Biogas Production and Use at Water Resource Recovery Facilities in the United States

NATIONAL biosolids PARTNERSHIP

Water Environment Federation®
the water quality people®

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Phase 1 Data Report
July 2013

Project 11-WSEC-01

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Executive Summary

Scope

Future energy trends are influenced by numerous factors including the relative cost of alternative energy supplies, new source discoveries, and the cost to extract and produce energy sources. If renewable energy becomes reliable and affordable, energy use may turn away from fossil fuels and towards greener fuel sources. As the renewable energy sources and related technologies are evaluated, wastewater, biosolids, and biogas show promise as future energy sources that could reshape energy trends in the United States (U.S.) and beyond. To fully realize the benefits of these programs and of renewable energy on the whole, renewable energy technologies must be further developed and applied widely to provide clean, reliable, affordable energy on a much larger scale.

In June 2011, the Water Environment Federation (WEF) identified an information gap and sought to fill that gap by assessing the current and potential utilization of biogas from US Water Resource Recovery Facilities (WRRFs) for energy production, by identifying opportunities to support expanded biogas utilization through WEF's core capabilities in areas such as technology evaluation/transfer and education and training. To that end, WEF released an RFP, which resulted in a contract with the North East Biosolids and Residuals Association (NEBRA) to provide WEF with data synthesis, development, and analysis concerning WRRFs with anaerobic digestion covering the size and scope of biogas generation.

A diverse project team, comprised of nonprofit organizations, communications outlets, consulting engineers, and vendors was established to assist with this project. With the help of the Project Steering Committee and Advisory Team convened by WEF, the team defined what data would be collected in the initial data collection effort described in this report. This "Phase 1" effort was considered a beginning to a longer ongoing data compilation process that would, in the future, involve collection of additional, more detailed data (Phase 2, etc.). Approximately 20 wastewater industry experts were involved in compiling these Phase 1 data, state-by-state, using an online survey and a unique online collection database created by the Mid-Atlantic Biosolids Association (MABA).

Initially, the database was populated from U.S. Environmental Protection Agency (U.S. EPA) data sources (e.g., Discharge Monitoring Reports [DMRs] and Clean Watersheds Needs Surveys [CWNSs]) and data collected by InSinkErator and others (that were generously contributed by them to the project). The data were then verified by cross checking the database, validating with knowledgeable people in certain regions (such as the federal and state biosolids coordinators), and contacting individual facilities.

An interactive online database (www.biogasdata.org) was created to present the data collected. The database illuminates (1) existing anaerobic digestion systems at U.S. WRRFs and (2) current uses of, and potential future opportunities for, using the biogas produced by these facilities.

To determine the relative abundance of anaerobic digestion at U.S. WRRFs, it was necessary to compare this study's data to national data. Data from 2008, reported in U.S. EPA's CWNS (2011), were used for this purpose (some data were used after first being updated to 2012 estimates based on population growth). Thus, for 2012, it was assumed that

- There are 14,780 operating WRRFs in the U.S. (Appendix I [U.S. EPA, 2011]), and
- Water resource recovery facilities in the U.S. treated an estimated 125,749 ML/d (33,223 mgd) in 2012.

Key Findings

Data reported at www.biogasdata.org and summarized here represent best current estimates based on the Phase 1 data collected by this study as of September 2012. Key findings are as follows:

- It is estimated that 48% of total wastewater flow in the U.S. is treated by anaerobic digestion;
- A total of 5,127 WRRFs, most of which have a capacity of 3.8 ML/d (1 mgd), are included in the current (September 2012) database. These represent about one-third of all permitted WRRFs; those not included are small facilities such as package plants, housing facilities, and so on;

- The solids from at least 1,238 WRRFs are processed through anaerobic digestion;
- Hawaii (41%), Washington (36%), and California (27%) have the highest percentages of WRRFs that process solids through anaerobic digestion;
- New Mexico (83%), Illinois (82%), California (77%), and Hawaii (75%) have the highest percentages of wastewater flow being treated by anaerobic digestion;
- It is estimated that 1,054 WRRFs beneficially use the biogas they produce (85% of the 1,238 facilities that process solids through anaerobic digestion);
- Facilities with anaerobic digestion use biogas in the following ways (from most common to least common): digester heating (an estimated 48% of anaerobic digestion facilities use gas in this way), building heating (27%), power generation (16%), driving process machinery (8%), and pipeline injection (1%);
- 270 WRRFs were confirmed to be generating electricity from the biogas they produce;
- Those WRRFs generating electricity use the following technologies (from most common to least common): internal combustion engines (76%), microturbines (12%), combustion turbines (7%), and fuel cells (5%);
- An estimated 1,148 WRRFs (or approximately 93%) of facilities with anaerobic digesters operate them at mesophilic temperatures. An estimated 40 WRRFs (or approximately 4%) operate anaerobic digesters at thermophilic temperatures. Approximately 34 of the WRRFs (or approximately 3%) operate anaerobic digesters at both temperature ranges; and
- An estimated 216 WRRFs (approximately 17%) import organic waste to co-digest with their wastewater solids.

Interest in anaerobic digestion is expanding rapidly, and changes are occurring throughout the country. It is hoped that, with additional funding and support, these data will be maintained, updated, further refined, and expanded through "Phase 2" and further data compilation efforts.

In the meantime, the initial Phase 1 data reported here are available for review at the following new online database: www.biogasdata.org.

Introduction

The wastewater profession has been striving to promote greater use of biogas produced at municipal WRRFs as a renewable and sustainable energy source. Biogas project developers, engineering consultants, and others require accurate data on biogas production to conceptualize, design, and develop renewable energy and resource recovery projects. However, finding accurate data has proved difficult. The following references from recent reports illustrate the current variety of messages regarding the magnitude of biogas production and energy potential from biogas:

- The U.S. EPA Combined Heat and Power Partnership (CHPP) estimates that if all 544 water resource recovery facilities (WRRFs) in the United States that operate anaerobic digesters and have influent flowrates greater than 19 ML/d (5 mgd) were to install combined heat and power (CHP), approximately 340 MW of clean electricity could be generated, offsetting 2.3 million metric tons of carbon dioxide emissions annually or the emissions of approximately 430,000 cars (U. S. EPA CHPP, 2007);
- "In the U.S., there are more than 167 anaerobic digesters on farms and approximately 1,500 more operating at WRRFs. For comparison, there are approximately 8,200 dairy and swine farms in the U.S. and over 2,000 more WRRFs that could support a digester…. Potential methane production from wastewater is 20 billion scf—enough for 200,000 homes or to make 2 billion kWh of electricity (NREL)" (American Biogas Council, 2011);
- Digester gas production from WRRFs in the U.S. is estimated to be between 3,180 to 4,764 Nm3/min (229 and 343 million scfd) (Black & Veatch, 2011); and
- "As of June 2011, CHP systems using biogas were in place at 104 WRRFs, representing 248 megawatts (MW) of capacity. CHP is technically feasible at 1,351 additional sites and economically attractive (i.e., payback of seven years or less) at between 257 and 662 of those sites" (U. S. EPA CHPP, 2011).

These statements provide some insight to the current and potential production and use of biogas produced at WRRFs. However, the data are either incomplete or not detailed enough. For example, the CHPP report, which is the most widely referenced, relied heavily on data from the CWNSs of 2004 and 2008. Unfortunately, CWNS data are not complete or discriminating enough to yield the quality of data needed to understand current production and potential for biogas use. For example, the term "use ADG" (anaerobic digester gas) is an inclusive term used in the collection of CWNS data. The U.S. EPA has confirmed that the term could mean anything from use of biogas for process heating up to and including use for full CHP. The U.S. EPA also relied on another database by ICF International, Inc. (ICF CHP Installation Database, September 2010) to identify those in the "use ADG" category that are doing CHP; however, that database is not comprehensive either.

The industry is in need of a clear and accurate baseline of the current and potential production and use of WRRF biogas, especially for policymakers and legislators. If baseline production and utilization values are inaccurate, there is a tendency to either understate actual utilization and overstate biogas potential or, conversely, to overstate utilization and understate potential.

Recognizing the economic and environmental value of using biogas as a source of renewable energy and the limits of existing data, WEF issued a request for proposals, "Preparation of Baseline of the Current and Potential Use of Biogas from Anaerobic Digestion at Wastewater Plants", in July 2011, which provided for this biogas data project.

With the help of the advisory consensus team convened by WEF, the team defined what data would be collected in the initial data collection effort described in this report. This "Phase 1" effort was considered a beginning to a longer ongoing data compilation process that would, in the future, involve collection of additional, more detailed data (Phase 2, etc.). Approximately 20 wastewater industry experts were involved in compiling these Phase 1 data, state-by-state, using an online survey and a unique online collection database created by the Mid-Atlantic Biosolids Association (MABA).

The resulting Phase 1 data, discussed in the following section, illuminate (1) existing anaerobic digestion systems at U.S. WRRFs and (2) the current uses of, and potential future opportunities for, using the biogas produced by these facilities.

Methodology

The project team for this data collection effort was diverse and comprised of nonprofit organizations, communications outlets, consulting engineers, and vendors (see page 2 for a list of contributing organizations). A team of approximately 20 wastewater industry experts from these organizations compiled data, state-by-state, using an online survey and a unique online collection database created by MABA. Initially, the database was populated from U.S. EPA data sources (e.g., DMR reports and CWNSs) and data generously donated by InSinkErator and others. The data were then verified by cross checking the database, validating with knowledgeable people in certain regions (such as federal- and state-level biosolids coordinators), and contacting individual facilities.

Each project team member was responsible for data compilation and verification for one or more states.

There were direct telephone calls with personnel from many U.S. WRRFs that confirmed whether they had operating anaerobic digestion or were sending solids to anaerobic digestion at another facility. Some WRRFs with operating anaerobic digestion provided information through an equivalent online survey.

Project administrators confirmed the level of effort and confidence in the data by requiring each data collector to complete a short questionnaire after they were done collecting data for each state. This "data verification spreadsheet" indicates that, for certain states, the data collection effort was comprehensive and, for others, it was less so. To convey the differences in levels of confidence in the data because of variability in the level of effort and expert confirmation, a qualitative confidence level was attached to the data for each state (see Figure 2).

Summaries and calculations of the data were completed in a spreadsheet and are reported here.

To determine the relative abundance of anaerobic digestion at U.S. WRRFs, it was necessary to compare the results from this study to national data. Data from 2008, reported in U.S. EPA's CWNS (2011), were used for this purpose (some data were used after first being updated to 2012 estimates based on population growth). Thus, for 2012, it was assumed that

- There are 14,780 operating WRRFs in the United States (Appendix I, U.S. EPA [2011]) and
- WRRFs in the United States treated an estimated 125,749 ML/d (33,223 mgd) in 2012.

Data Analysis and Summary

Water Resource Recovery Facilities with Operating Anaerobic Digestion

At the end of Phase 1 data collection, the spreadsheet included 5,127 WRRFs in the United States, the majority of which have a capacity of more than 3.8 ML/d (1 mgd). These represent about one-third of all permitted WRRFs; those not included are small facilities such as package plants, housing facilities, and so on. The project confirmed that the solids from approximately 1,238 individual WRRFs are treated by anaerobic digestion. Most of these facilities have their own operating anaerobic digestion systems, but some send their solids to another WRRF where they are processed through anaerobic digestion. By verifying with knowledgeable people in states and regions and cross checking various data sources, the project team concluded that the remainder of U.S. WRRFs are unlikely to have operating anaerobic digestion. Based on the comprehensiveness of data collection and the assurance of data verification, levels of uncertainties were assigned to data from each state. For most states, the level of uncertainty is low (Figure 2).

Figure 1 shows a summary of WRRFs with and without operating anaerobic digesters and the level of uncertainty. As noted previously, the total number of U.S. WRRFs were used as the denominator in calculations of percentages.

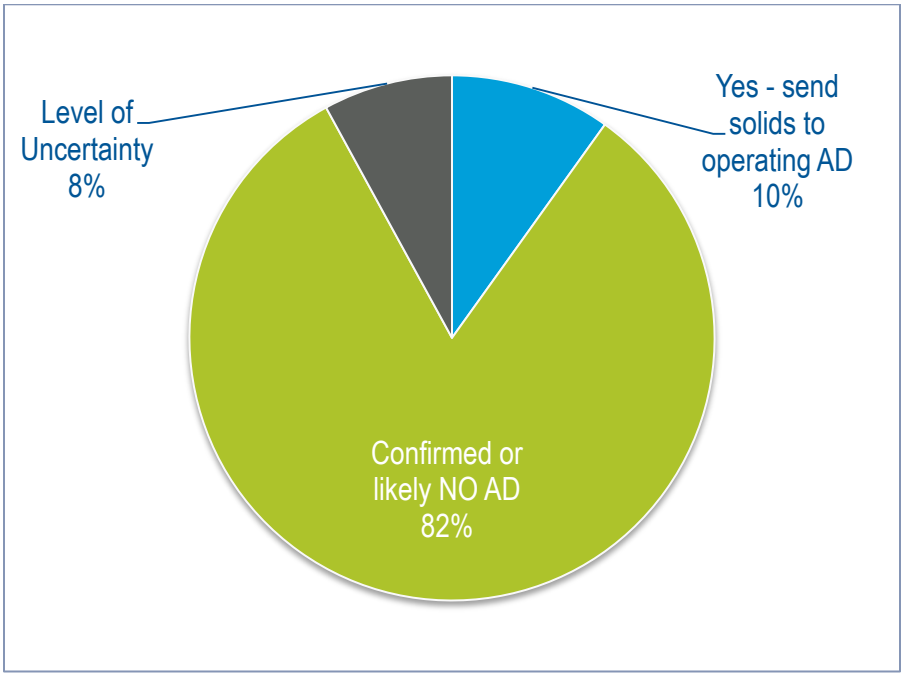

Figure 1—Percentage of WRRFs that process solids through anaerobic digestion (comparing survey data to CWNS 2008 total WRRFs).

In comparison, the previous best compilation by InSinkErator in 2011 (upon which the current effort was built) identified 858 WRRFs that apparently had anaerobic digestion based on Web site searches (this lower figure is attributable, in part, to that effort's focus on facilities that can handle more than 19 ML/d [5 mgd]). The U. S. EPA's CHPP (2011) estimated 1,351 WRRFs with anaerobic digestion, including 845 facilities from 3.8 to 19 ML/d (1 to 5 mgd). Considering only facilities greater than 19 ML/d (5 mgd), U.S. EPA's estimate was 506 facilities.

Figure 1 shows the percentages of WRRFs that process solids through anaerobic digestion and the level of uncertainty for each state. Once again, the total number of WRRFs in each state was derived from 2008 CWNS data; these numbers were used as the denominator in calculating the percentages shown. The states of Hawaii (41%), Washington (36%), and California (27%) have the highest percentages of WRRFs that process solids through anaerobic digestion.

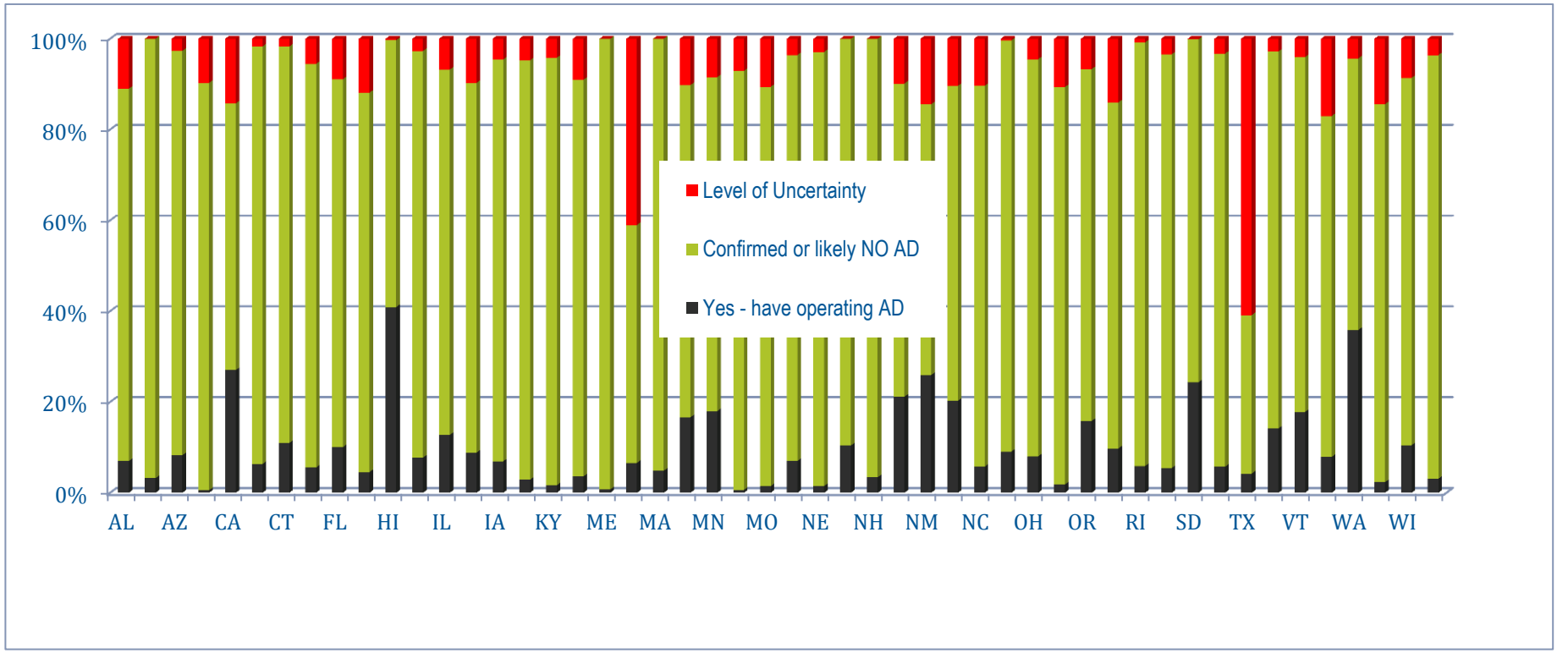

Figure 2—Percentages of WRRFs* that process solids through anaerobic digestion, by state.

*The total number of WRRFs in each state is from U.S. EPA's 2008 CWNS.

In Figure 2, purple bars represent the confirmed number of facilities that process solids through anaerobic digestion divided by the CWNS total number of facilities for that state. Green bars represent the large percentage of WRRFs in each state that are assumed or were confirmed as not having anaerobic digestion or sending solids to anaerobic digestion. Red bars indicate a qualitative measure of uncertainty about the data; the longer the red bar, the less certainty there is that all the WRRFs with anaerobic digestion in that state were identified.

Figure 3 shows the percentage of wastewater flow that is treated by anaerobic digestion in each state. Once again, to calculate these percentages, this project's data were compared with 2008 CWNS data. The states of New Mexico (83%), Illinois (82%), California (77%), and Hawaii (75%) have the highest percentages of wastewater flow being treated by anaerobic digestion.

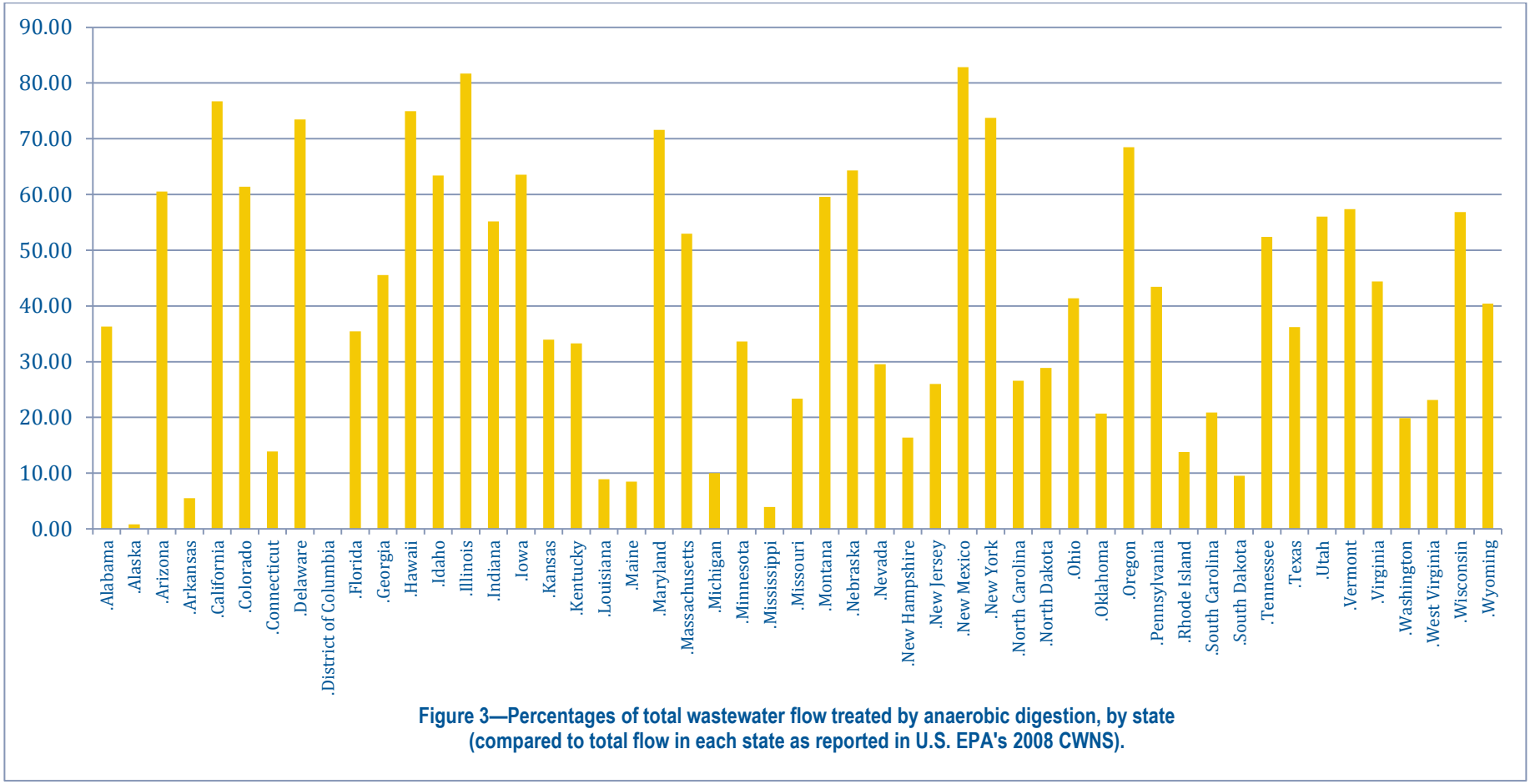

Figure 3—Percentages of total wastewater flow treated by anaerobic digestion, by state (compared to total flow in each state as reported in U.S. EPA's 2008 CWNS).

Notes on Figure 3

Total flow for each state was estimated based on the 2008 CWNS database, which is assumed to be the most complete and accurate data available for wastewater flow. The U.S. Census Bureau population data were used to determine the increase in population from 2008 to 2012. It was assumed that water resource recovery facility flow increased according to population during those years. Anaerobic digestion data was collected in 2012 and, as such, all flow data used in the calculations were updated to the year 2012.

Three states (Alaska, North Dakota, and Rhode Island) did not report total flow data in the 2008 CWNS. Total flow for those states was determined from DMRs for the year 2012. Although all facilities do not discharge, DMRs are assumed to be reliable and relatively complete flow data. It is also assumed that the percent of wastewater generated from septage vs infiltration, industry, and stormwater remain relatively stable from 2008 to 2012.

After initial calculations of the percentage of flow going to anaerobic digestion, Colorado, South Dakota, and New Mexico had anomalous percentages. This is likely from large facilities not having flow data in the 2008 CWNS, but having flow data for the anaerobic digestion survey. Total flow data for those states was calculated using DMRs, as for the states not reporting in 2008.

California, New Hampshire, and Utah were used as checks on the estimating methodology. Because total flow data existed from both the CWNS and DMRs, both were used to calculate percent of flow to anaerobic digestion for these states. The results showed comparable percentages as long as most facilities discharge and report in DMRs. This provided confidence that the analysis had resulted in reasonably accurate estimates.

Note that for some regions, such as California, increased population is not causing an increase in total flow to water resource recovery facilities. This is because water conservation measures and other factors are offsetting the effect of population growth. Therefore, assuming higher flows in 2012 compared to the data reported in CWNS 2008 is misleading for California and, perhaps, other states. A more accurate set of data for California is discussed in the main text of this report.

It is important to recognize that these data are best estimates. More accurate data on total wastewater flow may be compiled by some states, leading to more accurate estimates of percentages of flows treated through anaerobic digestion. For example, the California Association of Sanitation Agencies (CASA) tracks total flow and flow treated by anaerobic digestion at the state level. The CASA estimates that 91% of the solids from the total wastewater flow entering California WRRFs are treated through anaerobic digestion, rather than the 77% estimated in this study (Kester, 2013).

It is estimated that 48% of total wastewater flow in the U.S. is treated by anaerobic digestion. This is based on the following:

- Approximately 60,560 ML/d (16,000 mgd) are processed by anaerobic digestion (flow data are missing for ~140 small WRRFs, so this number is rounded up from 15,000);
- An estimated 125,749 ML/d (33,223 mgd) of total flow for all U.S. WRRFs based on adjusted 2008 CWNS data (see "Notes on Figure 3"); and
- Percentages of WRRFs with operating anaerobic digestion compared to their average influent flows (by range) are shown in Figure 4. In general, larger WRRFs are more likely to adopt anaerobic digestion for solids treatment. Smaller facilities might not find anaerobic digestion economically viable (Willis et al., 2012).

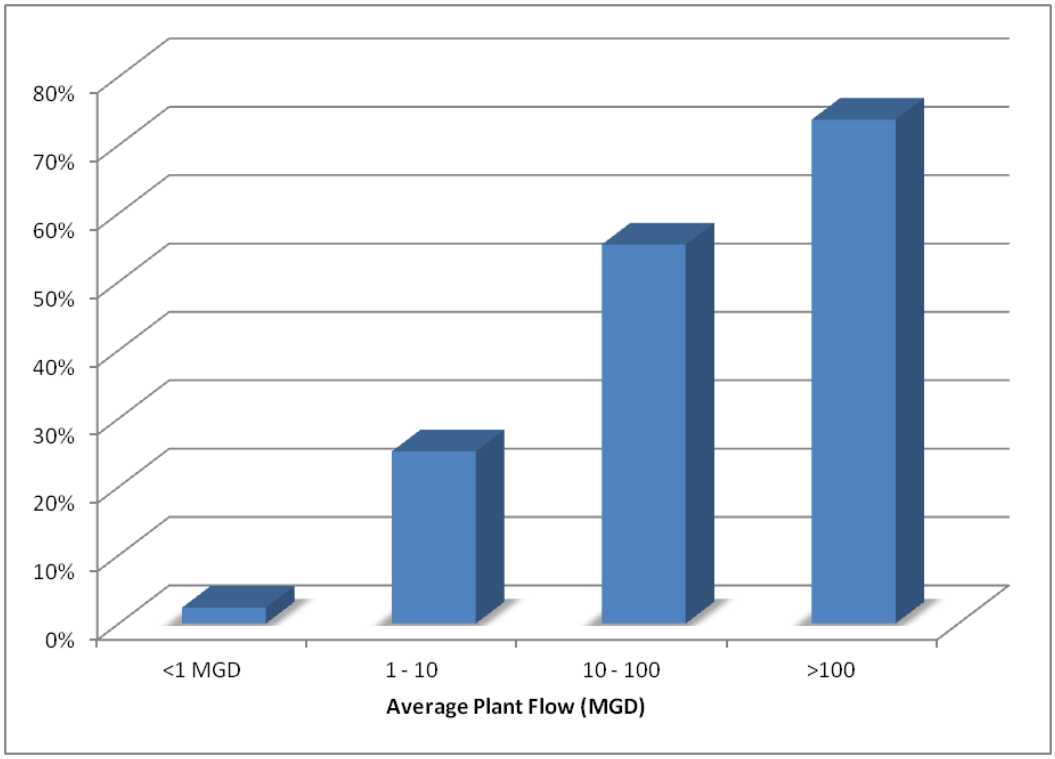

Figure 4—Percentage of WRRFs that process solids through anaerobic digestion, by existing facility flow (comparing survey data to total facilities reported in U.S. EPA's 2008 CWNS).

Biogas Use among Water Resource Recovery Facilities with Operating Anaerobic Digestion

Biogas produced at a WRRF is rich in methane, a powerful greenhouse gas, and should not be released to the atmosphere. Therefore, almost all WRRFs that produce biogas have a biogas combustor (i.e., a flare) that converts the methane to carbon dioxide and water. Although flaring biogas is common, it does not put to use the resources in biogas. Recognizing the energy value of biogas, many WRRFs have long used biogas in boilers that maintain the mesophilic temperature required for anaerobic digestion. Today, with increased interest in renewable energy sources, more and more WRRFs are putting biogas to use to generate electricity and heat in CHP systems.

As part of this Phase 1 data collection effort, the project team collected biogas use data from WRRFs with anaerobic digestion. The survey included the following uses of biogas: driving process machinery, digester heating, building heating, electricity generation, and pipeline injection of biogas (biomethane).

Data regarding biogas use were obtained from a large majority of WRRFs with operating anaerobic digestion. However, data on some uses of biogas were not compiled for some WRRFs. Therefore, to complete national estimates, data from those facilities with missing data were estimated based on known data from other WRRFs. It was assumed that the distributions of biogas use and biogas use technologies are the same for WRRFs with missing data as those with confirmed data.

As shown in Figure 5, it is estimated that 1,054 out of 1,238 WRRFs (85%) with operating anaerobic digestion beneficially use biogas. This estimate is derived by extrapolation from 860 of 1,010 anaerobic digestion facilities that confirmed they use biogas. The percentage of WRRFs with anaerobic digestion that use biogas increases as the facility average flow increases (Figure 6).

Among the 1,054 facilities that use biogas, some facilities use biogas in more than one way, resulting in a total of 1,686 distinct uses. The share of each biogas use technology is shown in Figure 7. Digester heating, building heating, and electricity generation are the three main

ways in which biogas is used at WRRFs in the U.S. Figure 8 shows how many different biogas use technologies are used at each WRRF that produces biogas. Many WRRFs (65%) use one or two biogas use technologies, such as electricity generation and digester heating.

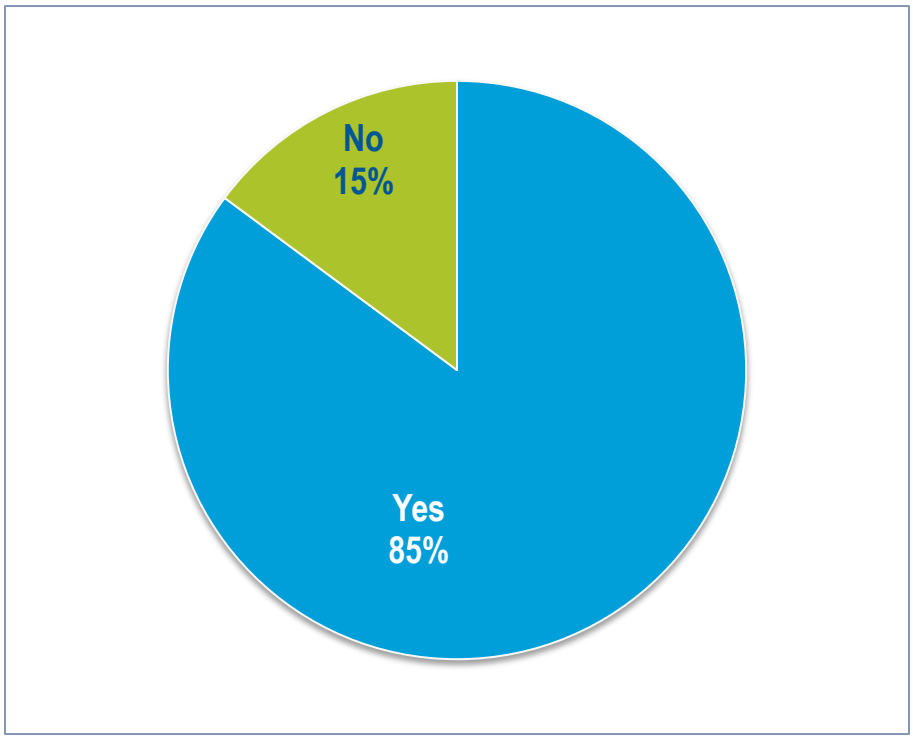

Figure 5—Percentage of WRRFs with anaerobic digestion that beneficially use biogas.

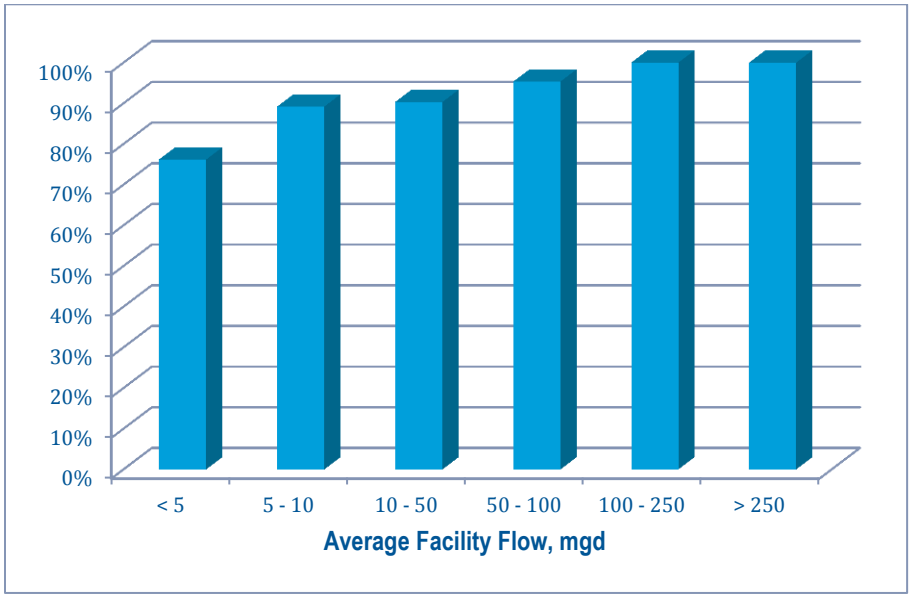

Figure 6—Percentage of WRRFs with anaerobic digestion that beneficially use biogas vs average facility flow (mgd ÷ 0.2642 = ML/d).

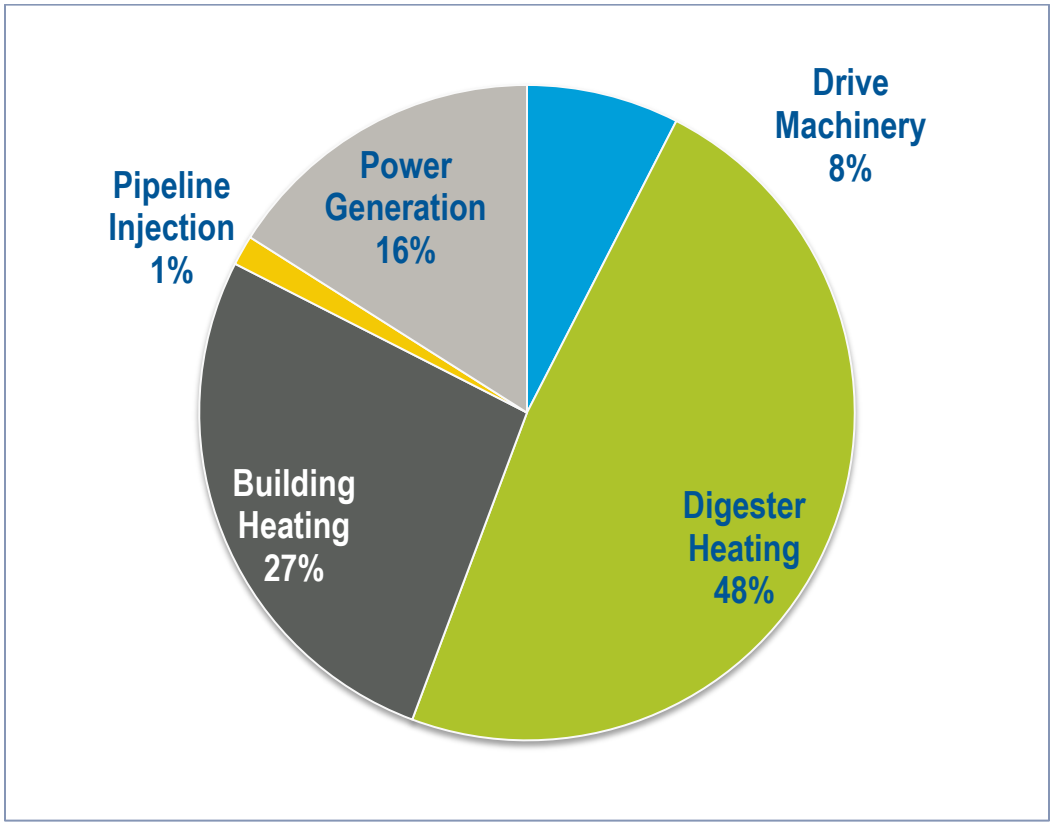

Figure 7—Percentage of distinct biogas use technologies.

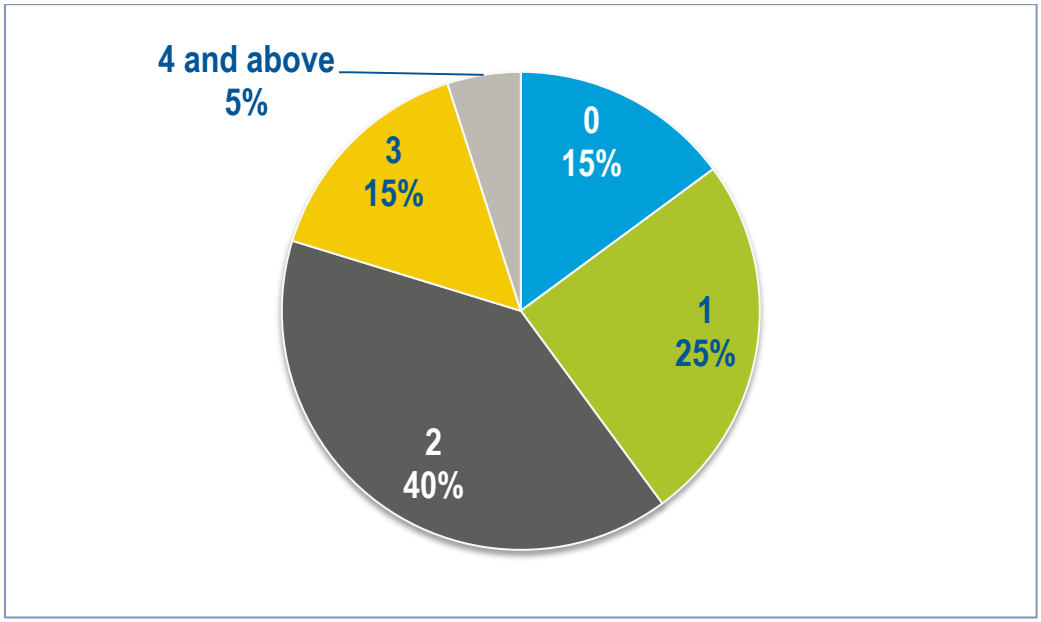

Figure 8—The number of different biogas technologies in use at WRRFs that produce biogas.

Use of Biogas for Power Generation

This study confirmed that approximately 270 WRRFs use biogas for electricity generation. Technologies include internal combustion engine generators, turbine generators, microturbines, and fuel cells. Internal combustion engine generators are the most commonly applied electricity generation technology. The share of these power generation technologies is shown in Figure 9.

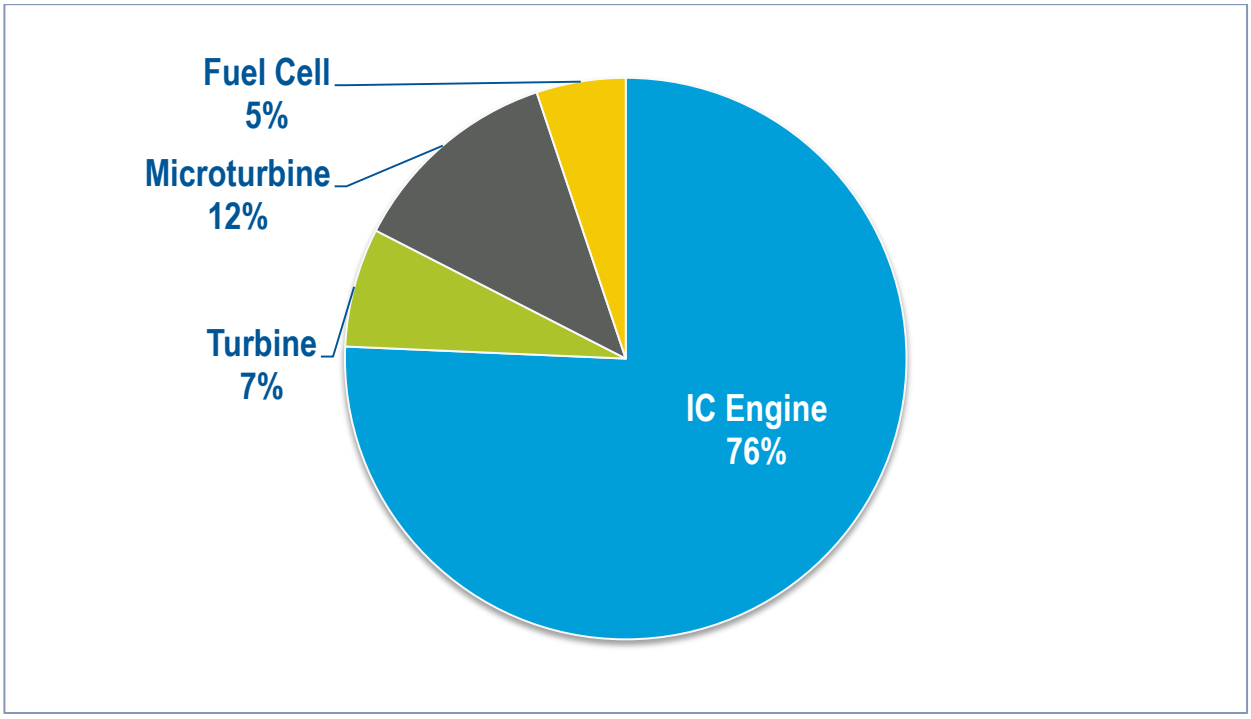

Figure 9—Electricity generation technologies.

Almost all WRRFs generating electricity from biogas (93%) use only one type of electricity generation technology. Less than 7% use biogas in two power generation technologies.

Anaerobic Digestion Operations

The results of this study indicate that approximately 93% of WRRFs with anaerobic digestion operate at mesophilic temperatures, 4% at thermophilic temperatures, and 3% have digesters operating in both temperature ranges (Figure 10).

Approximately 17% of WRRFs with anaerobic digestion import organic waste to their facilities and co-digest them with biosolids (Figure 11). Imported organic waste includes biosolids generated from other facilities, grease trap waste, food waste, animal processing wastes, and manures.

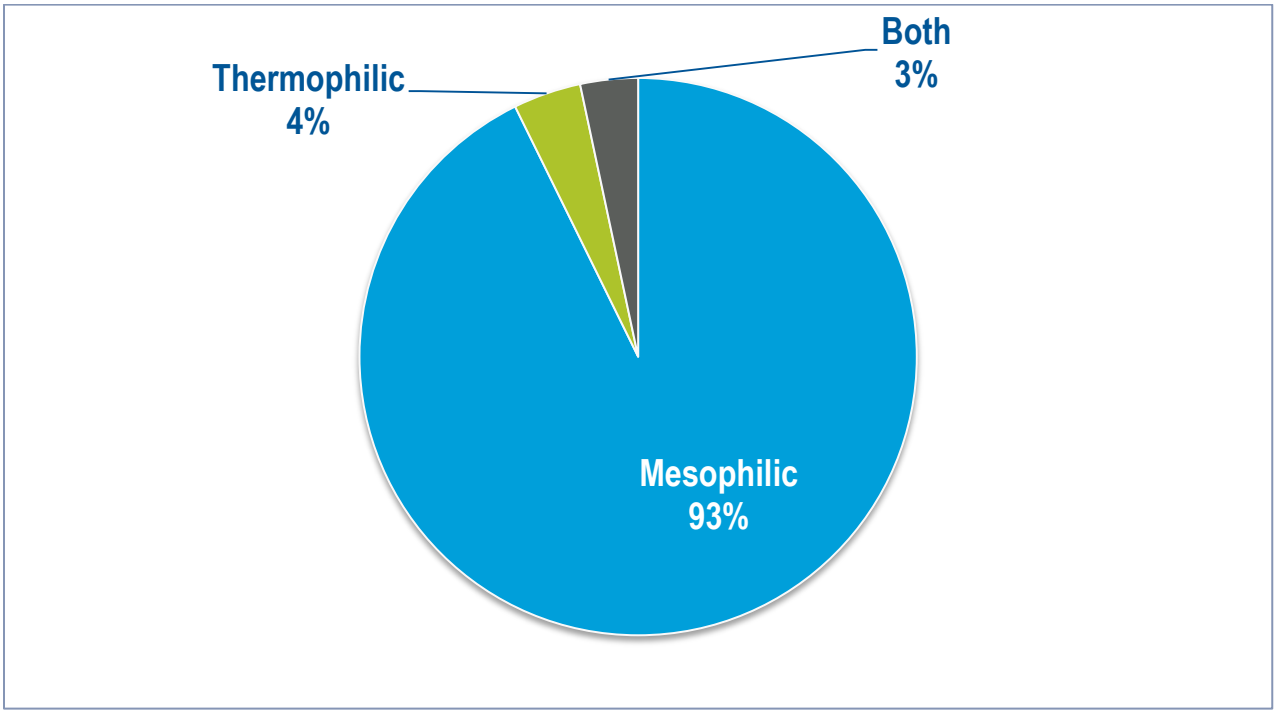

Figure 10—Digestion temperature.

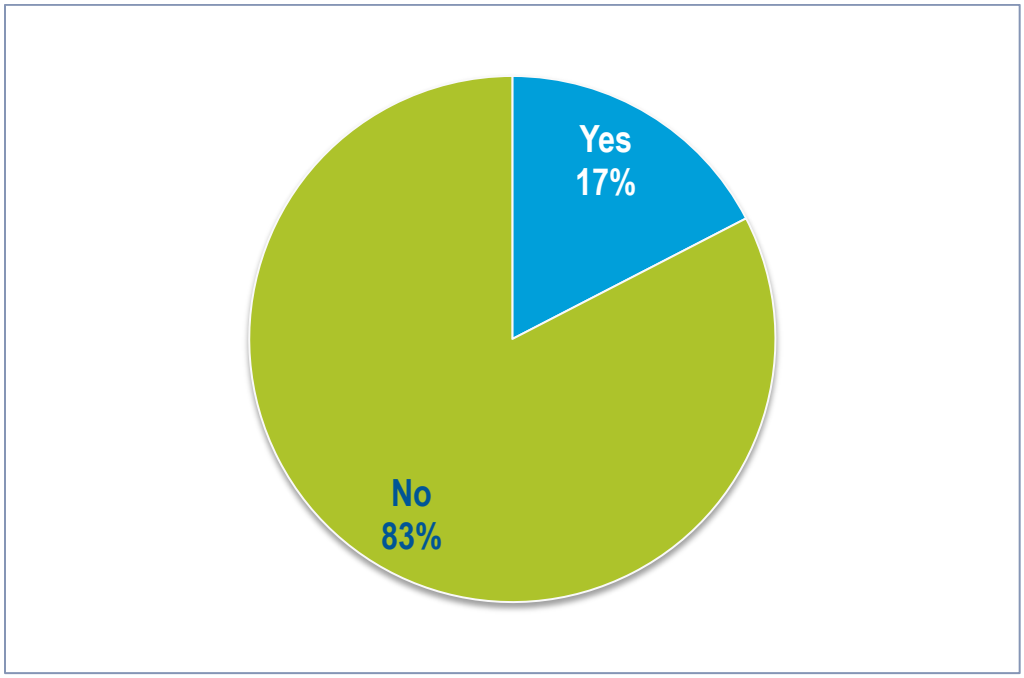

Figure 11—Do you import organic waste and feed it directly to digesters?

Online Database

The data compiled in this project are presented in an online database at www.biogasdata.org. The database provides the following:

- A map interface that allows users to click on "pin" icons to access data for a particular WRRF;
- A facility listing interface that provides another way of accessing the individual facility data, including sorting and browsing;
- The ability to print data files for each WRRF;
- Contact information for Web site administrators and a method for submitting comments and updates; and
- Reports and information about the data collection effort, including a listing of collaborative project team members (including funders).

This report and the aforementioned Web site provide policymakers, market analysts, project developers, and water quality professionals with key information about the current and potential production of biogas for renewable energy at U.S. WRRFs.

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