

Sustainable/Renewable Energy @ Puerto Rico

What, When, Who, Where, Why and How

Dr. José A. Colucci Ríos, PE
 Dr. Efrain O'Neill Carrillo, PE
 Dr. Agustín Irizarry Rivera, PE

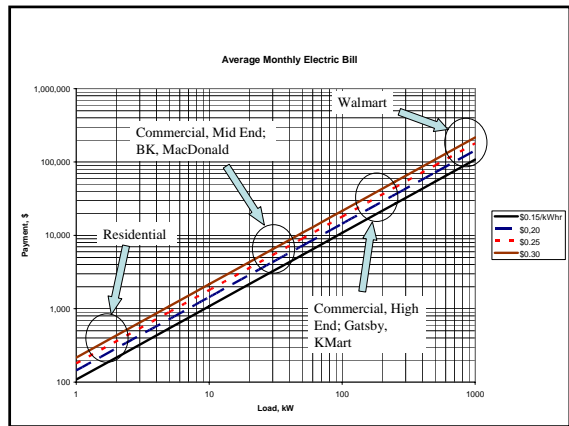
AGENDA

- ✦ 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

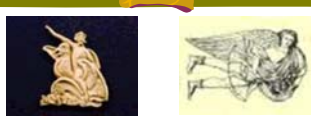
Introduction

✦ 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.

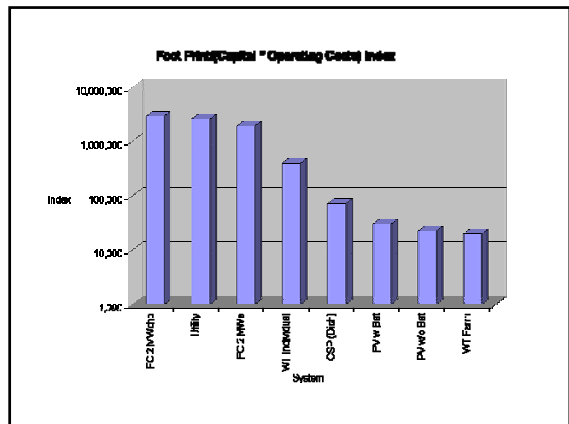
From *Sustainable Energy, Choosing Among Options*;
 J.E. Tester, E.M. Drake, M.J. Driscoll, M.W. Golay & W.A. Peters, MIT Press 2005

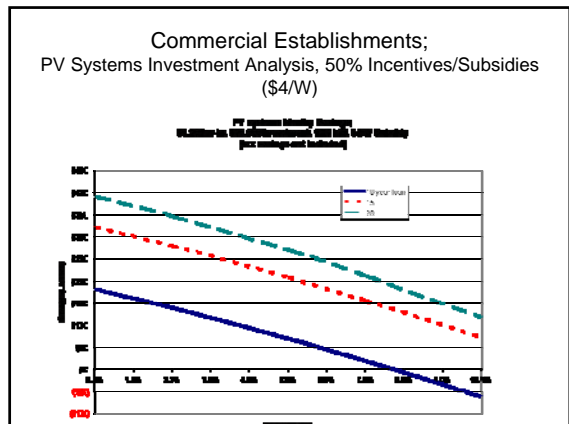
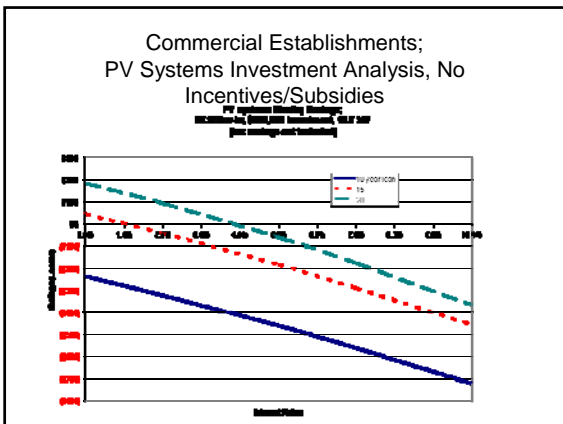
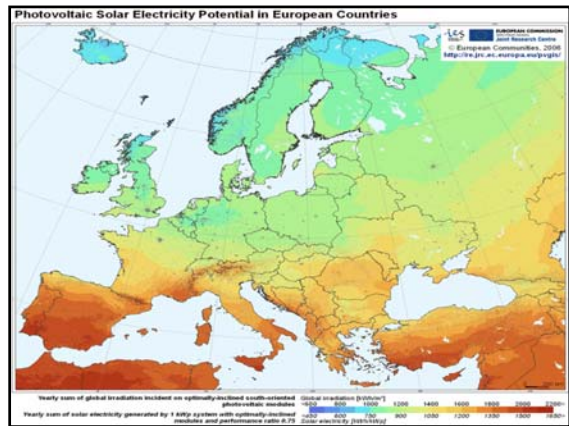
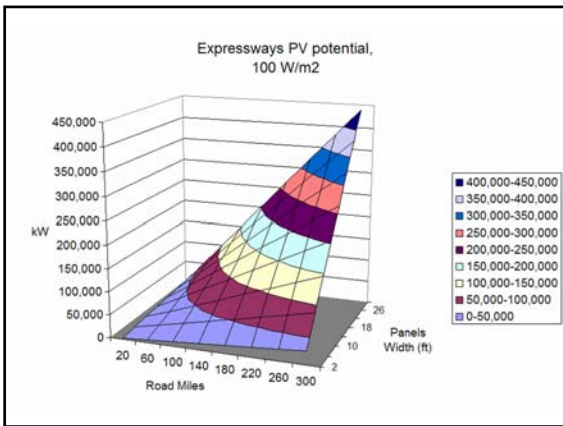
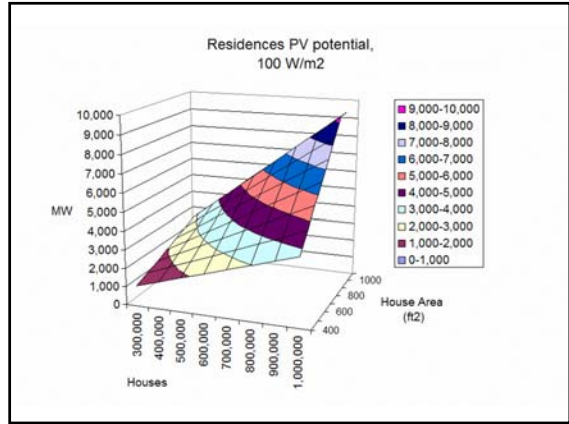
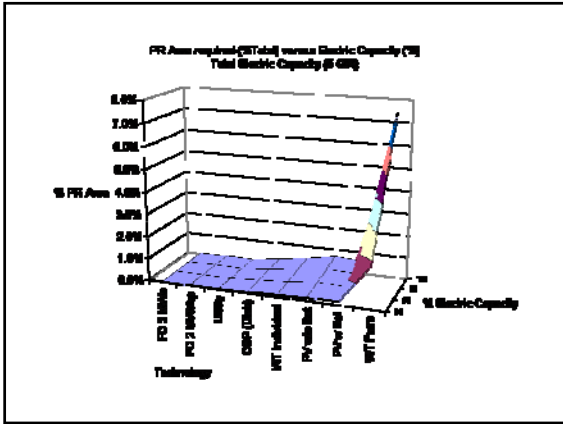


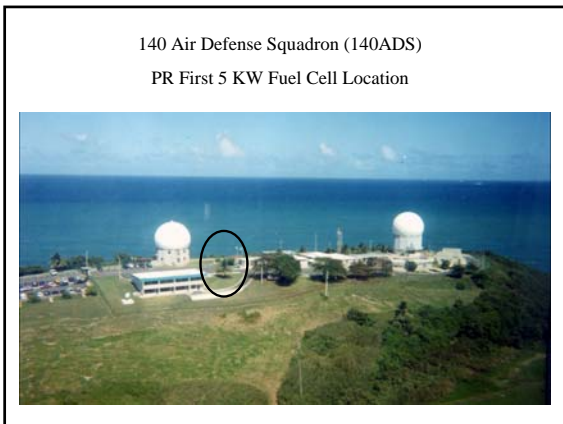
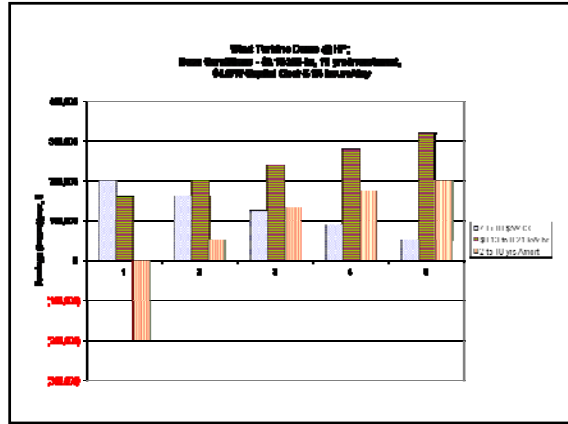
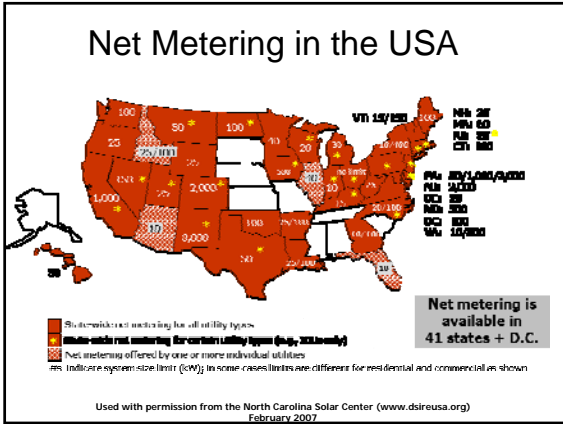
Fuel Cells/PV/Aeolic/CSP



Aeolus - Greek Mythology, Ruler of the winds
 CSP - Concentrated Solar Power
 PV - Photovoltaic







VIABILITY STUDY

Case 1 output

LEASE Calculations Summary
Hewlett Packard, Puerto Rico
2 x DFC300 (LPG)

KW Output of FC	450	kw	(units)
Availability (assumed)	90%		
Annual kWh Output	354,900	kWh	

Grid Electric Rate	Year 1	Year 10
	\$ 0.1600	\$ 0.1829
Annual Purchased Electric \$ Displaced by FC	\$ 567,648	\$ 636,062

LEASE CALCS	Year 1	Year 2	Year 3	Year 4	Year 5
Calculated Annual Savings = Electric + Thermal	\$ 719,552	\$ 710,782	\$ 702,147	\$ 745,481	\$ 742,335
Lease PMT = Annual O&M + Finance Costs	\$ 737,429	\$ 740,398	\$ 743,412	\$ 746,471	\$ 749,576
Customer Benefit \$ - NPV	(\$85,880)	\$ (17,876)	\$ (29,616)	\$ (41,265)	\$ (900)
					\$ (7,241)

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%

PPA CALCS	2007	2008	2009	2010	2011
Estimated Total Energy Savings	\$605,998	\$608,295	\$610,601	\$669,212	\$678,430
Total Annual Project Cost O&M+Finance	\$534,929	\$542,880	\$545,024	\$587,299	\$575,412
Forecast Sierra Pay Rate (\$/kWh)	\$0.1357	\$0.1420	\$0.1469	\$0.1439	\$0.1489
Customer Savings (\$/kWh)	\$0.0118	\$0.0107	\$0.0111	\$0.0196	\$0.0203
Customer Net Benefit \$ - NPV	\$629,493	\$71,069	\$65,415	\$65,577	\$101,912
					\$103,018

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.

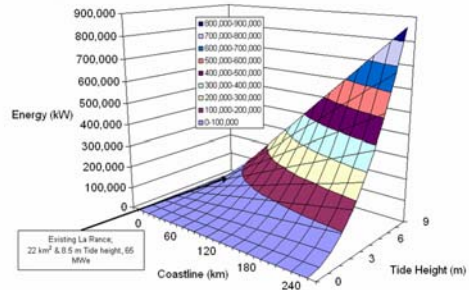
Ocean Tide/Waves/Thermal

Tidal Power Locations



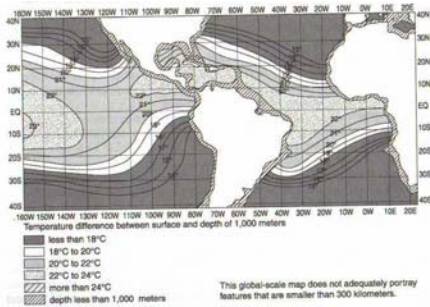
1. Cook Inlet; 2. British Columbia; 3. Baja California; 4. Chonos Archipelago; 5. Magellan Straits; 6. Gallegos/Santa Cruz
7. Gulf of San Jorge; 8. San Jose Gulf; 9. Marañón; 10. Anzagua; 11. Funchal/Coimbra; 12. Ungava Bay
13. Frobisher Bay; 14. Severn/Solway; 15. Rance; 16. Mizen/Kelays; 17. Okhotsk Sea; 18. Seoul River; 19. Shanghai
20. Amoy; 21. Rongson; 22. Carlsby Bay; 23. Ham of Kutch; 24. Kinnelty; 25. Darwin; 26. Broad Sound
27. Marukaz; 28. Abadan

PR Ocean Tide Energy Potential:
1 km depth

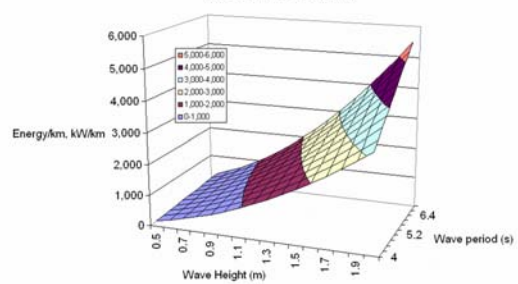


Existing La Rance,
22 km² & 8.5 m Tide height, 65
MW

Ocean Thermal Potential



PR Wave Energy Potential:
1 km Coastline, 10% Efficiency



Ocean Energy General Comments/Issues

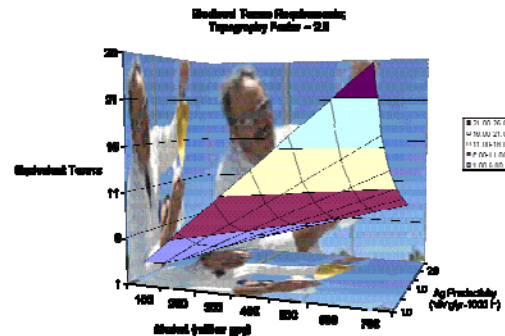
- ✦ Good wave power often correlates with offshore wind power sources.
- ✦ Shoreline sites are expensive. Cost structure not well known (capital and operational)
- ✦ Aesthetic, Fishing and Navigation hazards concerns must be addressed.
- ✦ Tidal/Wave control changes the regular cycle of wetting and dryout 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

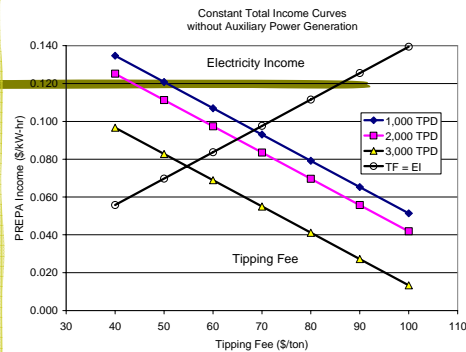
Liquid Fuels/Transportation Sector

- ✦ Diesel: Biodiesel Option
 - ✦ 200 to 300 MGPY Non-PREPA
 - ✦ Land not available (Microalgae ???)
 - ✦ 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



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



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 100 K units @ 10K per unit (\$1 billion total). Based on existing generator market. Similar to backup fuel cell systems (50 kW-hr units)

