State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Todd Olinsky-Paul
Clean Energy States Alliance
ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

– Information Exchange
– Partnership Development
– Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
– Clean Energy Program Design & Evaluations
– Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.
ESTAP* Overview

**Purpose:** Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

**Focus:** Distributed electrical energy storage technologies

**Outcome:** Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE

* (Energy Storage Technology Advancement Partnership)
ESTAP Key Activities

- Disseminate information to stakeholders
  - ESTAP listserv >500 members
  - Webinars, conferences, information updates, surveys

- Facilitate public/private partnerships at state level to support energy storage demonstration project development
  - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
  - DOE/Sandia provide $ for generic engineering, monitoring and assessment
  - Cost share $ from states, utilities, foundations, other stakeholders
Thank You:

Dr. Imre Gyuk
U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability

Dan Borneo
Sandia National Laboratories
Contact Information

Project website:
www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

Recording at www.cleanenergystates.org

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Today’s Speakers

James Ellison, Sandia National Laboratories
Dhruv Bhatnagar, Sandia National Laboratories
Dean Oshiro, Hawaiian Electric Company
Steven Rymsha, Maui Electric Company
Maui Electric Company Storage Evaluation Project: A Study for the DOE Energy Storage Systems Program

ESTAP Webinar

Jim Ellison, Dhruv Bhatnagar, and Ben Karlson

March 6, 2013 SAND 2013-1840C
Project

- Previous studies have indicated that significant levels of wind curtailment on Maui likely
  - Installed wind capacity to increase from 30MW to 72MW by 2015
  - Daily minimum around 70MW
- We were asked to evaluate various energy storage options for Maui, to determine
  - How different storage system characteristics and system operating assumptions impact wind curtailment, and
  - To what degree can energy storage projects be cost-effective
What is the value of storage to the grid?

- One definition: the present value of the stream of benefits from a project, minus the capital and maintenance costs (NPV to the grid)
  - Where the stream of benefits are simply the savings (in annual costs of generation) that accrue from having the storage resource in a grid

This is likely different from the value a resource owner can expect to obtain from a project (project NPV)

- A merchant storage resource in a competitive market
  - Can only monetize those benefits that are included in the market
  - Must depend on the market to differentiate based on capabilities

Focus here is on value to the grid
Is difficult because the value depends on

- The specific system the resource is planned for, including the
  - Load pattern and variability
  - Amount and variability of renewable generation
  - Characteristics of conventional units
- The application the resource is used for
- What it is compared with
- The size of the resource

How can a value be calculated?

- If in a market, can use historical price information to approximate
- If in a regulated system, need a different approach
What is a Production Cost Model?

- Answers the question: What is the least-cost dispatch to meet load?
- Consists of an interface, and an optimization solver
  - Interface – allows input of unit characteristics, load data, etc.
  - Solver – a commercial solver for solving large-scale optimization problems
- If we know the generator costs, why is this so complicated?
  - Optimizing for reserves as well as energy
  - Unit commitment decision
  - Economic dispatch
  - Operating reserves may be function of variable generation
Maui Grid Case Study

- 210 MW maximum load
  - 70 MW minimum

- Renewable Capacity
  - 72 MW of wind planned
  - 10 MW of biomass
  - 15 MW distributed PV

- Conventional Capacity (diesel)
  - 30 MW of steam
  - 95 MW of reciprocating engines
  - 100 MW of combined-cycle

Source: Google Maps, March 5, 2013
## Study Scenarios

<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>KPP Operations</th>
<th>Scenario Characteristics of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10MW / 15MWh battery</td>
<td>unchanged</td>
<td>spinning reserve value only</td>
</tr>
<tr>
<td>10MW / 70MWh battery</td>
<td>unchanged</td>
<td>spin + arbitrage</td>
</tr>
<tr>
<td>10MW / 70MWh battery, no K4</td>
<td>K4 not available</td>
<td>spin + arbitrage + K4 off</td>
</tr>
<tr>
<td>25MW Waena</td>
<td>K3/K4 not available</td>
<td>spin (w/minimum output) + K3/K4 off</td>
</tr>
<tr>
<td>25MW / 175MWh battery</td>
<td>K3/K4 not available</td>
<td>spin + arbitrage + K3/K4 off</td>
</tr>
<tr>
<td>25MW / 1200 MWh cryogen</td>
<td>K3/K4 not available</td>
<td>spin (w/min output) + large arbitrage + K3/K4 off</td>
</tr>
<tr>
<td>30MW Waena + 5MW/35MWh battery</td>
<td>KPP not available</td>
<td>flexible diesel (spin) + 5MW spin + KPP off</td>
</tr>
<tr>
<td>35MW Waena + trans. Line</td>
<td>KPP not available</td>
<td>flexible diesel (spin) + KPP off</td>
</tr>
</tbody>
</table>
Reference Run

Annual Curtailment

16.5%
10-MW/15-MWh Battery Scenario

Annual Curtailment 14.0%
10-MW/70-MWh Battery Scenario

Annual Curtailment: 9.5%
10-MW/70-MWh Battery, no K4

Annual Curtailment 7.1%
Wind Curtailment

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Wind Resource Curtailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Run</td>
<td>18%</td>
</tr>
<tr>
<td>10MW/15MWh BESS</td>
<td>16%</td>
</tr>
<tr>
<td>10MW/70MWh BESS, no K4</td>
<td>13%</td>
</tr>
<tr>
<td>25MW Waena</td>
<td>10%</td>
</tr>
<tr>
<td>25MW/175MWh BESS</td>
<td>7%</td>
</tr>
<tr>
<td>25MW / 1200 MWh cryogen</td>
<td>5%</td>
</tr>
<tr>
<td>30MW Waena + 5MW/35MWh BESS</td>
<td>4%</td>
</tr>
<tr>
<td>35MW Waena + transmission line</td>
<td>3%</td>
</tr>
</tbody>
</table>

- **Wind Curtailment** shows the percentage of wind resource that is curtailed under different scenarios.
- The scenarios include various combinations of battery energy storage systems (BESS) and transmission changes.

Source: Sandia National Laboratories
Wind Dispatched by Scenario

- Dispatchable S6
- S7
- S4
- S8
- S3
- S5
- S9
- Ref

Hour of the day

- Wind Dispatchable
- Ref Wind
- S2
- S3
- S4
- S5
- S6
- S7
- S8
- S9
## Economic Characteristics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Diesel</th>
<th>Wind</th>
<th>Diesel + Wind</th>
<th>Annual Savings</th>
<th>Estimated System Cost</th>
<th>Simple Payback (years)</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Run</td>
<td>194.8</td>
<td>45.0</td>
<td>239.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10MW/15MWh BESS</td>
<td>190.0</td>
<td>46.3</td>
<td>236.3</td>
<td>3.5</td>
<td>11</td>
<td>3.1</td>
<td>34.4</td>
</tr>
<tr>
<td>10MW/70MWh BESS</td>
<td>187.7</td>
<td>48.0</td>
<td>235.7</td>
<td>4.1</td>
<td>35</td>
<td>8.5</td>
<td>12.7</td>
</tr>
<tr>
<td>10MW/70MWh BESS, no K4</td>
<td>185.9</td>
<td>48.6</td>
<td>234.4</td>
<td>5.4</td>
<td>35</td>
<td>6.5</td>
<td>30.6</td>
</tr>
<tr>
<td>25MW Waena</td>
<td>189.8</td>
<td>47.7</td>
<td>237.6</td>
<td>2.2</td>
<td>25</td>
<td>11.4</td>
<td>5.3</td>
</tr>
<tr>
<td>25MW/175MWh BESS</td>
<td>180.2</td>
<td>49.4</td>
<td>229.7</td>
<td>10.1</td>
<td>87.5</td>
<td>8.7</td>
<td>29.6</td>
</tr>
<tr>
<td>25MW / 1200 MWh cryogen</td>
<td>185.2</td>
<td>49.4</td>
<td>234.6</td>
<td>5.2</td>
<td>31.25</td>
<td>6.0</td>
<td>40.3</td>
</tr>
<tr>
<td>30MW Waena + 5MW/35MWh BESS</td>
<td>185.5</td>
<td>48.6</td>
<td>234.1</td>
<td>5.7</td>
<td>47.5</td>
<td>8.3</td>
<td>31.0</td>
</tr>
<tr>
<td>35MW Waena + trans. Line</td>
<td>188.9</td>
<td>47.7</td>
<td>236.7</td>
<td>3.1</td>
<td>40</td>
<td>12.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Reference Run</td>
<td>10MW/15MWh BESS</td>
<td>10MW/70MWh BESS</td>
<td>10MW/70MWh BESS, no K4</td>
<td>25MW Waena</td>
<td>25MW/175MWh BESS</td>
<td>25MW / 1200 MWh cryogen</td>
<td>30MW Waena + 5MW/35MWh BESS</td>
</tr>
<tr>
<td>---------------</td>
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</tr>
<tr>
<td><strong>Change in Diesel Gen (GWh)</strong></td>
<td>(7.7)</td>
<td>(17.4)</td>
<td>(24.7)</td>
<td>(19.7)</td>
<td>(33.5)</td>
<td>(8.1)</td>
<td>(27.4)</td>
</tr>
<tr>
<td><strong>Change in Wind Gen (GWh)</strong></td>
<td>7.6</td>
<td>21.4</td>
<td>28.6</td>
<td>19.6</td>
<td>43.3</td>
<td>43.1</td>
<td>29.4</td>
</tr>
<tr>
<td><strong>Marginal Diesel Gen cost</strong></td>
<td>(1.7)</td>
<td>(3.8)</td>
<td>(5.5)</td>
<td>(4.3)</td>
<td>(7.4)</td>
<td>(1.8)</td>
<td>(6.1)</td>
</tr>
<tr>
<td><strong>Marginal Wind Gen cost</strong></td>
<td>1.4</td>
<td>3.0</td>
<td>3.6</td>
<td>2.8</td>
<td>4.5</td>
<td>4.4</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Expected cost diff</strong></td>
<td>(0.31)</td>
<td>(0.81)</td>
<td>(1.85)</td>
<td>(1.59)</td>
<td>(2.96)</td>
<td>(2.66)</td>
<td>(2.40)</td>
</tr>
<tr>
<td><strong>Actual cost diff</strong></td>
<td>(3.5)</td>
<td>(4.1)</td>
<td>(5.4)</td>
<td>(2.2)</td>
<td>(10.1)</td>
<td>(5.2)</td>
<td>(5.7)</td>
</tr>
<tr>
<td><strong>% due to increased system efficiencies</strong></td>
<td>91%</td>
<td>80%</td>
<td>66%</td>
<td>28%</td>
<td>71%</td>
<td>151%</td>
<td>58%</td>
</tr>
</tbody>
</table>
Conclusions

- All of the scenarios studied provided system savings compared to the reference case.
- In the scenarios with additional storage alone, 2/3 or more of the system savings is from the more efficient operation of the conventional units:
  - The efficient combined-cycle blocks, which typically provide spinning reserve, operate at higher levels with a storage system in place.
  - Peaking units are not operated at minimum load to provide reserve.
- Adding storage capacity to the 10MW battery helps to decrease wind curtailment:
  - But does not increase the efficiency of conventional unit dispatch.
Conclusions, contd.

- Storage provision of spinning reserve increases the efficiency of conventional unit use
  - Time-of-day shifting facilitates the dispatch of more wind
- Economics of time-of-day shifting depend on capturing large volumes
  - For two of the wind farms, PPAs specify volume discounts
- Waena biodiesel plants do not rank highly in terms of NPV
  - However, they allow the system to replace 150GWh/year of residual fuel-fired generation, at a net reduction in system operating cost
    - Even though they are required to burn biodiesel, which is about 3 times more expensive than residual fuel
- Significant upside to the Cryogen scenario if efficiencies can be increased above 50%
Future Tasks

- Is this study sufficient for MECO to make a decision on whether to install additional grid-level storage?
  - If not, what else is needed?
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