Tidal Turbine Cost Estimation Research

Introduction

To demonstrate that tidal stream energy extraction is a viable option for clean and renewable energy in Maine, our group has been trying to determine how much a full scale installation of tidal turbines would cost at the more attractive sites available in the state, such as the Western Passage near Eastport. We'll then compare the economic feasibility compared to more developed renewable energy sources, such as wind and solar power.

Since as students we don't have any experience on large scale projects, to try and estimate how much a full scale tidal turbine (or an entire "farm" of turbines) would cost, we've been trying to find as many estimates as we can from outside sources. Below you'll find a summary of the publicly available information we've found so far.

Summary of Information Gathered

The costs associated with constructing and maintaining tidal turbines seem to be very site specific, since there are a wide range of conditions that affect how difficult they are to install, and which designs can even be installed in the first place. Current velocities, seabed composition, and available local infrastructure are a few examples of the complicating factors. For these reasons, estimates made for locations other than the Western Passage (in this case) are less valuable than ones that are specifically geared toward the location of interest. So, it is useful to start with the most targeted information we were able to find.

EPRI Tidal In Stream Energy Conversion Project

Within the past few years the EPRI completed a survey of possible tidal energy locations in Maine (and other areas), and the Western Passage was one of the sites examined. Numerous reports for the project can be found in the EPRI's archive at: http://archive.epri.com/oceanenergy/streamenergy.html#reports. For the purposes of examining costs of a Western Passage tidal turbine installation, the most important document is report TP-006-ME [1].

This report contains a lot of useful information in terms of design parameters and an analysis of the performance and economic feasibility in the Western Passage of two turbine designs: Lunar Energy's Rotech Tidal Turbine (RTT), and Marine Current Turbines' (MCT) SeaGen. While the report contains a more in depth analysis of how each device would be appropriately used to maximize its potential for the Western Passage, only the summary of the cost and economic feasibility will be shown here, which was only completed for the MCT device.

For a single demonstration unit:

Table 1 – Capital cost breakdown of MCT pilot plant

	$/kW	$/Turbine	in %
Power Conversion System	1,428	1,182,000	25.1
Structural Steel Elements	517	428,000	9.1
Subsea Cable Cost	130	108,000	2.3
Turbine Installation	1,741	1,442,000	30.6
Subsea Cable Installation	1,636	1,355,000	28.7
Onshore Electric Grid Interconnection	241	200,000	4.2
Total Installed Cost	5,693	4,715,000	100.0

For a full scale commercial project the costs per unit go down since it becomes more efficient to install more units when you have all that equipment already set up already. The farm is assumed to have 12 turbines.

Table 2 – MCT commercial plant capital cost breakdown

	$/kW	$/Turbine	$/Farm	in %
Power Conversion System	894	740,693	8,888,000	37.6
Structural Steel Elements	506	419,149	5,030,000	21.3
Subsea Cable Cost	20	16,785	201,000	1.0
Turbine Installation	593	491,426	5,897,000	25.0
Subsea Cable Installation	313	259,436	3,113,000	13.2
Onshore Electric Grid Interconnection	50	41,667	500,000	2.1
Total Installed Cost	2,378	1,969,155	23,630,000	100.0
O & M Cost	63	52,540	630,477	64.0
Annual Insurance Cost	36	29,537	354,488	36.0
Total Annual O & M Cost	99	82,077	984,925	100.0

Each of the categories in Tables 1 and 2 is explained in more detail in the report, describing exactly what each of them includes for parts.

The report also goes onto estimate the Cost of Energy (COE) for the tidal turbines and compares it to other energy technologies.

Table 3 – COE for alternative energy technologies: 2010

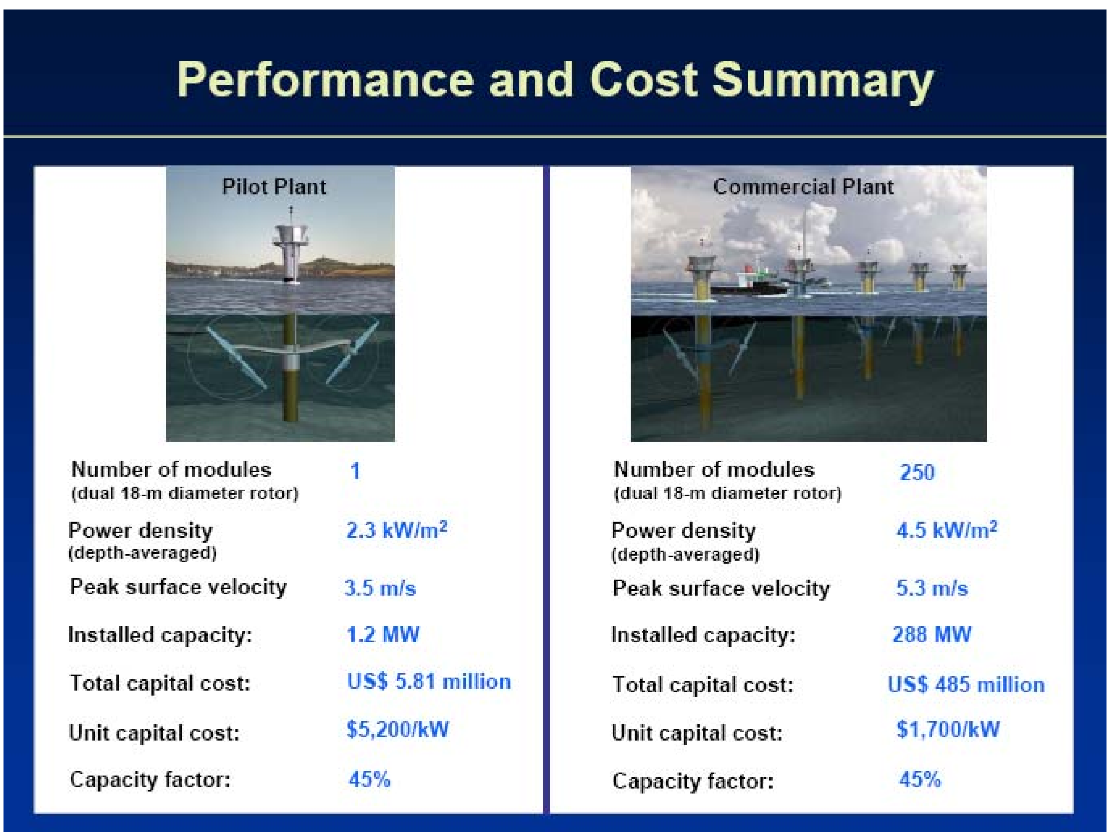
	Capacity Factor (%)	Capital Cost[1] (\$/kW)	COE (cents/kWh)	CO_2 (lbs/MWh)
Tidal In Stream	46	2000	4 – 6.5	None
Wind	30-42	1150	4.7 – 6.5	None
Solar Thermal Trough	33	3300	18	None
Coal PC USC (2)	80	1275	4.2	1760
NGCC[3] @ $7/MM BTU	80	480	6.4	860
IGCC[2] with CO_2 capture	80	1850	6.1	344[4]

Notes:

1. Costs in 2005$
2. 600 MW capacity; Pittsburgh # 8 coal
3. Based on GE 7F machine or equivalent by other vendors
4. Based on 85% removal

Energy Research and Development Forum 2006, Antigonish, Nova Scotia
Presentation: Tidal Stream Energy in the Bay of Fundy [2]

This presentation can be found at http://ns.energyresearch.ca/files/George_Hagerman.pdf. The information found here seems to be based on the same kind of analysis as above, with the scale being different since this is a larger potential site.



Slide 1 – Performance and cost summary

Cost of Energy Comparisons

	Capacity Factor (%)	Capital Cost (US $/kW)	Real COE (2005 ¢/kWh)	CO2 (lbs/MWh)
Tidal In-Stream Minas Passage (4.5 kW/m^2 mean power density)	45	1,700	3.9	none
Cape Wind (0.6-0.8 kW/m^2 mean power density)	36	1,900	not calculated	none
Solar Thermal Trough (Southwest US)	33	3,300	18	none
Coal PC USC (1)	80	1,300	4.2	1,760
NGCC @ $5/MMBTU (2) NGCC @ $7/MMBTU (2)	80 80	500 500	4.8 6.4	860 860
IGCC w/ 85% CO_2 capture	80	1,900	6.1	344

(1) 600 MW Plant, Pittsburgh #8 Coal;
(2) GE 7 F machine or equivalent

Slide 2 – Cost of energy comparisons

All of the figures found on these slides are similar to the ones found in the first example, though they are less detailed. This makes sense since the same MCT SeaGen device was examined in both cases.

UK – BERR DTI Report URN 07/575 [3]
http://www.berr.gov.uk/files/file37093.pdf

This report summarizes a lot of tidal energy information, and also compares a fixed blade device to a variable pitch device in many respects, including cost. Once again, the conditions and assumptions are explained in the report itself. The numbers are in British Pounds, so a conversion has to be made to compare to the previous examples. At the end of November 2007, when this summary document was first written, the exchange rate was about 2.06 U.S. Dollars to 1 British Pound. In February 2007, when the DTI was published, the rate was about 1.96:1. The analysis was performed using a 2006 cost base, when the rate was on average about 1.85:1. Basically, in U.S. Dollars, the cost will be about twice or slightly less than twice the figure shown in the tables.

Table 4 – Cost estimates: Fixed and Variable

Cost Item		Number per farm		Farm cost	
	Cost	Fixed	Variable	Fixed	Variable
Initial set-up cost	£ 3,750,000	1	1	£ 3,750,000	£ 3,750,000
Farm Level Capital Equip,	£ 4,500,000	1	1	£ 4,500,000	£ 4,500,000
Shore Based Equip.	£ 150,000	15	15	£ 2,250,000	£ 2,250,000
Mounting - Fixed	£ 300,000	15		£ 4,500,000	
Mounting - Variable	£ 322,500		15		£ 4,837,500
Line Replacement Unit - Fixed	£ 750,000	30		£ 22,500,000	
Line Replacement Unit - Variable	£ 806,250		30		£ 24,187,500
			Total	£ 37,500,000	£ 39,525,000
			Cost/MW	£ 1,250,000	£ 1,317,500

Table 5 – Operation and maintenance assumptions and estimates: Fixed and Variable

Operation and Maintenance	Intervals	Fixed Pitch Total Cost (2006 £)	Variable Pitch Total Cost (2006 £)
Routine O&M (per MW/year)	p.a.	£37,500	£40,300
Major servicing	5 yrs	included in above	included in above
Unscheduled Interventions (£/intervention)	as required	£24,000	£25,700
Fixed annual farm running cost	p.a.	£320,000	£320,000
Rates	p.a	included in above	included in above
De-commissioning costs, per mounting	At yr 25 after mounting commissioning	£25,000	£25,000

Publication – Matching Tidal Current Plants to Local Flow Conditions [4]
http://web.mit.edu/bepps/Public/alex/energy_papers/Bryden%201998%20E%20-%20matching%20tidal%20current%20plants%20to%20local%20flow.pdf

This publication is about a decade old, so the accuracy of the numbers for today is questionable. In this paper a cost optimization is performed and the resulting figures are for a 300 kW device. At the time this paper was published, 1998, the exchange rate was about 1.65 USD:1 GBP.

Table 6 – Cost estimates for a 300 kW device

HARDWARE and INSTALLATION COSTS (£)	
Total Device and Installation Costs	£911,360
Integration into Local Grid System	£99,000
Determination of Generation Costs	
Annual Generation Costs(capital and operation related)	£130,586
Annual Production of Energy(kWhr)	2628000
Cost of Generation (p/kWhr)	4.97

We'll continue to search for more cost estimates and analysis of economic feasibility. The more information we can gather, the better our understanding of the costs associated with tidal turbines will be.

References

[1] Previsic Mirko, Polagye Brian, Bedard Roger. 2006, "System Level Design, Performance, Cost and Economic Assessment – Maine Western Passage Tidal In-Stream Power Plant." EPRI – TP – 006 – ME http://archive.epri.com/oceanenergy/attachments/streamenergy/reports/006_ME_RB_06-10-06.pdf

[2] Hagerman, George. 2006. "Tidal Stream Energy in the Bay of Fundy." Presentation to session 3, Day 2, Energy Research and Development Forum, Antigonish, Nova Scotia. http://ns.energyresearch.ca/files/George_Hagerman.pdf

[3] DTI. 2007. "Economic Viability of a Simple Tidal Stream Energy Capture Device." Project No. TP/3/ERG/6/1/15527/REP http://www.berr.gov.uk/files/file37093.pdf

[4] Bryden, I. G., Naik S., Fraenkel P., and Bullen C. R., 1998, "Matching Tidal Current Plants to Local Flow Conditions," Elsevier Science Ltd., Vol 23, No. 9, pp. 699-709. http://web.mit.edu/bepps/Public/alex/energy_papers/Bryden%201998%20E%20-%20matching%20tidal%20current%20plants%20to%20local%20flow.pdf