Puerto Rico – St. Kitts and Nevis Electricity Inter-Connection Study
Energy and Climate Partnership of the Americas

Partnership of stakeholders on energy and climate change

Medium for exchange of best practices

Dialogue forum
- Working group meetings
- Ministerial events
- Summit processes related to energy and climate
Seven pillars of ECPA

- Energy efficiency
- Renewable Energy
- Cleaner and more efficient use of fossil fuels
- Energy infrastructure
- Energy poverty
- Sustainable forests and land use
- Adaptation

Energy and Climate Partnership of the Americas
ECPA
ECPA Project Initiatives in the Caribbean

• **Connecting the Americas 2022:** Hemispheric initiative (ECPA Infrastructure Pillar) designed to increase electricity interconnections among countries of the Americas

• **ECPA Caribbean Initiative:** US Department of State sponsored program, through the OAS, to support sustainable energy programs and initiatives in the region. Includes, sponsoring interconnection assessment – SKN-PR
Caribbean Interconnection: Pathways to a shared and sustainable energy future?

- Caribbean Interconnection Studies Completed or In-Process:
  - SKN-PR: Managed by OAS; funded by US Dept. of State; executed by KEMA Inc.
  - Puerto Rico-US Virgin Islands; funded by US Department of Energy; managed by NREL; Executed by Siemens
  - Puerto Rico-Dominican Republic; World Bank
  - Barbados-Grenada-St. Vincent and the Grenadines-St. Lucia; World Bank
  - Dominica-Martinique-Guadeloupe; EDF
  - Regional (preliminary) interconnection and supply side study – World Bank; executed by Nexant (source for photo above)
Energy Supply – Interconnections and Regional Sources of Energy

• According to recent World Bank Study, “Relying on diesel and HFO is the most costly solution”
• There are multiple fuel and power supply options that offer cost-effective alternatives to the current situation, including, pipeline gas, shipped LNG, and renewables (geothermal, wind) interconnected via submarine cable
• **Investment requirements** are large but production costs saving are huge
• A variety of **private, public and IFI** support will be necessary
• Requires countries to improve **legal, regulatory and institutional** framework and cross-country cooperation
Interconnection May Help Address Key Caribbean Energy Risks

- **High fossil fuel prices/fluctuations** (economic hardships/energy poverty associated with high and rising costs)

- **Fossil fuel/power supply disruptions** (transmission disruptions, generation outages, minimal storage capabilities, weather threats to shipping, etc.)

- **Climate risks** (Hurricanes, sea level rise, increased frequency/strength of extreme weather events, etc.)
Regional interconnection outlook

QUESTIONS
Two phase Interconnection study

1. Feasibility of the much larger interconnection
   – St. Kitts–Nevis and Puerto Rico; and
   – Optional connection to St Croix.

2. Feasibility of interconnecting St. Kitts and Nevis
• Long term Vision:
  – Utilize large-scale St. Kitts–Nevis geothermal power
  – Generate revenue for SKN based on royalties of power sales to PR
  – Part of a larger regional interconnection strategy

• Potential sizes
  – 200 MW
  – 400 MW
  – 600 MW
Elements of the interconnection

• St. Kitts–Nevis geothermal energy supply (when, how much available, cost...)
• Replace fossil fuels on Puerto Rico (& STX) (which fuels, oil vs. natural gas)
• Submarine cable (type, size, route, landing points)
• Terminal equipment
• St. Croix possible intermediate connection
Routes considered

- Puerto Rico
- Nevis
- St. Croix

Proposed routes:
- Alt A
- Alt B

Very deep region

Active boating area

Many existing cables to cross

Far too deep for present cable technology
Net savings

- Savings
  - PREPA reduced generation
  - St Croix reduced generation

Minus

- Costs

Equals

- Net savings (or costs)
Puerto Rico savings

- Generation fuel mix—replaced oil & LNG
  - More oil means more savings

- Value of savings
  - Generation efficiency (heat rates)
    - Less efficient means more savings
  - Fuel prices
    - Higher fuel prices mean more savings

- Amount of energy from St. Kitts–Nevis
  - More energy means more savings
Puerto Rico fuel mix—2014

- **Natural gas**: 71%
- **Oil**: 12%
- **Coal**: 7%
- **Renewables**: 10%

Replace oil first
Replace NG second

Assumed ½ of oil (6%) must continue for meeting peak loads. So, ½ can be replaced.
Fuel price forecasts

• **Low**
  - Oil 2%/yr
  - LNG -3%/yr

• **Flat**
  - 1.0%/yr all fuels

• **Mixed (½ of high)**
  - LNG 4%/yr
  - Oil 5%/yr

• **High**
  - LNG 8%/yr
  - Oil 10%/yr

Relative to prevailing inflation
## Energy from Nevis geothermal

### Nevis geothermal generation size

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
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</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>200</td>
<td>400</td>
<td>600</td>
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<tr>
<td>Hours</td>
<td>8,760</td>
<td>8,760</td>
<td>8,760</td>
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<tr>
<td>Geothermal capacity factor</td>
<td>75%</td>
<td>90%</td>
<td>75%</td>
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<tr>
<td>Annual production (GWh)</td>
<td>1,314</td>
<td>1,577</td>
<td>2,628</td>
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<td></td>
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<tr>
<td>Puerto Rico displaced energy (GWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil (6% maximum)</td>
<td>1,110</td>
<td>1,110</td>
<td>1,110</td>
</tr>
<tr>
<td>LNG</td>
<td>204</td>
<td>467</td>
<td>1,518</td>
</tr>
</tbody>
</table>

- Simple multiplication
- Assume \( \frac{1}{2} \) (6%) oil will be required by PREPA
- Oil is replaced first (most expensive)
- Then subtraction
- More geothermal replaces LNG all cases

### Puerto Rico displaced energy (GWh)

<table>
<thead>
<tr>
<th></th>
<th>Oil (6% maximum)</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
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<td>1,110</td>
<td>1,518</td>
</tr>
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19
## Puerto Rico savings—200 MW geothermal

Energy x Cost = Savings

<table>
<thead>
<tr>
<th></th>
<th>Fuel prices</th>
<th>Flat</th>
<th>High</th>
<th>Low</th>
<th>Mixed</th>
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<tr>
<td><strong>Displaced energy (GWh)</strong></td>
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<tr>
<td>Crude Oil (Oil)</td>
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<tr>
<td>LNG</td>
<td>204</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Energy cost ($/MWh)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Crude Oil (Oil)</td>
<td>315.75</td>
<td>1187.79</td>
<td>366.57</td>
<td>571.87</td>
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<td>LNG</td>
<td>98.79</td>
<td>277.85</td>
<td>54.11</td>
<td>154.35</td>
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<td><strong>Annual saving ($000)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Crude Oil (Oil)</td>
<td>350,478</td>
<td>1,318,446</td>
<td>406,892</td>
<td>634,778</td>
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<tr>
<td>LNG</td>
<td>20,153</td>
<td>56,682</td>
<td>11,038</td>
<td>31,488</td>
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<tr>
<td><strong>Total</strong></td>
<td>370,631</td>
<td>1,375,128</td>
<td>417,930</td>
<td>666,265</td>
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<tr>
<td>$/MWh</td>
<td>282.06</td>
<td>1046.52</td>
<td>318.06</td>
<td>507.05</td>
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<tr>
<td>¢/kWh</td>
<td>28.21</td>
<td>104.65</td>
<td>31.81</td>
<td>50.71</td>
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</table>

Similar calculation for 200 MW at 90% and 400 MW and 600 MW
Puerto Rico savings for all geothermal sizes

Very wide range of potential savings

<table>
<thead>
<tr>
<th>Fuel prices</th>
<th>Geothermal at 75%</th>
<th>Geothermal at 90%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Flat</td>
<td>High</td>
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<tr>
<td>200 MW</td>
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<td></td>
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<tr>
<td>¢/kWh</td>
<td>28.21</td>
<td>104.65</td>
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<tr>
<td>400 MW</td>
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<td></td>
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<tr>
<td>¢/kWh</td>
<td>19.04</td>
<td>66.22</td>
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<td>600 MW</td>
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<tr>
<td>¢/kWh</td>
<td>15.99</td>
<td>53.41</td>
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</tbody>
</table>
Costs

- Geothermal energy production cost: 10-15 ¢/kWh
- Transmission connection costs: 7.2-16.6 ¢/kWh
  - Submarine cable and installation: $2,000-2,400 million
  - HVDC converter stations: $92-240 million
  - Overhead transmission: $35-65 million
- Total cost: 17.2-31.6 ¢/kWh
Costs and savings—200 MW

- Costs and savings
- Clear net benefit: costs < savings
- Net loss: costs > savings
- Similar results for 400 MW and 600 MW

Fuel price forecast

- Low
- Flat
- Mixed
- High

Cost range

Savings

Fuel price forecast

€/kWh
Critical variables

- Fuel prices
  - Oil range
  - LNG range

- Puerto Rico savings
  (break-even = $17-31/kWh)
  - Assumed Oil/LNG mix in study
  - If all oil—break-even is $14-26/MMbtu
  - If all LNG—break-even is $19-35/MMbtu
Conclusions: St Kitts & Nevis to Puerto Rico Interconnection

• Interconnection is technically feasible
• Cable and installation is 90% of cost
• Fuel prices above ‘flat’ estimate needed to be economic (1%/yr for all fuels)
• Availability and cost of geothermal are critical components, tbd
• With high fuel prices, very economic
• St Croix is very economic as an add-on
Puerto Rico to St. Kitts–Nevis interconnection

QUESTIONS
Phase 2 study—St. Kitts–Nevis connection

• Key factors
  – New geothermal generation
    • Amount
    • Timing
    • Price
  – New transmission connection
    • Overhead versus underground
    • Timing
    • Cost
  – Cost of diesel generation
    • Where the savings are
Based on expected production of geothermal electricity in two stages

1. Initial generation
   a. 14,000 kW or
   b. 20,000 kW

2. Later generation
   a. 35,000 kW
   b. Not before 2021 or much later
## Four transmission plans

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<tr>
<th>Plan</th>
<th>Geothermal generation</th>
<th>Later</th>
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<td>Initial</td>
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<tr>
<td>1</td>
<td>14,000 kW</td>
<td>20,000 kW</td>
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<td></td>
<td>Submarine cable</td>
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<td></td>
<td>Nevis—Frigate Bay</td>
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<tr>
<td></td>
<td>Overhead line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frigate Bay—Basseterre</td>
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<tr>
<td>2</td>
<td>Submarine cable</td>
<td></td>
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<tr>
<td></td>
<td>Nevis—Frigate Bay</td>
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<td>3</td>
<td>Submarine cable</td>
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<td></td>
<td>Frigate Bay—Basseterre</td>
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<tr>
<td>4</td>
<td>Submarine cable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nevis—Basseterre</td>
<td></td>
</tr>
</tbody>
</table>
Transmission Plan 1

Submarine and overhead

- Nevis to Frigate Bay (3 miles, $7.8M) 14,000 kW
- Frigate Bay to Basseterre overhead (9 miles, $2.0M) 35,000 kW
Transmission Plan 2

All submarine in two stages

Frigate Bay to Basseterre (9.7 miles, $20.8M) 35,000 kW

Nevis to Frigate Bay (3 miles, $7.8M) 14,000 kW
Transmission Plan 3

Submarine and overhead

Frigate Bay to Basseterre overhead
(9 miles, $2.0M)
35,000 kW

Nevis to Frigate Bay
(3 miles, $7.8M)
20,000 kW

Plan 3 is same as Plan 1, but builds both at the beginning
All submarine, all at once

Nevis to Basseterre
(10.5 miles, $22.0M)
20,000 kW and
35,000 kW
Transmission cost summary

• Submarine and overhead
  – $9.8M
• All submarine
  – $22M to $28M
These are *annual* costs (10.3% of fixed costs)

The submarine plans are much more expensive

The other plans are about the same cost

<table>
<thead>
<tr>
<th>Plan</th>
<th>Small geothermal</th>
<th>Medium geothermal</th>
<th>Large geothermal</th>
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</thead>
<tbody>
<tr>
<td>Plan 1—sub +o/h</td>
<td>905,000</td>
<td></td>
<td>1,170,000</td>
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<tr>
<td>Plan 2—all sub</td>
<td>905,000</td>
<td>1,055,000</td>
<td>3,220,000</td>
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<td>Plan 3—sub+o/h</td>
<td></td>
<td>1,055,000</td>
<td>1,055,000</td>
</tr>
<tr>
<td>Plan 4—all sub</td>
<td></td>
<td>2,505,000</td>
<td>2,505,000</td>
</tr>
</tbody>
</table>
Break-even (part 1)

• Costs
  – Transmission
    • Plans 1 & 2 $9.8M
    • Plan 3 $28.6M
    • Plan 4 $22.0M

• Savings from geothermal
  – Geothermal costs (¢/kWh) 10 12
  – Avoided diesel costs (¢/kWh) 30 30
  – Savings (¢/kWh) 20 18
Break-even (part 2a)

Diesel cost = 30 ¢/kWh

<table>
<thead>
<tr>
<th></th>
<th>Plan 1</th>
<th>Plan 2</th>
<th>Plan 3</th>
<th>Plan 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal capacity (MW)</td>
<td>14</td>
<td>14</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Saving (¢/kWh)</td>
<td>18-20</td>
<td>18-20</td>
<td>18-20</td>
<td>18-20</td>
</tr>
<tr>
<td>Energy (kWh)</td>
<td>38,000,000</td>
<td>38,000,000</td>
<td>76,000,000</td>
<td>76,000,000</td>
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<tr>
<td>Annual saving ($M)</td>
<td>6.8 – 7.6</td>
<td>6.8 – 7.6</td>
<td>13.7 – 15.2</td>
<td>13.7 – 15.2</td>
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<tr>
<td>Transmission cost ($M)</td>
<td>9.8</td>
<td>9.8</td>
<td>28.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Break even (mo)</td>
<td>16 – 18</td>
<td>16 – 18</td>
<td>23 – 26</td>
<td>18 - 20</td>
</tr>
</tbody>
</table>

Break-even is pretty fast: 1½ to 2¼ yrs
Risk factors

• Geothermal generation
  – Available on Nevis 14, 35, 200 MW??
  – Initial development (14 vs 20 MW)
  – Price 10-12 ¢/kWh ??

• St. Kitts–Nevis load growth
  – Timing of 35 MW plant

• Transmission
  – Cost of submarine cable
  – Timing of 35 MW plant
St. Kitts – Nevis interconnection benefits

- Shared use of low cost/reliable renewable energy
- Increased resilience of power system
- Upgrade transmission/distribution
- Potential for integrated electric utility
St. Kitts and Nevis interconnection

QUESTIONS
Thank You!

Key Contacts:
Mark Lambrides (OAS)  mlambrides@oas.org
Kevin De Cuba (OAS)  kdecuba@oas.org
Starret Greene (OAS)  sgreene@oas.org
Sherry Hong (US State Department)  HongCS@state.gov
Jeff Palermo (Kema, Inc.)  jeff.palermo@kema.com