OTEC

Environmental and Socio-economic Aspects

Presentation to:

Institute of Electrical Engineers
College of Professional Engineers and Surveyors of Puerto Rico

José A. Martí, PE, DEE
Technical Consulting Group
San Juan, Puerto Rico
August, 2008

Two major classifications

- **Non-Renewable Sources**
  - Undergo reactions (combustion, etc) to release energy stored long ago.
  - Most common: fossil fuels. Provide about 80% of electric power on a global basis.
  - Other source: nuclear energy
- **Renewable Sources**
  - Those that are naturally (or artificially) replenished as they are consumed.

Environmental Impacts

- All energy sources have environmental impacts.
- Environmental impacts of non-renewable sources are different from those of renewable sources, not necessarily lower.

Environmental Effects of Various Energy Sources

- Land
- Water
- Air
- Greenhouse Gases
- Noise
- Biota
- Accidents/Catastrophes
- Public Acceptability
- Stability of Supply/Availability
  - Last two may be considered “socioeconomic”
  - However, **impact on quality of life may be severe**

Fossil Fuels

- Power Stations consume space
- Effects of Fuel Mining and/or Extraction
- Air Emissions (pollutants)
- Greenhouse Gases
- Cooling Water Discharges
- Acceptable by Public but “NIMBY”
- Catastrophic failure produces only local effects
- Will be eventually depleted.
- **Vulnerable to market and political factors.**
- **Must be imported to Puerto Rico**
- **Economic effects of price volatility**

Ethanol

- Being pushed as alternative to oil.
- Generated from cane, corn, etc.
- Crops used are not available as foods or feed. Effect on world food situation already is apparent.
- Vast amounts of land needed.
- Production for use as fuel difficult in PR. Large amounts of ethanol produced from imported molasses, sold as rum.
- Production generates offensive effluents
- Multimedia environmental effects may be greater than oil
- Combustion **generates CO2** and will be subject to eventual carbon tax.
- **Not the magic fix being touted by some**
- **Adverse effects already reported in global press.**

Carbon Tax

- To counteract global warming, a carbon tax is advocated to reduce CO_2 emissions.
- It is likely that a federally mandated tax of $10 to $15 per ton of carbon will be imposed on utilities within the next 4-5 years, and passed on to consumers.
- Alternatively, credits will be granted to sources that do not generate CO_2.
- Market for carbon credits is already under study in Puerto Rico
- Effective energy prices in Puerto Rico will increase even more, with additional adverse effects on our economy and competitiveness in a global market

Hydroelectric Power

- Requires dam to impound river and run generators with water flow
- Widely used in Puerto Rico in the past ("*Fuentes Fluviales*"), when demand was lower and island less populated.
- Area used for lake is permanently impounded and "lost" to other use.
- Public may not accept loss of scarce land
- Fairly high capital cost
- No emissions
- No effluents, but effect of inpoundment on river may be an issue.
- Water used to run generators may be lost for other uses.
- No wastes
- Cost is not volatile, nor susceptible to political factors
- Catastrophic failure of large dam may be major disaster
- Reservoirs eventually fill with sediment
- Large-scale use is not really feasible for Puerto Rico at present time

Wind Energy

- Uses large amount of land
- Energy only available when there is wind (~30% of the time)
- May harm wildlife, particularly birds
- Aesthetics may be objected by some
- No emissions
- No greenhouse gases
- No effluents
- Publicly acceptable
- Not suitable for baseload power generation
- Use when possible, but cannot be only source.

Nuclear Power

- Extremely high capital cost
- Same or less space than fossil plants
- Lower effects of fuel mining and/or extraction
- Essentially No Air Emissions (pollutants)
- Essentially No Greenhouse Gases
- Cooling Water Discharges
- Highly radioactive wastes, no real long-term solution
- Public is afraid (Hiroshima, Chernobyl, TMI) Public opposition in PR in the 1970's killed powerplant project.
- Catastrophic failure would be major disaster
- Supplies will last longer than fossil fuels.
- Less vulnerable to market factors, but still must be imported to Puerto Rico
- Historically less volatile than oil
- Political implications of nuclear program (Iran, Korea, Syria, Cuba)
- Will be very difficult to implement in Puerto Rico, due to negative public perceptions

Solar Power

- Feasible for small-scale water heating and lighting
- Cost of large scale electric generation using solar cells is still too high
- Large collection area needed to generate large amounts of power
- No emissions, discharges or wastes
- Worthwhile for limited applications
- What happens at night?

Tidal Energy

- Requires impounding coastal area (wetland) to run generators with changes with tidal levels
- Uses large amounts of coastal areas, which are not available in Puerto Rico
- May have effects on biota
- Effects similar to hydropower, but concentrated on coastal areas
- Catastrophic failure not as critical as hydro.
- Not feasible in Puerto Rico

Geothermal

- May allow generation of substantial amounts of power if resource is available.
- May require significant amount of land
- May generate heated effluents
- Public may object,
- Only feasible in some areas, not in Puerto Rico at present time, except possibly very small-scale projects in sites like Coamo.

OTEC

- No fuel needed
- No emissions of conventional air pollutants
- No solid wastes
- Discharge essentially similar to ambient water
- Stable supply- not vulnerable to external factors
- Very high availability factor.
- **Cost is known and fixed from day 1**. Very low volatility
- Public tends to receptive to idea, once the basic principle is understood.

OTEC's Impacts:

- Significant capital cost, but very low O&M cost.
- No emissions of air pollutants.
- Negligible CO2 (greenhouse gas) released. Much less than with any fossil fuel
- Hurricanes/ Earthquakes- can be considered in design
- Catastrophic failure (thermal fluid escape) has only local effects, not major disaster. Ammonia is managed daily in many cold storage facilities. Nearly 100 years of experience.
- Effect of biocides used for HX's- can be controlled.
- **Upwelling**- effect of bringing nutrient-rich deep water to the surface. Environmental disruptions can be reduced by proper design of the discharge. If water is discharged at proper depth, effect is essentially eliminated.

Energy-Water Nexus

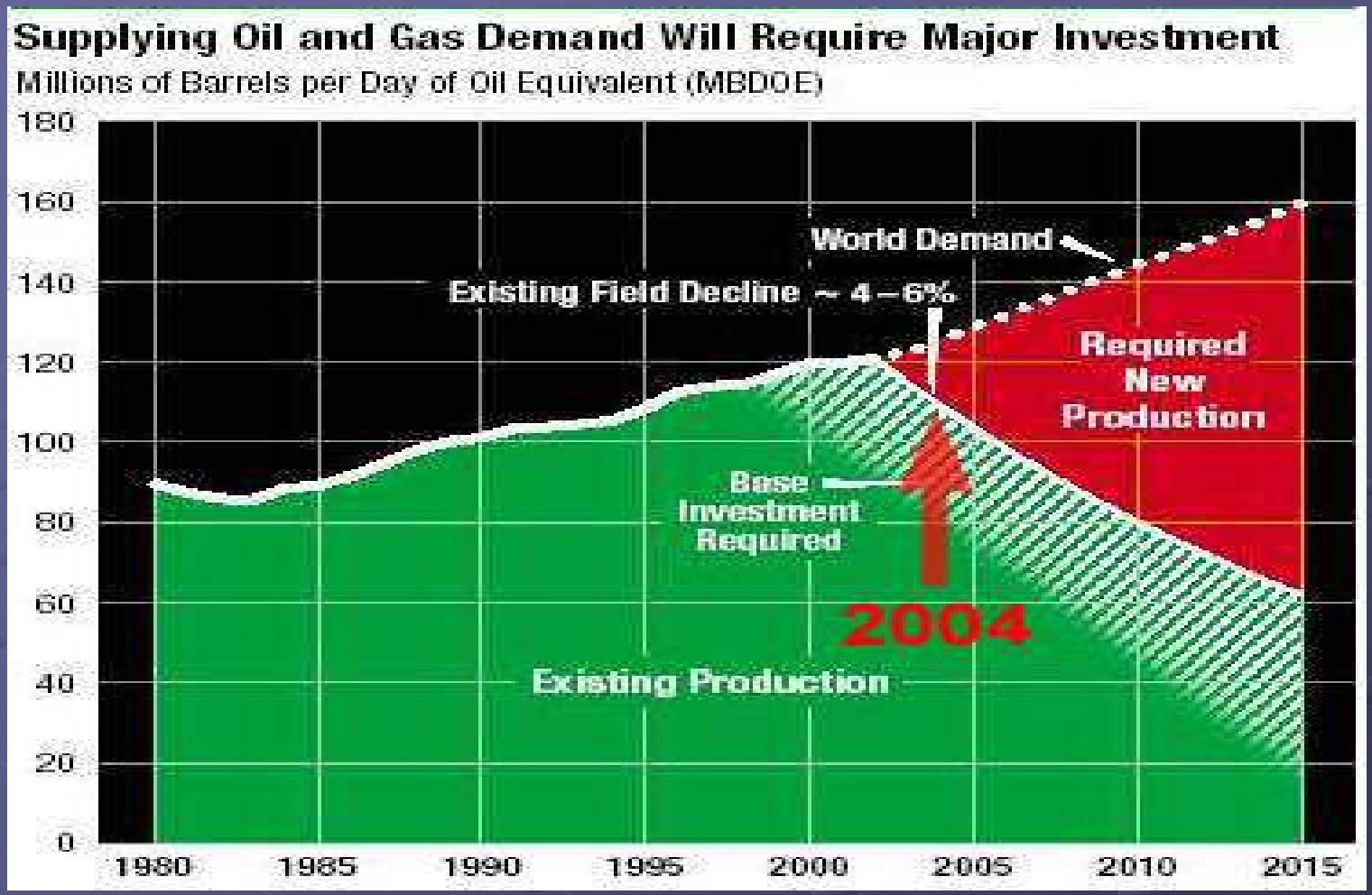
- Water production requires energy
- Energy requires water
- Lack of energy affects water supplies
- Lack of water affects energy production

Energy Technology	Average Water Consumption
Petroleum Refining	100 gallons/barrel crude oil
Power generation	20 gallons/kWh
Nuclear hydrogen	35 gallons/kg of H2 (I kg H2 is equivalent to one gallon of gasoline)
Ethanol (not including irrigation)	3 gallons/gallon of ethanol

OTEC is only form of energy that can generate potable water

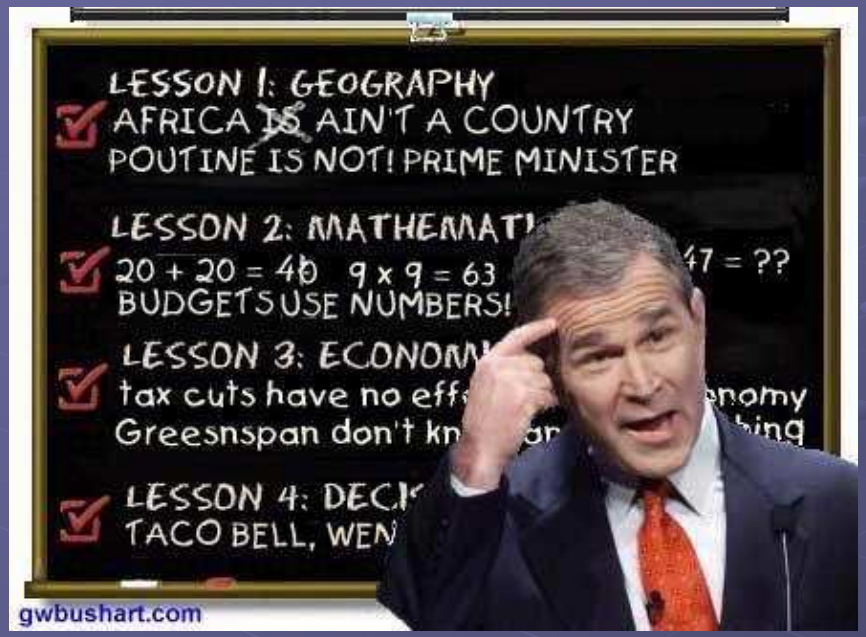
Socioeconomic Aspects

- On a long term basis, may be as important as environmental aspects
- Lack of stable and reliable energy source can cause major social and economic disruptions, and even lead to wars.
- Japan used concerns about oil supplies as an excuse to attack US in WWII.
- Fuels used as weapon (1970's oil embargo, Russia closes Ukraine pipeline).
- Current economic downturn directly tied to high energy prices.

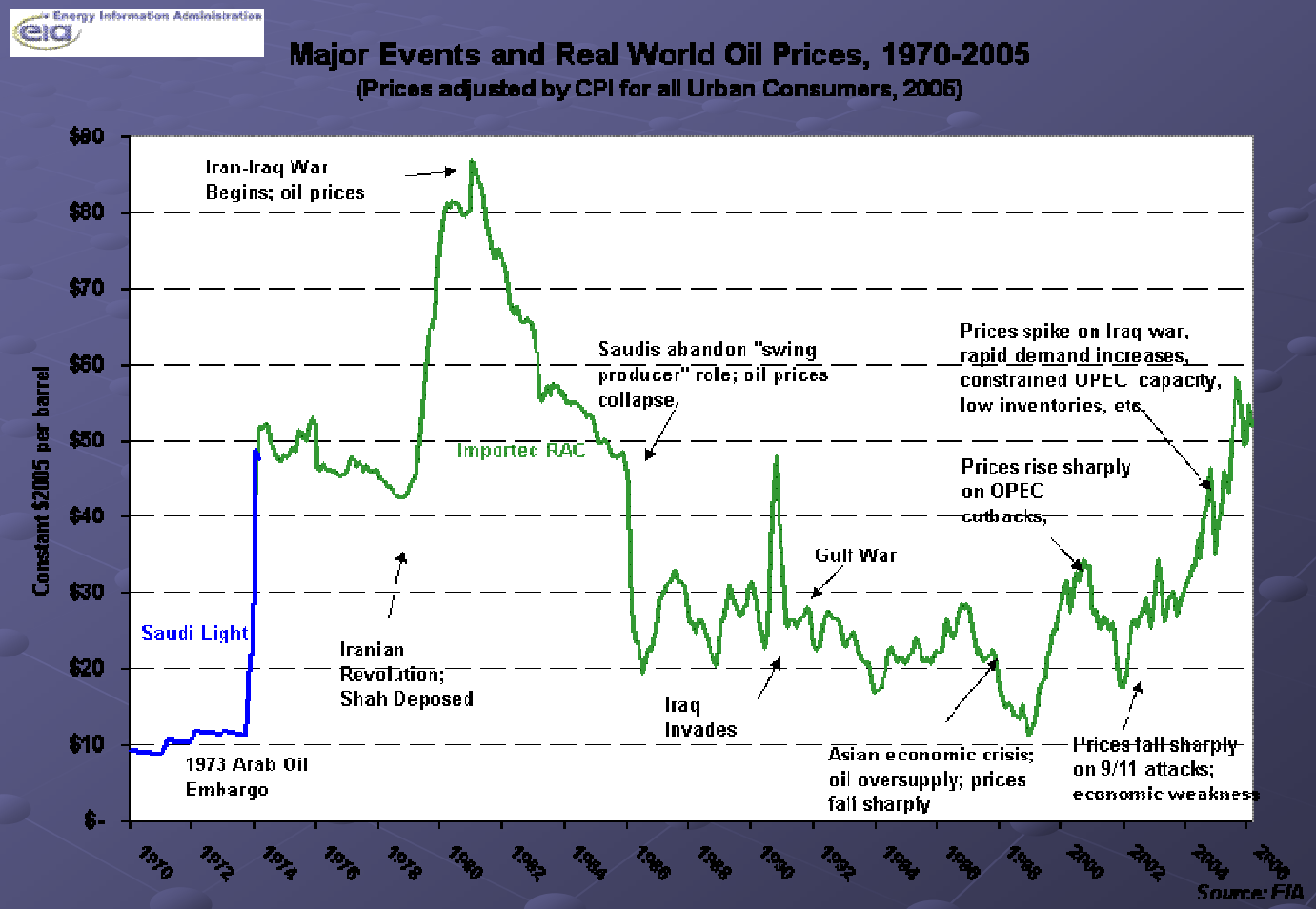


Peak Oil (Hubbert theory) Demand is expected to increase and to outstrip new production. As oil prices increase, prices for other fuels (LNG, coal, ethanol, etc) will rise accordingly. Some say peak oil will occur after 2015. Others say it's now.

Energywise, PR is at the mercy of outside factors:



Events out of the control of Puerto Rico cause surges in energy prices



Incident in Middle East (e.g. Israel attack on Iran nuclear program) could cause oil price to spike to $200/bbl.

Potential major risk for Puerto Rico

<u>Repeated border incidents</u> between Colombia, Venezuela and Ecuador may lead to regional war involving major fuel suppliers for Puerto Rico.

Severe Socioeconomic Effects

- Besides the adverse economic effects of energy price increases, there is an additional social effect.
- Cost increases over which Puerto Rico has no control affect every segment of society.
- The general mood of despair resulting from this lack of control affects consumers and discourages productive activities and investments, magnifying the economic impacts of energy costs.

Benefits of OTEC to Puerto Rico

- Shows real effort to reduce vulnerability of Puerto Rico to energy price spikes.
- A 75 MW plant saves over 1,000,000 barrels of oil per year.
- Plant construction will serve as economic stimulus
- Money paid for power will go to local and US economy, not shipped away to foreign oil producers.
- Shows concern for environment: Major CO2 offset, reduction in greenhouse gases and air pollution in general. **Totally renewable, clean energy**.
- PREPA becomes world leader in renewable energy

Conclusion

- **OTEC** is probably the most benign and less risky form of generating large amounts of energy presently available
- Available 24/7/365
- Not vulnerable to external factors (embargos, wars, demand hikes, etc)
- Usable for critical baseloads in systems
- Can generate potable water, if so desired.
- Can lead Puerto Rico towards eventual **energy independence.**