

Washington University in St. Louis

Environmental Studies Program

**Supporting Renewable Energy:
Lessons from the Deer Island Treatment Plant**

By

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Abstract

The United States is increasingly choosing to replace fossil fuels with renewable energy sources. Among the factors driving people to preemptively seek out different sources of energy are fears about a reliance on fossil-fuel imports, resource depletion, and anthropogenic climate-change. Developing renewable energy requires the creation of specific technologies, organizational structures, and financial incentives. This thesis analyzes the successes the Massachusetts Water Resource Authority (MWRA) has had installing renewable energy technologies at the Deer Island Treatment Plant (DITP). DITP, a wastewater treatment plant in Boston, Massachusetts, is an example of a large facility that has been able to generate over one fourth of its energy onsite from renewable sources. Understanding which structures have been successful at DITP will aid the development of a strategy for organizations in the future.

DITP was built as the centerpiece of the Boston Harbor Project (BHP), a multi-billion dollar project designed to bring Boston Harbor into compliance with national water quality standards. Technological, political, and financial factors led to the installation of renewable energy technologies at DITP. The court-ordered restructuring of the Metropolitan District Commission into the MWRA gave the organizational freedom necessary for long-term planning and fundraising. Anaerobic Digester Gas and Hydropower technologies were integrated into the facility itself, so the Boston Harbor Project subsumed their costs. Later, solar PV and wind turbines were funded largely by state renewable energy programs. Renewable Portfolio Standards, low-interest loans, and the Renewable Energy Trust helped overcome the unfavorable pay-back periods. The MWRA also benefited from policies that mandated certain goals for greenhouse gas reduction, renewable energy research, and the ‘green’ jobs.

The DITP indicates several useful points for other organizations interested in promoting renewable energy. Briefly stated, these include: integrating renewable energy into existing operations and new projects, outlining the variety of benefits of renewable energy, prioritizing renewable energy goals, creating the organizational and financial flexibility for long-term planning, and building upon past successes. As the case of DITP shows, there are many opportunities to reduce fossil fuels usage, but implementing renewable energy and energy efficiency technologies takes resources, long-term planning, and innovation.

Acknowledgments

This thesis would not have been possible without the support of several thoughtful and generous individuals. Foremost among those is my advisor, Professor Jill Pasteris, who has provided tremendous insight and guidance on a variety of topics, both within and outside of the realm of renewable energy. Two champions of renewable energy in Massachusetts, Douglas Fine and Kristen Patneau, also donated invaluable knowledge and time to my endeavor. In addition, I would like to extend my appreciation to all of those individuals, both in Massachusetts and across the globe, who develop more sustainable energy systems. Their efforts will benefit society for generations to come.

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Common Abbreviations

ADG	Anaerobic Digester Gas
ARRA	American Recovery and Reinvestment Act
BHP	Boston Harbor Project
cfs	Cubic feet of water per second (rate of flow)
CHP	Combined Heat and Power system
CREB	Clean Renewable Energy Bond
DITP	Deer Island Treatment Plant
DOER	Massachusetts Department of Energy Resources
EOEEA	Executive Office of Environmental and Energy Affairs of Massachusetts
EPA	United States Environmental Protection Agency
MassDEP	Massachusetts Department of Environmental Protection
MGD	Millions of Gallons of water per day (rate of flow)
MDC	Metropolitan District Commission
MWRA	Massachusetts Water Resource Authority
psi	Pounds per square inch (unit of pressure)
POTW	Publically Owned Treatment Works
REC	Renewable Energy Certificate/Credit
RPS	Renewable Portfolio Standard
SEP	Supplemental Environmental Project
SODAR	Sonic Detection and Ranging
SRF	State Revolving Fund of Massachusetts
STG	Steam Turbine Generator
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Renewable Energy Trends in the United States

As a country, the U.S. is increasingly replacing fossil fuels with renewable energy sources. Society faces the challenge of developing the technologies, organizational structures, and financial incentives to promote renewable energy (Committee on America's Energy Future 2009; Boyle 2004). In order to identify which technologies, structures, and incentives may be successful in the future, it is important to look at those that have been successful in the past. This understanding will help aid the evaluation of the extent to which implementing a certain strategy will be successful within a new context. The Deer Island Treatment Plant (DITP), a wastewater treatment plant in Boston, Massachusetts, is an example of a large facility that has been able to generate over one fourth of its energy onsite from renewable sources. DITP is simultaneously one of the largest energy users in New England and an example of the on-site production of renewable energy (Massachusetts Water Resource Authority 2009; Office of Governor Deval Patrick 2009). DITP exemplifies how the integration¹ of environmental energy issues can occur on both technological and ideological levels. On a technical level, processes traditionally used for environmental protection have been redesigned to produce renewable energy—namely anaerobic digestion and wastewater outflow. On an ideological level, the MWRA used a facility designed for environmental protection purposes to showcase renewable energy. At DITP the technical and ideological level of integration successfully build upon each other. Understanding

¹ The phrase *renewable energy integration* is used in this paper to refer to both the technological integration into the physical processes of a facility and the ideological integration into conceptions of environmental protection. Similar phrases previously have been used to describe the integration of renewable energy into the existing electricity market, as in the Department of Energy's Renewable and Distributed Systems Integration Program (RDSI).

the factors leading to the success of renewable energy at DITP will help to develop our understanding of a successful framework for implementing renewable energy.

Several factors have caused some people to preemptively seek out sources of non-fossil fuel energy. First, the global resources of oil and coal are limited in scope. It is expected that we have already seen or are experiencing the peak of oil extraction. With this in mind, it is expected that fossil fuels will become increasingly expensive to continue to recover and use as major fuel sources. Next, due to the geographic distribution of fossil fuel reserves, certain countries control the extraction and distribution of fossil fuels. For countries without fossil fuel resources, finding alternative energy sources is seen as a matter of national autonomy and, potentially, of national security. In a similar way, some facilities find that it is more economical to produce renewable energy onsite than to rely on fossil-fuel-based energy. Additionally, the handling and burning of fossil fuels are known to emit certain gases that affect the climate and air quality, including carbon dioxide, sulfur dioxide, and nitrogen oxides. Concerns about anthropogenic climate change have prompted social and political support for alternative energy, for example, in the United Nations Climate Change Conferences. Several countries are in the process of increasing their use of renewable and alternative energy sources, in order to maintain energy supplies while addressing all of these concerns (Boyle 2004).

Renewable energy sources are generally considered to be those that are replaceable on a human time scale and that have manageable environmental impacts (Boyle 2004). The conventional classification system for renewable energy is by source: solar, biomass, water, and wind (Energy Information Administration 2009b). Energy coming directly from the sun can be captured passively for its thermal properties, such as via water tanks, or actively for electricity, as with photovoltaic cells. Energy from biomass comes from vegetation, solid wastes, and the

gases they produce during decomposition. Biomass and produced gases are burned for heat, which in turn may be used to make electricity in conjunction with a turbine and generator. The physical energy in the flow of water and wind powers turbines, creating electricity. Finally, the heat from the decay of radioactive elements in the earth heats subterranean gases and liquids, which are tapped for heat and electricity production. The diverse renewable energy sources are harnessed through a variety of different technologies, both ancient and innovative (Boyle 2004; Energy Information Administration 2009b).

Within the United States there has been an increase in renewable energy production and consumption in recent years. As shown in Table 1, fossil fuels served as the source of 83.4% of the energy used in the United States in 2008, the most recent year for which the Energy

Energy Consumption in the United States from 2004-2008						
<i>(Listed by Source, in Quadribillion BTUs)</i>						
Energy Source	2004	2005	2006	2007	2008	% Change from 2004 to 2008
Total	100.349	100.485	99.876	101.552	99.305	-1.0
Fossil Fuels	85.830	85.817	84.690	86.174	83.436	-2.8
Coal	22.466	22.797	22.447	22.748	22.421	-0.2
Coal Coke Net Imports	0.137	0.045	0.061	0.025	0.040	-70.8
Natural Gas¹	22.931	22.583	22.224	23.628	23.838	4.0
Petroleum²	40.294	40.393	39.958	39.773	37.137	-7.8
Electricity Net Imports	0.039	0.084	0.063	0.106	0.113	189.7
Nuclear Electric Power	8.222	8.160	8.214	8.458	8.455	2.8
Renewable Energy	6.260	6.423	6.909	6.814	7.301	16.6
Biomass³	3.023	3.133	3.361	3.597	3.884	28.5
Biofuels	0.513	0.594	0.795	1.025	1.413	175.4
Waste	0.389	0.403	0.414	0.430	0.431	10.8
Wood Derived Fuels	2.121	2.136	2.152	2.142	2.041	-3.8
Geothermal Energy	0.341	0.343	0.343	0.349	0.358	5.0
Hydroelectric Conventional	2.690	2.703	2.869	2.446	2.453	-8.8
Solar/PV Energy	0.065	0.066	0.072	0.081	0.091	40.0
Wind Energy	0.142	0.178	0.264	0.341	0.514	262.0

Table 1. *Energy Consumption in the United States in 2004-2008*. This chart shows that over the years from 2004 to 2008 the total energy consumption in the United States decreased by roughly 1%, from 100.3 to 99.3 quadribillion BTUs. The consumption of electricity produced by fossil fuels fell by 2.8% while the consumption of energy from renewable sources grew by 16.6% (source: 67 Energy Information Administration 2009). Highlighting and final column added by author

Information Administration of the U.S. Department of Energy has data. In the same year, renewable sources constituted 7.3% of energy consumption. Nuclear power and electricity imports account for the rest of the consumed energy. Over the past five years the total energy consumption in the United States has decreased by 1%, with a 2.8% decrease in energy derived from fossil fuels. Despite the overall decrease in American energy consumption, renewable energy consumption grew by 16.6%. The sources that were increasingly consumed were wind energy, solar and solar photovoltaic, biomass (including biofuels and waste), and geothermal energy. Two sources of renewable energy decreased, namely wood-derived fuels and conventional hydroelectric. Overall, the two major sources of renewable energy were biomass and conventional hydroelectric. The trend over the past five years has been an increase in renewable energy from biomass, wind, and solar sources.

1.2 Energy and Environmental Protection in Massachusetts

Within the Commonwealth of Massachusetts, the growing concern about anthropogenic global warming has pushed energy production into the sphere of environmental protection. In the 2000s, Massachusetts recognized greenhouse gases as pollutants within the Massachusetts Environmental Policy Act². The Commonwealth also collaborated with several states, cities, and organizations to challenge the government to recognize greenhouse gases as pollutants in *Massachusetts v. the Environmental Protection Agency*³. By recognizing that greenhouse gases are likely to cause sea level rise, the Supreme Court's decision acknowledged a causal link between energy consumption and environmental threats. During the same time period, Massachusetts worked to initiate two programs that explicitly address reducing fossil fuel use in

² *Massachusetts Environmental Protection Act*, 301 CMR Executive Office of Environmental and Energy Affairs, 11.0 MEPA Regulations, pp 75-111 (2008)

³ *Massachusetts v. EPA, Bd.*, 549 U.S. 497 (2007)

order to slow global warming— the Regional Greenhouse Gas Initiative (a regional cap-and-trade system) and the Global Warming Solutions Act⁴. The Regional Greenhouse Gas Initiative is a cap-and-trade system for greenhouse gas emissions at large facilities within New England (Regional Greenhouse Gas Initiative 2008). The Global Warming Solutions Act requires Massachusetts to both reduce greenhouse gas emissions by 80% by 2050 and to develop strategies for adaptation to potential climate changes (Office of Governor Deval L. Patrick 2008).

In order to increase renewable energy production and consumption, Massachusetts has instituted several mandatory and voluntary initiatives. Massachusetts is one of twenty-four states to require electricity providers to use renewable energy sources through Renewable Portfolio Standards (Office of Energy Efficiency and Renewable Energy 2009, 1). This program has the added benefit of generating revenue for renewable energy suppliers, who can sell electricity as Renewable Energy Credits to electricity providers. Another initiative is the Green Communities Act, which increases renewable energy funding and net metering programs. Massachusetts also encourages voluntary development of renewable energy through grant and funding opportunities. In particular, a substantial number of renewable energy projects have received funding from the Massachusetts Renewable Energy Trust operated by the Massachusetts Technology Collaborative, the State Revolving Loan Fund, and state and federal tax breaks.

In addition to these mandates and incentives, the structure of the Massachusetts government is beginning to reflect an integration of environmental protection and energy issues. In Massachusetts, the Department of Energy Resources (DOER) and the Department of Environmental Protection (MassDEP) are both housed within the Executive Office of

⁴ *An Act Global Warming Solutions Act of 2007*, Massachusetts Senate No. 534, Chapter 298 of the Acts of 2008

Environmental and Energy Affairs (EOEEA). By combining environmental protection and energy affairs in one office at the state level, the EOEEA is unique among state governments (Executive Office of Environmental and Energy Affairs 2010). The EEOA also includes the Departments of Conservation and Recreation, Food and Agriculture, Fish and Game, Public Utilities, and the State Reclamation Board. Similar integration may be seen at the federal level, as in the Energy Star Program which is run by both the Department of Energy and the Environmental Protection Agency.

1.3 The Deer Island Treatment Plant as an Example of Renewable Energy Integration

The Deer Island Treatment Plant (DITP) exemplifies the integration of environmental protection and energy concerns. The DITP produces 26% of its energy needs on site, more than three times the national average of 7.3% for all sectors (Office of Governor Deval Patrick 2009; Energy Information Administration 2009b). At the same time, DITP is the core facility of the Boston Harbor Project (BHP), which has been internationally recognized as an environmental success. Prior to the BHP, Boston Harbor was in noncompliance with the Clean Water Act Amendments. High levels of pollution prompted two lawsuits, one from the United States

Environmental Protection Agency (EPA) and the other from the local town of Quincy, against the Metropolitan District Commission (MDC), the agency in charge of the



Figure 1. The Deer Island Treatment Plant, view looking west. Note the white egg-shaped anaerobic digesters in the forefront (MWRA.com 2009).

wastewater system. As a result of the lawsuits, the MDC was reorganized into the Massachusetts Water Resource Authority (MWRA) and the Boston Harbor Project took form. The Deer Island Treatment Plant, shown in Figure 1, was the centerpiece of the multi-billion dollar Boston Harbor Project, which also included a nine-mile outflow tunnel, management of combined sewer overflows, and numerous pieces of infrastructure throughout Boston and the harbor (Massachusetts Water Resource Authority 2009; Dolin 2004).

When the Boston Harbor Project began, the MWRA did not explicitly cite the need for renewable energy. However, during the two decades of its development, the DITP incorporated renewable technologies and has been involved in numerous public renewable energy programs (Massachusetts Water Resource Authority 2009; Dolin 2004). Several factors contributed to the integration of renewable energy at DITP. For example, the fact that the MWRA is an authority, not a government agency, is significant. As an authority, the MWRA controls its financial operations, staffing, and executive decisions without strong oversight by the state government. Being an authority allowed the MWRA to raise capital and hire experienced staff as a private business would. Yet, as the primary water distribution and treatment authority, the MWRA has been eligible for substantial federal funding and has the guaranteed patronage of citizens within its areas of control. Also, since energy costs are a large portion of DITP's operational cost, the MWRA has a significant financial incentive to develop renewable energy onsite. DITP also has access to multiple sources of Renewable Energy, including biomass and hydropower within the facility, and solar and wind power onsite. In addition, DITP benefited from developments in renewable energy technologies, such as egg-shaped digesters and solar photovoltaic cells. Concurrently, increasing concerns about the environment led to state requirements and support for renewable energy production, as in the Renewable Portfolio Standards.

This paper will analyze the factors that have allowed renewable energy to be integrated into the DITP. First, it will cover the genesis of the DITP, and the development and implementation of the renewable energy systems, in order to show how they fit into the context of DITP. Next, the paper will go through the political structures and financial incentives that influenced renewable energy at DITP. Then, these two sections will be analyzed together in order to draw conclusions about which factors were most important for renewable energy development. Finally, a conclusion section extrapolates from DITP to propose recommendations for other organizations, including the United States federal government.

Analyses in this document are based on information found in several different types of sources. Documents produced by the Massachusetts Water Resource Authority, the Commonwealth of Massachusetts, and the United State Federal Government have been particularly informative. Government reports and websites provide extensive data about specific facilities, states, and the country as a whole—data that has undergone extensive internal review. Articles within academic peer-reviewed journals tend to inform aspects of the broader context by analyzing nation-wide programs, trends, or processes relating to renewable energy. Specific trade journals and conferences, such as the Water Environment Federation, provide information about recent or past projects in POTWs or renewable Energy technologies. These articles and conference proceedings often serve as the most current source of such information. Personal communications with MWRA and MassDEP employees have provided a useful perspective on the intentions of MWRA, future projects, and the changes in environmental protection and renewable energy over time. Each type of source has specific strengths and weaknesses, but all are necessary for a complete understanding of this case.

2.0 Renewable Energy Development and Implementation at DITP

2.1 The Development of the MWRA and the DITP

A thorough understanding of the MWRA in its present form requires some background knowledge of its development out of the Metropolitan District Commission (MDC) and national water quality legislation. Prior to the MWRA-implemented Boston Harbor Project, the wastewater treatment systems of Greater Boston were inadequate. These inadequacies are documented in centuries of reports and multiple efforts to rectify the situation by the MDC, the agency in charge of wastewater. The treatment plants that preceded the contemporary facilities came out of a 1939 report to the Massachusetts Legislature on water quality. As a result of the report, the MDC began construction of primary treatment facilities on Nut Island (completed in 1952) and Deer Island (completed in 1968). Primary treatment reduces the biochemical oxygen demand by two thirds and suspended solids by 60%. Treated wastewater and sludge were released through underwater pipes between islands within Boston Harbor. These two facilities routinely had difficulty handling the volume of wastewater in the sewer system. Thus, untreated waste was often released through combined sewer overflows, and a facility on Moon Island routinely released waste out with the tide (Dolin 2004).

Several key pieces of legislation passed during the 1960s and 1970s increased water quality standards. In 1965 the U.S. Government passed an amendment to the Federal Water Pollution Control Act of 1948⁵, entitled the Water Quality Control Act, which required states to develop specific water quality standards. In 1966, Massachusetts passed the Massachusetts Clean Water Act⁶, which included water quality standards that allowed the contemporary levels of wastewater dumped from the MDC's facilities to continue. A few years later, the newly-

⁵ *Federal Water Pollution Control Act*, ch. 758, 62 Stat. 1155, 1948

⁶ *Massachusetts Clean Water Act*, Massachusetts General Laws Chapter 21, Sections 26-53.

formed EPA set national water quality standards through the Federal Water Pollution Control Amendments of 1972⁷ and required secondary treatment processes. Secondary treatment eliminates suspended solids and reduces biochemical oxygen demand by 85%. After considering the cost, the MDC applied to the EPA for an exemption from secondary treatment. However, the EPA and the Massachusetts Division of Water Protection brought forth enough challenges that the MDC eventually decided to consider secondary treatment (Dolin 2004).

The Clean Water Act set national levels for pollution control that were above the practices of the MDC. In particular, the Clean Water Act required that most discharges to bodies of water stop, including the discharge of sewage sludge and wastewater to Boston Harbor. Secondary treatment was now required for all treatment plants, and the EPA increased federal funding to alleviate the additional cost. The MDC still preferred not to build secondary treatment works and applied for a waiver that might be made for coastal cities (Dolin 2004).

While the EPA spent years deciding the criteria for the issuance of a waiver, the MDC made moderate improvements to the facilities. However the MDC faced challenges at an institutional level that impeded improvement efforts. As a state agency, the MDC budget was determined on an annual basis by the Massachusetts state legislature. In addition, the fees charged to citizens and businesses for water treatment were controlled by the legislature. Although wastewater was a known issue, it remained less visible than other public issues the legislature was required to fund. As a result, the MDC was consistently underfunded, leading to a general lack of resources including personnel, maintenance problems, and equipment. In addition, the MDC was required to follow the state salary system, which offered lower salaries than private sector water treatment jobs. This meant that MDC staffs were often under-qualified

⁷ Federal Water Pollution Control Act Amendments of 1972, P.L. 92-500, 33 U.S.C.

for their positions because trained workers would seek higher-paying private-sector jobs. Finally, relying on annual budgets and a bureaucratic structure meant that the MDC did not have control over large, long-range projects and planning (Dolin 2004).

The delays by the EPA and the MDC meant that by 1982 no decision had been made regarding secondary treatment, and sewage sludge was still being released into the Harbor. In December of that year, a city bordering Boston Harbor, Quincy, filed a suit against the MDC (and later high-level state environmental leaders) claiming that the MDC had violated its permits and state law. The Quincy suit examined the structural weakness of the MDC and was settled by the creation of the Massachusetts Water Resource Authority⁸. Modeled after the Massachusetts Port Authority and the Massachusetts Transportation Authority, the MWRA combined advantageous aspects of private business with government support.

As an authority, the MWRA holds primary control over its budget and staff, the two major problems that plagued the MDC. In terms of budgeting, the MWRA also has the authority to determine the fees for those who use its services, which allows it to raise or lower rates in accordance with the cost of providing those services. Having sufficient funds allows the MWRA to hire sufficient numbers of qualified staff. In addition, the MWRA can carry-out projects that are often neglected when funds are low, such as preventive maintenance and equipment upgrades (Dolin 2004). The most important measure in terms of funding is government-backed, tax-exempt municipal bonds, which allow the MWRA to raise the capital needed for large projects. In total, the MWRA has spent \$7.1 billion rebuilding the sewers, treatment plants, combined sewer overflows of the Boston region. The majority of this funding came from bonds, and to date

⁸ *MWRA Enabling Act*. MGL Ch.372 ACTS, 1984

MWRA debt includes \$4.6 billion in senior and subordinated revenue bonds, as well as \$2 billion in the State Revolving Fund and tax-exempt commercial paper notes. The MWRA devotes the largest portion of its revenue to repaying debts, and anticipates that debts will last until 2054 (MWRA Executive Office 2009).

In addition to the effects on the budget and staff, the fact that the MWRA was formed as an authority and not an agency has also affected its organizational structure, shown in Figure 2. In general, the MWRA has autonomy over its operations, much like a private business. Managerial and daily operations fall under the direction of the Executive Office. At a higher level, the MWRA is overseen by a Board of Directors that is concerned with long-term plans and reviews annual and quarterly reports from the Executive Office. The Board of Directors includes members of the State Government, such the Secretary of the Executive Office of Environmental and Energy Affairs. The Board of Directors communicates with an Advisory Board that includes representatives from the cities and towns served by the MWRA. Unlike for the MDC and other

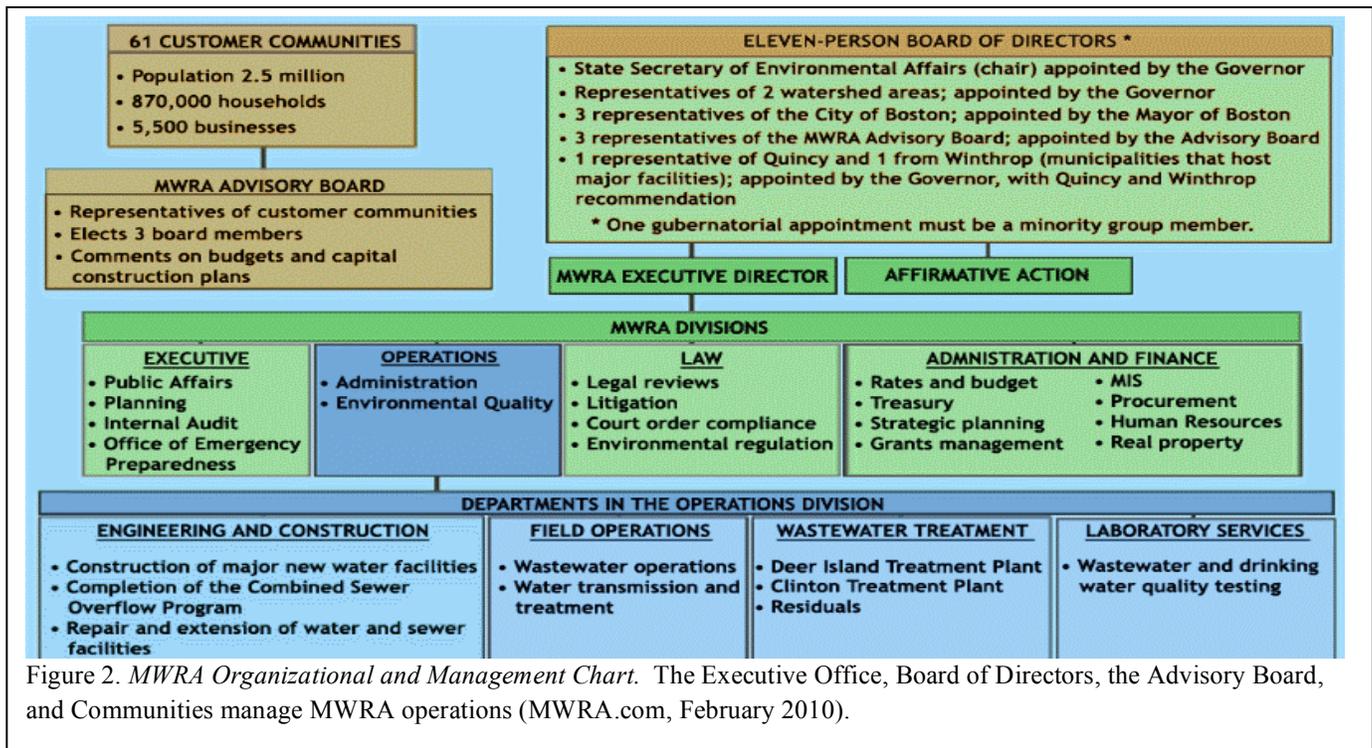


Figure 2. MWRA Organizational and Management Chart. The Executive Office, Board of Directors, the Advisory Board, and Communities manage MWRA operations (MWRA.com, February 2010).

agencies, the government does not have direct control in the operational structure of the MWRA (MWRA Executive Office 2009).

Over the decades since its founding, the MWRA has executed several major improvements to the water treatment system in its service area. The most costly of these improvements was the Boston Harbor Project (BHP), which eliminated the need to dump sewage in Boston Harbor. The BHP included constructing a new primary and secondary treatment plant on Deer Island, installing a 9.5 mile outflow tunnel, and creating a solid waste treatment system. In total, the BHP cost \$3,513,290 and was not considered complete until November of 2001 (Massachusetts Water Resource Authority 2009, 1). Without the court-ordered restructuring of water treatment from the MDC to the MWRA, it is unlikely that such an investment in time and capital would have been possible. Table 2 shows the development of DITP alongside major developments in State and Federal energy and environmental policies.

Table 2. Historical Timeline of the Development of the MWRA <i>Including Influential Events, Legislation, and Law Suits</i>		
Anaerobic Digesters brought online, sludge diverted from harbor to pelletizing plant	1991	
New primary treatment system begins	1995	
Secondary treatment begin	1997	Influential Events, Legislation, and Law Suits
DOER leads wind assessment of DITP site ³	1996	MA Legislature orders better sewage treatment facilities
	1949	Federal Water Pollution Control Act
	1997	Electricity Utility Restructuring Act, which includes a mandate for MA to develop Renewable Portfolio Standards
Nut Island primary treatment plant completed	1952	
Outflow tunnel begins operation	2000	
	1965	Federal Water Quality Control Act mandates that states create water quality standards
MWRA conducts wind testing with SODAR ³	2003	MA RPS begins
	1966	Massachusetts Clean Water Act sets water quality standards for MA, which allow Nut and Deer Island to remain as planned
MWRA seeks FAA approval to build wind turbines near Logan Airport	2005	
Deer Island primary treatment plant completed	1968	
DOER receives a grant to study the potential for solar PV	2006	
MDC enters various pollution control agreements with the Division of Water Pollution Control and the EPA	1971	EPA requires federally funded POTWs to install secondary treatment, with some exceptions.
	2007	MA v. EPA determines that greenhouse gases are air pollutants
	1972	MA Governor Deval Patrick passes Executive Order 484- "Lead by Example: Clean Energy and Energy Efficient Buildings" The Clean Water Act amendments to the Federal Water Pollution Control Act pass, prohibiting discharges to navigable waters and creating national water quality standards.
FAA grants approval to build wind turbines, on several conditions	2008	MA passes the Global Warming Solutions Act, requiring an 80% reduction of carbon emissions from 1990 levels by 2050
MDC applies for a secondary treatment waiver	1978	The Regional Greenhouse Gas Initiative begins operation, participating states include CT, DW, ME, NH, NJ, NY, RI, and MA
	1982	Quincy city solicitor William Golden files a civil suit against the MDC, claiming it violated various conditions of its permit and MA law (eventually includes charges against several top state-level environmental leaders)
MWRA receives an ARRA funded Clean Water State Revolving Loan fund to build a second solar PV installation (construction begins)	2009	
Secondary Treatment waiver denied	1983	Quincy case settled by the creation of the MWRA by the MA state legislature
Two wind turbines completed	1984	MWRA enabling act passed
Massachusetts Water Resource Authority (MWRA) created to replace the MDC (Sources: MWRA Enabling Act 1984; (Dolin 2009, 1)(Office of Governor Deval Patrick 2009, 1)(Office of Governor Deval Patrick 2008)	2004; 1985	EPA files suit against the MDC, the MWRA, and the Boston Water and Sewer Commission for violating the Clean Water Act
MWRA develops the Boston Harbor Project to reduce water pollution	1986	EPA suit settles with Judge overseeing MWRA facility upgrades

needs. DITP utilizes four different renewable energy technologies—Anaerobic Digester Gas technologies (ADG), hydroelectric turbines, solar photovoltaic panels, and wind turbines. In addition, DITP has invested in significant energy-reduction programs, such as installing more efficient turbine, pump, and lighting technologies. These technologies required high capital investment, but reduce the yearly operational costs by reducing energy demand. The renewable technologies also make the DITP eligible for several energy programs offered by energy companies, as well as local, state, and federal programs (Massachusetts Water Resource Authority 2009; Office of Governor Deval Patrick 2009).

Treating wastewater is a multi-stage process that aims to disinfect and reduce the volume of waste. Wastewater and sewage travel to the facility through sewers and are then pumped up to

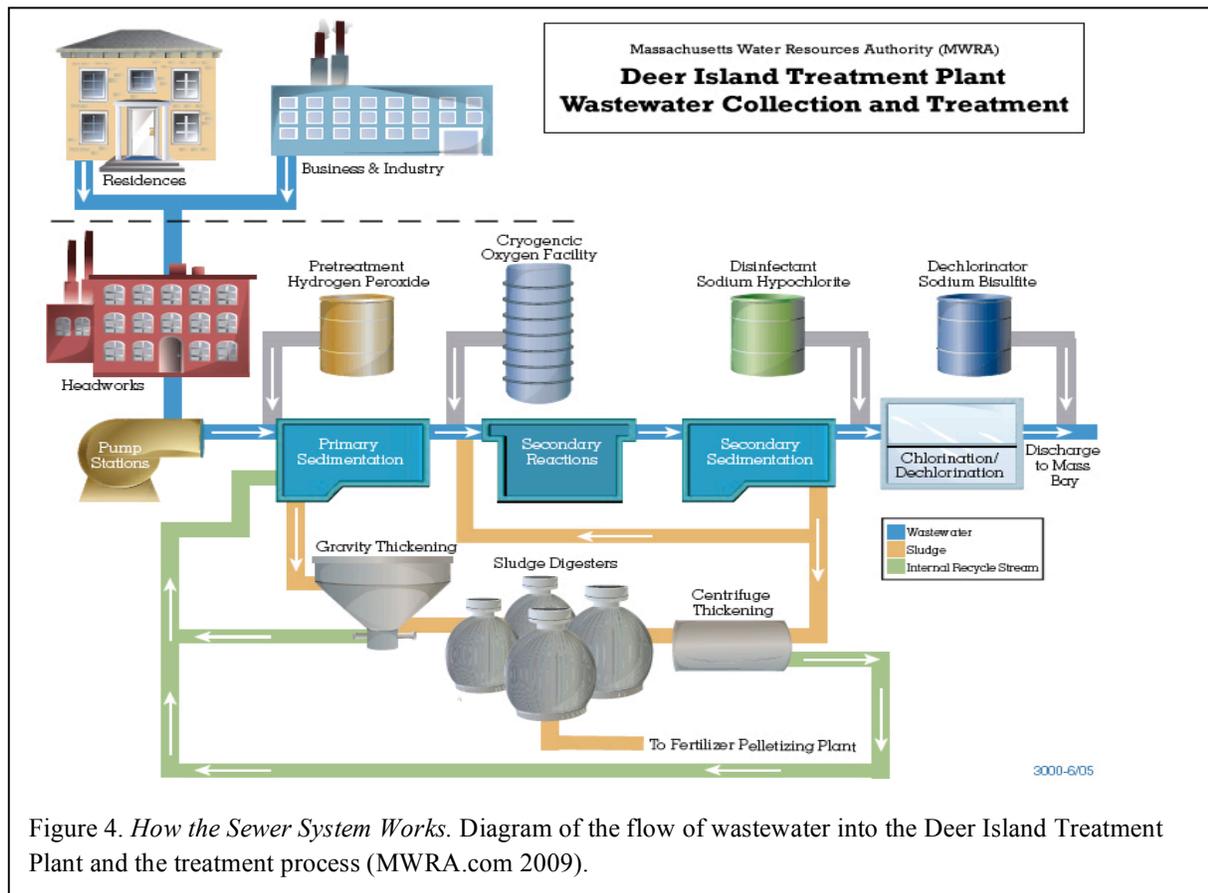


Figure 4. *How the Sewer System Works*. Diagram of the flow of wastewater into the Deer Island Treatment Plant and the treatment process (MWRA.com 2009).

the head of the DITP, as shown in Figure 4. After inorganic solids (such as rocks and plastics) have been removed, the wastewater moves into primary clarifier tanks where biosolids settle. Liquids continue on to additional settling tanks and disinfectors, and eventually flow through an outfall tunnel into the ocean. Solids that settle to the bottom of the clarifying tanks are sent to gravity thickeners, and then sent to sludge digesters, which contain anaerobic bacteria that use the sludge for energy. After the digestion process, sludge is more compact and non-toxic. It is sent to a facility to be turned into pellets, some of which are sold as fertilizer (Massachusetts Water Resource Authority 2009; Tyler, Waitt, and White 2002a, 734-756; Massachusetts Department of Environmental Protection 2009).

Each renewable energy technology is incorporated into the DITP in a different way, as highlighted in Figure 5. ADG is usually considered part of the wastewater treatment process and was used in the preexisting wastewater treatment facility for heat. In addition to heat, DITP currently burns methane to heat the water needed to power an electricity producing Steam Turbine Generator (STG). Hydroelectric turbines were installed after the DITP had been completed and take advantage of the head and flow of water exiting the system. The solar photovoltaic panels and wind turbines were added years after the completion of the facility and utilize site characteristics of sun and wind, rather than the treatment process itself.

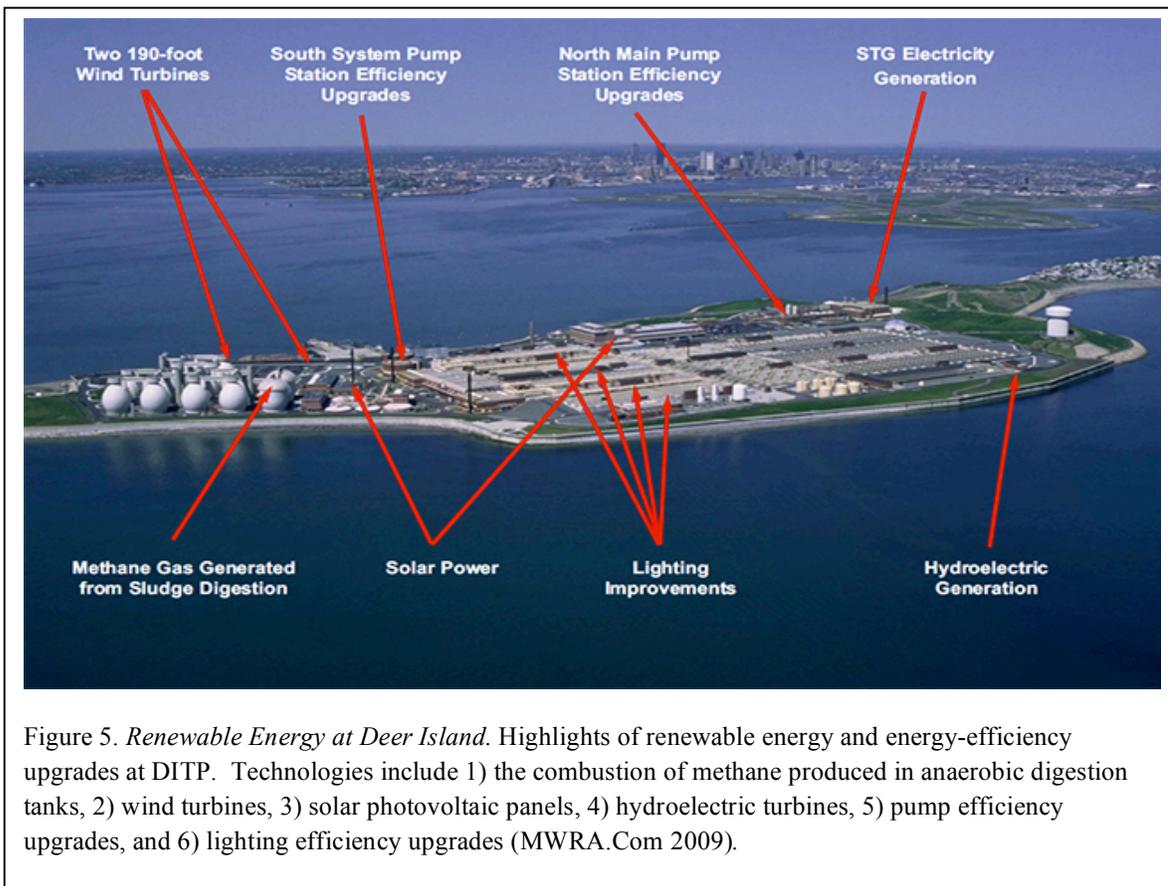


Figure 5. *Renewable Energy at Deer Island*. Highlights of renewable energy and energy-efficiency upgrades at DITP. Technologies include 1) the combustion of methane produced in anaerobic digestion tanks, 2) wind turbines, 3) solar photovoltaic panels, 4) hydroelectric turbines, 5) pump efficiency upgrades, and 6) lighting efficiency upgrades (MWRA.Com 2009).

The primary source of onsite energy production is anaerobic digester tanks. The tanks were built into the original system in order to capture the methane produced by decomposing sewage sludge and to reduce the volume of the sludge. (Tyler, Waitt, and White 2002a, 734-756; Volpe et al. 2004, 496-513). The digesters save the DITP over \$15 million a year in fuel oil costs and earn approximately \$1 million in Renewable Energy Credits per year. Hydroelectric turbines were incorporated into the outflow tunnel of the DITP in 2002 in order to capture the kinetic energy in the movement of treated wastewater out to sea. The two turbines have a combined capacity of 2 MW and save about \$500,000 annually in electricity costs. In the past two years solar photovoltaic panels and wind turbines have been added to the DITP. The wind turbines, added in August of 2009, take advantage of the strong coastal winds off of New England and have a combined capacity of 1200 kW. The turbines were funded by the Clean Water Stimulus

Funding and will save \$250,000 annually in electricity costs (Office of Governor Deval Patrick 2009). The solar photovoltaic panels have a 100 kW capacity. The panels were installed in 2008 with a Division of Energy Resources grant and a Clean Renewable Energy Bond (CREB) loan totaling \$870,000. The electricity produced can be sold as Renewable Energy Credits, like that of the anaerobic digesters (Laskey and Hornbrook 2009).

In addition to renewable energy technologies at the DITP, the MWRA operates several other energy and environmental initiatives. To reduce energy use, the MWRA is installing more efficient motors at pump stations. So far the MWRA has received a rebate of \$209,000 and has reduced its annual electricity needs by \$130,000 for this effort. With the Independent System Operators of New England (ISO-NE), the DITP participates in a load response (Laskey and Hornbrook 2009) program, which earned \$650,000 in 2008. In a load response program, the electricity provider can pay a facility to remove itself from the electrical grid during times of peak demand, and self-generate electricity. The MWRA is also working with NStar, an electricity provider, to reduce the amount of energy used in its lighting systems (Massachusetts Water Resource Authority 2009). Environmental projects beyond renewable energy include turning the residual biosolids from anaerobic digestion into fertilizer. This program, although not lucrative, does reduce the amount of land used for the disposal of the waste and recycles the elements within it. Additionally, the MWRA installed a public park around the DITP on Deer Island, largely to mitigate the visual and olfactory concerns of the town of Winthrop (Dolin 2004). Although these factors are not related to renewable energy, they demonstrate other ways in which a facility might engage in environmental protection and enhance its desirability to the local community. Table 3 summarizes the major renewable energy and energy-efficiency projects at DITP.

Table 3: Summary of Renewable Energy at Deer Island Treatment Plant
Unknown and Not-Applicable fields are blank

Energy Source	Construction timeline	Original project funding	Description of Technology	Rated Output (kW or equivalent)	Actual Annual Output (kWh/yr)	Use of energy	Energy Savings/ REC revenue	Payback period
Anaerobic Digester Gas	Part of the Boston Harbor Project	Subsumed in BHP	12 Digester Tanks, 140 ft tall, 40 ft in diameter		180,000 standard cubic foot per hour (180 MMBTU per hour), 4MW STG	Supplies 97% of Heat	\$10 -\$15 million savings in off-set fuel oil	
ADG SGT	Part of the Boston Harbor Project	Subsumed in BHP			28 million kWh/yr	17% of electricity demand	>\$500,000 per year in RECs	
Hydroelectric Turbine	Part of the Boston Harbor Project, came online in 2001	Subsumed in BHP	Hydroelectric Turbine	Two, 1.1 MW Kaplan Double Gear Bulb Turbines (Bouvier Hydropower and VATech Hydro)	5,900 MWH/yr	Onsite electricity	\$590,000 in energy savings, anticipate RECs of \$150,000 per year	
Solar	Feasibility study in 2006 as part of DOER initiative, came online in 2007	\$870,000 (\$310,000 CREB loan and \$560,000 DOER Grant)	190 Polycrystalline panels produced by Evergreen Solar	100kW	110,000kWh/yr	Onsite	\$10,000 per year in electricity savings	15 years to repay CREB Loan
<i>Solar (under construction)</i>		<i>\$1.1 million SRF Funding (\$735,000 will be covered by ARRA SRF)²</i>	<i>Panels produced by SunPower on Maintenance/Warehouse Roof²</i>	<i>180kW</i>	174,000 kWh/hr	<i>Onsite</i>		
<i>Solar (Proposed)</i>	<i>Solar Power Purchase Agreement²</i>		<i>250kW on Grit Roof, 25kW on Disinfection building roof, and 180kW in the parking lot</i>	<i>455kW</i>				
Wind	1996 wind assessment, 2003 anemometer/SODAR studies through UMASS REL, 2008 FAA approval, 2009 came online	Project cost: \$4 million (\$400,000 grant from MTC)	Two 190' Wind Turbines	1200 kW (2, 600 kW turbines)	Est. 2.3 million kWh/hr	Estimated \$230,000 per year	Est. \$250,000 ¹	11 years , 20 life expectancy
<i>Future Wind Project</i>	<i>2010-awaiting FAA approval</i>		<i>Three 190' Wind Turbines</i>	<i>1,800 kW (3,600 kW turbines) (about 23% efficient)</i>				

(Massachusetts Water Resource Authority 2009; Office of Governor Deval L. Patrick 2008; Patneau 2010a; Patneau 2010b; Renewable Energy Trust 2009)

2.3 Renewable Energy Technologies at DITP

2.3a Anaerobic Digester Gas

The 12 egg-shaped anaerobic digestion tanks are the oldest, most iconic, and most potent forms of alternative energy at the Deer island treatment plant (Tyler, Waitt, and White 2002a, 734-756). The anaerobic digestion process addresses two practical operational issues: the volume of solid waste and the amount of energy required to operate DITP. Anaerobic digestion reduces the volume and toxicity of the sewage sludge and generates a natural gas mixture dominated by methane that can be used as a source of heat and electricity. Anaerobic digester systems were included in the original design of DITP and have a long history of use in the United States and Europe. Although installing digesters involved a significant amount of capital and time, the system provides multiple benefits to the DITP. This section will discuss the technology behind anaerobic digestion in more detail than that of other renewable energy sources, because it is highly integrated into the renewable energy production process and generally less well known than other sources. This section will also cover the design, construction, and operation of the digesters at DITP (Massachusetts Water Resource Authority 2009; Tyler, Waitt, and White 2002a, 734-756; Massachusetts Department of Environmental Protection 2009; Volpe et al. 2004, 496-513).

In recognition that ADG technology remains lesser known than hydroelectric power, solar PV, and wind turbines, this section includes a greater level of detail than the others. The technology for ADG is over a century old and is widely used in industrialized metropolitan areas (Volpe et al. 2004, 496-513). The knowledge that decomposing organic materials in anaerobic environments release combustible gases is much older. The first recorded discovery of methane

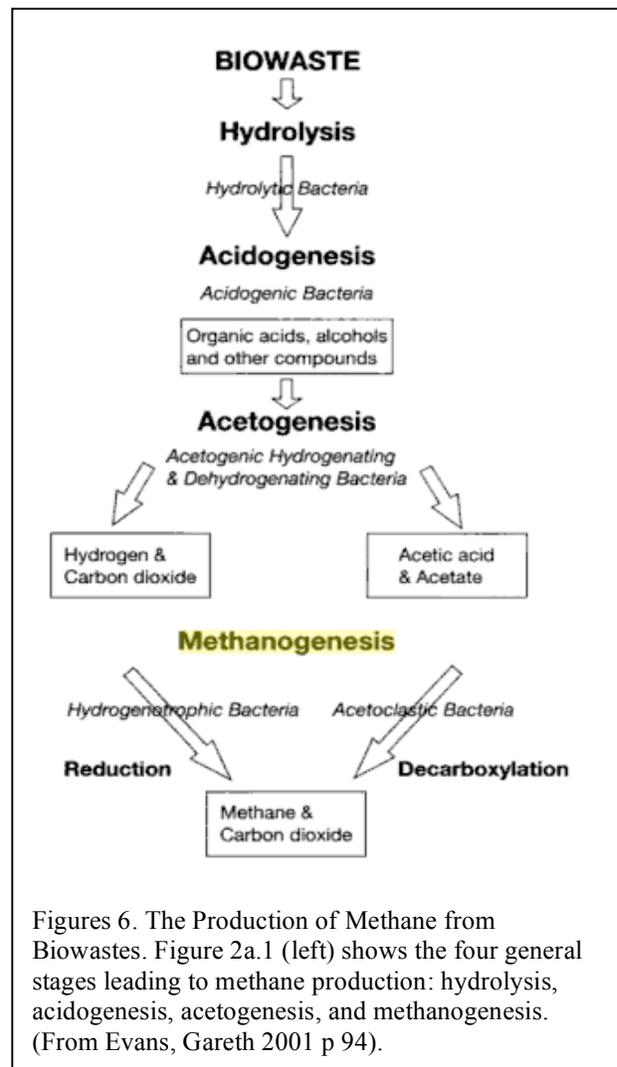
gases was in 1776, when the gases were observed in wetland sediments. It was later, in the mid 19th century that the production of methane was attributed to the decomposition of organics. These discoveries led to the development of a variety of early septic storage tanks and anaerobic filtering systems. As early as 1897, methane began to be collected from septic tanks and burned for heat and light (McCarthy 2001, 149-156).

Early in the 20th century anaerobic digestion of wastewater improved because of two significant discoveries. The first was that separating wastewater from solid sludge resulted in sludge that became easier to handle (less foul and voluminous) after it had been digested for several weeks. The second was that keeping the digestion tanks heated makes them operate much more quickly. Efficient processing of solid wastes, compounded with an appreciation for the value of digester gas, has led to the widespread use of anaerobic digesters at wastewater treatment plants worldwide (McCarthy 2001, 149-156).

Although anaerobic digesters come in a variety of shapes, designs, and sizes, most operate in essentially the same manner. Sewage sludge, which has been separated from wastewater, flows into a chamber and is digested by bacteria for two to three weeks at temperatures around 100°F. Sludge can be separated from wastewater through a variety of processes. These processes range from the simple gravity-induced settling of solids to the bottom of a settling tank to the more-complicated running of sludge through a centrifuge. Once the wastewater has been separated out, the sludge flows into the anaerobic digestion tank.

Within the tank, bacteria break down the sludge, producing carbon dioxide and methane. In each stage, microorganisms (bacteria and archaea) derive energy from the reduction potential of carbon in acetic acid, which serves as an electron acceptor, just as oxygen does in oxygenated

environments. Methanogenesis involves many different microorganisms that execute distinct breakdown processes, including hydrolysis, acidogenesis, acetogenesis, and finally methanogenesis, as depicted in Figure 6. In hydrolysis, hydrolytic bacteria use enzymes to breakdown carbohydrates, lipids, and proteins into sugars and amino and fatty acids. The products of hydrolysis are then fermented through acidogenesis into ammonia, organic acids, carboxylic acids, hydrogen sulfide, and carbon dioxide. In the next step, acetogenesis, acetic acid, carbon dioxide, and hydrogen are formed from the products of hydrolysis and fermentation. In the final stage, methanogenesis, archaeobacteria use the products of the previous stages to create carbon dioxide, methane, and water. Although the methanogenic process involves many intermediate steps, it can be summarized in the following simple chemical expression as one molecule of organic matter turning into three molecules of carbon dioxide and three molecules of methane, as in the following reaction: $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$ (Evans 2001). The interior of the digester is divided into two basic parts—the lower part, which is a sludge storage chamber, with a tapered, conical bottom, and the upper part, which is a gas collector.



Figures 6. The Production of Methane from Biowastes. Figure 2a.1 (left) shows the four general stages leading to methane production: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. (From Evans, Gareth 2001 p 94).

Although anaerobic digestion was part of the preexisting Deer Island Treatment Plant (built in 1968), an entirely new system was installed as part of the Boston Harbor Project. During the design phase, the overall form of the digesters changed in response to problems that operations and management had experienced with the cylindrical tanks used at DITP since 1968. The cylindrical tanks needed frequent cleaning, because insufficient mixing of sludge within the tank caused scum to build up on the top and solids to block pipes on the bottom. Also, the 1968 facility released treated sludge into Boston Harbor, a practice the federal courts ordered the MWRA to discontinue in the new treatment plant. In order to address these problems, the MWRA included a completely new set of anaerobic digesters in the DITP as well as a land-based sludge disposal system.

In designing the new system, the Project Management Division (PMD) of the MWRA went through several stages of engineering and many levels of contracts. First, the Secondary Treatment Facilities plan laid out the design for the overall secondary treatment of wastewater and sludge. The contract for a detailed design of the project was then bid out as a second contract, called the Lead Design Engineering (LDE) contract. The LDE was then split into Design Packages (DPs). The actual designs for the DPs were bid to Project Design Engineers (PDEs) who created the final Construction Packages (CPs) for the project. At each of these many stages, efficiency, cost, and long-term operation were of utmost importance. (Dolin 2004; Tyler, Waitt, and White 2002b, 734-756)

To ensure that the BHP was meeting these goals, “Value Engineering” surveys were conducted in the early stages of each project. In the case of anaerobic digesters, the value engineering review recommended egg-shaped digesters as more effective than cylindrical digesters. Egg-shaped digesters had been in use in Europe for many decades and successfully

reduced the footprint of the digesters and improved the sludge mixing process. Mixing sludge is important to maintain bacterial activity as well as to prevent pipes on the bottom of the tank from clogging. However, several practical considerations precluded immediate acceptance of the new technology. Few egg-shaped digesters were in operation in the US, so the technology was not considered proven. Also, egg-shaped digesters required more capital cost, in part because few American firms had experience in constructing them. And finally, the egg-shaped digesters are taller than cylindrical digesters, providing a visual nuisance to the town of Winthrop and a potential safety threat to airplanes flying out of Logan Airport. Despite the novelty of the technology, the increased capital cost, and the height issues, the Project Management Division chose to build egg-shaped digesters. PDM cited the fact that European experience showed that they required less maintenance service time, the chief problem with the 1968 digesters on Deer Island (Tyler, Waitt, and White 2002b, 734-756).

The final anaerobic digestion system, which began operating in 1995 and continues to this day, includes twelve individual digesters. Each digester is 140 feet tall and 40 feet in diameter and can accommodate up to 3 million gallons of sludge. One design feature includes a central mechanical mixer, in contrast to gas mixers or combined gas and mechanical mixing. Another feature is the rubber membrane system used to collect digester gas, in place of a floating solid barrier. The rubber system is able to compensate for the very low sludge volumes without letting oxygen into the sludge digestion area. The final product of anaerobic digestion is sludge, which is currently used to make fertilizer. Throughout history many societies have used wastewater and solids for soil fertilization, including the early settlers of Boston (Dolin 2004). Therefore, the MWRA sends digested sludge through a tunnel to Quincy where it is turned into

pellets by the New England Fertilizer Company at Fore River in Quincy (Massachusetts Water Resource Authority 2009; Ruddock et al. 2005).

Digestion cycles last for 15-25 days at temperatures around 100°F. The anaerobic digester gas is composed of approximately 60-70% methane and 30-40% carbon dioxide, and has an energy value lower than that of commercial natural gas, which is almost pure methane (Tyler, Waitt, and White 2002b, 734-756; Tyler, Waitt, and White 2002b, 734-756; Tyler, Waitt, and White 2002b, 734-756). Over the course of the year the anaerobic digester gas production rate averages 180,000 cubic feet per hour (108 MMBTU per hour), the annual equivalent of 6.5 million gallons of heating oil valued at \$10-\$15 million dollars, depending on the price of oil. The anaerobic digester gas is siphoned off of the tanks and burned to power boilers which heat DITP's buildings and digester tanks (The Manufacturer US 2007).

In addition to heat, 3 MW of electricity are generated by a steam turbine generator (STG) powered by the boiler steam (The Manufacturer US 2007; The Manufacturer US 2007). Processes such as this, which combine heat and electricity production, are called "co-generation" or combined heat and power (CHP) (Boyle 2004). The STG system produces 28,000 MWH per year, which satisfies 17% of the DITP energy needs. The electricity that is produced qualifies as renewable energy under Massachusetts Renewable Portfolio Standards Program, allowing the MWRA to sell renewable energy Credits (RECs) to electricity utilities. Therefore, anaerobic digester gas both reduces the MWRA fuel costs by over \$10 million and provides roughly \$1.2 million in RECs (Massachusetts Water Resource Authority 2009; Ruddock et al. 2005).

In another attempt to create electricity from anaerobic digester gas, the MWRA worked with New England Power Company on a fuel cell demonstration project. The MWRA cited

educational purposes as their primary interest in installing the fuel cell. The project began in 1997 with a United States Department of Energy award. The New England Power Company paid \$2 million to install, maintain, and repair the system. In the demonstration project (the second of its kind in the US), a 200kW fuel cell converted natural gas extracted from sludge digesters into electricity. Measuring 20 feet by 20 feet, the large fuel cell, was created by ONSI Corp. The majority of the electricity produced by the fuel cell was used onsite to power wastewater treatment in the Deer Island plant. The fuel cell was connected to the regional grid as well, to handle excess electricity (Power Engineering, 101). However, the system only produced \$53,200 worth of electricity (valued at \$.08/kWh) due to the cold climate and lack of personnel for proper maintenance (Bzura and Hill 2002; Bzura and Hill 2002).

Aside from providing an energy source for DITP, burning the methane produced by anaerobic digestion reduces the amount of methane released to the atmosphere. Burning methane does produce carbon dioxide, which is then released to the atmosphere. However, the atmospheric warming potential of methane is 20 times greater than that of carbon dioxide. Also, using the methane onsite reduces the amount of energy drawn in from the grid, where the majority of electricity is produced by greenhouse-gas-emitting fuels, such as coal (Blaha et al. 1999, 243).

In sum, the anaerobic digester tanks at DITP have a long precedent and serve many purposes. Although the specific tanks used at DITP are an innovative design, digestion tanks have been common at wastewater treatment plants for many decades. Since they were built as part of the DITP design, their cost was absorbed as part of the BHP. Inside the tanks, microorganisms reduce the volume of sewage sludge by half, lessening the amount of solid waste that must be disposed of. In the process, digestion produces a gas that is potentially 70%

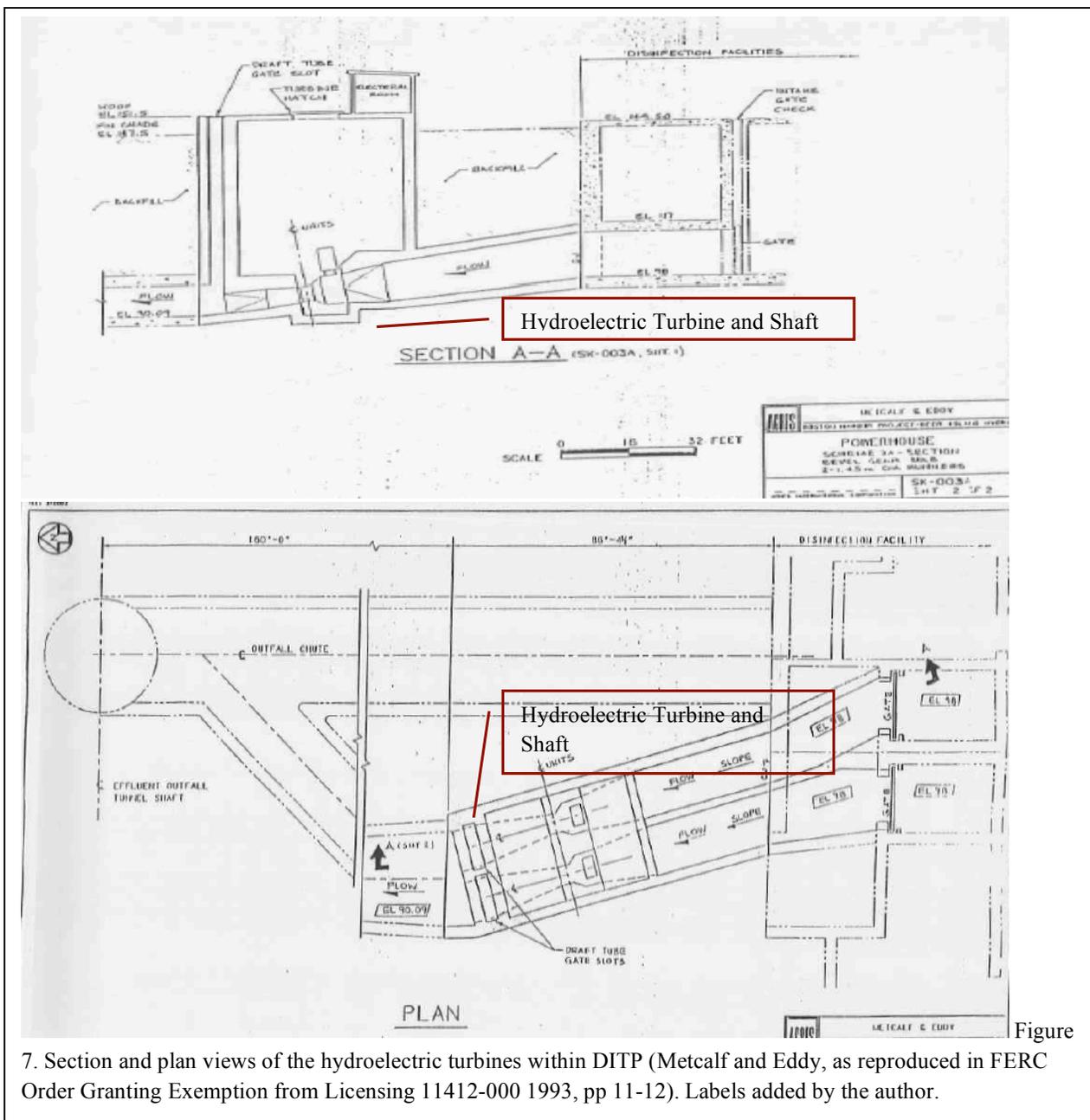
methane. The gas is siphoned off and used as fuel for boilers to heat the plant and digester tanks, saving approx \$15 million in fuel oil costs. The steam is also used to generate 28 million kWh of electricity, which is sold as Renewable Energy Credits for \$1.2 million per year. The anaerobic digester tanks at DITP are an example of integrating renewable energy technology so that the technology not only provides energy but also facilitates operations and provides ancillary benefits.

2.3b Hydroelectric Power

The second most potent source of renewable energy at DITP is a hydroelectric turbine system. The 2 MW system annually generates over 5,000 MWh of electricity. As with the anaerobic digester gas, this system is an example of renewable energy integration, because energy is produced by harnessing processes within DITP. The hydroelectric turbine at DITP is powered by the stream of processed water (from sewage treatment) flowing out of the facility through the outflow shaft. The water then continues its journey out into Massachusetts Bay through a nine-mile tunnel. However, unlike the anaerobic digester gas system, the hydroelectric turbine does not enhance the sewage treatment process, and it did not begin operation until after the DITP facility had been operating for several years. This section will examine the technical and environmental aspects of installing a hydroelectric turbine at DITP and within other Publicly Owned Treatment Works (POTWS).

Hydropower has long been used in a variety of forms ranging in scale and use from small pelton wheel mills to the Grand Coulee Dam (Boyle 2004). Whether the hydropower technology uses motion of water directly or converts it into electricity, hydropower technologies take advantage of two key characteristics of water flowing downward: head and flow. Head refers to the elevation difference between the water source and turbine, taking into account the weight of water. Head is an indication of the potential energy stored in water and is often measure in terms of pressure, e.g., pounds per square inch (psi). The term net head is commonly used to describe the effective head, after the loss of energy due to friction is taken into account. Flow refers to the volume of water passing through a defined area over a defined period of time, such as cubic feet per second (cfs) or millions of gallons per day (MGD). Hydroelectricity is produced when waters with substantial head and flow are directed through a turbine, which essentially captures the

energy stored in the water. Different types of turbines are designed to work best under specific conditions. For example, a reaction turbine works best in heavy-flow, low-head situations, whereas an impulse turbine works well in high-head, low-flow situations. These turbines in turn are connected to electric generators and an electricity distribution system (EIA glossary 2010, (Boyle 2004). There seems to have been little precedent for hydroelectric turbines at POTWs prior to the DITP design, and the DITP has served as the model for many municipalities and their design firms.



7. Section and plan views of the hydroelectric turbines within DITP (Metcalf and Eddy, as reproduced in FERC Order Granting Exemption from Licensing 11412-000 1993, pp 11-12). Labels added by the author.

At Deer Island, the 300 MGD of wastewater passing through Deer Island provide ample flow, while the elevation drop to the outflow shaft creates head. Plans for the turbines were complete enough by 1993 that the MWRA was able to file for an exemption from the Federal Energy Regulatory Commission, as shown in Figure 7 (Low Impact Hydro Institute 10/26,2009, 1). The MWRA was granted exemption because it proved that the facility would not disturb the pump station, which is listed on the state register of historic places. The MWRA was not required to file an environmental assessment, because the plans did not affect natural waters. The project included a substation and electrical building, a powerhouse for the generators, the conduits that channel wastewater to the turbines, and the turbines themselves (FERC exemption application). The hydroelectric turbine was designed to be part of the DITP facility, first appearing in a conceptual design by the engineering firm Metcalf and Eddy in 1991. The hydroelectric system has two Kaplan Double-Gear Bulb Turbines that have a rated capacity of 1.1 MW with a flow of 333 MGD. Based on the level of the tidal waters, net head ranges from 13 to 33 feet (Boyle 2004).

As with the Anaerobic Digesters, the design and installation of the hydroelectric system at DITP was funded as part of the Boston Harbor Project. Therefore, there is little information about the actual cost of the system. At the time of its construction, the 2 MW-system was estimated to produce about 12.4 million kWh per year, which would be used onsite. This translated into a 12-year payback period, after which DITP would profit from the system by avoiding electricity costs. However, since the system came online in 2001, it produces only half of the anticipated electricity annually, roughly 5,900 MWh per year, which has doubled the

length of the anticipated payback period as well⁹. With an estimated electricity cost of \$0.10 per kWh, the hydroelectric system saves roughly \$590,000 in energy costs per year. As a result of the controversial environmental effects some dams have on natural ecosystems, hydroelectric turbines must be approved by the Low Impact Hydro Institute before they can qualify for Renewable Energy Credits. In 2009 the MWRA received approval from the Hydro Institute and anticipates being able to sell \$150,000 in RECs per year in the future. (Patneade 2010a; Low Impact Hydro Institute 10/26,2009, 1). Design specifications of the turbines are summarized in Table 4.

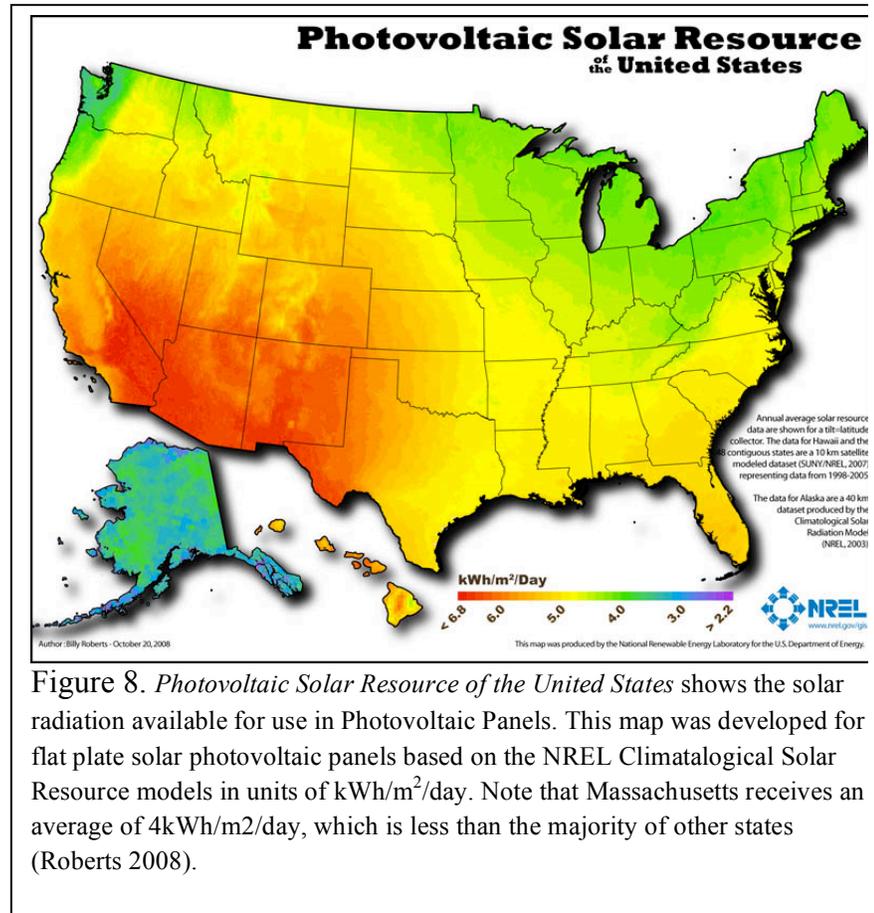
The DITP hydroelectric installation								
Head	Flow	Turbine	Production	Use of the Electricity Produced	Value of the electricity generated	Revenue	Cost	Estimated system Payback time
13 -33 ft, 6-14 psi	rated capacity of 500 cfs each (330 MGD)	2, 1-MW turbine	Capacity: 2 MW. Average 5,900,000 kWh per year	Onsite	\$590,000/yr	5,900 RECs/year	\$8,000,000 as part of a \$36,200,000 construction project	Originally estimated at 12 years (based on 12.4 M kWh/r), now 20-25 years

Table 4. Information on the hydroelectric installation at the DITP. Two, 1-MW turbines produce an average of 5.9 MWh annually, saving the facility approximately \$590,000 in electricity costs. The francis turbines operate with a head of 13-33 ft (6-14 psi) and a flow of 330 MGD. (61 Heidell, Pamela 2004; 58 Massachusetts Water Resource Authority 2009; 97 Patneade, Kristen 2010)

⁹ Current MWRA employees were not aware of the original estimated production and thus had could not explain the shortfall (Patneade 2010a).

2.3c Solar Power Photovoltaic Panels

While solar photovoltaic (PV) electricity is generally too expensive to be a viable replacement for conventional electricity, DITP has secured significant funding to support two major solar PV installations. The high cost of solar PV is directly related to the cost of the materials needed to produce solar PV panels and the low efficiency of commercial panels, around 10%. In addition, the high



latitude of Massachusetts and frequent cloud-cover lowers the intensity of sunlight and limits winter daylight hours, making solar PV less efficient than the majority of the U.S., as shown in Figure 8 (Boyle 2004);(Roberts 2008).

The MWRA became interested in installing solar PV at DITP in 2006, after the Massachusetts Department of Energy Resources (DOER) received grant money for solar power installations on state facilities. The DITP proved to be one of the most viable facilities the DOER studied. In 2007, the MWRA began designing a solar photovoltaic system in order to generate more electricity onsite. The MWRA was the first of about a dozen facilities that received funding from the DOER. The system was produced by Evergreen Solar, a Massachusetts company, and is mounted on the Residual Odor Control building. During its first year of operation the system

produced 110,000kWH, 10% more electricity than had been estimated (Laskey and Hornbrook 2009)

The specific financing options that helped make the installation of solar panels more affordable for the MWRA result in a payback period of 15 years. The total cost of the 100kW installation was \$870,000 which was financed by \$310,000 from a Clean Renewable Energy Bond (CREB) loan and \$560,000 in a Department of Energy Resources Grant. The 15-year timeframe applies to paying back the CREB loan, through the annual avoided electricity costs of \$10,500 as well as RECs. To put into perspective the significance of the DOER grant and the CREB loan, it is worth noting that without similar grants and loans, the MWRA currently estimates that it would take 40 years for a solar PV system to repay its cost. This payback period is twice as long as the 20 year anticipated lifetime of the solar PV system (Office of Governor Deval L. Patrick 2008; Patneau 2010a).

After the first solar project, the MWRA Energy Task Force made an inventory of solar projects that would be feasible at DITP based on the available open spaces and rooftops. Due to the long payback time of the projects most are not economically feasible (Patneau 2010a). In 2008, the MWRA was able to pursue another solar PV project when the DOER received funds from the American Recovery and Reinvestment Act also known as the “Stimulus Bill”. The DOER created a Stimulus Task Force to list qualifying “shovel ready” projects that could begin in a short time-frame, which included the MWRA Energy Task Force’s solar PV projects (Commonwealth of Massachusetts FERII Task Forces 2009) The MWRA solar PV project was expedited through the application process, because in March 2009, the DOER and MWRA realized that the project qualified for part of the \$25 million awarded to Massachusetts in the Clean Water State Revolving Loan fund. The MWRA was awarded a grant and began

construction in the summer of 2009 for a 180 kW solar PV installation on the Warehouse/Maintenance building. Lighthouse Electrical Contracting, Inc. is currently under contract for the design and construction of the \$1.2 million dollar photovoltaic system. The new system will cover 13,000 square feet of the 75,000 square feet roof of the Warehouse and Maintenance building. The system is a modular SunPower PowerGuard made of 592 350-watt panels, and is designed to lay flat against the roof. Placing the system flat allows for a more compact installment and for the panels to act as an extra layer of insulation on the building (Patneau 2010a). It is expected to be complete and operating by April 2010 (Massachusetts Water Resource Authority 2009, 1--14, Appendices 1-8).

In total, by the end of 2010, solar PV panels will produce 280 kW of electricity for the DITP. Additional solar PV projects are under consideration both at DITP and other MWRA facilities. The MWRA will most likely finance these projects through a variety of strategies, including contracting a private company to own and operate the solar PV system on the DITP site. Private solar power installation businesses may pursue a Solar Power Purchase Agreement, which allows them to install and operate solar panels on another organization's buildings. Although this purchase agreement significantly reduces the cost of electricity produced by the solar PV, it does not guarantee that the electricity will cost the same or less than conventional electricity. To remove this uncertainty, the DOER provides the funding necessary to make up the difference between the price of solar PV electricity and conventional electricity (Commonwealth Solar and Solar Energy Business Association of New England 2009). The MRWA will identify a contractor by March 2009 for a project that will involve installing 450 kW of solar PV on the roofs of two buildings and an unused area of the parking lot near the existing wind turbines (Massachusetts Water Resource Authority); (Patneau 2010a).

2.3d Wind Turbines

The New England coastline has long been considered ideal for wind power because of the demand for electricity and the suitability of the wind patterns. In particular, the DITP has been under consideration for the installation of wind turbines since 1996, when the Massachusetts Department of Energy Resources (DOER) funded an initial wind Assessment. The information from that assessment warranted a more detailed study to understand the exact wind patterns and

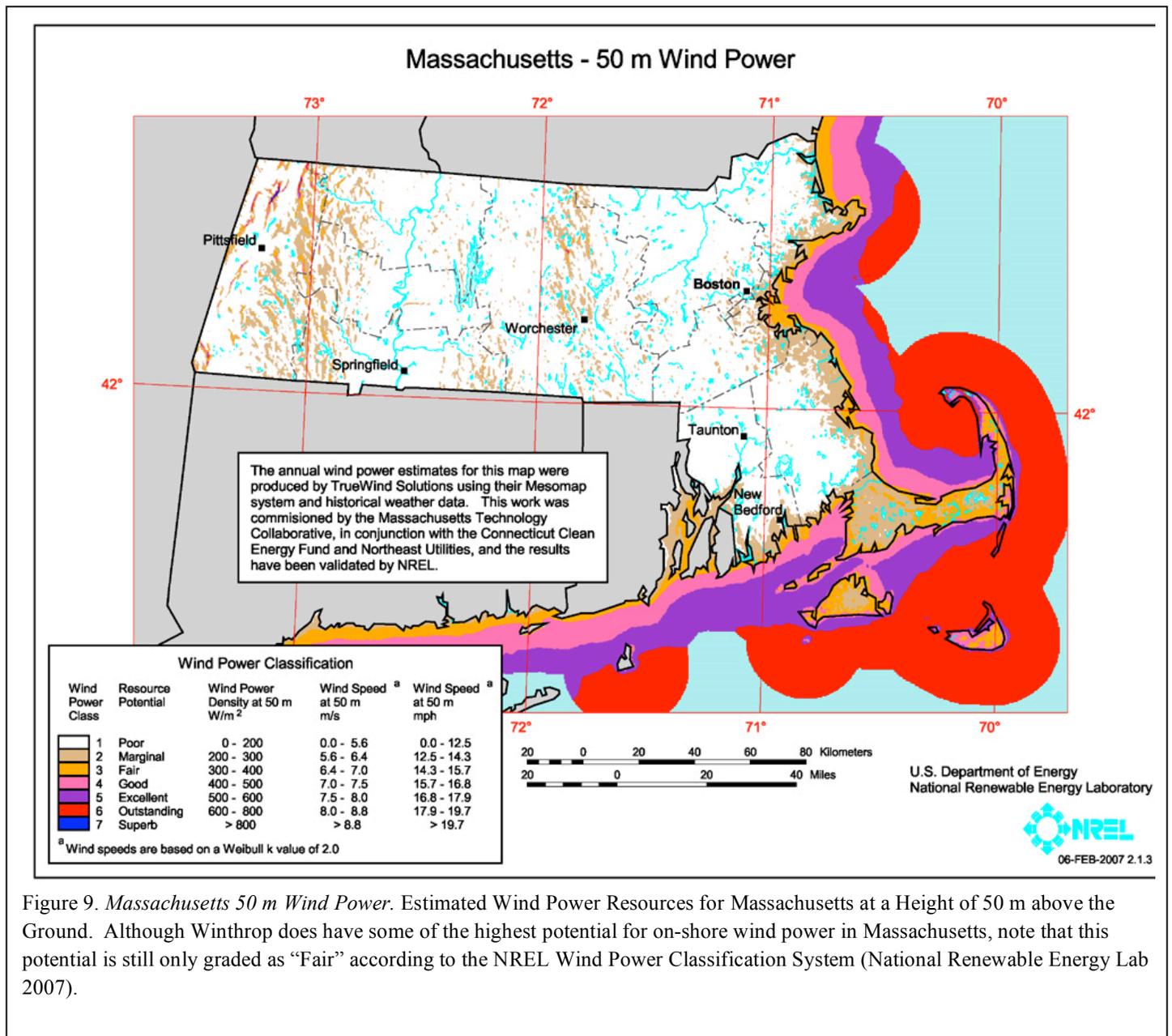


Figure 9. *Massachusetts 50 m Wind Power*. Estimated Wind Power Resources for Massachusetts at a Height of 50 m above the Ground. Although Winthrop does have some of the highest potential for on-shore wind power in Massachusetts, note that this potential is still only graded as “Fair” according to the NREL Wind Power Classification System (National Renewable Energy Lab 2007).

potential for wind power. In 2003, the Renewable Energy Laboratory at the University of Massachusetts and the Community Wind Collaborative Program of the Massachusetts Technology Collaborative (MTC) assisted the MWRA in carrying out the study. SODAR equipment was used since there was no space on the DITP site for an anemometer tower. Again, the promising results from the SODAR study allowed the MWRA to move forward with plans for installing wind turbines (Patneaude 2010a).

The first plans for wind turbines were developed by Black and Veatch after a feasibility study in 2005. However, since the DITP is located within a few miles of Boston's Logan Airport, the Federal Aviation Administration had to review and approve the plans for turbines before construction. Between 2005 and 2008, the MWRA sought FAA approval and ultimately received approval for two turbines after reducing the height of the turbines to 190ft over concerns about the height and radar interference (Hevelone-Byler 2008). The MWRA also received approval for three additional turbines to be installed one at a time, on the condition that the existing turbines operate for a 30-day trial period after each new installment. The first two turbines were installed in August of 2009 and have successfully passed their 30-day trial period. However, before the MWRA installs the next three turbines, it would like to receive FAA approval to install all three at the same time, to reduce total cost of installation. In addition, the MWRA is looking for funding, particularly from the MTC although, as with solar, the MWRA did include the turbines in the State Task Force request for ARRA funding. With MTC funding for the turbines, their payback period is about 11 years, which means that during 45% of their 20 year life expectancy, the turbines may generate a profit for the MWRA (Patneaude 2010a).

The MWRA is currently pursuing many other wind turbine projects, including one at the Nut Island Facility and one at the DeLauri Pump Station in Charlestown. The MWRA has found

net metering to be particularly helpful in pursuing wind power projects because it allows sites that do not have high onsite electricity demands to be considered for renewable energy projects (Patneaude 2010b).

2. 4 Energy-Efficiency Efforts

Although the focus of this paper is renewable energy, it is important to comment on energy efficiency. Energy-efficiency products can be evaluated according to their end result of decreasing the energy needed to operate machines, systems, or buildings. Efforts that reduce the amount of energy needed serve many of the same purposes as renewable energy in terms of increasing energy independence, decreasing dependence on fossil fuels, and reducing greenhouse gas emissions (Boyle 2004). The MWRA has pursued energy efficiency projects as a way to reduce electricity demand from the grid at DITP and other MWRA facilities. Just as several different renewable energy technologies have been installed, so too have many different energy efficiency projects been undertaken at DITP. There are currently three major areas of interest for energy efficiency at DITP—pumps, lighting and fixtures, and steam-powered turbines.

At DITP there are two major pump stations that serve to raise incoming wastewater from the sewer 150 feet up to the head of the treatment process. The North Main Pump station handles the inflow from the northern MWRA service area using six 600-horsepower pumps and ten 3,500-horsepower pumps. The remaining service area's wastewater is pumped up by the Lydia Goodhue Pump Station (South Main Pump Station), which relies, on eight 1,250-horsepower pumps (Massachusetts Water Resource Authority, 1). After considering how much energy is required to raise water, the MWRA lowered the level to which water must be raised. This adjustment alone saves \$300,000 per year. Efforts to increase the efficiency of the pumps

themselves led the MWRA to install variable frequency drives. By controlling the frequency of the electricity supplied to a motor, variable frequency drives are able to adjust the pump's electricity demand to match wastewater flow. Upgrades were completed at the South Station in 2007 (Massachusetts Water Resource Authority 2009). The upgrades to the South Station qualified for a rebate because of their reduction in electricity demand, and they also save over \$150,000 per year in electricity costs. The upgrades to the North System Pump station began in fall 2009 (Massachusetts Water Resource Authority 2009; Patneau 2010b).

Another energy-efficiency initiative that the MWRA is undertaking at DITP is upgrading its steam turbine generator (STG) to include a back-pressure turbine. The STG is part of the system that utilizes anaerobic digester gas (ADG). As discussed in section 2.3, after ADG has been siphoned off from the digesters, it is burned. The heat and steam from combustion are used to heat the DITP facilities and to power the STG, which converts the thermal energy into electricity. The STG does not currently convert all of the thermal energy into electricity, so the MWRA is going to install a back-pressure turbine. The back-pressure turbine system will generate electricity from the currently un-utilized steam. The new system is expected to recover 5 million kWh per year (Massachusetts Water Resource Authority).

A third, more general energy-reduction effort is underway for lighting and appliances. For this part of the overall energy-reduction strategy, DITP worked with NStar to complete an energy audit of the facility and then to determine where efficiency upgrades could be made. The efforts following the audit include limiting the amount of time light fixtures are on by adding automatic sensors that are responsive to natural/ambient light and to the occupancy status of a room. Another aspect of the strategy was reducing the energy demand from lighting fixtures. This meant installing low-wattage fluorescent lights and LED fixtures (such as "Exit" signs) in

place of existing fixtures where possible (Massachusetts Water Resource Authority 2009). By saving \$350,000 per year in electricity spending, these measures are expected to repay their installation costs in two to three years. In a separate measure, the MWRA is adding controls to equipment, such as computers, that monitor energy use and automatically switch to the lowest power mode when not in use (Patneau 2010b).

2.5 Socio-Political Context of Renewable-Energy and Energy-Efficiency Programs

It is important to place the installation of renewable energy technologies at Deer Island within the socio-political context of the Commonwealth of Massachusetts. The priorities of the Commonwealth largely dictate the allocation of federal and state funds and push selected projects forward. Over the three decades during which DITP has been in design, construction, and operation, the Commonwealth of Massachusetts has developed a strong stance encouraging the reduction of fossil-fuel-based energy. As mentioned in the introduction of this paper, there are many different reasons to want to reduce fossil-fuel-based energy use, ranging from energy-security to reducing operational costs. However, one reason has risen above the rest within the past decade as a priority for energy policy actions within the Commonwealth. This is the idea that the greenhouse gases released by fossil fuels are the cause of climate change. This section will outline the major actions of the state to reduce greenhouse gas emissions, some of which contributed to the installation of renewable energy at DITP.

Over the past several decades there has been growing scientific and public support for the idea of anthropogenic global warming due to what is commonly known as the greenhouse effect. As the survey in Table 5 shows, a comparison of public opinion regarding climate change shows that in the mid 1980s, when the MWRA was designing DITP, only 39% of those surveyed had heard of the greenhouse effect. That percentage grew rapidly during the 1990s and 2000s, so that by 2006 it was 90% (Nisbet and Myers 2007, 444-470; Kellstedt, Zahran, and Vedlitz 2008, 113-126). During the same period, opinions on the validity of the science behind global warming, its portrayal by the media, and what governments should do about it have varied widely portray it. Maximum belief in the effects of global warming and support for preventative actions occurred around the year 2000 and again towards the end of the 2000s. In particular, surveys since the

year 2001 show a slight increase in support for more regulation of carbon dioxide emissions as well as the regulation of automobiles and industrial sources. In all, roughly 80% (+ - 1%) of people surveyed in 2007 supported such measures (Nisbet and Myers 2007, 444-470; Kellstedt, Zahran, and Vedlitz 2008, 113-126; Leiserowitz 2007). These trends show that public awareness, belief in, and approval of action to combat global warming has increased over the past decades.

	Cambridge ^a	Harris ^b	Parents ^c	Analysis ^d	Cambridge ^e	Cambridge ^f	Cambridge ^g	CBS ^h	HarrisIT ⁱ	LA			Pew
	07/86	10/86	09/88	09/88	05/89	02/90	09/92	11/97	08/00	04/01	08/01	09/02	05/06
Yes (%)	39	45	58	58	68	74	82	85	89	82	88	85	91
No (%)	55	55	40	42	28	22	17	14	10	14	11	14	9
Not sure (%)	6		2		4	5	1	1	1	4	*	1	*
N	1,500	1,273	1,000	1,001	1,502	1,250	1,250	953	1,010	813	1,017	1,011	1,001

^aSample size is approximate.
^bHave you heard or read much about . . . greenhouse effect?
^cHave you heard or read anything about the greenhouse effect?
^dHave you heard anything about a "greenhouse effect"?
^eHave you heard anything about the greenhouse effect in the atmosphere that could cause global warming?
^fOn the subject of environment, have you heard anything about the greenhouse effect in the atmosphere that could cause global warming?
^gHave you heard or read anything about the enhanced greenhouse effect, also called global warming?
^hGlobal warming is a term used to describe changes in the earth's climate. How much have you heard or read about global warming—a lot, some, not much, or nothing at all?
ⁱHave you ever seen, heard, or read about the theory of global warming—that average temperatures are rising slowly and will continue to rise mainly because of the burning of coal, oil, and other fuels?
^jHave you heard or read anything about the issue of global warming?
 *Less than .5%.

Table 5. Increase in Public Awareness of the greenhouse effect from 1986 to 2006. This table compiles subjects responses to comparable questions asking whether they had heard or read anything about the greenhouse effect. Footnotes list the specific question asked in each poll. Polling agency abbreviations include Cambridge Reports of Research International (Cambridge), Louis Harris & Associates (Harris), Parents Magazine (Parents), Analysis Group (Analysis), CBS News (CBS), Harris Interactive (HarrisIT), Pew Research Center (Pew). (From Nisbett, Matthew. and Myers, Teresa 2007, p 446).

Reflecting this social and scientific trend, the Commonwealth of Massachusetts has officially classified greenhouse gases as pollutants that damage the environment. In 2007, Massachusetts successfully challenged the national Environmental Protection Agency to do so as well, bringing the regulation of greenhouse gases into its scope of power. MEPA, managed by the Executive Office of Environmental and Energy Affairs, requires an environmental review of

all state-affiliated projects that are above a certain size. This includes land transfers, licenses and permits, and financial assistance as in grants and loans. Recognizing the potentially harmful effects of greenhouse gases means that the emissions associated with the lifetime of a construction projects are subject to environmental review as well (Massachusetts Environmental Protection Act 2009). The MEPA revision requires environmental reviews to explicitly identify measures to reduce and mitigate the estimated greenhouse gas emissions associated with proposed projects. The Commonwealth also filed a lawsuit against the Environmental Protection Agency, arguing that greenhouse gases posed a real danger to the Commonwealth and the EPA was neglecting its regulatory statute. Eleven other states joined Massachusetts as plaintiffs as the suit eventually came before the Supreme Court¹⁰. The court decided that greenhouse gases are air pollutants and as such the EPA has the authority to regulate them, but it is not required to do so. Prior to this case and the MEPA revision, greenhouse gases were not considered pollutants that the government had the authority to regulate (Greenhouse 2007).

Recognizing the impact of greenhouse gases on the environment has created a strong ideological link to form between energy concerns and environmental protection. In order to facilitate coordination of environmental and energy projects, Governor Deval Patrick combined multiple agencies into the Executive Office of Environmental and Energy Affairs (EOEEA) including:

- Department of Agricultural Resources
- Department of Conservation and Recreation
- Department of Energy Resources
- Department of Environmental Protection
- Department of Fish and Game
- Department of Public Utilities

¹⁰ *Massachusetts v. EPA, Bd.*, 549 U.S. 497 (2007)

State Reclamation Board

One example of collaboration between departments of the EOEEA is energy-based Supplemental Environmental Projects (SEPs). SEPs are commonly carried out by entities that have been found to be in non-compliance with an environmental regulation, in addition to or instead of a financial penalty. Most SEPs involve some sort of mitigation effort for the environmental damage caused by the violation. Energy-based SEP's open up the option for projects such as energy audits of civic buildings, funding an alternative energy source, or installing more energy efficient lighting (Patrick et al. 2007).

One of the first steps to encourage renewable energy in Massachusetts came in 1997, in the Electric Utility Restructuring Act¹¹. While electricity restructuring is meant to deregulate utilities and break up local monopolies, this act also mandated that Massachusetts develop a Renewable Portfolio Standard (RPS)¹². A RPS is meant to ensure that a certain portion of the state's electricity comes from renewable sources. Through this system, Massachusetts requires electricity retailers to buy a percentage of their electricity from renewable sources. The percentage they are required to buy began at 1% in 2003 and is increasing to 10% in 2015, as outlined in Table 6. Monitoring this information requires a comprehensive tracking system for the New England grid and the adjacent grids that exchange electricity with it. (Thus, even though the RPS applies to energy supplied in Massachusetts, the electricity may come from six different states and two Canadian Provinces.) Independent Systems Operator-New England (ISO-NE), is a non-profit organization that has managed long-term planning and reliability of electricity within the New England grid system since deregulation. Electricity generated within ISO-NE (or

¹¹ *An Act Relative to Restructuring the Electric Utility Industry in the Commonwealth, Regulating the Provision of Electricity and other Services, and Promoting Enhanced Consumer Protections Therein*. Chapter 164 of the Acts of 1997

¹² *Renewable Energy Portfolio Standard: Class I and II*. 225 CMR 14-15 (1997)

exchanged with a neighboring grid) is tracked by a serial number in the NEPOOL Generation

Information System in quantities of megawatt-hours. If the energy comes from qualified renewable energy sources, then it is labeled a Renewable Energy Credit (REC) and can be purchased by electricity providers to help them meet their RPS. If the electricity supplier is not able to meet the RPS requirement, then it must pay a penalty to the Massachusetts Technology Collaborative, an organization affiliated with the Massachusetts

Year	Actual/Projected Load Obligation, MWh	RPS % Obligation	RPS MWh Obligation
2003	49,834,324	1.0	498,344
2004	50,063,092	1.5	750,954
2005	51,558,778	2.0	1,031,176
2006	50,143,130	2.5	1,253,600
2007	50,978,101	3.0	1,529,359
2008	51,370,602	3.5	1,797,971
2009	51,370,602	4.0	2,054,824
2010	51,370,602	5.0	2,568,530
2011	51,370,602	6.0	3,082,236
2012	51,370,602	7.0	3,595,942
2013	51,370,602	8.0	4,109,648
2014	51,370,602	9.0	4,623,354
2015	51,370,602	10.0	5,137,060

Table 6. Amount of Renewable Electricity used to meet Renewable Portfolio Standards in Massachusetts. Note that information on the amounts for 2003-2007 are the recorded amounts, whereas amounts for 2008-2015 are projections. In the coming years the amount of renewable energy is likely to increase in two different ways—first because overall demand increases, and second, because the percentage required by RPS increases. However, the DOER has projected that the demand for electricity will decrease, due to energy efficiency programs. (83 Department of Energy Resources 2008, 13)

Government that supports renewable energy development (Department of Energy Resources 2008, 1-23).

In order to push for the construction of new sources of renewable energy, Massachusetts limited the type of facility that could earn MA RPS qualified RECs to those that commenced commercial operation after 1997 (with some exceptions). In addition, only facilities that are powered by certain low-emission biomass technologies, landfill and anaerobic digester gas, wind energy, and solar PV can qualify. Three of the renewable energy technologies at DITP currently qualify as RECs—the anaerobic digester, the solar PV, and the wind turbines. The revenue from RECs was considered in the preparation of pay-back timelines for solar PV and wind turbines.

Since RPS did not exist at the time of the design of the ADG system, REC revenue was not considered in the decision to build the digesters at DITP (Department of Energy Resources 2008, 1-23).

Other major initiatives stem from the priorities of the current Governor, Deval Patrick. Governor Patrick has used many different aspects of his power to push forward renewable energy and energy efficiency programs, including the Global Warming Solutions Act¹³, Executive Order 484¹⁴, and by joining the Regional Greenhouse Gas Initiative¹⁵. All of the programs target the reduction of fossil fuel emissions and energy use in various ways. The major reasons for these acts are variously listed as becoming a leader in clean energy, creating jobs, and addressing the threat of global warming.

Several policies directly address reducing energy use and greenhouse gas emissions by setting reduction targets. The first to be implemented was Executive Order 484: Leading By Example-Clean Energy and Energy Efficient Buildings in 2007. This act requires all Commonwealth agencies are required to reduce greenhouse gas emissions as well as energy and water use. In addition, Executive Order 484 targets many energy issues dealing with physical infrastructure such as requiring new large construction and renovation projects to meet MassLEED plus standards, conduct energy efficiency reviews in existing large buildings, and to conduct training on sustainable practices (Patrick 2007). Following shortly thereafter, in August of 2008 The Global Warming Solutions Act set the specific target for the reduction of

¹³ *An Act Global Warming Solutions Act of 2007*, Massachusetts Senate No. 534, Chapter 298 of the Acts of 2008

¹⁴ *Executive Order 484: Leading by Example- Clean Energy and Energy Efficient Buildings*, Office of Governor Deval Patrick, MA (2007)

greenhouse gases produced by Massachusetts—80% reduction from 1990 levels by 2050-- through more gradual reduction targets, such as up to 25% by 2020 (Office of Governor Deval L. Patrick 2008).

Governor Patrick also joined the Regional Greenhouse Gas Initiative (RGGI) in 2007, which had been seen as too restrictive by the previous Governor, Mitt Romney. RGGI is a collaboration of northeastern states dedicated to documenting and trading carbon credits between coal-, oil-, and gas-fired electricity power plants. Development of the RGGI began in 2005 as Memorandum of Understanding between the governors of Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont. With the addition of Rhode Island and Massachusetts in 2007, RGGI states total 9% of the US emissions of carbon dioxide from fossil fuels, the gas RGGI covers. The RGGI begins with a period where emissions are capped at current levels, then reduced gradually by approximately 35% over by 2020. Power plants may buy and sell allowances, according to their needs (Ruth et al. 2008, 2279-2289).

Attaining the goals outlined by these acts requires prioritizing renewable energy and energy efficiency in funding allocation and economic development. One source of support for implementing these initiatives comes from the Act Relative to Green Jobs in the Commonwealth, hereafter referred to as Green Jobs Act¹⁶. The Act mandated an analysis of state owned lands for their potential for renewable energy installations and has discovered 947 MW of potential at 44 locations so far. In addition, the Act offers financial support of up to \$58 million for green energy technology and research (Massachusetts Department of Energy Resources 2009);(Office of Governor Deval L. Patrick 2008). In addition, preference for the allocation of Commonwealth

¹⁶ *An Act Relative to Green Jobs in the Commonwealth*, HB 5018, Chapter 307 of the Acts of 2008.

Capital is based on adherence to Smart Growth principals. Commonwealth Capital is the primary state level source of grants for municipalities in Massachusetts for development projects. The Smart Growth Principles were outlined to increase “sustainable development through integrated energy and environment, housing and economic development, transportation and other policies, programs, investments and regulations” (Gaertner et al. 2007). These priorities, also called Sustainable Development Principles, are largely the same as those laid out by Governor Mitt

Romney, when he established the Office of Commonwealth Development, as shown in Table 7. However, “Promote Clean Energy” is distinctly new, reflecting a change in priorities for development (Gaertner et al. 2007;

Smart Growth Principles	
2007	2003
Concentrate Development and Mix Uses	Redevelop First
Advance Equity	Concentrate Development
Make Efficient Decisions	Be Fair
Protect Land and Ecosystems	Restore and Enhance the Environment
Use Natural Resources Wisely	Conserve Natural Resources
Expand Housing Options	Expand Housing Opportunities
Provide Transportation choice	Provide Transportation Choices
Increase Job and Business Opportunities	Increase Job Opportunities
Promote Clean Energy	Foster Sustainable Businesses
Plan Regionally	Plan Regionally

Table 7. Change Over Time in the Ten Smart Growth Principals. Note the increasing attention to clean energy. [Smart Growth/Smart Energy Toolkit, 2007. & Smart Growth Resources for Cities and Towns, 2003]

Romney, Healy, and Gottlieb 2006).

Principles similar to those outlined as Smart Growth have been used most recently to prioritize projects that many receive American Recovery and Reinvestment Act (ARRA)¹⁷ funds. All of the projects included in the Mobilization for Federal Economic Recovery Infrastructure Investment Report supported The Guiding Principles outlined by the governor. These principles include investing for the long term, limiting impacts on operating budgets, buying from in-state

¹⁷ American Recovery and Reinvestment Act of 2009, P.L. 111-5, 123 Stat. 115 (2009)

sources as well as Executive Order 484¹⁸. Other projects were sponsored by agencies ranging from the Massachusetts School Building Authority to the Massachusetts Transit Authority, suggesting the widespread ability of development proposals to comply with the Guiding Principles and Executive Order 484 (Commonwealth of Massachusetts FERII Task Forces 2009). The MWRA ultimately received \$9.2 million for four renewable energy projects. These projects include the 180 kW photovoltaic installations at DITP, a photovoltaic installation at Carroll Water Treatment Plant, an in-pipe hydroelectric system at the Loring Road facility, and a wind turbine at DeLauri Pump Station. In total, the MWRA will receive \$32,000,000 in ARRA funding through the State Revolving Fund, which will ultimately cover \$40.9 million in debt service payments (Massachusetts Water Resource Authority 2009, 1-14, Appendices 1-8).

In addition to general programs for renewable energy, Massachusetts has developed a few programs that promote specific types of renewable energy. Governor Patrick set the goal for the installed capacity of solar power in Massachusetts to be 250 MW by 2017. Two programs that support the installation of solar power technologies are Solar Power Purchase Agreements and Commonwealth Solar. In Solar Power Purchase Agreements, a private entity installs and operates solar panels on another entity's property. The solar installation company then sells electricity back to the host organization. This arrangement allows the solar installation company to pursue tax credits and Commonwealth Solar rebates that may or may not be available to the host organization (Commonwealth Solar and Solar Energy Business Association of New England 2009). In addition to Purchase Agreements, the state government established the Commonwealth Solar program. Commonwealth Solar has provided rebates for 23 MW of solar

¹⁸ The total proposed budget for shovel-ready projects (\$1, 5159, 289,990) included \$10,000,000 for two additional 600 kW Wind Turbines at DITP, \$6,800,000 for 800 kW solar photovoltaic panels, and \$1,000,000 for lighting improvements and efficiency upgrades. So far this has resulted in pushing the 180 kW solar photovoltaic project forward, by funding \$735,000 through the SRF.

power to 1,200 groups, including municipalities, private individuals, and businesses. Rebates range from \$0.50/watt direct current to \$1.50/watt based on the total capacity of the system. Commonwealth Solar is operated by the Massachusetts Clean Energy Center, which was created in 2008 as part of Governor Patrick's Green Jobs Act and is part of the Massachusetts Technology Collaborative (Massachusetts Clean Energy Center 2010). Between 2007 and 2009, companies in the Solar PV industry added 2,000 jobs in Massachusetts¹⁹. In 2009 Massachusetts announced the expansion of Commonwealth Solar to include \$8 million in ARRA funding (Wall 2009, 1).

A similar program, Commonwealth Wind, offers a total of \$38,990,000 million over four years (FY09-FY13) in rebates for wind installations. The categories for installations include residential/micro, community, and commercial. Both Commonwealth Solar and Commonwealth Wind come from the Renewable Energy Trust, a designated state fund for renewable energy financing. The State government intends that Commonwealth Wind will help promote the

installation of 2,000 MW of wind power by 2020

(Massachusetts Department of Energy Resources 2009).

In addition to direct funding for wind power,

Massachusetts competitively bid to be the site of the Wind Technology Testing Center

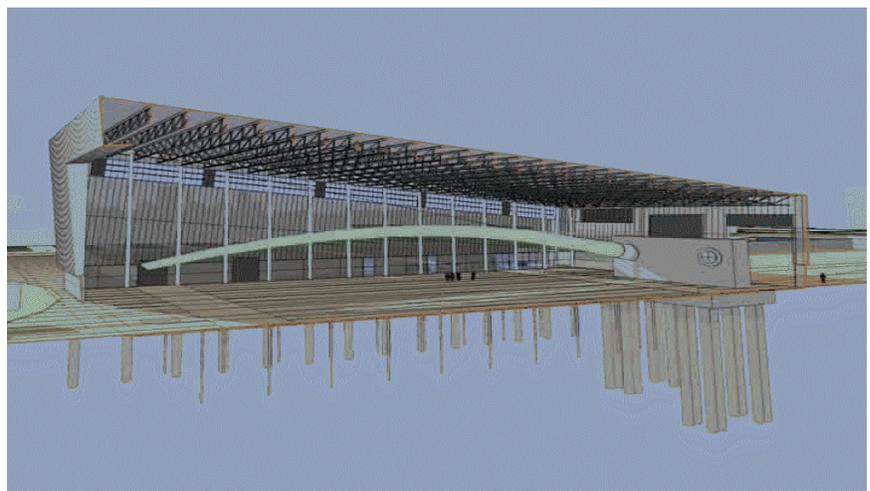


Figure 10. *Cross-sectional view showing interior and foundation sub-structure.* Initial Design for the Wind Technology Testing Center. While the WTTC will be operated by the National Renewable Energy Lab, the government of Massachusetts anticipates that the WTTC will focus wind power technology and development in Massachusetts. This focus would support several Massachusetts renewable energy initiatives including the 2008 Green Jobs Act (Massachusetts-NREL Wind Technology Testing Center Pamphlet 2009, p 1)

¹⁹ The survey covered 98 companies (Carter 2009).

(WTTC). The National Renewable Energy Laboratory is developing the WTTC to test wind turbines and develop wind power technologies (National Renewable Energy Laboratory 2007).

In addition to targeting specific renewable energy technologies, Massachusetts has created programs targeted at the renewable-energy and energy-efficiency potential within certain industries. In 2007, Massachusetts began the Energy Management Pilot program for publicly owned treatment works (POTWs). The Pilot's objective is to study the energy use at 14 drinking water and wastewater facilities and then to develop strategies for them to reduce by 20% the greenhouse gases associated with plant operations. Although the Pilot involves a partnership between multiple organizations, it is housed within MassDEP. EPA Regions 1, the EOEEA, and DOER have helped to sponsor and guide management of the project. The Massachusetts Renewable Energy Trust, the Consortium for Energy Efficiency, and the University of Massachusetts at Amherst have provided technical support and studies. In addition, major utilities provided energy audits for electricity, natural gas, and fuel oil (Massachusetts Department of Environmental Protection 2008, 02/20/2010). Thus far, the Pilot has completed energy audits and reduction strategies for each facility. In addition to energy efficiency, the strategies include adding 4.6 MW of solar photovoltaic installations, 2.4 MW of wind power (on Cape Cod), 140 kW of in-pipe hydroelectric power, and 165 kW of Combined Heat and Power generation from biogas. Currently, the Pilot is focused on attaining funding for these projects from the State Revolving Loan fund, DOER's Energy Conservation Improvement and Alternative Energy funds, MTC Renewable Energy Trust grants, and the ARRA (Massachusetts Department of Environmental Protection 2009).

Overall, the Government of the Commonwealth of Massachusetts has created many different mandates, initiatives, and programs for renewable energy and energy efficiency across

the state. The goals, including the GWSA and Executive Order 484, provide specific numerical criteria for different entities within the state to achieve. Financial incentives, including programs such as Commonwealth Solar and Wind, reduce the barriers citizens, communities, and businesses often encounter while implementing renewable energy. Programs such as the Energy Management Pilot not only push specific facilities to achieve their goals, but also set an example for other similar facilities across the state. The state has made a demonstrable effort to increase the renewable energy research and development, working with manufacturing and research centers to make Massachusetts their location of choice. Essentially, the state has developed a mutually reinforcing interplay between the goals, incentives, and opportunities.

3.0 Analysis

The Deer Island Wastewater Treatment Plant has successfully integrated multiple forms of renewable energy technologies into its facilities. Examining the factors that made this possible provides key insights into how other facilities may have similar successes. This section will analyze the factors that provided the impetus for renewable energy and the factors that provided the support for the attainment of renewable energy goals. These factors fall into three general categories: environmental protection, financial, and socio-political.

3.1 Impetus and Support for Renewable Energy at DITP

3.1a Environmental Protection Impetus for Renewable Energy

An analysis of the reasons for installing renewable energy at DITP shows that the desire to protect the environment has been one of the major factors behind the push for the development of renewable energy. However, the specific focus of those environmental protection efforts has changed over time, progressing from water quality issues to anthropogenic global warming.

Initially, environmental concerns were focused on water quality at DITP. Anaerobic digester technology had been in use in the previous treatment facility (built in 1968) and was already a widely used method for sewage treatment. In the preexisting plant, anaerobic digestion served the primary purpose of reducing the volume of sewage sludge and the harmful bacteria within it. The facility siphoned off the digester gas produced to use as fuel. The lawsuits and clean water legislation of the 1970s and 1980s confirmed the importance of the role of anaerobic digestion. In particular, the Clean Water Act made releasing sludge to the harbor illegal, so all sludge ultimately now had to be disposed of on land. This made anaerobic digestion even more crucial to reducing the volume and toxicity of the sludge (Dolin 2004). Thus, anaerobic digesters were

installed to directly enhance the intended environmental protection function of the DITP facility while also reducing the operational cost of the plant.

Unlike anaerobic digesters, hydroelectric turbines do not explicitly aid the wastewater treatment process. However, the turbines are thoroughly incorporated in the plant's processes. The turbines recapture the energy used by pumps that lift water to begin the water treatment process, by recapturing the energy left in water as it drops down at the end of the process. Also, at some facilities, hydroelectric turbines have been installed in place of pressure-reducing valves that help control the flow rate (Patneau 2010a). This may have been the case at DITP, where moderating the flow in the outflow tunnel is important to ensure equal and low levels of mixing in the outflow caps. Most importantly, the primary function of the turbines is to generate electricity for the facility (Massachusetts Water Resource Authority 2009). This installation shows increased interest in on-site renewable energy compared to the previous plant.

Producing renewable energy on-site is the main goal driving the installation of solar PV arrays and wind turbines and reflects the more recent focus in environmental protection on global warming due to an increase in greenhouse gases. This objective is clear; solar PV and wind turbines were installed for stated environmental protection reasons but are not integrated into wastewater treatment processes. Both solar PV and wind technology were installed during a period of increasing concern about energy security, and global warming. This concern led to an increase in political action and funding that promoted renewable energy. The first solar PV array and wind turbines came out of MA DOER studies on the potential for renewable energy at state facilities (wind: 1996; solar, 2006). Much of the funding used to install the turbines comes from grants and loans designed specifically for renewable energy (e.g., CREB, DOER, Clean Water State Revolving Loan Fund). The solar and wind systems were installed after the 2007 statement

by the Executive office of Environmental and Energy Affairs that greenhouse gases are harmful to the environment (Massachusetts Environmental Protection Act 2009). Since then, the state government has showcased the solar PV and wind-generated electricity at DITP in announcements regarding greenhouse gas reduction such as those about Executive Order 484 (Office of Governor Deval Patrick 2009).

The change in renewable energy systems at DITP over time parallels changes in national environmental protection priorities. The Boston Harbor Project is the direct outgrowth of national legislation regarding water quality, namely the Clean Water Act. Therefore, it is not surprising to note that the first types of renewable energy at the plant supported the wastewater treatment facilities. As Boston's water quality became a less pressing issue, resources could be diverted to address the growing concerns over anthropogenic global warming and energy security.

3.1b Political Support for Renewable Energy at DITP

Over the past decade, Massachusetts chose to create the mandate, funding, and support for reducing greenhouse gases at state facilities such as DITP. Section 2.5 of this paper outlines the variety of legislative, financial, and technological initiatives Massachusetts developed in order to promote renewable energy and greenhouse gas reductions. These programs reinforce each other and represent a multi-sector approach towards achieving state-wide goals. On reviewing the objectives of these renewable energy efforts, it is apparent that several different factors led to the prioritization of greenhouse gas reduction.

As addressed in the previous section, the state government considers greenhouse gases harmful pollutants that lead to global warming, a particularly serious threat to the Massachusetts

coastal areas. Therefore, the state declared greenhouse-gases pollutants and took measures to regulate them both at state-affiliated facilities, through Executive Order 484, and across the state, through the Global Warming Solutions Act. However, greenhouse gas emissions are a global issue. The Massachusetts Government acknowledges the powerful role states can have in driving national policies, as in the example of *Massachusetts v. EPA*. By addressing its own emissions, Massachusetts exemplifies the behavior it would like to see from the federal government, other states, and its own citizenry (Patrick 2007).

In addition to the environmental protection aspect, there may be economic advantages to encouraging the renewable energy industry. The Patrick/Murray administration sees Massachusetts as poised to develop its renewable energy industry, because of the concentration of scientists, engineers, and other skilled laborers within the state. This support comes in many forms. Some forms of support encourage renewable energy businesses by guaranteeing a demand for their product. Executive Order 484 guarantees that state facilities will purchase and install renewable energy systems in the coming years. In addition, the state Renewable Portfolio Standard guarantees that electricity utilities will have increasingly larger portions of their supply from renewable energy. Other forms of support are more specific to certain industries, such as a state financing package to attract Evergreen Solar to Massachusetts (Office of Governor Deval L. Patrick 2008). Developing the renewable energy industry creates more skilled and high-tech jobs, which is in anticipation of industry growth on a national scale.

Finally, developing renewable energy in Massachusetts is also a matter of developing a more self-reliant energy supply. Massachusetts, along with the rest of New England, lacks substantial fossil fuel resources. In the past half century, concerns have grown over the reliability of the energy supply. Imports may be interrupted or prohibitively expensive in the near future due to a

combination of international politics and decreasing reserves (Boyle 2004). Energy security, along with environmental protection and economics, has influenced Massachusetts' decision to prioritize renewable energy.

In general, renewable energy installations at any state-affiliated facility support Massachusetts' energy goals. The surprising point remains why DITP has received so much focus and money for solar PV and wind turbines renewable energy. However, within the state-wide focus on renewable energy, the Government of Massachusetts has directed a considerable amount of resources to the MWRA for use at DITP and other facilities. The factors leading to this direction of resources have to do with the physical geography of the DITP site, its public nature, and MWRA management.

The site on which DITP is located has both the wind and space needed to operate wind turbines. DITP is located on a peninsula (formerly an island) that juts into Boston Harbor. As a result, the high potential for wind power stood out among other locations within Massachusetts in DOER studies (1996, Patneau). Additionally, there is space to install wind turbines and solar PV arrays on unused tracts of land, including a parking lot on the southeast corner, and large roofs. With some unused space and appropriate wind velocities, DITP meets the physical requirements to install solar PV and wind turbines.

Next, DITP stands out among state facilities as particularly visible, on both a literal and figurative level. Figuratively, the MWRA and DITP are well known because the MWRA provides water and wastewater treatment services for 40% of the 6.5 million residents of Massachusetts (US Census Bureau). Everyone within the DITP service area receives bills from the MWRA for this service. Therefore, millions of people have a vested interest in reducing the

energy demand and operating costs at DITP. In addition, each of these customers receives an annual update on water quality, which includes various facility upgrades, such as renewable energy installations. On a more literal level, the DITP is a visible symbol to all residents and visitors to Boston. All passengers flying into Logan airport and all spectators touring Boston Harbor have a view of the Anaerobic Digester Tanks and wind turbines. This visibility promotes Massachusetts as a leader in renewable energy and adds a dimension of climate-protection to the image of the Boston Harbor Project, which is already known as an environmental success.

There is no definitive reason why Massachusetts has prioritized renewable energy—the reasoning has been multifaceted, involving environmental concerns, economic development, and energy security. The programs put in place supporting renewable energy encourage organizations such as the MWRA and private businesses to continue expanding their renewable energy. Thus, considering the advantageous physical site, public nature, and organized management of the DITP, it is little surprise that it should emerge as a facility that has high levels of renewable energy.

3.1c Organizational Support for Renewable Energy within the MWRA

One of the most significant elements of political support for renewable energy at DITP appears to have been creating the MWRA to take over the water management role of the MDC. The structure and funding of the MDC was not conducive to the innovation and capital needed for renewable energy. Legislative control of the budget and salary-scale also contributed to chronic understaffing, under-qualified employees, and poor maintenance and prohibited long-term planning. Viewing the structure and funding of the MCD as a barrier to renewable energy clarifies the important sequence of events that lead to the creation of the MWRA.

Although the water quality in Boston Harbor had been known for centuries to be very poor, the Massachusetts government chose to improve it through incremental measures. These included the installation of only primary treatment and the setting of water quality standards that were high enough so as not require secondary treatment. The Clean Water Act amendments overruled the Massachusetts water quality standards and mandated secondary treatment. Thus, while the EPA considered the MDC's application for an exemption from secondary treatment, the water quality in Boston Harbor remained worse than the federal standard. Boston Harbor's nonattainment status paved the way for the lawsuit from the City of Quincy. The lawsuit examined the work of the MDC and determined that it would not be able to meet the EPA standards in its present form. In recognition that the fundamental problem with water supply and treatment was the structure of the organization in charge of it, the courts decided that the best conclusion of the suit was to create a water management authority, the MWRA. By transforming the organization in charge of Metropolitan Boston's water treatment into an *authority*, the courts provided the key tools not only for a successful water treatment system, but also for installation of renewable energy technologies.

The MWRA's managerial and financial structures have greatly contributed to renewable energy installation. First, the management structure of the MWRA gives it the authority to develop and implement long-term goals which means that the MWRA can execute projects it feels are a priority. The MWRA is organized much more like a business than a typical state agency. Rather than being controlled by bureaucrats who report in successively higher levels to the legislature and governor, the MWRA has a Chief Executive Officer and a Board of Directors. Having a CEO to manage daily and shorter-term operations increases the speed and efficiency of the organization. The Board of Directors reviews and manages the overall direction of the

organization, and communicates with the communities supplied by the MWRA. The state government is involved, but is limited to the Board of Directors. This autonomy enabled the MWRA to invest in developing strategies for energy reduction before the state made renewable energy and energy efficiency a priority. The autonomy also increased the speed of wind and solar projects, allowing them to move forward as soon as the funding and approval became available. Autonomy may have also contributed to the installation of the in-pipe hydroelectric turbines and the egg-shaped anaerobic digesters. These two technologies were relatively unprecedented in the US and may not have been implemented if brought before the state legislature.

Second, as noted above, the ability to raise large amounts of capital has been crucial in giving the MWRA the means to invest in renewable energy. Electricity production from fossil fuels generally requires less of an initial investment, but greater annual payments for fuel. This is in direct contrast to renewable energy technologies, which generally require a large initial investment, but no annual fuel costs(Boyle 2004). When the MDC relied on the state legislature to determine its annual budget, it rarely received enough funding for essential operations, maintenance, and personnel. This record indicates that additional projects that were not necessary for daily operations would not have been approved. With the ability to raise capital (through tax-exempt bonds and rate increases) and autonomy over long-term projects, the MWRA has been able to pursue renewable energy.

Finally, having the resources to hire and train qualified staff has been crucial for the success of renewable energy at DITP. The personnel at the MWRA have played a key role in developing renewable energy and energy efficiency strategies and in taking advantage of the resources for renewable energy that are made available by the state. The MWRA has created an energy task force continually evaluates opportunities for renewable energy and then matches them to new

grants, loans, and programs. For example, by late 2008 the MRWA had a list of solar PV projects that would be built if the funding became available. Thus, the MWRA was able to submit some of these projects to the DOER to be included in the list of state projects that were “shovel-ready” to receive ARRA Stimulus funding. Another example of the MWRA’s successful management includes the alacrity with which they installed the first PV array (one year prior to all other state facilities receiving funding). Outside of the energy task force, people who work on the ground in the DITP facility have suggested several key energy reduction ideas, including the installation of more energy-efficient pump systems (Patneau 2010a).

One additional factor that contributed to the MWRA’s success with the Boston Harbor Project (and thus with renewable energy) was court supervision of its timeline. After the MWRA was formed, the EPA sued it for noncompliance with federal water quality standards. Since the MWRA had just taken control of water treatment from the MDC, the solution to the suit was judicial oversight of the planning and implementation of a strategy to bring Boston’s waters into compliance. It is not unreasonable to suggest that without this external and legally binding oversight, the Boston Harbor Project would not have been as well executed or timely.

Due to the restructuring of the MDC into an economically independent authority with control over staffing, salaries, and long-term planning, the MWRA has been a leader in taking advantage of renewable energy opportunities in Massachusetts. While Massachusetts has prioritized renewable energy in the past decade, renewable energy installations at DITP may not have happened without the managerial and financial independence of the MWRA.

3.1d Financial Support for Renewable Energy at DITP

Compared to fossil fuel sources of energy, renewable energy often faces prohibitively large capital costs. Thus, even if an organization has the will to install renewable energy and develops the plans to do so, a lack of funding for those projects often serves as the final deterrent. An analysis of funding for renewable energy at DITP reveals that MWRA has used two different methods to overcome funding issues. The first method is subsuming the cost of renewable energy technology into another necessary project. The second is utilizing alternative funding programs that mitigate the amount of money the MWRA needs to pay upfront for the technology. These two methods were useful during different time periods, indicating that funding renewable energy is a flexible endeavor.

The MWRA used the first method, subsuming renewable energy costs within larger construction projects, during the development of the BHP. Within the context of the BHP, anaerobic digesters were an essential mechanism to reduce the volume of sewage sludge that needed to be disposed of. In addition, siphoning off ADG for heating fuel and electricity generation had been successful at the previous facility on Deer Island. The combination of needing anaerobic digesters and knowing that ADG could be used for electricity made the incorporation of ADG utilization technology part of the initial plans for the facility. Viewed in isolation, this is not surprising. However, as section 3.6 shows, the DITP is one of only a handful of POTWs that has successfully incorporated the technology to utilize ADG. In a similar manner, the cost of installing hydroelectric turbines was subsumed by the larger project of building an outflow tunnel. It is important to note that retroactive installation of renewable energy may have led to additional costs associated with the disruption of services, tearing down and rebuilding existing infrastructure, and adapting the technology to fit the existing conditions of the facility. Therefore, by incorporating these technologies into the multibillion-dollar BHP, the MWRA not

only made them seem relatively less expensive, but also eliminated the costs that surely would have been associated with retroactive installations.

The MWRA used the second funding strategy, for solar PV and wind turbines. Two factors made it impossible to subsume solar and wind installation costs into a larger project. First, the plans to install wind turbines and solar panels began long after the majority of the design and construction of the BHP. Second, in their present form, solar panels and wind turbines are not as physically integrated into DITP operations, which reduced the financial advantage of building them at the same time as the entire facility. As a result, the MWRA sought funding from loans and grants in order to make the payments reasonable enough to begin the projects. In its most generous form, a reasonable financial payback means that the technology will at least repay its building costs to build through energy savings over the course of its lifetime.

Several specific state programs were particularly important for making the solar PV and wind technology a viable financial investment for the MWRA. Foremost among these are Renewable Portfolio Standards (RPS). On the one hand, having an RPS system helps to establish renewable energy, because it guarantees a market for renewable energy. This market provides renewable energy suppliers the opportunity to sell Renewable Energy Credits, which shorten the payback time for renewable energy technologies by increasing the revenue that they generate. On the other hand, RPS systems can directly fund renewable energy if noncompliance payments are used for renewable energy grants and loans, as is done in Massachusetts. Beyond RPS, solar panels and wind turbines at DITP were partially funded by government grants from the DOER and MTC as well as CREB and SRF low interest loans for renewable energy. In some regards, a zero- to low-interest loan on a renewable energy investment makes its long-term cost comparable to fossil fuels. Such loans decrease the capital cost by increasing the annual payments, in effect

mimicking the annual cost of fuel for fossil fuel sources. Without funding options such as these, the renewable energy technologies would have had too long of a payback period for the MWRA to install.

The example of why and how the MWRA went through two distinct methods for securing the funding to install renewable energy resources, suggest that there is no single solution to the problem of securing enough funding for renewable energy technologies. Both the timing of the installation and the specific technology to be installed play a role in determining what may be successful. Overall, the case of the DITP supports the incorporation of renewable energy technologies in the design/construction of facilities and seeking financial support from outside sources to reduce the pay-back time.

3.2 Other Trends Indicated by the DITP

The insights apparent within the renewable energy at DITP indicate two important ideas for the rest of the country. First, the greatest potential for renewable energy may lie in the physical integration of renewable energy technologies into the physical systems of infrastructure. Such technologies take advantage of the physical, chemical, and mechanical energy that is being transferred by the major operations of the facility. Second, the greatest force pushing renewable energy forward may be the ideological integration of climate change into the realm of environmental protection. Essentially, this means that while the greatest advances in renewable energy may lie in taking advantage of existing systems, they will not be pursued unless those allocating resources believe that installing renewable energy is a priority.

At the DITP, the most physically integrated systems, the anaerobic digesters, hold by far the most potential for renewable energy. Similarly, the hydroelectric turbines were built as part of the outflow tunnel and offer the second largest amount of energy. Since the ADG/STG and

hydroelectric systems offset such a large amount of annual energy costs and were built as part of the plant, they were financially worth pursuing. The solar PV and wind systems are not integrated into the physical processes of DITP. As of now, they both provide less energy than the other renewable systems. The solar PV and wind systems clearly stem from the prioritization of renewable energy by both the MWRA and the government of Massachusetts for environmental protection and energy security issues.

3.3 Additional Notes on the Potential for ADG and In-Pipe Hydropower

Although this paper has covered renewable energy from four different sources, ADG and in-pipe hydropower stand out as unique to POTWs. While solar photovoltaics and wind turbines are generally placed on the outside of buildings, ADG and hydropower technologies at DITP are integrated into the mechanical processes of the facility. Since the processes at DITP are common to POTWs across the country, other POTWs may possess the same potential for renewable energy integration. Considering that POTW's account for 3% of total US electricity consumption and that 30% of most POTW budgets goes towards electricity, there is a demonstrated need for on-site electricity production(Grumbles 2008).

3.3a Anaerobic Digester Gas

The potential for utilizing anaerobic digester gas depends on the amount of wastewater a POTW treats. Five million gallons per day is seen as the lower limit needed to make the capture and use of anaerobic digester gas feasible from an economic and technical standpoint. Out of the 16,000 municipal POTWs in the US, over 1,000 have a capacity of over five million gallons per day. Of these 1,000, only 544 POTWS actually use anaerobic digestion to reduce the volume of their solid waste. Of these 544, only 106 utilize the anaerobic digester gas for electrical and thermal

energy production²⁰. Even within the range of plants above 5 MGD, larger WWTPs tend to utilize anaerobic digester gas more than smaller WWTPs, as seen in the final column of Table 8. Collectively these POTWs could have a capacity of up to 340 MW of electricity (Grumbles 2008)(Eastern Research Group and Energy and Environmental Analysis, Inc., and ICF international Company 2007, 1-42). Based on this information, there is widespread need and potential for utilizing gas at other POTWs.

WWTFs by Wastewater Flow Rates (MGD)	Total WWTFs	WWTFs with Anaerobic Digestion	WWTFs with Anaerobic Digestion and Gas Utilization	Percentage of WWTFs with Anaerobic Digestion that Utilize Biogas
> 200	15	10	5	50
100 – 200	26	17	9	53
75 – 100	27	16	7	44
50 – 75	30	18	5	28
20 – 50	178	87	25	29
10 – 20	286	148	19	13
5 – 10	504	248	36	15
Total	1,066	544	106	19

Table 8. Comparison of the use of anaerobic digestion and digester gas at wastewater treatment facilities in the U.S. There is a total of 1,066 WWTFs with a capacity of over 5MGD, the specified lower limit for feasible anaerobic digester gas utilization. Only 10% of the facilities use anaerobic digester gas for electric or thermal energy (From EPA Combined Heat and Power Project 2007, p. 3).

There are three different technologies available for combined heat and power from anaerobic digester gas—microturbines, fuel cells, and internal combustion engines. Research has shown that the fuel cell CHP technology may yield the highest electrical efficiency (0.43) and thermal efficiency (1.95). However, micro-turbine and internal combustion CHP systems are more common because they are less expensive to install and operate, as demonstrated by the Fuel Cell Project at DITP (Easter Research Group/EPA CHPP 2007).

²⁰ Facilities with anaerobic digestion that do not burn the ADG for heat and electricity typically flare off the gas or release it the atmosphere according to environmental regulations (Eastern Research Group/EPA CHPP 2007).

Although the potential for utilizing anaerobic digester gas at POTWs is substantial, it is important to note that there are many other sources of methane. Any facility that has to deal with the decomposition of organic matter may be able to utilize the technology. Examples with notable success are landfills and animal farms (Eastern Research Group and Energy and Environmental Analysis, Inc., and ICF international Company 2007, 1-42). It is also important to note that while anaerobic digestion may provide a substantial amount of heat and power to one facility; it does not constitute a large portion of the total methane release to the atmosphere from anthropogenic and natural sources. A 1998 study of methane production in Massachusetts compares the relative significance of the following sources of methane: wetlands, active landfills, closed landfills, ruminants, residential wood combustion, motor vehicles, manure, natural gas, and wastewater treatment. Soils that may serve as a potential sink of methane were also studied. In Massachusetts, landfills produced 88%²¹ of total state emissions, measured in grams per year, and wetlands produced 7%. Wastewater treatment produced the equivalent of only 0.07% of total state emissions, 0.3×10^9 g CH₄ yr⁻¹ of methane. Methane sources vary considerable by state. For example, in Maine natural sources of methane far outweigh anthropogenic sources. Landfills produce 10% of Maine's emissions and wetlands produce 82% (Blaha et al. 1999, 243). Although wetlands are a natural and renewable source of methane, it is difficult to capture and utilize the methane with current technologies. The potential for using renewable sources of methane for energy varies greatly based on our ability to capture the methane and convert it into heat or electricity.

²¹ Percent values are calculated from Table 1 on p.249, where total methane emissions is considered the total before sinks are accounted for, rather than the net total, which is listed in the final column (Blaha 2009).

3.3b *Hydroelectric Power*

Many water treatment facilities contain the necessary head and flow required to power hydroelectric turbines. Examples of places within a POTW where conditions might be suitable for hydroelectric turbines include: in the outlet from a reservoir, in pipes between reservoirs, in overflow channels, within a treatment facility, and at the outflow point of a treatment facility.

In conventional hydroelectric power production, flowing water is engineered to pass through turbines—often requiring dams and reservoirs which disrupt the ecology and supply of water both above, around, and below the dam (Boyle 2004). Conventional hydropower produces 2.5% of the national energy supply, although that number is relatively stable or shrinking (Energy Information Administration 2009a; Energy Information Administration 2009a). Integrating hydropower technologies into existing water infrastructure avoids several of the issues associated with conventional hydropower. Since natural flowing waters are not altered with in-pipe hydropower, there is little to no concern about disrupting ecosystems or water supplies adjacent to or downstream of the dam. Thus, facilities seeking to install hydroelectric turbines are not subject to the same level of environmental review and supervision by regulatory departments (MassDEP, 2009). Being largely exempt from licensing and regulation is one advantage in-pipe hydropower has over conventional hydropower.

In addition, in-pipe hydropower generally has a lower capital cost than conventional hydropower. In-pipe turbines utilize wastewater that is already sequestered in reservoirs, so there is no cost in terms of reservoir construction. The waters may not need to be pumped or moved, because they already may have elevation (head) in the POTW. No additional shafts or pipes may be required because the water is already designed to flow in a set area. Finally, some

facilities may even be able to use hydroelectric turbines as a way to moderate the flow of water, in the place of equipment such as pressure-reducing valves.

Innovations in turbine design are allowing for more widespread use of hydropower. The field of hydrokinetics has expanded hydropower to flowing bodies of water that lack head, as in tidal energy or flat river systems. Advances such as these will allow for the expansion of hydropower into more POTWs.

4.0 Conclusion

Implementing renewable energy at the DITP has been the result of several factors relating to the resources and priorities within the MWRA and the Commonwealth of Massachusetts. The initial successes can be seen as a result of the MWRA's acquisition of the financial and material resources. Renewable energy technologies were directly integrated into DITP because they appeared to have a moderate payback period and were in line with the plant's function. However, in order to push renewable energy development when the financial payback is not favorable for private entities to implement it themselves, the Government of Massachusetts and the MWRA have had to address several issues. The way that both entities responded to these issues could help inform the actions of other leaders of private and public organizations. The conclusion of this thesis summarizes these issues in an effort to guide other organizations through the process of implementing renewable energy.

4.1 Developing a General Model for Renewable Energy Implementation

The general process of installing renewable energy at DITP can be described in terms of the following steps. First, the financial and managerial structures were put in place to allow for innovation within the MWRA. Next, the options for integrating renewable energy technologies into the plant were developed. Then, reducing fossil-fuel use and establishing renewable energy became an explicit priority for a variety of reasons. In order to act on this priority, the government created specific goals for the MWRA, as a state agency through Executive Order 484 and through the Global Warming Solutions Act. With specific energy goals, the State channeled human and capital resources toward renewable energy projects and structures, which led to the more efficient, and widespread renewable energy installations. Finally, by

emphasizing public examples of success, Massachusetts and the MWRA have tried to maintain public support for their energy initiatives.

This process represents a general pattern that may be a successful way of thinking about renewable energy and energy efficiency across the US. In order to extrapolate from DITP, the set of processes must be generalized to become applicable to organizations in every stage of the implementation of renewable energy and energy efficiency projects. Such a rephrasing could be:

1. Have renewable energy and energy efficiency projects that present short-term financial gain been developed and implemented?
2. Is renewable energy an institutional priority?
3. What are the specific renewable energy goals the institution would like to achieve?
4. Are the resources and processes in place for renewable energy projects?
5. How can public interest and support of renewable energy projects be maintained?

Developing the answers to these questions should help organizations focus their efforts and evaluate whether they have addressed the fundamental barriers to renewable energy. Table 9 compares a sampling of the actions taken by the MWRA, the Commonwealth Massachusetts, and the Government of the United States within the framework of the questions posed above.

Table 9. Comparative Summary of Renewable Energy Initiatives <i>Responses by local (MWRA), state (Massachusetts), and federal (U.S. government) levels</i>				
Guiding Question	General Solution	MWRA	Massachusetts	United States
Have the renewable energy and energy efficiency projects that present short-term financial gain been developed and implemented?	<ul style="list-style-type: none"> Conduct an energy audit Upgrade inefficient technologies 	<ul style="list-style-type: none"> Anaerobic digester gas (Heat and STG) 	<ul style="list-style-type: none"> Specific industries, such as the POTWs in the Energy Management Pilot 	<ul style="list-style-type: none"> Some specific areas have been studied, but widespread implementation has not occurred
Are the resources and processes in place for developed and renewable energy projects?	<ul style="list-style-type: none"> Direct Financial support with a payback of <7 years 	<ul style="list-style-type: none"> Energy efficiency Management Projects (pumps, lights, etc.) 	<ul style="list-style-type: none"> State-sponsored funds and funding organization (RET of the MTC) State programs for specific technologies (e.g. CombiSolar) 	<ul style="list-style-type: none"> DOE & EPA funding available to states and individual projects
Is renewable energy an institutional priority?	<ul style="list-style-type: none"> Establish the relative importance of environmental protection and energy security 	<ul style="list-style-type: none"> Created Energy Task Force Created Energy Management Pilot 	<ul style="list-style-type: none"> Established that GHG are pollutants at state level (HoFEA) and national level (EPA) Mandated inclusion of renewable energy in state electricity grid (RPS) REC and RPS non-compliance payments 	<ul style="list-style-type: none"> EPA recognized greenhouse gases as pollutants
What are the specific energy goals the institution would like to achieve?	<ul style="list-style-type: none"> Develop narrative and numerical goals 	<ul style="list-style-type: none"> Install 5 wind turbines 	<ul style="list-style-type: none"> Executive Order 484 Evergreen Solar finance Global Warming 	<ul style="list-style-type: none"> Executive Order 13514 on Federal Sustainability National Renewable Energy Act No national system of

	<ul style="list-style-type: none"> • Industry and Technological support 	<ul style="list-style-type: none"> • Energy Task Force 	<ul style="list-style-type: none"> • Evergreen Solar finance package • Wind Technology Testing Center • Energy Management Pilot 	<ul style="list-style-type: none"> • National Renewable Energy Lab (sponsoring WTTC) • EPA and DOE publications on Energy management (e.g., Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities).
	<ul style="list-style-type: none"> • Evaluate potential across a broad area 	<ul style="list-style-type: none"> • Energy Task Force Solar PV studies 	<ul style="list-style-type: none"> • State wide site evaluations, such as the Online Wind Viewer • State-property feasibility studies (e.g., as part of the Green Jobs Act) • ARRA Task Force Report 	<ul style="list-style-type: none"> • Nation-wide assessments for wind, solar, and hydropower by the National Renewable Energy Laboratory
How can public interest and support of renewable energy projects be maintained?	<ul style="list-style-type: none"> • Focus initial efforts on public areas to spread awareness • Celebrate successes with public events 	<ul style="list-style-type: none"> • Publicized rate-payer benefits of energy reduction in annual report • Created onsite displays about renewable energy 	<ul style="list-style-type: none"> • Installed renewable energy in visible locations (MWRA, Cape Cod Community College, etc.) • Held public events at renewable energy sites. • Installed signage about renewable energy in high traffic areas 	<ul style="list-style-type: none"> • Emphasize in public speeches (e.g. State of the Union, 2010) • Emphasize public benefits (e.g., allocation of money for renewable energy jobs)

4.2 Comments on the Renewable Energy Efforts by the United States Federal Government

As with the Commonwealth of Massachusetts, the United States Government has taken several steps to push renewable energy forward across the nation. Based on the success of renewable energy installations at DITP, the following section offers recommendations for the national government's policies on renewable energy and energy-efficiency.

First, the US Government should develop a plan to implement renewable energy and energy efficiency measures that are known to offer short-term financial payback. Reports such as America's Energy Future have revealed that there are numerous opportunities to reduce the amount of energy the US needs. Implementing the most efficient technologies currently available

could keep US energy needs 30% lower than predicted levels for 2030(Committee on America's Energy Future 2009). Either through direct contact with facilities themselves, or delegation of the responsibility to the states, reduction in unnecessary energy use should be a top priority. In addition, energy-efficiency upgrades may have payback periods on the scale of a few years, so the financial benefits of such reductions could be used to gain popular support for other renewable energy initiatives.

Next, the US Government must continue to clearly present the variety of reasons why reducing fossil fuel-based energy needs is important for the country as a whole. It is important that the government not focus on one reason above the others, because each reason holds a different weight with different constituent groups. Saying that the country must reduce greenhouse gases to slow global climate change will not hold weight with those who do not believe in anthropogenic climate change or feel a responsibility to stop it. Saying that the country needs to increase its energy independence because of the insecurity of relying on foreign petroleum suppliers will not convince those who believe international trade will continue indefinitely without serious interruptions. Saying that the country must reduce its reliance on fossil fuels because they are limited resources will not convince those who are reassured of the abundance of fossil fuels by their relatively low price. However, citing all of these reasons should provide a broad enough base of support to push energy initiatives forward through the various levels of our government.

President Obama has been forthright in describing the variety of reasons why energy issues are important to the country as a whole, both in his policy actions and public appearances, such as the 2010 State of the Union Address (Office of the Press Secretary 2009). However, debates about passing legislation that would set specific targets and programs to reduce greenhouse gas

emissions through renewable energy and energy-efficiency programs have focused primarily on issues related to global warming. That focus has placed the science of global warming at the center of the debate and has required proof from research panels such as the International Panel on Climate Change. Thus, the process for establishing what is often referred to as “climate-change legislation” is often thrown off by reports of conflicting or weak scientific evidence that supports the theory of climate change, as in (Border 2010, A11). Despite the remaining doubts about climate-change, Massachusetts recognized greenhouse gases as pollutants, allowing for greenhouse gas regulatory legislation in 2007 and 2008. The US Government has also taken this step, which gives the EPA the authority to regulate greenhouse gases. Yet Massachusetts has also taken care to emphasize the specific goals for renewable energy industries within legislation. This emphasis has proved beneficial in promoting renewable energy jobs, technology, and rebate programs. Rather than wait for national or international greenhouse gas regulation, national legislation could target specific goals for different renewable energy technologies. This focus would allow the emphasis to shift away from anthropomorphic climate change to energy security and job creation, placing the United States at the center of burgeoning industries.

While emphasizing the variety of reasons why renewable energy technologies should be a national priority, the government should also set a concrete example of how specific goals can be met. In late 2009, President Obama began this process with Executive Order 13514 on Federal Sustainability²², which demands that specific agencies develop their own reduction targets for 2020. Each of the 35 government agencies targeted in the Executive Order 13514 developed their own reduction goals, for a total of 28% reduction from 2008 levels by 2020 (Office of the

²² *Executive Order 13514—Federal Leadership in Environmental, Energy, and Economic Performance*, Federal Register Vol 74, No 194, Doc. E9–24518, October 2009, pp 52117-52127

Press Secretary 2010, 1). Executive Order 13514 acknowledges the both the physical and ideological presence of the government in a similar manner as Governor Patrick's Executive Order 484. Setting standards for government property is a relatively efficient way to impact total US energy use without passing legislation that covers the entire country. Physically, the federal government comprises of 500,000 buildings and 600,000 cars and 1.5% of national spending on energy. Ideally, the federal government could stand as an example to states, businesses, and individuals if this order is successfully executed. The justification for the order includes reducing carbon emissions, but also emphasizes the current amount the government spends on energy (\$28 billion) and the amount that may be saved by the implementation of this policy (\$8-11 billion). In addition to specifically targeting the federal government, nationwide reductions of greenhouse gas emissions by 17% have been proposed by the Obama administration (Office of the Press Secretary 2010).

Having the government set and strive towards specific goals not only shows what is technologically feasible, but it can also establish the resources needed to expand renewable energy more efficiently. In Massachusetts, Executive Order 484 preceded the Global Warming Solutions Act by one year. Programs established to support Executive Order 484 also support the GWSA, showing how renewable energy and energy efficiency programs can build on each other. Therefore, as Executive Order 13514 on Federal Sustainability begins to be implemented, the feasibility of a national policy may become more apparent. For example, in order to carryout Executive Order 13514 the 2008 baseline greenhouse gas emissions must be established. Once established, this data could be used for as the basis for many other policies. Also, the Executive Order 13514 will require widespread implementation of new energy technologies, which will

drive industry and development. In many ways, setting a standard for greenhouse gas emissions reduction for the federal government supports future efforts to create a broader national policy.

Creating a national policy supporting renewable energy need not include regulations that cover all businesses, residents, and organizations within the US. Massachusetts provides the example of Renewable Portfolio Standards, standards that target electricity producers. Currently 33 states have renewable portfolio standards (EPA) that set minimum percentage requirements for the sources of electricity to be from renewable energy. This approach targets the sources used for electricity production, which may be more effective than targeting the multitude of consumers of the electricity. The US Congress has begun considering programs such as RPS as part of a larger energy bill. In June of 2009, American Clean Energy and Security Act (ACES) passed through the House of Representatives²³. ACES proposes to require 20% of electric utilities to be supplied by renewable energy by 2020, roughly \$190 billion in clean energy technology research and development, raise energy efficiency standards, reduce point sources of carbon, and keep energy costs manageable (Committee on Energy and Commerce 2009). The senate has not yet passed ACES. While there is debate over the efficacy of ACES, the experience in Massachusetts with the GWSA and RPS shows that establishing binding legislation with quantitative goals drives renewable energy where it would otherwise have not been considered feasible.

Once such legislation is in place, the MWRA's experience shows that having adequate resources is key for implementing renewable energy when economics alone will not support it. The federal government provides multiple layers and types of resources. Financial support is

²³ *American Clean Energy and Energy Security Act, H.R. 2454, (2009)*

available through grants and loans sponsored by the DOE, EPA, and the ARRA. Technical support is available in many forms from the DOE. For example, reports such as “Opportunities for Combined Heat and Power at Wastewater Treatment Facilities” state where specific renewable energy technologies could reasonably be implemented in the future (Eastern Research Group and Energy and Environmental Analysis, Inc., and ICF international Company 2007, 1-42). However, in order to ensure that organizations consistently have access to these resources, it may be beneficial for the federal government to organize an office for renewable energy implementation. This office could provide either direction or direct support in tailoring the process of renewable energy and efficiency technologies to specific applicants. It might be most logical to have a branch of this office in each state (or operated by states under existing energy agencies) since many of the resources currently available vary by states.

In sum, as the US begins to establish goals for energy reduction, it may be helpful to look at successful examples from around the US. The success of renewable energy and energy efficiency at DITP resulted from the integration of renewable energy technologies into plant facilities and an ideological prioritization of renewable energy. The case study has shown that having both specific goals and the means to achieve those goals is pivotal for success. Whether achieving wastewater goals or implementing a new renewable energy technology, it crucial that an organization have the structural flexibility to plan for the future and raise capital. As the case of DITP shows, there are many opportunities to reduce the usage of fossil fuel, but implementing renewable energy and energy efficiency technologies takes resources, long-term planning, and innovation.

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