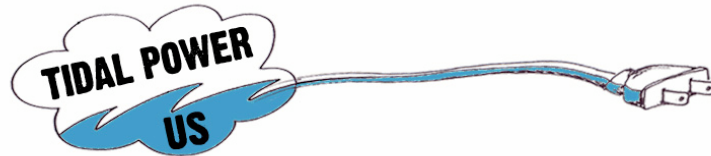


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The State of Technology

Tidal Power as an Immerging Energy Industry

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Reviewed by Elizabeth Murphy

Our Mission

“To publically present the basics: environmental, technical and economic, of the immerging and highly promising renewable energy field known as tidal power in an objective and educational manner.”

Introduction

Tidal power is rapidly becoming a feasible alternative energy resource throughout the world. With oil reaching its peak production point and climate change a looming concern, renewable energies have been pinpointed as the key future energy resource. The fantastic increases in the use of solar power, wind farms, biodiesel, and fuel cells have provided a base for growth in using “green” technologies for power generation. Recent developments have brought attention to hydrokinetic energy, which harnesses the power of moving water for electrical generation. Although there are several applications of hydrokinetic energy, this report focuses specifically on tidal power. Because tidal power is a newly emerging industry, the technology is pre-commercial and highly varied by company. As we look ahead in research and development in tidal energy, it is of utmost importance to examine the various technologies currently being designed and implemented. This report serves as an introduction to innovative hydropower and electricity generation, and features a table comparing over 25 companies currently developing tidal power. This table provides details of the company’s technology and its state of development: from conceptual design to working turbines that generate electricity!

1. Types of Hydropower

a. Conventional Hydropower

The traditional uses of hydropower utilizes the head, or vertical drop of water to generate energy and comprise traditional hydroelectric dams and “micro-hydro” using old-fashioned water wheels. Dams are essentially large concrete walls that halt the path of a river, flooding the area behind it in order to control the flow of water (see Figure 01). Within the concrete structure, turbines are usually located at the bottom so that water can flow from the top of the dam and provide enough kinetic energy to spin the turbines. The turbines spin, which turns magnets in a generator and creates an electric current.

Dams can generate huge amounts of electricity - generally referred to in megawatts - enough to power multiple cities. However, their construction is very disruptive to local habitats due to massive flooding that results from blocking the path of a river. Fish and other aquatic life can be severely damaged as well as the massive loss of land use when entire valleys are submerged. Dams currently supply almost every country on earth with electricity and more projects are built every day. Although this resource is relatively clean to operate, the effects of construction can be devastating. While dams generate electricity on a large scale, other forms of hydroelectric power can be used for smaller power loads.

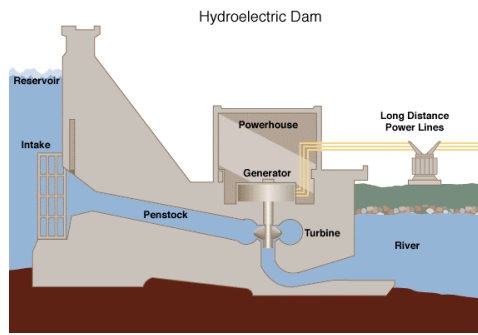


Figure 01 , Basics of a hydroelectric damⁱ

“Micro-hydropower” refers to hydroelectric power used by individual homes or communities usually generating less than 100 kW of electricity. Rushing water from a nearby stream or river provides enough force to turn old-fashioned water wheels (see Figure 02). These can then turn generators and operate machinery such equipment used in gristmills or cider presses. Micro-hydro has been used since Roman times when aqueducts and mills relied on water wheels. Since then, the most prevalent use of micro-hydro was seen in the early part of the Industrial Revolution. These days, modern applications of micro-hydro can be used to power a single home or even a small business off the grid. (A single home usually requires between 3 and 5 kW to operate).

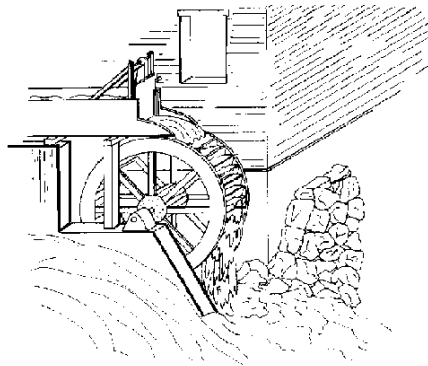


Figure 02, Example of an old-fashioned water wheel.ⁱⁱ

b. Innovative Hydropower

Recent advancements have led to the development of innovative hydropower, also known as hydrokinetic energy. Although there are various types of hydrokinetic power, wave and in-stream energy are the most developed. Wave energy harnesses the kinetic, or up and down motion of ocean waves. In-stream energy utilizes the lateral flow of water, from a river or the tides (TISEC - Tidal In-Stream Energy Conversion, or tidal power for short).

Tidal power uses turbines placed in a channel or waterway that experiences significant tidal current flow (usually exceeding 2 meters-per-second or approximately 4 knots). The regular movement of tides provides enough power to spin the turbines when used in the right location (see Figure 03). Since in-stream power generation is related to the cube of the velocity, the difference between a 2 m/s site and a 3 m/s site is about eight times the power. Turbines vary greatly in size, scale and design. The “size” usually refers to the diameter of the turbines themselves while scale refers to electrical output in kilowatts and megawatts. Turbines can either be oriented with a vertical or horizontal axis, or a completely different design such as those based on fish tails or even sails. Tidal power technology is developing at all stages with companies simply beginning to design prototypes and others with installed turbines that have been operating for over a year.

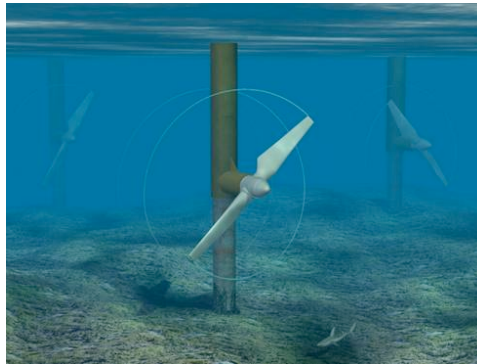


Figure 03, Example of a horizontal-axis tidal power turbine.ⁱⁱⁱ

Tidal power presents numerous advantages as a renewable source of energy. The systems are environmentally friendly, efficient, invisible, predictable, and extremely powerful. Despite these pros, the reality is that the technology is not commercialized to the extent that it needs to be. The processing for obtaining permits to test sites as well as actually install technology is long and arduous, often taking many months to complete. These are obstacles that be overcome with the help of numerous companies investigating the possibilities and building turbines as well as public awareness of the need for alternative energies. Tidal power will develop into a reliable energy source for the entire world, and the process has already started!

2. Electricity and Power^{iv}

Power is a measure of energy over time and is often expressed in Watt (W) units. 1,000 watts (W) makes up 1 kilowatt (kW) and 1,000 kilowatts (kW) or 1,000,000 watts (W) makes up 1 megawatt (MW).

Electricity is a measure of power produced for a given time and the average US household requires 13-kilowatt hours per square foot. This electric current is then transported over modern infrastructure into homes and offices, etc.

Important Equations:

$$\text{Power} = \text{Energy (Joule)} / \text{Time (sec)} = \text{J/s or Watt (W)}$$

$$\text{Electricity} = \text{Power (kW)} \times \text{Time (hours)} = \text{kilowatt hour (kWh)}$$

The power generation of a tidal turbine can be determined by using Bernoulli's Principle:

$$P \text{ (W)} = 0.5 * \eta * \rho * A * v^3$$

P (W) = power in Watts (W)

η = mechanical turbine efficiency (%/100)

ρ = density of seawater (~1000 kg/m³)

A = area swept by turbine cross-section (m²)

v = water current velocity (m/sec.)

3. Comparison of Tidal Technologies

The following table compares companies that are currently developing tidal power by their turbine name, size, scale, axis and state of development.

STATE OF TECHNOLOGY TIDAL POWER TURBINE SYSTEMS

COMPANY	LOCATION	NAME	SIZE	SCALE	AXIS	STATE OF DEVELOPMENT
Clean Currents Power Systems, Inc.	Vancouver Island, British Columbia	European Patented design	< 20 m	65 kW	Horizontal	Operating at Race Rocks Ecological Reserve since early 2006
Marine Current Turbines Ltd.	Stangford Laugh, Ireland	SeaGen	15 – 20 m	1.2 MW	Horizontal	Seagen operating in Northern Ireland, ready for commercial development
	Island of Anglesey, Wales	7 SeaGen turbines	15 – 20 m	Combined 10.5 MW	Horizontal	Tidal farm in development for 2011 commission
Tidal Generation Limited	UK	TGL Turbine	-	1 MW	Horizontal	Working on a prototype
Open Hydro	Ireland	Open-centre turbine	6 m	250 kW	Horizontal	Connected to grid May 2008
Hammerfest Strom	Norway / UK	HS1000	-	1 MW	Horizontal	Prototype 2003 Operational by 2011
Tidal Stream	UK	Tidal Stream	20 m	1 – 2 MW	Horizontal	Testing
Pulse Generation	UK	“HydroFoilS”	-	100 kW	Horizontal	Developing
Tidal Sails	Norway / UK	Tidal Sails	-	-	Sails move horizontally	Patented designs testing soon
Biopower Systems Pty Ltd	AUS	“BioStream”	20 m	250 kW, 500 kW and 1000 kW	Single point of rotation, mimics swimming	Pilot project being developed
GCK Technology	TX, USA	“Gorlov Helical Turbine”	2.5 m	5 kW	Barrel – shaped turbine with vertical axis	Testing in Maine and the Amazon River Possible project in South Korea
Greenheat Systems Ltd	Scotland	“GENTEC Venturi”	-	-	Combine wind and tidal	Project under development, pending licensing
UEK Corporation	MD, USA	Underwater Electric Kite	10 x 18 x 14 ft	90 kW	Horizontal	Testing in Chesapeake Bay
Minesto	Sweden	“Deep Green”	Confidential	Confidential	Confidential	Confidential
Tocado Tidal Energy	Holland	“Torcardo”	-	500 MW	Vertical	Commercial demonstration
Aquascientific	UK	Confidential	Confidential	Confidential	Confidential	Confidential

Hydro Green Energy	TX, USA	HTA	12 ft	250 kW per unit	Horizontal	Developing prototype
Verdant	USA	RITE project CORE project	16 ft	24 kW 15 MW	Horizontal	Installed in NYC East River, redesigning Planned for operation in St. Lawrence River
Ocean Renewable Power Company	Delaware, USA	Tidal TGU	10 ft	250 kW	Vertical	Preliminary permits acquired for 2 sites in Maine, 1 site in Alaska and 6 sites in Florida
Lunar Energy	UK	Rotech Tidal Turbine (RTT)	-	1 MW array of 100 – 500 units	Horizontal	Planned to be operational in 2011
Natural Currents	USA	“RedHawk”	3.2 m	25 kW	Vertical	Proprietary / In Design
Oceana	USA	Confidential	Confidential	Confidential	Confidential	Confidential
Atlantis Resources Corporation	SG	Nereus II Solon	< 25 m -	400 kW 500 kW	Horizontal Horizontal	Successfully tested in July 2008 Successfully tested in August 2008
Blue Energy International	CAN	Dalupiri Ocean Power Plant	-	2200 MW	Vertical	Build Own Operate Transfer project
Voith Siemens	Germany	Kaplan Turbine	9.5 m	N/A	Vertical	Producing turbines
Voith Siemens	Germany	Pelton Turbine	2400 mm	N/A	Vertical	Testing
Voith Siemens	Germany	Francis Turbine	N/A	N/A	Vertical	In service
Voith Siemens	Germany	Pump-turbine	50 – 800 m	10 – 800 MW	Vertical	Successful testing completed
Voith Siemens	Germany	Bulb/Pit/S Turbine	800– 8400 mm	50 – 50,000 kW	Horizontal	In service world wide since 1955

ⁱ http://www.madphysics.com/ask/dam/Hydroelectric_dam.gif

ⁱⁱ <http://www.historical-archives.com/pics1/Overshot-WaterWheel-1a.bmp>

ⁱⁱⁱ http://www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/Tidal%20power%20files/image016.jpg

^{iv} Murphy, E. 2008. Model to Assess a Hydroelectric Tidal Power Site: Physical Site Evaluation, Policy and Economics.