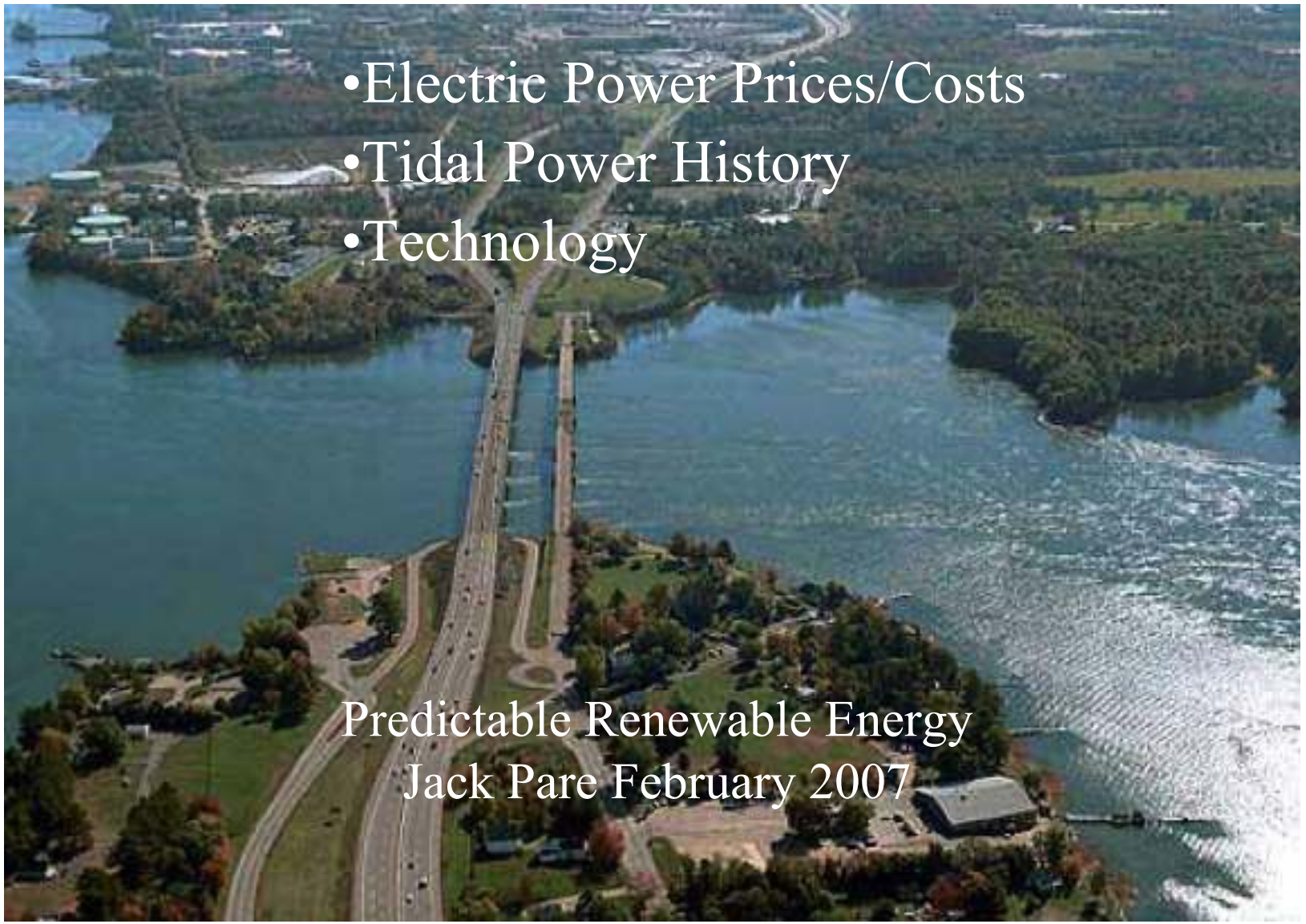
Tidal Power for coastal NH



NH Electricity Prices/Costs

- In 2005, NH had the 3rd highest electricity prices in the US, behind Hawaii and New York.
- In 2006, NH prices held steady, while other rose. NH is now 6th - behind Hawaii, Connecticut, Massachusetts, New York and Rhode Island.
- Cost of energy generation sources (e.g. coal, oil, gas) is a major contributor - all must be imported.

from US Dept of Energy - Electric Power Monthly January 12, 2007
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
State-by-state rank values computed from data

New England Electricity Prices

Table 5.6.A. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, October 2006
(Cents per Kilowatthour)

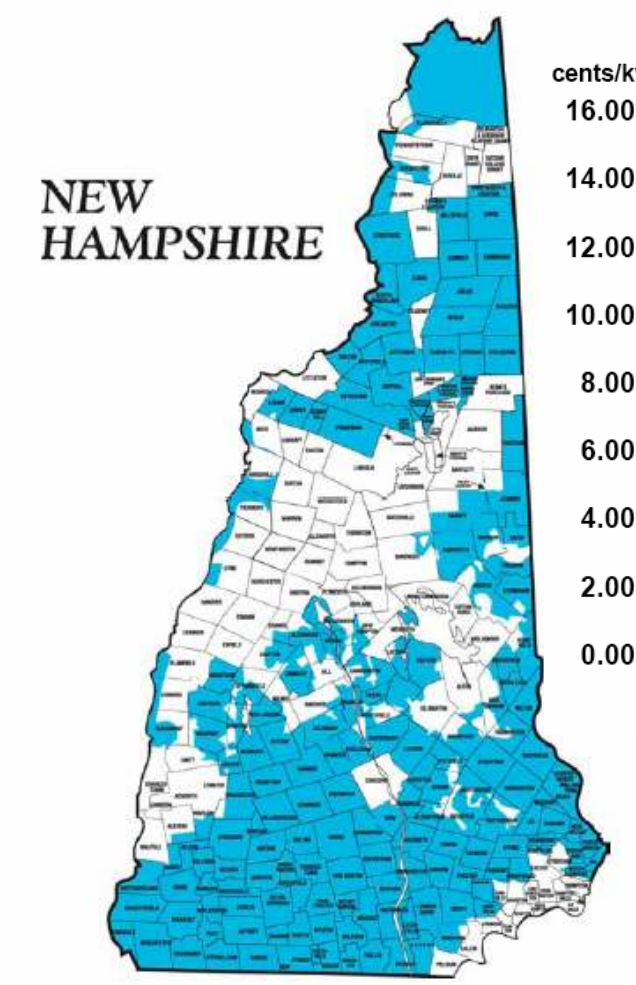
	Residential	rank	Commercial	rank	Industrial	rank	Transportation[1]		All Sectors	rank
New England	**16.08**		**13.76**		**11.69**		**7.03**		**14.12**	
Connecticut	17.27	2	14	4	11.7	6	11.71		14.79	2
Maine	14.14	8	11.72	11	10.4	8	--	--	12.15	8
Massachusetts	16.45	4	14.27	2	12.66	3	4.76		14.62	3
New Hampshire	**14.93**	**7**	**13.25**	**5**	**11.63**	**7**	**--**	**--**	**13.53**	**6**
Rhode Island	15.04	6	13.12	6	12.78	2	--	--	13.75	5
Vermont	13.84	9	11.95	8	8.1	12	--	--	11.48	10

vs. National average price
8.83 cents per kilowatt hour

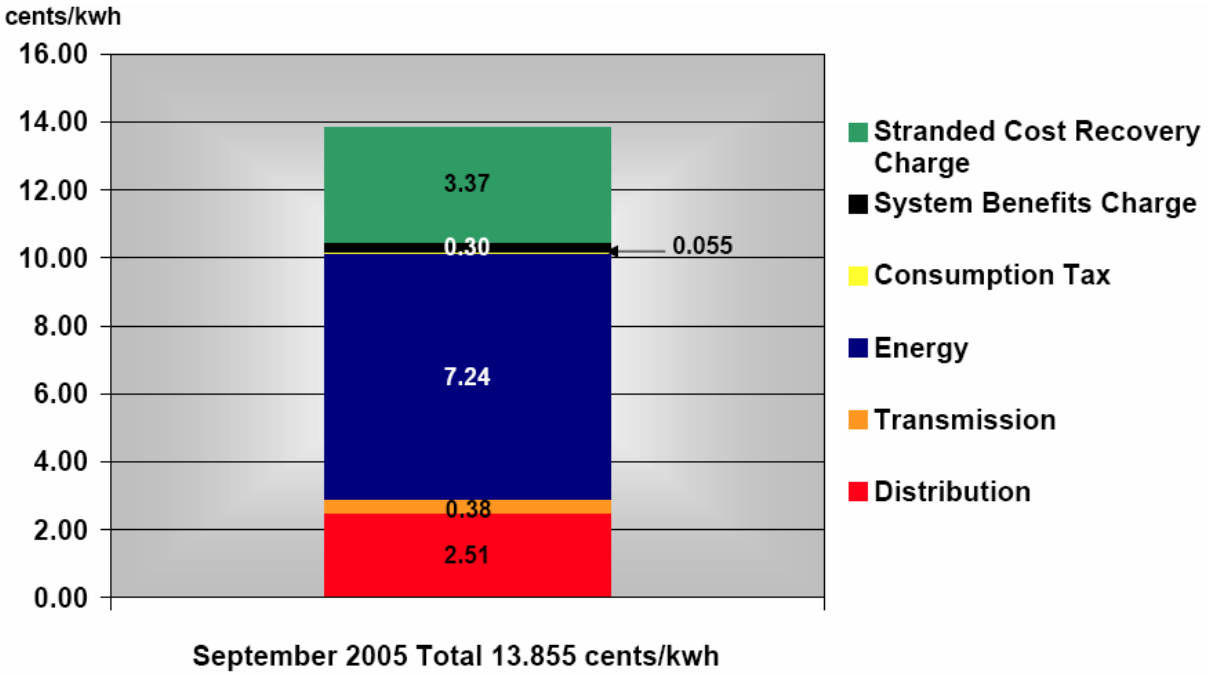
from US Dept of Energy - Electric Power Monthly January 12, 2007
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
State-by-state rank values computed from data
2005 comparison data omitted due to space (see electricity_costs_2006.xls)

PSNH Costs

- PSNH serves the Rockingham / Strafford planning areas (in blue)



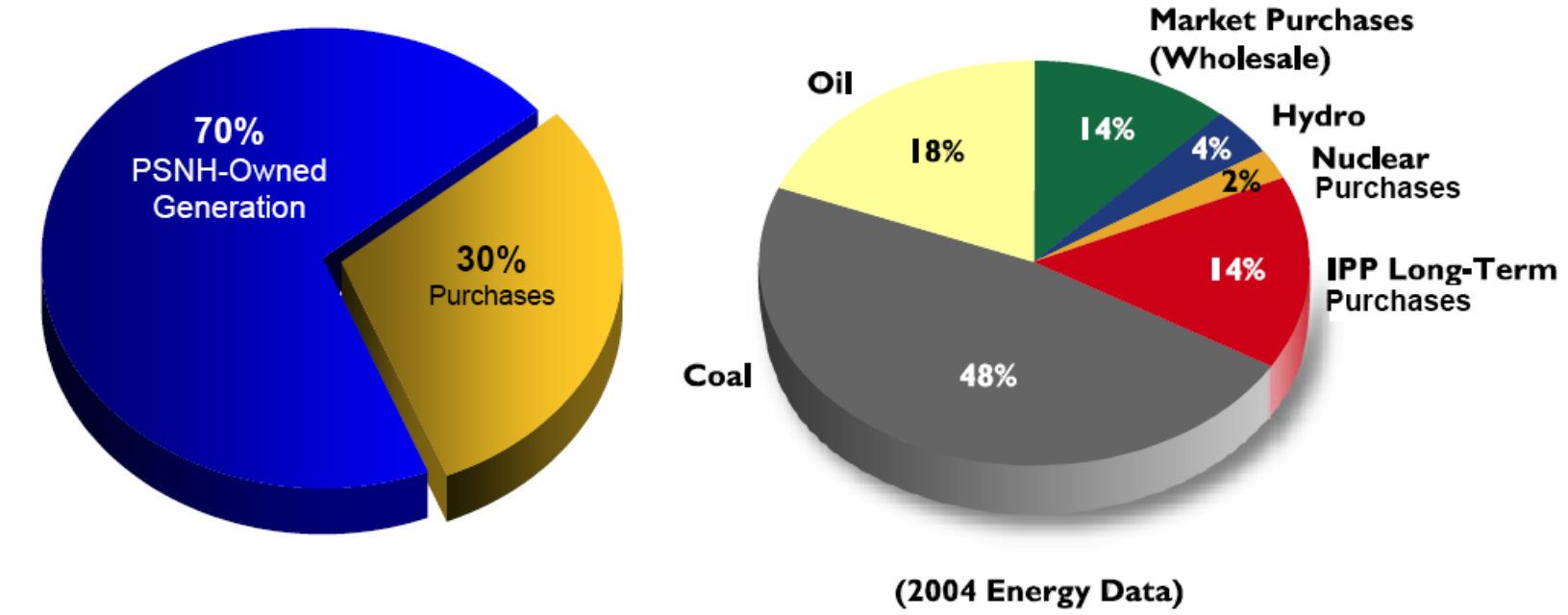
breakdown of PSNH 13.855 cents/kwh



from Northeast Utilities PSNH Overview presentation by Gary Long, President & COO Sept 23, 2005

PSNH Power Sources

- 70% owned (48% coal, 16% oil, 4% hydro, 2% wood**)
- 16% purchased from Nuclear & Independent Power Producers averaging 7.24 cents/kwh
- 14% purchased from wholesale market at 8.50 cents/kwh (PSNH forecast estimate)



from Northeast Utilities PSNH Overview presentation (**added Schiller wood boiler online summer 2006) by John MacDonald, Vice President of Operations, Sept 23, 2005

National Comparison
Mix of Electric Generation Sources

- Coal 52%
- Nuclear 19%
- Gas & Fuel Oil 18%
- Hydro 7%
- Wood/Biomass, Wind, Solar 4%

from 'Electric Vision' by Robert Preston Sept 7, 2005
using figures from US Department of Energy, September, 2005
http://www.renewableenergyaccess.com/rea/news/story?id=35854

National average cost of Electricity
8.83 cents per kilowatt hour

from US Dept of Energy - Electric Power Monthly January 12, 2007
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

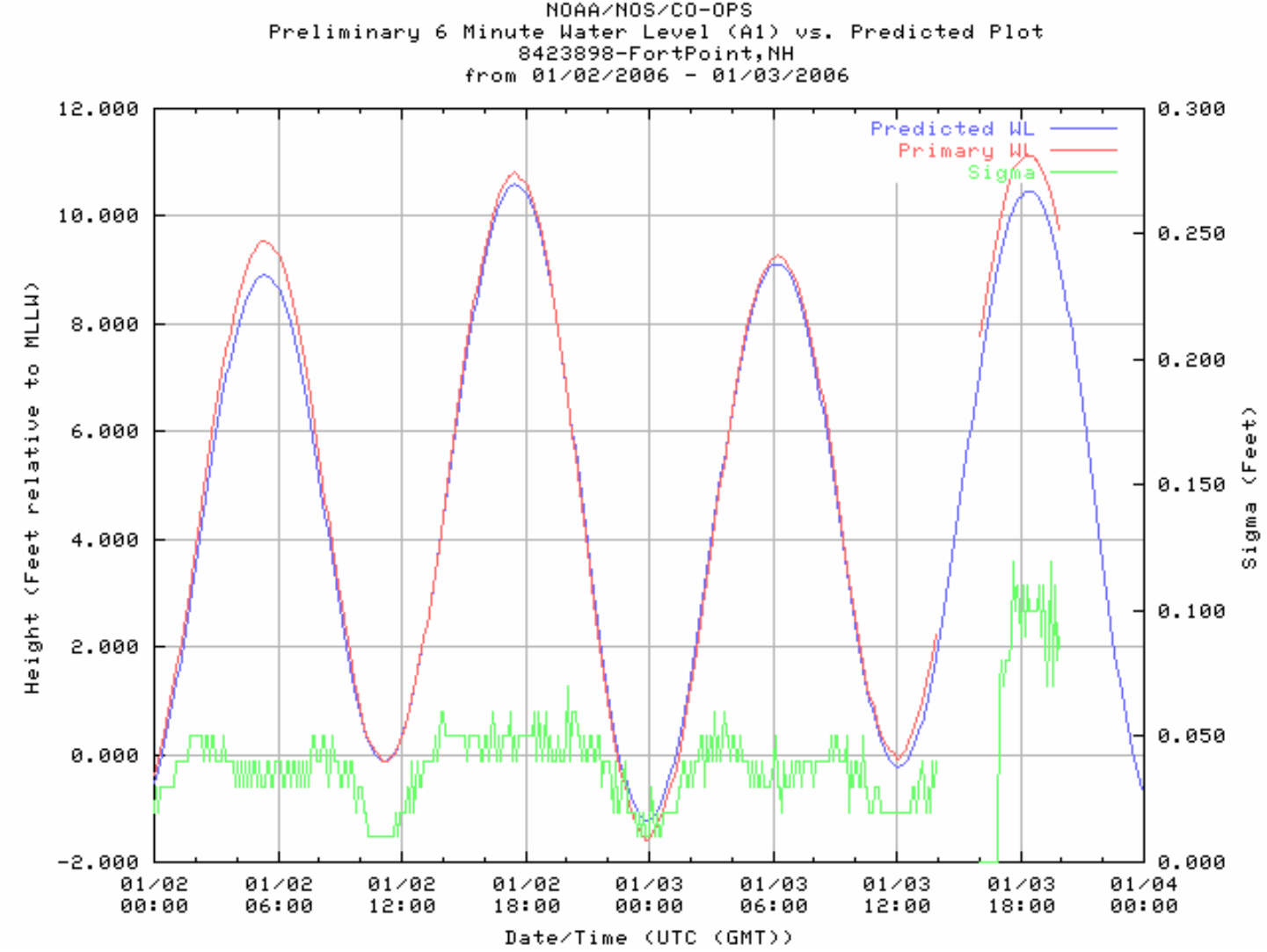
Energy Cost Comparisons

Costs in cents per delivered Killowatt Hour

Technology	Capital Cost	Capacity Factor	O&M Cost	Fuel Cost	Direct Costs	Indirect Social Costs	Total Costs
Coal	0.72	95%	1	2.14	3.14	6.43	10.29
Nuclear	0.9	95%	1.4	0.76	2.16	0.25 + other not quantified	3.31
Natural Gas	0.42	95%	0.5	4.9	4.95	2.27	8.09
Solar	17.12	15 - 20%	1	none	18.12	not quantified	18.12
Wind	2.45	25 - 35%	1	none	3.14	not quantified New England	3.45 6 - 7

Cost Comparisons derived from 'Electric Vision' by Robert Preston Sept 7, 2005
http://www.renewableenergyaccess.com/rea/news/story?id=35854

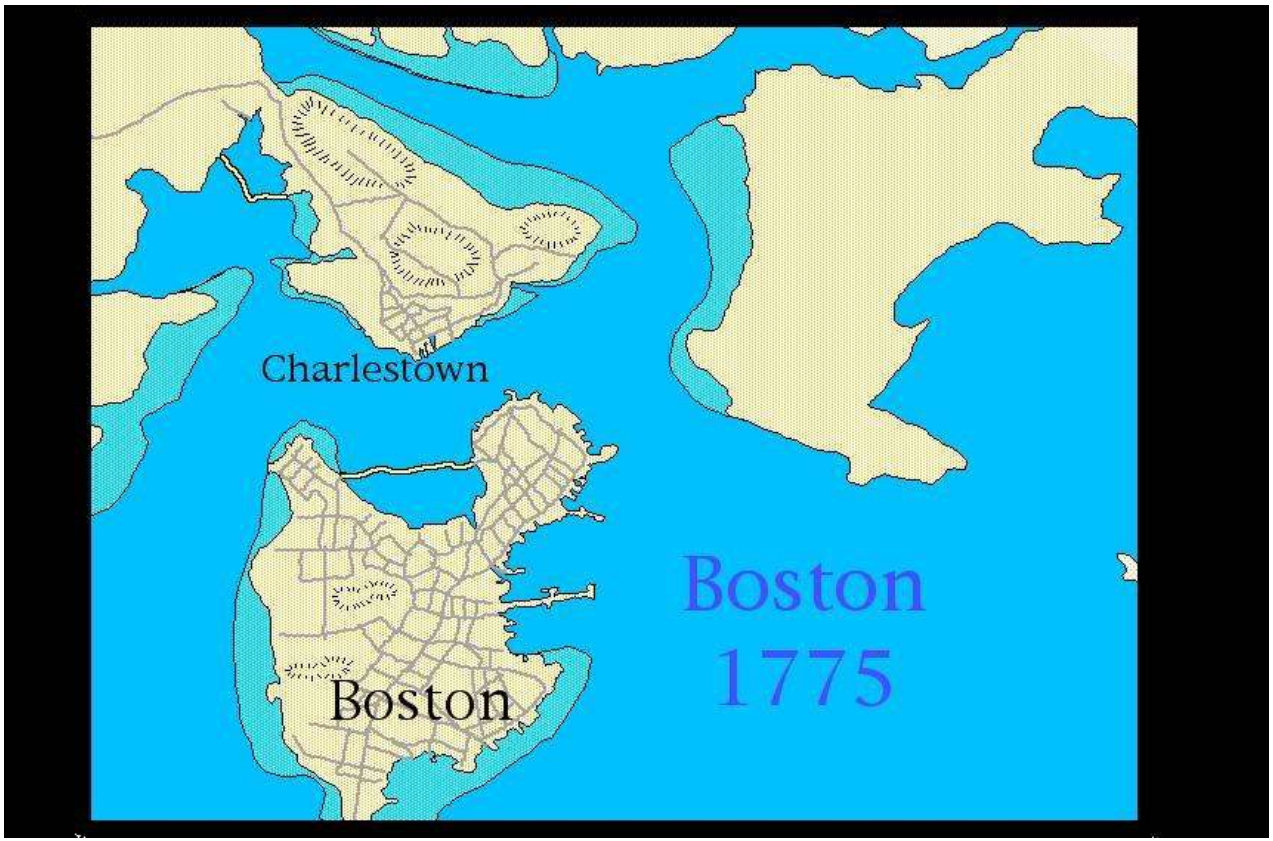
Unlike conventional hydroelectric power (river flow), tidal currents can be predicted YEARS in advance



Tidal Station no. 8423898 Fort Point, NH (Fort Constitution)

http://www.co-ops.nos.noaa.gov/cgi-bin/station_info.cgi?stn=8423898+Fort+Point,+NH

Tidal Power History



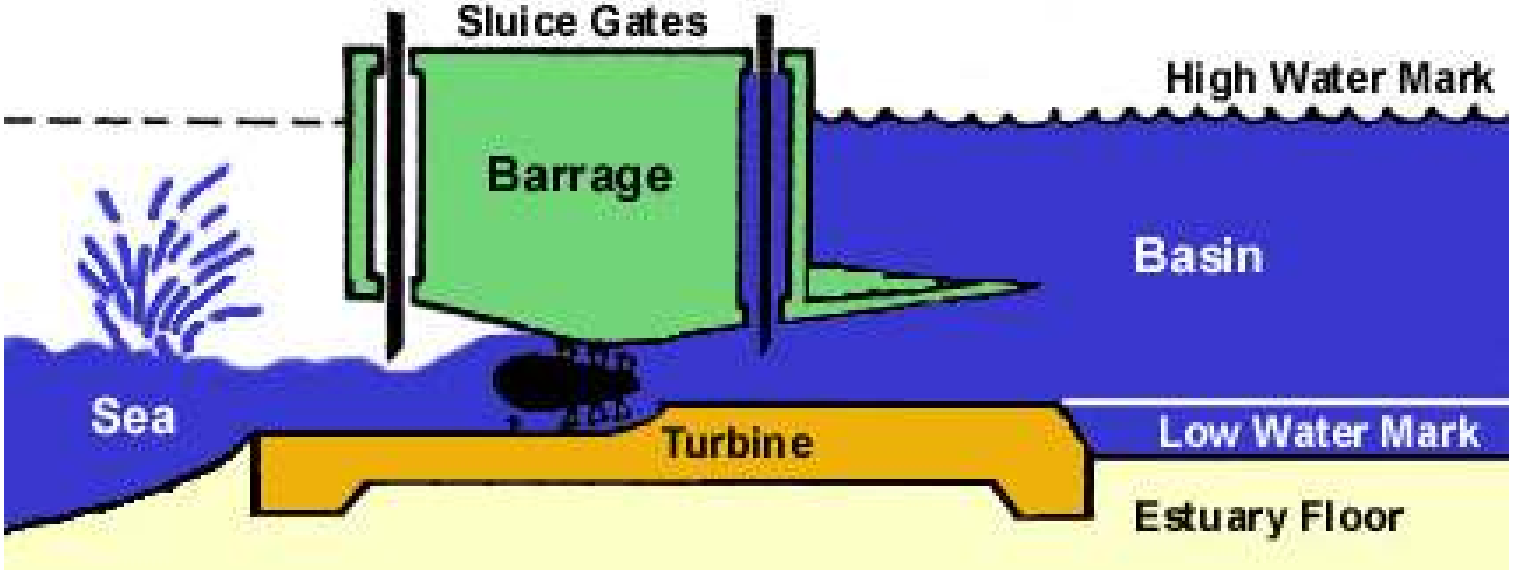
Tides have been dammed for powering grist mills since the 11th century in England and France.

1775 Boston shows a tide mill dam (now Causeway Street).

Operation: Let high tide into millpond
Wait for low tide
Release water through grist mill's water wheel

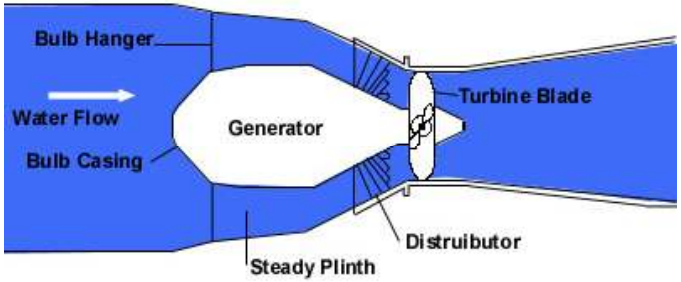
1960s to Present - Dams (Barrages)

- Operates like historical grist mills
- Pro - powerful, reasonably simple
- Con - 15 - 20% capacity factor (outgoing tide only), expensive structure, obstructs navigation, sediment in basin, fish kill (typically rotate 600 - 700 rpm)

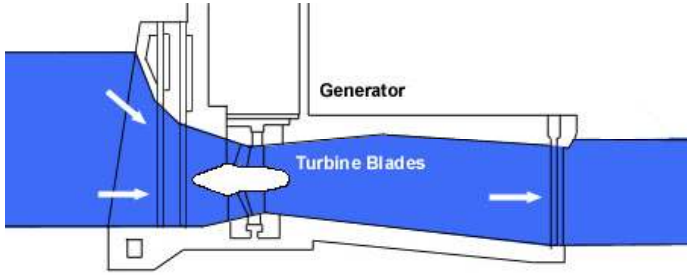


from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

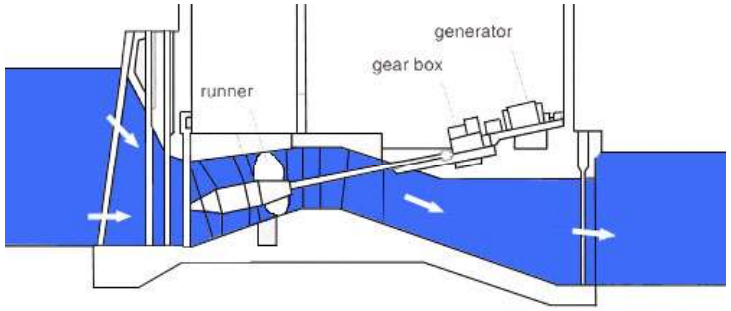
Three turbine technologies used in Dams/Barrages



- Bulb Turbine



- Rim Turbine



- Tubular (Ducted)Turbine

from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

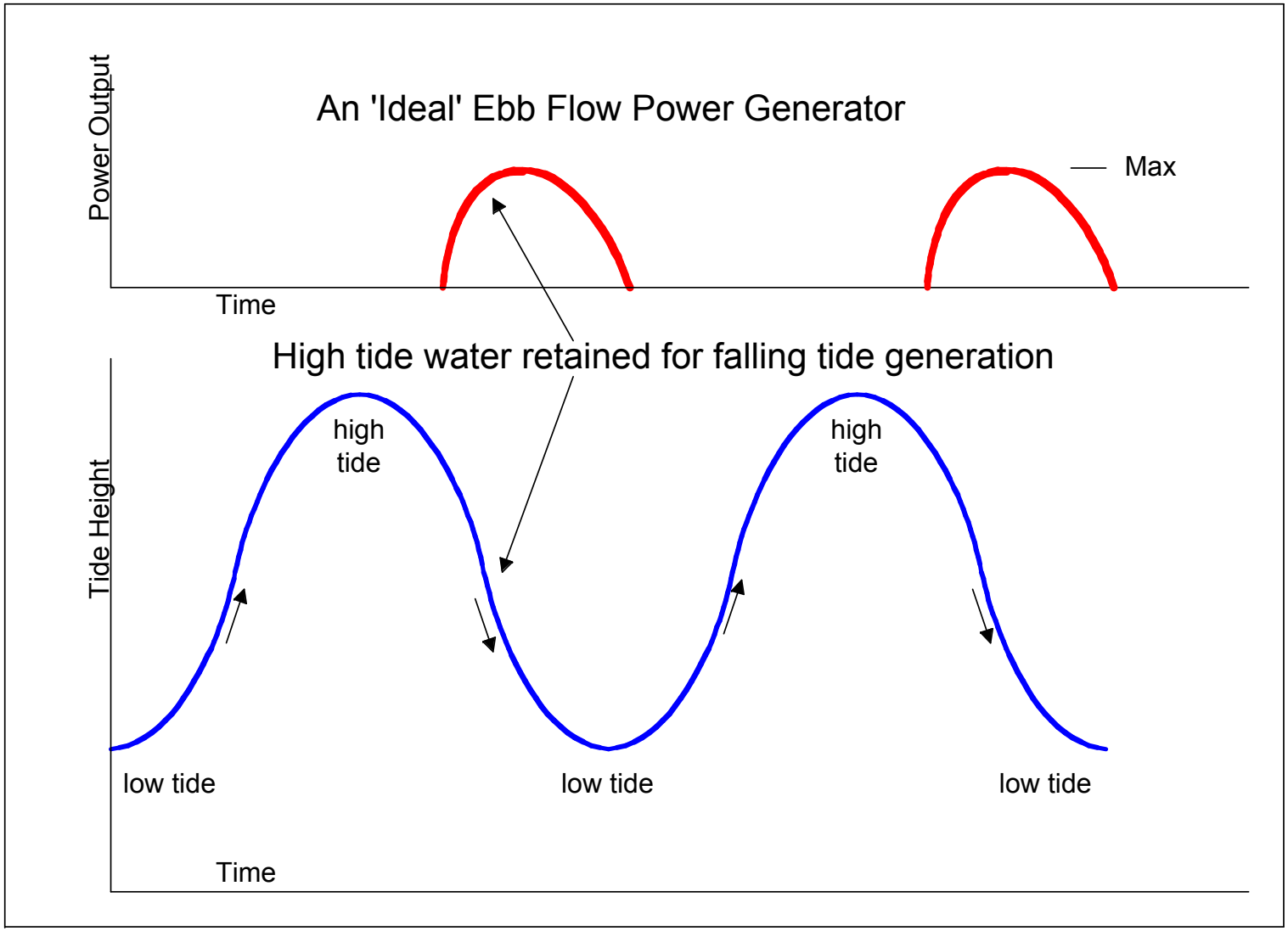
Tidal Barrage classic example

The La Rance dam
mid ‘60s, St. Malo, France
2,362 feet long
bulb turbines to right
4-lane highway on dam
lock (at the left)
213 feet by 43 feet

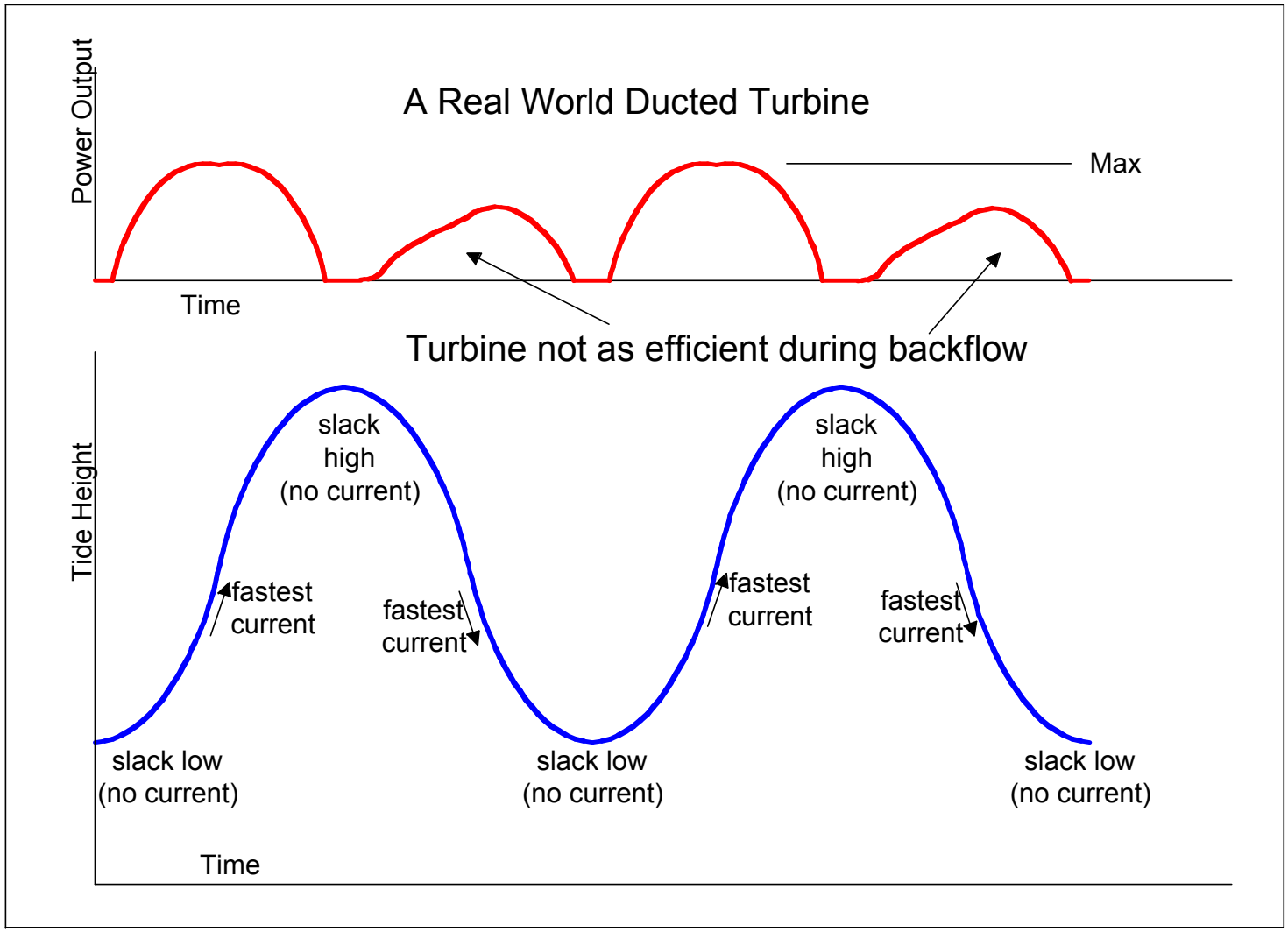
from
http://www.alternative-fuels.com/tidal.html

Another 1984 rim turbine example is in Annapolis Royal, Nova Scotia.

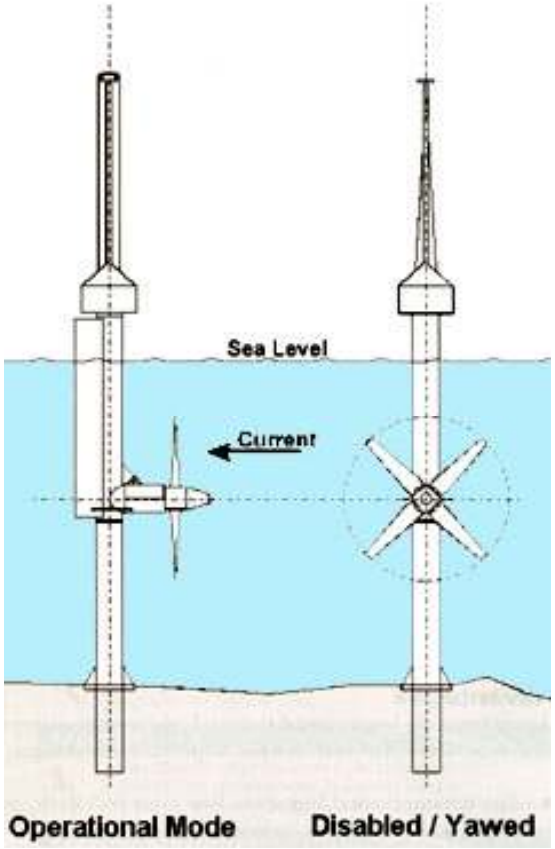
Ebb Flow Power from Barrage



Bi-Directional Ducted Turbine Output



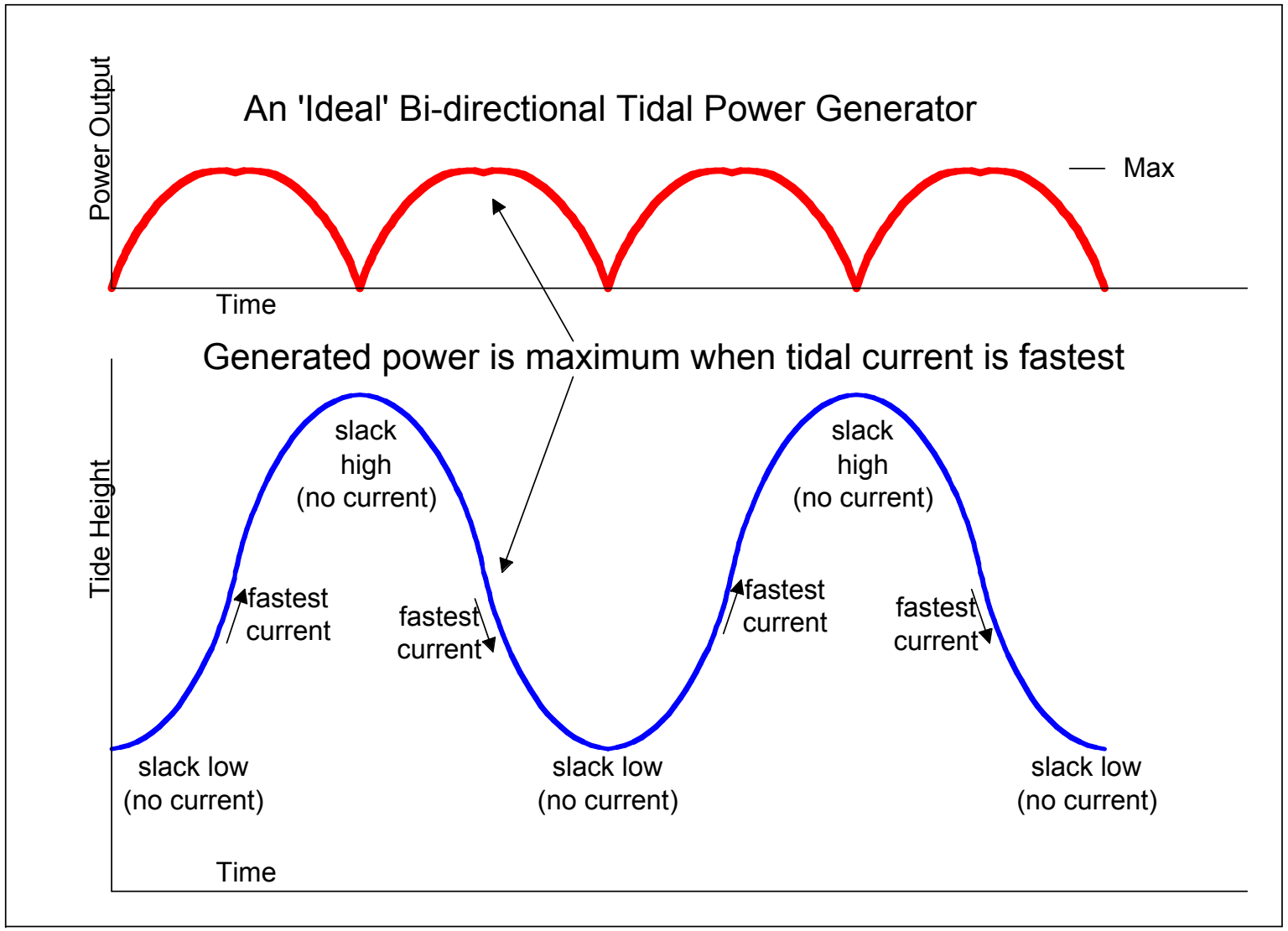
1990s to Present - Exposed Axial Tidal Turbines



- Underwater Wind Farm with smaller blades and towers sticking out of water
- Pro - less environmental impacts, slow turning
- Con - may obstruct navigation

from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

Bi-Directional Turbine Output



The Power of Water

from http://www.newwindenergy.com

- "Sea water is 832 times denser than air and a non-compressible medium, an 8 knot tidal current is the equivalent of a 390 km/hr wind."
- (In other words, 242 miles per hour – the pressure of an F4 tornado.)

From http://VerdantPower.com

Quote from Blue Energy, Canada website http://www.BluEnergy.com

Marine Current Turbine

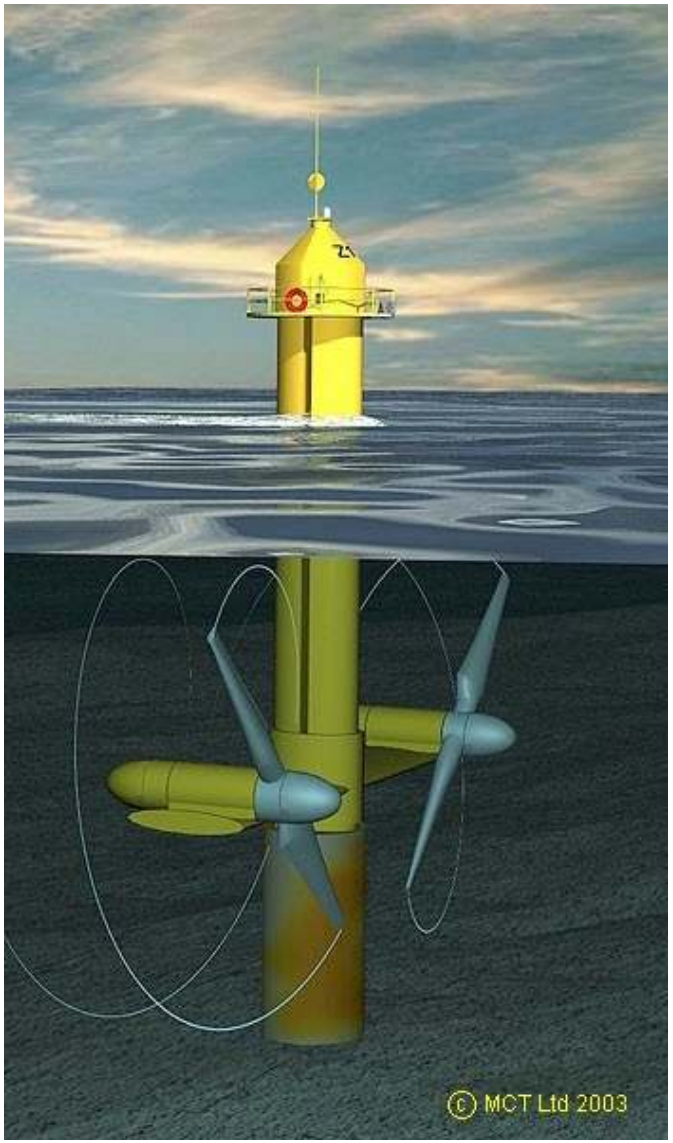
Devon, UK coast

Operational

- May 2003
- Axial Tower Turbine raised for maintenance.
- Vane at rear causes unit to pivot - capturing both tides

http://www.marineturbines.com

Marine Current Turbine



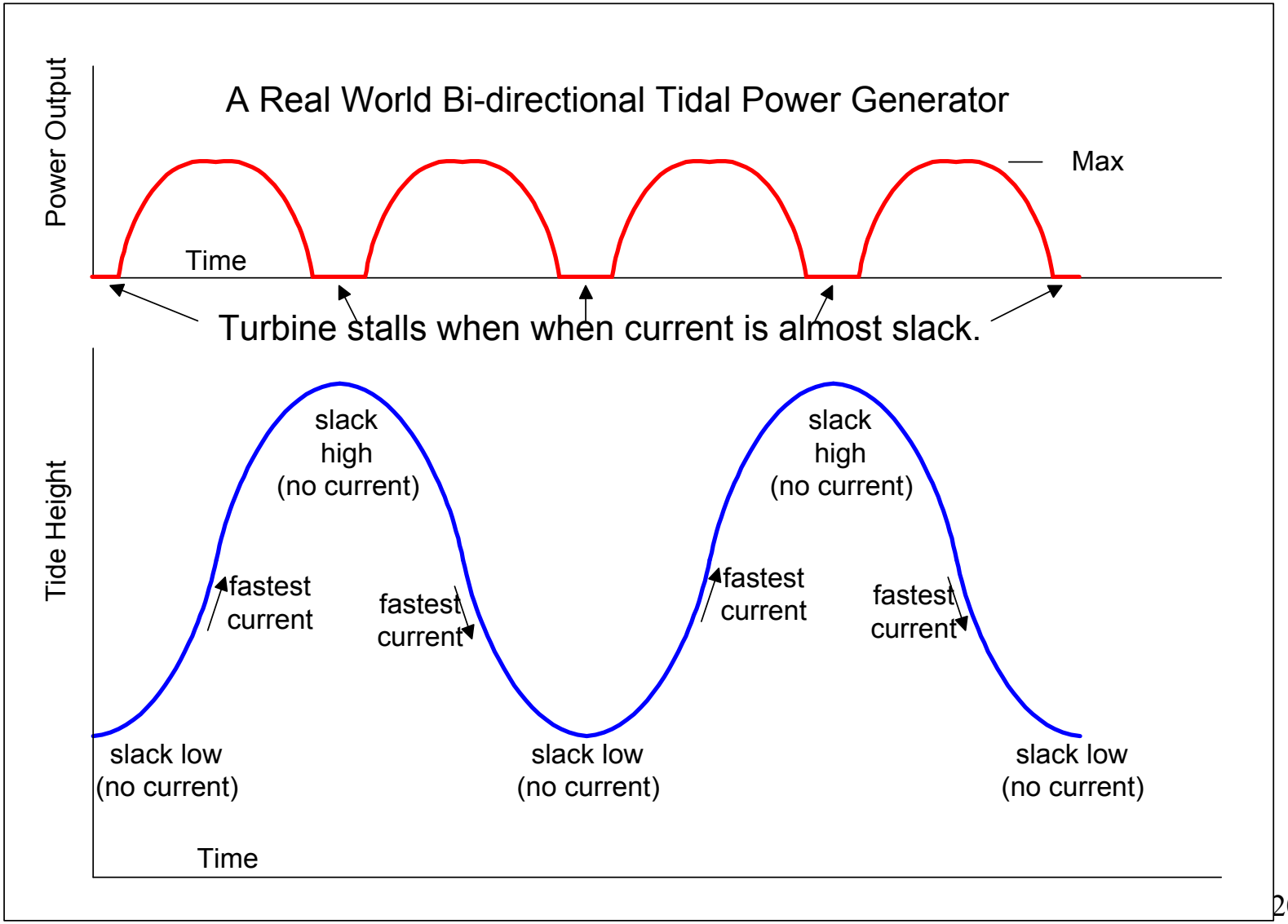
1 MW bidirectional version

- Above surface mast reduces servicing costs
- Blades rotate in opposite directions to reduce water pressure interaction

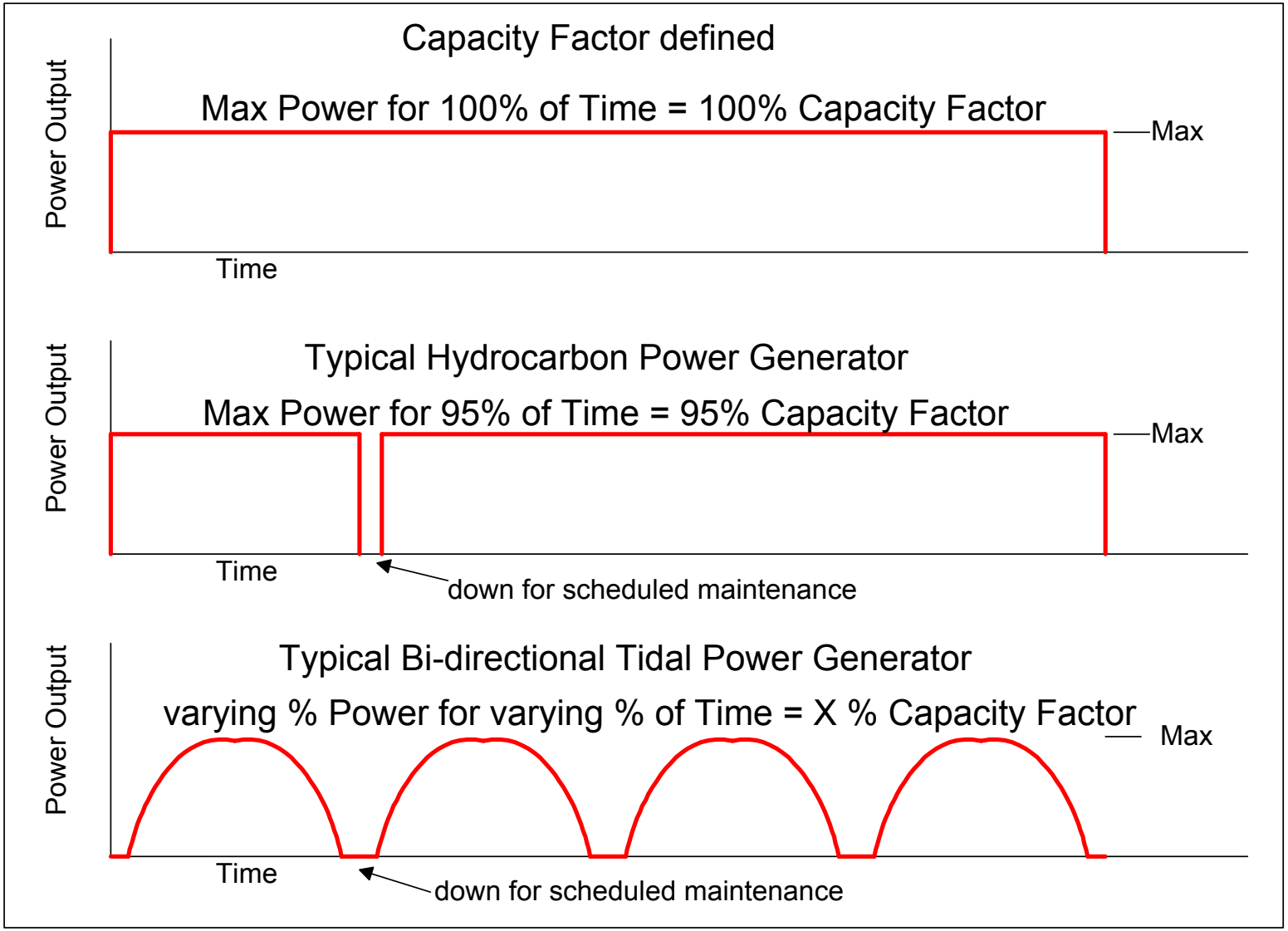
http://www.marineturbines.com

Real World Tidal Turbine Output

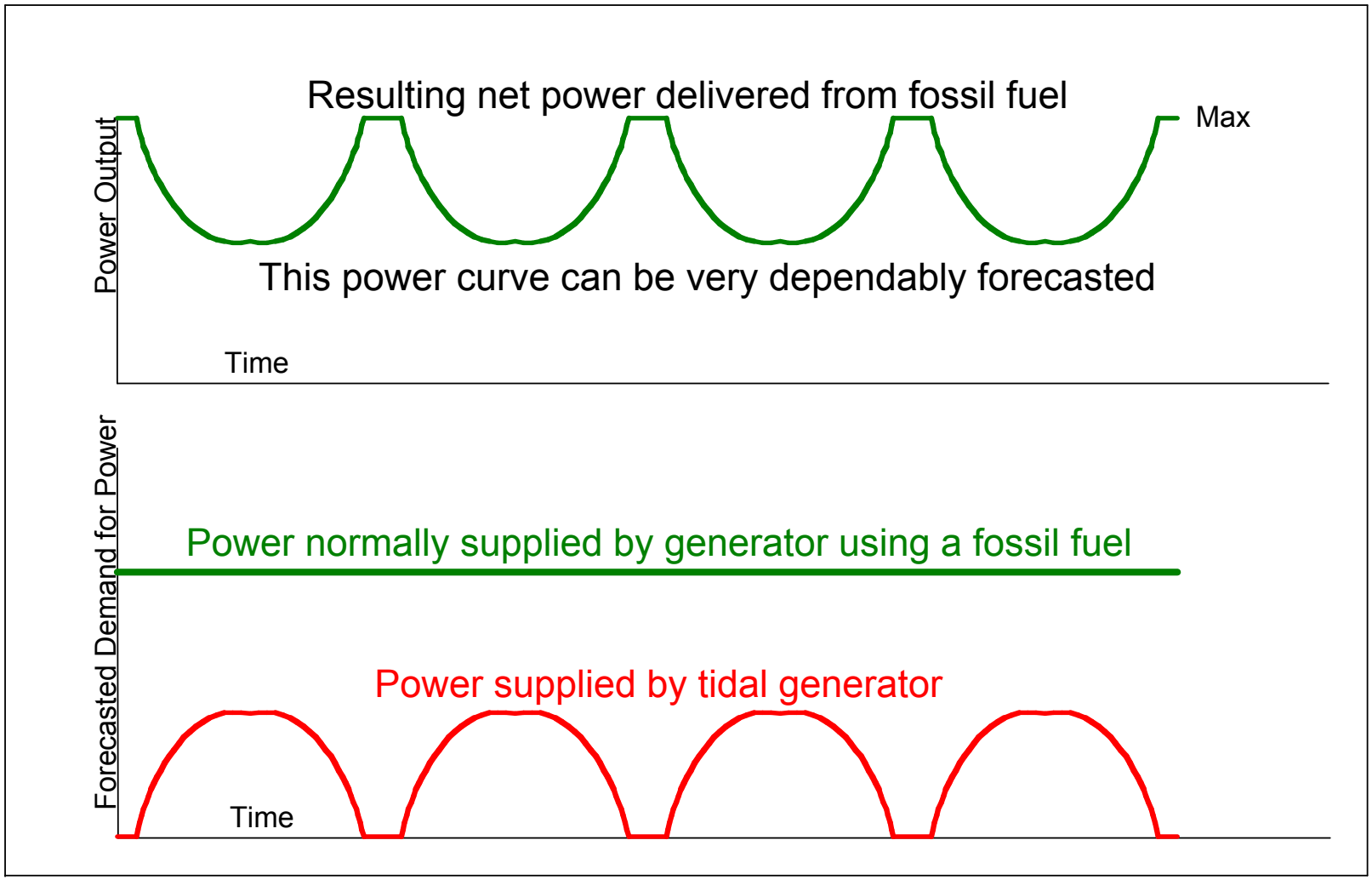
Two-knot “stall point” approx. 1 hour or more in free tidal current



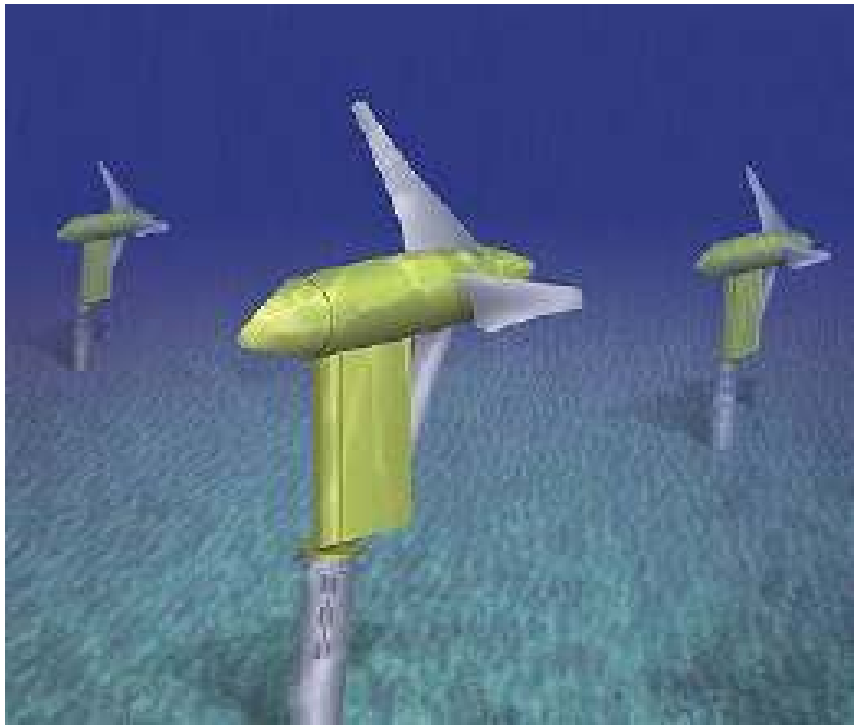
CAPACITY FACTOR



TIDAL - FOSSIL FUEL COMBINATIONS



Mid-1990s to Present - Bulb Turbines - Verdant Power



- Free-flow underwater windmill (pivoting bottom-mount captures both tides)
- Pro - No dams or fences, 45% Capacity Factor, low environmental impact, does not block navigation, slow turning (32-38 rpm), 7 - 10 cents/kWh in NYC
- Con - Maintenance difficult

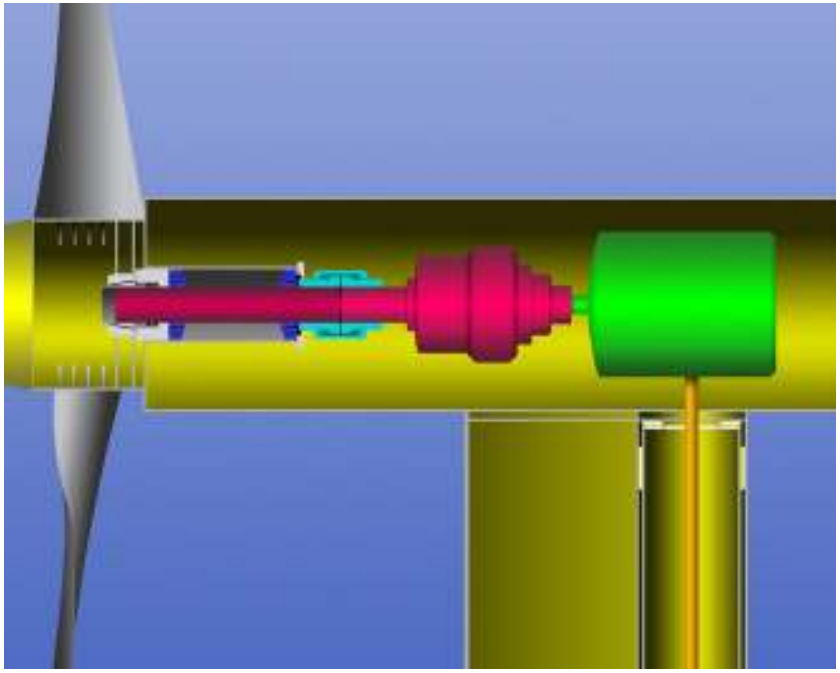
from Verdant Power (USA) website
http://VerdantPower.com

Verdant Power, 2

- Turbine servicing done from special motor barge

from Verdant Power (USA) website
http://VerdantPower.com

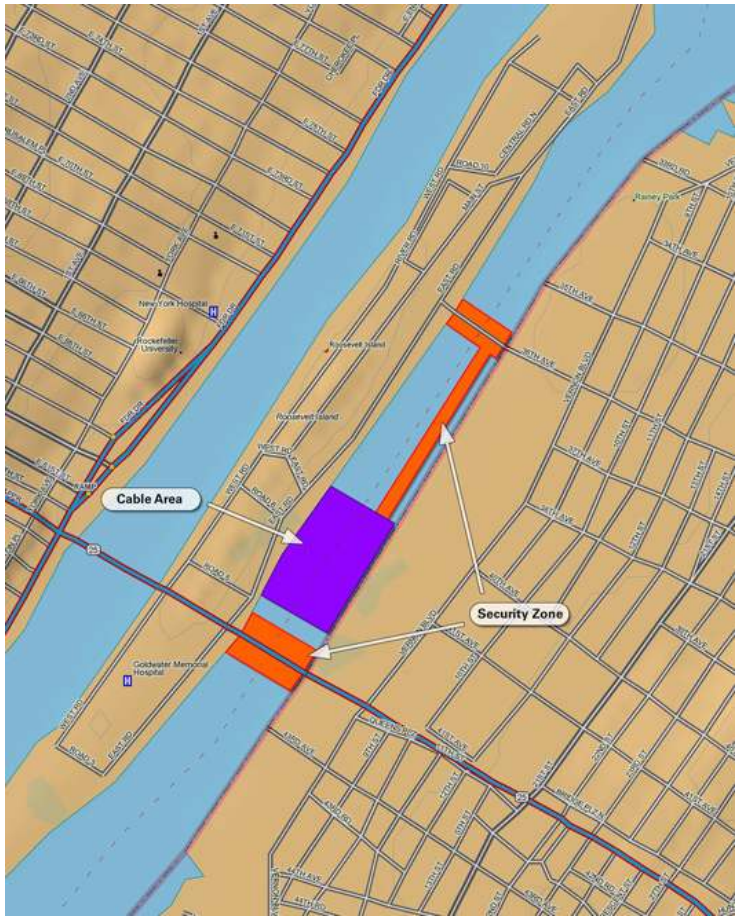
Verdant Power, 3

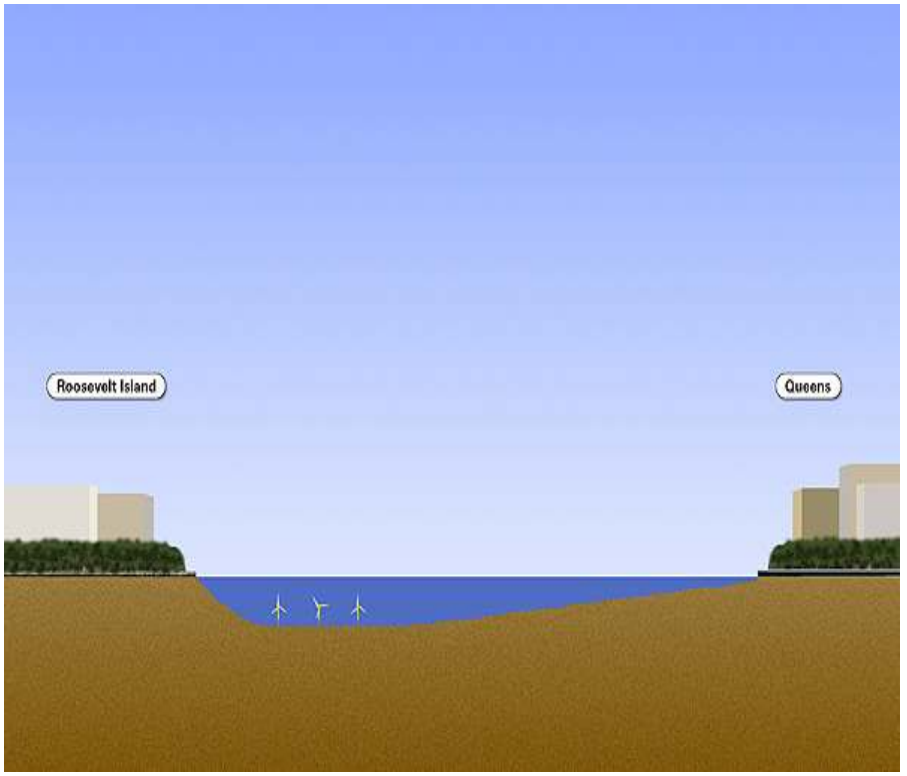


from Verdant Power (USA) website http://VerdantPower.com

Verdant Power, 4

New York's Roosevelt Island Tidal Energy (RITE) Project - 2003 onward





from Verdant Power (USA) website
http://VerdantPower.com

Other Bulb Turbine Variations

Similar features, but hangs from an above structure

from ee.ntu.edu.au/ntcer/projects/tidalpower/main.html

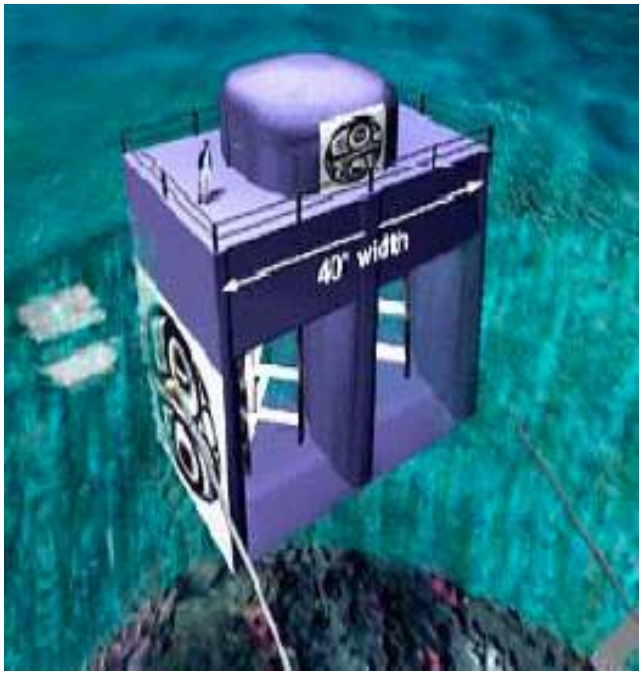
Ganged array of bulb turbines (also used for rim turbines)

from http://www.hydromatrix.at/

Submerged and Floating "Kites"

Underwater Electric Kite twin axial turbines to be anchored to the bottom.

from http://uekus.com



Blue Power twin vertical-axis Davis Turbines in a free-floating array.

from http://www.bluenergy.com/technology.html

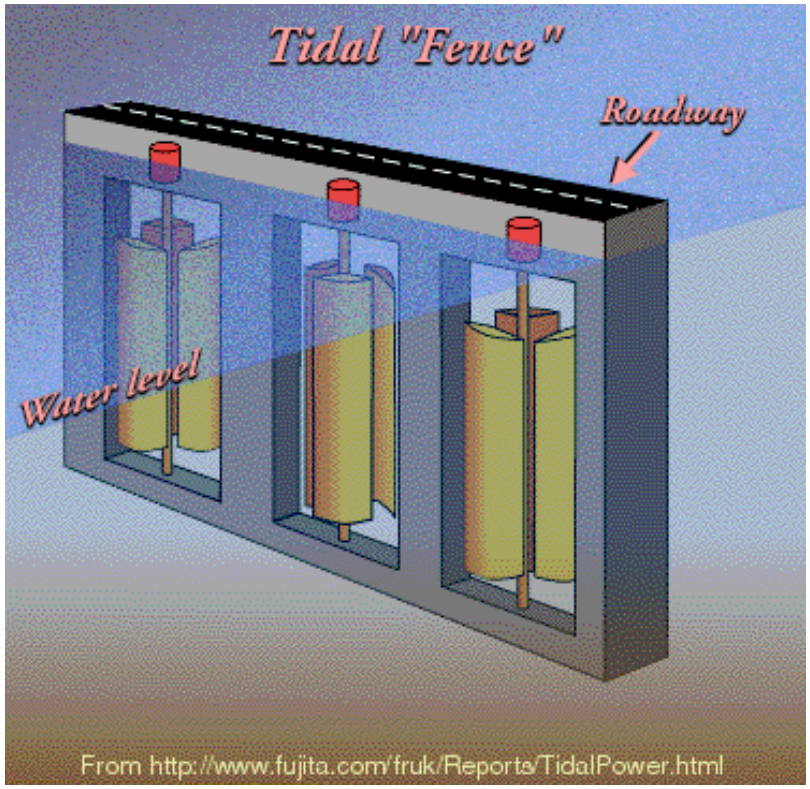
These need counter-rotating turbines to cancel torque applied to the generator.

Underwater Electric Kite

- Can raise or lower itself in current - finding greatest velocity
- Wires on right (up-current) side shield the turbine from fish, aquatic birds and marine mammals.

from http://uekus.com

1990s to Present - Tidal Fences (Blue Energy, Canada)



- Can use Cross-Axis Turbines (Daerrieus Turbine a.k.a. Davis Turbine shown) or arrays of bulb or rim axial turbines
- Pro - less costly than dam, Davis Turbine generators above water, no silting, slower turning, 35 - 40% capacity factor (uses both tides)
- Con - Above-water fence structure still expensive to build, obstructs navigation

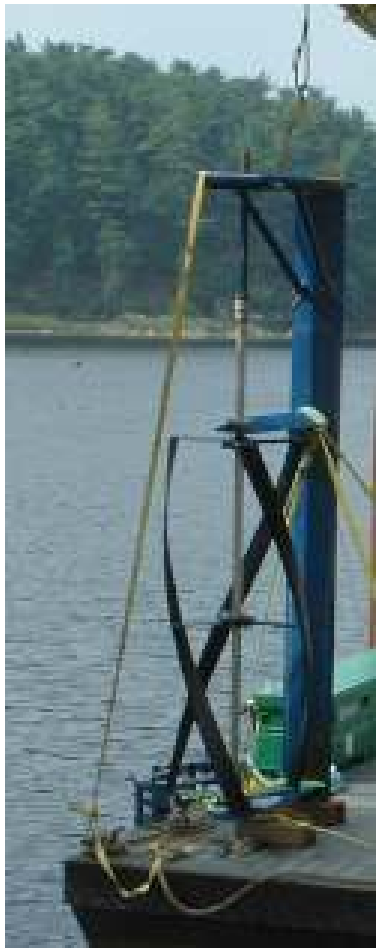
from Fujita Research (Japan) website
http://www.Fujita.com/archive-frr/TidalPower.html

Darrieus Turbine

Davis water turbine was adapted from Darrieus Turbine (windmill)

from http://www.bluenergy.com/technology.html

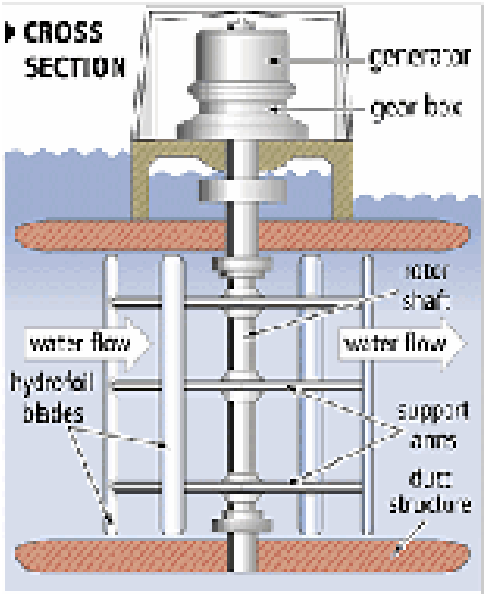
Gorlev Helical Turbine

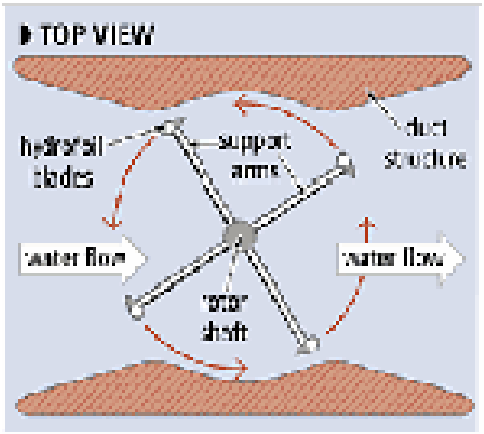


- Horizontal or vertical axis
- Deployed in free stream
- Demonstration project - Merrimack River 2005
- Arrayed turbines interact - cannot closely space

from http://www.gcktechnology.com/GCK/

Davis Turbine in Tidal Fence

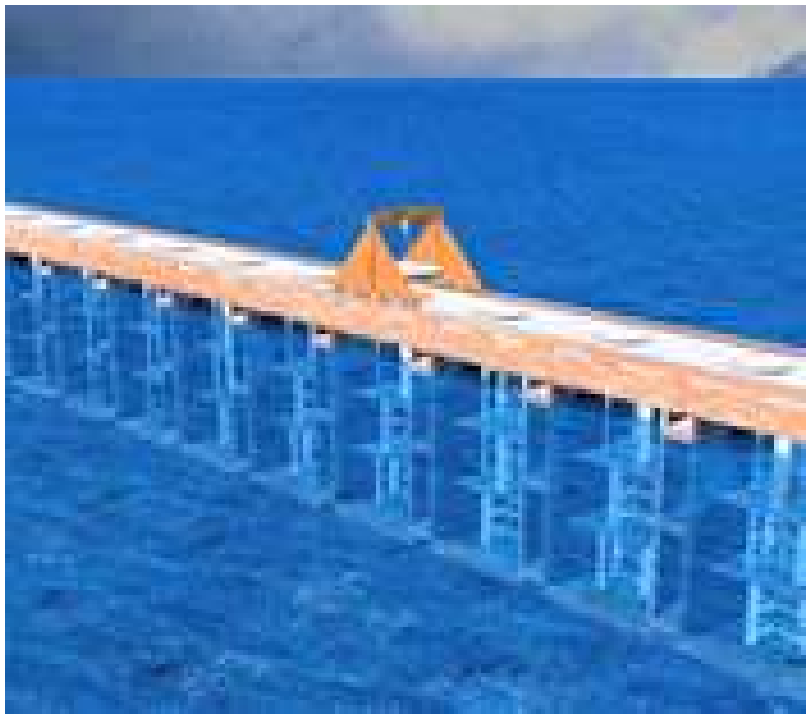




- Vertical cross-axis turbine
- Generator and gearbox above water
- Possible improvement: Add open-air clearance above water surface to avoid ice and debris
- Duct structure eliminates interaction of adjacent turbines

from http://www.bluenergy.com/technology.html

Tidal Fence as Bridge



from http://www.bluenergy.com/technology.html

- Proposed by Blue Energy (Canada) for Tacoma Narrows, WA and San Juan Straits, Phillipines
- Proof-of-concept for Detroit-Windsor bridge over Detroit River (summer 2005)
- Pro - avoids most costs of Tidal Fence (co-fund with bridge)
- Con - obstructs navigation, vertical generator linkage may get hit by ice or debris

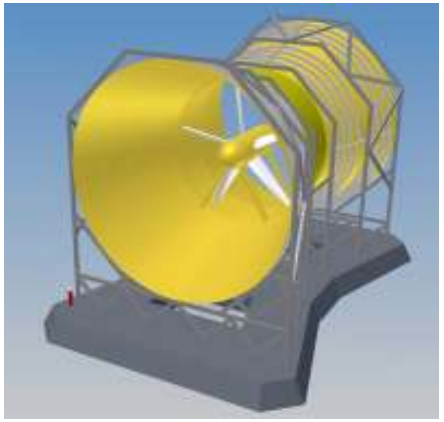
HydroVenturi Ltd, UK

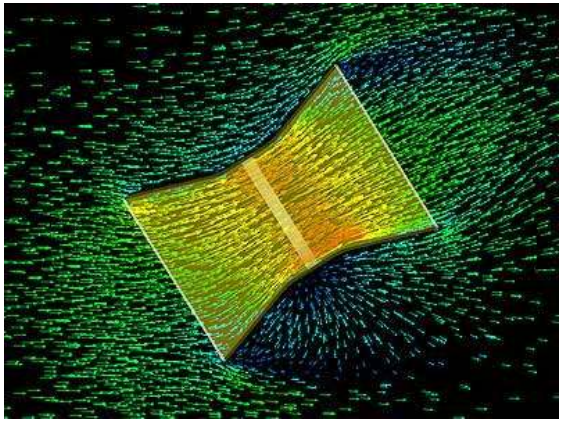
Rochester Venturi nozzle operational Derby, England June, 2002

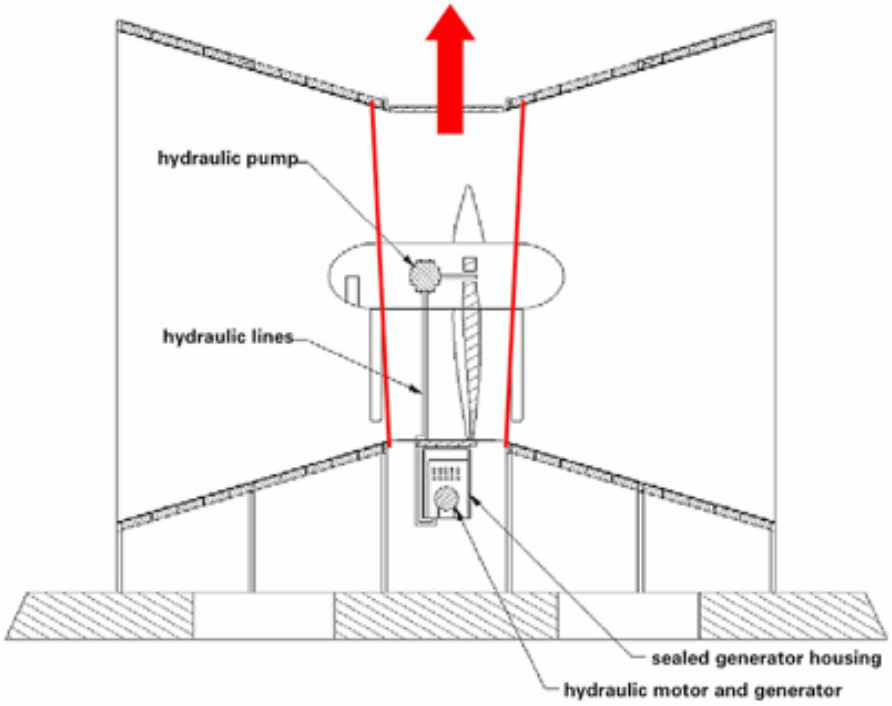
- No moving parts, all concrete
- Sucks in water or air
- Many can be tied into one turbine/generator on shore
- Might be permitted in navigation channels
- Works like venturi hose pump (at left)

from http://www.HydroVenturi.com

Lunar Energy Ltd, UK







- Venturi-Ducted axial turbine
- Allows 40 degrees off-axis flow
- Ducts reduce interference with nearby turbines
- Multiple hydraulic pumps can be connected into a single generator

from http://www.lunarenergy.co.uk

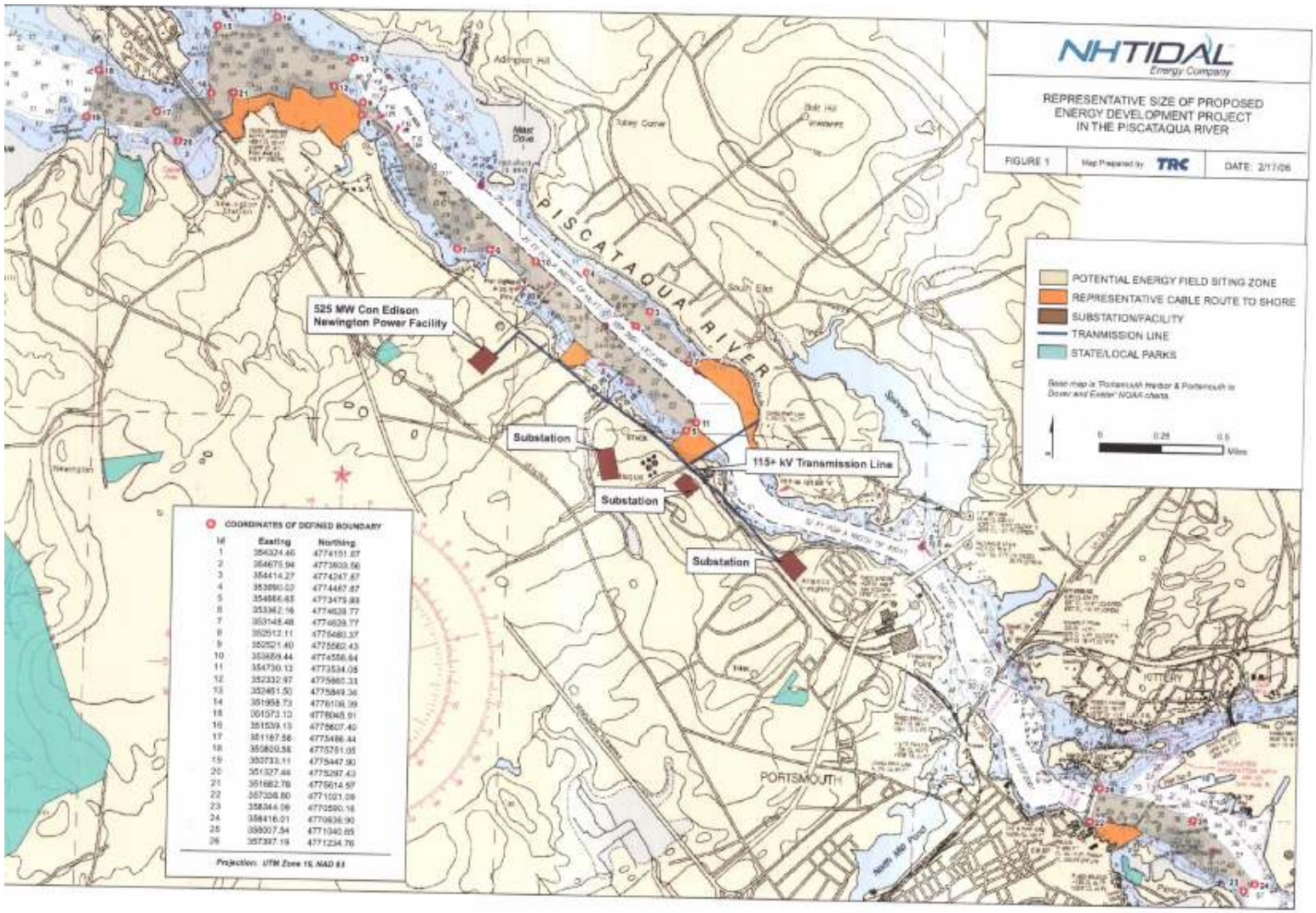
Cost Comparisons

	Costs in cents per delivered Killowatt Hour				Estimates shown with question mark?		
Technology	**Capital Cost**	**Capacity Factor**	**O&M Cost**	**Fuel Cost**	**Direct Costs**	**Indirect Social Costs**	**Total Costs**
Coal	0.72	95%	1	2.14	3.14	6.43	10.29
Nuclear	0.9	95%	1.4	0.76	2.16	0.25	3.31
						+ other not quantified	
Natural Gas	0.42	95%	0.5	4.9	4.95	2.27	8.09
Solar	17.12	15 - 20%	1	none	18.12	not quantified	18.12
Wind	2.45	25 - 35%	1	none	3.14	not quantified	3.45
						New England	6 - 7
Tidal							
Barrage / Low Dam	7 - 10?	12 - 18%?	1?	none	8 - 11?	not quantified	8 - 11?
Free-Flow Current	5 - 8?	30 - 50%	2?	none	7 - 10	not quantified	7 - 10
Tidal Fence	6 - 9?	35 - 40%	2?	none	8 - 11?	not quantified	8 - 11?
Submerged Array	5 - 7?	40 - 60%?	1.5?	none	6.5 - 8.5?	not quantified	6.5 - 8.5?

The Applications to FERC

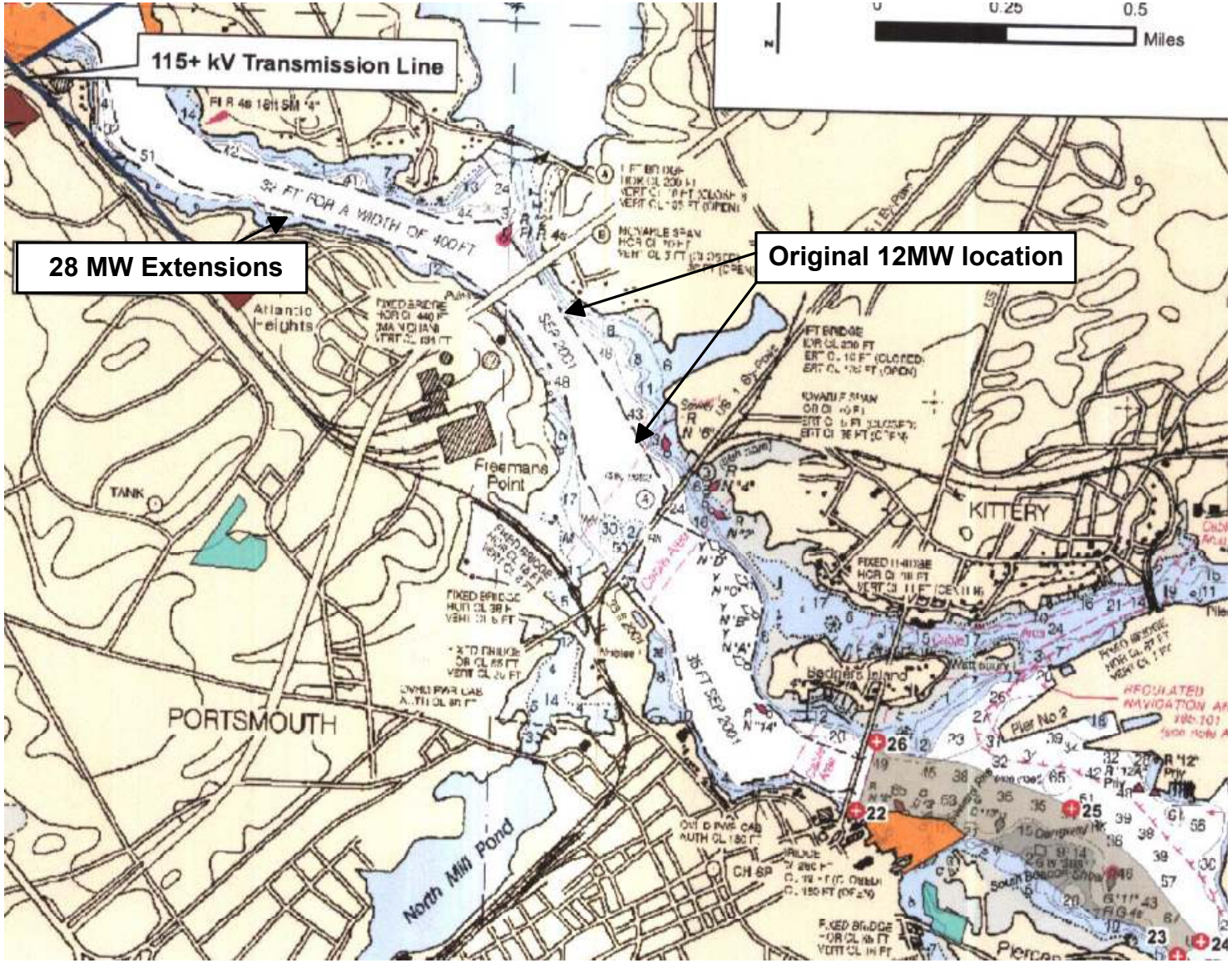
- New Hampshire Tidal Energy Co.
  - Application March 28, 2006
  - "Portsmouth Area Tidal Energy Project"
  - Four Permit Areas
  - 50 to 100 Tidal In Stream Conversion (TISEC) devices 20 to 50 ft diameter , 500 kW to 2 mW
  - 80 percent Capacity Factor (target) Source: FERC docket # 12264-000
- Underwater Electric Kite Corp.
  - "Competitive"Application July 28, 2006
  - "Piscataqua Tidal Hydrokinetic Energy Project"
  - Two Permit Areas: 12 mW initial, 28 mW follow-on
  - 17 ft diameter dual turbine units, 336.8 kW
  - 64 percent Capacity Factor Source: FERC docket # 12722-000

NH Tidal Energy Co
Four Energy Field Siting Zones



Source: FERC docket # 12264-000

UEK's Two Energy Field Siting Zones



Source: FERC docket # 12722-000 information superimposed onto map from FERC docket # 12264-000

Great Bay / Little Bay and River