Sustainable/Renewable Energy @ Puerto Rico

What, When, Who, Where, Why and How

Dr. José A. Colucci-Ríos, PE, Presenter
Dr. Efraín O’Neill-Carrillo, PE
Dr. Agustín A. Irizarry-Rivera, PE
AGENDA

- INTRODUCTION
  - Sustainable Energy Definition
- Social/Acceptance/Other Issues
  - LCA, Externalities, Population Trends, Interconnection issues
- Puerto Rico Assessment (today)
  - PV, Concentrated Solar Power (CSP), Aeolic (wind energy), Fuel Cells & Solar Thermal Water Heaters
  - Capital ($), Footprint & Operational costs ($)
- Others
  - Biomass (biodiesel, waste) & Ocean (waves, tides, thermal & deep water effervescence)
  - Liquid Fuels (Diesel and Gasoline)
- The Dream, The Plan and The Players
- Acknowledgements
- 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.

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
140 Air Defense Squadron (140ADS)

PR First 5 KW Fuel Cell Location
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.
Case Study

Generation Displacement, Power Loss and Emissions Reduction due to Solar Thermal Water Heaters

Jennifer Jiménez-González & Agustín Irizarry-Rivera
## Preliminary Results, Mayagüez only

<table>
<thead>
<tr>
<th>Category</th>
<th>Estimated reductions</th>
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<tbody>
<tr>
<td>Electricity Demand</td>
<td>10 MW (PR~400 MW)</td>
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<tr>
<td>Electric System Losses</td>
<td>0.36 MW and 3.9 MVAR</td>
</tr>
<tr>
<td>Electric Generation</td>
<td>10.36 MW and 3.9 MVAR</td>
</tr>
<tr>
<td>Emissions, lbs</td>
<td>$CO_2$ - 8,600, $NO_x$ - 6.48 and $SO_2$ - 5.25</td>
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</tbody>
</table>
Ocean Tide/Waves/Thermal
Tidal Power Locations

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.
Other Renewable Energy Alternatives
Liquid Fuels/Transportation Sector

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

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

Equivalent Towns

Market (million gpy)

Ag Productivity (MMg/yr-1000 H)
Solid Waste Energy Generation

- **Existing Landfill gases**
  - 10 year window
  - 50 to 100 MWₑ 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
Sustainable Energy Technologies @ PR
The Dream, The Plan, The Players
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<td>1 or 3 MW FC Demo (Scope)</td>
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- Project: RE Future PR
- Date: Tue 11/8/00

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**Timeline:**

- **2006:**
  - Development Long Term Plan
  - Dev Short Term Plan (DEMODS)
  - Biodiesel Facility Financing
  - Commercial Wind Farms Dev
- **2007:**
  - 5 kW FC Demo
  - Screen Conc Solar Power Tech
  - 250 kW/1 NW PV Demo (Scope)
  - 1 or 3 MW FC Demo (Scope)
  - 250 kW FC Demo
- **2008:**
  - Scope CSP Damos (6xW=100MW)
  - BD Facility Construction
  - PV Companies Negotiations
  - CSP Companies Negotiations
  - 1 to 3 MW PV Demo (Ind)
- **2009:**
  - CSP Damos
  - 1 to 3 MW FC Demo
  - BD Long Term Study
  - AEolion Companies Negotiations
  - Establish PV Industry @ PR
  - Establish PV Industry @ PR
  - Establish CSP Company @ PR
  - AEolion Farming @ PR
  - Scope Ocean Energy Demos
  - Commercial FC Market
  - Industrial FC Market
  - Residential FC Market
  - CSP Commercialization
  - Implement Ocean Energy Demo
  - Ocean Energy Commercialization
The Time has come for Sustainable Energy @ PR
Social (soft) Factors

- Technology literacy/acceptance
- Include Environmental/Health/Quality of life “soft” costs in the project estimates.
  - Life Cycle Analysis
  - Internalization of externalities
- Consider all segments of the population economic resources
- Distributed versus centralized generation
- Population ageing/location
- Nature of new loads
  - Transportation (electric vehicles)
  - Entertainment (electronic)
General Information; Population Trends @ PR, Growth and Ageing
Sol Aire Gente Agua de Puerto Rico

Sea Water
- Wind Energy
- Hydropower
- Biomass Energy
- Solar Energy

Hydrogen Production

Hydrogen Storage

Air
- Fuel Cells

Electricity

Energy Efficiency

Heat

Puerto Rico