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Current and Potential Methane Production for Electricity and Heat from New York State Wastewater Treatment Plants

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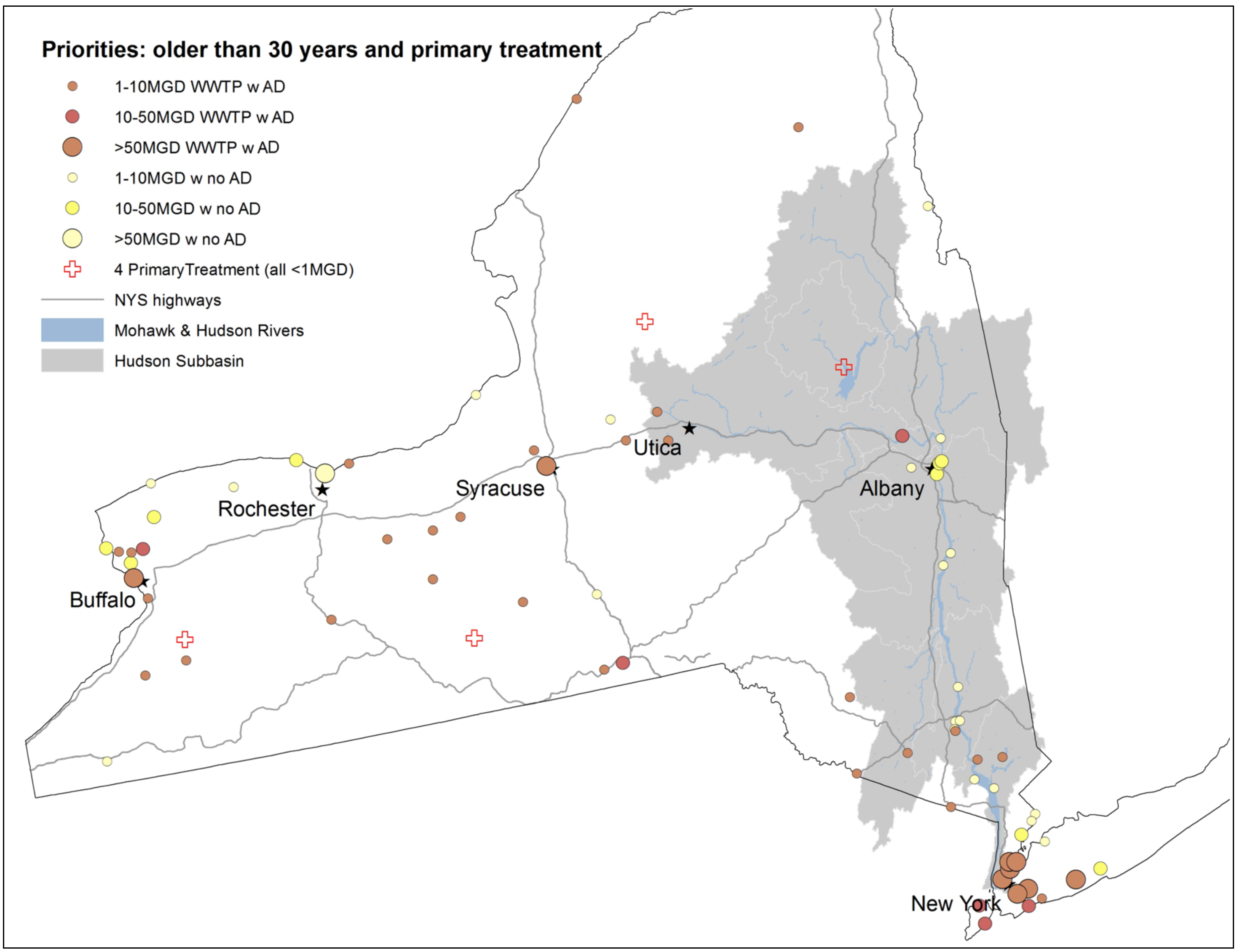

Abstract

This report addresses the question "What is the potential for increased biogas production and use to provide an economic return for wastewater treatment plants (WWTP) in New York State?" To answer this question, we used existing data sets and developed case studies from WWTP throughout the northern USA. Currently, WWTP in New York State use 1.8 million cf CH_4/yr out of a total production potential of 3.6 million cf CH_4/yr. We estimate that retrofitting a selected subset of WWTP could increase methane use by 1 million cf CH_4/y. By extrapolating from the case studies, we estimated simple financial returns (capital cost divided by annual savings) for three size classes of WWTP. Smaller plants (1-10 MGD) had the greatest simple return (14%), but accounted for very specific cost-effective retrofits and addressed only 9% of the total effluent flow. Medium plants (10-50 MGD) had a 4% simple return with 8% of the flow. Large plants (>50 MGD) had a 3% simple return with 82% of the flow. The total cost for retrofitting this selected subset of plants was estimated to be $511 million based on very limited case studies. Notably, this report demonstrates that there is a serious data gap in financially evaluating WWTP for using CH_4. Our analysis is only intended as a first step toward investigating options for cost-effective WWTP retrofits to increase biogas production and use and energy efficiency.

Three Summary Points of Interest

Point 1: Of 570 Waste Water Treatment Plants (WWTP) in NY there are 162 WWTP that are greater than 1 MGD. Of the 570, there are 143 WWTP with Anaerobic Digestion (AD) infrastructure. There are 86 WWTP that are both >1MGD and have some kind of AD infrastructure. It is estimated to cost $511 million to retrofit this subset of WWTP for improved energy capture and use.

Point 2 Of WWTP >1MGD, 72 have not been retrofitted in over 30 years and these would be excellent priority candidates for retrofitting, with the opportunity to include energy and greenhouse mitigation in the retrofit. Of these older plants, 42 have Anaerobic Digestion infrastructure and might be good targets for both building on existing infrastructure and improving methane destruction for GHG mitigation purposes. All 57 very small WWTP (<1MGD) that have anaerobic infrastructure should be evaluated for flaring any unused biogas for GHG mitigation.

Point 3 Focusing specifically on the Mohawk/Hudson Basin there are 168 WWTP. Of these WWTP, 38 have AD infrastructure and 21 are >1MGD. Retrofitting these 21 is estimated to cost $127 million to retrofit.

Keywords

Wastewater treatment plant, biogas, methane, bioenergy, energy efficiency, infrastructure, cost, greenhouse gases, electric generation, anaerobic digestion, New York State.

Executive Summary

The Clean Water Act of 1972 dramatically improved water quality in the USA. However, the resulting water infrastructure is aging and requires significant retrofitting. Climate change and the concomitant need for renewable energy sources are current environmental challenges. This project aims to identify opportunities to integrate energy and climate change improvements into the next generation of retrofits for New York State waste water treatment infrastructure.

The projected cost for replacing and updating New York's municipal water infrastructure is $36.2 billion by 2028 (NYDEC 2008). While funds are limited, next generation retrofits could be planned to incorporate not just improved water quality but also greenhouse gas mitigation and energy conservation and renewable energy production. After labor, energy is the 2nd most expensive cost category in wastewater treatment plants (WWTP). WWTP can produce biogas that can be used to produce heat and electricity and reduce energy costs. Because there is limited federal and state financial assistance for infrastructure improvements, we undertook to answer the question "What is the potential for increased biogas production and use to provide an economic return for WWTP in New York State?" To answer this question, we used existing data sets and developed case studies from WWTP throughout the northern USA.

Currently, WWTP in New York State use 1.8 million cf CH_4/yr out of a total technical production potential of 3.6 million cf CH_4/yr (NYSERDA 2008). We assessed the proportion of this technical potential that is most readily achievable at affordable costs based on 8 case studies. We include only WWTP larger than 1 million gallons per day (MGD) because it is unlikely to be feasible to retrofit smaller plants to increase usable methane production at a reasonable cost. This category (<1 MGD) comprises 72% of the total number of WWTPs in the State, but only 3.5% of the total methane production potential based on flow. We focused on WWTPs that already had some type of anaerobic digestion (AD) infrastructure on site, because such facilities are more likely to be able to increase biogas production and use at an affordable cost. We estimate that the potential usable methane from retrofitting this subset of WWTP is 2.8 million cf CH_4/yr, an increase of 1 million cf CH_4/y above current use. By extrapolating from the case studies, we estimated simple financial returns (capital cost divided by annual savings) for each of 3 size classes of WWTP. The smallest plants (1-10 MGD) had the greatest simple return (14%), but accounted for only 9% of the flow. The medium-sized plants (10-50 MGD) had a 4% simple return and accounted for 8% of the flow. The large plants (>50 MGD) had a 3% simple return and accounted for 82% of the effluent flow in AD systems. The cost for retrofitting to improve the use of methane for energy for all identified plants >1 MGD was estimated to be $511 million.

Our analysis is intended only as a first step toward investigating options for cost-effective retrofits of WWTP to increase biogas production and use, and increase energy efficiency. While the case studies represent "real world" results, they may not be representative of the WWTP in the State. However our spatial analysis identified plants that might be prioritized based on 1) primary treatment to impact water quality, 2) age to identify oldest infrastructure that could gain from simple technology improvements effecting overall efficiency and long-term benefit, 3) design capacity to identify plants running over or under capacity impacting its efficacy, 4) existence of anaerobic digestion infrastructure to identify potential methane production and capture of the biogas for both greenhouse gas mitigation as well as energy production.

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Introduction

Since the Clean Water Act of 1972, New York State (NY) has improved its wastewater infrastructure (NYWRI 2014). However, the projected cost for "replacing and updating New York's municipal infrastructure is $36.2 billion over the next 20 years" (NYDEC 2008). Of that total, $13.6 billion is for facility upgrades. The rest is for sewer system maintenance, sewer outflow corrections, and protecting water resources. These shared systems treat wastewater for 15 million people across the State. Because there is limited federal and state financial assistance, maintaining this infrastructure is the responsibility of local governments.

In the USA, energy is the 2nd largest cost for wastewater treatment plants (WWTP) (WERF 2014). In New York State, electricity constitutes between 25 and 40% of the budget of a typical wastewater treatment plant (NYPA 2014). Energy costs can be reduced in many ways, including: 1) energy savings from efficiency projects, 2) energy savings from installation of renewables such as wind and solar, 3) energy savings from combustion of biogas and/or incineration of solids to displace energy inputs.

Biogas is a mixture of gases produced by anaerobic (without oxygen) digestion of organic materials such as sewage sludge. Biogas includes methane, carbon dioxide, and smaller amounts of sulfur compounds and other gases. Methane is the key energy component of biogas that can be used for energy and provide economic as well as environmental value to WWTP. Methane is also a greenhouse gas that is 34 times more potent than carbon dioxide (IPCC AR5, 2013). Combusting methane for energy reduces GHG emissions 34-fold while also generating electricity and heat in a WWTP.

Understanding that 1) New York State WWTP infrastructure is aging, 2) energy use is the 2nd highest cost category for WWTP, 3) methane is a potent greenhouse gas, and 4) cost-effective renewable energy production is a reasonable municipal goal, we undertook to answer the question "What is the potential for increased biogas production and use to provide an economic return for WWTP in New York State?" While there are many other benefits to retrofitting WWTP and improving biogas management, we focused on identifying opportunities to do so with cost savings due to the very limited funding currently available for infrastructure improvement. Our analysis synthesized published research and analyzed publicly available data. Our analysis is part of a larger coordinated research program on water resource infrastructure in NY, with a focus on the Hudson and Mohawk River basins being conducted by NYWRI and the New York State Department of Environmental Conservation (NYDEC) Hudson River Estuary Program (HREP). The primary objective of this multi-year research program is to bring innovative research and analysis to watershed planning and management. In particular, HREP is working to address the related topics of water infrastructure, environmental water quality, and economic vitality, especially as they pertain to planning, management, and smart growth in the Hudson and Mohawk river basins.

Results & Discussion

In year 2011, there were 2,018 State Pollutant Discharge Elimination System (SPDES) permits throughout the State (NYS GIS clearinghouse, 2011). Of these, 684 were municipal permits. According the NYSERDA (2008) report, there were 590 WWTP in New York State and they accounted for 10% of the national capacity. Of the 590 plants, 145 plants are equipped with anaerobic digestion (AD) infrastructure and these 145 plants account for 75% of the wastewater treatment capacity. Based on a survey of WWTP in the State, a potential methane production and conversion to electricity was calculated (NYSERDA 2008). Of the 590 surveyed, 67 responded. Seventeen of these respondents converted their methane to electricity while 36 converted it to heat for various uses. Notably, 40 of 67 respondents reported that they flare or vent some portion of the biogas produced at the facility. The amount flared is difficult to quantify because very few facilities have accurate gas metering equipment and biogas is wasted due to limited capacity for gas storage and fluctuations in gas production.

Figure 1 shows the current theoretical methane production of the 145 plants with AD by extrapolating from the 67 WWTP survey respondents as per NYSERDA (2008). This theoretical biogas production is the value for end-use as reported by the WWTP. The total methane that could be generated from facilities with AD is 2.8 billion cubic feet CH_4 per year. If all 590 plants were equipped with anaerobic digesters, the facilities could produce 3.6 billion cubic feet CH_4 per year. These estimates are derived from the NYSERDA report (2008) that assumes 54% methane in biogas and does not account for losses or unmetered flaring as discussed above.

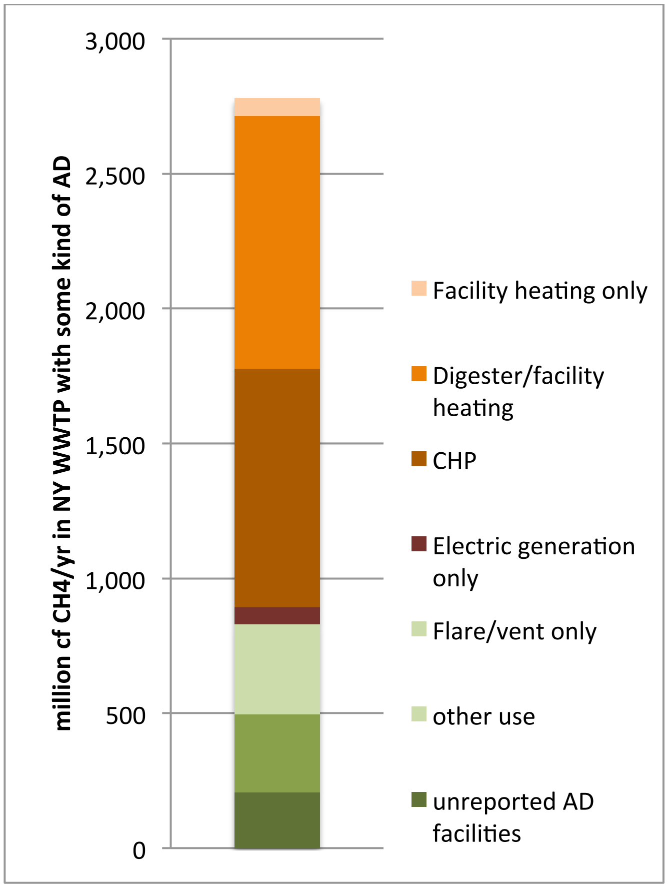


Figure 1. Theoretical amount of methane (2.78 billion ft^3 /yr.) produced from 145 existing WWTP AD systems. Pink, orange, brown, and red colors indicate current use for heat or electricity. Green colors indicate opportunity for increased utilization. Data from NYSERDA (2008).

We obtained the complete dataset used for the above analysis and performed further analyses based on average daily influent flow. The database included 585 (as opposed to 590 reported above) WWTP. After merging these data with the more recent spatial SPDES permit data (NYS GIS clearinghouse, 2011), the total number of WWTP was reduced to 570. We further removed one site due to erroneous data resulting in a total of 569 WWTP. This NYSERDA database included 143 WWTP with Anaerobic Digestion infrastructure. Independently, there are 162 WWTP that are >1 MGD.

Having infrastructure to anaerobically process wastes does not mean that there is infrastructure to generate, capture, and use biogas, but it does mean that the facility has experience with anaerobic systems and their products. Thus we judge that having at least some amount of AD infrastructure increases the likelihood of a plant being able to modify its operations to produce or increase biogas production and use. We grouped the plants by size and calculated the amount of influent currently being processed with some type of anaerobic digestion as opposed to those with none (Table 1).

Table 1. Summary of key characteristics related to methane production capacity for wastewater treatment plants in New York State in 7 size classes.

Size of WWTP	WWTP	Estimated total flow	WWTP w AD*	Flow+ w AD*	WWTP w/o AD*	Flow+ w/o AD*	Flow+ w/o AD*
MGD	**Num.**	**MGD**	**Num.**	**MGD**	**Num.**	**MGD**	**%**
<1	422	101	57	26	365	75	74%
1-5	94	205	48	98	46	107	52%
5-10	32	216	15	106	17	110	51%
10-20	9	141	2	35	7	106	75%
20-50	11	322	5	151	6	171	53%
50-75	5	301	5	301	0	0	0%
>75	12	1,633	11	1,525	1	107	7%
TOTAL	**585**	**2,919**	**143**	**2,242**	**442**	**677**	**23%**

+ This is the total of the average daily flow from each plant in each size category.
* AD refers to WWTP that have Anaerobic Digestion Infrastructure

Only 14% of smallest plants (<1 MGD) have AD (Table 1). Notably, only 23% of the influent (677 million gallons per day [MGD]) is in systems without AD and 16% of that is from a single large plant in Rochester NY (Table 1).

We reclassified the WWTP into four size categories: very small (<1MGD), small (1-10 MGD), medium (10-50 MGD), and large (>50 MGD) (Table 2). We did not assess energy production potential from plants smaller than 1 MGD because it is unlikely to be feasible to retrofit such plants to increase usable methane production at a reasonable cost. Note that this very small size category comprises 72% of the total number of WWTPs in the State, but only 3.5% of the total flow. This results in 86 plants being both greater than 1 MGD average daily flow and having some kind of anaerobic digestion infrastructure.

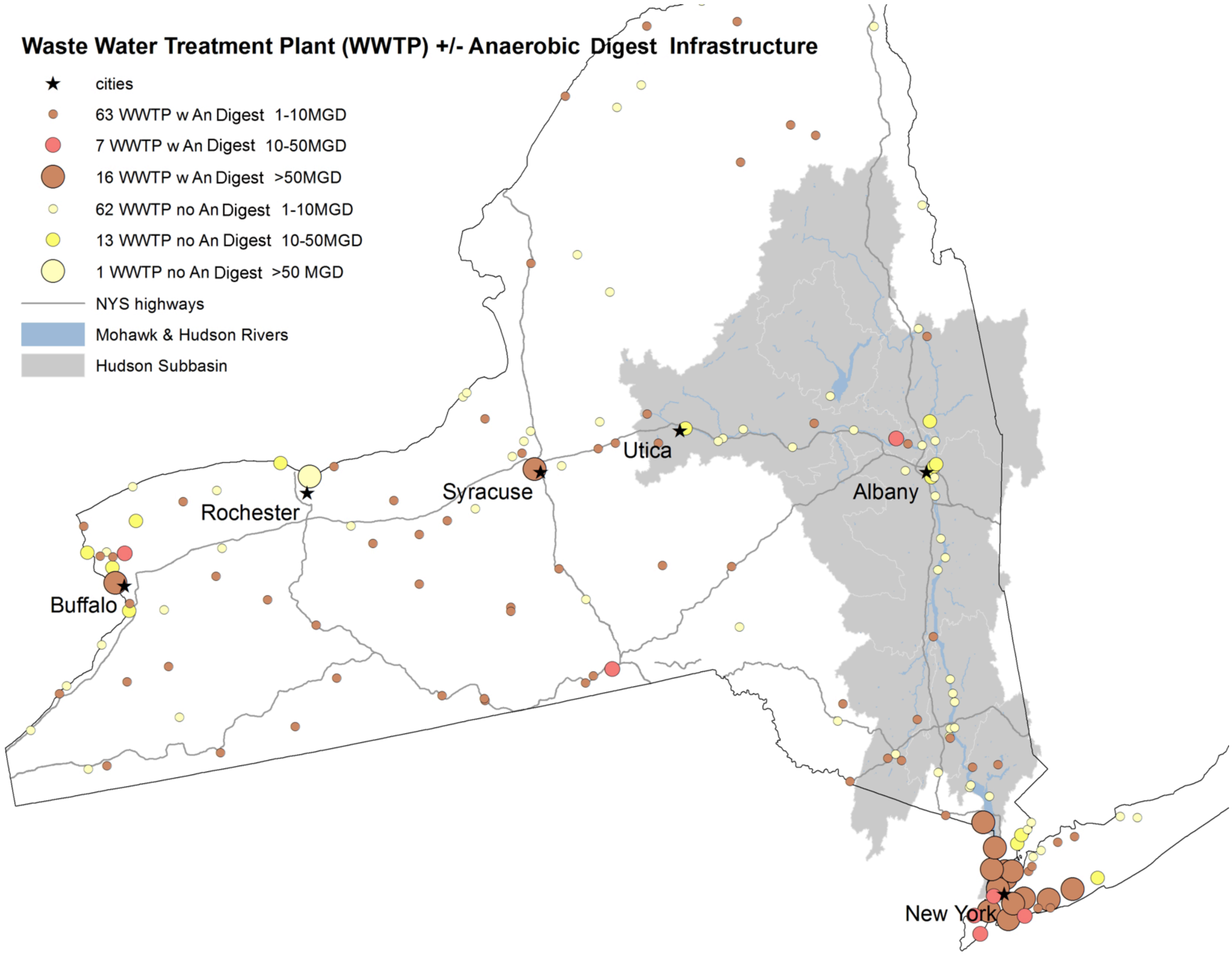


Figure 2. Waste Water Treatment Plants (of 684 Municipal SPDES) >1MGD by Location, Size, and With and Without Anaerobic Digestion Infrastructure (AD).

The NYSERDA 2008 dataset containing 585 WWTP was merged with the 2,018 SPDES permits (NYS GIS clearinghouse, 2011). There were 570 WWTP from the NYSERDA dataset that were permitted in 2011 by NYDEC. There are 408 very small (<1MGD), 125 small (>1MGD but <10MGD), 20 medium (>10MGD but <50MGD) and 17 large (>50MGD) WWTP in the State. Of these, 143 WWTP have Anaerobic Digestion infrastructure.

Table 2. Summary of key characteristics related to methane production capacity in wastewater treatment plants in New York State in 4 size classes.

Size	WW TP	Estim-ated flow+	WWTP w AD*	Flow in AD*	WWTP w/o AD*	Flow w/o AD*	Potential CH4 w AD*	Potential CH4 w/o AD*	% CH4 w/o AD*	%CH4 of NY potential
MGD	Num.	MGD	#	MGD	#	MGD	cf CH4/yr	cf CH4/yr	%	% of total
<1	422	101	57	26	365	75	28,660,169	95,493,512	77%	3%
1-10	126	421	63	204	63	217	252,166,841	263,364,894	51%	14%
10-50	20	463	7	186	13	277	217,592,373	349,274,253	62%	16%
>50 #	17	1,933	16	1,826	1	107	2,200,053,285	166,555,091	7%	66%
TOT.	**585**	**2,919**	**143**	**2,242**	**442**	**677**	**2,698,472,668**	**874,687,751**	**24%**	**100%**

+ Based on daily averages per plant.
* AD refers to WWTP that have Anaerobic Digestion

A total of 76% of the CH_4 potential is from systems that have some type of AD infrastructure. As discussed above, while presence of AD infrastructure does not mean capacity for electric generation, such systems are more likely to be able to increase biogas production and use than systems without any type of AD.

We then searched for case studies in the Northern US that have reported investment for improving production and use of methane for electricity and heat (Table 3).

Table 3. Summary of key characteristics from case studies of Northern US wastewater treatment plants with recent retrofits to increase heat and electricity production from methane.

Location+	Size	Cost	Savings	Use Type	Simple Invest-ment^ Return	Time to recoup Invest-ment	Methane	Electricity generated	Ratio
	MGD	$	$/yr		%	years	ft^3 CH_4/ day	kWh/yr	ft^3 CH_4/ MG
Essex Junct. VT	3.3	$303,000	$37,000	electric	12%	8.2	15,736	412,000	4,775
Alberta Lea, MN	4.3	$250,000	$40,000	electric+ heat	16%	6.3		800,000	
Olympia WA	11.5	$2,100,000	$180,000	electric+ heat	9%	11.7		2,800,000*	
Janesville WI	17.8	$910,000	$150,000	electric+ heat	16%	6.1	67,320	719,600	3,782
Rochester MN	23.9	$4,000,000	$564,398	electric + heat	14%	7.1	223,080		9,353
Shakopee MN	29.0	$27,800,000	$550,000	heat (pellets)	2%	50.5	368,160		12,695
Allentown PA	32.0	$1,107,000	$65,000	electric+ heat	6%	17.0	210,575		6,580
Brooklyn NY	120.0	31,630,396	$990,875	electric+ heat	3%	31.9	505,479	13,336,000	4,212

* Electricity saved (by both biogas use and energy efficiency).
+ See Appendix III for case study summaries.
^ Annual saving divided by initial total cost.

The data from these very limited and diverse case studies were averaged within each size class (except in the >50 MGD) and applied to WWTP that already have some kind of AD infrastructure (63 small, 7 medium, 16 large) as shown in Table 4. These retrofits were based on a variety of different uses of methane for electricity and heat (e.g. vehicle fuel in Janesville WI and heat for drying solids into pellets for agricultural land application in Shakopee, MN). While these case studies should not be directly compared, they represent a screening level or preliminary estimate of costs and methods in which site-specific retrofit of very different existing infrastructure can activate energy resources from the methane.

Table 4. Estimated cost for retrofit of existing systems with some anaerobic digestion (AD) infrastructure in NY.

Category	Size	WWTP w AD	Estimated + Retrofit Cost	Cost Savings	Simple Financial Return	Total Cost
	MGD	Num.	$ costs	$ savings	%	Million $
Small	1 to 10	63	$276,500	$38,500	14%	$17
Medium	10 to 50	7	$7,183,400	$301,880	4%	$50
Large	>50	16*	$31,630,396	$990,875	3%	$443

*Removed 2 large plants (Owls Head and Newtown Creek in New York City) from total cost as it was the plant used in case studies; project completed in 2011.
+ See Appendix III for details.

Based on extrapolation from the case studies to all of the WWTP in the State, we estimate the total cost for retrofitting 86 plants with some AD infrastructure to be $511 million (Table 5). This total includes 86 plants minus two large recent-known retrofits. Notably, these case studies have a range in the simple financial returns, retrofitting strategies, and CH_4 produced per million gallons of influent. The average cost is $0.23 per gallon influent. This estimate is meant only as a preliminary or screening-level analysis to begin to investigate the potential costs and returns of increasing biogas production in WWTP throughout the State. The specific plants with AD are listed in Appendix I (Table A1-1), including age since retrofit, level of treatment, and proportion of design capacity used.

Table 5. Estimated cost of retrofitting wastewater treatment plants to improve methane capture and use based on case studies and plant size.

Category MGD	Case Study Ave Size MGD	Unit Cost $/MGD *	Total Effluent MGD	Effluent in AD MGD	Proportion AD by Size %	Ave NY WWTP Size^ MGD	Total Cost Million $
1 to 10	3.8	$72,763	421	204	9%	3.3	$17
10 to 50	22.8	$314,647	463	186	8%	23.2	$50
> 50	120.0	$263,587	1,933	1,826	82%	113.7	$443
Total			2,817	2,216			$511

* As calculated based on case studies in Table 3.

^Average plant size means ALL plants in this size category.

While the potential would be 3,500 million cubic feet methane per year, this is unrealistic given the number of plants and the cost for retrofitting plants already partially equipped with some kind of anaerobic digestion. Figure 3 summarizes NYSERDA 2008 reported use (1.8 million cf CH_4/yr), the potential usable methane from retrofitting systems with existing AD infrastructure (2.8 million cf CH_4/yr), and the total technical production potential (3.6 million cf CH_4/yr) based on the NYSERDA survey.

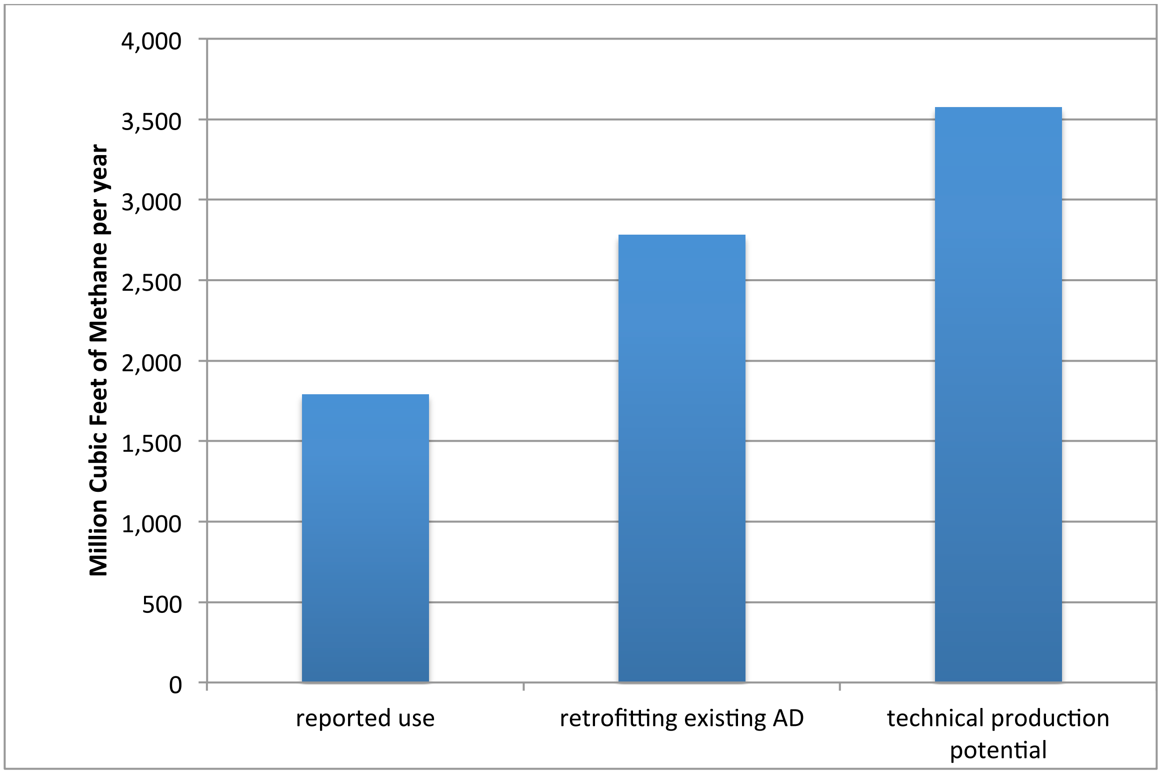


Figure 3. Current and potential methane production from wastewater treatment plants in New York State.

Figure 4 reframes the energy production potential shown in Figure 3 into financial terms. While the smallest plants had the greatest simple return (14%), they also account for only 9% of flow in AD systems (1-10 MGD, Table 5). The medium-sized plants with 4% simple return accounted for 8% of the effluent flow in AD systems (10-50 MGD). The large plants (>50 MGD) accounted for 82% of the effluent flow in AD systems but only had a 3% simple return.

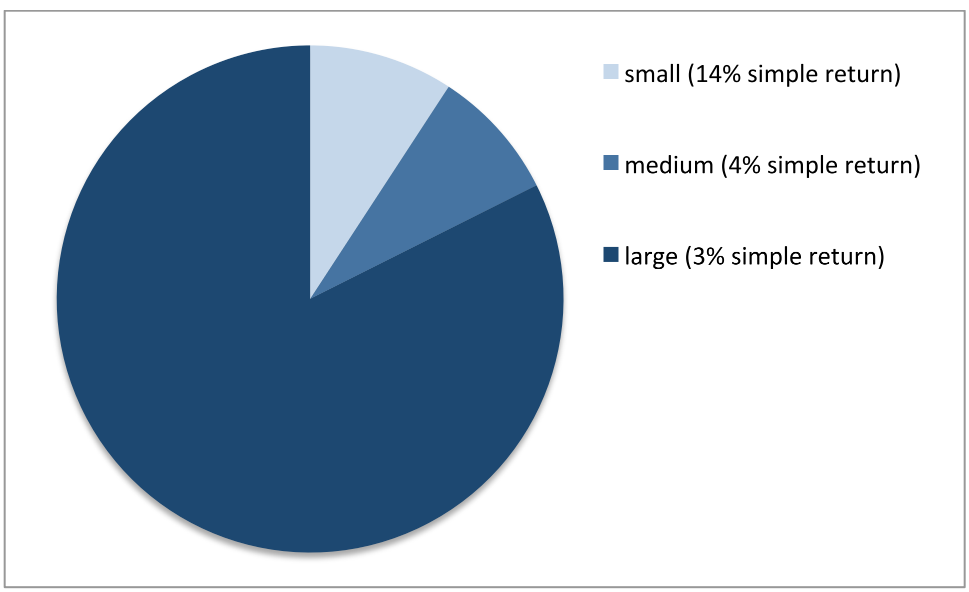


Figure 4. Estimated financial returns by proportion of influent flow in New York State WWTP that currently have Anaerobic Digestion Infrastructure.

This biogas-to-bioenergy analysis could be incorporated into plans for retrofitting aging infrastructure for other reasons, such as improved water quality. Our geospatial analysis identified 72 plants that have not been updated since before 1984 and identified 4 plants with only primary treatment (see Figure 5). For greater detail, See Appendix I Figure A1-2 for treatment levels (including secondary and tertiary treatment.), or Table A1-1 by WWTP name.

Grey highlights in Figure 5 show the 9 sub-basins of the Mohawk-Hudson watershed (using USDA/NRCS HUC-8). Blue lines show the Hudson and Mohawk Rivers and major tributaries (based on the USGS Hydrography shape file).

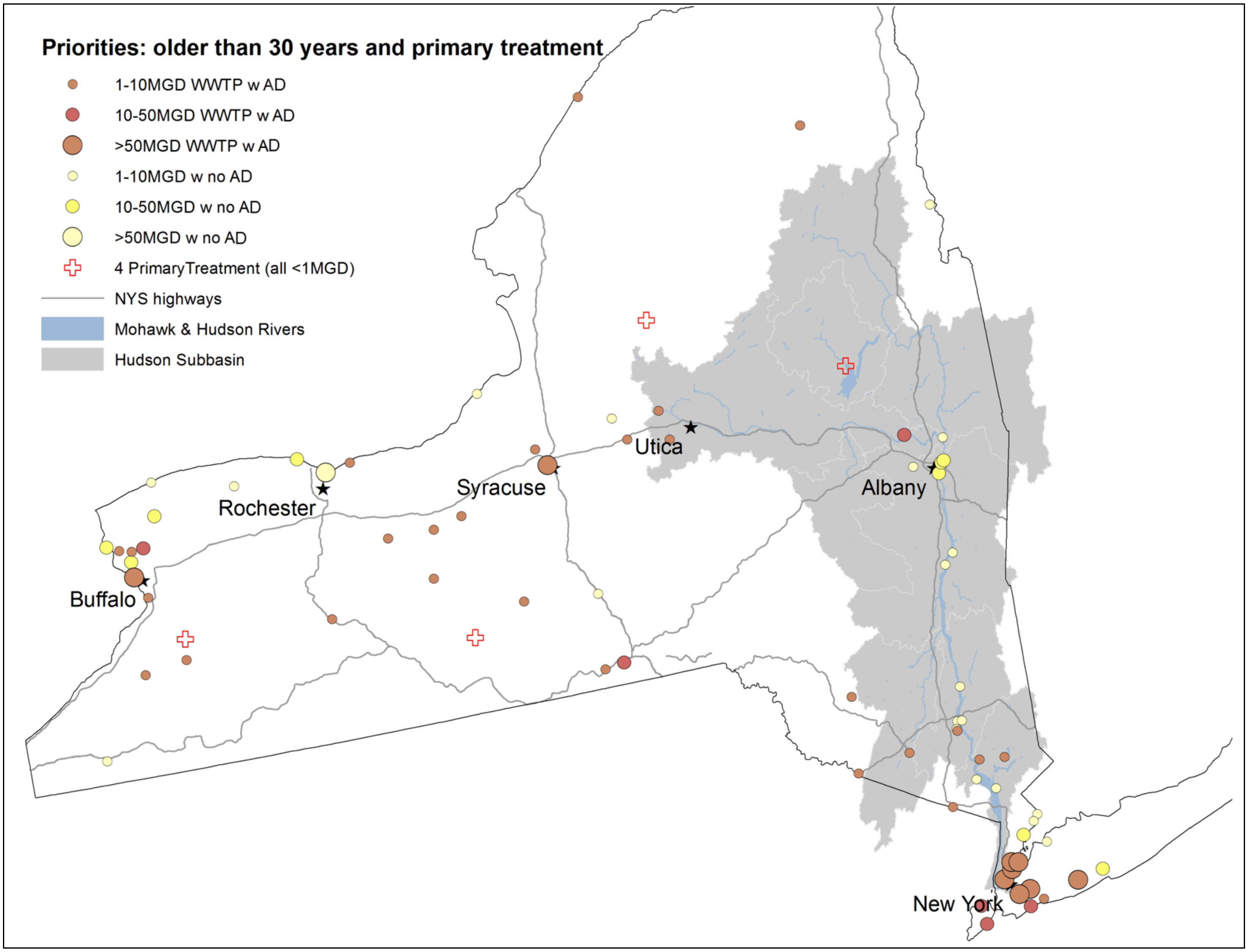


Figure 5. Primary treatment plants and plants more than 30 years since last retrofit (<1985). 570 common WWTP from NYSERDA were permitted SPDES in 2011 by NYDEC. From the NYSERDA data, it was determined that 4 of these are primary treatment, 72 have infrastructure that hasn't been updated for >30 years.

The State or other organizations might prioritize these older plants for retrofitting for water quality reasons and then more accurately assess individual plant capacity for also addressing energy efficiency, greenhouse gases, and energy production. These attributes are shown in map form in Appendix I. For plants that have some kind of anaerobic digestion infrastructure in plants >1MGD see Figure A1-3. For plants <1MGD that have Anaerobic Digestion that could be sources of non-flared methane see Figure A1-4). To identify plants that could be running inefficiently due to under or over capacity using equipment not well sized to the tasks see Figure A1-5.

Discussion and Recommendations

Because NYS water infrastructure is aging, and yet funds for improvements are very limited, we identified the potential for increased biogas production and use that would provide a financial return. We focused on energy because it is the 2nd largest cost in running WWTP after labor. Specifically, we identified systems with anaerobic digestion in plants greater than 1 MGD in size and estimated the cost to retrofit these systems to use biogas for electricity. Retrofitting 86 plants would address 2,200 MGD of wastewater and would cost $0.23 per gallon capacity, for a total of $511 million dollars. However, as shown in Figure 4 and discussed further below, the cost and returns vary considerably for different sized WWTP.

Retrofitting electric generating systems may occur every 20 years for multiple reasons A) the equipment is reaching the end of its useful life, B) there are more efficient systems, C) Hydrogen Sulfide (H_2S – a byproduct) is corroding equipment and new systems remove H_2S, 4) creating duel fuel sources (can use both biogas and natural gas) to maintain consistent system energy production. To help target plants that might be prioritized for retrofits to increase biogas production and use, in Appendix I we provide a table (Table A1-1) that corresponds to Figure 5 for identifying WWTPs that have not been retrofitted for more than 30 years. In total, 72 plants (>1MGD) have not been retrofitted since before 1984. Table A1-2 also includes treatment level (primary and secondary) as another important factor to consider in retrofits, though notably, the only large WWTP with primary treatment, we believe, has been retrofitted since this 2008 NYSERDA survey.

We analyzed a range of different-sized WWTP with anaerobic digestion (>1 MGD). There are 162 WWTP (>1MGD) that could be targeted for increased energy production and use. While there is greater opportunity in the larger plants, they have a lower financial return based on our case study analysis as compared to the smaller plants. Notably, one large plant (107 MGD), in Rochester, NY decommissioned their incineration facility and is currently hauling raw (undigested solids) to landfill. This facility accounts for 16% of all flow that is not in anaerobic digestion treatment and could present a viable full retrofit for energy production with if supported by further site-specific analysis.

According to the 2011 USEPA Combined Heat and Power Partnership (CHPP), 43% of US WWTP greater than 1 MGD operate anaerobic digestion (WERF 2014). Only 8% of these facilities generate electrical or thermal energy using biogas. This low proportion is attributed primarily to inadequate financial payback. There is limited available capital for 20-30 year payback periods. Plants >5 MGD have been identified as the minimum size necessary for efficient production (CHPP 2007). However, a survey found that 5-10 MGD facilities have found means to justify biogas-use projects for communities, but plants in the 10-25 MGD were identified as problematic due to inadequate gas production functioning as a barrier to implementation (WERF, accessed February 2014). However, WWTP in this size class could be targeted for receiving food waste that would increase biogas production. Notably, our analysis indicates the best return on investment in the smaller plants (1-10MGD) but it is likely, those retrofits were highly targeted for small municipalities to engage in infrastructure development. That said, those kinds of opportunities clearly do exist. However, According to the EPA market analysis of WWTP, the vast majority of economic opportunity comes from WWTP >30MGD (EPA 2011).

There are other reasons besides electricity cost savings to increase biogas production with anaerobic digestion. First, digestion reduces solids, thus reducing the volume and weight of solids that must be transported to a landfill or other location. Also given that the State has a cool climate, biogas can be combusted to help heat the plant space or to help maintain digestion temperature requiring far less technical expertise and cost than electrical generation but still providing energy savings. See Appendix IV for other considerations such as using renewable compressed natural gas (R-CNG) to run fleet vehicles.

Notably, 40 out of 67 NYSERDA survey respondents reported that they flared or vented some portion of the biogas produced. This is an indication of both an opportunity and problem; it is unused energy as well as a significant source of greenhouse gas emissions if not flared. Even the smallest size class of plants reported some anaerobic digestion systems. At minimum, policy makers might look at all AD-containing systems and initiate a simple methane capture and flare policy incentive to address the issue of GHG emissions from non-combusted methane emission. In Appendix I Figure A1-3, we have identified 162 plants (>1MGD) in New York State with some kind of anaerobic system to be targeted for simple retrofit with flare if conversion of methane to energy is inefficient. Additionally, there are 57 very small (<1MGD) plants that have anaerobic digestion but it is unclear if these systems also have a method of flaring the gas before it is released (See Figure A1-4).

A significant number of plants are running far under capacity (as low as 23%) as shown in Figure A1-5. This low capacity also poses both an opportunity and a problem. These plants could be targeted to receive other wastes to increase capacity and fill a treatment need if suitably equipped. However, when a plant is running under capacity, it generally has equipment running inefficiently. Many WWTP have undergone minor energy efficiency retrofits that are very cost effective simply by downsizing oversized equipment. While consolidation is a strategy to potentially improve water quality, performance and cost in a micro-region, there are a myriad of considerations to be evaluated (Woodbury 2014).

Finally, we include an Appendix II that focuses on the opportunities in the Hudson-Mohawk Watershed. The Hudson-Mohawk watershed basin is composed of 9 sub-basins. While it would cost 127 million to mitigate all the selected WWTP in the watershed (that are >1MGD and have some kind of AD), the priority should be 22 plants older than 30 years (See Figure A2-3).

In sum, 72 of NYS WWTP (>1 MGD with some kind of AD) are more than 30 years old (See Figure 5). Because they will be requiring retrofitting to maintain water quality, it seems reasonable to also investigate options for also increasing energy production, reducing energy use, and reducing greenhouse gas emissions in a cost-effective fashion. Our preliminary estimate of $511 million is only 4% of the proposed 13.6 billion required for facility upgrades (NYDEC 2008). However, there are barriers to overcome. When there is capital available, it is often used for higher priority demands. There is a perception that the economics do not justify the investment (WERF, 2014). There are regulatory policy factors such as power utilities charging for back-up power when the system goes down. Other regulatory policies involve air permitting requirements with regard to nitrogen oxides and carbon monoxide emissions. Finally, it would help if biogas was added to the US Department of Energy list of renewable energy to receive other benefits.

Data Needs

Our analysis is intended only as a first step toward investigating options for cost-effective retrofits to WWTP to increase biogas production, methane destruction, and increase energy efficiency. While the case studies represent “real world” results, they may not be representative of all of the remaining WWTP in the State. It is possible that the case studies were performed on facilities with greater than average potential for increased biogas production and use, or facilities with greater than average potential financial return from the retrofit. If so, our preliminary estimates of cost savings may be too optimistic. Conversely, there are other benefits to retrofits in addition to increased biogas production and use and energy savings. If such benefits are substantial, our preliminary estimates of cost savings attributed to energy conservation and increased biogas production may be too pessimistic. More detailed information on the case studies, including the suite of benefits and further details on both costs and savings would be very useful. Further analysis of the extent to which the case studies are representative of all WWTP in the State would likewise be very useful. Finally, there is the opportunity in some WWTP to add food waste or other “high-strength” wastes to increase biogas production (NYSERDA 2007). We discuss one such case study in Appendix IV. However, such potential should be compared to opportunities to process the food waste at the manufacturing plant to provide local heat and power and avoid transportation costs for both finances and energy.

We believe that our results are useful to support strategic planning efforts, but more detailed site-specific data on costs and benefits are needed to evaluate any given potential retrofit project. We note that NYSERDA has suggested there may be a more targeted survey completed in 2015 (personal communication, Kathleen O'Connor). This survey might provide additional valuable data to improve our analysis. In conclusion, in the subsequent section entitled "Promising Opportunities and Policy Implications" we summarize opportunities to improve wastewater treatment infrastructure, reduce greenhouse gas emissions, increase biogas production and use, and reduce energy costs.

Promising Opportunities and Policy Implications

1) The 72 plants built or retrofit before 1985 should be considered high priority for retrofit for multiple reasons including increased energy efficiency and increased biogas production and use (Figure 5). Additionally, sites that discontinued incineration to meet new regulations (EPA 2012, Cornell University Legal Information Institute) may be prioritized for retrofit (Such as the Large Rochester Plant).

2) The 4 plants with only primary treatment should be assessed for potential retrofitting to improve water quality (Figure 5). However, these plants are very small.

3) The 162 WWTP larger than 1 MGD could be targeted for energy production with the 86 that have some kind of Anaerobic Digestion infrastructure evaluated first. The largest plants have the greatest opportunity for total energy production, but have lower expected financial return. The smaller plants have less energy production potential per plant, but have a higher likely average financial return (Figure 4). Large plants without any reported AD infrastructure, such as the relatively large Rochester WWTP (107 MGD) should be evaluated for development of AD systems. Such a retrofit would likely be very costly since it has no reported AD infrastructure and may have space limitations. While there were 52 WWTP identified without AD (>1MGD) only 6 of them were >10 MGD.

4) From a greenhouse gas perspective, all 143 WWTP with AD should be evaluated for adding a simple flare to destroy methane. Given that methane has an extremely high impact on climate, simple flaring should be considered as an important first step because it is relatively inexpensive and easy (For <1 MGD, See Appendix I, Figure A1-4, for plants >1MGD, See Figure 2). More complex and costly retrofitting for increased biogas production and/or use for energy be should evaluated as a second step for plants >1MGD (Figure 2).

5) All plants running at less than 50% capacity should be evaluated as to the reason why. Low use poses both an opportunity and a problem. These plants could be targeted to receive food wastes or other high-strength wastes to increase capacity utilization and fill a currently untreated effluent nearby. With suitable equipment such plants could also increase methane production for electric generation. However, when a plant is running under capacity, it generally has equipment running inefficiently. Many WWTP have undergone minor energy efficiency retrofits that are very cost effective simply by downsizing over-sized equipment. Retrofitting these plants to have some components replaced that run more efficiently is likely to be much less expensive and have a better financial return, but any proposed retrofit to a specific facility will require further detailed data collection and analysis.

6) While consolidation is worth considering as a strategy to improve water quality and performance, and possibly reduce costs, there are a myriad of considerations to be evaluated for a given consolidation option (see Woodbury 2014). However, proximity does indicate a level of opportunity for energy efficiency that could be advantageous if combined with other benefits. To see the potential in the Mohawk-Hudson Watershed, see Appendix II, Figure A2-1.

7) For more detailed analysis of the Mohawk-Hudson basin composed of nine sub-basins, please see Appendix II. Targeted areas are: 22 plants older than 30 years that also have anaerobic digestion infrastructure, and two plants with only primary treatment (Figure A2-3).

Methods

We searched for journal articles and technical reports on biogas production and use in WWTP, with a focus on New York State. Sources included the web sites of the Water Environment Research Foundation (WERF), New York State Energy Research and Development Authority (NYSERDA), New York State Department of Environmental Conservation (NYDEC), Environmental Facilities Corporation (EFC), New York Power Authority (NYPA), United States Environmental Protection Agency (USEPA) and others. A key source was a 2008 report produced for NYSERDA that analyzed energy use by WWTP throughout New York State. Most notably, we used this evaluation to estimate the upper limit of the technical potential for biogas production. We obtained the dataset that was the basis of this report and used it for further analysis such as size based on flow as million gallons per day (MGD), capacity for producing biogas as represented by having some type of anaerobic treatment, location (latitude and longitude), and other characteristics. From these data we were able to group WWTP by size and total flow. We chose not to assess the methane production potential from the effluent as it requires data on the quantity of volatile solids (VS) in the effluent. The amount of VS difficult to assess as some systems are only municipal wastewater (higher percentage of volatile solids) while others process storm-water thus diluting the concentration of VS while increasing the total volume measured.

We also searched for reports of case studies of WWTP capital projects in northern climates that increased biogas production and use and increased energy efficiency. These case studies came from a variety of public and private publications, including NYSERDA, WERF, consulting firms, as well as municipal government fact sheets. The basis of these case studies range from comprehensive white papers to 2-page fact sheets with information ranging from population served, biogas production, methane content in the biogas, gallons of wastewater entering the system, energy saved, energy expended, etc. From these case studies we were able to develop preliminary estimates of the cost to retrofit plants to increase biogas production and use by size category.

We also performed spatial analysis of WWTP throughout the State. We used several publicly available datasets and combined them with our NYSERDA WWTP dataset. Specifically, we used the New York State Pollution Discharge Elimination System (SPDES) for geo-located WWTP identification. It is also useful because it is from 2011, thus updating the 2008 NYSERDA dataset. Hydrography data layers came from USGS (2014) and sub-basin (HUC-8) data came from NRCS/USDA (2014). Cities and Highways came from the ESRI corporation.

Abbreviations

CH_4: Methane
CHPP: Combined Heat and Power Partnership
CO_2: Carbon Dioxide
EFC: Environmental Facilities Corporation
ft^3/day: cubic foot per day
GHG: Greenhouse Gas
GIS: Geographic Information Systems
HREP: Hudson River Estuary Program
MGD: Million Gallons per Day
NRCS: Natural Resources Conservation Service
Num.: Number
NYDEC: New York State Department of Environmental Conservation
NYPA: New York Power Authority
NYSERDA: New York State Energy Research and Development Authority
SPDES: State Pollution Discharge Elimination System
USDA: United States Department of Agriculture
USEPA: United States Environmental Protection Agency
USGS: United States Geological Survey
WERF: Water Environment Research Foundation
WRI: Water Resource Institute
WWTP: Wastewater Treatment Plants
Yr: year

Acknowledgements

We appreciate assistance from Lara Bertoia in obtaining case study information. We thank Kathleen O'Conner of NYSERDA for sharing a database on water infrastructure in New York State. We thank Kathleen O'Conner and Nancy Andrews for comments on a draft of this report. We thank Brian Rahm, Sridhar Vedachalam, Susan Riha, and David Kay for discussions throughout the project and comments on earlier drafts of this report. This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the New York State Environmental Protection Fund.

Appendix I: Location and Characteristic of NYS Wastewater Treatment Plants

All SPDES permits in New York State in 2011

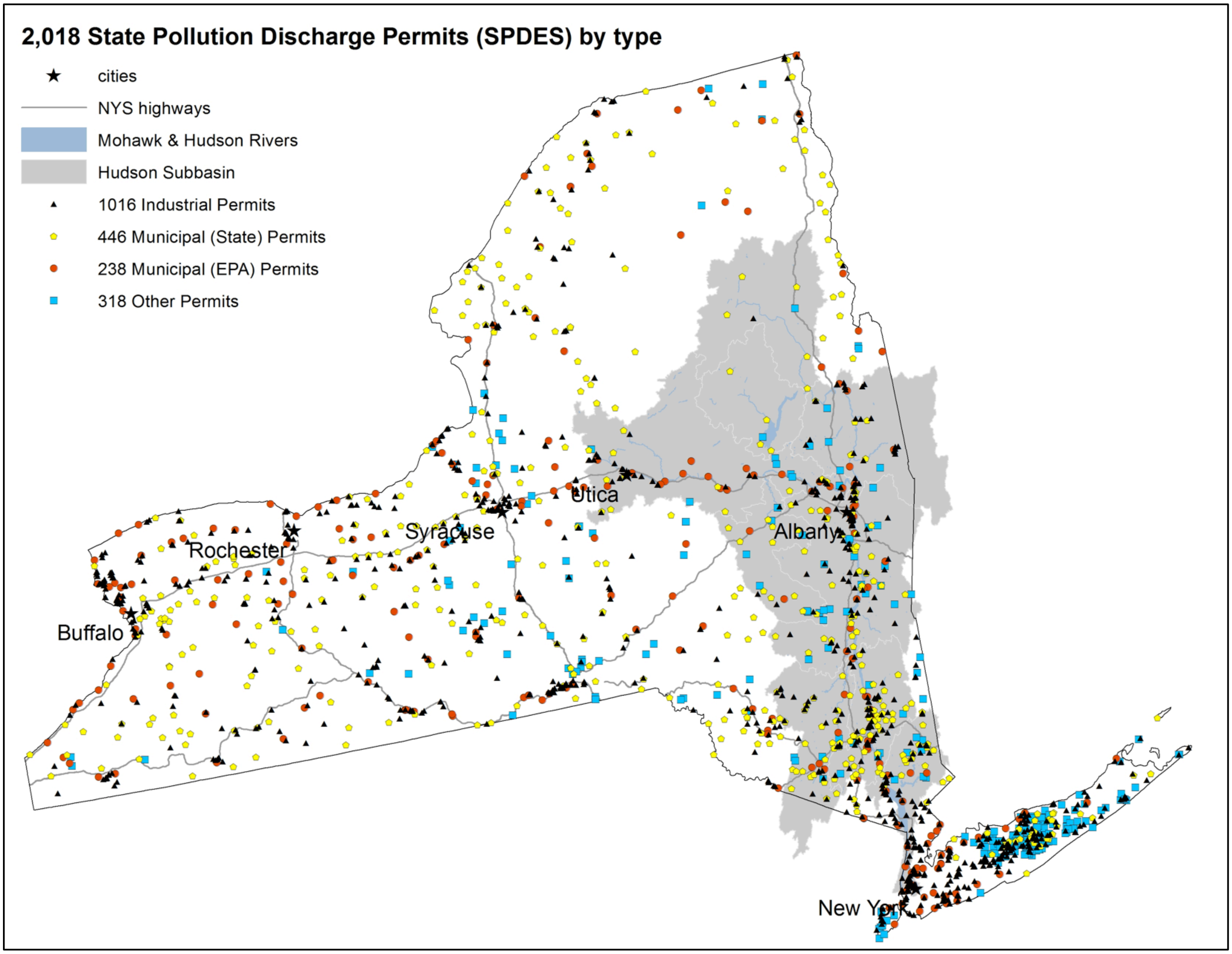


Figure A1-1. New York State Pollutant Discharge Permits by Type.
Based on NYS DEC 2011 SPDES and USDA/NRCS HUC-8 sub-basin boundaries
Results: 2018 SPDES (1018 Industrial, 684 Municipal, 318 Other) and sub-basins (blue)

Treatment Level

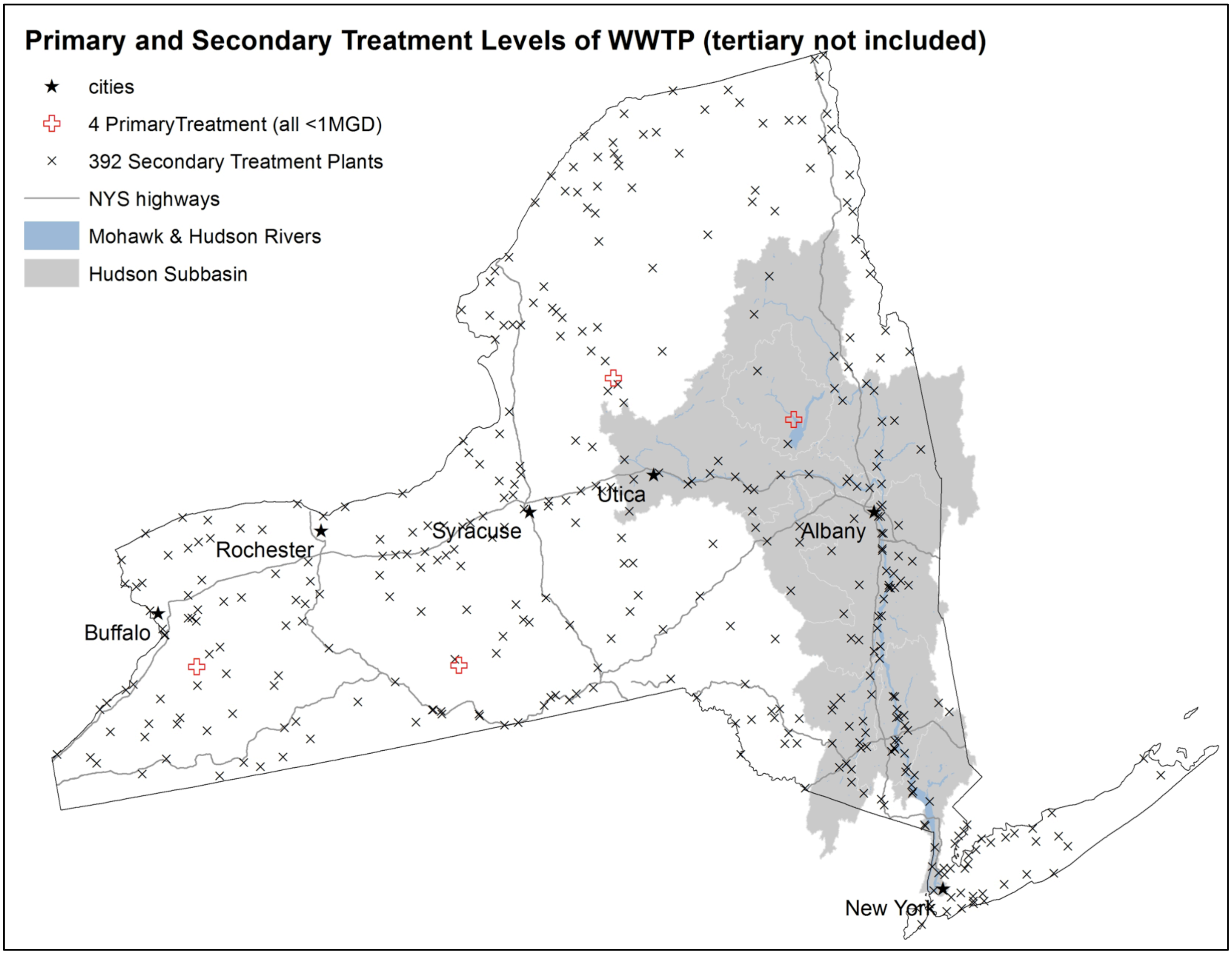


Figure A1-2. New York State wastewater treatment plants identified by level of treatment.

Note that 5 WWTP were primary treatment “red crosses” (4 were very small = <1MGD and it is believed that the large plant in NYC is no longer primary). There a 392 Secondary Treatment plants (‘orange dots’) and 162 Tertiary or Advanced Treatment (data not shown).

Plants with Anaerobic Digestion Systems

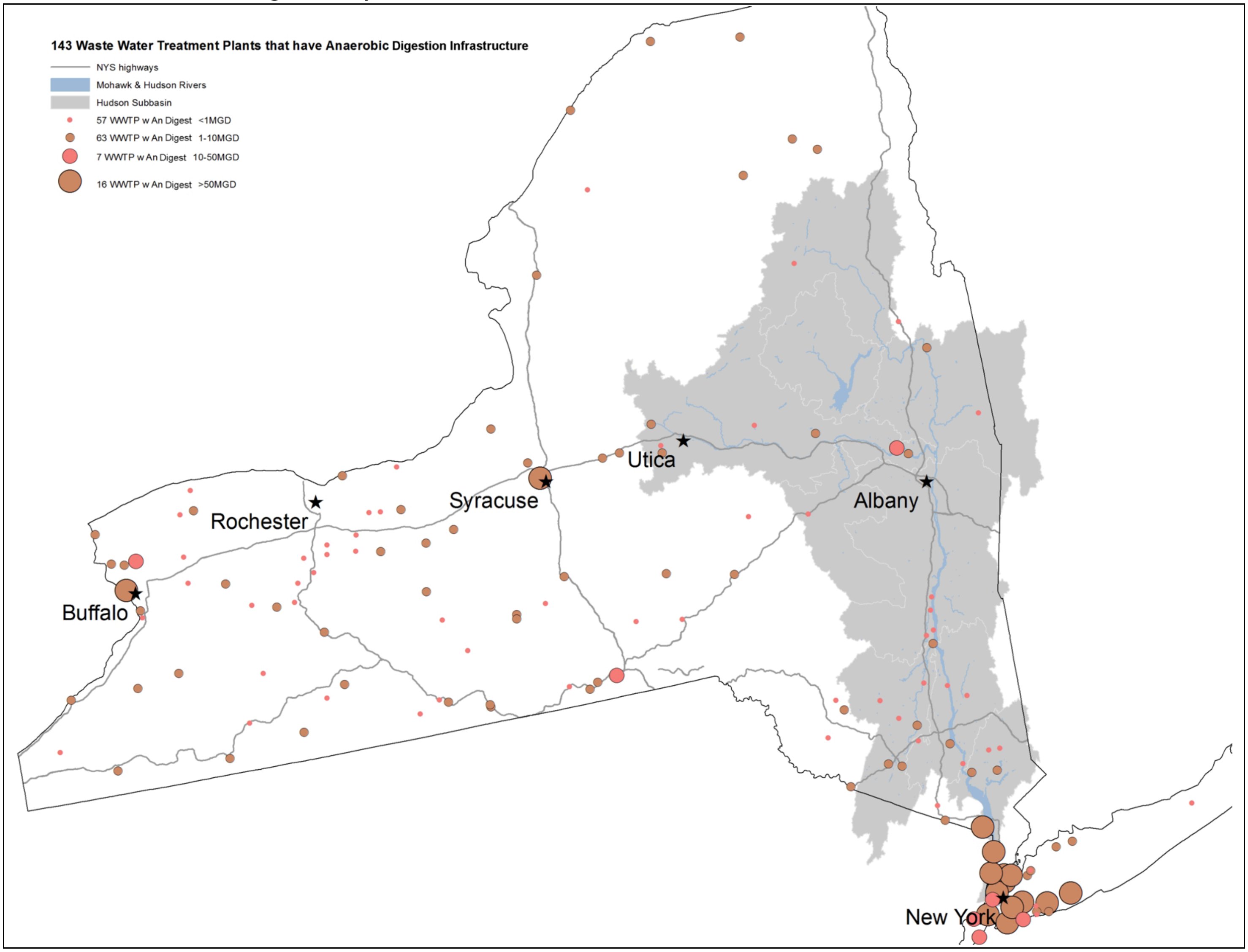


Figure A1-3. New York State wastewater treatment plants >1 MGD with some kind of anaerobic digestion. Based on NYSERDA 2008 dataset daily flow and indication of AD system (AD = having an "Anaerobic Digestion System") 86 Plants (>1MGD) have existing AD infrastructure. Using the case study averages by plant size, it will cost $511 million to retrofit all the plants >1MGD for improved biogas capture and use.

Discussion of Greenhouse Gases

It is unlikely that in the near future there will be any direct financial benefit from collecting methane from very small plants. However, for plants that have some kind of anaerobic treatment, it may be valuable to assess opportunities to capture and flare methane generated from anaerobic treatment.

With WWTP, it should be noted that active or passive digestion of solids will generate methane, a powerful greenhouse gas (GHG). Methane is a potent but short-lived GHG. It is considered 34 times as potent as CO_2 on 100-year time scale and 86 times a potent in a 20-year time horizon (IPCC, AR5, 2013). As such, it can accrue carbon credits quite quickly. Simple flaring mitigates this risk and combustion for electric generation has an additional benefit by displacing fossil fuel emissions that might otherwise be used. However, active digestion of solids to maximize methane production for electricity production should not be considered a methane destruction credit. Therefore GHG accounting for AD systems should not consider this additional and intentional CH_4 production as a mitigation of state, county, or municipal GHG. This increased methane production/destruction should only be credited for fossil fuel displacement. Furthermore, all WWTP should be retrofitted to allow capture and flare of system emissions, if not used for energy generation.

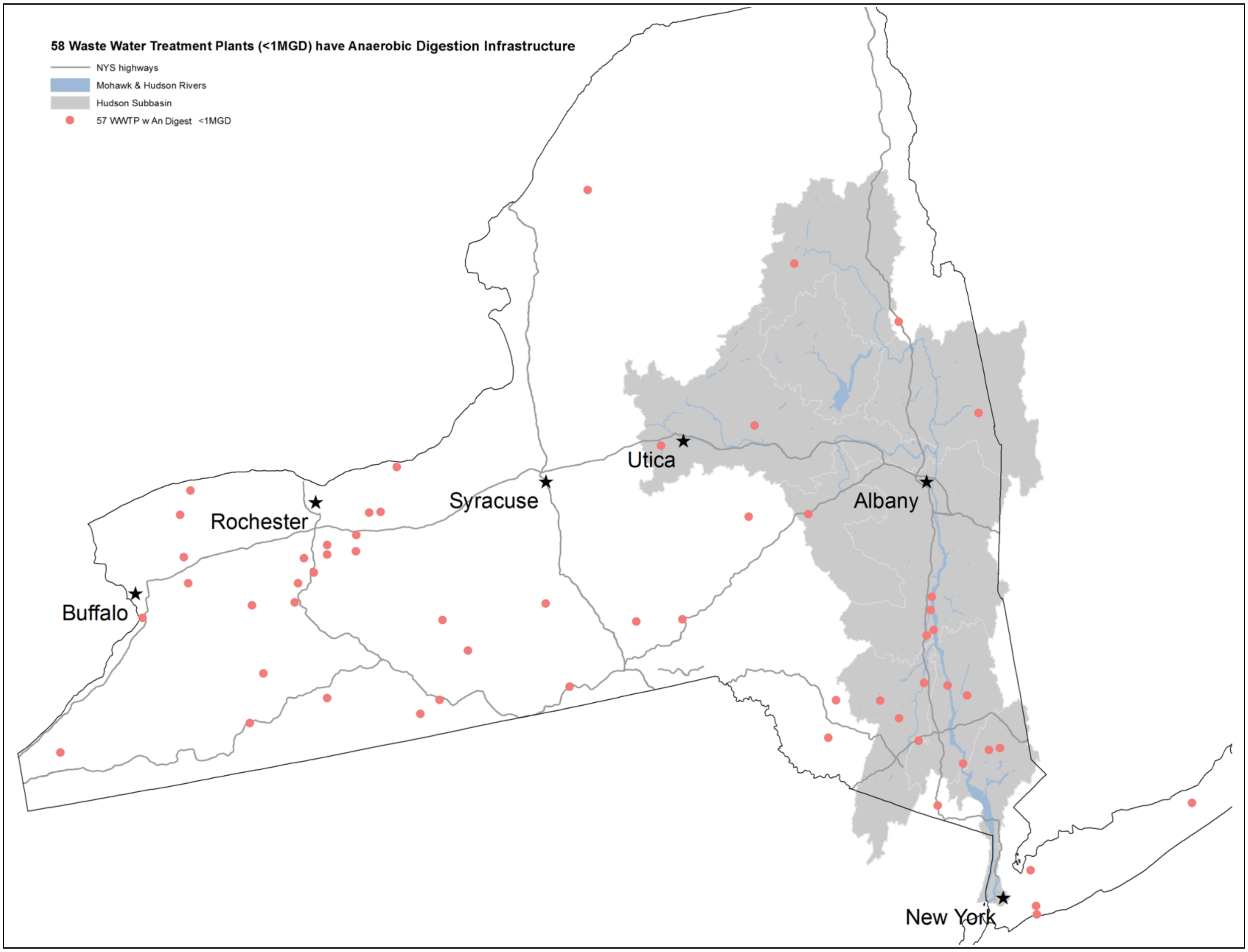


Figure A1-4. New York State WWTP <1 MGD with some kind of anaerobic digestion identified for possible methane flare systems. Based on NYSERDA 2008 dataset daily flow and indication of AD system (AD = having an "Anaerobic Digestion System") There are 57 are very small (<1MGD, small stars) AD system WWTP and these should be evaluated for installing flares to mitigate methane-based GHG emissions.

System Capacity

A significant number of plants are running far under capacity. Often, these plants have equipment and procedures that are over-sized for the flow. Retrofitting and downsizing these operations could produce substantial gains in energy efficiency.

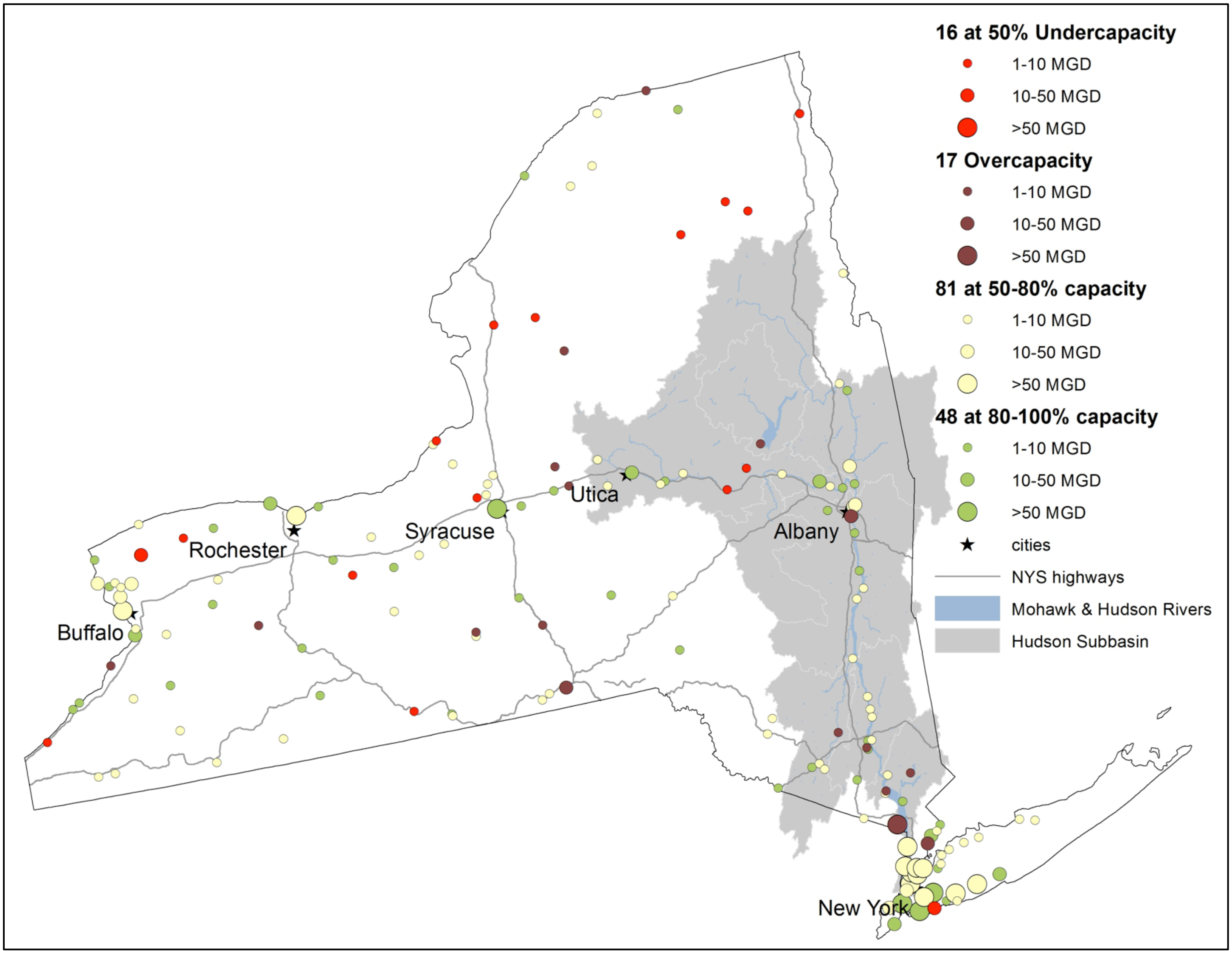


Figure A1-5. Wastewater treatment plants under and over design flow capacity. Based on NYSERDA 2008 dataset using average daily flow divided by plant design capacity a percentage of capacity was calculated. There are 16 plants that are operating below 50%. There are 81 plants that are operating between 50 and 80%. Notably, 17 are running over capacity (but this could be due issues in the reported data or should be looked at for water quality purposes).

Table A1-1: Key Characteristics of Selected WWTP in New York State

This table includes 162 Wastewater Treatment Plants in NYS with >1 MGD flow (based on NYSERDA 2008). Highlighted in peach color are WWTP that are >30 years old that have anaerobic digestion treatment infrastructure.

SPDES NUM	CITY	Built or Most recent update	Treatment Level	Anaerobic Digestion	size	% Capacity+
NY0027979	LOCKPORT	2003	Secondary		Small	0.61
NY0028401	ALBION	1979	Secondary		Small	0.92
NY0028436	BUFFALO	1987	Tertiary		Small	0.68
NY0028533	WEST HAVERSTRAW	1977	Secondary		Small	0.65
NY0028851	STONY POINT	1984	Secondary		Small	1.08
NY0029050	GLENS FALLS	1987	Secondary		Small	0.53
NY0029106	OSWEGO	1979	Tertiary		Small	0.78
NY0029114	OSWEGO	1996	Secondary		Small	0.38
NY0029173	WATERFORD	1978	Secondary		Small	0.88
NY0029351	KINGSTON	1985	Secondary	y	Small	0.78
NY0029475	NEWARK	1987	Tertiary	y	Small	0.55
NY0029726	PENN YAN	1983	Secondary	y	Small	0.78
NY0029807	CANASTOTA	1987	Secondary	y	Small	0.90
NY0029831	OGDENSBURG	1980	Secondary	y	Small	0.90
NY0029939	TUPPER LAKE	1992	Secondary	y	Small	0.28
NY0030317	SYRACUSE	2000	Secondary		Small	0.62
NY0030376	MALONE	1999	Secondary	y	Small	0.95
NY0030490	WALDEN	1986	Secondary	y	Small	1.05
NY0030571	SYRACUSE	2003	Secondary		Small	0.50
NY0030864	ROME	1977	Secondary	y	Small	0.62
NY0031151	ONEONTA	1994	Secondary	y	Small	0.69
NY0031194	MASSENA	2001	Secondary	y	Small	0.67
NY0031518	GOSHEN	1969	Secondary	y	Small	0.70
NY0032093	GOWANDA	1960	Secondary	y	Small	0.63
NY0033308	SENECA FALLS	1970	Secondary	y	Small	0.56
NY0020125	LOWVILLE	1994	Secondary		Small	1.07
NY0020290	AMSTERDAM	1999	Secondary		Small	0.66
NY0020354	LAWRENCE	1966	Secondary	y	Small	0.96
NY0020389	CATSKILL	1970	Secondary		Small	0.72
NY0020486	HERKIMER	1988	Secondary		Small	0.86
NY0020567	LONG BEACH	2003	Secondary	y	Small	0.75
NY0020621	WELLSVILLE	1997	Secondary	y	Small	0.59
NY0020818	POTSDAM	1999	Secondary		Small	0.61
NY0020958	ITHACA	1974	Tertiary	y	Small	1.03
NY0021334	WESTFIELD	1988	Tertiary		Small	0.39
NY0021342	HUNTINGTON	1987	Secondary	y	Small	0.76
NY0021385	CLINTON	1980	Advanced	y	Small	0.64
NY0021423	NORWICH	1989	Secondary	y	Small	0.94
NY0021474	SPRINGVILLE	1973	Secondary	y	Small	0.91
NY0021610	WEBSTER	1982	Secondary	y	Small	0.85
NY0021733	SARANAC LAKE	1973	Secondary	y	Small	0.50
NY0021822	OYSTER BAY	1992	Secondary	y	Small	0.67
NY0021849	ATTICA	1986	Tertiary	y	Small	0.91
NY0021873	MEDINA	1986	Secondary	y	Small	0.24
NY0021903	AUBURN	1993	Tertiary		Small	0.73
NY0022039	HUDSON	1980	Secondary		Small	0.65
NY0022136	BUFFALO	1982	Secondary	y	Small	0.66
NY0022144	CORNWALL	1969	Secondary	y	Small	0.82

NY0022187	LAKE PLACID	2004	Secondary	y	Small	0.44
NY0022225	GUILDERLAND	1978	Tertiary		Small	0.88
NY0022403	LITTLE FALLS	1999	Secondary		Small	0.80
NY0022446	NEW WINDSOR	1974	Secondary		Small	1.11
NY0022454	MONTICELLO	1984	Tertiary		Small	0.54
NY0022748	SUFFERN	1983	Advanced	y	Small	0.78
NY0023485	CANAJOHARIE	1995	Secondary		Small	0.40
NY0023531	FARMINGTON	1990	Tertiary		Small	0.81
NY0023647	HORNELL	1986	Tertiary	y	Small	0.94
NY0023973	SCHENECTADY	1989	Secondary	y	Small	0.80
NY0024384	DANSVILLE	1978	Secondary	y	Small	0.91
NY0024422	MIDDLETOWN	1989	Secondary		Small	0.76
NY0024520	SOUTH FALLSBURG	1982	Secondary	y	Small	0.65
NY0025151	CARTHAGE	1992	Secondary		Small	0.31
NY0022543	BUFFALO	1996	Tertiary		Small	1.47
NY0236586	CANTON	1995	Secondary		Small	0.76
NY0079324	HAUPPAUGE	1996	Tertiary		Small	0.62
NY0027863	FORT COVINGTON	1987	Secondary		Small	11.75
NY0028363	MARATHON	1976	Secondary		Small	95.23
NY0025721	CORNING	2001	Secondary	y	Small	0.41
NY0025739	DELMAR	1992	Secondary		Small	0.93
NY0025798	APALACHIN	2002	Secondary	y	Small	0.69
NY0100803	WHITE PLAINS	1981	Secondary	y	Small	0.72
NY0106895	CELORON	1980	Advanced		Small	0.59
NY0108324	WHITE PLAINS	1981	Secondary		Small	0.83
NY0035742	ELMIRA	1987	Secondary	y	Small	0.67
NY0036528	HERKIMER	2003	Secondary		Small	0.77
NY0036706	TICONDEROGA	1979	Secondary		Small	0.78
NY0036790	SYLVAN BEACH	1979	Tertiary		Small	1.59
NY0036986	ELMIRA	1987	Secondary	y	Small	0.99
NY0149209	WAPPINGERS FALLS	1987	Secondary		Small	0.73
NY0183695	FORT EDWARD	1988	Secondary	y	Small	0.88
NY0206644	HAUPPAUGE	1988	Tertiary		Small	0.74
NY0025968	CANANDAIGUA	1980	Secondary	y	Small	0.48
NY0025976	BEACON	1972	Secondary		Small	0.63
NY0025984	WATERTOWN	1988	Secondary	y	Small	0.50
NY0026018	PLATTSBURGH	1987	Secondary		Small	0.36
NY0026034	EAST GREENBUSH	1991	Secondary		Small	0.88
NY0026042	JOHNSTOWN	1991	Advanced	y	Small	0.48
NY0026051	ORANGEBURG	1995	Secondary		Small	0.77
NY0026255	POUGHKEEPSIE	1990	Secondary		Small	0.75
NY0026271	POUGHKEEPSIE	1969	Secondary		Small	0.74
NY0026280	NORTH TONAWANDA	1981	Advanced	y	Small	0.51
NY0026301	FULTON	1991	Secondary	y	Small	0.66
NY0026310	NEWBURGH	1970	Secondary		Small	0.97
NY0026328	MIDDLETOWN	1989	Secondary	y	Small	0.94
NY0026409	FREDONIA	1999	Secondary	y	Small	0.81
NY0026514	BATAVIA	2005	Tertiary		Small	0.59
NY0026522	FLUSHING	1951	Secondary	y	Small	0.85
NY0026620	MINEOLA	1981	Secondary		Small	0.68
NY0026638	ITHACA	1987	Secondary	y	Small	0.55
NY0026719	WHITE PLAINS	1981	Secondary		Small	0.75
NY0026743	YORKTOWN HEIGHTS	1973	Tertiary	y	Small	1.06
NY0026778	PORT WASHINGTON	1991	Secondary		Small	0.73

NY0026786	WHITE PLAINS	1978	Secondary		Small	0.85
NY0026841	GREAT NECK	1995	Secondary	y	Small	0.83
NY0026956	ONEIDA	1982	Secondary	y	Small	1.16
NY0026999	GREAT NECK	1990	Advanced	y	Small	0.73
NY0027049	GENEVA	1983	Secondary	y	Small	0.84
NY0027154	WALTON	2002	Tertiary		Small	0.95
NY0027162	OLEAN	1990	Secondary	y	Small	0.63
NY0027561	CORTLAND	1995	Secondary	y	Small	0.86
NY0027570	JAMESTOWN	1985	Secondary	y	Small	0.63
NY0027596	SYRACUSE	2001	Tertiary		Small	0.67
NY0027618	SYRACUSE	1969	Secondary	y	Small	0.71
NY0027669	ENDICOTT	1972	Secondary	y	Small	0.78
NY0027693	GRAND ISLAND	1979	Secondary	y	Small	0.80
NY0027723	SYRACUSE	2003	Secondary		Small	0.81
NY0027758	NEWTONVILLE	1999	Secondary		Small	0.82
NY0027766	LEWISTON	1993	Secondary	y	Small	0.85
NY0027774	NEWFANE	1977	Tertiary		Small	0.72
NY0027901	GOSHEN	2005	Tertiary		Small	0.86
NY0027961	DUNKIRK	1984	Secondary		Small	0.86
NY0033545	COXSACKIE	1996	Secondary		Small	0.86
NY0022985	PERRY	1995	Secondary	y	Small	1.06
NY0023574	ELLICOTTVILLE	2002	Secondary		Small	0.74
NY0252042	MAYFIELD	?	Secondary		Small	16.77
NY0028231	ROCHESTER	1972	Secondary		Medium	0.84
NY0028240	BALLSTON SPA	1999	Secondary		Medium	0.54
NY0020516	SCHENECTADY	1975	Secondary	y	Medium	0.83
NY0024414	BINGHAMTON	1973	Secondary	y	Medium	1.18
NY0025780	UTICA	1987	Secondary		Medium	0.90
NY0087971	TROY	1976	Secondary		Medium	0.77
NY0095401	BUFFALO	2004	Tertiary		Medium	0.86
NY0104809	HAUPPAUGE	1981	Secondary		Medium	0.86
NY0025950	BUFFALO	1980	Tertiary	y	Medium	0.70
NY0026107	FLUSHING	1973	Secondary	y	Medium	0.62
NY0026174	FLUSHING	1978	Secondary	y	Medium	0.82
NY0026221	FLUSHING	1970	Secondary	y	Medium	0.44
NY0026336	NIAGARA FALLS	1983	Secondary		Medium	0.67
NY0026395	BUFFALO	1978	Tertiary		Medium	0.71
NY0026697	WHITE PLAINS	1981	Secondary		Medium	1.18
NY0026701	WHITE PLAINS	1993	Secondary		Medium	0.86
NY0026867	ALBANY	1974	Secondary		Medium	1.00
NY0026875	ALBANY	1974	Secondary		Medium	0.67
NY0027057	LOCKPORT	1973	Secondary		Medium	0.46
NY0027073	FLUSHING	1989	Secondary	y	Medium	0.53
NY0028339	ROCHESTER	1975	Secondary		Large	0.80
NY0028410	BUFFALO	1980	Secondary	y	Large	0.79
NY0031895	NEW CITY	1988	Secondary	y	Large	7.72
NY0026115	FLUSHING	1977	Secondary	y	Large	0.80
NY0026131	FLUSHING	1999	Secondary	y	Large	0.75
NY0026158	FLUSHING	1975	Secondary	y	Large	0.76
NY0026166	FLUSHING	1990	Secondary	y	Large	0.81
NY0026182	FLUSHING	1985	Secondary	y	Large	0.83
NY0026191	FLUSHING	1978	Secondary	y	Large	0.57
NY0026204	FLUSHING	1967	PRIMARY	y	Large	0.72
NY0026212	FLUSHING	1970	Secondary	y	Large	0.69

NY0026239	FLUSHING	1977	Secondary	y	Large	0.71
NY0026247	FLUSHING	1985	Secondary	y	Large	0.78
NY0026450	MINEOLA	1986	Secondary	y	Large	0.78
NY0026689	WHITE PLAINS	1990	Secondary	y	Large	0.69
NY0026859	MINEOLA	1983	Secondary	y	Large	0.80
NY0027081	SYRACUSE	1979	Secondary	y	Large	0.92

+ When overcapacity, it may just be an error in the original NYSERDA spreadsheet

Appendix II – Focus on the Hudson and Mohawk River Basins

Promising Opportunities and Policy Implications in the Hudson and Mohawk River Basins

1) **WATER QUALITY**, primary treatment: There is 1 plant with only primary treatment should be assessed for potential retrofitting to improve water quality. Note however that it is a very small plant (<1MGD).

2) **AGE**, 30 years since last retrofit: The 22 plants built or retrofit before 1985 should be considered high priority for retrofitting. See Figure A2-3.

3) **GHG**, flares on small plants: From a greenhouse gas perspective, all WWTP with AD should be evaluated for adding a simple flare to destroy methane. Given that methane has an extremely high impact on climate, simple flaring should be considered as an important first step because it is relatively inexpensive and easy (See Appendix I). More complex and costly retrofitting for increased biogas production and/or use for energy be should evaluated as a second step.

4) **COST for IMPROVING ENERGY PRODUCTION**: The WWTP larger than 1 MGD that have some kind of AD should be targeted for energy production. The largest plants have the greatest opportunity for total energy production, but have lower expected financial return. The smaller plants have less energy production potential per plant, but have a higher likely average financial return. Only 6 of 9 sub-basins would be impacted (summarized in Table A2-1).

6) **CAPACITY.** All plants running at less than 50% capacity should be evaluated as to the reason why. Low use poses both an opportunity and a problem. These plants could be targeted to receive food wastes or other high-strength wastes to increase capacity utilization and fill a currently untreated effluent nearby. With suitable equipment such plants could also increase methane production for electric generation. However, when a plant is running under capacity, it generally has equipment running inefficiently. Many WWTP have undergone minor energy efficiency retrofits that are very cost effective simply by downsizing over-sized equipment. Retrofitting these plants to have some components replaced that run more efficiently is likely to be much less expensive and have a better financial return, but any proposed retrofit to a specific facility will require further detailed site-specific data collection and analysis. See 'red dots' of Figure A2-1 for plants running <50% capacity.

7) **CONSOLIDATION.** While consolidation is worth considering, there are a myriad of considerations, and it may not always result in cost savings (Woodbury 2014). However, proximity does indicate a level of opportunity for consolidation and energy efficiency that could be advantageous if combined with other benefits. To see all SPDES permitted discharges that are within 1 mile of other discharges see the 'white polygons' in Figure A2-1.

In summary, the Hudson-Mohawk basin (composed of 9 sub-basins) was assessed in greater detail following the same methodology as the State-wide analysis. It would cost $127 million to retrofit the plants identified for increased methane capture in WWTP with already existing AD infrastructure. Targeted priorities are: 22 plants older than 30 years that also have anaerobic digestion infrastructure, and 2 plants that may have only primary treatment (Figure A2-3).

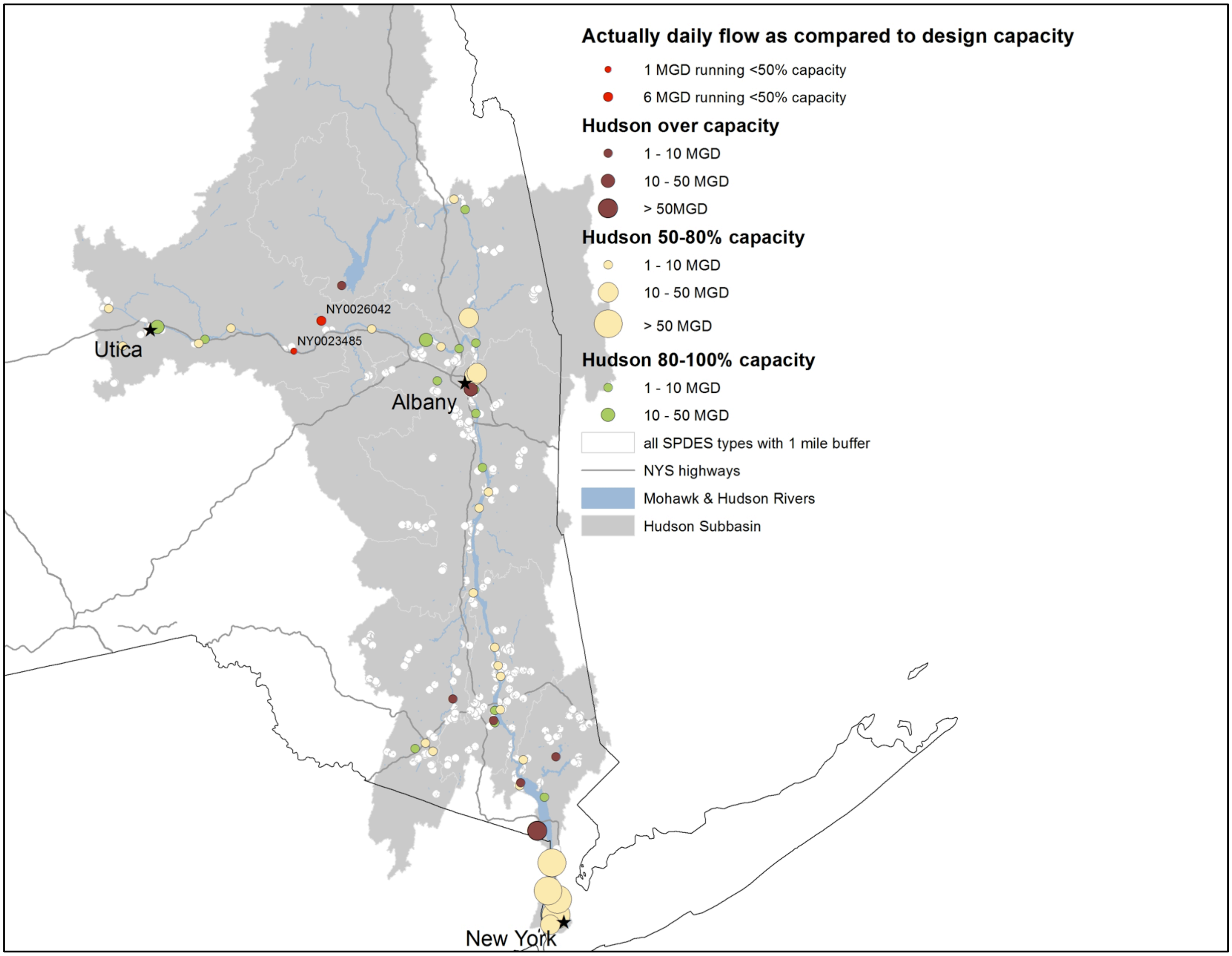


Figure A2-1: **Opportunities for consolidating WWTP in the Hudson-Mohawk Basin.**
Analysis is based on the NYSERDA 2008 dataset and NYDEC SPDES permits (see text for details).

There are 2 plants running <50% (red dots) capacity with 10 total with 27 running between 50-80% capacity (yellow dots. There are many opportunities for potential consolidation, either to bring the under-capacity plants up with neighboring SPDES permits, or by bringing in additional high-strength wastes such as food waste. However, combining industrial and municipal waste can be complicated if significant toxins are present in the industrial processes. Alternatively, these under-capacity plants should be targeted for retrofit with re-sized equipment to increase energy efficiency. In contrast, there are 7 WWTP that are running over capacity (see dark brown circles)

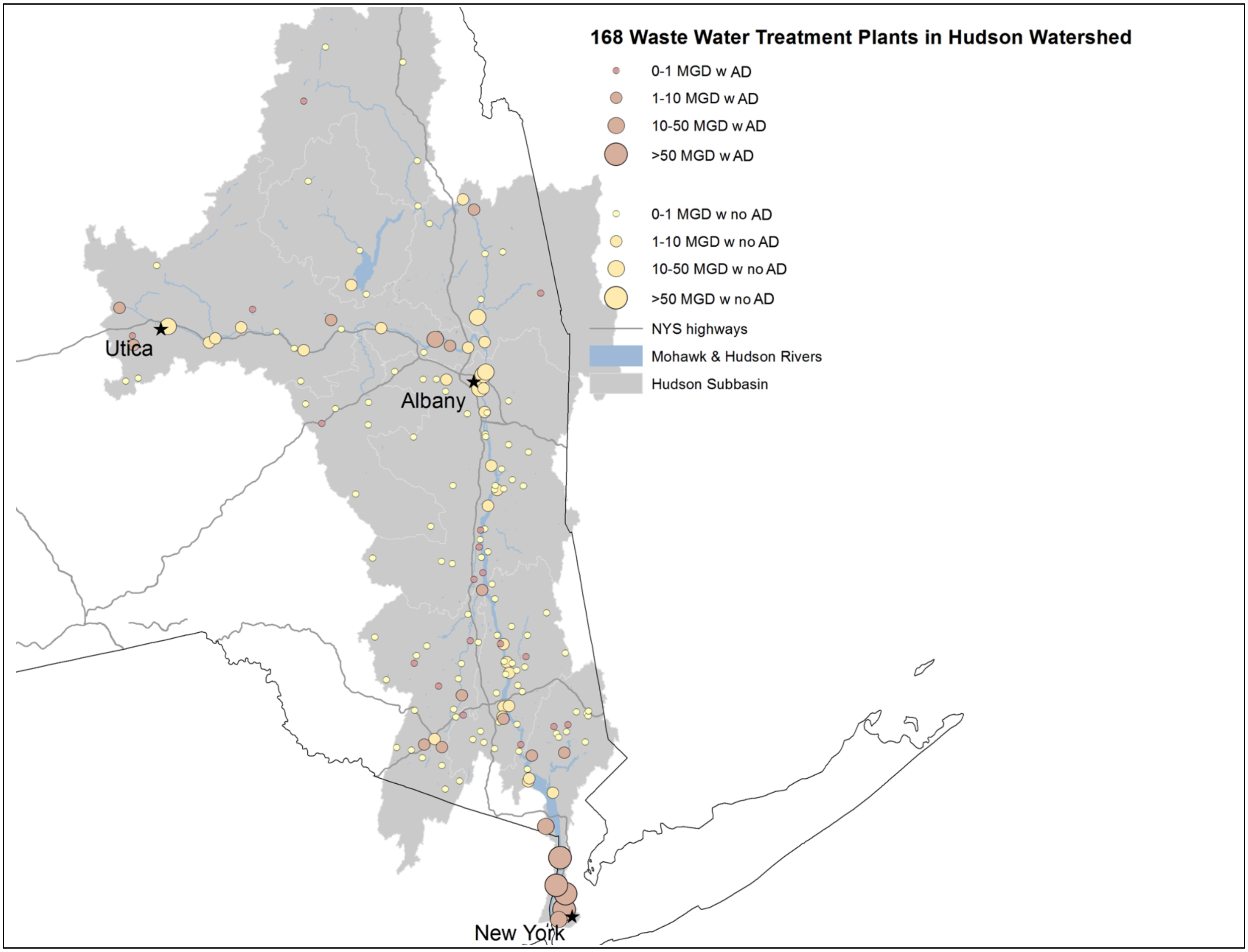


Figure A2-2. Identifying wastewater treatment plants that have Anaerobic Digestion (AD) Infrastructure in the Mohawk-Hudson river basin.

Of the 168 WWTP in the Hudson-Mohawk basin, 37 have Anaerobic Digestion treatment. Note, dark grey shading indicates Hudson-Mohawk River basin. Data are from the NYSERDA 2008 dataset.

Table A2-1. Number and size of wastewater treatment plants with AD in the Hudson-Mohawk river basin by sub-basin with estimated total retrofitting cost to increase biogas production and use.

Sub-Basin	Total WWTP Num.	V small WWTP w AD Num.	Small WWTP w AD Num.	Med WWTP w AD Num.	Large WWTP w AD Num.	Cost small $276,500	Cost medium $7,183,400	Cost large^ $31,630,396	Total Cost $
Upper Hudson	5	1	0	0	0	$0	$0	$0	$0
Sacandaga	4	0	0	0	0	$0	$0	$0	$0
Mohawk	24	1	5	2	0	$1,382,500	$14,366,800	$0	$15,749,300
Hudson-Hoosic	8	1	1	0	0	$276,500	$0	$0	$276,500
Schoharie	7	1	0	0	0	$0	$0	$0	$0
Middle Hudson	39	4	0	0	0	$0	$0	$0	$0
Rondout	25	3	4	0	0	$1,106,000	$0	$0	$1,106,000
Hudson-Wappinger	33	4	1	0	0	$276,500	$0	$0	$276,500
Lower Hudson	23	2	2	2	4	$553,000	$14,366,800	$94,891,188	$109,810,988
TOTAL	168	17	13	4	4	$3,594,500	$28,733,600	$94,891,188	$127,219,288

^ One Large plant (Newtown Creek) was removed from the calculation as it has undergone renovation recently.

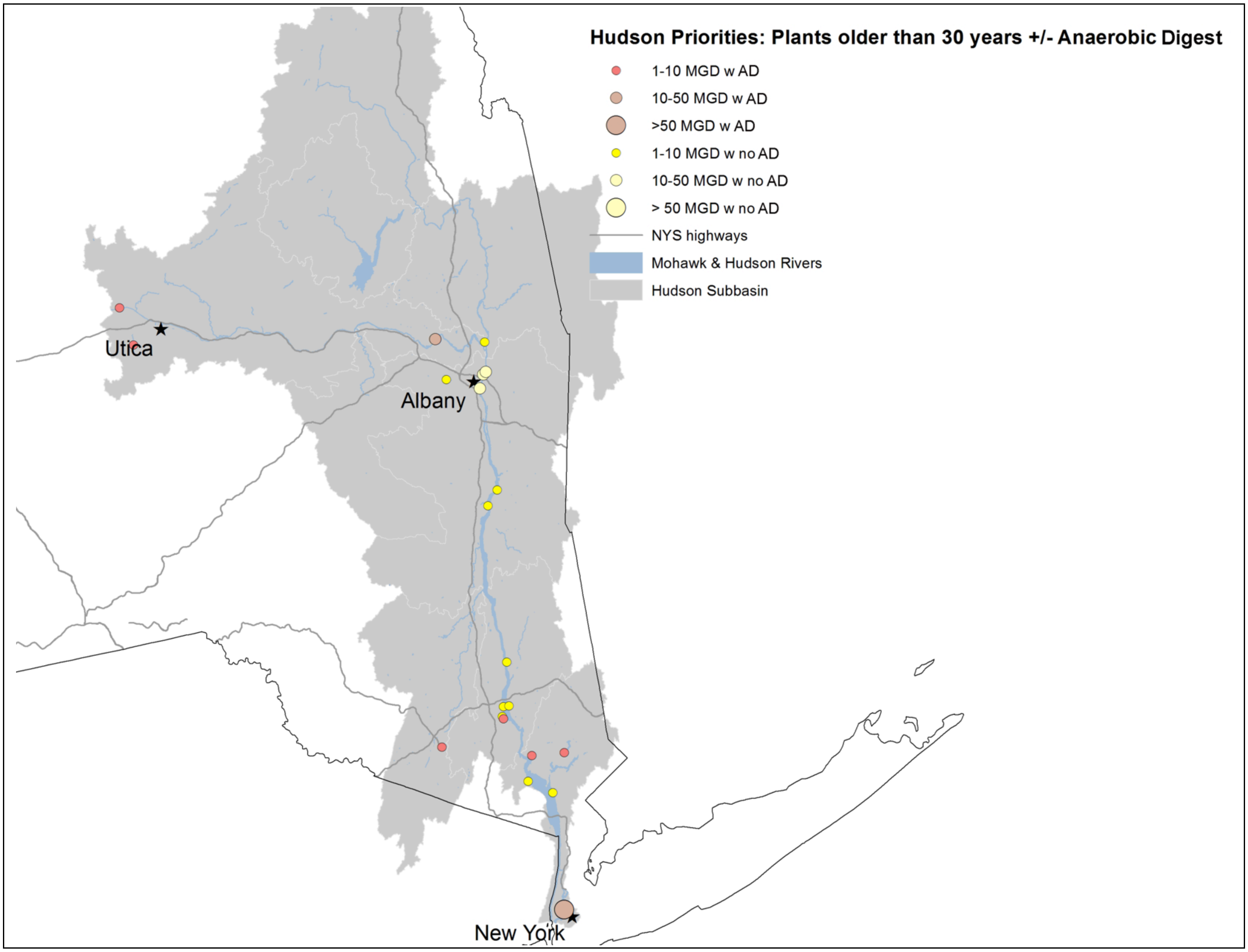


Figure A2-3. Prioritizing wastewater treatment plant retrofitting in the Hudson-Mohawk river basin.
Of the 168 Waste Water Treatment plants, 21 (>1MGD) have not been retrofit for over 30 years (built before 1985 and not retrofit). Eight of these older plants have Anaerobic Digestion Infrastructure. Note the 1 large plant in the NYC area has been retrofit since this NYSERDA Dataset was created.

Appendix III – Case Studies

This appendix includes basic notes summarizing the case studies but is not exhaustive nor a final product.

Large: Owl's Head

Location	Brooklyn, NY, Kings County	Owned by NY DEP
Built		
Flow	120MGD	Serve 771,367
Treatment		
Installation date		Retrofit 2011
High Strength Waste		
Equipment		Digester gas holder: 100,000 cf low pressure storage Generators: three 2,250kW continuous duty
Fuel	307,500,000cf/yr DG at 600BTU/cf or ~60%	2006 was 278,086,563 cf/yr DG (digester gas) BTU/cf DG= 600
Use		Electric consumption 36,473 MWh/yr in 2006 (not necessarily from DG)
System Efficiency		
Project Cost	31 to 67 million	$67 million, DEC, <http://www.nyc.gov/html/dep/html/dep_projects/cp_owls_head_plant.shtml> $31.6 million Malcolm Pirnie, NYSERDA, (NYCMWFA Owls Head GPR Energy Business Case). $43 million, EFC 2010, (project # C2-5227-2000 <http://www.efc.ny.gov/Default.aspx?tabid=492)>
Project Funding		EFC
Annual Energy Savings		
Heat or electric generated/ not used		
Reported simple payback		
CO_2		
Maintenance		
Issues		

More Detailed Project Description:

The project improves the existing digester (DG) handling systems and combined heat and power (CHP) systems at the Owl's Head Water Pollution Control Plant (WPCP).

1. Existing DG piping systems do not properly allow DG to flow from AD to the CHP such that excess DG is flared and diesel is used for heat and power
2. Two engines will run continuously instead of one.
3. Diesel will be replaced with Natural Gas
4. Control and combustion systems of CHP (3, 2,250kW engine generators) will be improved to increase efficiency of use.

Individual improvements are considered one energy efficiency measure as the DG handling and CHP are being improved as a complete system.

Baseline:

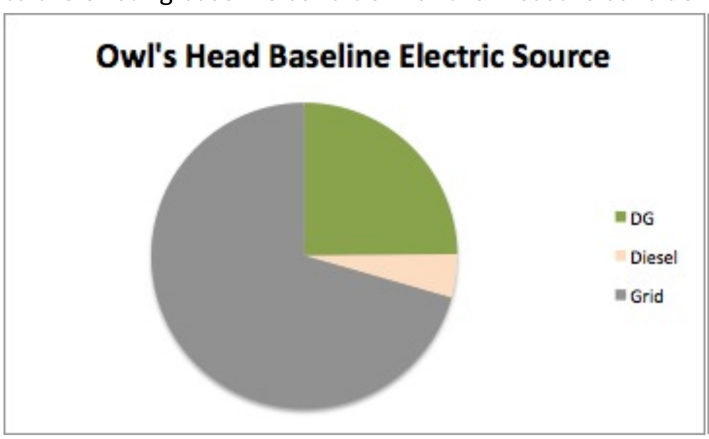
In 2006, the baseline DG created was 278,086,563 cf/yr. After completion of project, there will both be a 10% increase in DG to 307,500,000cf/yr in addition to improved use of existing gas (flared gas and inefficient engine generators).

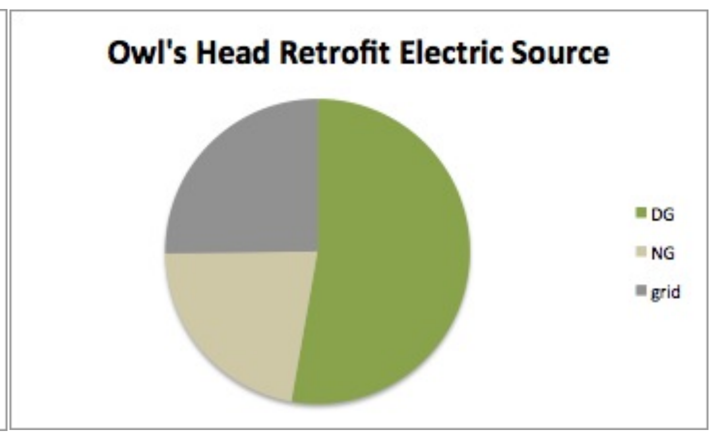
Improvements:

Increased run time meets nearly all winter digester and space heat needs (previously diesel). The electric production doubles (additional 13,639MWh/yr) as there are now 2 generators working full time, providing 75% of the design electric demand.

Results:

The identified energy efficiency measure included in the existing design is estimated to reduce electricity consumption by 60%, use nearly 100% DG produced on site, and slightly increase thermal energy consumption by 3% when compared to the existing baseline condition for the measure considered.





Essex Junction, VT

<http://www.northeastcleanenergy.org/uploads/EssexJunctionCHPprofile.pdf>

Location	Essex Junction, VT	
Built		
Flow	2MGD	
Treatment		
Installation date	2003	
High Strength Waste		
Equipment	Two 30kw dual fuel capstone c-30 micro-turbines, Micogen MG2C2 heat recovery system	
Fuel	Self-generated methane gas + natural gas	Produces 30,300 ft^3 CH_4 per day with a typical energy content of 520 BTU per ft^3. Both micro-turbines are running (48 hrs/day)
Use/Primary benefit of retrofit	Winter and summer heat recovery to heat AD	
System Efficiency	80%	
Project Cost	$303,000	
Project Funding		
Annual Energy Savings	($37,000 in costs or 36%)	Average price of electricity is $0.1/kWh. Before Co-gen, electric use was 1.1 million kWh/yr and cost 100,000. Cost dropped by $37,000.
Heat or electric generated/not used	412,000kWh/yr	GENERATED
Reported simple payback	7 years	
CO_2	Prevents 600,000 pounds of CO_2e	(I think this is simple flaring of CH_4, not fossil fuel displacement)
Maintenance		
Issues	The methane gas is saturated with water – so maintenance on the methane compressors has proven difficult and expensive.	

Alberta Lea, MN

<http://www.midwestchptap.org/profiles/ProjectProfiles/AlbertLea.pdf>

<http://www.biogasdata.org/facilities/albert-lea-wwtp>

Location	Alberta Lea, Minnesota	
Built		
Flow	4.3MGD	Capacity is 12
Treatment		
Installation date	2003	
High Strength Waste		
Equipment	120kW system (4 capstone c-30 micro-turbines)	
Fuel		
Use		
System Efficiency		
Project Cost	$250,000	
Project Funding	$85,000 from MN CIP $89,000 from Alliant Energy $76,000 City of Albert Lea	Since 1992, Minnesota public electric and gas utilities are required to spend 1.5% of annual revenue on energy conservation improvements (CIP program). Funding included early maintenance costs since the micro-turbine technology was new at the time.
Annual Energy Savings	$40,000-$60,000	
Heat or electric generated/not used	800,000kWh/yr of 3,600,000kWh/yr (25%) and 28 million BTU of heat recovered for anaerobic digester temp control and a portion of building space heat.	
Reported simple payback	4-6 years	
CO_2		
Maintenance	“low”	
Issues	Quiet, addresses odor.	

Olympia, WA

<http://www.prnewswire.com/news-releases/waste-not-new-cogeneration-system-enables-wastewater-treatment-plant-to-use-treatment-byproducts-as-fuel-92663074.html>

<http://www.lottcleanwater.org/plant.htm>

Location	Olympia WA	
Built		
Flow	11.5 MGD, Rainy season, 15MGD.	33.8MGD on storm events
Treatment	Secondary	
Installation date		
High Strength Waste		
Equipment	One GE Jenbacher 208 (335 kW) IC engine	
Fuel	Biogas	
Use		
System Efficiency	99% of methane flare efficiency	
Project Cost	2.4 million (300,000 for aeration blower)	
Project Funding		1.7 million Energy Conservation Grant from Puget Sound Energy (PSE)
Annual Energy Savings	$180,000/yr ($48,000/yr in saved utility costs from the new blower)	
Heat or electric generated/not used	2.8 million kWh/yr and all plant space heating	
Reported simple payback		
CO_2		
Maintenance		
Issues		

Janesville, WI

<http://www.midwestchptap.org/profiles/ProjectProfiles/JanesvilleWWT.pdf>

Goal: reduce energy costs. Replace 1985 aging CHP system in 2002. – 17 years

Location	Janesville, WI	
Built	1970, CHP installed in 1985	
Flow	17.8 MGD	
Treatment		
Installation date	2002	
High Strength Waste		
Equipment	3 digesters w total capacity for 2.5MMgal – two Waukesha reciprocating engines (200kW each). Waste heat warms 645,000 gallon digester to 130F as well as increase temp of biogas prior to burning which makes it more efficient	1985 system had 2, 150kW reciprocating engines with modest heat recovery
Fuel	Up to 66% methane in biogas	
Use	Reduce H_2S, replace aging CHP to reduce costs	
System Efficiency		
Project Cost	$910,000	
Project Funding		City of Janesville, Earth Tech, Waukesha Engine, Focus on Energy, Alliant Energy
Annual Energy Savings	$150,000	
Heat or electric generated/not used	719,600 kWh (12% of annual electric energy)	
Reported simple payback	~6yr	
CO_2		
Maintenance		
Issues	Goal, reduce H_2S content. Uses iron sponge scrubber to reduce H_2S (brings it down from 175ppmv to 10ppmv) by impregnating iron oxide onto redwood chips.	2 digesters heated w natural gas to 98F (mesophilic) and a third heated w biogas to 130F (thermophilic) for CH4 production.

Rochester, MN

<http://www.midwestchptap.org/profiles/ProjectProfiles/RochesterWWT.pdf>

Location	Rochester Minnesota	Goal -- update existing CHP – 20 years old.
Built	CHP since 1982 (800kWCHP)	
Flow	23.85	
Treatment		
Installation date	2-phases from 2002-2008, increased from 800kW CHP to 2,000kwCHP	2000kW is for back up electricity (they have a 50ft-diameter biogas storage facility – 208,000cu ft, compressed at 46psig) and can use natural gas.
High Strength Waste		
Equipment	Two, 1000kW Waukesha engines(20% more efficient and can use natural gas). Typically operate one – second is a back-up	Two AD to process sludge
Fuel	338,000 cu ft./day biogas at 66% CH_4	
Use	700-850 kW of electric power (from a 2000 kW system) and 4.5 MMBTU/hr. heat from engine jacket and exhaust gas(2.6-9MMBTU/hr.) for AD heating and facility space heating	2.5 MMBTU/hr. from engine jacket water and 2 MMBTU/h per engine exhaust gases.
System Efficiency		
Project Cost	$4,000,000	
Project Funding		
Annual Energy Savings	$564,398 (197,453 in electric energy, $336,945 in natural gas costs)	
Heat or electric generated/not used		
Reported simple payback		
CO_2		
Maintenance		
Issues	Two AD (3.7 million gal capacity), detention of 34 days, mesophilic at 98F and produce 3 cu ft. biogas per gallon sludge	No gas treatment, increasing engine maintenance requirements. Planning to add moisture removal equipment.

Shakopee, MN

<http://www.metrocouncil.org/Wastewater-Water/Publications-And-Resources/ES_Bluelake2012_combined-pdf.aspx>

Has an aggressive efficiency program (including lighting etc.) and a goal of 25% reduction of energy by 2015 and 50% by 2020 compared to 2006 levels.

Location	Shakopee Minnesota	
Built	2006 – new anaerobic digestion facility installed upstream of an existing natural gas fired dryer.. Completed in 2012	Biogas displaces previous 9 million BTU/hr. natural gas requirement for the drying facility (drying and pelletizing the solids for organic fertilizer). Looking at adding 1.25 MW/yr of solar
Flow	28MGD	285,000 residents capacity for 38MGD
Treatment		
Installation date		
High Strength Waste		
Equipment	3 tanks w fixed steel covers, 1 tank w membrane cover for gas storage. For a volume of 1.4 million gallons	2 stage mesophilic digestion 98F, 26 days retention
Fuel	26,000 scf/hour at 57-61% CH_4 12 million BTU	
Use		
System Efficiency		
Project Cost	27.8 million	(Sept 09 to April 2012, 32 months construction)
Project Funding		25.8 million from Minnesota state revolving loan 2 million in grant funds from Minnesota public facilities thru the American reinvestment and recovery "green" infrastructure act.
Annual Energy Savings	$550,000	$500,000 savings for drying fertilizer, when offline, ~$50,000 savings for facility heating
Heat or electric generated/not used		Problematic… not clear how many hours… when offline, it heats facilities, saving 1.2 billion BTU annual.
Reported simple payback		

CO_2		
Maintenance		
Issues	With other energy conservation projects, since 2010 has reduced 17% below 2006 annual energy consumption	Goal: 25% reduction of 2006 energy consumption by 2015. 50% of 2006 energy consumption by 2020.

Allentown, PA

<http://www.midatlanticchptap.org/profiles/allentown_wwtp_project_profile.pdf>

Location	Allentown, PA	
Built	1929	33 acres, 200,000 customers, two stack trickling filter design
Flow	32MGD	
Treatment		
Installation date	2001 chp started operation	
High Strength Waste		
Equipment	13 micro-turbines and 3 exhaust heat recover units	
Fuel		
Use	Peak load: 1.5MW 34,117 MMBTU per year for AD temperature control	
System Efficiency	CHP total efficiency: 58%	
Project Cost	1,107,000	
Project Funding		100% PA guaranteed energy savings act provided low-interest loans for capital costs
Annual Energy Savings	$65,000-125,000	
Heat or electric generated/not used		
Reported simple payback	15	
CO_2		
Maintenance		
Issues		

Appendix IV - Other considerations, strategies, and paths forward.

While transforming WWTP into methane producing energy facilities is one reasonable approach to fuel a plant, destroy greenhouse gases, and reduce solids for later disposal, there are a myriad of approaches a community might take that better uses the resources of this waste stream. These include lipid extraction for biodiesel production, the aforementioned pelletization of solids for land application (if contaminants are low enough), high-value commodity extraction, and addition of food wastes to increase CH_4 production. We provide a few brief notes on these opportunities below, but further research is warranted to identify viable opportunities in New York State.

Lipid extraction for biodiesel:

Drexel University to Perform Extraction of Lipids from Wastewater Research. WERF has selected Drexel University (near Philadelphia, PA) to perform research that will monitor and quantify the composition of waste greases to improve knowledge about the feasibility of grease-to-biodiesel processes.

Recovering high-value carbon and other commodities:

Hazen & Sawyer Selected to Investigate Recovering Carbon and Other Commodities from Wastewater. WERF has awarded Hazen & Sawyer a contract to further investigate nutrient recovery. The project team will develop a consolidated review of technologies available for the recovery of high-value carbon and other non-nutrient commodity products from wastewater.

Adding Food waste, Newtown Creek WWTP

<http://www.nyc.gov/html/dep/html/press_releases/13-121pr.shtml#.U5BoeS8wIaY>

Over the summer of 2013, Waste Management's Varick I transfer facility in Brooklyn, NY began processing organic food waste collected from local schools into a liquefied feedstock using the company's proprietary Centralized Organic Recycling equipment (CORe)SM process. The feedstock is delivered in sealed tankers to the Newtown Creek Wastewater Treatment Plant where it is added to wastewater sludge to produce additional biogas. Waste Management is currently processing 2 tons per day of organic waste at the Varick I facility and plans to increase its volume to 5 to 10 tons per day during the initial pilot phase, with the potential to raise capacity to 250 tons per day over the next three years. If the pilot proves successful, there is the potential to process up to 500 tons of organic food waste per day at the Newtown Creek Plant. Taken together, the initiatives have the potential to reduce greenhouse gas emissions by more than 90,000 metric tons a year. Of this reduction, 54,500 tons will come from diverting the approximately 153,000 tons of organic waste from landfills, 32,400 tons will come from using the biogas, a renewable energy source, and offsetting emissions from traditional means of harvesting the natural gas, 2,290 tons from reducing the 2.1 million miles of truck trips, and 840 tons from diverting the excess biogas from the flare at the Newtown Creek Wastewater Treatment Plant.

Renewable Compressed Natural Gas (R-CNG) Vehicle Fuel Projects

http://energy-vision.org/organics-to-fuel-case-studies/

The Janesville WI WWTP now 'cleans' is Renewable Natural Gas (RNG) for use in its fleet vehicles. "The facility will initially produce 3,650 gasoline gallon equivalents (GGE) of R-CNG annually." The gas treatment module for cleaning, compressing and dispensing cost $350,000. (http://energy-vision.org/wordpress/wp-content/uploads/2013/09/Janesville-BioCNG-Profile.pdf)

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Case Studies

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