

Integrated Resource Planning in Hawai'i Going where no Jurisdiction has gone before

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+ 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

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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



70,000

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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



http://www.theiet.org/membership/membernews/31a/ev-charging-course.cfm



http://allthingsd.com/files/2012/10 /Nest-Cooling-2.jpg



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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





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







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



Option 2. Pursue integration solutions



Option 3. Determine optimal mix of solutions and overbuild

 Optimal solution combines multiple strategies based on costs and benefits







Optimal solution balances nonrenewable 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



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 **intermediate years**, the total cost of the portfolio is calculated by linear interpolation between the two adjacent modeled years

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- 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





Will the System be Reliable?



Utilized installed capacity for Oahu LNG Market DGPV case



Sample Day Dispatch 2045, 100% RPS



1 3 5 7 9 11 13 15 17 19 21 23

Hour of Day

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----Load+Battery



+ 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





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





 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