Hawaii Power System Transitions

• Increasing renewable share to 100% by 2045
• Two major infrastructure proposals on the table:
  – Liquefied natural gas (LNG)
    • HECO containerized approach
    • Hawaii Gas bulk delivery approach
  – New 383 MW combined-cycle power plant at Kahe
• Uncertainty and complexity:
  – Future fuel prices
  – Ability to site new infrastructure
  – Identify least-cost mix of available options
Questions

• The big question:
  – What should we build between now and 2045?
• An easier question:
  – What should we build between now and 2030, if we are strongly risk-averse?
• Approach:
  – Limit ourselves to “no-risk” strategies:
    • Fully hedge fossil fuel prices
    • Recover cost of new LNG infrastructure and/or power plant before 2030 (no stranded assets)
  – Consider all permutations of the LNG and power plant choices
    • Build containerized, bulk or no LNG; build/don’t build combined-cycle (CC)
  – Use SWITCH power system optimization model to identify least-cost power system design and operation, built around each major choice
  – Compare results to identify “no-regrets” strategies, if any
SWITCH Power System Planning Model

Objective
• minimize total cost of electricity production in 2020-29 (net present value)

Optimized Decisions
• Investments: How much capacity to add of each technology
  – Wind, solar, fossil-fueled and hydro power plants; batteries and hydrogen storage
  – Investments occur in 2020 and 2025
• Operation: Power production by each project each hour, to meet hourly load
  – 24 sample days of weather conditions are modeled during each investment period

Constraints
• RPS: 30% in 2020-30
• LNG: use full quota of LNG in containerized case, even if more expensive than oil

Data Sources
• HEI PSIP (April 1, 2016)
  – Plant retirements and near-term additions (Theme 2)
  – Capital and interconnection costs of renewable and conventional generators and batteries
  – Peak and average electricity demand
  – Relationship between commodity and delivered prices for oil and containerized LNG
• Hawaii Gas
  – Hedged prices for commodity oil and gas
  – Formula for delivered price for LNG
• FERC Form 714 filings
  – Hourly electricity demand shape (based on 2007-08)
• Oahu Wind Integration and Transmission Study (NREL/AWS Truepower)
  – Hourly wind and solar conditions for 2007-08
• Google Maps API
  – Oahu rooftop inventory

Differences from PSIP
• Optimize selection of resources
• Optimize AES retirement
• Hedge oil and gas prices
• Recover cost of LNG infrastructure and new combined cycle plant before 2030 (no risk of stranded assets)

SWITCH-Hawaii maintained and run by Dr. Matthias Fripp, University of Hawaii, Manoa
Open-source model and data available at http://www.switch-model.org
LNG Price at Oahu Port

• Representative hedged prices for Henry Hub and Brent Crude in 2019-2028 from Hawaii Gas
  – extrapolated for 2029
• Build up price for delivered LNG from Henry Hub and Brent Crude prices:
  – HECO commodity LNG price: 1.1578 * Henry Hub + $8.0776/MMBtu
  – Hawaii Gas commodity LNG price: 0.1333 * BC ($/bbl) + $0.4521/MMBtu
  – Both inferred from price series provided by the parties (100% fit)
• Convert from nominal to real prices using EIA inflator
LNG Infrastructure Costs

• HECO (containerized) option
  – from LNG application to PUC 5/18/16
  – Receiving facilities at Kahe: $148M
  – Receiving facilities at Kalaeloa: $46M (inferred)
  – ISO containers for Oahu: $52M

• Hawaii Gas (bulk) option
  – From HG Response to PSIP 1/15/16
  – Turret system, subsea pipeline, nitrogen injection facility, onshore pipelines to Kahe and Kalaeloa: $200M
  – Floating storage and regasification unit (FSRU): $36M/y

• Both options: K5 & K6 burner upgrades: $18M
# Hedged Fossil Fuel Costs

## Fuel Cost ($/MMBtu)

<table>
<thead>
<tr>
<th>Year</th>
<th>Bulk LNG</th>
<th>Containerized LNG</th>
<th>LSFO</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020-24</td>
<td>$7.33</td>
<td>$10.78</td>
<td>$9.45</td>
<td>$2.95</td>
</tr>
<tr>
<td>2025-29</td>
<td>$7.32</td>
<td>$10.61</td>
<td>$9.47</td>
<td>$3.11</td>
</tr>
</tbody>
</table>

## Infrastructure and Plant Upgrades (cost if fully utilized)

<table>
<thead>
<tr>
<th></th>
<th>Bulk LNG</th>
<th>Containerized LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed cost ($/MMBtu)</td>
<td>$1.28</td>
<td>$1.03</td>
</tr>
<tr>
<td>Capacity (tpa)</td>
<td>1,000,000</td>
<td>680,000</td>
</tr>
</tbody>
</table>
Power Plants

- New Kahe Combined Cycle
  - As shown in PSIP Update 4/1/16
  - 383 MW Combined Cycle
    - Can burn LNG, LSFO, biodiesel, etc.
    - $1,718/kW (2016$) if built in 2020
    - Total cost: $658M

- Other thermal and renewable technologies as shown in PSIP Update

- Following PSIP, only K5, K6, Kalaeloa and new combined cycle are modeled as LNG-capable
## Cost of Optimal “Risk-Free” Power Systems

<table>
<thead>
<tr>
<th>PSIP Theme 2 Preferred Plan</th>
<th>Containerized LNG</th>
<th>Bulk LNG</th>
<th>No LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>$10 B</td>
<td>$8 B</td>
<td>$8 B</td>
</tr>
<tr>
<td>no CC</td>
<td>$9 B</td>
<td>$7 B</td>
<td>$7 B</td>
</tr>
</tbody>
</table>

NPV of electricity costs, 2020-29 ($billion)
Optimal Power System Designs, Without New Combined Cycle Plant

- **PSIP Theme 2 Preferred Plan**
- **Containerized LNG, Optimized**
- **Bulk LNG, Optimized**
- **No LNG, Optimized**

| Year     | Offshore Wind | Onshore Wind | Utility-Scale PV | DistPV | HPOWER | Kalaeloa | IC Projects | Kahe/Waiau/CIP | Combined Cycle | Cogen | AES |
|----------|---------------|--------------|------------------|--------|--------|----------|-------------|----------------|----------------|-------|-----|-----|
| 2020-25  |               |              |                  |        |        |          |             |                 |                 |       |     |     |
| 2025-29  |               |              |                  |        |        |          |             |                 |                 |       |     |     |
Optimal Power System Designs, With New 383 MW Combined Cycle Plant

Installed capacity (MW)

PSIP Theme 2
Preferred Plan

Containerized LNG,
Optimized

Bulk LNG,
Optimized

No LNG,
Optimized

- Offshore Wind
- Onshore Wind
- Utility-Scale PV
- DistPV
- HPOWER
- Kalaeloa
- IC Projects
- Kahe/Waiau/CIP
- Combined Cycle
- Cogen
- AES
Optimal Power System Operation, Without New Combined Cycle Plant

HECO PSIP Theme 2
Preferred Plan
(39% renewable)

Containerized LNG,
Optimized
(30% renewable)

Bulk LNG,
Optimized
(40% renewable)

No LNG,
Optimized
(49% renewable)

Annual power production (GWh)

- Offshore Wind
- Onshore Wind
- Large Solar
- Dist Solar
- Pellet biomass
- Biodiesel
- Pellet biomass
- Waste
- LNG
- LSFO
- Coal

2020-2024
2025-2029

680 ktpa
680 ktpa
680 ktpa
499 ktpa
467 ktpa
Optimal Power System Operation, With New Combined Cycle Plant

HECO PSIP Theme 2
Preferred Plan
(39% renewable)

Containerized LNG, Optimized
(30% renewable)

Bulk LNG, Optimized
(30% renewable)

No LNG, Optimized
(30% renewable)

Annual power production (GWh)

- Offshore Wind
- Onshore Wind
- Large Solar
- Dist Solar
- Biodiesel
- Pellet biomass
- Waste
- LNG
- LSFO
- Coal

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<th>Bulk LNG</th>
<th>No LNG</th>
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</thead>
<tbody>
<tr>
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<td>680 ktpa</td>
<td>680 ktpa</td>
<td>499 ktpa</td>
<td>467 ktpa</td>
</tr>
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<td>2025-2029</td>
<td>680 ktpa</td>
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(Values are illustrative and subject to change based on actual power production data.)