SUSTAINABLE SEWAGE

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ABSTRACT

Urban wastewater treatment is an energy intensive process that is typically powered by fossil fuels. Does cleaning up urban waters necessitate such a large carbon footprint? Some leading wastewater treatment facilities are charting a different course with sewage-based renewable energy and a prospect of becoming net renewable energy exporters.

Wastewater contains the potential to be a renewable source of energy that simultaneously reduces carbon and energy costs. The biggest source of potential energy is in biosolids in the wastewater, which can be anaerobically digested to make biogas. This chapter will provide three case studies of best practices in reducing the carbon footprint of municipal wastewater treatment facilities, one from Austria and two from the United States. The chapter will describe the innovations made at these facilities and identify several policy drivers that could accelerate this critical transition from fossil fuels to renewable sewage energy.

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1. INTRODUCTION

Treating large amounts of human sewage is the often-criticized job of the municipal wastewater treatment facility. These facilities are sometimes spurned as bad neighbors, dischargers of raw or partially treated sewage during storms, and the cause of health advisories that keep people away from natural bodies of water. In the process of providing the necessary service of treating municipal sewage, these facilities can also have a large carbon footprint because cleaning municipal sewage is an energy intensive process.[2]

Cleaning up urban sewage, however, does not necessitate a large carbon footprint nor fouled public waters. Some leading wastewater treatment facilities are charting a different course with renewable sewage-based energy and a prospect of becoming net energy neutral, and even energy producers. In light of climate disruption and the need to significantly reduce greenhouse gas emissions, redesigning municipal wastewater treatment to be more sustainable is an area where action is needed and which makes environmental and fiscal sense.

This chapter will show the renewable energy potential hidden in urban sewage, which, if tapped, can simultaneously reduce greenhouse gas emissions and energy costs. There are a variety of potential sources of renewable energy at sewage treatment facilities; but the single biggest source is biosolids, which can be anaerobically digested to make biogas.[3]

Municipal systems around the world, from Birmingham, England to Washington, D.C., are redesigning their sewage treatment processes to produce renewable sewage power.[4] This

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[2] Milwaukee Metropolitan Sewerage District, *Landfill Gas,* http://www.mmsd.com/sustainability/landfill-gas [last visited Jan. 28, 2015].

[3] Water Environment Research Foundation Factsheet, *Energy Production and Efficiency Research – The Roadmap to Net Zero Energy,* at 4.

[4] Emily Atkin, "People in England are Harnessing the 'Power Locked in Poo' to Fuel Their Homes," Climate Progress (Oct. 3, 2014), http://thinkprogress.org/climate/2014/10/03/3575503/the-power-of-poo/ [last visited 10-8-

chapter provides three case studies of best practices that are already being implemented at municipal wastewater treatment facilities. The case studies come from Austria and the United States and cover facilities serving various sizes of populations (from 68,000 to 1.1 million). These facilities are simultaneously reducing dependence on fossil fuels and energy costs. The first case study is of the wastewater facility in Strass, Austria, which has been a net energy producer for a decade. The second case study is of a similarly-sized regional wastewater treatment facility in Sheboygan, Wisconsin, in the United States, which currently produces 90% of its annual electrical needs and 85% of its heating needs.[5] The final case study is the Milwaukee Metropolitan Sewerage District in Wisconsin, in the United States, which is implementing and experimenting with a variety of renewable energy options with a goal of becoming net energy neutral by 2035. The case studies illustrate the energy demands of treating municipal waste, the energy potential contained in the waste, and specific steps facilities have taken to reduce their carbon footprint. The chapter identifies several drivers that have influenced changes at the facilities studied and further opportunities that could accelerate the transition from fossil fuels to renewable sewage power.

2. MUNICIPAL WASTEWATER FACILITIES TRANSITION TO SUSTAINABLE ENERGY

A. Municipal Wastewater Energy Demands

Treating municipal wastewater is an energy intensive process. A municipal wastewater treatment facility with an average flow of 10 million gallons per day uses as much energy as

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14]. A facility in Washington, D.C., is converting sewage gas in order to fuel 11,000 homes in the D.C., Maryland and Virginia area. *Id.*

[5] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].

almost 3,000 average U.S. homes.[6] In addition to a large carbon footprint, all this purchased energy costs a lot of money. In the United States alone, wastewater facilities spend around $4 billion per year for energy.[7] Severn Trent, a company in the United Kingdom, has switched to producing energy from sewage as a way to reduce expenses because "energy is its second-highest operating cost . . . [and harnessing sewage power] "enables the company to save as much as 1.7 million pounds a year on its gas bill."[8]

It is typical for municipal wastewater facilities to meet their energy needs through fossil fuel combustion, and spend a large portion of their budgets on external purchases of energy.[9]

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[6] Author's calculations based on Water Environment Research Foundation Factsheet, *Energy Production and Efficiency Research – The Roadmap to Net Zero Energy,* Table 2, www.werf.org/c/RFP/2013/ENERc13/ENER1_Fact_Sheet.aspx.

Plant Capacity	**Plants Operating at 80% Influent Capacity**		**Plants Operating at 50% Influent Capacity**	
Average Daily	Primary (Source) Energy	Secondary (Site) Electrical	Primary (Source) Energy	Secondary (Site) Electrical
1 MGD	19.6	1,629 kWh/MG	27.2	2,263 kWh/MG
5 MGD	15.2	1,264 kWh/MG	22.8	1,898 kWh/MG
10 MGD	13.3	1,107 kWh/MG	20.9	1,741 kWh/MG
20 MGD	11.4	950 kWh/MG	19.0	1,584 kWh/MG
50 MGD	8.9	742 kWh/MG	16.5	1,377 kWh/MG
100 MGD	7.0	585 kWh/MG	14.7	1,220 kWh/MG

U.S. EPA Energy Star®; WERF, 2011.

For plants operating at 80% influent capacity, primary source energy needs are 13.3 Gj/MG. (13.3Gj/MG * 365 days * 10 MGD = 48545 Gj) (48545Gj = 13484722.2 kWh = primary source energy annually). Secondary source energy needs are 1,107 kWh/MG. (1,107 kWh/MG * 365 days * 10 MGD = 4040550 kWh secondary source energy annually). 4040550 kWh + 13484722.2 kWh = 17525272.2 kWh. (Ave. home uses 6,000 kWh/yr. so 17525272.2/6000 kWh = energy to power 2921 homes annually.

[7] MILWAUKEE METRO. SEWERAGE DIST., SUSTAINABLE WATER RECLAMATION 40 (2012), http://www.mmsd.com/-/media/MMSD/Documents/Sustainability/Sustainability%20Plan.pdf [hereinafter Sustainability Plan]. This chapter is focused on the energy footprint of treating municipal sewage. However, another angle on the water-energy nexus, is the water footprint of energy. The production of electricity from fossil fuels and nuclear energy requires 190,000 million gallons of water per day, accounting for 39% of all freshwater withdrawals In the United States. *Id.*

[8] Louise Downing, "Severn Trent 'Poo Power' Helps Fuel Homes, Save on Costs," Bloomberg (Oct. 1, 2014) http://www.bloomberg.com/news/2014-10-01/severn-trent-poo-power-helps-fuel-homes-save-on-costs.html [last visited 10-8-14].

[9] "As the largest source of U.S. greenhouse gas emissions, CO2 from fossil fuel combustion has accounted for approximately 78 percent of GWP-weighted emissions since 1990, and is approximately 78 percent of total GWP-weighted emissions in 2012." US Greenhouse Gas Emissions Inventory, Executive Summary, at ES-9 (2014). The greenhouse gas emission inventory presents emissions from fossil fuel combustion by "end use sector", but these are so broad (e.g., industrial, commercial, residential) that they do not show the level of municipal waste water treatment. *Id.* at ES-11. As noted above, in the U.S., water reclamation facilities spend around $4 billion for energy

However, as noted earlier, these facilities have the potential to be net energy neutral and to even be exporters of energy. "The energy contained in wastewater and biosolids exceeds the energy needed for treatment by ten-fold."[10] As will be illustrated in the case studies, wastewater treatment facilities can redesign treatment processes to harness this renewable energy and reduce greenhouse gas emissions from fossil fuel combustion. A municipal sewage treatment facility that serves 2.5 million people in England projects that switching from fossil fuels to sewage power will result in a reduction in its "carbon emissions by 300,000 metric tons, the emissions reduction equivalent of taking about 63,000 cars off the road."[11]

The largest source of greenhouse gases (GHG) [12] in the U.S. comes from fossil fuel combustion by the electric power industry.[13] In addition to the GHG emissions associated with the electricity municipal wastewater treatment facilities purchase from the power industry, municipal treatment facilities also produce GHGs when treating wastewater. According to the U.S. greenhouse gas emissions inventory, wastewater treatment (not limited to municipal

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annually. MILWAUKEE METRO. SEWERAGE DIST., SUSTAINABLE WATER RECLAMATION 40 (2012), http://www.mmsd.com/-/media/MMSD/Documents/Sustainability/Sustainability%20Plan.pdf [hereinafter Sustainability Plan].

[10] Water Environment Research Foundation Factsheet, *Energy Production and Efficiency Research – The Roadmap to Net Zero Energy,* at 1.

[11] Emily Atkin, "People in England are Harnessing the 'Power Locked in Poo' to Fuel Their Homes," Climate Progress (Oct. 3, 2014), http://thinkprogress.org/climate/2014/10/03/3575503/the-power-of-poo/ [last visited 10-8-14].

[12] "Greenhouse gases trap heat and make the planet warmer. The most important greenhouse gases directly emitted by humans include CO2 [carbon dioxide], CH4 [methane], N2O [nitrous oxide], and several other fluorine-containing halogenated substances. Although the direct greenhouse gases CO2, CH4, and N2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2012, concentrations of these greenhouse gases have increased globally by 40, 151, and 20 percent, respectively (IPCC 2007 and NOAA/ESLR 2013)." US Greenhouse Gas Emissions Inventory, Executive Summary, at ES-2 (2014).

[13] US Greenhouse Gas Emissions Inventory, Executive Summary, at ES-22 and Figure ES-13 (2014).

sewage) accounts for 2.2 percent of U.S. methane emissions, and 1.2 percent of U.S. nitrous oxide emissions.[14]

Because removing pollutants from municipal sewage is such an energy-intensive process, the first step in becoming net energy neutral is to make the facility more energy efficient. "Approximately, 60% of the energy used at wastewater treatment facilities is for aeration."[15] Changing biological treatment processes "from aerobic to anaerobic or anoxic microbes" contains the greatest potential for energy reductions.[16] The second step is to capture the energy potential contained in the sewage and use it to power the municipal wastewater treatment facility. If more energy exists, it can be exported to other nearby users to replace their dependence on fossil fuel-based energy. The case studies below show how facilities have reduced energy demands to treat municipal sewage and describe several methods for capturing and using sewage energy.

B. Municipal Wastewater Energy Potential

After reducing energy demands, there are a variety of options to harness the energy contained within the wastewater process and use it to meet the facility's remaining energy needs. Municipal wastewater contains three different types of energy that can be harnessed: thermal, hydraulic, and chemical.

> **Thermal energy** is the energy contained in the wastewater which is governed by the specific heat capacity of water.
> **Hydraulic energy** can be of two types. *Potential energy* is the energy due to the water elevation while *kinetic energy* is the energy from moving water (velocity).

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[14] US Greenhouse Gas Emissions Inventory, Executive Summary, at ES-21..

[15] Water Environment Research Foundation Factsheet, *Energy Production and Efficiency Research – The Roadmap to Net Zero Energy,* at 1. Aeration is providing oxygen for a biological system like activated sludge treatment. *Id.*

[16] *Id.,* at 4.

> **Chemical (calorific) energy** is the energy content stored in the various organic chemicals in the wastewater. The organic strength is typically expressed as a chemical oxygen demand (COD) in mg/L.[17]

These potential sources of energy at wastewater treatment facilities can be harnessed and used in at least five ways: 1) fuel cells emit light energy that degrades organic compounds in wastewater, generating electrons that provide a renewable source of electrical power; 2) biosolids in wastewater can be anaerobically digested to make biogas; 3) algae can be grown in nutrient-rich wastewater and harvested to make biofuel; 4) wastewater's thermal energy can be harvested and used for heating and cooling; and 5) wastewater's gravity-driven movement can turn propellers and turbines to produce electricity.[18]

"The most developed opportunity for energy recovery at treatment plants is from biosolids. Unprocessed biosolids typically contain 18,000 kJ/kg (8,000 Btu/lb) on a dry weight basis."[19] The typical way to access this is through anaerobic digestion, where the volatile solids are converted to biogas, and then onsite power generation units convert the biogas to electricity.[20] The heat from the power generation units can be recovered and used to heat the digesters.[21] When combined with energy efficiency improvements to reduce overall demands, biogas production has the potential to move wastewater treatment facilities entirely off of fossil fuels.[22]

Some facilities are following the process used on some 200 farms in the U.S., and creating biomethane, which is an upgraded biogas from anaerobic digestion. "The normal biogas

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[17] *Id.,* at 1.
[18] *Id.,* at 4-7.
[19] *Id.,* at 4.
[20] *Id.,* at 4. This biogas is composed of greenhouse gases (60-65% methane and 35-40% CO^2). *Id.*
[21] *Id.*
[22] Malin Jonasson, Dep't of Indus. Elec. Eng'g & Automation, Lund Univ., Energy Benchmark for Wastewater Treatment Processes: A Comparison Between Sweden and Austria 56 (2007), https://www.iea.lth.se/publications/MS-Theses/Full document/5247_full_document.pdf.

produced from anaerobic digestion is comprised of about 60 percent methane and 40 percent carbon dioxide. Biomethane is an upgraded version of biogas that can be injected and distributed through the natural gas grid, and can be used in vehicles the same way as natural gas . . ."[23] Further, this can be used in place of diesel. "Western Washington University researchers estimate an engine powered with bio-methane emits about 95 percent less carbon than a traditionally fueled engine."[24]

Traditionally, pollutants and waste are viewed as problems and things to be disposed. For a sustainably designed wastewater treatment facility, however, these are bonus sources of energy. Adding high strength organic waste, such as fats, oils and grease discarded from food production, to co-digest with biosolids, can boost biogas production.[25] "Other organic wastes that could be used in the co-digestion process include glycerin from biodiesel production, airplane de-icing fluid waste, manure, and other organic wastes (brewery, cheese production, etc.)."[26] After removing contaminants, biogas can be used as a vehicle fuel, injected into a natural gas pipeline, or the methane converted into liquid biofuel – called methanol.[27]

Additionally, municipal wastewater facilities can build algae bioreactors. These use wastewater to grow algae to produce biofuels (including methane, biodiesel, ethanol, hydrocarbon chains, and hydrogen).[28]

This chapter provides three case studies of urban sewage treatment facilities to illustrate

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[23] Emily Atkin, "People in England are Harnessing the 'Power Locked in Poo' to Fuel Their Homes," Climate Progress (Oct. 3, 2014), http://thinkprogress.org/climate/2014/10/03/3575503/the-power-of-poo/ [last visited 10-8-14].

[24] *Id*.

[25] Water Environment Research Foundation Factsheet, *Energy Production and Efficiency Research – The Roadmap to Net Zero Energy,* at 5.

[26] *Id*.

[27] *Id*.

[28] *Id*. at 7. There are significant limitations to using algae to produce biofuels.

how to implement strategies to become energy efficient and then meet remaining energy needs by using the energy potential contained in sewage.

C. Three Case Studies Showing a Transition to Sustainable Sewage Energy

(i) Strass im Zillertal, Austria

a. Background

Located near Strass im Zillertal, the Strass wastewater treatment facility (Strass facility) serves 31 communities in the Achental and Zillertal valleys east of Innsbruck, in Austria. The plant provides wastewater treatment for a population that ranges from 60,000 in the summer to 250,000 in the winter tourist season. The peak winter flow and load is equivalent to a plant treatment capacity of 10 MGD. The Strass facility is one of the best performing wastewater treatment facilities in Europe and the most energy-efficient wastewater treatment plant in Austria. For a decade, the facility has been producing more energy than it requires for its operations.[29] It has been way ahead of other European facilities. For example, the first facility in the United Kingdom to be a net energy producer was just announced in 2014. It will "make biomethane power available to the public, injecting the biomethane into the electric grid."[30] As will be seen through a comparison to the case studies in the U.S., although this facility produces less energy than the similar-sized one in Sheboygan, Wisconsin, it uses far less energy because of its focus on energy efficiency.

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[29] WATER ENV'T RESEARCH FOUND., SUSTAINABLE TREATMENT: BEST PRACTICES FROM THE STRASS IM ZILLERTAL WASTEWATER TREATMENT PLANT 1 (2010), *www.werf.org/c/_FinalReportPDFs/OWSO/OWSO4R07b.aspx*.

[30] Emily Atkin, "People in England are Harnessing the 'Power Locked in Poo' to Fuel Their Homes," Climate Progress (Oct. 3, 2014), http://thinkprogress.org/climate/2014/10/03/3575503/the-power-of-poo/ [last visited 10-8-14].

b. Energy Demands and Production

By 2005, the Strass facility was a net energy producer; the Strass facility consumed 7,860 kWh/day[31] and produced 8,490 KWh/day of electricity from the biogas-driven generators.[32] It became a net energy producer through a process of improvements that started with an intense focus on energy efficiency. It then effectively invested in technology that allowed it to capture the renewable energy contained in the municipal sewage. In 2001, the Strass facility installed a new, higher-efficiency, eight-cylinder, cogeneration engine that provides 340 kW of power.[33] The new cogeneration units convert biogas to electrical energy at an average efficiency of 38%.[34] Between 1996 and 2005, the percentage of energy self-sufficiency improved steadily from 49% to 108%,[35] and as of 2008, self-sufficiency reached 120%.[36]

c. Overview of Strass' Sustainable Energy Transition

Successive sustainability efforts since 1999 resulted in significant cost and energy savings. An overview of these efforts include:

- Reduction of chemical costs for sludge thickening by 50%.
- Reduction in sludge dewatering costs by 33%.
- Reduction in energy consumption on mass treated basis from approximately 6.5 euro/kg NH_4-n removed in 2003 to 2.9 euro/kg NH_4-n removed in 2007/2008.
- Reduction in energy consumption for sidestream treatment from 350 kwh/d to 196 kwh/d by implementing a novel sidestream nitrogen removal system (DEMON®).

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[31] WATER ENV'T RESEARCH FOUND., SUSTAINABLE TREATMENT: BEST PRACTICES FROM THE STRASS IM ZILLERTAL WASTEWATER TREATMENT PLANT at 3.
[32] *Id.,* at 3.
[33] *Id.*
[34] *Id.*
[35] *Id.*
[36] DIMITRI KATEHIS, BAY AREA CLEAN WATER AGENCIES, ENHANCING SUSTAINABILITY PRACTICES OF WASTEWATER TREATMENT: THE STRASS CASE STUDY 49 (2011), http://bacwa.org/Portals/0/Strass%20Case%20Study.pdf.

- Enhanced utilization of the digester gas by converting to a state-of-the-art cogeneration unit, boosting electrical efficiency from 33% to 40% and overall usage efficiency from 2.05 to 2.30 kwh/m^3 of digester gas.[37]

d. Reducing Energy Demands Through Deammonification (DEMON process)

Nitrogen removal is the most costly and most energy-intensive part of wastewater treatment.[38] Energy is consumed in the powerful blowers during the aeration process, additional carbon (methanol) is needed as a fuel for the bacteria, and dewatering the sludge from sidestreams, which have a significantly higher nitrogen load than ordinary wastewater, is particularly costly.[39]

Using biological treatment processes are the most cost-effective ways to reduce energy consumption and chemical usage.[40] In recent years, the nitritation/denitritation and deammonification processes have been implemented successfully in Europe and are being adopted in the United States.[41]

The Strass facility engages in a two-stage primary and secondary biological treatment process. This two-stage approach removes organic compounds and converts organics to biogas.[42]

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[37] *Id.*

[38] *Id.* at 4.

[39] *Id.*

[40] U.S. ENVTL. PROT. AGENCY (EPA), EMERGING TECHNOLOGIES FOR WASTEWATER TREATMENT AND IN-PLANT WET WEATHER MANAGEMENT 3-1 (2013), http://water.epa.gov/scitech/wastetech/upload/Emerging-Technologies-Report-2.pdf.

[41] *Id.*

[42] WATER ENV'T RESEARCH FOUND., SUSTAINABLE TREATMENT: BEST PRACTICES FROM THE STRASS IM ZILLERTAL WASTEWATER TREATMENT PLANT at 2. In the first stage, they eliminate 55-65% of the organic load and operate at a half-day sludge retention time (SRT). In the next stage, the low-loaded stage, eliminates nitrogen at an annual efficiency of about 80% and is operated at a ten-day SRT. This two-stage approach "results in high-rate entrapment of organics without excessive aerobic stabilization in the A-stage system. Due to the reduced SRT, organic compounds are removed mainly by adsorption from the A-stage onto solids and are immediately conveyed through thickening and digestion, where conversion of organics to biogas occurs." *Id.*

The Strass facility achieved energy savings from sidestream treatment using the patented DEMON® process for deammonification.[43] Bernhard Wett at the University of Innsbruck developed the DEMON® process.[44] The deammonification process utilizes the recently discovered Anammox bacteria, which requires no additional carbon and only 40% of the oxygen required for conventional nitrogen removal.[45] The deammonification process can save up to 63% of the oxygen demand compared to conventional nitrification/denitrification processes, with nearly 100% reduction in carbon demand, 80% reduction in biomass production, and no additional alkalinity requirement.[46] The deammonification process can achieve up to 95% ammonia removal,[47] thus reducing costs and environmental impact.[48] The nitritation and denitritation process offers energy and carbon savings. Less carbon means as much as 40% less sludge production.[49] The average nitrogen removal efficiency ranges from 85 to 95%.[50]

The Strass facility successfully implemented the technology in 2002, which was a key to making the Strass facility Austria's most energy-efficient wastewater treatment plant.[51] By 2005, the Strass facility was the first to be operated successfully under a full load.[52] This process treats

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[43] *Id.,* at 3.

[44] Thomas Wirthensohn, *Turning Waste into Watts: Producing and Reducing Energy in U.S. Wastewater Treatment with Austrian Knowledge*, BRIDGES, Apr. 2009, at 2.

[45] WATER ENV'T RESEARCH FOUND., SUSTAINABLE TREATMENT: BEST PRACTICES FROM THE STRASS IM ZILLERTAL WASTEWATER TREATMENT PLANT at 2, 5.

[46] U.S. ENVTL. PROT. AGENCY (EPA), EMERGING TECHNOLOGIES FOR WASTEWATER TREATMENT AND IN-PLANT WET WEATHER MANAGEMENT at 3-16.

[47] U.S. ENVTL. PROT. AGENCY (EPA), EMERGING TECHNOLOGIES FOR WASTEWATER TREATMENT AND IN-PLANT WET WEATHER MANAGEMENT at 3-17.

[48] DIMITRI KATEHIS, BAY AREA CLEAN WATER AGENCIES, ENHANCING SUSTAINABILITY PRACTICES OF WASTEWATER TREATMENT: THE STRASS CASE STUDY at 45.

[49] U.S. ENVTL. PROT. AGENCY (EPA), EMERGING TECHNOLOGIES FOR WASTEWATER TREATMENT AND IN-PLANT WET WEATHER MANAGEMENT, at 3-20.

[50] *Id.*

[51] Thomas Wirthensohn, *Turning Waste into Watts: Producing and Reducing Energy in U.S. Wastewater Treatment with Austrian Knowledge*, BRIDGES, Apr. 2009, at 5.

[52] *Id.*

certain sidestreams with particularly high nitrogen loads, decreasing energy consumption by more than 50%.[53]

e. Benchmarking

Austria's success in energy-efficient wastewater treatment is due in part to the benchmarking process.[54] The first benchmarks were developed in 1999, and roughly 950 wastewater treatment facilities participated in the process, which annually compares individual costs to overall national performance.[55] Participating facilities compare their own data to the overall benchmarks, stimulating a competition between facilities and the drive to improve.[56] As a result, Austrian municipal wastewater treatment facilities have decreased their electricity costs by about 30% since 1999.[57] Compared to Sweden, which initiated its energy saving program in 2005, Austrian facilities use roughly 45% less electrical energy.[58]

f. Conclusion

As noted by Wett, et al., "In sum, those allegedly perfect European [wastewater treatment facilities] offer an astounding average energy saving potential of about 30-50% without the need to compromise on treatment efficiency. It is hence safe to assume that the worldwide existing energy saving potential . . . is enormous. "[59] The Strass facility case study shows that redesigning a 10 MGD wastewater treatment to be sustainable is an immediately viable option;

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[53] *Id.* at 2.
[54] B. WETT, K. BUCHAUER & C. FIMML, INST. OF INFRASTRUCTURE & ENV'T ENG'G, UNIV. OF INNSBRUCK, AUSTRIA, ENERGY SELF-SUFFICIENCY AS A FEASIBLE CONCEPT FOR WASTEWATER TREATMENT SYSTEMS 3 (2007).
[55] *Id.*
[56] *Id.*
[57] MALIN JONASSON, DEP'T OF INDUS. ELEC. ENG'G & AUTOMATION, LUND UNIV., ENERGY BENCHMARK FOR WASTEWATER TREATMENT PROCESSES: A COMPARISON BETWEEN SWEDEN AND AUSTRIA 55 (2007), https://www.iea.lth.se/publications/MS-Theses/Full document/5247_full_document.pdf.
[58] *Id.*
[59] B. WETT, K. BUCHAUER & C. FIMML, INST. OF INFRASTRUCTURE & ENV'T ENG'G, UNIV. OF INNSBRUCK, AUSTRIA, ENERGY SELF-SUFFICIENCY AS A FEASIBLE CONCEPT FOR WASTEWATER TREATMENT SYSTEMS, at 3.

the technology exists to substantially reduce energy usage related to sewage treatment and to meet the remaining energy demands with renewable sewage power.

(ii) Sheboygan, Wisconsin, USA

a. Background

Located near Lake Michigan, one of the United States' Great Lakes, the Sheboygan wastewater treatment plant (Sheboygan facility) serves seven communities with a total of 68,000 people in eastern Wisconsin, in the United States.[60] The annual treatment capacity is the same as the Strass facility, at 10 MGD, which provides a solid comparison.[61] The Sheboygan facility is one of a few wastewater treatment plants in the United States that is producing most of the energy required to run the facility. This transition has provided financial benefits: the use of onsite renewable sewage power saves the facility about $78,000 annually for electricity and $60,000 for heat.[62]

b. Energy Demands and Production

In 2002, the facility did a study of its energy demands and renewable energy potential. Whenever an equipment upgrade is needed, they consider how the investment in new equipment can improve energy efficiency. The facility now uses 20% less energy compared to a baseline figure in 2003.[63] The drive to make the facility more energy efficient was led by the facility superintendent and facilitated by Wisconsin's Focus on Energy, a statewide ratepayer-funded energy efficiency program. Focus on Energy provided technical assistance and grants to pay for

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[60] Sheboygan Regional Wastewater Treatment Facility, http://www.sheboyganwwtp.com [last visited 3-11-15].
[61] *Id*.
[62] American Council for Energy Efficiency Economy, *Sheboygan Wastewater Treatment Plant Energy Efficiency Initiatives*, (May 2012), http://aceee.org/sector/local-policy/case-studies/sheboygan-wastewater-treatment-plant- [last visited 3-11-15].
[63] *Id*.

the energy-efficiency improvements.[64] Another nudge towards greater energy efficiency comes from the Wisconsin Department of Natural Resources, which encourages including energy considerations when conducting required project cost-effectiveness calculations.[65] Facility staff are able to better assess and communicate the value of energy efficiency because they analyze the "life cycle cost of all projects, instead of implementing the least capital cost fix for replacing failing equipment."[66]

Currently, the Sheboygan facility produces 90 percent of its annual electrical energy and 85 percent of its heat requirements. It uses the biogas it produces to fuel boilers that heat the anaerobic digesters and the plant buildings.[67] It also uses the biogas to produce electricity to power the facility's operations.[68] Processing 10 MGD of wastewater, the Sheboygan facility can produce biogas at a rate of 500,000 ft^3/day @ 65% methane.[69] The Sheboygan facility produces electrical and thermal energy at a rate of 16,500 kWh/day (at peak gas production) and 55 million BTU/day.[70] This is almost double the electricity production of the Strass facility; and yet the Strass facility is able to export the excess electricity it produces because it requires much less energy to run the Strass facility due to its even greater investments in energy efficiency.[71]

c. Overview of Sheboygan's Sustainable Energy Transition

Although the Sheboygan facility has made strides to become more energy efficient, its greatest results have been in the second step in the sustainable energy transition: harnessing

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[64] *Id.* In 2006, Wisconsin's Focus on Energy produced *Water and Wastewater Energy Best Practice Guidebook*. *Id.*
[65] *Id.*
[66] *Id.*
[67] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].
[68] *Id.*
[69] *Id.*
[70] *Id.*
[71] The Strass facility produces 8,490 KWh/day of electricity from the biogas-driven generators. WATER ENV'T RESEARCH FOUND., SUSTAINABLE TREATMENT: BEST PRACTICES FROM THE STRASS IM ZILLERTAL WASTEWATER TREATMENT PLANT, at 3.

renewable energy from sewage. In order to transition to this more sustainable energy produced at the Sheboygan facility, they installed a variety of equipment in two stages.

In 2006, the equipment improvements included: ten 30kW Capstone Micro-turbines, Unison Solutions Gas Conditioning Equipment, and two Cain Heat Recovery Units. In 2008, they started codigestion of high-strength wastes. This produced so much more energy that in 2010, they installed new equipment to utilize the additional biogas. They invested in two 200kW Capstone Micro-turbines to convert the biogas to electricity.[72]

d. Utilizing Digester Gas

The Sheboygan facility uses primary and secondary digesters with a total volume of 4,855,000 gallons. The sludge is retained in the digesters for 30 days. "While the sludge is in the primary digesters, the sludge is heated and mixed to create the appropriate environment for the anaerobic bacteria to stabilize the sludge. The methane gas produced is used as a fuel to heat the digesters and to fuel 10 Capstone Micro-turbines that produce 30 kW each for a combined production of 2,300 megawatts of electricity annually. Excess methane gas can be used to fuel a caterpillar engine that powers one influent lift pump."[73]

In 2006, the Sheboygan facility initially installed these 10 micro-turbines to produce electricity from the biogas, along with heat recovery units, and gas conditioning system. The facility partnered with Alliant Energy – Wisconsin Power & Light, which provided the funding for the new equipment. The power company recovered its investment through the sale of

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[72] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].

[73] Sheboygan Regional Wastewater Treatment Facility, *Solids Handling,* http://www.sheboyganwwtp.com/4_solids.php [last visited 3-11-15].

electricity back to the Sheboygan facility.[74] The Sheboygan facility superintendent explains that the transition to energy self-sufficiency made fiscal sense:

> With energy costs increasing each year, we were actively looking at different ways to reduce our total energy bill. Since we were wasting excess biogas produced at the wastewater treatment plant, it became evident that we could use the excess biogas as fuel for the Capstone Micro-Turbines and reduce our energy cost. Our partnership with Alliant Energy made this project a reality.[75]

In 2008, the facility found it produced a lot more biogas when it started injecting high-strength, organic wastes directly into the anaerobic digesters.[76] This is called codigestion. The source of the high-strength wastes for the Sheboygan facility is food processing and ethanol production. Adding high-strength waste to their waste stream boosted biogas production by 150%.[77]

In 2010, they installed two more Capstone micro-turbines to utilize the excess biogas produced as a result of codigestion. These turbines each have the capacity to produce 200 kW. Then in 2012, the Sheboygan facility exercised its option to purchase all of this equipment from Alliant Energy, the power company that had originally paid for the equipment upgrades.[78] The Sheboygan facility's energy production capacity now stands at 700 kW of cogeneration and 2.4 million BTU of heat per hour.[79] The Sheboygan case study demonstrates the ability to produce significant amounts of energy from sewage, especially when boosting energy production with high-strength wastes from food and ethanol production.

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[74] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].

[75] American Council for Energy Efficiency Economy, *Sheboygan Wastewater Treatment Plant Energy Efficiency Initiatives*, http://aceee.org/sector/local-policy/case-studies/sheboygan-wastewater-treatment-plant- [last visited 3-11-15].

[76] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].

[77] *Id.*

[78] Sheboygan Regional Wastewater Treatment Facility, *Microturbines,* http://www.sheboyganwwtp.com/4a_microturbines.php [last visited 3-11-15].

[79] *Id.*

It also provides an example of a facility that, despite its energy efficiency improvements of approximately 20%, still uses much more energy to process 10 MGD of sewage than the Strass facility. Perhaps other countries could learn from Austria's successful policy of benchmarking to drive energy efficiency at wastewater treatment facilities. The Strass facility's reduction in energy usage was driven by Austria's benchmarking, in which approximately 950 wastewater treatment facilities compete in comparing their energy usage and costs to overall national performance of the sector.[80] Although the Sheboygan facility communicates its energy usage to its staff to encourage energy efficiency, there is not the same type of comparison and competition across the municipal wastewater sector in the United States.[81]

(iii) Milwaukee Metropolitan Sewerage District, Wisconsin, USA

a. Background

The Milwaukee Metropolitan Sewerage District (Milwaukee facility) is a regional government agency serving 1.1 million people in 28 communities in the Greater Milwaukee Area, in southeastern Wisconsin, in the United States.[82] A large percentage of the Milwaukee facility's annual budget, 18% in 2012, is spent on purchasing energy.[83]

Just like the Sheboygan facility, the Milwaukee facility is in Wisconsin, a state where the utility rate structure "favors the production of new energy by burning cheap coal . . . ."[84] Yet, in 2005, the Milwaukee facility adopted a sustainability policy to "encourage and optimize the use of renewable, recyclable, eco-friendly materials; reduce energy consumption and emissions from

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[80] B. WETT, K. BUCHAUER & C. FIMML, INST. OF INFRASTRUCTURE & ENV'T ENG'G, UNIV. OF INNSBRUCK, AUSTRIA, ENERGY SELF-SUFFICIENCY AS A FEASIBLE CONCEPT FOR WASTEWATER TREATMENT SYSTEMS 3 (2007).

[81] http://aceee.org/sector/local-policy/case-studies/sheboygan-wastewater-treatment-plant-#performance

[82] MILWAUKEE METRO. SEWERAGE DIST., *About Us*, http://www.mmsd.com/about/about-us [last visited 3-11-15].

[83] MILWAUKEE METRO. SEWERAGE DIST., SUSTAINABLE WATER RECLAMATION 39 (2012), http://www.mmsd.com/-/media/MMSD/Documents/Sustainability/Sustainability%20Plan.pdf.

[84] Susan Nusser, *A Giant of Renewable Energy*, URBAN MILWAUKEE, Sept. 3, 2013, http://urbanmilwaukee.com/2013/09/03/a-giant-of-renewable-energy/.

fossil fuels; and have a positive impact on the region's economic, social and environmental resources while maintaining the desired level-of-services in a financially responsible manner."[85] The Milwaukee facility's goal is to achieve complete energy independence by 2035.[86] Like the Sheboygan facility, this focus on sustainability appears to be driven in large part by the leadership of the facility and supported by the economic case.[87]

b. Energy Demands and Production

The Milwaukee facility has two sewage treatment locations: Jones Island and South Shore. As of 2012, the Milwaukee facility has been able to set up South Shore to create two-thirds of the energy it uses to run the treatment plant.[88]

c. Overview of Milwaukee's Sustainable Energy Transition

The Milwaukee facility has continued to optimize its energy efficiency during the past several years by installing newer, more sustainable equipment and implementing new treatment technologies. At South Shore, these efforts start with reducing energy demands, which they have done through installing new high-efficiency blowers, new instrumentation and control systems and power monitors.

Two-thirds of the remaining energy needs are met by harnessing energy produced at South Shore. They installed new digester mixing systems to increase biogas production and produce more electricity to power the facility. They are adding high-strength wastes into digesters to generate more biogas. They installed five engine/generators that are fueled by the digester biogas, and these power the facility's sewage treatment process.[89]

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[85] MILWAUKEE METRO. SEWERAGE DIST., SUSTAINABLE WATER RECLAMATION, at 15.
[86] *Id.* at 42.
[87] *Id.*
[88] *Id.* at 40.
[89] MILWAUKEE METRO. SEWERAGE DIST., DEP'T OF PLANNING, RESEARCH & SUSTAINABILITY, REQUEST FOR PROPOSAL: ENERGY PLAN A-5–A-6 (2013),

At Jones Island, they are reducing energy needs by installing new instrumentation, control systems, and power monitors. They are meeting some of the remaining energy needs through a 20kW photovoltaic solar array and methane brought through a pipeline running from the regional landfill, which fuels new turbine generators at the facility.[90]

Landfill gas, a local source of energy, is being recycled into power at Jones Island.[91] A 19-mile long pipeline transports landfill gas from the Emerald Park Landfill in Muskego, Wisconsin.[92] Three new turbines, which replaced two 40-year-old natural gas turbines, transform the landfill's methane into electricity.[93] Through this conversion process, the Milwaukee facility will be able to produce a significant amount of the energy Jones Island needs, saving wastewater treatment customers tens of millions of dollars over a 20-year period.[94] The Milwaukee facility's10-year contract with Veolia Water Milwaukee for the operation and maintenance of the sewers and reclamation facilities is expected to save customers 35 million dollars.[95]

d. Sewage Treatment & Digester Gas Production Process

The Milwaukee facility implements a four-stage wastewater treatment process: screening, primary clarification, biological treatment, and disinfection. First, during the screening stage, large and small objects are screened out and removed.[96] Next, during the primary clarification stage, grease and oil float to the top of large settling tanks, and organic solids sink to the bottom

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https://mmsd.diversitycompliance.com/FrontEnd/ProposalSearchPublicDetail.asp?XID=4343&TN=mmsd&PID=C18D60773FD2C225380C6B931D05A861C794F79FD6413E77.

[90] *Id.*

[91] MILWAUKEE METRO. SEWERAGE DIST., *Landfill Gas*, http://www.mmsd.com/en/Sustainability/Landfill-Gas.aspx [last visited 3-11-15].

[92] *Id.*

[93] *Id.*

[94] *Id.*

[95] *Id.*

[96] MILWAUKEE METRO. SEWERAGE DIST., *Wastewater Treatment*, http://www.mmsd.com/wastewatertreatment/treatment-process [last visited 3-11-15].

and are collected to make energy.[97] The organic solids, called primary sludge, are then turned into a renewable energy source.[98] A higher carbon content in the sludge results in greater energy production.[99] The Milwaukee facility's six anaerobic digesters take in the sludge, which is processed and produces methane.

The sludge needs to be agitated for maximum efficiency, and the Milwaukee facility is currently testing new systems that may increase efficiency by 10–20%.[100] These new agitation systems will also enable the Milwaukee facility to treat high-strength wastes, such as glycol used for de-icing airplanes, which produce more heat and gas than sewage from household sources.[101] The Milwaukee facility partnered with Marquette University researchers to conduct an industrial survey of potential high strength wastes available within a 100-mile radius. The addition of these high-strength wastes could more than double energy production, producing an equivalent of enough energy to power 2,000 homes.[102]

After the biosolids are separated and pumped into the digesters, the wastewater is ready to be treated biologically.[103] During the biological treatment, microscopic organisms called "bugs" break down the organic material.[104] After the "bugs" eat the remaining waste, they die, and their bodies become the organic matter that is turned into fertilizer.[105] Finally, during the

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[97] *Id.*

[98] Susan Nusser, *A Giant of Renewable Energy*, URBAN MILWAUKEE, Sept. 3, 2013, http://urbanmilwaukee.com/2013/09/03/a-giant-of-renewable-energy/.

[99] *Id.*

[100] *Id.*

[101] *Id.*

[102] *Id.* The researchers anticipate high-strength waste additions to increase energy production from 800,000–900,000 cubic feet per day to 2 million cubic feet per day. *Id.*

[103] *Id.*

[104] MILWAUKEE METRO. SEWERAGE DIST., *Wastewater Treatment*, http://www.mmsd.com/wastewatertreatment/treatment-process [last visited 3-11-15].

[105] Susan Nusser, *A Giant of Renewable Energy*, URBAN MILWAUKEE, Sept. 3, 2013, http://urbanmilwaukee.com/2013/09/03/a-giant-of-renewable-energy/.

disinfection stage, disease-causing organisms are killed by chemicals that are then neutralized, and the water is returned to Lake Michigan.[106]

e. Sewer-Thermal Energy

After setting a goal of meeting 100% of its energy needs with renewable resources by 2035,[107] the Milwaukee facility hired consultants to investigate sewage heat recovery technologies and their applicability to its sustainability goals.[108] The consultants explored heat recovery strategies within the conveyance system only; but they recommended further investigation of heat recovery opportunities at the wastewater treatment facilities.[109] Sewage heat recovery is an emerging technology in the wastewater treatment sector in the U.S., but a significant number of projects have been implemented in Europe.[110] The energy that is inherent in wastewater can be captured using heat-exchange technology.[111] Heat exchangers can be placed directly in sewers to harvest the heat energy to offset heating demands at nearby land uses.[112] The energy can also be harvested and used in water reclamation facilities with the added benefit of reducing the temperature of the water before it is returned to a natural water body.[113]

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[106] MILWAUKEE METRO. SEWERAGE DIST., *Wastewater Treatment*, http://www.mmsd.com/wastewatertreatment/treatment-process [last visited 3-11-15].

[107] MILWAUKEE METRO. SEWERAGE DIST., DEP'T OF PLANNING, RESEARCH & SUSTAINABILITY, REQUEST FOR PROPOSAL: ENERGY PLAN at A-1; ARCADIS U.S., INC., ASSESSMENT OF SEWAGE HEAT RECOVERY TECHNOLOGY AND APPLICABILITY TO THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT 1 (2013), http://www.mmsd.com/-/media/MMSD/Documents/Sustainability/Sewer%20Heat%20Recovery.pdf.

[108] ARCADIS U.S., INC., at 1.

[109] ARCADIS U.S., INC., at 18. The consultants' recommendation of further analysis of the facilities was based on:

- Wastewater treatment facilities receive wastewater with a more consistent base flow and temperature than the collection system, likely resulting in a more robust heat recovery system.
- Heat exchangers could be incorporated at the wastewater treatment facility influent or effluent.
- There are usually higher heating loads at the wastewater treatment facilities that would directly utilize recovered heat. *Id*.

[110] ARCADIS U.S., INC., at 1. In the U.S., Philadelphia is implementing a project, and Seattle plans to launch a project in 2015. *Id*.

[111] MILWAUKEE METRO. SEWERAGE DIST., Sustainability Plan, at 43.

[112] *Id*., at 43; ARCADIS U.S., INC., at 1.

[113] MILWAUKEE METRO. SEWERAGE DIST., Sustainability Plan, at 43.

A companion technology to a heat exchanger is a heat pump, which "converts the low-temperature heat recovered from the sewer into high-temperature heat that can be used in building heating or hot water systems."[114] Recovered sewer heat can be used directly for building heat or hot water, or to preheat a boiler or a domestic hot water system.[115]

The consultants could not provide a payback for the evaluated technologies as applied to the sewage conveyance system because implementation under current conditions will not save money, due in part to the relatively low cost of natural gas.[116] However, they noted that for in-sewer heat exchangers, there could be an opportunity to install this technology as part of the overall cost of otherwise required sewer replacement in discrete parts of the system.[117]

f. Future Efforts

The Milwaukee facility continues to explore and develop existing and new sources of renewable energy, including wind, solar, sewer-thermal, and algae biofuels.[118] Algae can be cultivated, harvested, and refined as biofuel.[119] Algae needs sunlight, water, and nutrients to grow, and using wastewater to grow algae and create biofuel can reduce waste and help the facility meet its permit limits on nutrients.[120] The Milwaukee facility hopes to remain involved with this research.[121] The Milwaukee facility also plans to continue to evaluate ways to use all the waste heat generated by the solids drying process, the boiler system, and the landfill gas-powered turbines; and plans to continue pursuing new sources of high-strength waste and the

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[114] ARCADIS U.S., INC., at 16.

[115] *Id.*, Recovered sewer heat can be used for building heat if flows are generally greater than 150 gpm. *Id.* at 17.

[116] *Id.*, at 13.

[117] *Id.*, at 13. A 20 year payback is required for this technology to be considered based on economics. *Id.*

[118] MILWAUKEE METRO. SEWERAGE DIST., Sustainability Plan, at 42.

[119] *Id.*.

[120] *Id.*

[121] *Id.*

mixing and staging of waste.[122] This case study adds an example from a facility that is treating at least 20 times more waste per day than the Strass and Sheboygan facilities. It shows the power of setting goals for sustainability and experimenting with different aspects of the system to make progress towards that goal.

3. CONCLUSION

The United Nations Intergovernmental Panel on Climate Change reports that "the world is dangerously close to no longer being able to limit global warming to 2°C over pre-industrial times."[123] At a time when all countries need to be focused on a rapid transition to reduce reliance on fossil fuels, redesigning municipal sewage treatment infrastructure to result in net energy production of renewable energy can be a critical part of progress.

Importantly, cities do not need to wait until they are building a *new* treatment system. The three case studies in this chapter demonstrate that existing sewage treatment facilities can be redesigned to be more energy efficient and to recapture for use or sale the energy contained in the sewage they are processing. The case studies involve different sizes of facilities providing a proof of concept for facilities that process the waste produced by as few as 68,000 people to as many as more than 1 million people. The case studies highlight several key drivers for this transition:

- the importance of thought leaders within the facility management,
- benchmarking across the sector on both costs and energy usage to encourage competition between facilities to be the most efficient,

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[122] *Id.*

[123] Trinh Theresa Do, "UN Climate Summit: 4 Things to Know About the Talks," CBC News (Sept. 23, 2014) http://www.cbc.ca/news/world/un-climate-summit-4-things-to-know-about-the-talks-1.2774110 [last visited 9-24-14].

- economic savings from energy efficiency and greater reliance on renewable sewage power,
- utilizing life cycle analysis and energy costs when determining how to invest in new equipment,
- grants for energy efficiency to offset the initial upfront costs, and
- partnering with a local energy utility to fund the renewable energy investments.

Several additional opportunities exist that could accelerate this transition to renewable sewage power. These are beyond the scope of this chapter so will only be briefly outlined, but each may deserve analysis for municipal systems considering modifications for greater sustainability:

- count energy generated by sewage towards meeting Renewable Portfolio Standards (RPSs);[124]
- allow sewage power to create tradable Renewable Energy Credits or Certificates (RECs) to meet RPS goals or to be sold to others that must meet such goals;
- use "Supplemental Environmental Projects" in consent decrees with municipal wastewater treatment facilities to require investments in energy efficiency and use of renewable sewage power at those facilities; and

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[124] A Renewable Portfolio Standard in the U.S. is "A state or federal level policy that requires that a minimum amount (usually a percentage) of electricity supply provided by each supply company is to come from renewable energy." Green-e, *Dictionary,* http://www.green-e.org/learn_dictionary.shtml#rec [last visited 3-11-15]. Around the late 1990s, states in the U.S. started adopting renewable energy targets – RPS – for their public utilities. When a utility purchases renewable electricity along with the Renewable Energy Certificate (REC) associated with it, the utility can use that to meet the Renewable Portfolio Standard requirements. Environmental Tracking Network of North America, *REC Questions and Answers,* http://www.etnna.org/images/PDFs/ETNNA-REC-QandA.pdf . Whether sewage-based energy qualifies as renewable for these purposes is based on individual state laws.

- require future government investments in sewage treatment infrastructure to assess life cycle and energy costs.

If municipal wastewater treatment facilities could sell the renewable attribute of their excess renewable energy produced by sewage as a REC, it would generate an additional stream of financing to justify the investment in energy efficiency and renewables at these facilities. "Purchasers of RECs are buying the renewable attributes of those specific units of renewable energy, which helps offset conventional electricity generation in the region where the renewable generator is located."[125] That "offset" can be used to meet either voluntary or mandatory efforts to shift electric generation away from conventional fossil fuel combustion. Underlying the concept of RECs is the assumption, verified at a system-wide level, that the sewage facility's efficiency gains or generation output will replace or offset greenhouse gas (GHG) emissions from conventional power plants that would otherwise have needed to burn fossil fuels to generate power. Whether sewage power counts as renewable for purposes of selling the attribute as a REC varies by program, mostly on the basis of whether the regional electric grid accepts as factual the assumption that that offset will occur.[126]

The market value of RECs turns on whether buyers have voluntary or mandatory reasons to purchase credits for those GHG reductions. As an example of the voluntary market for RECs, federal agencies, such as the U.S. Environmental Protection Agency, and companies that wish to procure renewables but lack the ability to produce all the renewable energy they need could purchase RECs from sewage-based energy generation. As an example of the compliance market

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[125] Green-e, *Dictionary*, http://www.green-e.org/learn_dictionary.shtml#rec [last visited 3-11-15]. Green-e is an entity that certifies RECs.

[126] Environmental Tracking Network of North America, *REC Questions and Answers,* http://www.etnna.org/images/PDFs/ETNNA-REC-QandA.pdf .

for RECs, public utilities could purchase the sewage-based RECs when bundled together with the sewage-based renewable electricity to meet their state-required Renewable Portfolio Standards.[127] The price for RECs varies by market, so in states with a higher demand for renewables and a lower supply, municipal wastewater treatment facilities would get a higher price for the RECs they sell.[128]

Related to the last item, in the U.S., Congress created a federal system for underwriting the cost of municipal wastewater treatment facilities when it passed the Clean Water Act. "For a 20-year period, starting in 1972, the federal government paid up to 75 percent of the cost of building sewage treatment plants."[129] Now many of those sewage treatment facilities are in need of major upgrades. A primary mechanism to deliver this financing is the Clean Water State Revolving Fund (CWSRF). Since its inception over two and half decades ago, the CWSRFs have provided over $100 billion in funding for water infrastructure in the United States, primarily through low interest loans.[130] This program is essentially an infrastructure bank where the repayment on the loans gets funneled back to the government to be used for future funding of infrastructure. Governmental funding for this wastewater treatment infrastructure could require life cycle analysis and energy cost analysis. If so, it could provide an incentive for a more rapid transition from fossil fuels to renewable sewage power.

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[127] Environmental Tracking Network of North America, *REC Questions and Answers,* http://www.etnna.org/images/PDFs/ETNNA-REC-QandA.pdf .

[128] Environmental Tracking Network of North America, *REC Questions and Answers,* http://www.etnna.org/images/PDFs/ETNNA-REC-QandA.pdf .

[129] Brad Plumer, " Our Cities' Water Systems are Becoming Obsolete. What Will Replace Them?" Vox (Oct. 6, 2014) http://www.vox.com/2014/10/6/6900959/water-systems-pollution-drinking-water-desalination [last visited 10-8-14].

[130] U.S. EPA, *Clean Water State Revolving Fund,* http://water.epa.gov/grants_funding/cwsrf/cwsrf_index.cfm [last visited 3-12-15]. Congress created the CWSRF with the 1987 amendments to the Clean Water Act. "Through the CWSRF program, each state and Puerto Rico maintain revolving loan funds to provide independent and permanent sources of low-cost financing for a wide range of water quality infrastructure projects." http://water.epa.gov/grants_funding/cwsrf/basics.cfm [last visited 3-12-15].

In 2009, the American Recovery Act created the Green Project Reserve as a subset of money allocated through the CWSRF; this funds energy efficiency projects specifically.[131] In fact, one municipal wastewater facility in Ohio used this funding source to pay for a project to capture excess methane gas and use it to meet 60-70% of the facility's energy demands, saving $300,000 annually in energy costs.[132] In other words, it has both conceptual and field experience to demonstrate its feasibility. However, to date only a very small portion of the total expenditures from the CWSRF are used for these types of projects.[133] The U.S. government could accelerate the transition to renewable sewage power if it dedicated more of these revolving loan funds for sustainable energy projects at wastewater treatment plants.

In sum, the climate imperative is clear, the technology exists for energy efficiency and renewable sewage power, and the financial incentives are beginning to emerge. Now we need to remove roadblocks and bolster support for the drivers to make this a reality at municipal wastewater treatment plants across the U.S. and throughout the world.

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[131] U.S. EPA, *Green Project Reserve*, http://water.epa.gov/grants_funding/cwsrf/Green-Project-Reserve.cfm [last visited 3-12-15].

[132] U.S. EPA, *Green Project Reserve, Case Study: Struthers Water Pollution Control Facility Powers Up with Methane Gas,* EPA-832-F-12-019, http://water.epa.gov/grants_funding/cwsrf/upload/Struthers-Water-Pollution-Control-Facility-Case-Study-FINAL.pdf [last visited 3-12-15].

[133] The U.S. EPA reports that, "For FY 2010 and FY 2011, each state was directed to allocate 20% of its CWSRF capitalization grant to eligible [Green Project Reserve] GPR projects. For FY 2012, the GPR amount was reduced to 10% of each state's capitalization grant." http://water.epa.gov/grants_funding/cwsrf/Green-Project-Reserve.cfm [last visited 3-12-15].