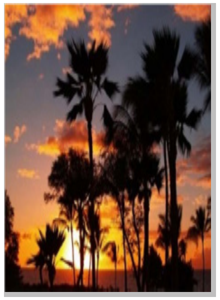


Sandia National Laboratories

Exceptional service in the national interest

Maui Electric Company Storage Evaluation Project

DOE Energy Storage Program
Peer Review 2012

Jim Ellison, Dhruv Bhatnagar, and Ben Karlson

September 28, 2012

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

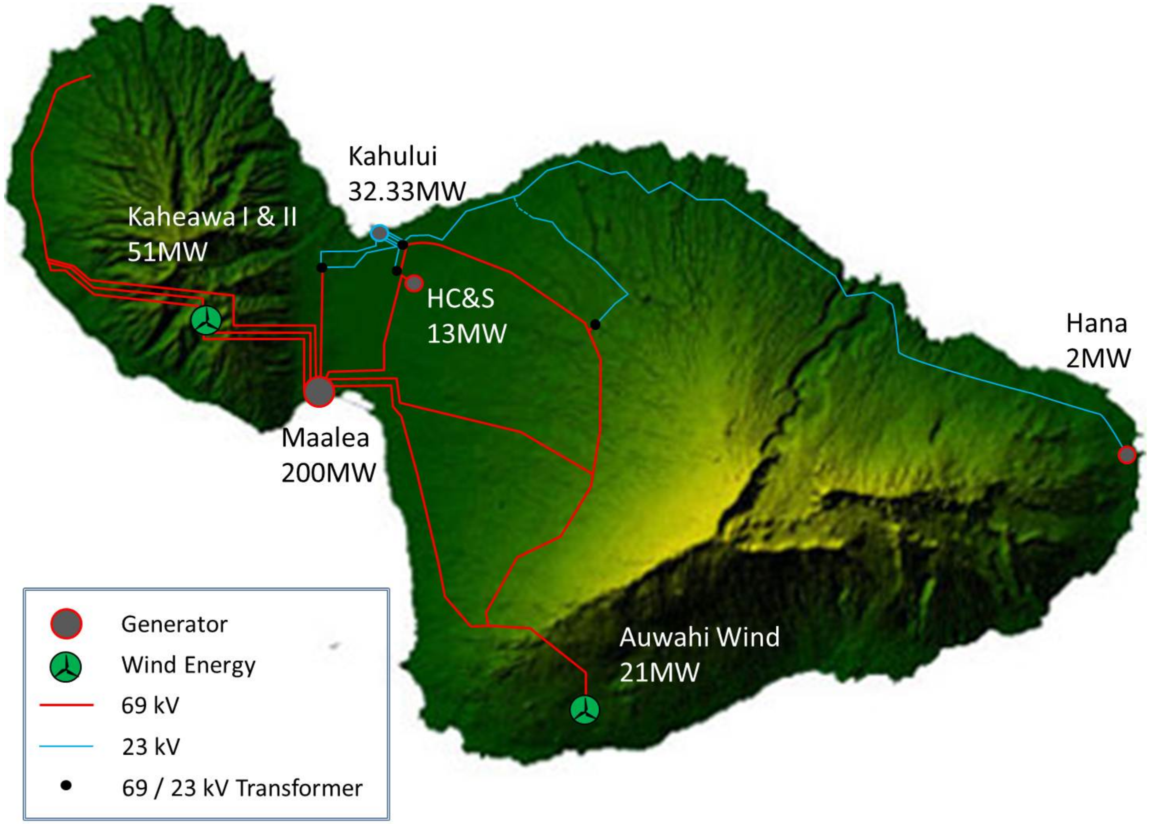
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Project

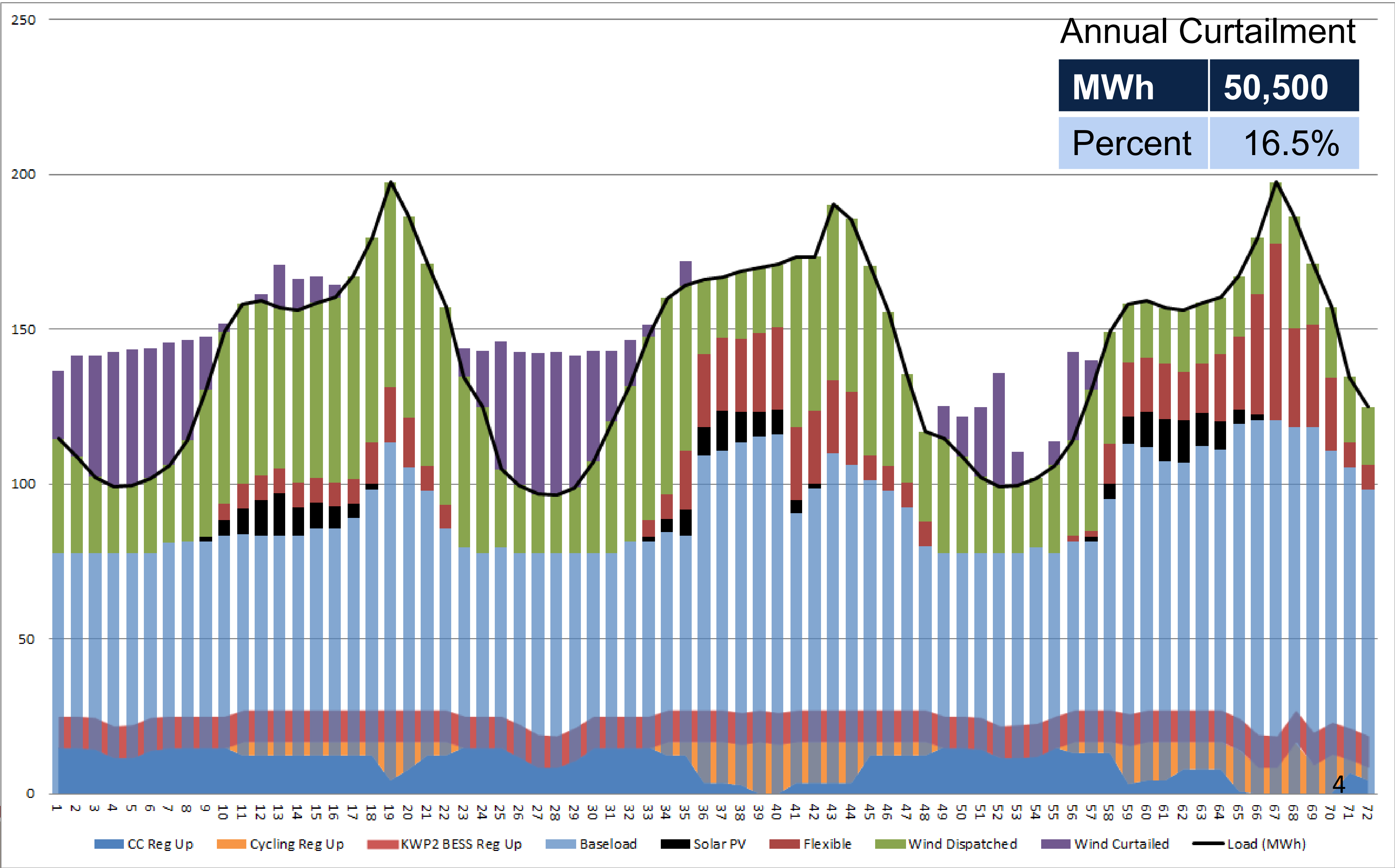
- Previous studies have indicated that significant levels of wind curtailment on Maui likely
  - Installed wind capacity to increase from 30MW to 72MW by 2015
  - Daily minimum around 70MW
- We were asked to evaluate various energy storage options for Maui, to determine
  - How different storage system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

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



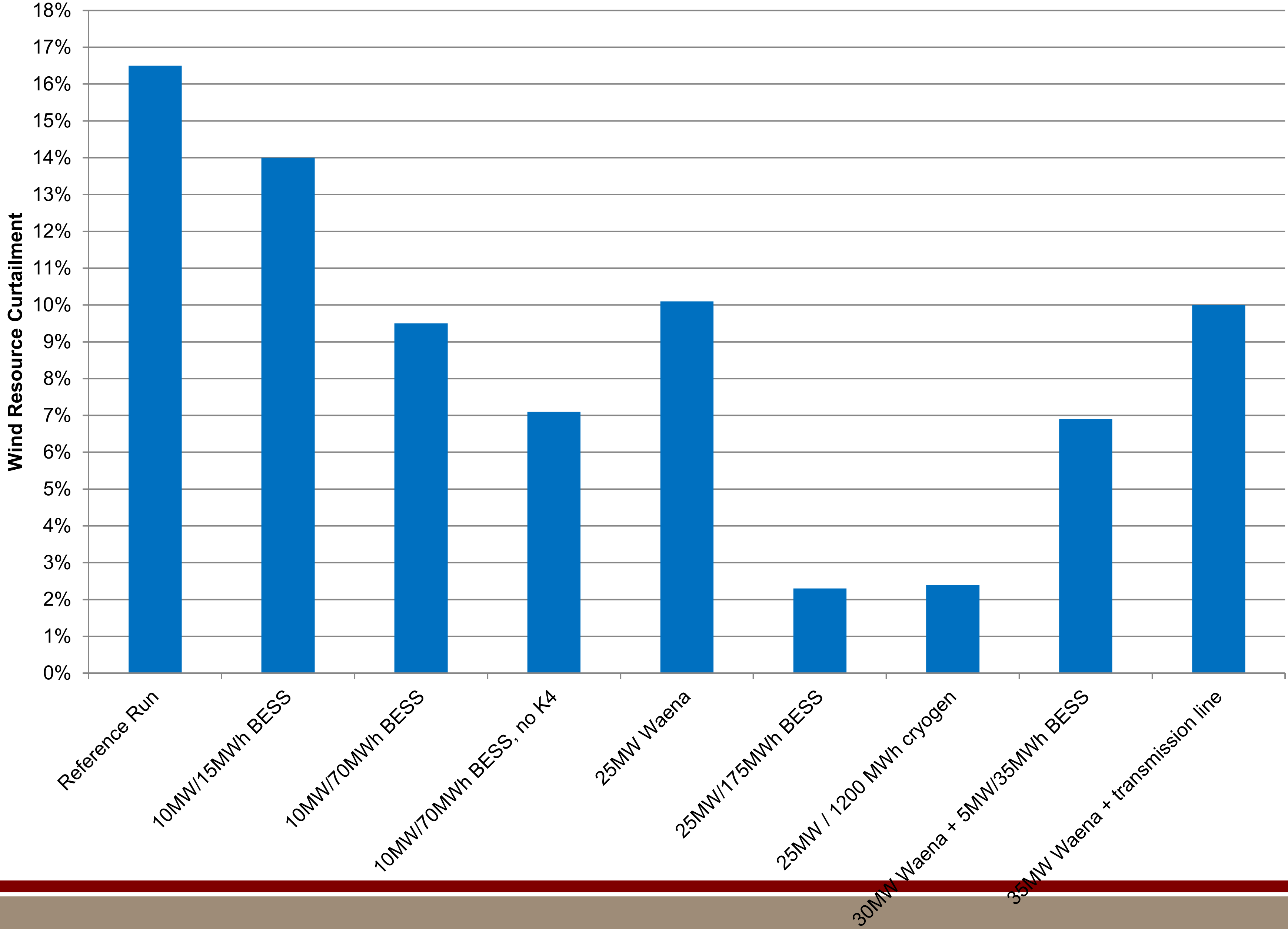
Reference Run



Study Scenarios

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

Wind Curtailment



Economic Characteristics

Scenario (Note: all figures in millions of USD, unless otherwise noted)	Diesel	Wind	Diesel + Wind	Annual Savings	Estimated System Cost	Simple Payback (years)	NPV
Reference Run	194.8	45.0	239.8	-	-	-	-
10MW/15MWh BESS	190.0	46.3	236.3	3.5	11	3.1	34.4
10MW/70MWh BESS	187.7	48.0	235.7	4.1	35	8.5	12.7
10MW/70MWh BESS, no K4	185.9	48.6	234.4	5.4	35	6.5	30.6
25MW Waena	189.8	47.7	237.6	2.2	25	11.4	5.3
25MW/175MWh BESS	180.2	49.4	229.7	10.1	87.5	8.7	29.6
25MW / 1200 MWh cryogen	185.2	49.4	234.6	5.2	31.25	6.0	40.3
30MW Waena + 5MW/35MWh BESS	185.5	48.6	234.1	5.7	47.5	8.3	31.0
35MW Waena + trans. Line	188.9	47.7	236.7	3.1	40	12.9	2.7

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
    - This increases the efficiency of these units, and decreases the use of less efficient units
- Adding storage capacity to the 10MW battery helps to decrease wind curtailment
  - But does not increase the efficiency of conventional unit dispatch
  - Does not seem to be economical, given the small differential between wind and diesel pricing at this level of wind production – and the large increase in battery cost

Conclusions, contd.

- Ability of storage to provide spinning reserve adds value by increasing the efficiency of conventional unit use
  - Ability to do time-of-day shifting adds value by facilitating the dispatch of more wind
- 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%

Recommendation: consider both the 10MW/15MWh battery (least financial/technical risk) and the Cryogen scenario (greatest NPV and upside potential) as potential projects

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?
    - A multi-year analysis, using multiple years of wind/solar data, as well as incorporating any anticipated changes to the MECO system?
    - A sub-hourly production cost model analysis?
- We are well-positioned to support MECO with the analysis needed to make a decision

Contact Information

Sandia National Laboratories

- Jim Ellison
  - E-mail: jelliso@sandia.gov
  - Telephone: (505) 286-7811
- Dhruv Bhatnagar
- Ben Karlson

OFFICE OF ELECTRICITY DELIVERY & ENERGY RELIABILITY

The study team gratefully acknowledges the support of Dr. Imre Gyuk and the Department of Energy's Office of Electricity Delivery & Energy Reliability.

Cost Savings Breakdown

(Note: figures in millions of USD, unless otherwise noted)	Change in Diesel Gen (GWh)	Change in Wind Gen (GWh)	Marginal Diesel Gen cost	Marginal Wind Gen cost	Expected cost diff	Actual cost diff	% due to increased system efficiencies
Reference Run	-	-	-	-	-	-	-
10MW/15MWh BESS	(7.7)	7.6	(1.7)	1.4	(0.31)	(3.5)	91%
10MW/70MWh BESS	(17.4)	21.4	(3.8)	3.0	(0.81)	(4.1)	80%
10MW/70MWh BESS, no K4	(24.7)	28.6	(5.5)	3.6	(1.85)	(5.4)	66%
25MW Waena	(19.7)	19.6	(4.3)	2.8	(1.59)	(2.2)	28%
25MW/175MWh BESS	(33.5)	43.3	(7.4)	4.5	(2.96)	(10.1)	71%
25MW / 1200 MWh cryogen	(8.1)	43.1	(1.8)	4.4	2.66	(5.2)	151%
30MW Waena + 5MW/35MWh BESS	(27.4)	29.4	(6.1)	3.7	(2.40)	(5.7)	58%
35MW Waena + transmission line	(19.9)	19.8	(4.4)	2.8	(1.61)	(3.1)	48%