

Overview of Environmental Effects

OTEC vs Other Power Generation Methods

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May, 2007

Society Needs Energy

- There is no “free lunch”
- All forms of energy have:
 - Costs
 - Environmental Impacts
 - Risks
- To support a modern lifestyle, large amounts of energy are needed.
- Is society willing to pay the cost and accept the environmental impacts and risks?
- Are people willing to forego modern lifestyle to save the environment?

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 may be **different** from those of renewable sources, not necessarily lower.

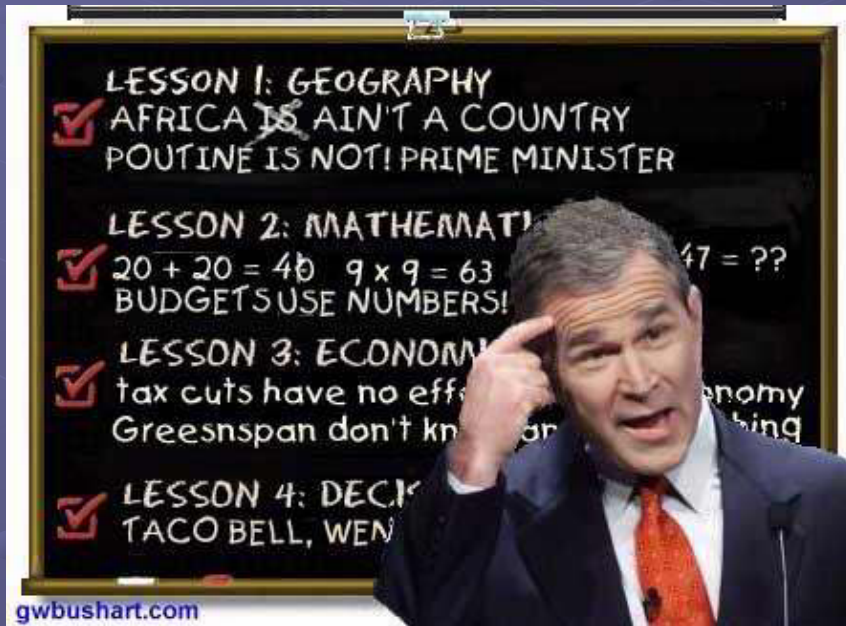
Environmental Effects of Various Energy Sources

- 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**

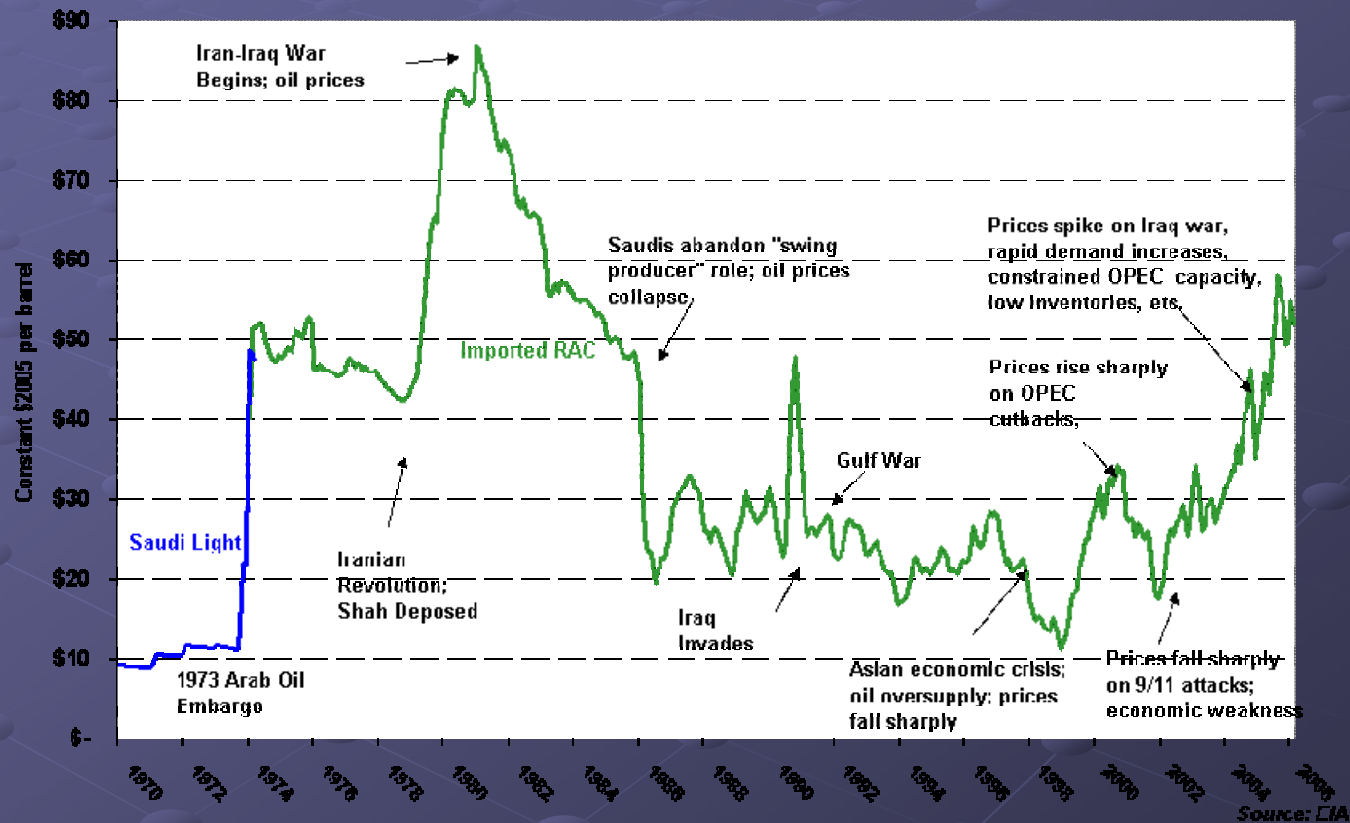
Energywise, PR is at the mercy of outside factors:



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

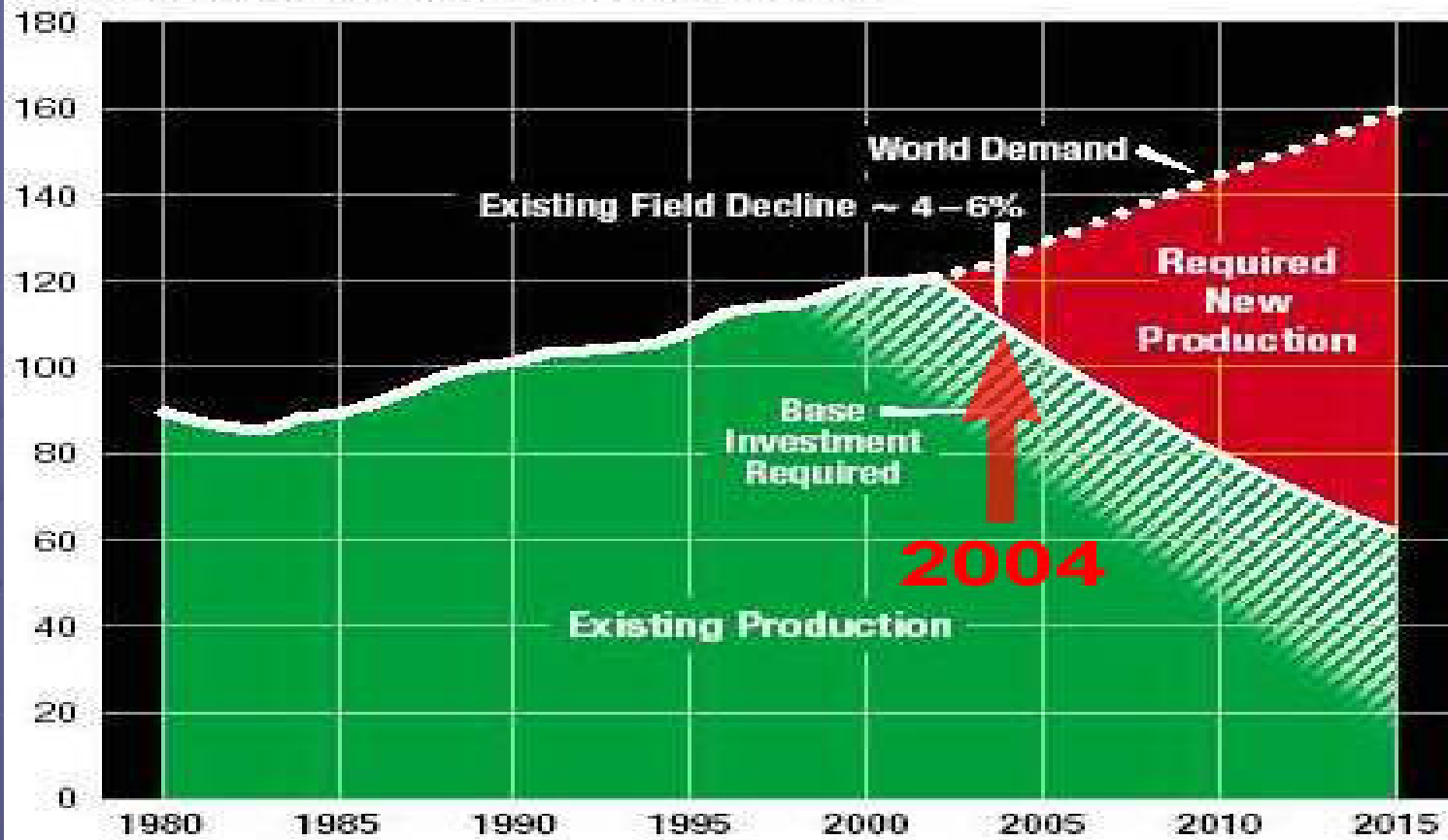


Major Events and Real World Oil Prices, 1970-2005
(Prices adjusted by CPI for all Urban Consumers, 2005)



Supplying Oil and Gas Demand Will Require Major Investment

Millions of Barrels per Day of Oil Equivalent (MBOOE)



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.

Carbon Tax

- To counteract global warming, a carbon tax is advocated to reduce CO2 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
- **Effective energy prices in Puerto Rico will increase even more**, with additional adverse effects on our economy and competitiveness in a global market

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.

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, Cuba)
- **Will be very difficult to implement in Puerto Rico, due to negative public perceptions**

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.
- Vast amounts of land needed.
- Production for use as fuel difficult in PR
- Production generates offensive effluents
- Multimedia environmental effects may be as high as those of oil
- Combustion generates CO₂ and will be subject to carbon tax.
- **Not the magic fix being touted by some now**

Wind Energy

- Uses large amount of land (>700 cdas for 40 MW)
- Energy only available when there is wind (~30% of the time)
- May harm wildlife, particularly birds
- Aesthetics may be objectionable to some
- No emissions
- No greenhouse gases
- No effluents
- Publicly acceptable
- Not alternative for large-scale power generation

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 impoundment 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

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

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?

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 small-scale projects in sites like Coamo.

OTEC

- Uses difference in temperature between surface and deep water to run a heat engine and generate power.
- Very high availability factor
- Small surface area required. If located in a platform, only land needed is that for the cable and connection station.
- People may object since it is a “New technology”. Actually, idea was invented by Jules Verne in 1800’s.

OTEC- Part II

- 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 be receptive to idea, once the basic principle is understood.

OTEC's Impacts:

- Significant capital cost, but very low O&M cost.
- 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.
- **Upwelling**- effect of bringing nutrient-rich deep water to the surface. May be beneficial, but needs further study. Environmental disruptions can be reduced by proper design of the discharge. If water is discharged at proper depth, effect is essentially eliminated.

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 lead Puerto Rico towards eventual energy independence.