Energy+Environmental Economics

Integrated Resource Planning in Hawai'i

Going where no Jurisdiction has gone before

Ren Orans

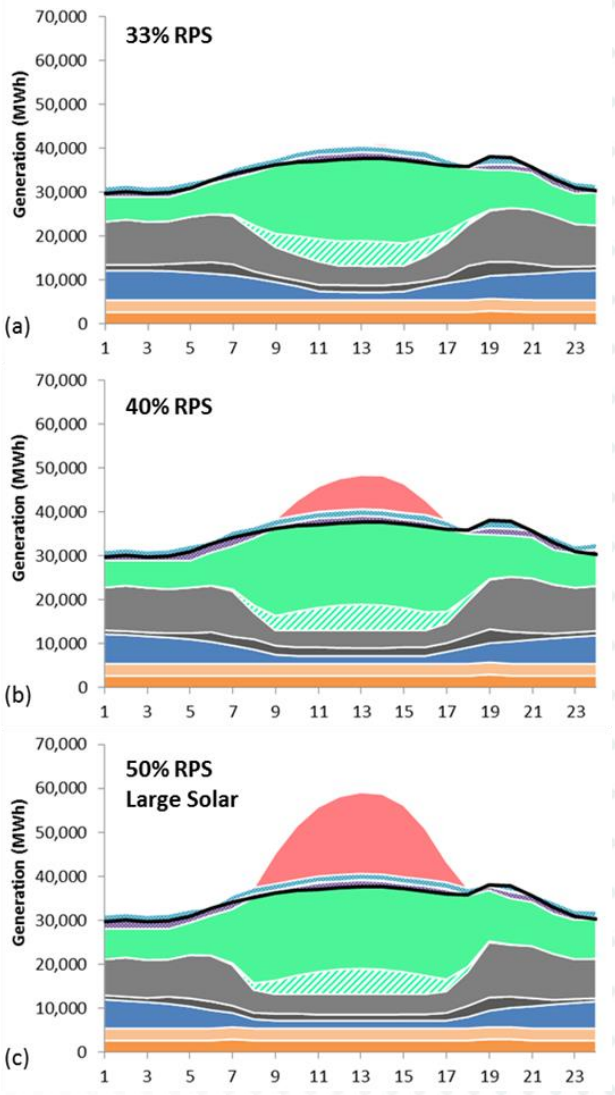
Overview

- **Question: How to align the planning process in Hawaii with the customer's vision of the future grid?**

- **Need a set of new models designed to:**
  - "Affordable"
    - Least-cost resource portfolio of renewables and integration solutions to meet RPS targets
  - "Choice"
    - Considers all resource options on level playing field
  - "Technology"
    - Evaluates long term benefits of investments as renewable portfolio evolves over time
  - "Consistent with policy direction"
    - Allows investigation of new policy and regulatory reforms
- **Complemented by detailed operations modeling to validate planning assumptions**

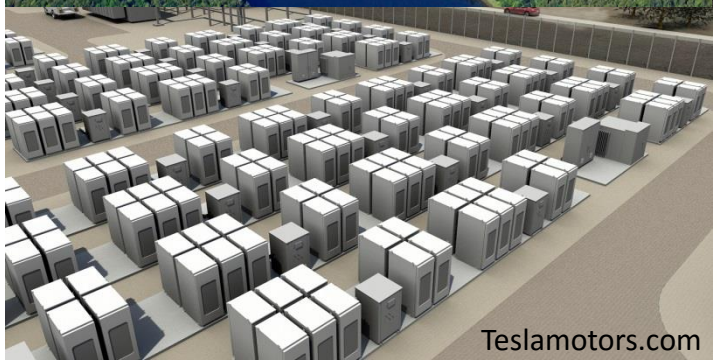
The renewable integration challenge

- **Primary drivers of renewable integration challenges at high penetrations:**
  - Renewable oversupply during low load periods
  - Inflexible conventional generation
    - Must-run resources
    - Self-scheduled resources/ contract limitations
    - Technical constraints on ramping, minimum stable levels, minimum up and down times
    - High costs associated with cycling
  - Small balancing areas where diversity of renewables is limited, and generator fleets are constrained



Renewable integration solutions

- **Various solutions have been proposed, with different performance characteristics and costs**
  - Energy storage (batteries, compressed air, etc)
  - Flexible loads or advanced DR
  - Flexible resources (new flexible CCGTs, Aero CTs, Reciprocating Engines or retrofits to existing plants)
  - Tariff design, regulatory and market changes



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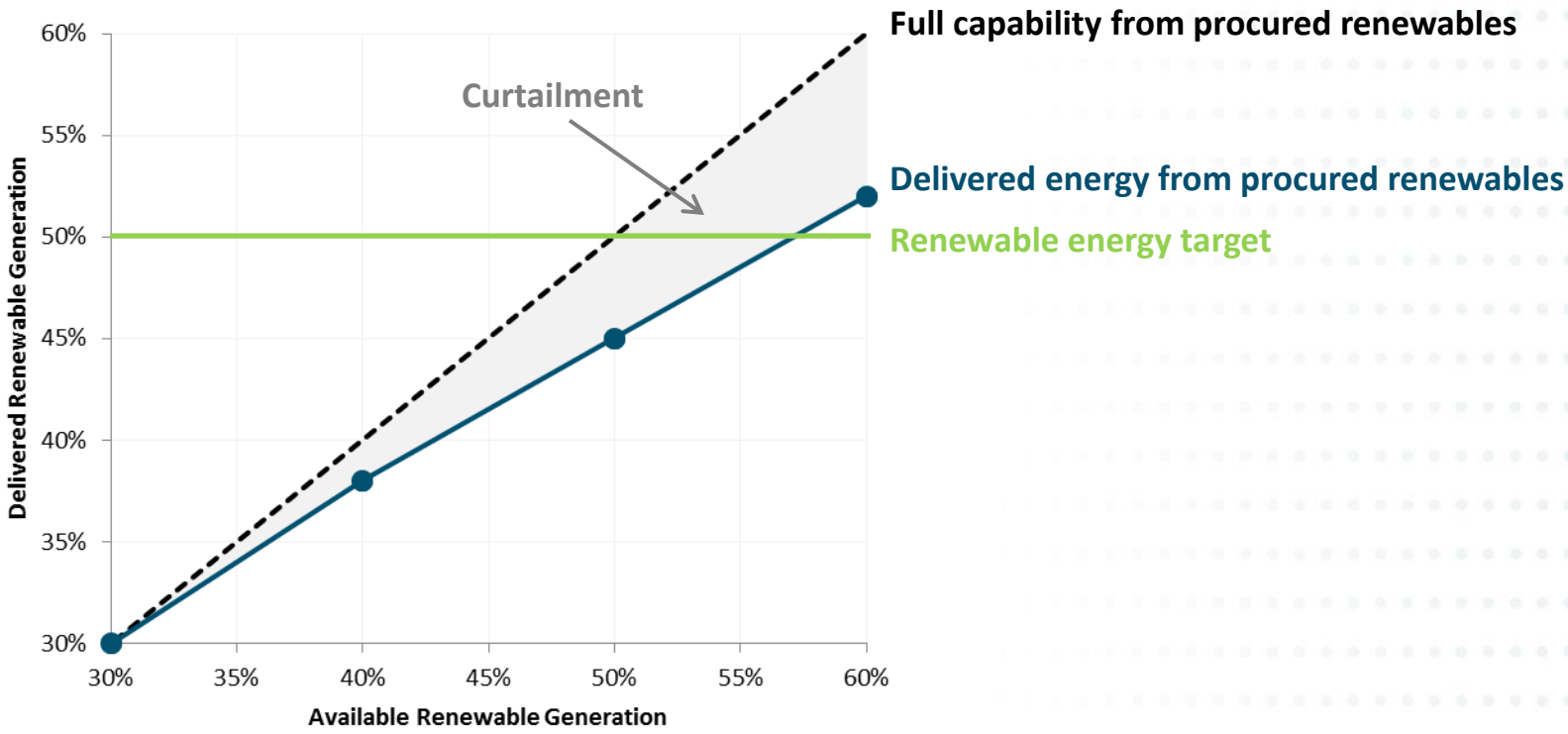
Economic Framework for Selection of Optimal Renewable Integration Solutions

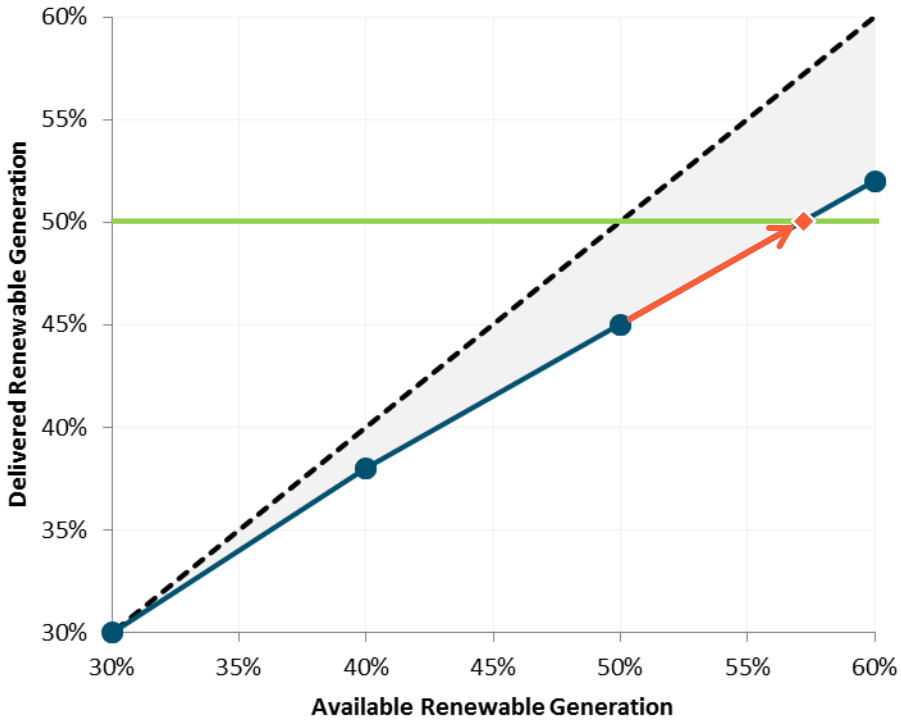
Economics of renewable integration

- **The consequence of failing to supply enough flexibility to integrate renewables is renewable curtailment, or reliability issues**

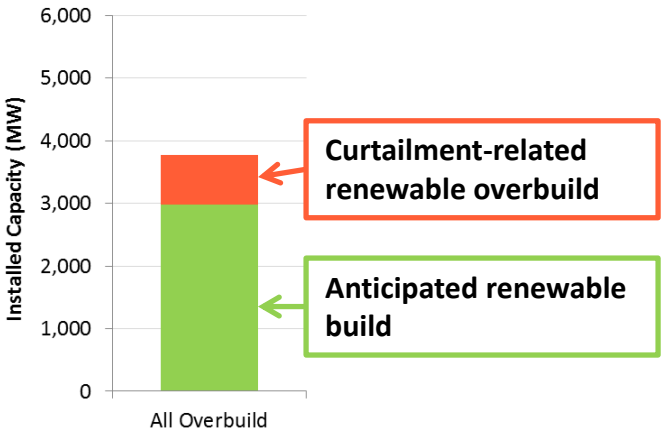


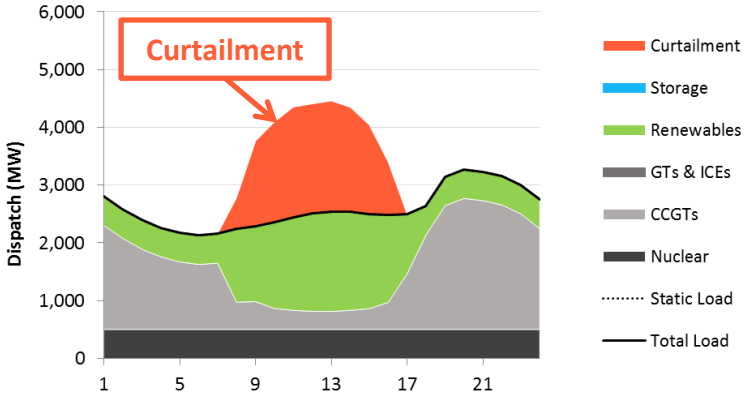
Option 1. Overbuild renewables

+ **Overbuilding the renewable fleet allows for policy goal to be met with some allowance for curtailment**



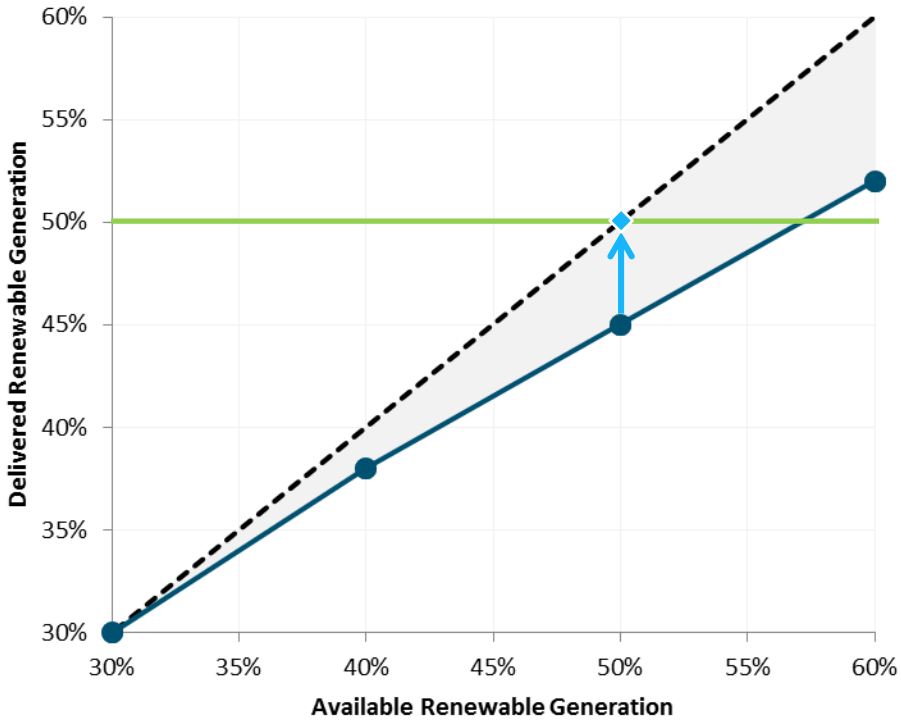
Option 1. Overbuild the renewable fleet





Option 2. Pursue integration solutions to avoid overbuild

+ **Integration solutions (eg. storage, balancing area consolidation) permit more effective delivery of existing renewable fleet**



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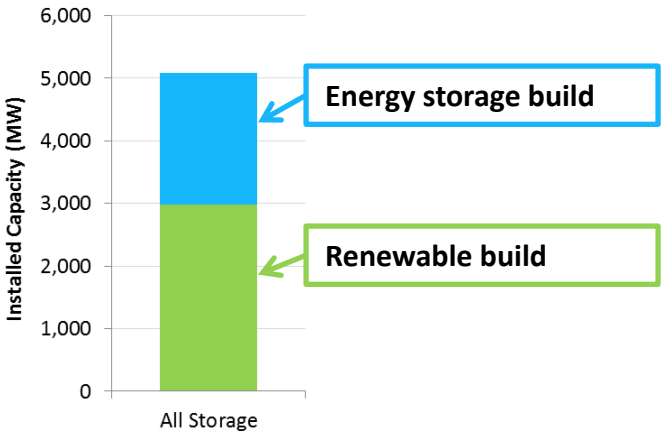
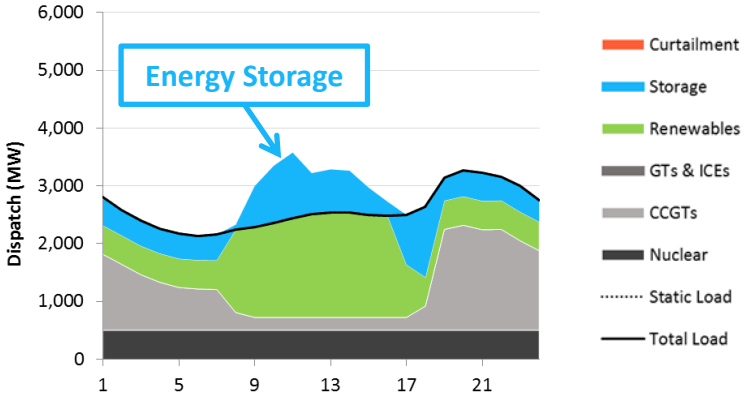
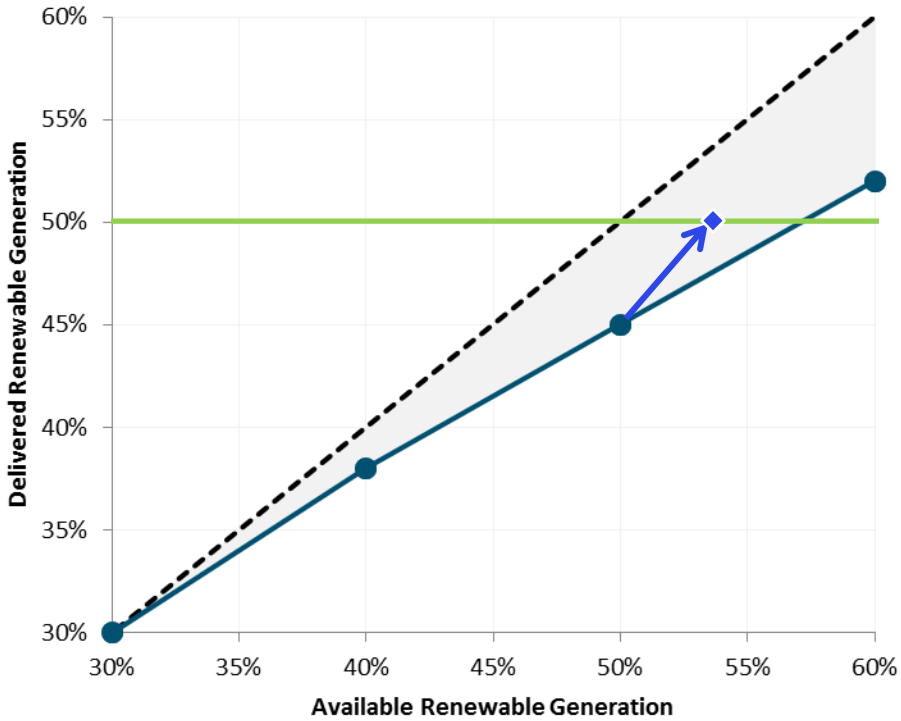


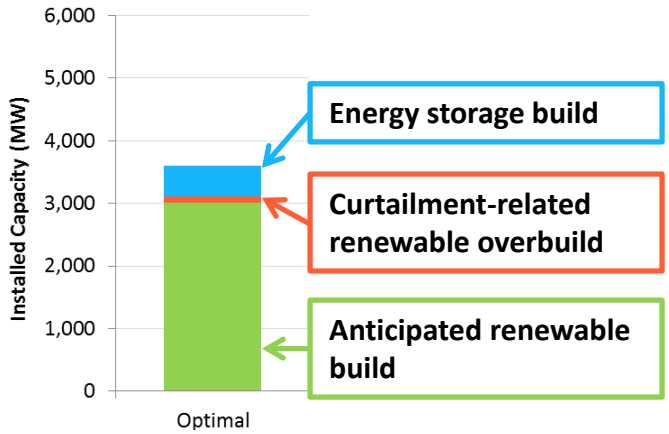


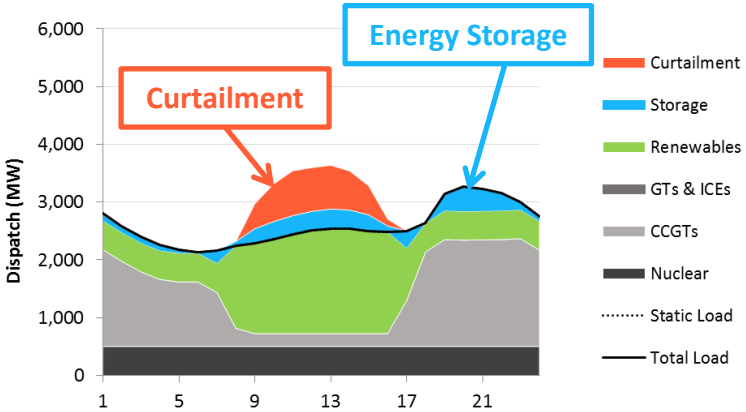
Option 3. Determine optimal mix of solutions and overbuild

+ **Optimal solution combines multiple strategies based on costs and benefits**

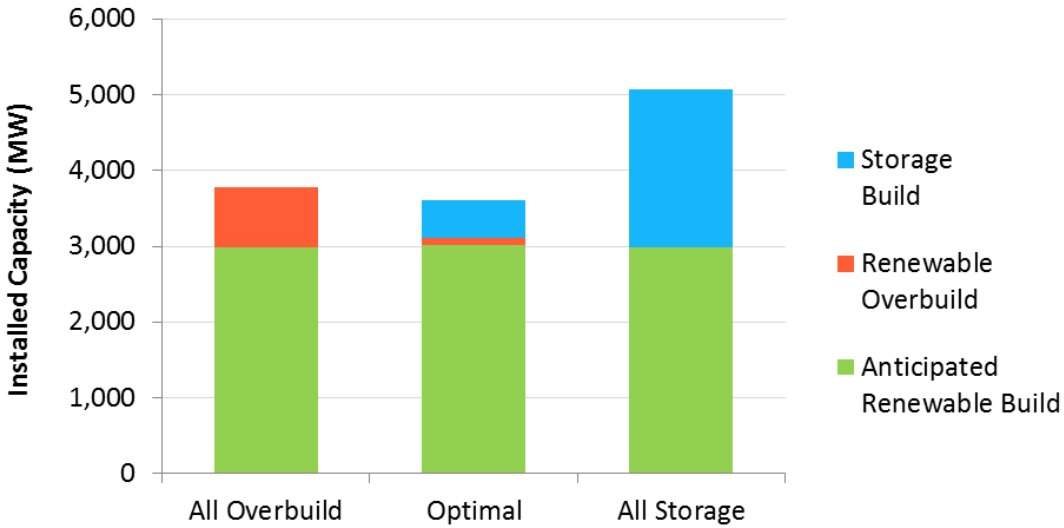


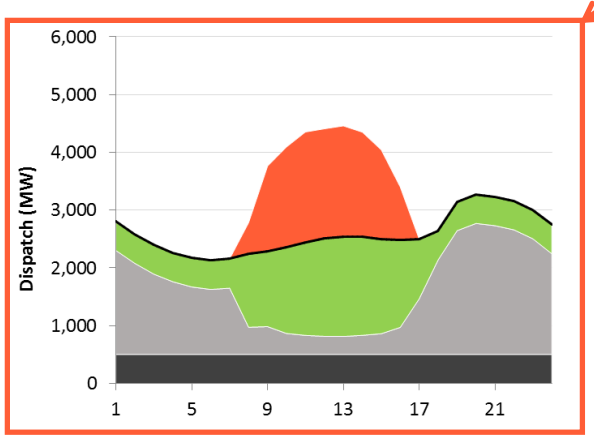
Option 3. Find optimal solution

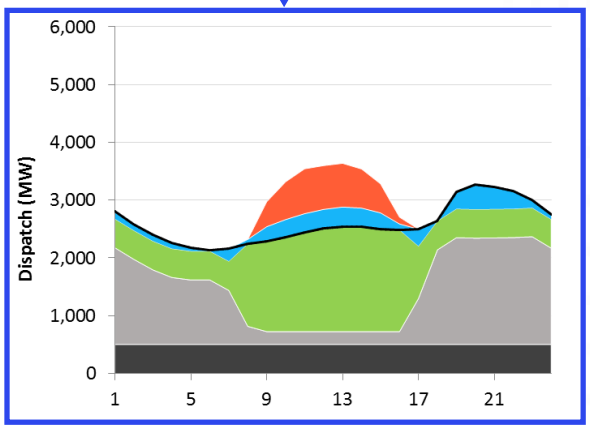


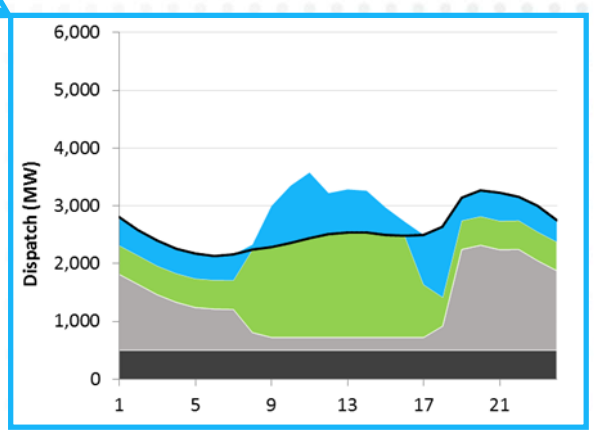


Optimal solution balances non-renewable solutions with overbuild









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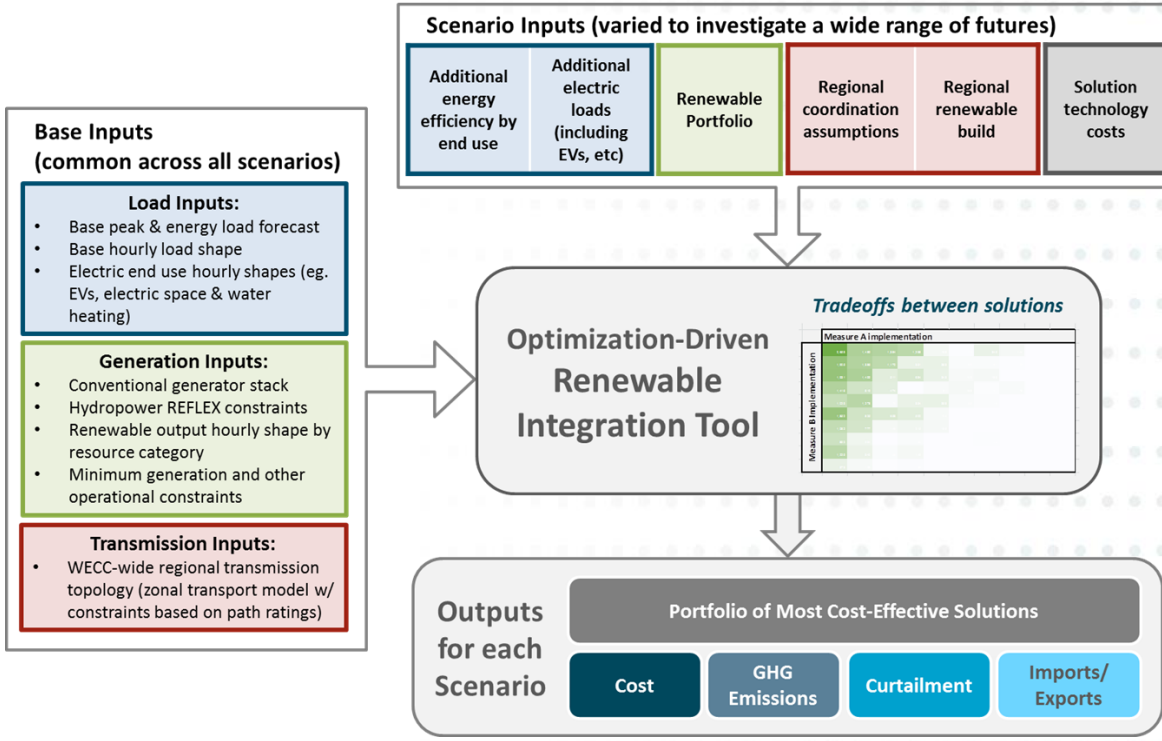
RESOLVE Model

RESOLVE Modeling Framework

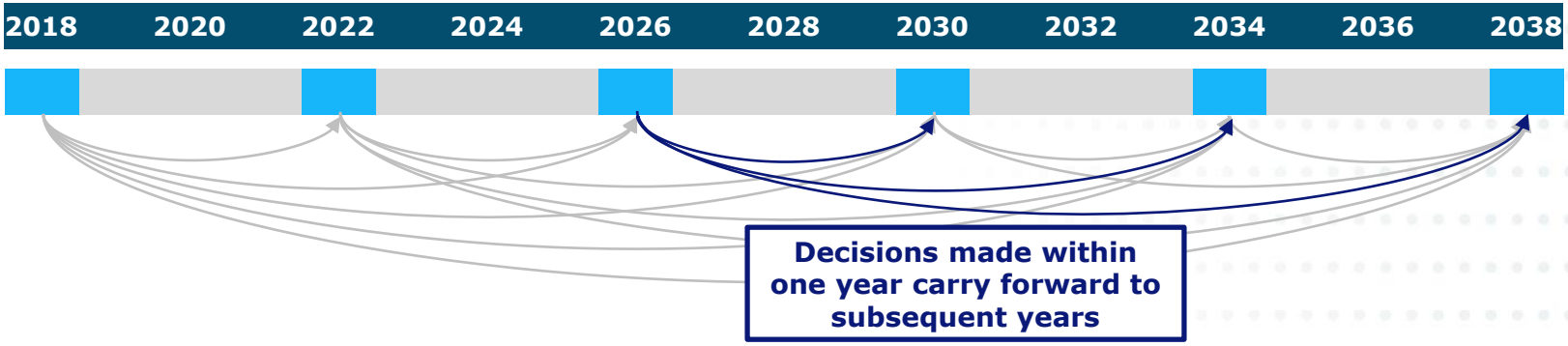
+ **Co-optimizes investment and operational decisions over multiple years**
  - Can solve for optimal investments in renewable resources, energy storage, conventional generators
  - Can test value of solutions with unknown or uncertain supply curves, like flexible loads & time-of-use rates



+ **Operational detail focuses on primary drivers of renewable integration challenges**
  - Hourly dispatch with reserve and operating constraints
  - Zonal treatment of interconnection to model flows with increased granularity in primary zone of study

Model Time Horizon

- **RESOLVE minimizes the <u>NPV of total costs</u> across a 20+ year time horizon**
  - Additional weight applied to last year of analysis to account for end effects
  - Because of computational complexity, RESOLVE is typically not used to model all years in analysis horizon



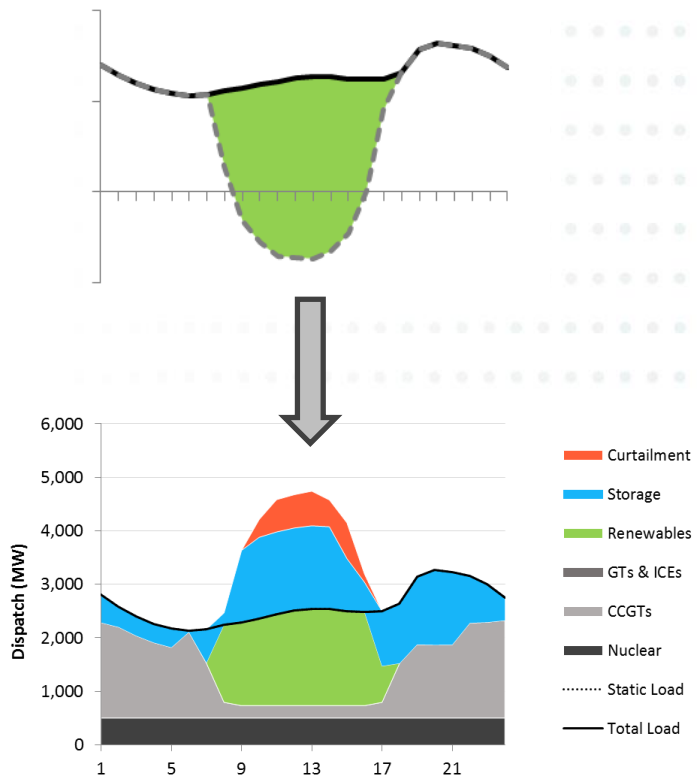
In each **<u>modeled year,</u>** the portfolio is explicitly modeled, and total cost is calculated as the sum of fixed costs of investment and operating costs

In **<u>intermediate years,</u>** the total cost of the portfolio is calculated by linear interpolation between the two adjacent modeled years

Detailed hourly model brings operational challenges into investment decisions

- **For each year in the simulation, a subset of days are selected and weighted to reflect long-run distributions of:**
  - Daily load, wind, and solar
  - Monthly hydro availability (in CA)
- **Operations modeled using linear dispatch formulation**
  - MIP possible for small systems or when runtime is not a constraint; linear approximations for large systems
  - Upward and downward operating reserve constraints

Captures operational impacts of renewable integration challenges



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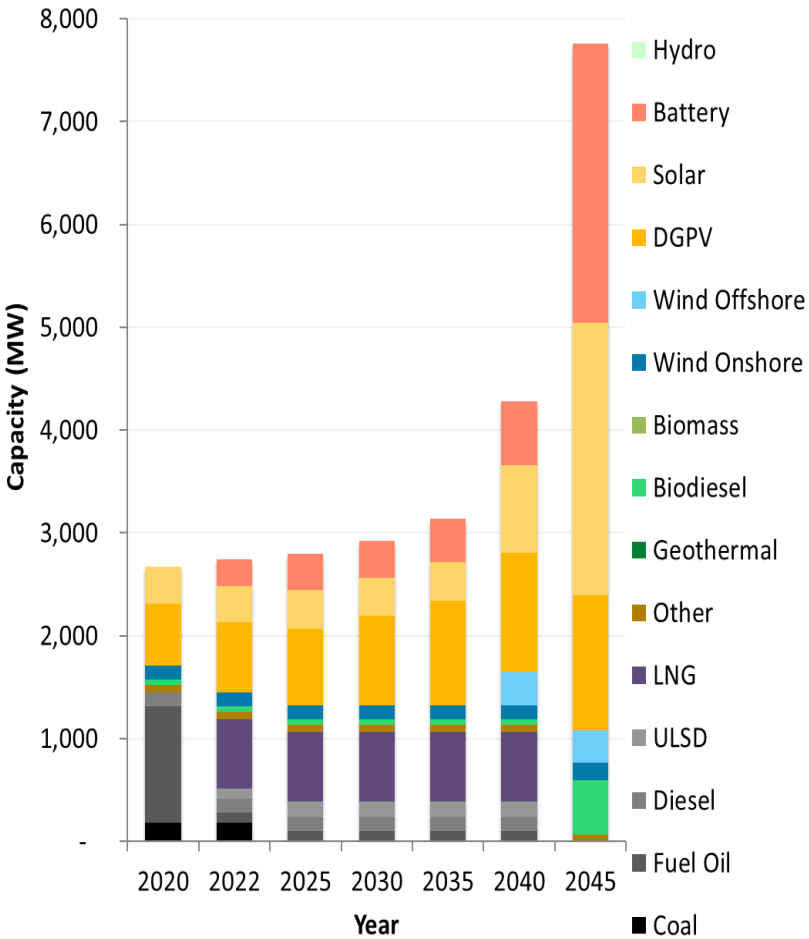
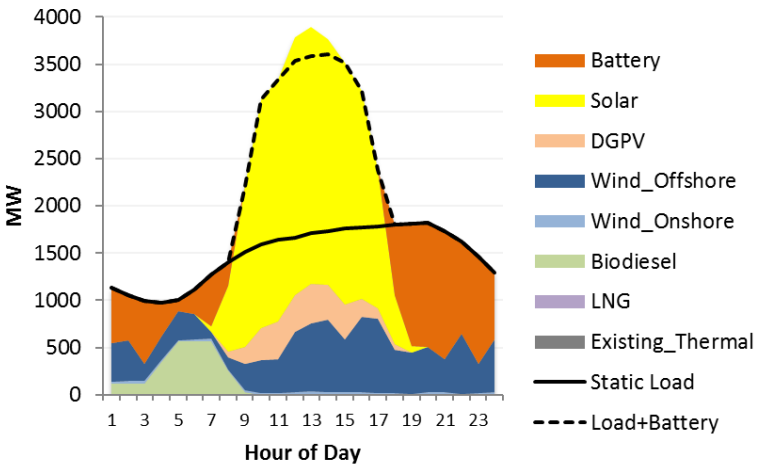
Will the System be Reliable?

One Expansion Plan for Oahu

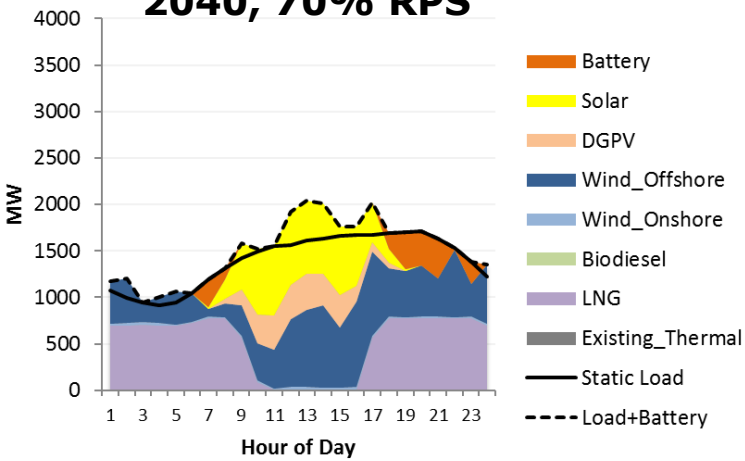
Utilized installed capacity for Oahu LNG Market DGPV case



Sample Day Dispatch 2045, 100% RPS



Sample Day Dispatch 2040, 70% RPS

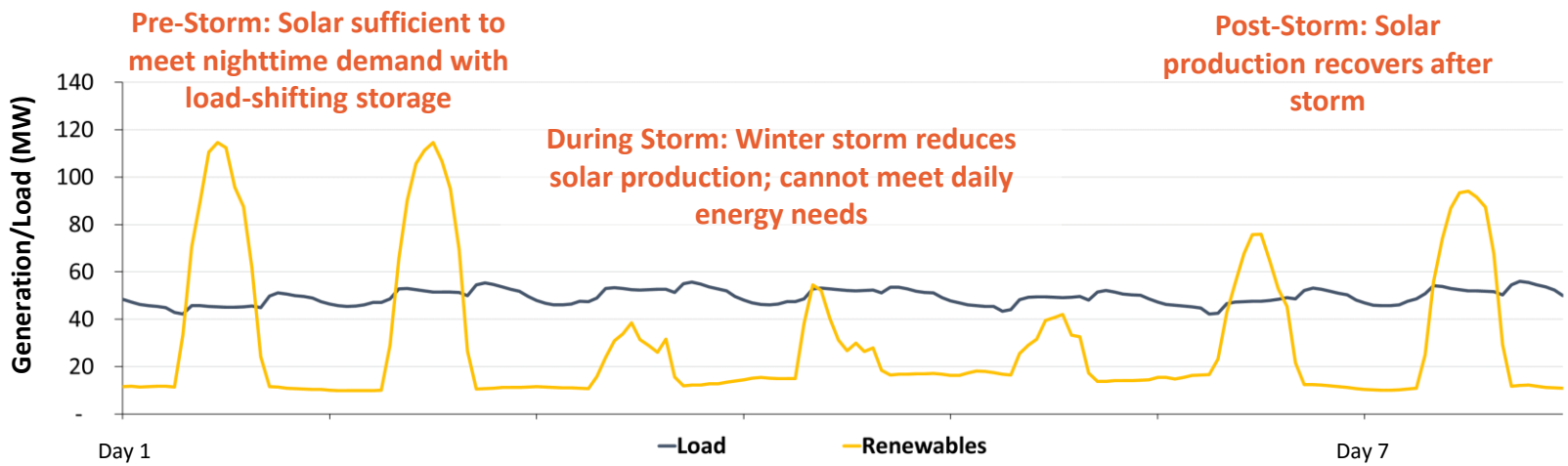


Resource Reliability

- **In the event of a multi-day winter storm system could have insufficient generation to meet system load**
  - Reliability issues could be exacerbated by contingencies on dispatchable generators
- **Detailed studies of operating reliability are needed to illustrate the resource sufficiency of highly renewables-reliant systems**

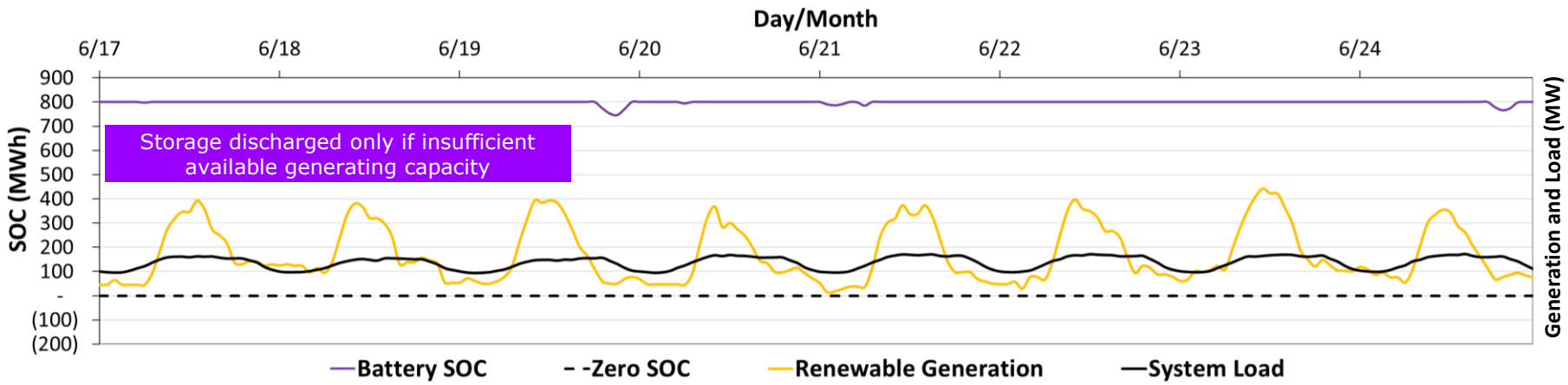
For illustration purpose only

Example of Loads and Renewable Resources For One Week

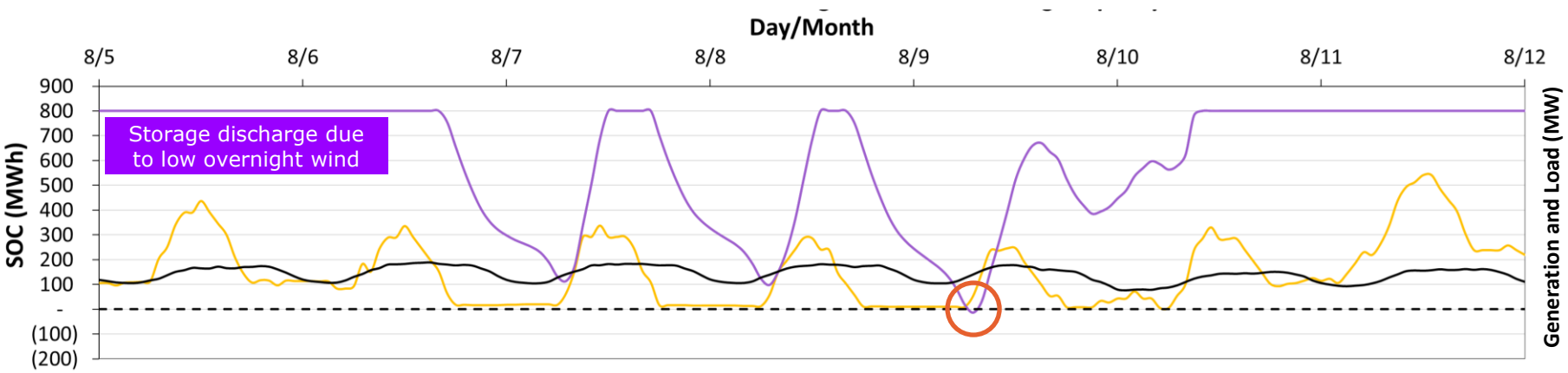


Week-Long View of BI Resource Reliability
Dispatch in 2045

+ **Summer week where renewable and thermal generation are generally sufficient to meet load without discharging storage in most hours**



+ **Summer week with multiple days of low nighttime wind production lead to significant usage of stored energy and one loss of load event**



Discussion
Value of Long Duration Storage

- **RESOLVE selected four-hour storage, and demonstrates that if used conservatively, system operator can provide energy to maintain resource sufficiency for most hours.**
  - However, storage can provide other benefits that need to be traded-off against energy stored for reliability purposes
  - Balance between best storage operations (perfect foresight in RESOLVE) and conservatism to meet unexpected system challenges
- **Multi-day extreme weather events are an opportunity for longer term storage**
  - RESOLVE builds short-term energy storage for daily energy needs (including extreme weather days) but does not consider longer-term storage for extreme multi-day events
  - Long duration storage can provide value in highly renewable-dependent systems during extreme multi-day events