Sustainable/Renewable Energy @ Puerto Rico

What, When, Who, Where, Why and How

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AGENDA

## INTRODUCTION
- Sustainable Energy Definition

## Puerto Rico Assessment (today)
- PV, Concentrated Solar Power (CSP), Aeolic (wind energy) & Fuel Cells
- Capital ($), Footprint & Operational costs ($)

## Others
- Biomass (biodiesel, waste) & Ocean (waves, tides, thermal & deep water effervescence)
- Liquid Fuels (Diesel and Gasoline)

## Near Term Commercial Opportunities

## "The Plan"

## QUESTIONS
Introduction

Sustainable Energy: a living harmony between the equitable (including financial) availability of energy services to all people and (Renewable Energy) the preservation of the earth for future generations.

Fuel Cells/PV/Aeolic/CSP

*Aeolus* - Greek Mythology, Ruler of the winds
CSP - Concentrated Solar Power
PV - Photovoltaic
Foot Print/(Capital * Operating Costs) Index

System

- FC 2 MWchp
- Utility
- FC 2 MWe
- WT Individual
- CSP (Dish)
- PV w Bat
- PV w/o Bat
- WT Farm
PR Area required (%Total) versus Electric Capacity (%)
Total Electric Capacity (5 GW)
Expressways PV potential, 100 W/m²

- Road Miles
- kW
- Panels Width (ft)

Legend:
- 400,000-450,000
- 350,000-400,000
- 300,000-350,000
- 250,000-300,000
- 200,000-250,000
- 150,000-200,000
- 100,000-150,000
- 50,000-100,000
- 0-50,000
Commercial Establishments;
PV Systems Investment Analysis, No Incentives/Subsidies

PV systems Monthly Savings;
$0.20/kw-hr, $100,000 investment, 12.5 kW
(tax savings not included)
Commercial Establishments;
PV Systems Investment Analysis, 50% Incentives/Subsidies ($4/W)

PV systems Monthly Savings;
$0.20/kw-hr, $50,000 investment, 12.5 kW, $4/W Subsidy (tax savings not included)
Net Metering in the USA

State-wide net metering for certain utility types (e.g., IOUs only)

- NH: 25
- MA: 60
- RI: 25*
- CT: 100

Net metering offered by one or more individual utilities

- PA: 50/1,000/2,000
- NJ: 2,000
- DE: 25
- MD: 500
- DC: 100
- VA: 10/500

50s indicate system size limit (kW); in some cases limits are different for residential and commercial as shown.

Net metering is available in 41 states + D.C.

Used with permission from the North Carolina Solar Center (www.dsireusa.org)
February 2007
Wind Turbine Demo @ HP;
Base Conditions - $0.15 kW-hr, 10 yrs investment, $4.0/W Capital Cost & 24 hours/day
140 Air Defense Squadron (140ADS)

PR First 5 KW Fuel Cell Location
# VIABILITY STUDY

## Case 1 output

### LEASE Calculations Summary
**Hewlett Packard, Puerto Rico**

<table>
<thead>
<tr>
<th>KW Output of FC</th>
<th>450 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability (assumed)</td>
<td>90%</td>
</tr>
<tr>
<td>Annual KWh Output</td>
<td>3547800 kWh</td>
</tr>
</tbody>
</table>

**Grid Electric Rate**

<table>
<thead>
<tr>
<th>Year 1</th>
<th>$0.1600</th>
<th>$/kWh</th>
<th>Year 10</th>
<th>$0.1829</th>
<th>$/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Purchased Electric $$ Displaced by FC</td>
<td>$567,648</td>
<td>$</td>
<td>$636,062</td>
<td>$</td>
<td></td>
</tr>
</tbody>
</table>

### LEASE CALCS

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calculated Annual Savings •• Electric + Thermal</strong></td>
<td>$719,552</td>
<td>$710,782</td>
<td>$702,147</td>
<td>$745,481</td>
</tr>
<tr>
<td><strong>Lease PMT = Annual O&amp;M + Finance Costs</strong></td>
<td>$737,429</td>
<td>$740,398</td>
<td>$743,412</td>
<td>$746,471</td>
</tr>
<tr>
<td><strong>Customer Benefit $$...NPV</strong></td>
<td>($89,880)</td>
<td>$(17,876)</td>
<td>$(29,616)</td>
<td>$(41,265)</td>
</tr>
</tbody>
</table>

**Case-1 Conclusion:** **Negative Customer NPV**
COMPARATIVE STATE SIDE PROJECT

California - model output

Sierra Pacific Packaging
Power Purchase Agreement Summary

2 DCE DFC300 MA Fuel Cell Power Plants 500 kW
Forecast Power Plant Operating Availability 90%

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Total Energy Savings</td>
<td>$605,998</td>
<td>$608,295</td>
<td>$610,601</td>
<td>$669,212</td>
<td>$678,430</td>
</tr>
<tr>
<td>Total Annual Project Cost O&amp;M+Finance</td>
<td>$534,929</td>
<td>$542,880</td>
<td>$545,024</td>
<td>$567,299</td>
<td>$575,412</td>
</tr>
<tr>
<td>Forecast Sierra Pay Rate ($/kWH)</td>
<td>$0.1357</td>
<td>$0.1420</td>
<td>$0.1469</td>
<td>$0.1439</td>
<td>$0.1489</td>
</tr>
<tr>
<td>Customer Savings ($/kWH)</td>
<td>$0.0118</td>
<td>$0.0107</td>
<td>$0.0111</td>
<td>$0.0196</td>
<td>$0.0203</td>
</tr>
<tr>
<td>Customer Net Benefit $$...NPV</td>
<td>$628,593</td>
<td>$71,069</td>
<td>$65,415</td>
<td>$65,577</td>
<td>$101,912</td>
</tr>
</tbody>
</table>
# Available Fuel Cell Subsidies

## State & federal

### Federal Subsidy
1. Incentive Tax Credits
   - $1000/kW not to exceed 30% of installed equipment

### State Subsidy
1. California
   - $2,500/kW or $4,500/kW (non-renewable vs. renewable)
2. Connecticut
   - $4,700/kW DG and $500/kW from the 2005 EIA
   - $0.01/kWh for 10 years in constrained area
3. New Jersey
   - $4,000/kW CHP max of $1,000,000
4. New York
   - Low interest loans
5. Massachusetts
   - Low interest loans
Concentrated Solar Power Comments; Power Towers, Trough & Dish Engine Systems

- Highly versatile 5 kW (residential) to 200 MW options.
- Competitive foot print - cost index.
- Effective in arid/desert regions with sustained high levels of direct normal insolation (i.e., Peñuelas/Guayanilla brownfields).
- Over 20 years of operating experience at MW levels (no surprises technical or financial).
- Designed with energy storage systems to operate 24/7.
Ocean Tide/Waves/Thermal
Existing La Rance; 22 km² & 8.5 m Tide height, 65 MWte
Ocean Thermal Potential

Temperature difference between surface and depth of 1,000 meters

- less than 18°C
- 18°C to 20°C
- 20°C to 22°C
- 22°C to 24°C
- more than 24°C
- depth less than 1,000 meters

This global-scale map does not adequately portray features that are smaller than 300 kilometers.
**Ocean Energy General Comments/Issues**

- Good wave power often correlates with offshore wind power sources.
- Shoreline sites are expensive. Cost structure not well known (capital and operational).
- Aesthetic, Fishing and Navigation hazards concerns must be addressed.
- Tidal/Wave control changes the regular cycle of wetting and dryout resulting in changes in the mix of species.
- OTEC may bring $CO_2$ and preserved pathogens to the surface from the bottom.
Other Renewable Energy Alternatives
Liquid Fuels/Transportation Sector

**Diesel: Biodiesel Option**
- 200 to 300 MG PY Non-PREPA
- Land not available (Microalgae ???)
- Import Tallow (100 MG PY)
  - Byproduct 10 MG PY Glycerine
  - Develop Glycerine derivative technology (i.e., propylene glycol)
- Renewable options minimize peak turbines operation and fuel consumption (today 400 MG PY)

**Gasoline ~ 1.2 billion GPY**
- Waste to Fuel Option
  - 50 to 100 MG PY maximum
  - Based on 2,000 to 4,000 tons/day
Biodiesel Towns Requirements;
Topography Factor ~ 2.5
Solid Waste Energy Generation

- **Existing Landfill gases**
  - 10 year window
  - 50 to 100 MW$_e$ potential
    - PEM to Solid Oxide

- **Steady State Energy Generation**
  - Waste to Energy Facilities
  - 120 MW potential
  - 2,000 to 4,000 tons/day basis
  - 30 MW/1,000 tons/day
Constant Total Income Curves without Auxiliary Power Generation

Electricity Income

PREPA Income ($/kW-hr)

Tipping Fee ($/ton)

1,000 TPD

2,000 TPD

3,000 TPD

TF = EI
The Plan

“Near/Mid term” Commercial Opportunities
Near/Mid Term Commercial Opportunities

- **Energy Efficiency/Conservation**
  - Phosphorescent versus incandescent
- **Fuel Cell/hybrid Commuter vehicles**
  - Recurring $120 to $240 million per year industry (10% market penetration)
- **PV panels (residential) and backup FC**
  - Potential market 100K units @ 10K per unit ($1 billion total). Based on existing generator market. Similar to backup fuel cell systems (50 kW-hr units)
Sol Aire Gente Agua de Puerto Rico

Diagram:
- Sea Water
  - Wind Energy
  - Hydropower
  - Biomass Energy
  - Solar Energy
  - Hydrogen Production
  - Electricity
  - Heat
  - Nature

- Hydrogen Storage
- Fuel Cells
- Air
- Electricity
- Heat
- Puerto Rico

- Energy Efficiency
Muchas Gracias