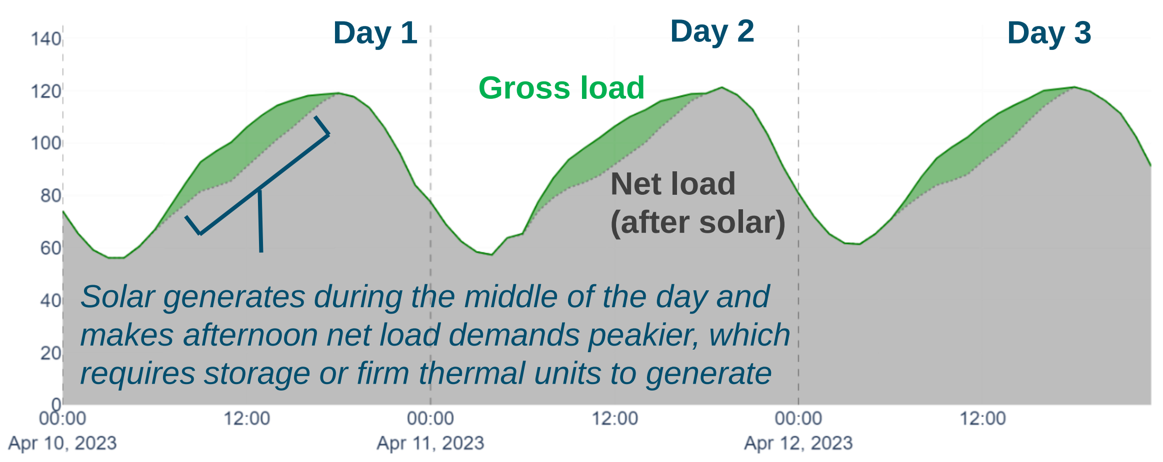
2027 CUC Calibrated System Reliability Challenges

+ **In a CUC grid comprised of mostly dispatchable thermal resources, forced outages during periods of high load drive simulated loss-of-load events**
  - Risk concentrated in the summer late afternoons*
+ **Existing solar resources help mitigate loss-of-load risk in the early afternoon, shifting the "net load" peak to the late afternoon / evening period and making remaining load peaks shorter**
  - Two 10 MW/10MWh battery resources can discharge to serve net loads but are constrained by duration limitations

Month Hour Loss-of-Load Risk Heatmap for Existing System

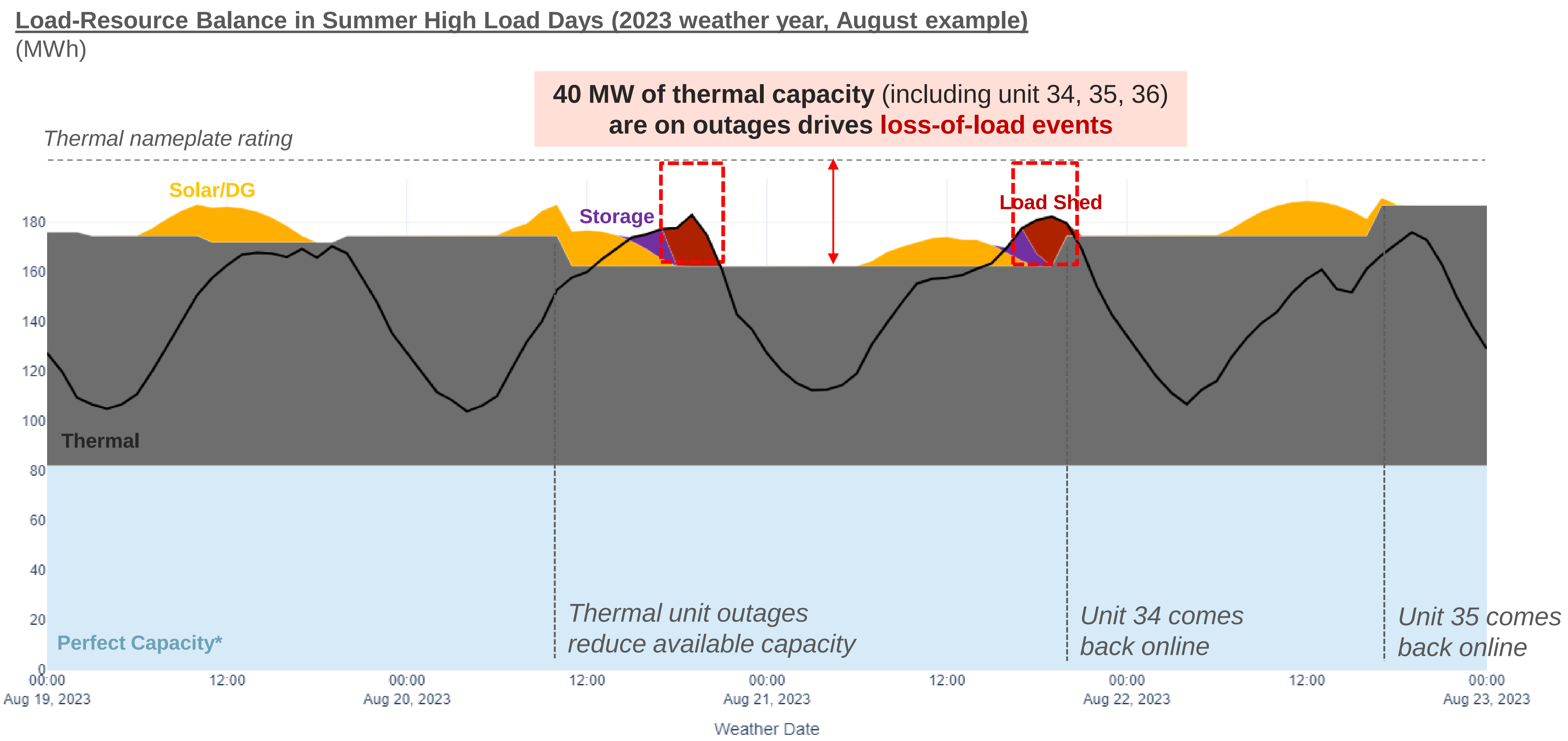


Gross & Net Load on Representative Summer Days



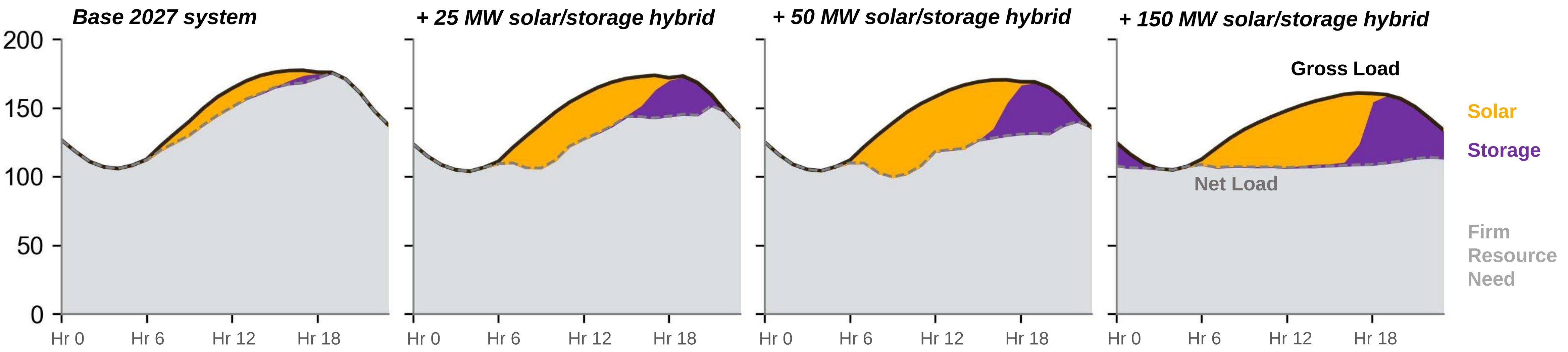
* Small loss-of-load risks shown in June are due to modeled planned maintenance outages for two of the baseload units, which potentially can be addressed by adjusted outage schedules

Illustrative Loss-of-Load Day Dispatch in 0.1 LOLE System

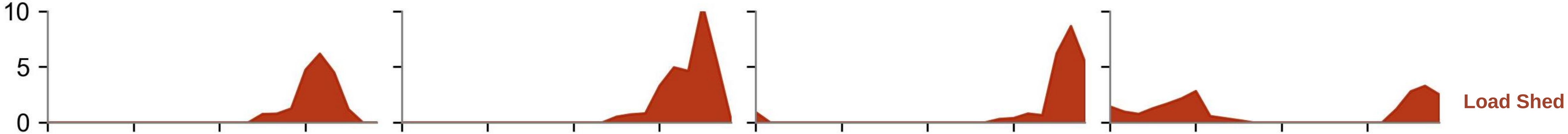


Evolving grid challenges at increasing renewable penetrations

Load and Resource Balance in System with Various Hybrid Penetration (MWh)



System Load Shed Pattern (MWh unserved energy)



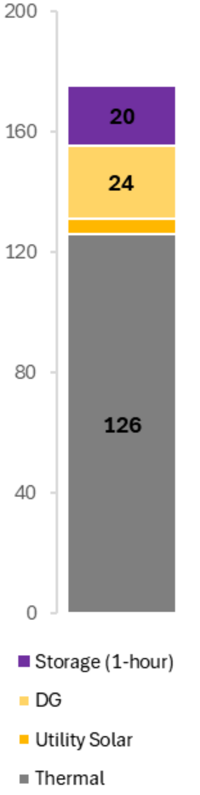
In the current system, system risks are focused on **summer late afternoons** when **high gross loads coincide with thermal forced outages**

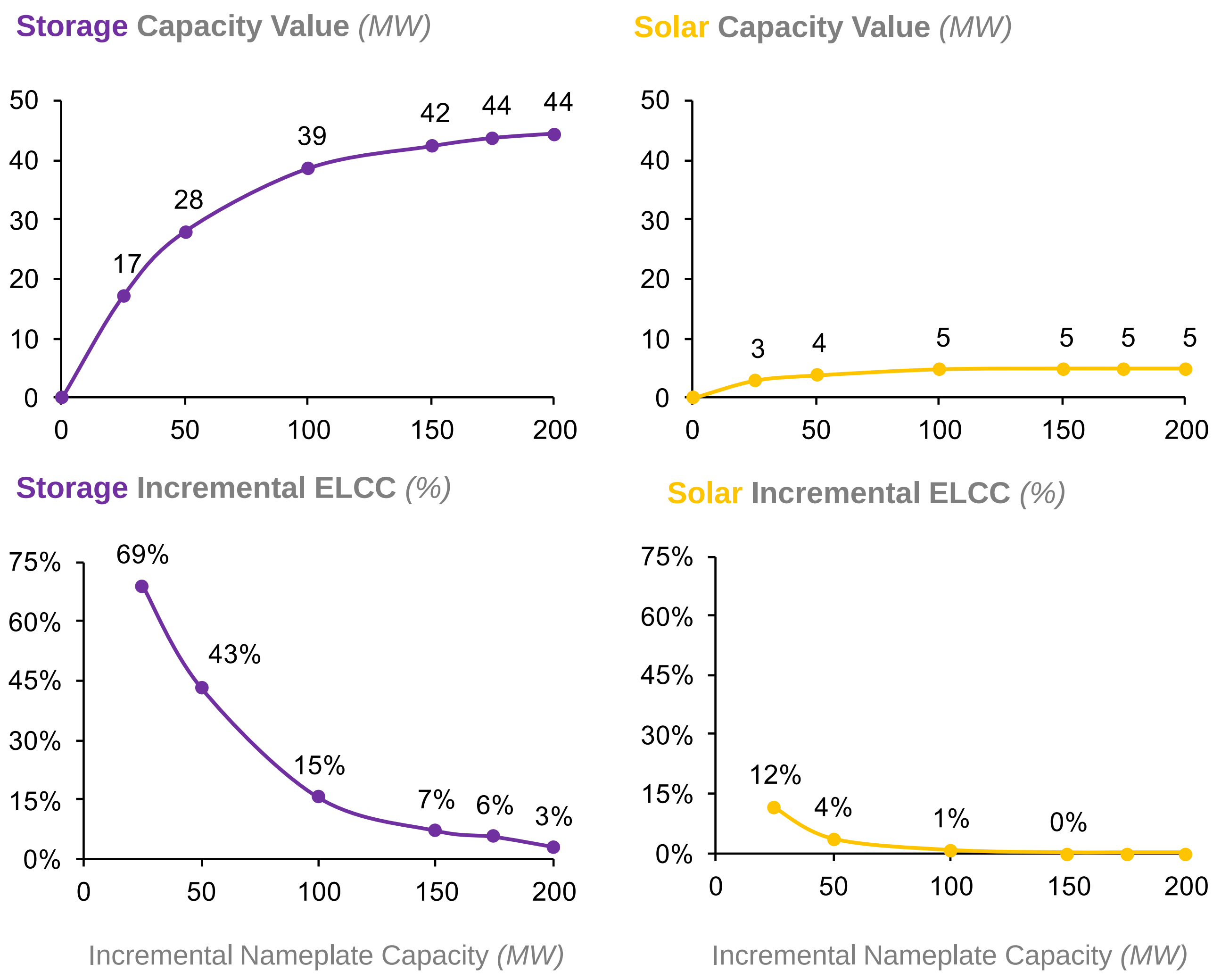
As solar + storage is added, risk periods **become longer** and shift to **high net load periods outside solar hours,** requiring firm capacity with extended duration output

Standalone Solar and 4-hour Storage Capacity Value

- **4-hour storage brings high marginal capacity value at low penetration, but becomes less effective as storage additions increase**
  - Storage is well suited to dispatch during early evening net peak periods at low penetrations, but saturation effects becomes evident after ~25 MW of installed capacity addition
  - Net peaks become too long for 4-hr storage and charging sufficiency may become a challenge
- **Atop existing DG and utility solar, the additional marginal capacity value of solar is relatively low and declines towards zero with increasing levels as net peak load shifts to non-solar hours**

<u>2027 Existing Capacity (MW)</u>

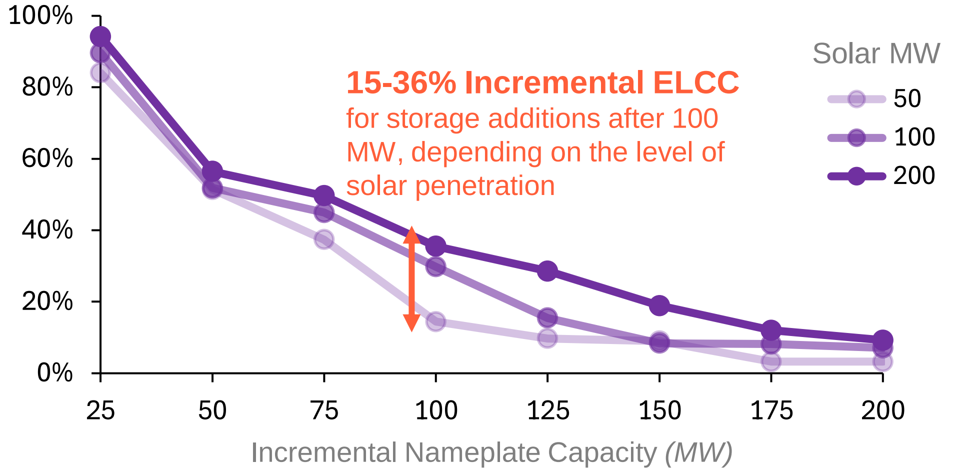




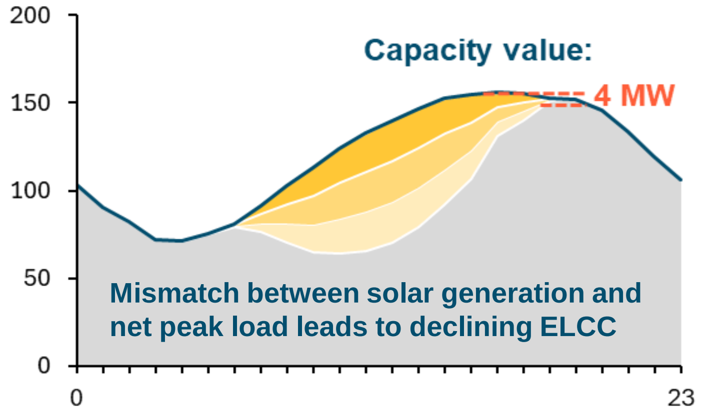
Combining Solar and Storage Creates a Diversity Benefit

- **Adding standalone solar and storage quickly exhibits saturation effects in CUC grid, while combinations of the two resources exhibit interactive effects**
  - Positive interactive effects between solar and storage are referred to as "diversity benefits"
- **This comes from the complimentary nature of the two resources**
  - Additional solar makes the net load evening peaks sharper, which improves value of limited duration energy storage resources

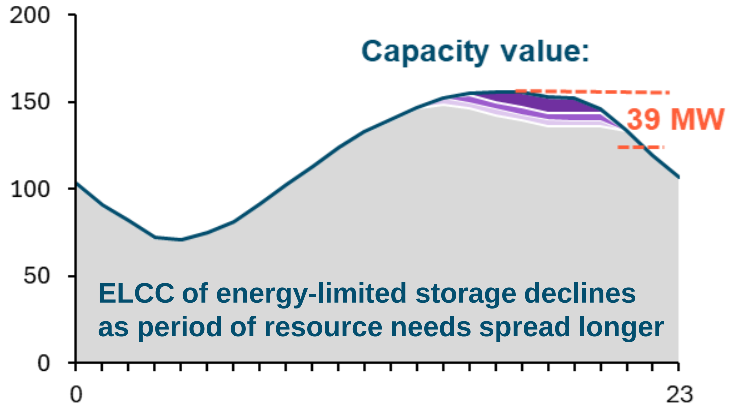
4-hr Storage Incremental ELCC with varying Solar MW *(%)*



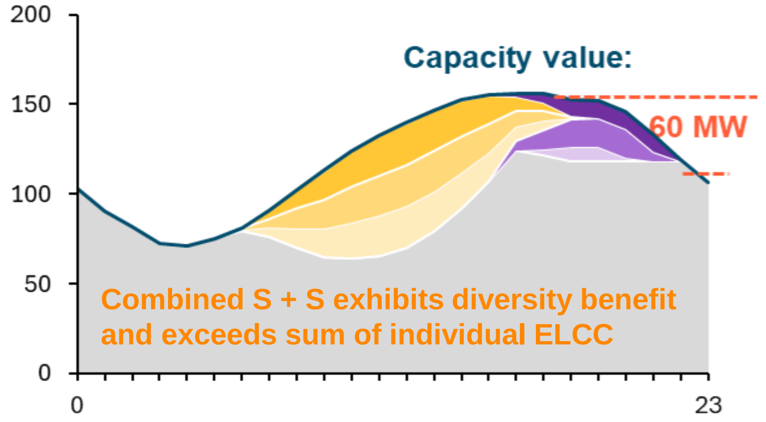
Solar Impact on Net load
(MW)



Storage Impact on Net load
(MW)



Combined Impact on Net load
(MW)



Reliability Value of Adding Solar and Storage Hybrids

Hybrid Solar and Storage Capacity Value *(ELCC MW)*

Assuming 2.0 ILR for hybrid solar

Increasing storage duration (MWh) →

Increasing solar + storage capacity (MW) ↓

Inverter size *(MW)*	2 hour	4 hour	6 hour	8 hour
25	15	24	25	25
50	26	39	48	49
75	35	52	62	66
100	41	62	71	76
125	49	71	78	83
150	56	77	84	90
175	61	82	90	96
200	66	86	95	102

With 2 ILR paired solar, solar provides sufficient energy to charge paired storage; longer duration is generally needed to maximum resources' capacity value

- **E3 modeled incremental solar and storage growth as DC-coupled hybrids with a 2.0 inverter loading ratio (ILR)*, and grid-charging is allowed**
  - E.g., a 100 MW DC-coupled hybrid with 4-hour storage duration would have 200 MW DC solar, 400 MWh of storage, and a maximum output of 100 MW from the shared inverter
  - In DC-coupled hybrid systems, excess solar generation beyond inverter's rated output is used to charge storage, shifting output to late afternoon or evening, which increases the (AC) capacity factor and the ELCC
- **Longer duration hybrids provide longer storage discharge relative to the same inverter size, which increases the resource's capacity value**
  - 125 MW hybrid with 4-hour storage → 71 MW ELCC
  - 125 MW hybrid with 6-hour storage** → 78 MW ELCC
  - 125 MW hybrid with 8-hour storage → 83 MW ELCC
- **With increased inverter size, incremental storage capacity value diminishes; this would be exacerbated with ILRs higher than the value assumed in this study**

* The inverter loading ratio (ILR) is defined as the ratio of solar DC capacity behind the DC-to-AC inverter and the AC output of the inverter itself

** 125 MW hybrid 6-hour storage resource value is equivalent to a 62.5 MW 4-hr hybrid + a 62.5 MW 8-hr hybrid

Reliability Value of New Thermal

+ **E3 evaluated the reliability value of generic new thermal unit with perfect capacity (i.e., ELCCs)**
+ **Reliability value reflects its availability to serve load in all hours, accounting for the time when offline due to forced outage events**
  - Forced outage rate input is based on historical performance of similar thermal unit model sourced from CUC

New Thermal Resource Input and Capacity Value Summary

	Unit Capacity *(Nameplate MW)*	Forced Outage Rate *(%)*	Maintenance Schedule	Capacity Value *(%)*
Generic Thermal	18.25	0.66%	-	99.34%

High thermal ELCCs due to low outage rate assumption, which is based on historical performance of similar, existing thermal plants

Note that weather-dependent outages and fuel-availability related outages are not explicitly modeled and incorporated in accreditation

PLEXOS Production Cost Modeling Results

Operational Cost Savings, Achieved Clean Energy, and Emissions Reductions

Emissions Reduction and Clean Energy Achievement

PLEXOS Scenario for Calibrating 2027 Portfolio						Emissions* Relative to 2019	Clean Energy Generation	Curtailment
		Thermal *(MW)*	Solar *(MW ac)*	Hybrid Storage *(MW)* 4 Hour	Hybrid Storage *(MW)* 8 hour	%	%	%
Scenario 1: Thermal BAU	1.1	90.1	-			13%	4%	0%
Scenario 2: Standalone Solar + Thermal	2.1	90.1	25	-		1%	14%	0%
	2.2	90.1	50			-11%	24%	0%
	2.3	90.1	75			-22%	33%	4%
	2.4	90.1	100			-27%	38%	15%
	2.5	90.1	150			-32%	42%	35%
	2.6	90.1	200			-35%	44%	48%
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	2%	13%	0%
	3.2	52.1	50	50		-8%	21%	0%
	3.3	36.1	75	75		-18%	30%	0%
	3.4	36.1	100	100		-28%	39%	0%
	3.5	18	150	150		-48%	55%	0%
Scenario 4: Hybird S+S	4.1	-	175	175	-	-56%	62%	2%
	4.2		200	200		-63%	68%	5%
	4.3		150	-	150	-48%	55%	0%
	4.4		175	50	125	-57%	63%	0%
	4.5		175	100	75	-56%	62%	2%

Solar **curtailment** increases substantially** with higher penetration levels, but **is minimized by scaling storage with solar growth**

Note higher levels of curtailment would result with a higher-than-assumed ILR hybrid solar

Under the challenge of a high load growth scenario, at least 100 MW of incremental solar capacity is needed to **achieve the 2027 emission reduction target** (~ 25% reduction relative to 2019)

Meeting the **2027 clean energy target of 13% of generation** can be achieved with at least 25 MW of solar additions, with higher increments reaching >60% clean energy

Energy+Environmental Economics

* Total emission calculated from fuel-based emission rate for diesel generators (163.45 lb/MMbtu) according to EIA Carbon Dioxide Emissions Coefficients

** Curtailment includes generation above demand as well as excess solar behind the hybrid inverter that does not reach the grid

Operating and Investment Costs

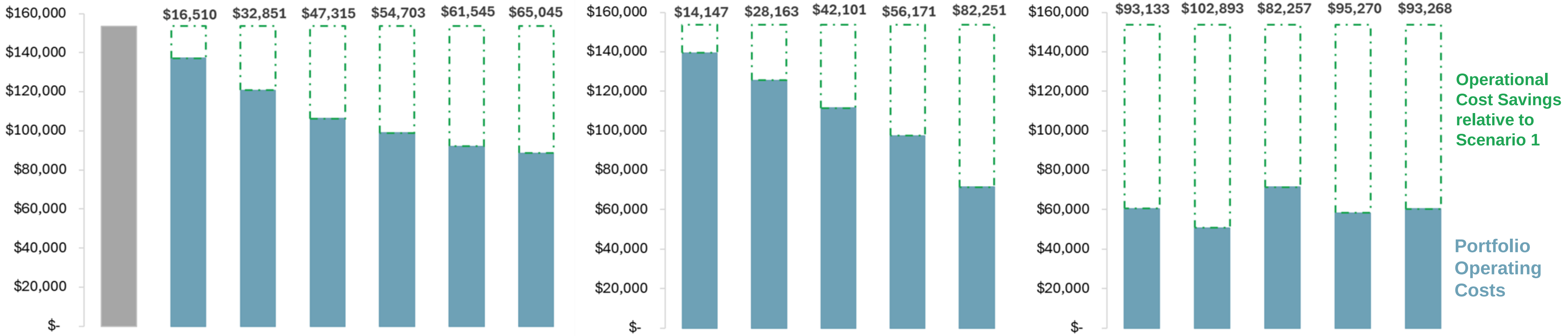
PLEXOS Scenario for Calibrating 2027 Portfolio						Annual Fixed Resource Cost on a Levelized Basis*	Operating Cost	Total Cost	*Total Cost Variance to Scenario 1 BAU*
		Thermal *(MW)*	Solar *(MW ac)*	Hybrid Storage *(MW)* 4 Hour	Hybrid Storage *(MW)* 8 hour	2027 COD ($'000)			
Scenario 1: Thermal BAU	1.1	90.1	-			$ 14,060	$153,637	$167,697	
Scenario 2: Standalone Solar + Thermal	2.1	90.1	25	-		$ 18,118	$137,128	$155,245	-8%
	2.2	90.1	50			$ 22,522	$120,787	$143,309	-17%
	2.3	90.1	75			$ 27,051	$106,322	$133,374	-26%
	2.4	90.1	100			$ 31,455	$ 98,935	$130,390	-29%
	2.5	90.1	150			$ 40,544	$ 92,093	$132,636	-26%
	2.6	90.1	200			$ 49,654	$ 88,593	$138,247	-21%
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	$ 22,585	$139,491	$162,075	-3%
	3.2	52.1	50	50		$ 32,588	$125,474	$158,062	-6%
	3.3	36.1	75	75		$ 42,937	$111,536	$154,473	-9%
	3.4	36.1	100	100		$ 53,799	$ 97,466	$151,266	-11%
	3.5	18	150	150		$ 76,476	$ 71,386	$147,862	-13%
Scenario 4: Hybird S+S	4.1	-	175	175	-	$ 88,183	$ 60,505	$148,688	-13%
	4.2		200	200		$100,781	$ 50,745	$151,525	-11%
	4.3		150	-	150	$102,103	$ 71,381	$173,483	3%
	4.4		175	50	125	$110,281	$ 58,367	$168,648	1%
	4.5		175	100	75	$101,442	$ 60,369	$161,811	-4%

*Investment costs are for indicative purposes only and should not be construed as actual costs.

Operating Costs Benefit from CUC Scenarios

- Increasing penetration of solar capacity results in reduced operating costs due to the displacement of fuel and variable operating costs of thermal resources.
- At higher penetrations of standalone solar in Scenario 2 the operating benefits plateau; however, with hybrid solar and storage in scenarios 3 and 4, at higher solar penetrations additional operational cost benefits are achieved due to lower curtailment of solar.

Operation Cost *Savings* relative to Scenario 1 BAU Thermal Portfolio, 2027 COD
($'000/year)

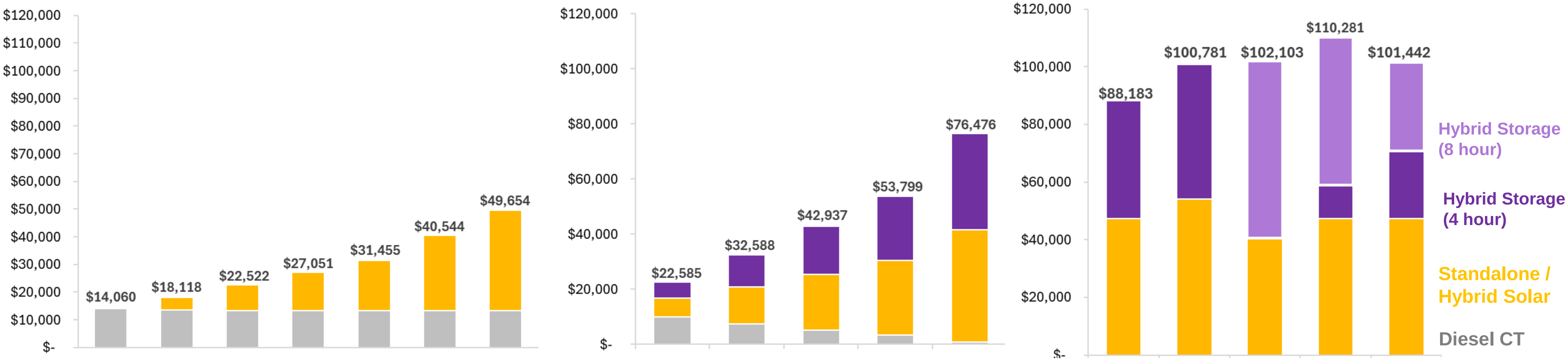


Scenario	SC1.1	SC2.1	SC2.2	SC2.3	SC2.4	SC2.5	SC2.6	SC3.1	SC3.2	SC3.3	SC3.4	SC3.5	SC4.1	SC4.2	SC4.3	SC4.4	SC4.5
Solar / Hybrid Size	0	25	50	75	100	150	200	25	50	75	100	150	175	200	150	175	175

Illustrative Investment Costs for Portfolios

+ **Indicative portfolio investment costs* generally follow the size of new solar and storage additions.**
  - Costs of portfolios with different penetrations of 4- and 8-hr hybrid storage vary due to the costs differences in these systems and may not scale linearly with hybrid size.
+ **While investment costs generally increase with more solar and hybrid capacity, the annual operational costs of these portfolios decrease as shown in previous slides.**

Annualized Investment Costs by Components, 2027 COD ($'000)



Scenario	SC1.1	SC2.1	SC2.2	SC2.3	SC2.4	SC2.5	SC2.6	SC3.1	SC3.2	SC3.3	SC3.4	SC3.5	SC4.1	SC4.2	SC4.3	SC4.4	SC4.5
Solar / Hybrid Size	0	25	50	75	100	150	200	25	50	75	100	150	175	200	150	175	175

*Investment costs are for indicative purposes only and should not be construed as actual costs, shown as Annual Fixed Resource Cost on a Levelized Basis.

Sensitivity Analyses

Natural Gas Fuel Replacement Sensitivity

- **CUC thermal units, which currently run on diesel, may see fuel cost reductions as well as lower emissions from a switch to natural gas. This sensitivity explores the potential effects of shifting specific thermal units in CUC's fleet as well as new thermal additions to natural gas.**
  - Natural gas fuel costs and emissions rates were utilized in place of base diesel assumptions for existing units 32-36 and all new thermal units.
- **Natural gas fuel costs include a cost adder that reflects the local storage, regasification and transport as well as shipping and liquification.**
  - All the costs required to enable fuel switching are not included in the current study. Additional costs for generator upgrades and CUC-sited gas infrastructure, among others, are not considered.

	Diesel		Natural Gas	
	Fuel Cost[1] ($2027/MMBtu)	Emissions Rate[2] (lbCO2/MMBtu)	Fuel Cost[1] ($2027/MMBtu)	Emissions Rate[2] (lbCO2/MMBtu)
Unit 32	$23.53	163.45	$14.21	110.95
Unit 33	$23.53	163.45	$14.21	110.95
Unit 34	$23.53	163.45	$13.23	110.95
Unit 35	$23.53	163.45	$13.55	110.95
Unit 36	$23.53	163.45	$14.56	110.95
New Thermal	$23.53	163.45	$14.24	110.95

[1] Fuel Cost from CUC including fuel delivery adder
[2] Rates from U.S. Energy Information Agency

Fuel Replacement Sensitivity

Emissions Reduction Achievement Compared to Base Case

PLEXOS Scenario for Calibrating 2027 Portfolio						***Base case**** Emissions Relative to 2019	***Fuel Replacement*** Emissions Relative to 2019
		Thermal *(MW)*	Solar *(MW ac)*	Hybrid Storage *(MW)* 4 Hour	Hybrid Storage *(MW)* 8 hour	%	%
Scenario 1: Thermal BAU	1.1	90.1	-			13%	-32%
Scenario 2: Standalone Solar + Thermal	2.1	90.1	25	-		1%	-40%
	2.2	90.1	50			-11%	-47%
	2.3	90.1	75			-22%	-53%
	2.4	90.1	100			-27%	-57%
	2.5	90.1	150			-32%	-60%
	2.6	90.1	200			-35%	-61%
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	2%	-38%
	3.2	52.1	50	50		-8%	-43%
	3.3	36.1	75	75		-18%	-48%
	3.4	36.1	100	100		-28%	-55%
	3.5	18	150	150		-48%	-67%
Scenario 4: Hybird S+S	4.1	-	175	175	-	-56%	-71%
	4.2		200	200		-63%	-76%
	4.3		150	-	150	-48%	-65%
	4.4		175	50	125	-57%	-72%
	4.5		175	100	75	-56%	-71%

*Base Case emissions reduction presented here for comparison.

All cases achieve the 2027 emissions reduction target in the fuel replacement sensitivity where diesel is offset by natural gas generation in select units. (~32% reduction relative to 2019)

Operating Cost and Total Cost Benefit Compared to Base Case

PLEXOS Scenario for Calibrating 2027 Portfolio						Annual Fixed Resource Cost on a Levelized Basis	Fuel Replacement Operating Cost	Fuel Replacement Total Cost	Total Cost Variance to Base Case
		Thermal *(MW)*	Solar *(MW ac)*	Storage *(MW)* 4 Hour	Storage *(MW)* 8 hour	2027 COD ($'000)	($'000)	($'000)	%
Scenario 1: Thermal BAU	1.1	90.1	-			$14,060	$83,367	$97,427	-42%
Scenario 2: Standalone Solar + Thermal	2.1	90.1	25	-		$18,118	$74,256	$92,374	-40%
	2.2	90.1	50			$22,522	$65,320	$87,842	-39%
	2.3	90.1	75			$27,051	$57,496	$84,547	-37%
	2.4	90.1	100			$31,455	$53,544	$84,999	-35%
	2.5	90.1	150			$40,544	$49,867	$90,411	-32%
	2.6	90.1	200			$49,654	$47,897	$97,551	-29%
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	$22,585	$75,770	$98,355	-39%
	3.2	52.1	50	50		$32,588	$68,742	$101,330	-36%
	3.3	36.1	75	75		$42,937	$62,058	$104,995	-32%
	3.4	36.1	100	100		$53,799	$53,651	$107,450	-29%
	3.5	18	150	150		$76,476	$39,603	$116,079	-21%
Scenario 4: Hybird S+S	4.1	-	175	175	-	$88,183	$35,179	$123,362	-17%
	4.2		200	200		$100,781	$29,052	$129,833	-14%
	4.3		150	-	150	$102,103	$41,378	$143,481	-17%
	4.4		175	50	125	$110,281	$33,084	$143,365	-15%
	4.5		175	100	75	$101,442	$34,627	$136,069	-16%

Fuel switching enables **reduced fuel costs** compared to a diesel-fired only portfolio; Investment costs do not change in this sensitivity.

DG + Standalone Storage Sensitivity

- E3 evaluated two additional DG solar cases to explore alternatives to high-penetration utility-scale hybrid solar + storage portfolios, given potential development risks in Grand Cayman, such as land-use permitting, and environmental risks among others
- Cases 3.4.1 and 3.4.2 include 20 MW of incremental DG resources as well as 4- and/or 8-hour standalone storage, to replace 50 MW of hybrid solar + storage and maintain the reliability value
  - The need for thermal firm capacity remains unchanged but actual dispatch behavior of the thermal unit may change
- RECAP analysis shows significant need for standalone storage resources to meet system reliability needs

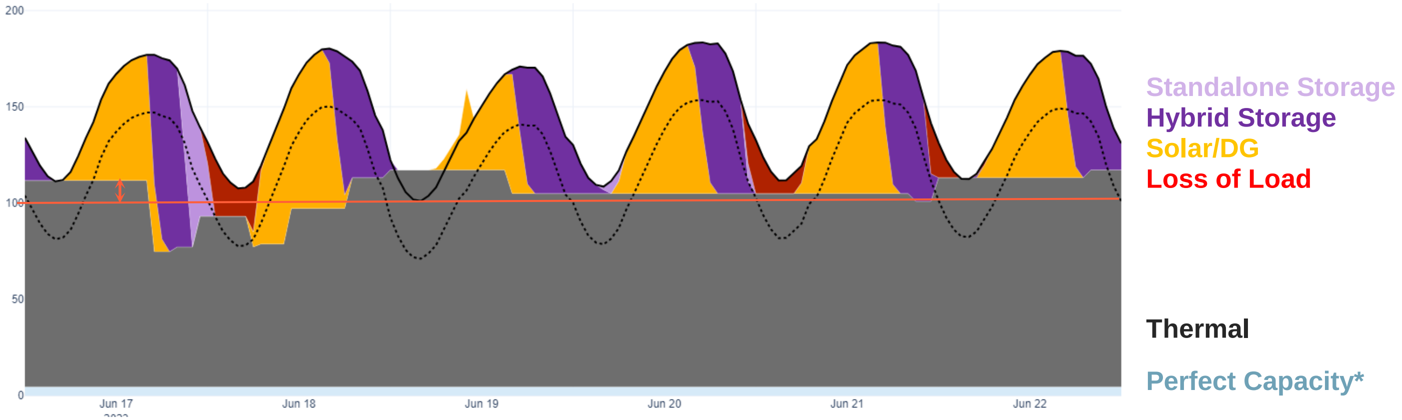
Additional Sensitivity Design

DG + Standalone Storage Sensitivity							
		Thermal *(MW)*	Hybrid Solar *(MW ac)*	DG Solar *(MW ac)*	Hybrid Storage *(MW)*	Standalone Storage *(MW)* 4 Hour	Standalone Storage *(MW)* 8 hour
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25		25	-	-
	3.2	52.1	50		50	-	-
	3.3	36.1	75		75	-	-
	3.4	36.1	100		100	-	-
	3.4.1	18.0	100	20	100	200	-
	3.4.2	18.0	100	20	100	70	60
	3.5	18.0	150		150	-	-

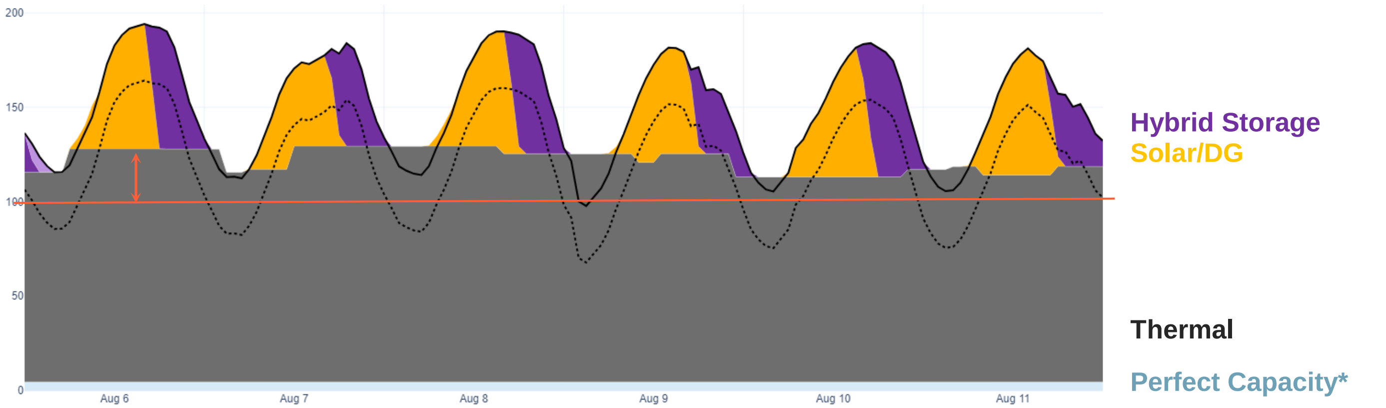
1. ***200 MW** of incremental 4-hour storage needed to have same capacity value as 50 MW hybrid S+S*
2. ***130 MW** of 4- and 8-hour storage same capacity value as 50 MW hybrid S+S*

Significant amounts of Standalone Storage needed for Reliability

Resource Dispatch During Outage Period



Resource Dispatch During Other Peak Load Period



- **System LOL events are highly driven by thermal fleet outages, not renewable lulls**
  - More LOL events around thermal outages than in August during peak gross load
- **Hybrid storage is more effective in providing reliability value given the excess amount of solar energy for charging**
  - 200 MW of standalone 4-hour storage has equal capacity value to 50 MW hybrid solar and storage
- **System is severely energy constrained from June – September**
  - Renewable penetration is not high enough to charge storage in mid-day, and standalone batteries rely on thermal generation in the evening to refill
  - Storage could be severely energy-constrained when thermal outages happen for consecutive days, which limits storage discharge during risky late afternoon periods

DG + Standalone Storage Sensitivity

Emissions Reduction and Clean Energy Achievement

DG + Standalone Storage Sensitivity								Emission Relative to 2019	Clean Energy Generation	Curtailment
		Thermal *(MW)*	Hybrid Solar *(MW ac)*	Hybrid Storage - 4 hour (MW)	DG Solar *(MW ac)*	Standalone Storage *(MW)* 4 Hour	Standalone Storage *(MW)* 8 hour	%	%	%
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	-	-	2%	13%	0%
	3.2	52.1	50	50	-	-	-	-8%	21%	0%
	3.3	36.1	75	75	-	-	-	-18%	30%	0%
	3.4	36.1	100	100	-	-	-	-28%	39%	0%
	3.4.1	18	100	100	20	200	-	-31%	41%	0%
	3.4.2	18	100	100	20	70	60	-31%	41%	0%
	3.5	18	150	150	-	150	-	-48%	55%	0%

While DG can provide limited capacity value, the additional of distributed solar generation can further reduce emission and achieve higher clean generation rate.

Note that pairing DG with battery could increase the combined resource capacity value, similar to storage paired with utility-scale solar; however, operational challenges associated with managing solar and storage facilities on the distribution grid can potentially impact operational value of the resource combo

Net Operating and Investment Benefits

DG + Standalone Storage Sensitivity								Annual Fixed Resource Cost on a Levelized Basis Cost	Operating Cost	Total Cost
		Thermal *(MW)*	Hybrid Solar *(MW ac)*	Hybrid Storage - 4 hour (MW)	DG Solar *(MW ac)*	Standalone Storage *(MW)* 4 Hour	Standalone Storage *(MW)* 8 hour	2027 COD ($'000)		
Scenario 3: Hybrid S+S + Thermal	3.1	72.1	25	25	-	-	-	$ 22,585	$139,491	$162,075
	3.2	52.1	50	50	-	-	-	$ 32,588	$125,474	$158,062
	3.3	36.1	75	75	-	-	-	$ 42,937	$111,536	$154,473
	3.4	36.1	100	100	-	-	-	$ 53,799	$ 97,466	$151,266
	3.4.1	18	100	100	20	200	-	$112,205	$ 94,184	$206,389
	3.4.2	18	100	100	20	70	60	$106,236	$ 94,188	$200,423
	3.5	18	150	150	-	150	-	$ 76,476	$ 71,386	$147,862

+40%

+36%

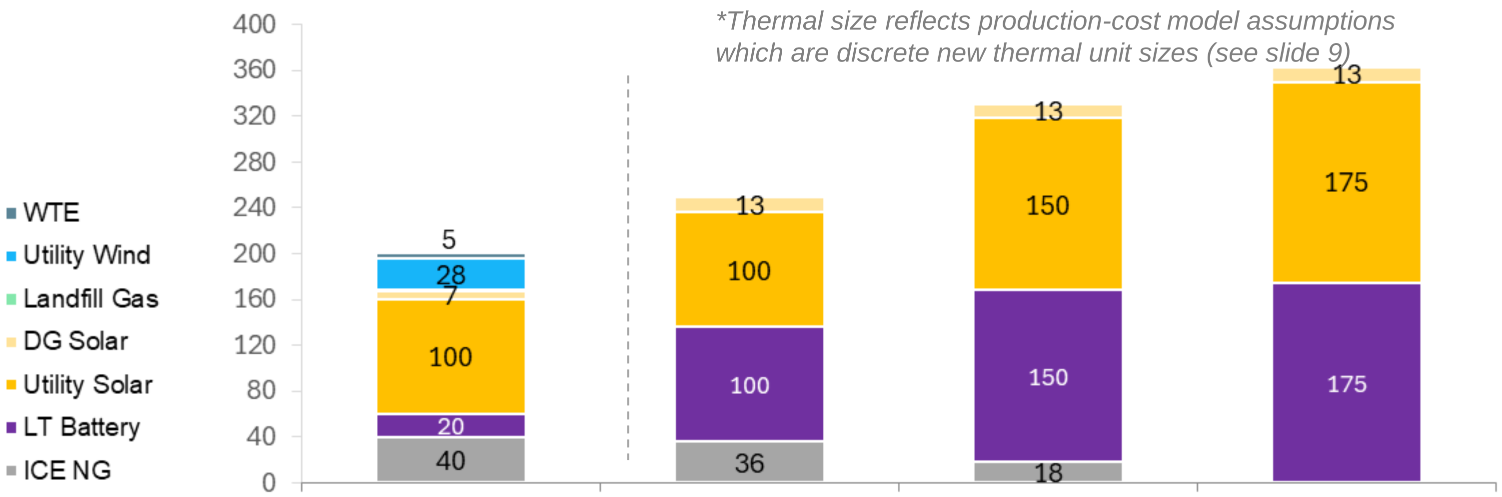
- Standalone storage + DG investment costs substantially increased total cost, relative to scenario 3.5, of scenario 3.4.1 and 3.4.2, which are ~40% higher.
- However, the operational cost reductions of adding the DG solar are minimal.

Conclusion and Recommendations

Comparison with 2017 IRP Preferred Portfolio

- **E3 compared the results from three current study scenarios to CUC IRP Portfolio 5 that achieve similar 2027:**
  1. Clean energy generation
  2. Emission reductions
- **The current study considers a select set of thermal and hybrid solar and storage resource additions which differ from those in the CUC's 2017 IRP broader candidate technology set (e.g., wind).**
- **Additional solar and storage resource *(in hybrid configuration)* are necessary in the current study scenarios as firm thermal capacity additions are reduced.**
  - All three current study scenarios bring the system to reliable (0.1 LOLE).
- **To reach similar emissions levels as IRP Portfolio 5** (granted differing study assumptions) in the absence of wind resources, requires significant solar and storage additions (SC4.1).

2027 Portfolio Incremental Resources *(MW)* and Results Summary



	2017 IRP Portfolio 5	E3 SC3.4 (100 MW Hybrid + Thermal)	E3 SC3.5 (150 MW Hybrid + Thermal)	E3 SC4.1 (175 MW Hybrid; No thermal)
RE Penetration (nameplate %)	58%	59%	70%	75%
Emission (tons CO2)	177,955	325,435	238,349	202,015
Clean Energy Gen (%)	50%	39%	55%	62%
Curtailment (%)	39%	0%	0%	2%

** Emission data subject to change based on load growth assumption; current study uses a higher load growth assumption than the 2017 IRP*

Conclusions

- By 2027 with load growth and contract expirations, CUC has a large capacity shortfall of 82 MW (ELCC) to fill to ensure adequate system reliability.
  - E3's loss of load probability analysis found an installed capacity (ICAP) based planning reserve margin need of 53% to meet a one day in ten-year loss of load standard, at the high end of the 35-55% existing reserve margin range.
- The island's aggressive clean energy goals will require adjustments to CUC resource adequacy planning methods.
  - Increasing shares of non-firm resources (such as solar, battery storage, and wind) will impact the required ICAP reserve margin; a PRM based on equivalent perfect capacity (PCAP) provides a more durable, fairer, and resource agnostic long-term approach to reliability planning and procurement.
  - Accrediting resources at their effective load carrying capability towards a PCAP based need ensures a level playing field that considers the operational limitations of both non-firm clean energy resources and firm capacity.
- Solar and storage can provide reliable capacity as well as clean energy, with hybrid solar and storage systems providing higher reliability value due to "diversity benefits".
  - However, the value of hybrids also saturates with increased penetrations, requiring the continued long-term use of firm capacity resources to maintain reliability. While firm resources (e.g., thermal today, potentially ultra long duration storage or other technologies in the future) will be necessary as CUC's clean energy resource portfolio grows, they will be dispatched less (lower operating costs and emissions).
- Modeled 2027 clean energy targets are achievable with 25-200 MW of new clean energy capacity, while staying on track for the latest 2030 emissions targets is more challenging and requires at least 100 MW of new clean energy resources amidst forecasted load growth.
  - Distributed generation may help overcome development challenges for building this level of utility-scale solar; however, relying on new battery storage requires significant charging energy from solar and feasible near-term growth of DG may be insufficient to support concurrent reliance on new battery storage instead of new firm thermal capacity.
- Increasing renewables reduces system operating costs by offsetting expensive diesel fuel. Switching to natural gas, in place of diesel, as the primary fuel for select thermal units reduces both emissions and operating costs for CUC.

Recommendations

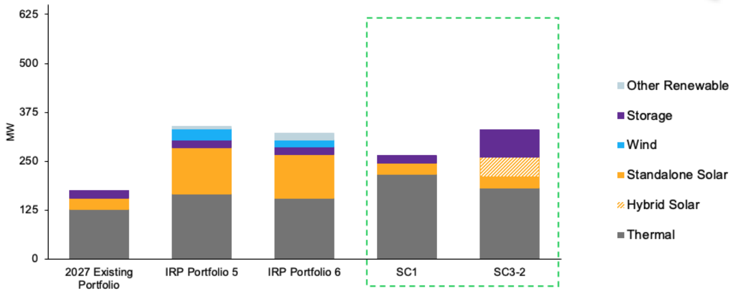
+ E3 has provided CUC with a Scenario Comparison Tool to facilitate exploration of the study results.
+ E3 recommends use of this tool as an aid in bid evaluations in response to future Certificate of Need (CoN) filings.

Scenario Selection

Scenarios to Compare

	Scenario 1	*Scenario 2*
Active Scenario	SC1	SC3-2

2027 Nameplate Capacity Comparison



2027 Existing portfolio include planned resource additions and scheduled thermal retirements in the next three years.

1. The Scenario Comparison Tool enables comparison of Study Resource Portfolio nameplate capacity, the 2027 base Portfolio, and select CUC IRP scenarios

2. The Total Resource Need and select portfolio capacity values (Perfect MW) allow for evaluation of reliability values of bids

Reliability Value Illustration

2027 Total Resource Need *(Perfect MW)* 194 >> Based on LOLP modeling

Selected Portfolio Effective Capacity *(Perfect MW)* 201

Comparison of Reliability Value
(perfect MW)

	Existing Portfolio*	IRP	IRP	Active Scenario 1	Active Scenario 2
	2027 Existing Portfolio	*IRP Portfolio 5*	*IRP Portfolio 6*	*SC1*	*SC3-2*
Thermal	102	134	125	191	156
Standalone Solar	2	8	8	2	-
Hybrid Solar + Storage	-	-	-	-	39
Storage	8	3	3	8	8
Wind	-	8	5	-	-
Other Renewable	-	6	17	-	-
Total Portfolio Effective Capacity	112	159	157	201	202
CUC Procurement Need *(perfect MW)*	82	35	37	-	-

**IRP Portfolios Procurement Needs are based on E3 estimation on resource capacity values*

3. The operational costs, policy-related results, and energy contribution of resources allow for evaluation of the relative energy value of bids

Operational Value Illustration

Total operational cost of portfolio *($000s)*	$ 125,474	Savings Compared to BAU	$ 28,163

Renewable Generation Comparison

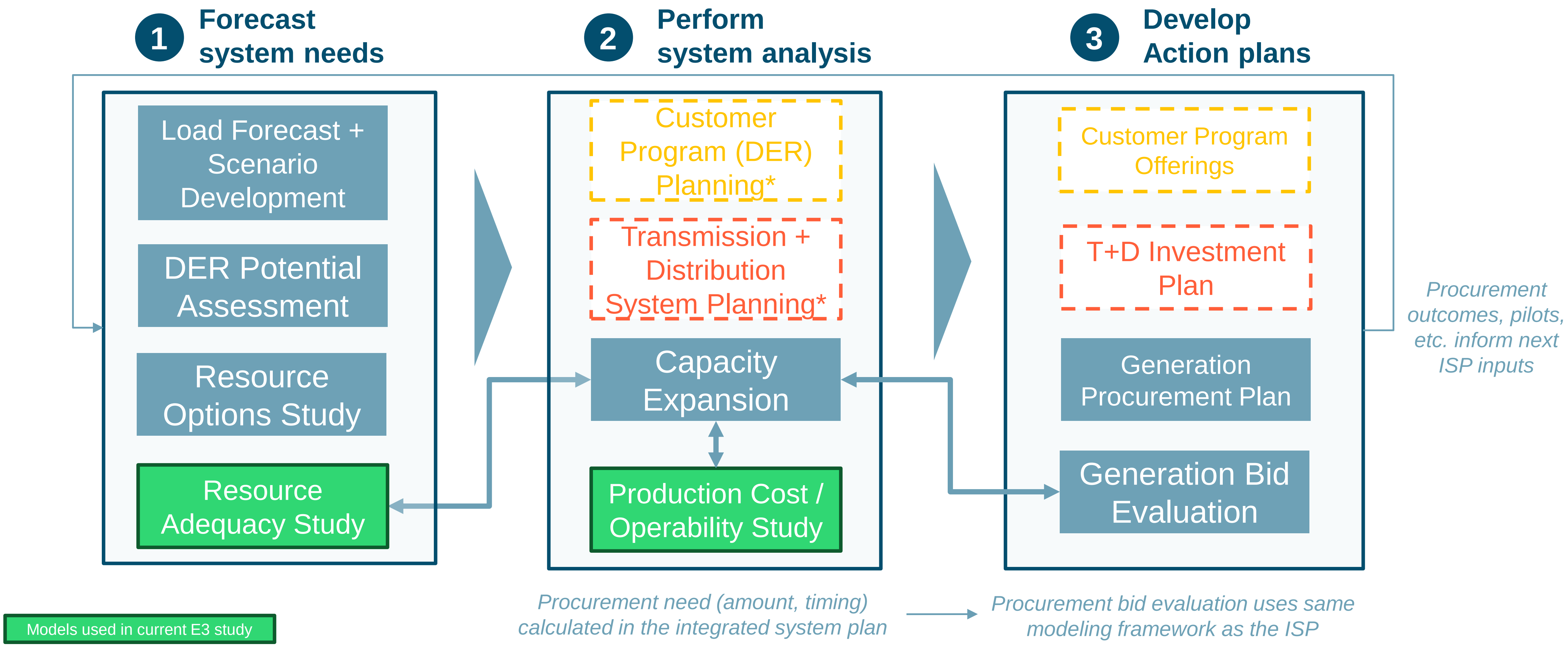
	IRP	IRP	Active Scenario 1	Active Scenario 2
	IRP Portfolio 5	*IRP Portfolio 6*	*SC3-2*	*SC1*
RE Penetration (nameplate MW %)	51%	52%	45%	18%
Emissions (tons CO2)	177,955	151,841	418,962	513,001
Emissions Intensity (lb/MWh)	483	412	883	1,081
Clean Energy Gen (%)	50%	57%	21%	4%
Curtailment (%)	39%	45%	0%	0%

Net Generation by Type
(GWh)

	IRP	IRP	Active Scenario 1	Active Scenario 2
	IRP Portfolio 5	*IRP Portfolio 6*	*SC3-2*	*SC1*
Thermal	367	315	746	913
Standalone Solar	273	259	-	-
Hybrid Solar	-	-	171	-
Storage	-	-	-	-
Wind	54	32	-	-
Other Renewable	44	132	-	-
Total Generation	737	738	917	913

In the long-term, a procurement process can be integrated into an integrated system planning process

An integrated system planning (ISP) process would allow CUC to better integrate planning and procurement models with strategies for future generation and grid needs



* Transmission and distribution planning and customer / DER planning processes may be adjacent or may be directly integrated into an ISP process

Thank You

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Energy+Environmental Economics

Appendix

Energy+Environmental Economics

LOLP Model Appendix

2027 CUC Capacity Position with RFQ Hybrid Resources

Loads & Resources	2027			2027 - base		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Thermal	126	102	81%	126	102	81%
Utility Solar	5	1	22%	5	1	22%
DG	24	1	3%	24	1	3%
Storage (1-hour)	20	8	42%	20	8	42%
RFQ Resources *	23 MW solar + 23 MW storage	22	94%	-	-	
Total Supply	**221**	**134**		**175**	**112**	
Median Peak Demand	143			143		
Total Effective Capacity Need	194			194		
Net Perfect Capacity Shortfall	**60**			**82**		
Achieved ICAP Reserve Margin	10%			-5%		
Target ICAP Reserve Margin	52%			52%		
Achieved PCAP Reserve Margin	-6%			-21%		
Target PCAP Reserve Margin	36%			36%		

* Note that RFQ storage is assumed to be charging only from paired solar

RFQ resource has a very high effective capacity rating due to two factors:

- **Synergies between solar and storage from storage charging from excess solar energy**
- **A 4-hour storage unit being more capable of mitigating loss-of-load events**

With the addition of RFQ resource, 2027 CUC resource procurement need is reduced by 22 MW

Moving planned outages to off-peak months could reduce procurement needs or 2027

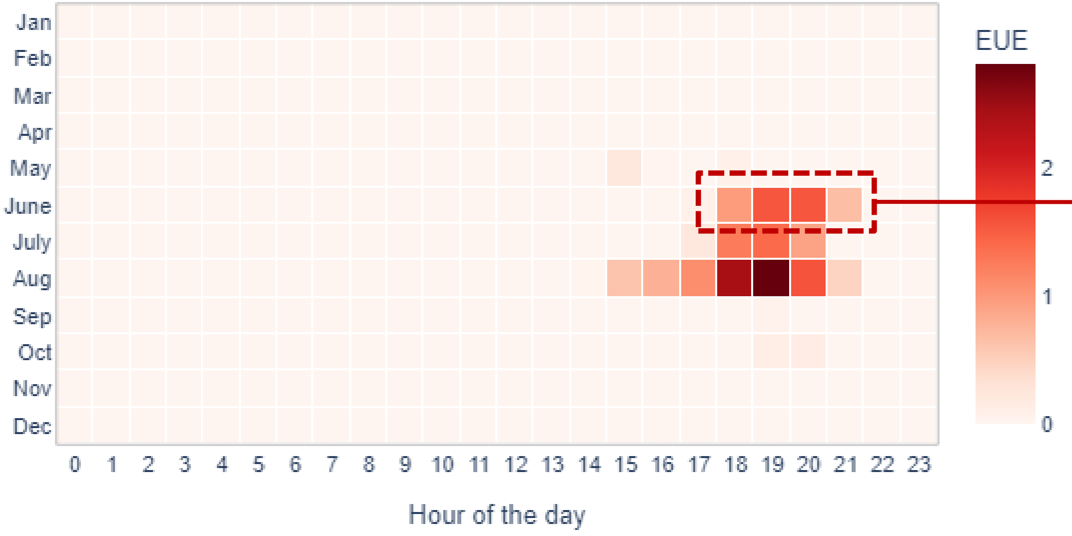
Modeled unit maintenance schedule

Unit	Start Date	End Date	Service Type
20	4/23/2026	6/18/2026	Major Overhaul
36	5/28/2026	6/27/2026	Top Overhaul
31	12/24/2026	12/31/2026	Major Overhaul

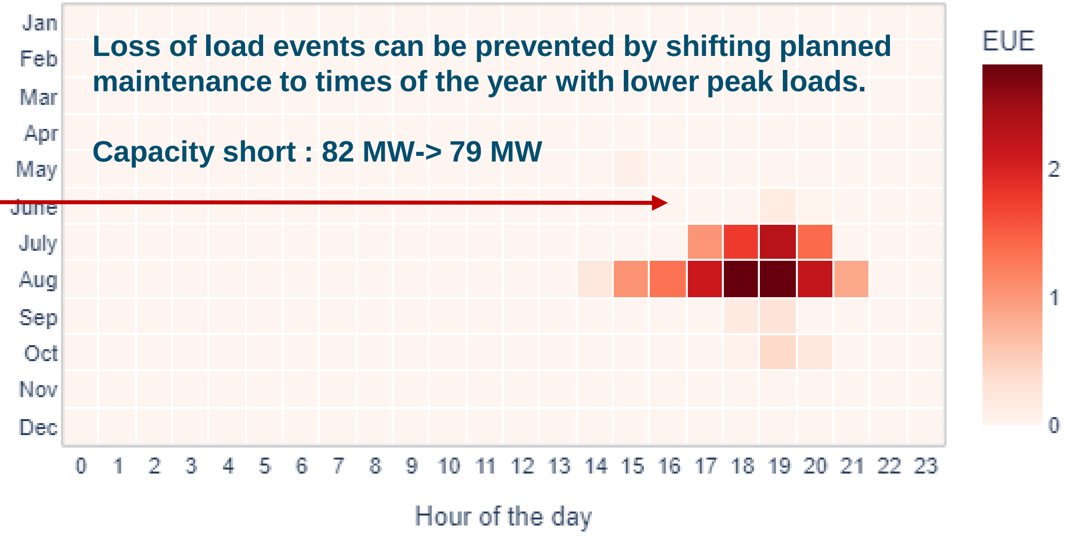
***Illustrative* maintenance schedule in shoulder months**

Unit	Start Date	End Date	Service Type
20	1/23/2026	3/18/2026	Major Overhaul
36	3/01/2026	3/31/2026	Top Overhaul
31	12/24/2026	12/31/2026	Major Overhaul

Month Hour Average Load Shed for Base System
(MWh)



Month Hour Average Load Shed for Shifted Maintenance System
(MWh)



2027 CUC Capacity Position under Different Load Growth Scenario

Loads & Resources	2027 - Low Growth			2027 - Mid Growth			2027 - High Growth		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Thermal	126	102	81%	126	102	81%	126	102	81%
Utility Solar	5	1	22%	5	1	22%	5	1	22%
DG	24	1	3%	24	1	3%	24	1	3%
Storage (1-hour)	20	8	42%	20	8	42%	20	8	42%
Total Supply	**175**	**112**		**175**	**112**		**175**	**112**	
Median Peak Demand	129			134			143		
Total Effective Capacity Need	177			183			194		
Net Perfect Capacity Shortfall	**64**			**71**			**82**		
Achieved ICAP Reserve Margin	6%			2%			-5%		
Target ICAP Reserve Margin	55%			54%			52%		
Achieved PCAP Reserve Margin	-13%			-16%			-21%		
Target PCAP Reserve Margin	37%			37%			36%		

A 10% difference in median peak load between low and high load scenarios drives the need

As load increases, achieved planning reserve margin decreases

As load increases, fixed spinning reserve requirements have less impact on target PCAP margin

2026-2028 CUC Capacity Position

Loads & Resources	2026			2027			2028		
	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)	Installed Capacity (MW)	Effective Capacity (MW)	Effective Capacity (%)
Thermal	158	128	81%	126	102	81%	126	102	81%
Utility Solar	5	1	22%	5	1	22%	5	1	22%
DG	24	1	3%	24	1	3%	24	1	3%
Storage (1-hour)	20	8	40%	20	8	40%	20	8	40%
Total Supply	**207**	**138**		**175**	**112**		**175**	**112**	
Median Peak Demand	138			143			148		
Total Effective Capacity Need	188			194			201		
Net Perfect Capacity Shortfall	**50**			**82**			**88**		
Achieved ICAP Reserve Margin	22%			-5%			-8%		
Target ICAP Reserve Margin	58%			52%			52%		
Achieved PCAP Reserve Margin	0%			-21%			-24%		
Target PCAP Reserve Margin	36%			36%			36%		

Thermal retirement schedule changes firm generation available to the grid

Total resource need increases in 2027 and 2028 because of projected load growth

Increasing loads and /or retiring thermal lead to varying Net Capacity shortfalls between 2026 and 2028

Target ICAP Reserve Margin is the highest in 2026 due to larger thermal fleet with outage risks

PLEXOS Model Appendix

PLEXOS: Existing Resource Assumptions

Thermal Unit	Make/Model	Capacity (MW)	No. of Units	Start date	Retirement date	Forced Outage Rating (MW)	Min Load (MW)	% Min Load
1	Mak 8M601C	9	2	5/1/1997	12/31/2026*	8.75	5.4	0.7
2	Mak 8M601C	9	2	5/1/1997	12/31/2026*	8.46	5.4	0.7
3	Caterpillar 3616	4.4	2	5/1/1998	12/31/2026*	3.53	2.7	0.7
4	Caterpillar 3616	4.4	2	5/1/1998	12/31/2026*	4.28	2.7	0.7
19	Caterpillar 3616	4	2	5/1/1986	7/31/2026	3.78	2.4	0.7
20	Caterpillar 3616	4	2	5/1/1988	2/28/2029	3.59	2.4	0.7
25	Solar Centaur 50 Combustion Turbine	3.5	1	5/1/1996	4/30/2026	3.18	3	1
26	MAN THM-1304-11 Combustion Turbine	6.4	1	7/1/2006	6/30/2031	5.34	7.2	1
27	Solar Taurus SMT60	4.6	1	8/30/2022	11/20/2039	4.15	4.1	1
28	M+M KT597-8 Steam Turbine	2.6	1	6/24/2016	11/20/2039	2.49	1.1	0.5
30	Man B&W 18V 48/60	18.5	2	6/1/2016	11/20/2039	18.11	2.5	0.15
31	Man B&W 18V 48/60	18.5	2	5/10/2016	11/20/2039	18.38	2.5	0.15
32	Man B&W 14V 48/60	15.617	2	10/1/2009	11/20/2039	15.36	2.2	0.15
33	Man B&W 14V 48/60	15.617	2	6/1/2007	11/20/2039	15.36	2.2	0.15
34	Man B&W 12V 48/60	12.25	3	8/1/2003	11/20/2039	11.63	1.5	0.15
35	MAN B&W 12V 48/60	12.25	3	8/1/2000	11/20/2039	11.67	1.5	0.15
36	Man B&W 12V 48/60	12.25	3	8/1/2000	11/20/2039	10.29	1.5	0.15
41	Caterpillar 3516B	1.45	2	3/31/2007	12/31/2026*	1.44	0.6	0.7
42	Caterpillar 3516B	1.45	2	3/31/2007	12/31/2026*	0.89	0.6	0.7
43	Caterpillar 3516C	1.5	2	12/1/2011	11/30/2031	1.14	0.5	0.7
44	Caterpillar 3516C	1.5	2	12/1/2011	11/30/2031	0.41	0.5	0.7

Non-Thermal Unit	No. of Units	Technology	Capacity (MW)	Energy (MWh)	Duration (Hours)	Cycles Per Year	Charging Efficiency (%)	Discharging Efficiency (%)	Max Depth of Discharge (%)
Bodden Solar	1	Solar PV	5						
Hydesville Substation Battery	1	Battery	10	10	1	365	87	100	100
Prospect Substation Battery	1	Battery	10	10	1	365	87	100	100
Distributed Generation	1	Solar PV	24						

*For modeling purposes, all resources scheduled for retirement before 2027 summer were made unavailable by end of December 2026.

PLEXOS: New Resource Assumptions

Thermal Unit	Make/Model	Max Capacity (MW)	Forced Outage Rating (MW)	Fuel	Min Load (MW)	% Min Load
New Thermal	MAN Gensets 18V51/60	18.025	17.91	Diesel	4.50625	0.25
New Thermal (Fuel Sensitivity)		18.025	17.91	Natural Gas	4.50625	0.25

Non-Thermal Unit	No. of Units	Technology	Max Capacity (MW)	Energy (MWh)	Duration (Hours)	Cycles Per Year	Charging Efficiency (%)	Discharging Efficiency (%)	Max Depth of Discharge (%)
New Standalone Solar	1	Solar PV	By scenario						
New Hybrid Solar	1	Solar PV	By scenario						
New 4-hr Hybrid Battery	1	Battery	By scenario	By scenario	4	365	87	100	100
New 8-hr Hybrid Battery	1	Battery	By scenario	By scenario	8	365	87	100	100
New 4-hr Standalone Battery	1	Battery	By scenario	By scenario	4	365	87	100	100
New 8-hr Standalone Battery	1	Battery	By scenario	By scenario	8	365	87	100	100

PLEXOS Scenarios based on Reliability Input

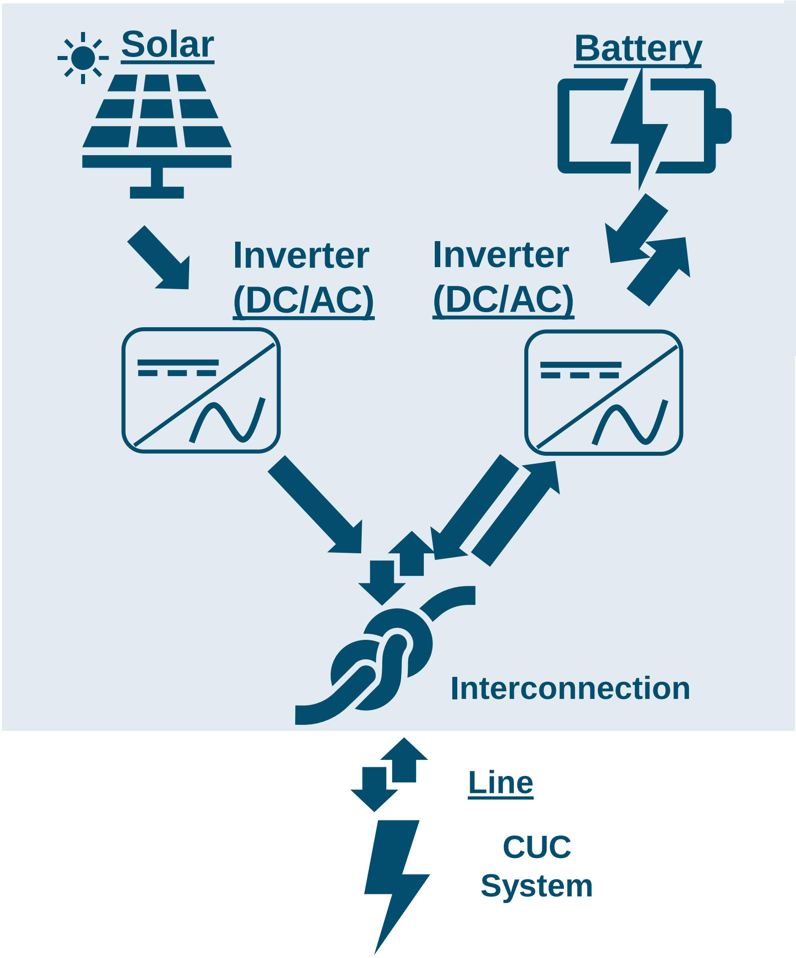
+ **In this table, New thermal capacity reflects <u>actual MWs necessary for grid reliability</u> identified in LOLP modeling, instead of thermal size with discrete unit numbers**

Production Cost Model Scenarios: 2027 CUC Portfolio Incremental Capacity					
		Thermal *(MW)*	Solar *(MW ac)*	Storage *(MW)*	
				4 Hour	8 hour
Scenario 1: Thermal BAU	1.1	82.1	-		
Scenario 2*: Standalone Solar + Thermal	2.1	79.2	25	-	
	2.2	78.3	50		
	2.3	78.2	75		
	2.4	77.3	100		
	2.5	77.2	150		
	2.6	77.2	200		
Scenario 3: Hybrid S+S + Thermal	3.1	58.3	25	25	-
	3.2	43.2	50	50	
	3.3	30.0	75	75	
	3.4	19.9	100	100	
	3.5	5.2	150	150	
Scenario 4: Hybrid S+S	4.1	-	175	175	-
	4.2		200	200	
	4.3		150	-	150
	4.4		175	50	125
	4.5		175	100	75

Other Inputs and Assumptions

Hybrid Solar and Storage Representation

Hybrid AC Solar and Storage



In AC-coupled systems, the solar inverter Max AC output limits solar production curtailing/clipping excess solar, and multiple inverters are required.

In DC-coupled systems, excess solar production, exceeding max output of inverter, can be used to charge the battery, and only a single DC/AC inverter is required.

Hybrid DC Solar and Storage