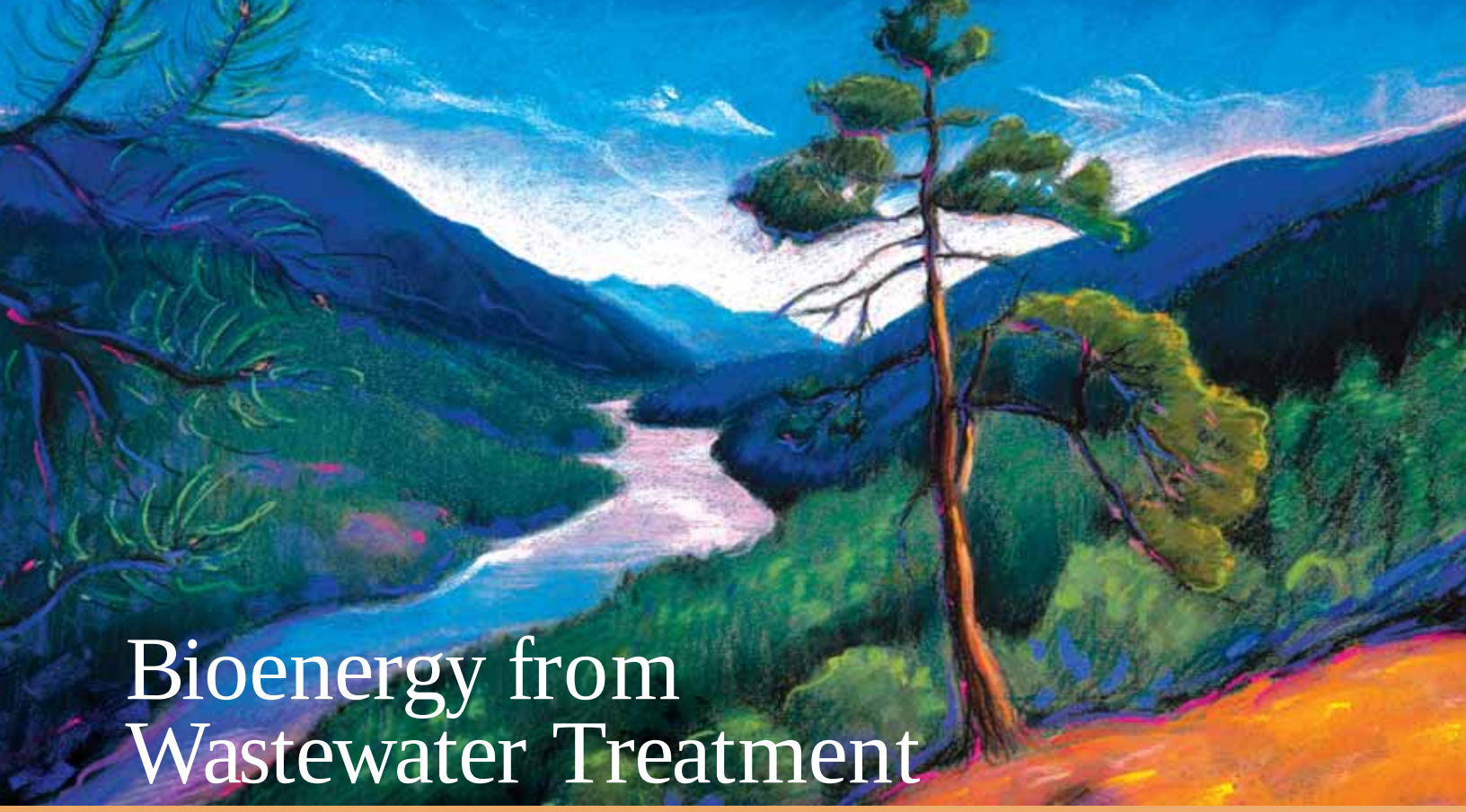

Bioenergy from Wastewater Treatment

A CLEAN, AFFORDABLE ENERGY SOURCE

Across the United States and throughout the world, increasing populations and growing environmental awareness will put continued pressure on wastewater utilities to clean more water, more quickly, and to manage an increasing volume of residuals safely and cost-effectively. Bioenergy and other thermal technologies can meet or exceed regulatory requirements and satisfy public expectations.

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Introduction

TODAY, MORE THAN HALF THE TOTAL NATIONAL VOLUME OF BIOSOLIDS is applied to land as fertilizer or soil conditioner. The organic nutrients that make biosolids ideal for land application also give them a significant bioenergy value. At 10,000 to 12,000 BTUs per dry pound of volatile solids, biosolids can be a valuable biomass fuel.

Biomass is the most used non-fossil fuel in the world. In the United States, more than 10 gigawatts of biomass electrical generation capacity (about 1.4 percent of national usage), have been installed since the Public Utilities Regulatory Act was passed in 1978. Although forest products have traditionally been the primary source of biomass, a number of other sources—including energy-rich wastewater residuals—are now being tapped.

Wastewater agencies face increasing economic challenges, as well as pressure to improve biosolids quality to satisfy users and the public. Bioenergy and other thermal biosolids technologies can provide an additional revenue source for wastewater agencies and can help them reduce energy and transportation cost and increase biosolids quality.

Wastewater agencies can choose among several such technologies to help meet their biosolids processing goals. Three of them—thermal oxidation, biogasification, and anaerobic digestion—can enable agencies to produce some or all of the energy they need to operate. A fourth, thermal drying, can create a valuable product that they can sell to help offset operating costs. Thermal drying is often used in conjunction with the other three processes to reduce operating costs or improve processing operations.

Thermal Oxidation

ABOUT 150 U.S. MUNICIPALITIES USE THERMAL OXIDATION TO TURN BIOSOLIDS into an energy source, producing carbon dioxide, water, and the inert material called ash. Thermal oxidation is generally carried out in one of two types of reactors, fluidized bed or multiple hearth. Although multiple-hearth reactors are more prevalent, virtually every new thermal oxidation facility built in the past 15 years has used a fluidized-bed unit.

Fluidized-bed reactors can be highly energy-efficient and can become autogenous, or self-sustaining without auxiliary fuel, when the combustion air is preheated to high temperatures (1,000 to 1,200°F). These entirely self-fueling reactors actually recover more energy—in the form of heated air, gas, steam, water, or oil, any of which can be converted to electricity—than they use. Fluidized-bed reactors' rapid combustion gives them generous processing capacity. And, properly outfitted, they comply with all recent stringent emissions regulations.

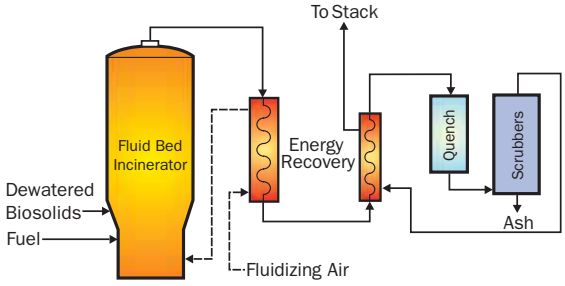

FIGURE 1 Thermal Oxidation Process

ADVANTAGES

–Has low life-cycle cost and is therefore often the least expensive biosolids handling alternative for medium and large facilities.

–Produces recoverable energy that can be used to produce heated air, gas, water, and oil that can be used for process and building heating or converted to electricity in steam-driven equipment.

–Requires small land area and can operate continuously in all weather conditions.

–Does not require pre-stabilization.

–Destroys all volatile solids and pathogens.

–Minimizes potential for onsite or offsite odors.

–Gives agency/municipality greater control of their overall operation by reducing dependency on others to accept and use the biosolids.

–Assures public of proper operation due to strict permitting, monitoring and reporting requirements.

DISADVANTAGES

–Has high initial capital costs.

–Requires public education to change perceptions that incineration is not a "green" process.

–Is not the most appropriate technology for non-continuous operation (though fluidized-bed systems are commonly operated 24 hours a day, four to five days a week).

–Requires complex permitting process.

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Anaerobic Digestion

ONE OF THE OLDEST WASTE REDUCTION AND STABILIZATION PROCESSES, anaerobic digestion uses the process of bioenergy conversion to change volatile solids into biogas. The biogas can then be used either to produce hot water or steam in boilers, or to produce both electricity and heat in combined heat and power (CHP) systems. Numerous CHP systems have been installed in wastewater treatment plants to meet their continuous power and heat demands. Heat recovered from a digester gas-fueled CHP system is usually adequate to meet the plant's space heating requirements as well as the heating requirements of the anaerobic digester process. In addition, such a system can generate enough electricity to provide as much as 60 percent of the plant's average electricity demand.

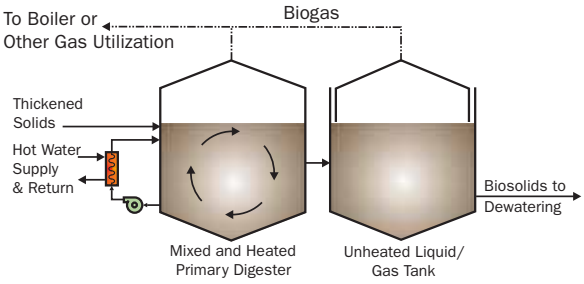

FIGURE 2 Anaerobic Digestion Process

There are two types of anaerobic digestion: mesophilic and thermophilic. Mesophilic digestion uses bacteria that are active at body temperature (95-98°F, 35-37°C). Thermophilic digestion uses bacteria that are active at considerably higher temperatures (122-135°F, 50-57°C).

Mesophilic is the more prevalent type of anaerobic digestion, used at many mid- to large-size wastewater treatment plants to produce Class B biosolids. As a result, many operators are familiar with desired operating parameters and how to control them. Compared with the higher temperature process, mesophilic digestion rates are slower, more tank volume is required, and solids reduction may not be as good, but the process requires less energy and puts less stress on concrete tanks.

Thermophilic digestion's higher temperatures destroy pathogens more quickly, shortening retention time, increasing capacity, and making it possible to produce Class A biosolids. Although thermophilic digestion can produce highly volatile fatty acids, this problem can be avoided with subsequent mesophilic digestion.

ADVANTAGES

–Is a proven technology in use worldwide for many years.

–Reduces solids-processing and transportation costs because of reduced volume.

–Greatly reduces pathogens and odors.

–Produces a readily usable fuel with many potential energy conversion options.

–Generally results in a product that meets either Class A (thermophilic) or Class B (mesophilic) land application standards.

DISADVANTAGES

–Requires the approval of the U.S. EPA Pathogen Equivalency Committee for Class A biosolids produced by thermophilic digestion.

–Still requires substantial wet biomass handling and disposal.

Thermal Drying

A PROVEN TECHNOLOGY FOR PRODUCING MARKETABLE BIOSOLIDS, thermal drying reduces the volume and mass of solids by evaporating their water content. High temperatures can also help meet U.S. EPA requirements for Class A and Exceptional Quality (EQ) biosolids. There are two general categories of thermal dryers: direct and indirect.

Direct thermal dryers heat air or gas, which then comes into direct contact with wet solids and heats them to evaporation temperature. The dried material is separated from the warm exhaust gas, screened, and either recycled back to the dryer as seed material for the drying process or stored in silos. Exhaust gas is either cooled and recycled or treated and released into the atmosphere.

Indirect thermal dryers use steam, hot water, or hot oil to heat a metal surface over which the solids are passed. The solids, which never directly contact the steam, water or oil, are heated to evaporation temperature by conduction. Exhaust is sent to a condenser, and exhaust and odors are either combusted in the furnace that produces the steam, hot water, or hot oil, or may be passed through another process for subsequent treatment.

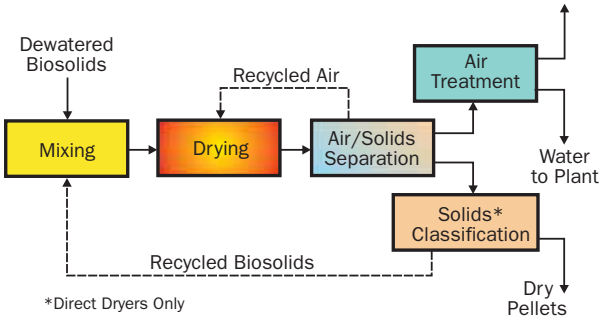

FIGURE 3 Convective Thermal Drying System

ADVANTAGES

–Is a proven technology in use in more than a hundred plants, large and small.

–Creates a highly stabilized product that meets EPA requirements for Class A and Exceptional Quality (EQ) biosolids; is easily handled, stored, and transported in bulk or in bags or other containers; and can be sold or given away as a fertilizer or soil conditioner.

–Can provide revenue of up to $40 per ton of dry material, depending on market and nutrient content.

–Reduces odors and has greater public acceptance than other processes.

–Reduces record keeping and reporting requirements for land application.

–Is easily combined with anaerobic digestion to provide a nearly self-fueling process.

DISADVANTAGES

–Is typically more expensive to build, operate and maintain than other alternatives.

–Is subject to fluctuations in the cost of auxiliary fuel.

–Has a history of environmental and safety concerns, most of which are addressed by current design measures.

–Requires qualified operating staff and considerable maintenance.

–Requires air permitting and air pollution control.

–Is subject to regional market conditions, which should be evaluated to determine optimum uses and value for the product.

–Can result in odorous product if primary solids are not pre-digested before drying.

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Biogasification

AND OTHER CONVERSION TECHNOLOGIES

BIOGASIFICATION USES HEAT AND A CHEMICAL REACTION TO CONVERT larger-molecule non-fossil biomaterials such as municipal solids into smaller-molecule combustible gas products. A wide range of devices can then be used to convert biogas to energy, including gas turbines, reciprocating engines, and hydrogen-powered fuel cells, and recent innovations have helped to lower capital costs and increase efficiency. One such advancement uses hydrogen from the biogasification process to produce electrical current.

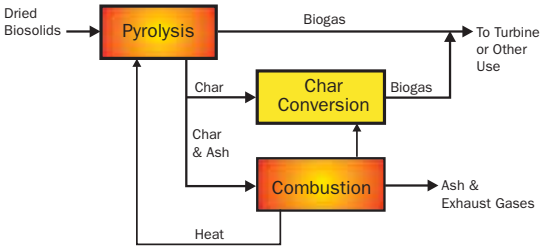

FIGURE 4 Simplified Gasification Process

ADVANTAGES

–Captures and converts CO_2, avoiding greenhouse gas emissions.

–Destroys pathogens, viruses and other harmful organic compounds.

–Immobilizes heavy metals.

–Significantly reduces odor.

DISADVANTAGES

–Has been a costly energy source because converting the energy of a hydrogen fuel into electricity has been expensive. However, recent advances in fuel cell materials and gasification-produced hydrogen processes are lowering the cost, and the rising price of other fuels puts the cost of biogasification into perspective.

–Requires continued research and development to design sustainable and economical processes.

Combining Biosolids Processes

INCREASINGLY, BIOSOLIDS HANDLING OPTIONS ARE BEING COUPLED FOR MUTUAL benefit. For example, waste heat boilers can be used for energy production or in combination with thermal conditioning systems or thermal dewatering systems to produce an operation that is entirely self-fueling.

In another example, odors from thermal drying can be reduced by pairing it with anaerobic digestion or thermal oxidation, either of which can also provide fuel for the energy-intensive thermal dryers. Moreover, in combination with thermal drying, mesophilic digestion can produce Class A biosolids.

The European trend is to use the available energy in biosolids as a fuel source in dedicated power generation facilities. Most power generation stations in North America have not shown interest, however, in part because of their perceptions of biosolids and fears of additional regulations.

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Founded in 1928, the Water Environment Federation (WEF) is a not-for-profit technical and educational organization with members from varied disciplines who work toward the WEF vision of preservation and enhancement of the global water environment. The WEF network includes water quality professionals from 76 Member Associations in 30 countries.

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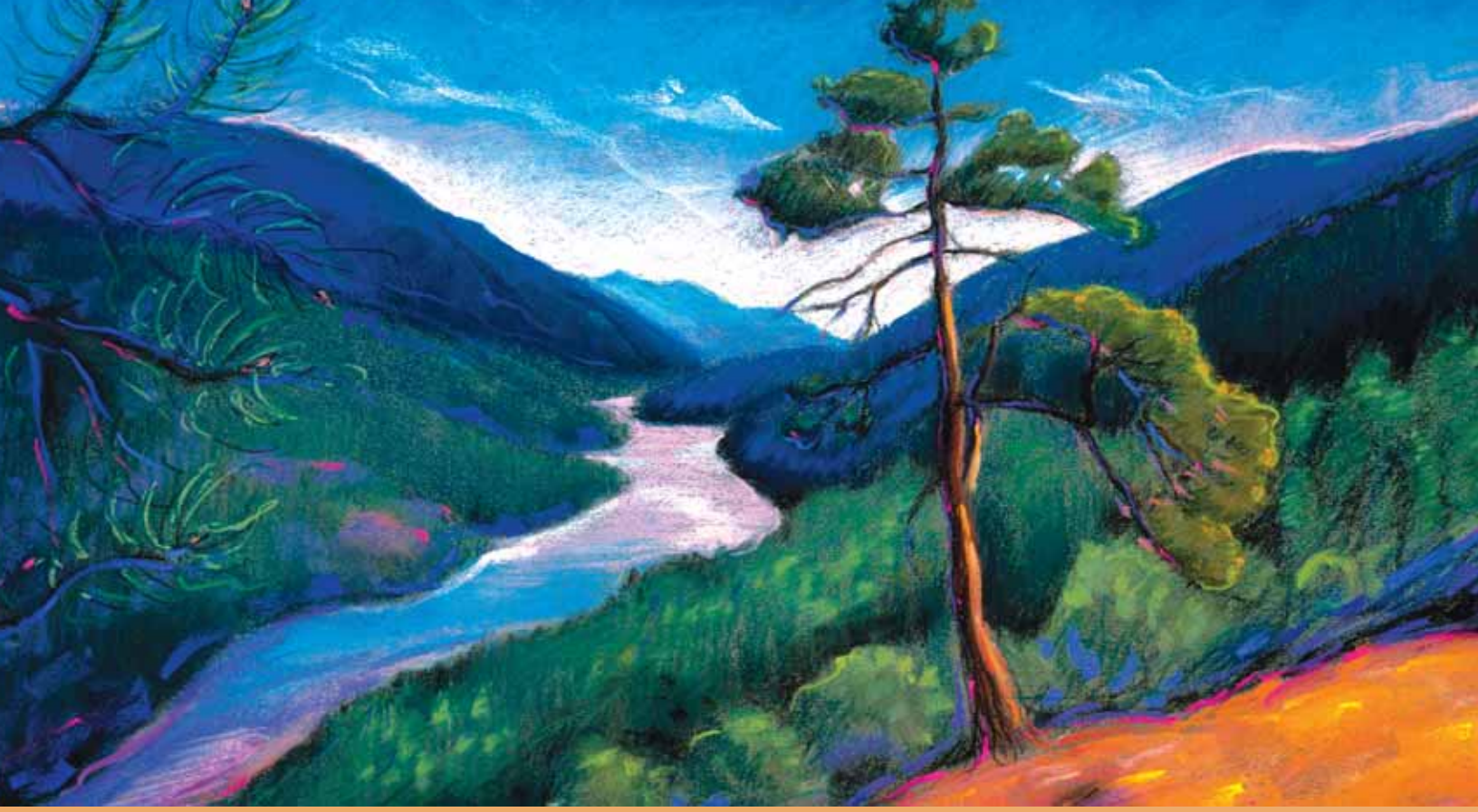

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