SEVERN TIDAL POWER

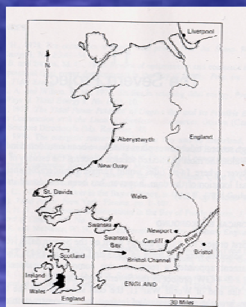


Fig. 11.1. Estuary of the Severn River.

p. 276, Charlier

Science Behind Tidal Power

- Tide definition: "The tidal phenomenon is the periodic motion of the waters of the sea, caused by celestial bodies, principally the moon and the sun, upon different parts of the rotating earth" (Charlier 75).
- The sun's contribution to these forces, however, are negligible compared to that of the moon.
- Although tide-producing forces are distributed evenly over the globe, variations on size and shape of ocean basins, as well as the interference produced by land masses create differences in actual tidal current.
- The tidal patterns of a certain area are determined by its location in a certain basin.

FIGURE 1: The moon's gravitational force is the main influence in creating tidal bulges on the earth. In this diagram the arrow indicates the direction of the earth's rotation.

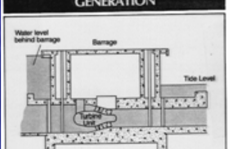
http://power.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Fwww.iclei.org%2Fefacts%2Ftidal.htm

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.

FIGURE 2

THE PRINCIPLE OF TIDAL POWER GENERATION



The barrage, or dam, holds back the water in the estuary as the tide falls. Then, gates are opened and the water rushes seaward through the turbine. Later, the rising tide will be held back by the barrage, then released to flow through another turbine into the river estuary.

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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.

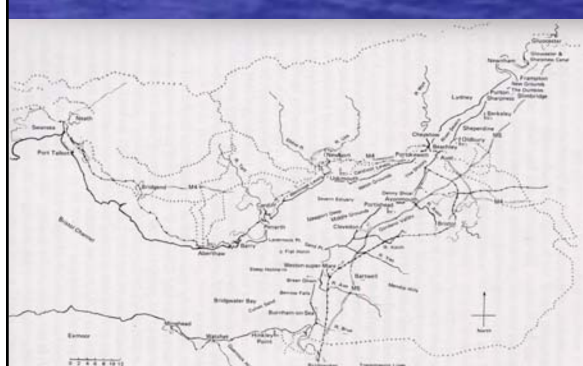


Fig. 11.2. Location map of the Bristol Channel.

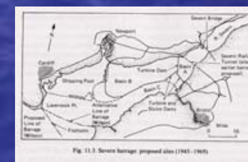
p. 277, Charlier

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.



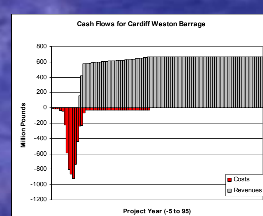
p. 280, Charlier

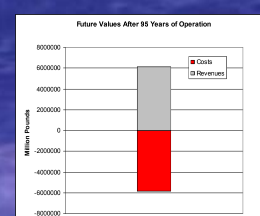
Conclusions

- 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

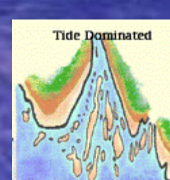
Full-Scale Annual Energy Output	13.7	TWh
Base Price of Energy	3.9	p/KWh
Operating Costs as a % of Revenue	0.055	%/100
Cost of Improvements as a % of Revenue	0.055	%/100
Operating Cost (Improvements Incl.)	-0.429	p/KWh
Discount Rate	0.08	%/100
Present Worth at year zero	184.2263	M Pounds





Environment

Environment



Large Intertidal Zones

Large tidal range

High turbidity

Varying salinity

Distinct sedimentation patterns

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.

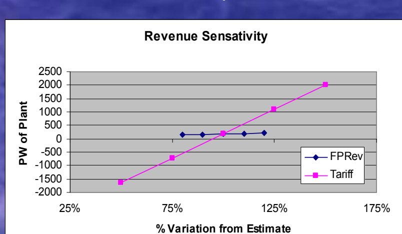
What are the effects of inaccurate estimates of price and tariff on profitability?

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%



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?

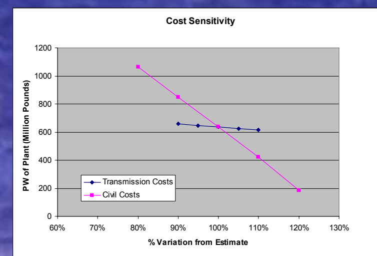
Capital Costs

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



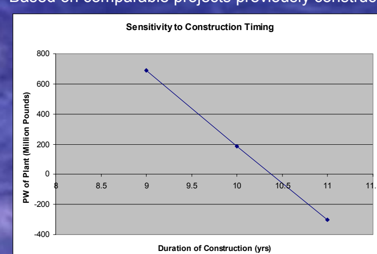
Timing

- 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



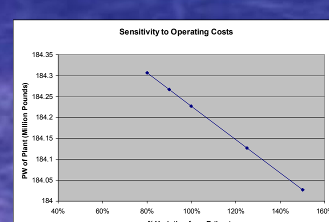
Operating Costs

- Royalties to the Crown
- Little experience in running a tidal power plant
  - Probable unexpected external expenses

How will variations in Operating Costs affect profitability?

Operating Costs

- Variation expected to be from –20% to +50%
  - Asymmetry is due to Royalties always ADDING to costs

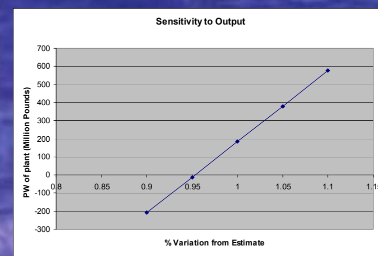


Output Efficiency

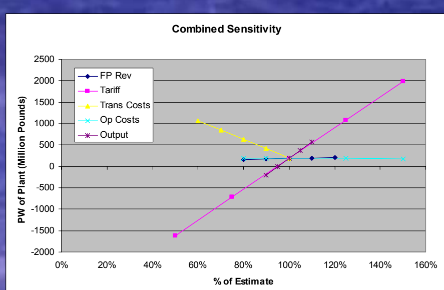
- Given a chosen turbine, will the output be what is expected?
  - Flow patterns within the estuary?
  - Cavitation?

How will variation in expected output affect profitability?

Output Efficiency



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

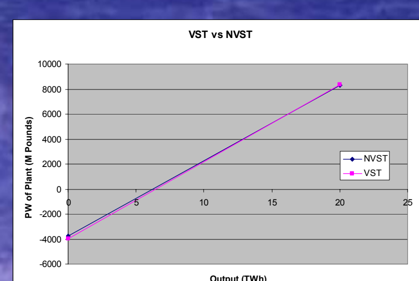
- Requires DC Transmission
- 300M Pounds additional Cap Costs
- Up to 25 % losses
- 2.3% higher Output

NVST

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

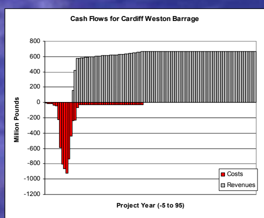
Choose Design Flow Speed

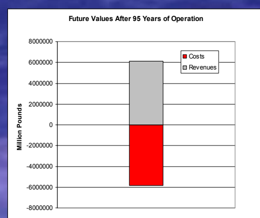
Variable Flow Speed



Scenario1: *Base Case*

Full-Scale Annual Energy Output	13.7	TWh
Base Price of Energy	3.9	p/KWh
Operating Costs as a % of Revenue	0.055	%/100
Cost of Improvements as a % of Revenue	0.055	%/100
Operating Cost (Improvements Incl.)	-0.429	p/KWh
Discount Rate	0.08	%/100
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

$Output_{NVST}$ = 13.7 TWh $Output_{VST}$ = 13.7 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_{NVST} = .43 p/KWh OC_{VST} = .49 p/KWh

Full-Scale Annual Energy Output	14.0151	TWh
Base Price of Energy	3.9	p/KWh
Operating Costs as a % of Revenue	0.07	%/100
Cost of Improvements as a % of Revenue	0.055	%/100
Operating Cost (Improvements Incl.)	-0.4875	p/KWh
Discount Rate	0.08	%/100
Present Worth at year zero	70.38158	M Pounds

Scenario 3: VST over NVST

NVST

Full-Scale Annual Energy Output	14.75	TWh
Base Price of Energy	8.55	p/KWh
Operating Costs as a % of Revenue	0.055	%/100
Cost of Improvements as a % of Revenue	0.055	%/100
Operating Cost (Improvements Incl.)	-0.9405	p/KWh
Discount Rate	0.08	%/100
Present Worth at year zero	5136.53	M Pounds

VST

Full-Scale Annual Energy Output	15.08925	TWh
Base Price of Energy	8.55	p/KWh
Operating Costs as a % of Revenue	0.055	%/100
Cost of Improvements as a % of Revenue	0.055	%/100
Operating Cost (Improvements Incl.)	-0.9405	p/KWh
Discount Rate	0.08	%/100
Present Worth at year zero	5136.644	M Pounds

PW(VT) - PW(NVT) = -0.113847 M Pounds

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

Find output where VST's become favorable

Scenario 4: Worst Case

- Nonvariable Speed Turbines
- Max Operating, Fixed Costs
- Min Price of Electricity, Firm Rev

Full-Scale Annual Energy Output	13.015	TWh
Base Price of Energy	1.95	p/KWh
Variation of Base Price of Energy	0.5	%/100
Variation of Firm Power Revenue	0.8	%/100
Operating Costs as a % of Revenue	0.066	%/100
Cost of Improvements as a % of Revenue	0.066	%/100
Operating Cost (Improvements Incl.)	-0.2574	p/KWh
Discount Rate	0.08	%/100
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

Full-Scale Annual Energy Output	15.07	TWh
Base Price of Energy	5.85	p/KWh
Variation of Base Price of Energy	1.5	%/100
Variation of Firm Power Revenue	1.2	%/100
Operating Costs as a % of Revenue	0.044	%/100
Cost of Improvements as a % of Revenue	0.044	%/100
Operating Cost (Improvements Incl.)	-0.5148	p/KWh
Discount Rate	0.08	%/100
Present Worth at year zero	3482.331	M Pounds