Hydropower and Its Use at Public Water Systems in Massachusetts

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I. Hydropower

Hydropower is the dominant form of renewable energy available in the U.S. today and an essential component of our electrical infrastructure. Hydropower uses the energy of flowing water to power mechanical systems, such as a mill for grinding grain or to spin a turbine/generator assemblage and create an electric current[3]. The term hydropower is often used to refer to both hydroelectric (uses a change in elevation in the water flow) and hydrokinetic (uses flow and/or currents without a flow elevation change) power systems. In both systems, the energy in flowing water causes a turbine to spin. The turbine is connected to a generator which also begins to spin, creating an electric current[3]. Hydroelectric and hydrokinetic power differs in their site requirements.

(a). Hydroelectric Power (Uses Flow and Head)

The majority of hydropower in the U.S. is produced at hydroelectric power plants. There are two major requirements for a site to be considered for hydroelectric power production. First, the site must have a water source that is elevated above the turbine. The elevation creates potential energy and is referred to as the "head" of the system. Second, the water must be able to travel down from the reservoir with enough speed and pressure to cause the turbine to spin; this kinetic energy is referred to as the "flow."

The three main types of hydroelectric power systems consist of:

Impoundment systems: water is blockaded behind a dam and then funneled through a channel or penstock to a turbine and generator.

Pumped storage systems: water is pumped up to a reservoir during periods of low electricity demand and then directed from the reservoir to the turbine during periods of high electricity demand.

Diversion systems: or "run of the river" systems, a portion of the water in a river is diverted temporarily to flow through a turbine but is returned to the river after electricity has been generated.

The two main types of turbines that are used in hydroelectric systems are:

Impulse turbines: Water causes impulse turbines to spin by striking individual buckets or curved vanes on a wheel. Impulse turbines work best in high head and low flow situations and common types include the Pelton turbine and the Turgo turbine.

Reaction turbines: resemble propellers and are commonly used in wastewater and drinking water hydropower installations because they operate in the low head and heavy flow conditions found at those sites. Reaction turbines are placed directly in the water stream and spin as water flows through them across a pressure drop. Common types include Kaplan, Francis, Deriaz, and Propeller[5].

Hydropower plants are often categorized by their maximum electricity production capacity, rated in kilowatts (kW) and megawatts (MW). The three official categories of hydroelectric power plants, as defined by the US Department of Energy (DOE), are:

Large Hydro: 30 or more MW
Small Hydro: 100 kW to 30 MW
Micro Hydro: less than 100 kW[2].

(b.) Hydrokinetic Power (Uses Flow)

While hydroelectric power production requires both head and flow, hydrokinetic turbines are able to produce electricity from flow alone. Sometimes called "free-flow turbines," Hydrokinetic turbines do not need to be situated below an elevation change or to divert water away from bodies of water. Hydrokinetic turbines can be installed in flowing rivers, channels, or ocean currents. Hydrokinetic technologies are rapidly evolving and several projects are set to be installed across the U.S. in the coming years[6].

Web link -> Hydrokinetics Power Systems in Massachusetts

Predictions regarding the annual electricity production and the amount of time it will take for any chosen system to pay for itself vary with the actual electrical output of that particular facility. The capacity rated for a given hydropower system is generally the maximum amount of electricity the facility can produce when factors such as water flow and temperature are optimal. In fewer cases, both the maximum capacity and the actual capacity are available for existing and proposed systems. Most facilities operate below their maximum capacity, especially during seasons that are dry or have below freezing temperatures.

II. Hydroelectric Power at Public Drinking Water and Wastewater Facilities in Massachusetts

Public water facilities, such as drinking water and wastewater treatment plants, are well suited for hydroelectric installations because they may already have the two major site requirements: head and flow. Most of the hydropower installations at public water systems in Massachusetts are within the micro hydropower size category. In Massachusetts, there are currently less than twenty facilities known to be operating or developing hydropower. Three of these sites are part of the MassDEP Energy Pilot Program[7,8].

These installations produce enough electricity to cover a large portion of the public water facility's electricity needs and thus substantially lower the amount of electricity that must be bought from utility companies through the grid. Rather than generate revenue for the facility, onsite production of electricity off-sets annual spending on electricity. According to a survey of drinking water and waste water facilities in Massachusetts, most hydroelectric systems should pay-back their installation costs within one or two decades. Facilities that produce more electricity than they use onsite can receive creditfor their excess electricity from their utility company in a process called Net Metering (described in "Incentives and Support). In this case, the turbine must be connected to the electrical grid through transmission lines.

Process & Regulations

There are many factors beyond head and flow to consider when deciding whether or not to pursue the installation of hydroelectric power at a public water facility. A sampling of these considerations includes:

- ☐ **Is there a need for electricity onsite or in the surrounding area?**
- ☐ **Would the electricity be used efficiently, or would a free energy audit by a utility company show that there are other ways to reduce electricity usage?**
- ☐ **Would a hydroelectric installation have a positive, negative, or negligible effect on the**

water quality and quantity at the public water facility?

- ☐ **Would a hydroelectric installation have a positive, negative or negligible effect on the ecosystem surrounding the public water facility?**
- ☐ **Would the site comply with environmental regulations surrounding hydroelectric power installations?**
- ☐ **Are there financial incentives available to reduce the cost to the public water facility and the payback period for the project?**

After consideration of the points above, one would have to determine feasibility and regulations around installing hydropower at the site. All modifications to drinking water facilities must be approved by MassDEP. However, since the turbines would be installed within the drinking water or wastewater system, the project is not likely to require additional permits from the Wetlands Act or FERC.

III. Hydrokinetic Power

Since hydrokinetic turbines only require flow to produce electricity, they are suitable for a wide variety of situations. Research is currently being conducted across the country into various kinds of hydrokinetic power, including wave attenuators, tidal projects, and river systems. The U. S. Department of Energy recently created a database of hydrokinetic projects, http://www1.eere.energy.gov/windandhydro/hydrokinetic/default.aspx . The first commercial hydrokinetic project in the U.S. was completed in January of 2009 in Minnesota by the Hydro Green Energy, LLC[9]. Several projects have received preliminary permits from the Federal Energy Regulatory Commission (FERC). Most of these projects are along the Mississippi and Missouri Rivers, the Northwestern coast, and the New England coast[10].

In Massachusetts, three hydrokinetic power projects have received FERC preliminary. These projects include two by the Natural Currents Energy Ser, LLC., one in the Cape Cod Canal and one near Cuttyhunk/Elizabeth Islands, and a project by the Town of Edgarton in Nantucket Sound[11].A complete list of projects that have received preliminary permits can be found under "Hydropower-Hydrokinetics" on the FERC website at http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp.

Process and Regulations

As with hydroelectric power, there are many aspects to consider before installing hydrokinetic turbines and the associated supports and transmission lines. In addition to the points listed above, the special considerations for flowing waters include:

- ☐ **Would installing hydrokinetic turbines have an impact on human use of the water for recreation, transportation, or fishing?**
- ☐ **Would installing hydrokinetic turbines have an effect on organisms within the local ecosystem, such as migrating fish or fish that may be caught in the turbine?**

The regulations pertinent to turbines that will be installed in flowing water and wetlands are more involved than those for turbines installed in existing pipes (as described above, under hydroelectric power). The siting of hydrokinetic facilities in Massachusetts' offshore waters is subject to the provisions of the Massachusetts Ocean Plan (available online at www.mass.gov/envir), administered by the Secretary of the Executive Office of Energy and Environmental Affairs (EEA). The Secretary's office should be consulted for pre-application guidance for any project subject to the Ocean Plan proponent seeking to site a facility. The local conservation commission administers the state's Wetlands Protection Act regulations at 310 CMR 10.00. Early consultation with MassDEP is also recommended to discuss the requirements of the 401 Water Quality Certification regulations at 314 CMR 9.00, the c. 91 regulations at 310 CMR 9.00, and possibly the Massachusetts Water Management Act[12].The initial formal review of the project's compliance with state environmental requirements may come under the Massachusetts Environmental Policy Act (MEPA), administered by the EEA The federal Clean Water Act (33 U.S.C. 1251) regulates dredging and filling under Sections 401 and 404 and is administered by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. The Federal Energy Regulatory Commission (FERC) also regulates hydrokinetic energy projects at the national level and requires environmental impact assessments and licenses, with some exemptions for smaller installations at existing facilities[14].

IV. More Information and Financial Incentives

There are many financial incentives available for the development and operation of hydroelectric power within Massachusetts. National agencies, such as the Department of Energy and EPA, and state agencies, such as the

Massachusetts Clean Energy Center (MassCeC), offer grants and loans for the construction of new hydropower facilities. Complete listings are available on several online databases, including the Database for State Incentives for Renewable Energy (www.dsireusa.org)[15] and the Office of Energy Efficiency and Renewable Energy (www.eere.energy.gov/). Some of the informative websites, databases, and incentives are listed below.

Federal Resources and Financial Incentives

- ☐ **Hydropower technologies**, visit the "Wind and Hydropower Technologies Program" site of the Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy, at www.eere.energy.gov.
- ☐ **Energy Information Association of the U.S. Department of Energy** has information on the use of energy, electricity, and hydropower in the U.S. at www.eia.doe.gov/.
- ☐ **Environmental Protection Agency's "Water" website** has information on federal water programs and regulations at www.epa.gov/water .
- ☐ **REC (Renewable Energy Certificates):** Micro-hydro facilities may be able to earn extra revenue for their renewable energy through RECs. The revenue comes from the premium some consumers will pay in order to claim the renewable energy component of all of the energy within the grid. Renewable energy generators are typically paid a few cents per kilowatt-hour by their utility. More information can be found on the EPA website at http://www.epa.gov/grnpower/gpmarket/rec.htm.
- ☐ **CREB (Clean Renewable Energy Bonds):** Interest free loans in the form of tax credit bonds are available for renewable energy projects, as established by the Energy Policy Act of 2005. These bonds can be issued by public power systems and electric cooperatives. A complete description of CREB can be found at http://www.house.gov/jct/x-60-05.pdf.
- ☐ **Renewable Energy Production Credit** has incentive for the production of renewaqble energy from waste. Visit http://www.epa.gov/osw//hazard/wastemin/minimize/energyrec/rpsinc.htm.

The United States Geological Survey keeps a record of flow rates in rivers across the country which can be accessed through the USGS website, http://waterdata.usgs.gov/ma/nwis/current/?type=flow.

Massachusetts Based Resources and Financial Incentives

- ☐ **MassDEP** water programs and regulations, at http://www.mass.gov/dep/water/
- ☐ **MassDEP Energy Management Pilot Program** with energy projects at drinking water and wastewater facilities in Massachusetts, at http://www.mass.gov/dep/water/wastewater/empilot.htm.
- ☐ **MassCeC (Massachusetts Clean Energy Center)**: A public agency that assists the development of the innovation sector of the state's economy and renewable energy projects. Many different grants are available for renewable energy projects at various stages—from the feasibility study to the design and construction phase. Funding comes from the John Adams Innovation Institute and the Renewable Energy Trust. The **Large Onsite Renewables Initiative (LORI)** grant is particularly applicable to micro-hydro projects. For more information visit the MassCeC website: http://www.masscec.com.
- ☐ **The State Revolving Loan Fund** provides low interest loans for drinking water and wastewater facility projects. Visit http://www.mass.gov/dep/water/wastewater/wastewat.htm
- ☐ **Renewable Energy Trust and Greenhouse Gas Emission Credits**, visit http://www.mass.gov/dep/energy.htm.

Commercial Incentives and Support

- ☐ **Net Metering:** A system that allows operators of renewable energy facilities to receive credit from their utility company for the excess electricity they produce. In most cases the credit is paid per kWh at market rates and carries over from moth to month over one billing year. The Massachusetts Department of Public Utilities differentiates actual policies on net metering by type (public, private, residential, etc.) and size class. Class I is less than 60kW, Class II is between 60kW and 1MW, and Class III is between 1 MW and 2MW. All public electric utilities are now required by the Energy Policy Act of 2005 to have net metering available upon request.

- **Energy Audits:** Most electricity providers and utility companies are capable of providing energy audits. The audit shows how electricity is being used onsite and ways to reduce energy consumption.

More information is available on the Database for State Incentives for Renewables and Efficiency website, http://www.dsireusa.org/index.cfm?EE=0&RE=1.

V. Hydropower Technical and Professional Associations

Hydropower Research Foundation

"The Hydro Research Foundation, Inc. [HRF] was established in 1994 and became an independent 501 (c) (3) non-profit corporation in 1996. The foundation has two principal objectives: to facilitate research and to promote educational opportunities that communicate the value of hydropower…

"The HRF was formed to build support for, and facilitate partnerships among industry, government and others for projects that would preserve and enhance the viability of hydropower as a clean, renewable and reliable provider of energy."

("HRF History and Mission." *www.hydrofoundation.org*. Hydro Research Foundation.)

Contact: HRF, One Massachusetts Ave NW, Suite 850, Washington D.C., 20001

An email contact form is available on the HRF website under "Contact Us."

International Hydropower Association

"The International Hydropower Association (IHA) addresses the role of hydropower in meeting the world's growing water and energy needs as a clean, renewable and sustainable technology. With members in more than 80 countries, IHA is a non-governmental, mutual association of organisations and individuals. Its membership is open to all those involved in hydropower.

("About IHA: Introduction." *www.hydropower.org*. International Hydropower Association. 2005)

Contact: IHA, Nine Sutton Court Road, Sutton, London, SM1 4SZ, United Kingdom

Phone: (44) 208 652-5290

Email: iha@hydropower.org

National Hydropower Association

"Founded in 1983, NHA represents 61percent of domestic, non-federal hydroelectric capacity and nearly 80,000 megawatts overall in North America. Its membership consists of more than 140 organizations including public utilities, investor owned utilities, independent power producers, equipment manufacturers, environmental and engineering consultants and attorneys."

("Who We Are." *www.hydro.org* National Hydropower Association, 2006)

Contact: NHA, 25 Massachusetts Ave., NW, Suite 450, Washington, DC 20001

Phone: 202-682-9478

Email: help@hydro.org

Northeast Sustainable Energy Association

"The Northeast Sustainable Energy Association (NESEA) is the nation's leading regional membership organization promoting sustainable energy solutions….For more than thirty years, NESEA has supported and inspired a growing network of professionals and sustainable energy advocates committed to responsible energy use. NESEA is committed to advancing three core elements: sustainable solutions, proven results and cutting-edge development in the field."

("About NESEA." *www.NESEA.org*. Northeast Sustainable Energy Association. 2007)

Contact: NESEA, 50 Miles Street Greenfield, MA 01301

Phone: 413-774-6051

Email: nesea@nesea.org

PennWell Hydro Group

"PennWell Corporation is a diversified business-to-business media and information company that provides quality content and integrated marketing solutions for the following industries: Oil and gas, electric power, water and wastewater, renewable, electronics, semiconductor, contamination control, optoelectronics, fiberoptics, enterprise storage, converting, nanotechnology, fire, emergency services and dental. Founded in 1910, PennWell publishes over 100 print and online magazines and newsletters, conducts 60 conferences and exhibitions on six continents, and has an extensive offering of books, maps, web sites, research and database services. In addition to PennWell's headquarters in Tulsa, Oklahoma the Company has major offices in Nashua, New Hampshire; Houston, Texas; London, England; Mountain View, California; Fairlawn, New Jersey, Moscow, Russia, and Hong Kong, China."

("HydroGroup: About PennWell." *www.hcipub.com*. PennWell Hydro Group. 2009)

Contact: PennWell Hydro Group, 410 Archibald Street, Kansas City, Mo 64111 USA

Phone: 816-931-1311

US Hydropower

"**US Hydropower** is a trade association representing hydropower issues in the global market. The organization is a member run council with industry leaders working to provide input to global hydropower development strategies. US Hydropower provides a point of contact for the U.S. and foreign governments reaching out to the U.S. hydropower industry."

("Additional Resources." *www.hcipub.com*. PennWell Hydro Group. 2009)

Phone: 202-251-5577

Email: debbys@us-hydropower.org

VI. Definitions and Information.[16]

- Btu (British thermal unit): The amount of heat it takes to raise one pound of water at 39 degrees Fahrenheit by one degree.
- Capacity: The maximum amount of electricity that a micro-turbine can supply, usually given in Kilowatts or Megawatts.
- cfs (cubic feet per second): A measurement used to describe the flow rate of moving water.
- Head: The elevation difference between the water source and the turbine (also taking the weight of the water into account). An indication of the potential energy stored in the elevated water. Head is often measured either in feet or with a pressure gauge in psi (pounds per square inch).
- Net Head: The head available to a turbine after losses due to friction and other factors have been subtracted from the gross head.
- kW (Kilowatt): A unit of electrical power equivalent to 1,000 watts (1.34 horsepower)

- ☐ kWh (Kilowatt-hour): The amount of electrical energy supplied over one hour by one kilowatt of power—the same as 3,412 Btu. As a point of comparison, the Energy Information Administration cites the average U.S. household use of electricity as 936 kWh in 2007.
- ☐ Micro-hydro: hydroelectric installations that are generally below 100 kW in capacity and do not significantly disrupt the surrounding water flow.
- ☐ Psi (pounds per square inch): A measurement used to describe the flow rate of moving water, based on pressure.
- ☐ Turbine: Converts mechanical energy into electrical energy in conjunction with a generator. The primary types are impulse or reaction turbines.

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[2] “Types of Hydropower Plants.” *EERE.energy.gov*.Office of Energy Efficiency and Renewable Energy, US DOE. 8 Sept. 2005. Web. 20 July 2009.

[3] “How Hydropower Works.” *Eere.energy.gov.* Office of Energy Efficiency and Renewable Energy, US DOE. 30 Aug. 2005. Web. 20 July. 2009.

[4] “Glossary of Hydro Power Terms.” Eere.energy.gov. Office of Energy Efficiency and Renewable Energy, U.S. DOE. 10 March. 2005. Web 20 July. 2009.

[5] “Types of Hydropower Turbines.” Office of Energy Efficiency and Renewable Energy. US DOE, 8 Sept. 2005. Web. 20 July. 2009. < http://www1.eere.energy.gov>.

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[7]Sargent, Kira (Intern, MassDEP). *Hydroelectric Power in Massachusetts*. Document developed for this report. July 20 2009.

[8] “Water, Wastewater, and Wetlands: Massachusetts Energy Management Pilot.” *Mass.gov/DEP.* Massachusetts Department of Environmental Protection. n.d. Web. 20 July 2009.

[9] “First Commercial Hydrokinetic Power Turbine Installed; DOE Unveils Hydropower Database.” *RenewableEnergyWorld.com.* Renwable Energy World. 6 Jan 2009. Web. July 2009.

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[11] “Issued Hydrokinetic Projects Preliminary Permits.” FERC.gov. Federal Energy Regulatory Commission. 6 Aug. 2009. Web. 6 Aug. 2009.

[12] “Water, Wastewater, and Wetlands: Regulations and Standards.” *Mass.gov/DEP.* Massachusetts Department of Environmental Protection. n.d. Web. 20 July 2009

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[14] “Hydropower.” *FERC.gov*. Federal Energy Regulatory Commission. 8 July 2009. Web. 20 July 2009.

[15] "Massachusetts: Incentives/Policies for Renewable Energy." *DSIRUSAE.org*. Database of State incentives for Renewable Energy. N.C. Solar Center/ N.C. State University. 2009. Web 20 July 2009.

[16] References for "Definitions":
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"Impulse turbine." Encyclopædia Britannica. 2009. Encyclopædia Britannica Online. 03 Jul. 2009 <http://www.britannica.com/EBchecked/topic/492767/reaction-turbine>.
"Micro-hydro." The Ashden Awards for Sustainable Energy. 2008. Ashden Awards Onlin. 03 Jul. 2009 <http://www.ashdenawards.org/micro-hydro>