Ocean Energy- Panama

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Our Purpose Today

Promote the development of systems for harnessing Ocean Energy for the Generation of Electricity in Panama
Presentation Goals

- Identify the issues
- Ocean Energy, Harnessing the Tides and Waves
- Explore the Alternatives
The Current Situation

- Population (2009 est.): 3,360,474
- Total net energy generation in 2006-2007: 5,805 billion kWhr (1394.00 kWh/capita)
- Generating Capacity, 2007: 1,509 million kW
- In Panama, Percentage of people connected to the grid (electricity) 85.1%
The Issues

- **Growth in Demand for Electricity will surpass population growth**
  Population Growth est. 1.5%; Growth in Energy Demand 3.5-6%, according to various sources

- **Urbanization- the percentage of the labor force in agriculture has declined, from 46 percent in 1965 to 26 percent in 1984, and continuing**
  Source: Library of Congress (US), CIA Country Fact Book

- **The recent construction boom Panama has enjoyed is attracting a more affluent clientele, from areas of the world where per capita energy consumption is 10 times or more greater than in Panama**

- **Significant segments of Population not served by grid due to distance from population centers and geographical constraints to expanding the grid to remote areas**
THIS demands more energy...
Than this...
Electrical Generation in Panama

- 50.1% Hydro-electric
- 49.5% Thermo-Electric

Electricity Imports- In 2007, imported 9 million kWhr


Every year, Peak demand nears peak capacity

i.e., As reported in La Prensa, April 16, 2007, Demand reached 1,024 MW, capacity at the end of 2006 was 1,324 MW
Ocean Energy

- Wave
- Tidal
- Ocean Thermal Energy Conversion (OTEC)
Ocean Thermal Energy Conversion
Wave Energy

Probably more appropriate for Caribbean Coast, although there are some potential sites in Western Panama.
Tidal Energy

- Two approaches
- Barrage: La Rance produces an average of 60 MW; Ealing Mill dates from Roman times
- In Stream: 2 knots gives 8 W/m² (1 knot = 0.514 m/s); Newer technology
- Issue: Intermittent. We need continuous power
Tidal Barrage
In Stream Tidal
Another Turbine Style

The removable cassette
The generator module
The turbine
The duct
The gravity base

1MW RTT UNIT
Duct Diameter 15 metres
Duct Length 19.2 metres
Turbine Diameter 11.5 Metres
Turbine Farm
Combined Barrage and In Stream

![Typical Tidal Cycle Diagram]
Low Tide

Low Tide

Low pressure reservoir

Hydraulic Motor Driven Electrical Generator

Backup Diesel-powered Hydraulic Pump

High pressure accumulator
High Tide

- Diesel-powered Hydraulic Pump
- Hydraulic Motor
- Driven Electrical Generator
- Low pressure reservoir
- High pressure accumulator
Ebb Tide

Low pressure reservoir

Hydraulic Motor
Driven Electrical
Generator

Backup
Diesel-powered
Hydraulic Pump

High pressure accumulator
What other Options are available for Panama?

- New Hydro-electric facilities
- New Thermo-electric facilities
- Alternative Fuel Sources for conventional thermo-electric facilities
- Solar Energy
- Wind Energy
Bayano Hydro-electric facility
Hydro-electric

Based on an analysis of 4 current hydro-electric projects, it is estimated that each megawatt of generating capacity requires 5 hectares of land.
Source: “Análisis de costo beneficio de cuatro proyectos hidroeléctricos en la cuenca Changuinola-Teribe”, Julio 2006

More than 30 new hydroelectric plants will be functioning in Panama by the year 2013 (ASEP). It is estimated that the total investment is over $2 billion and will provide 1,047 MW of electricity (nearly doubling the current capacity) to the national grid by 2013. (Reported in La Prensa, 2009)

Some experts estimate that up to one-third of net CO2 emissions to the atmosphere since 1850 are the result of land-use change, primarily from the clearing of forests (Source: Various Internet references)
Hydro-electric (cont)

- Viable hydro-electric sites are getting harder to find
- Destruction of Tropical Rain Forest = Destruction of Natural carbon sink + increased generation of methane from rotting vegetation
- Anecdotal evidence that hydro-electric installations can have negative impact on subterranean aquifer recharge rates
Land

Panama has about 7.7 million hectares (75,991 sq km) total area, with about 1.782 million hectares used for agriculture and about 4.1 million hectares forested.


Based on the Cinta Costera, it costs $6 million per hectare to add more land

From published reports of the Construction Costs
Land for Agriculture

- It is estimated that bioconversion of solar energy to food energy is accomplished at about 1.2 Watts/m²
  Source: “Sustainable Energy, Without the Hot Air”, David JC MacKay
- It takes about 15 kWhr per day to grow enough food to provide a typical person’s energy requirements
- Based on current population, we need to maintain on the order of 462,000 hectares to feed the population and the 1,000,000 annual visitors. Since normal practice is to till for 2 years and allow the land to lay fallow for 5 years, this requirement becomes 1.6 million hectares, about what is currently used for agriculture in Panama. This does not include land for export crops.
  Source: CIA Country Fact Book
Water in lake under growing pressure

- Expansion of the Canal
- Growing demand for Electricity due to construction boom
- Loss of watershed due to development
- Increased silting due to development
Thermo-electric Facilities
Thermo-electric

- Diesel/fuel oil most viable option for this sector
- Panama lacks native sources of fossil fuels—total must be imported
- Limited land area required for new installations
- Relatively easy to locate near demand centers, reducing distribution costs.
- Noise is generally an issue with these facilities.
Alternative Fuels

- Methane Generation from Landfills

- Animal/agricultural waste conversion (est. 0.4% of electricity produced in Panama today is derived from agricultural wastes-about 18,641 TJ/year)

- Biodiesel (Power density for biofuels is on the order of 0.5 to 2 W/m$^2$, requiring about 2 km$^2$ per MW to produce electricity)
  
  Source: McKay

- LNG- Difficult to transport to remote installations

- Reportedly, Panama does not have sufficient demand to justify the proposed pipeline from Colombia
  
  Source: Private conversation
Plasma Incineration of Wastes

- Arijan Project - terminated?
- Plasco Energy Group Plasma Process = 1 tonne of waste yields 1.2 MWh of electricity, 300 l of potable water, 5-10 kg of commercial salt, 150 kg of construction aggregate, 5 kg of sulfur used for agricultural fertilizer.
Solar

- Average sunshine throughout the world ranges from 87 to 273 W/m²
- Solar energy density 1000W/m²- actual power from photovoltaic is more like 5W/m²
- Solar power costs about 4 times current rates
Solar Requires a Lot of Land

On average this 25-hectare farm is expected to deliver 0.7 MW (17 000 kWh per day) (10 W/m²)

A 32 m² reflector delivers up to 10 kW of heat and 1.5 kW of electrical power. 80 W/m² of heat and 12 W/m² of electricity

“The world’s most powerful solar power plant,” has sun-tracking panels occupying 60 hectares, expected to generate 2.3 MW on average.
That’s a power per unit area of 3.8 W/m²
Wind

- Wind energy density - 2W/m²
- Offshore wind - 3 W/m²
- Requires about 50 Hectares per MW of Capacity
- Due to variability of wind, one still needs other sources on standby
- Grid Issues in Germany with switching
The country's main problem is its size, meaning that centers of natural resource generation, whether hydroelectric or geothermal, are located at great distances from the centers of population. Panama has very limited geothermal potential.
## Cost Comparison of Various Options

<table>
<thead>
<tr>
<th>Type</th>
<th>Scheme</th>
<th>Construction Cost-$/MW</th>
<th>Land Area Required-Hectare/MW</th>
<th>Cost of Electricity-$/kWhr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro-Electric</td>
<td></td>
<td>$1 - 2 Million</td>
<td>5</td>
<td>$0.015</td>
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<tr>
<td>Thermo-Electric</td>
<td>Diesel/Fuel Oil</td>
<td>$0.1 Million</td>
<td>Minimal</td>
<td>$0.13-0.19</td>
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<tr>
<td></td>
<td>Waste Inceneration</td>
<td></td>
<td>Use existing landfill</td>
<td>$0.062</td>
</tr>
<tr>
<td></td>
<td>Plazma Inceneration</td>
<td></td>
<td>Use existing landfill</td>
<td>$0.062</td>
</tr>
<tr>
<td></td>
<td>Biofuels</td>
<td></td>
<td>200</td>
<td>$0.086</td>
</tr>
<tr>
<td></td>
<td>LNG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coal</td>
<td>$1.3 Million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>On shore</td>
<td>$3.2 Million</td>
<td>50</td>
<td>$0.105-0.145</td>
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<tr>
<td></td>
<td>Off shore</td>
<td>$4.89 Million</td>
<td>Minimal</td>
<td>$0.015</td>
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<tr>
<td>Solar</td>
<td>Photovoltaics</td>
<td></td>
<td>20</td>
<td>$0.930</td>
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<tr>
<td></td>
<td>Solar Thermal</td>
<td>$3.3 Million</td>
<td>20</td>
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</tr>
<tr>
<td>Ocean</td>
<td>Wave</td>
<td></td>
<td>Minimal</td>
<td>$0.288</td>
</tr>
<tr>
<td></td>
<td>Tidal Barrage</td>
<td>$1-2 Million</td>
<td>Minimal</td>
<td>$0.015</td>
</tr>
<tr>
<td></td>
<td>In Stream Tidal Thermal</td>
<td>$1.7 - 4 Million</td>
<td>Minimal</td>
<td>$0.04-$0.12 est.</td>
</tr>
<tr>
<td></td>
<td>Thermal</td>
<td></td>
<td>Minimal</td>
<td></td>
</tr>
</tbody>
</table>
# Issues and Benefits of Various Options

<table>
<thead>
<tr>
<th>Type</th>
<th>Scheme</th>
<th>Benefits</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro-Electric</td>
<td>Low operating Costs</td>
<td>Extensive land requirements</td>
<td></td>
</tr>
<tr>
<td>Thermo-Electric</td>
<td>Diesel/Fuel Oil</td>
<td>Easily implemented, low land requirement</td>
<td>Variable costs, no domestic source of fuel</td>
</tr>
<tr>
<td>Waste Inceneration</td>
<td>Reduces landfill area</td>
<td>Air pollution</td>
<td></td>
</tr>
<tr>
<td>Plazma Inceneration</td>
<td>Reduces landfill area, additional products</td>
<td>Possible air pollution issues</td>
<td></td>
</tr>
<tr>
<td>Biofuels</td>
<td>Reduces landfill area</td>
<td>Air pollution</td>
<td>Repurposes land from food production</td>
</tr>
<tr>
<td>LNG</td>
<td></td>
<td>No domestic source, transport issues</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Cheap</td>
<td>No viable long term source of supply</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>Low operating costs</td>
<td>Intermittent, unpredictable power supply</td>
<td></td>
</tr>
<tr>
<td>Off shore</td>
<td>Higher energy density</td>
<td>Intermittent, unpredictable power supply, higher maintenance costs</td>
<td></td>
</tr>
<tr>
<td>Solar</td>
<td>Low operating costs</td>
<td>High cost, extensive land area required, needs energy storage</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>Low operating costs</td>
<td>High cost, extensive land area required</td>
<td></td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>Low operating costs</td>
<td>High cost, extensive land area required</td>
<td></td>
</tr>
<tr>
<td>Ocean</td>
<td>Wave</td>
<td>Intermittent, but predictable days in advance</td>
<td></td>
</tr>
<tr>
<td>Tidal Barrage</td>
<td></td>
<td>Intermittent, but predictable months in advance</td>
<td></td>
</tr>
<tr>
<td>In Stream Tidal</td>
<td></td>
<td>Intermittent, but predictable months in advance</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>Limited appropriate sites close to population centers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Proposed Site for Tidal Energy Project
Other Potential Sites