The Potential Power of Renewable Energy Generation From Wastewater and Biosolids Fact Sheet

BACKGROUND

Wherever people live, there will be human and organic waste (wastewater, septage, food waste, restaurant grease, etc.) with biogenic carbon that can be converted to energy, as well as nitrogen and phosphorus nutrients that can be recovered. Consistent recognition as a renewable energy source will stimulate production of energy from water resource recovery activities, create more clean energy jobs, and help reduce greenhouse gas emissions by reducing electricity demand from fossil-fuel-based power plants.

Wastewater utilities worldwide are involved in all areas of renewable energy, from traditional sources such as wind, solar, and hydropower, to energy derived from biomass (such as biogas), to research in emerging technologies. With the energy contained in wastewater and biosolids greater than the energy required for treatment, water resource recovery facilities have the potential to be energy neutral or even net energy producers, and some plants have already achieved that status. [1,2,3,4,5]

Reaching the goal of energy neutrality will require a holistic energy management approach, incorporating conservation practices and generating renewable energy through the management of water resource recovery and its byproducts. According to a United Nations report released in May 2011, renewable energy sources such as biomass could meet nearly 80% of the world's energy supplies by 2050 if governments implement policies that harness their potential. [6]

Did you know that… Biosolids, a natural byproduct of wastewater treatment, are a renewable resource that is too valuable to waste given our growing needs for renewable energy and sustainability. There is growing awareness that wastewater treatment plants are not waste disposal facilities, but rather water resource recovery facilities that produce clean water, recover nutrients (such as phosphorus and nitrogen), and have the potential to reduce the nation's dependence on fossil fuel through the production and use of renewable energy.

Did you know that… Energy derived from wastewater treatment is being recognized as a renewable energy resource. Energy generated from water resource recovery processes can include:

- Electrical energy, heat, or biofuels from utilization of digester gas [biogas that consists mainly of methane (natural gas) and carbon dioxide]
- Electrical energy and heat from thermal conversion of biomass (biosolids)
- Electrical energy from biosolids products used by other entities (*e.g.*, pellets used in power plants, cement kilns, or industrial furnaces)
- Heating or cooling energy using plant influent or effluent as heat source or sink for a heat pump

Did you know that… Emerging technologies being researched may have the potential to further enhance the renewable energy contribution from wastewater, including:

- Biofuel generated by using carbon and nutrients in wastewater for growing algae
- Biofuel energy via microbial fuel cells
- Thermal conversion of biomass (biosolids) from gasification or pyrolysis

Did you know that… The water sector is continuing its participation in both energy conservation efforts and traditional renewable energy activities, including:

- Solar radiation captured at facilities
- Wind power captured at facilities
- Electrical or mechanical energy from hydropower of plant influent or effluent

Dou you know that… There are renewable energy generation technologies available at water resource recovery facilities.

BIOGAS FROM ANAEROBIC DIGESTION

Anaerobic digestion decomposes and stabilizes organic material in the absence of oxygen, and produces biogas that consists mainly of methane (natural gas) and carbon dioxide. Anaerobic digestion is recognized by the U.S. Environmental Protection Agency (EPA) as an accepted technology for biosolids stabilization allowing its beneficial use as fertilizer or energy production. Numerous water resource recovery (WRR) facilities employ anaerobic digestion to achieve waste solids reduction and stabilization. In addition to reliably stabilizing biosolids and generating biogas, anaerobic digestion has much lower energy costs than aerobic digestion, another prevalent solids stabilization technology, because it does not require oxygen. A typical anaerobic digestion system converts 35% to 50% of the biomass into biogas, thus reducing downstream energy and hauling costs by reducing the volume of biosolids to be handled post-digestion.

With growing interest in recovering energy from wastewater, a continuously available source of biomass-based energy, more anaerobic digestion units are likely to be built, especially if additional incentives are available. Experience with numerous anaerobic digestion facilities indicates that even a small to medium plant can generate enough electricity to power 50 to 100 homes. With respect to larger plants, if the more than 550 remaining facilities in the U.S. that treat at least 5 million gallons per day (mgd) and do not currently have anaerobic digesters were to install this technology, additional biogas could be generated each day, enough to generate sufficient electricity to power 50,000 to 80,000 homes. [7]

Co-Digestion

Anaerobic digestion of energy-rich organic waste materials such as restaurant grease and food waste along with wastewater treatment sludge is defined as "co-digestion." In addition to diverting food waste and these fats, oils, and grease (FOG) away from landfills and collection systems, co-digestion of these energy-rich waste streams increases biogas generation and methane content.

Did you know that…

- **Greenhouse Gas Emissions Mitigation** – Avoids the release of methane from landfills that occur from food decomposition and contributes onsite electrical generation of renewable energy, offsetting conventional fossil fuel generated electrical energy use.
- **Economic Benefits** – Using available digestion capacity for co-digestion enables cost recovery from producing onsite power, collecting a tipping fee, and reducing maintenance costs associated with collection systems.
- **Diversion Opportunities** – Municipalities are investing to divert organic materials away from landfills. Water resource recovery facilities offer the opportunity to accept food waste (14% of the total municipal solid waste stream in the U.S.) to generate renewable energy. [8]

Biogas Fueled Combined Heat and Power

Did you know that… There is a long history of using biogas as a reliable, and renewable, source of fuel that can be used in engines, turbines, fuel cells for electricity generation, as well as for "combined heat and power (CHP)." CHP, electricity generation with the capture of the historically wasted heat energy, is an efficient, clean, and reliable approach to generating power and thermal energy. Biogas CHP can greatly increase the facility's operational efficiency and decrease energy costs. At the same time, CHP reduces the emission of greenhouse gases, which contribute to global climate change. If the more than 500 plants that currently use anaerobic digestion without CHP were to install CHP facilities, they could generate approximately 340 megawatts (MW) of electricity that could offset 2.3 million metric tons of carbon dioxide emissions annually – the equivalent of planting 640,000 acres of trees or removing 430,000 cars from the road. [7]

THERMAL CONVERSION OF WASTEWATER AND BIOSOLIDS

The process of converting biosolids to energy is either through biodegradation as presented above or through thermal conversion. Thermal oxidation (incineration), the complete oxidation of organics (biomass) to carbon dioxide and water in the presence of excess air, is a well-established technology. Other methods, such as gasification and pyrolysis, are emerging technologies.

Did you know that… Noted benefits of thermal conversion include: reduction in biosolids mass, generation of heat for use in heating or electricity generation, reduction of the facility's overall carbon footprint, lowering the reliance on fossil fuels, generation of ash for use in building materials and other beneficial uses, and generation of additional revenue to utilities. Here are more details on thermal conversion and thermal energy recovery.

Thermal Oxidation (Green Energy Boiler)

Did you know that… Thermal oxidation is a proven technology that is often used because of the simple operating and pretreatment requirements and the high efficiency of the energy recovery. Given the right combination of technology and biomass fuels, including biosolids, fats oils and grease (FOG), and local community green waste, such as wood chips, a combustor can process a wide range of solid and gaseous materials, and convert them into useful energy. [9,10]

THERMAL ENERGY RECOVERY FROM WASTEWATER

In addition to thermal energy recovery from biosolids, thermal energy can be recovered from raw wastewater or effluent by exploiting the often significant temperature differential between wastewater and ambient conditions. This temperature difference can be recovered for use in heating and cooling systems, which is generally used for buildings at the facility, and sometimes in the buildings of areas surrounding the facility. The wastewater or effluent is used as a heat source or sink for a heat pump that can provide heating or cooling energy. [11] Generally the economics favor this type of thermal recovery in colder climates and locations where fossil fuel prices are high.

EMERGING TECHNOLOGIES FOR ENERGY RECOVERY FROM WASTEWATER

The following sections discuss a number of emerging technologies that have the potential to further enhance the renewable energy contribution from wastewater. Naturally, research remains to be conducted to develop stable and cost-effective processes and standards must be developed to bring the technologies to industry so that they are cost-effective, predictable, controllable, and capable of achieving compliance with regulatory requirements.

Pyrolysis

Pyrolysis is a thermal process that uses high temperature and pressure in the absence of air to decompose organic material in the biosolids into gas, liquid, and solid (or char). Char is a carbon-based material formed by incomplete combustion of the organic material. The process yields a product that can be pelletized into solid fuel, which can be used with coal in power plants. Currently, pyrolysis has limited application for biosolids, but the future for potential energy recovery is promising.

Gasification

Gasification, the process that powered coal gas lights in the 1700s, has been used for decades in Europe and Japan for converting biosolids to energy in the form of heat and electricity, and is an emerging technology in the U.S. Gasification is the partial oxidation of organics (biomass) and conversion to carbon monoxide, hydrogen, and methane (syngas) in the presence of limited air for partial oxidation. New gasification technologies are emerging and demonstrations of these using biosolids to generate electricity or hydrogen fuel are under way. [12]

Algae Culture

Research has shown that algae can recover nutrients from wastewater and use the biogenic carbon to generate biomass with high energy content. [13,14] Algae-based wastewater solutions have the potential to manage carbon, phosphorus, and nitrogen lifecycle issues and make significant net energy gains. Algae used for wastewater nutrient remediation and recovery could mitigate the high energy consumption required by current technologies. Algal biofuels from wastewater could offset coal and imported oil, while nutrient recovery could reduce use of fossil fuel in fertilizer manufacturing and improve environmental quality.

Microbial Fuel Cells and Other Microbial Conversions

Did you know that… Anaerobic systems can be engineered to produce electrical energy by using Microbial Fuel Cell technology to take advantage of the electrical potential in wastewater. [15,16] Research shows that other microbial conversions of wastewater constituents to biofuel are possible, including butanol and methanol. Developing these promising concepts into reliable sources of biofuel require adequate funds for research and development. [17]

TRADITIONAL RENEWABLE SOURCES AT WASTEWATER TREATMENT FACILITIES

Did you know that… Wind, solar, and hydropower can be effective renewable energy sources for meeting the energy demands at water resource recovery facilities. While the applicability of these sources is very much dependent on site conditions – wind speeds, intensity and duration of solar energy, and available elevation heads and hydraulic flows – they represent an important opportunity for reducing facility requirements for external sources of energy. Current wind technologies have made significant advancements, notably with large, multi-megawatt wind turbines, for utility-scale applications. The availability of turbines in intermediate size ranges appropriate for many facilities (100 kW to 1 MW) is more limited, and could benefit from expanded product research and development.

Did you know that… Solar electric technologies, notably photovoltaics systems are improving in efficiency and becoming more cost-competitive with conventional sources of electricity in selected markets. Given the modular characteristics of the solar technologies, they can be situated in many areas at water resource recovery facilities – on buildings, integrated into buildings or structures, or as free-standing arrays of photovoltaic modules.

Did you know that… Unlike traditional hydropower sources such as rivers and streams, developing hydropower from water resource recovery facility outflows does not require additional costs for flow diversions and potential environmental consequences. Reductions in costs, improvement in technologies. and notable financial incentives would be beneficial in expanding the use of micro-hydropower technologies at facilities.[18,19]

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