Science, continued

• Tidal current is the horizontal flow of water accompanying the vertical movement of the tide.
• Tidal amplitude, the difference between high and low tide, is a key factor in determining the energy output of a power plant.
• Barrage is the damming part of the plant, although generally must be much stronger than a regular dam due to stress from waves (and, therefore, adds quite an expense).
• The cost per kilowatt drops with the size of turbine.
• The typical “bulb” turbine (used at the Rance tidal plant) also functions as a pump and regulates the flow in both directions.

History of Tidal Power at Severn

• First projected in 1918, but ridiculed.
• After end of WWII, thirst for energy revived interest in tidal power.
• The Severn River, near the Bristol Channel, has the largest tidal difference in Europe.
• Although vetoed by Parliament, hindsight reveals that a plant built in 1949 would have more than paid for itself in ten years, and had negligible costs afterwards.

Severn as a Possible Site

• Severn River estuary has 3rd greatest tidal amplitude in the world.
• Some concern about build-up of already worrisome amounts of industrial and agricultural waste, however, thermodynamic study showed this to be unfounded.
• Highway has been proposed for area, and a tidal plant could serve as plant/road.
• Already 50 million tons of dirt/waste that can be used for foundation less than 40 km (24 miles) from estuary.
Current (1977) Severn Situation

- Generally, tidal power has to prove cheaper than the amount of coal (cheapest) need to produce an equivalent amount of energy.
- Also, in 1977, competing with nuclear and possibility of thermal (ocean) power.
- Assuming a capacity of 5,000 MW (probably more), a tidal plant would generate in its lifetime (100 years) as much as all the oil suspected to be in the British North Sea.
- Plant could produce 8,000-14,000 GW/hr, or about 5% of current British energy consumption.
- Would produce about $2.2 million a day.

Current Situation, continued

- Be a constant, reliable source of energy for next 100 years (as opposed to oil, nuclear, etc. that have political ties and such).
- Impact on ascetics of area would be minimal, as barrage would bring tidal amplitude to normal level for Britain.
- Also, barrage holding back tides would also hamper soil erosion in area, and use of waste soil around area would reclaim agricultural land.

Conclusions

- Tidal power plant would bring economic development to Severn River region of Britain, as well as produce a stable source of energy for the entire country.
- Economics of building such a plant seem to be quite expensive, and will need a professional analysis.
- Environmental impacts should be investigated to a greater extent for consideration of project.

Expected Profitability

- Full-Scale Annual Energy Output
- Base Price of Energy
- Operating Costs as a % of Revenue
- Cost of Improvements as a % of Revenue
- Operating Cost (Improvements Incl.)
- Discount Rate
- Present Worth at year zero
- Cash Flows for Cardiff Weston Barrage

Environment

- Large Intertidal Zones
- Large tidal range
- High turbidity
- Varying salinity
- Distinct sedimentation patterns

Destroy this unique ecosystem?
Environment

RESTRICT

PRODUCTIVITY!

Environment

• Fish Populations?
  – Threat to salmon young who require strong currents
  ★ Low head turbines not threatening to fish

• Intertidal Zones?
  – Converted to subtidal zones
  – Reduce foodstock to birds
  ★ Foodstock NOT limiting to bird population

Revenue wrt Market

• Revenue depends on firm power revenue and tariff revenue.
  – Firm power revenue = base revenue received regardless of amount of power consumed
    = Firm power rate x Firm power
  – Tariff depends on total Market Supply and the Market Demand.

What are the effects of inaccurate estimates of price and tariff on profitability?

Revenue Parameters

• FP revenue = FP rate x FP
  – FP rate determined by the CEGB
  – Allowed to grow with price of coal for 30 years, then capped at 40 pounds/KWh
  – Firm Power determined by CEGB = 1.1GWh

• Tariff
  – Determined by Bulk Supply Tariff (BST) which is an effect of market supply and demand
  – Modeled by the Sizewell B Project

Revenue Sensitivity

• Firm Power Revenue variation estimated up to 20%
• Tariff variation estimated up to 50%

Revenue Sensitivity

-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
25% 75% 125% 175%

% Variation from Estimate

Capital Costs

• Few tidal power plants are in operation

• Is there sufficient experience to accurately predict capital costs?

• How much error can we expect in the estimates of capital costs?

What will the effects of the error be?
**Capital Costs**

**Mechanical Works**
- Turbines
- Negligible Variations

**Electrical Works**
- Transmission and Control
- Up to 10% Variations

**Civil Works**
- Only area of little experience
- Barrage
- Caisson
- Up to 20% Variations

**Capital Costs Sensitivity**

**Timing**

- How long will the project take to build?

What will the effects be if construction runs over schedule?

**Construction Timing**

- Variation Estimated to 1 year
  - Based on comparable projects previously constructed

**Operating Costs**

- Royalties to the Crown

- Little experience in running a tidal power plant
  - Probable unexpected external expenses

How will variations in Operating Costs affect profitability?
**Output Efficiency**

- Given a chosen turbine, will the output be what is expected?
  - Flow patterns within the estuary?
  - Cavitation?

How will variation in expected output affect profitability?

**Combined Effects**

**Variable Flow Speed**

- Turbines operate at max efficiency over a narrow range of flow speed.
  - Tides exhibit a large variation in flow speeds
  - Turbines must be chosen for the expected conditions

How will this variation affect technology decisions and output?

**Variable Flow Speed**

Anticipated Conditions

- VST
  - Requires DC Transmission
  - Up to 25% additional Cap Costs
  - 2.3% higher Output

- NVST
  - Requires AC Transmission
  - Up to 20% losses
  - Lower efficiency

Choose Design Flow Speed
**Scenario 1: Base Case**

- **Full-Scale Annual Energy Output**: 13.7 TWh
- **Operating Costs as a % of Revenue**: 0.055%
- **Cost of Improvements as a % of Revenue**: 0.055%
- **Operating Cost (Improvements Incl.)**: -0.429 p/KWh
- **Discount Rate**: 0.08%
- **Present Worth at year zero**: 184.2263 M Pounds

**Scenario 2: VST**

- **Variable Speed Turbines produce 2.3% more power than nonvariable under the same conditions**
  - Output_{VST} = 13.7 TWh x 1.023 = 14.02 TWh
- **VST’s add 300M Pounds to Fixed Costs**
- **VST’s have a higher operating cost due to DC transmission maintenance**
  - OC_{VST} = 0.43 p/KWh
- **Discount Rate**: 0.08%
- **Present Worth at year zero**: 14.75 M Pounds

**Scenario 3: VST over NVST**

VST’s have higher capital costs, higher power output at given flow speed

- **Present Worth at year zero**: 70.38158 M Pounds

Find output where VST’s become favorable

**Scenario 4: Worst Case**

- **Nonvariable Speed Turbines**
- **Max Operating, Fixed Costs**
- **Min Price of Electricity, Firm Rev**
- **Discount Rate**: 0.07%
- **Present Worth at year zero**: -1765.02 M Pounds

**Scenario 5: Best Case**

- **Nonvariable Speed Turbines**
- **Min Operating, Fixed Costs**
- **Max Price of Electricity, Firm Rev**
- **Discount Rate**: 0.07%
- **Present Worth at year zero**: 5136.53 M Pounds

\[ PW(VT) - PW(NVT) = -0.113847 M Pounds \]