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A Brief on Biosolids: Options for Biosolids Management

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Options for Biosolids Management

By Rosa Maria Moller, Ph.D.

Prepared at the Request of
Former Senator Richard Alarcón

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EXECUTIVE SUMMARY

This paper was requested in 2006 by former Senator Richard Alarcón. The objective of the research was to provide an overview and analysis of issues on and options for biosolids management.

Biosolids are municipal sewage treated to meet federal and state standards required for land application. This paper describes the production and management of biosolids in California; the regulatory framework that controls the use and disposal of biosolids; and, the controversy surrounding their use as a soil amendment and alternatives to the current management practices for biosolids with emphasis on their potential use as a source of energy.

Communities face the challenge of what to do with the growing amount of sewage they produce. Currently, about 50 percent of the approximately 800,000 dry tons of biosolids produced annually in California are used as a soil amendment. About 30 percent are put in landfills and surface impoundments or used as alternative daily cover in landfills. Eleven percent of biosolids are transported out of the state. U.S. Environmental Protection Agency (EPA) data reports that 81,400 dry tons of biosolids were transported from California to Arizona, Nevada, and tribal lands in 2003. Other management options for biosolids include incineration, long-term storage, their use in cement and construction materials manufacturing, and use as a biofuel.

For biosolids to be applied to land, they must satisfy the requirements for pathogen reduction, pollutant limitations, and vector-attraction reduction established in the Code of Federal Regulations (CFR), Title 40, Part 503. In California, Water Quality Order No 2004-0012-DWQ (July 2004) was approved that regulates the discharge of biosolids to land for use as a soil amendment in agricultural, silvicultural, horticultural, and land-reclamation activities. This general order is in some aspects more stringent than the federal Part 503 rule.

Biosolids are classified into either "Class A" or "Class B." Class A biosolids have had sufficient treatment to essentially eliminate all pathogens, while Class B biosolids have been treated for pathogens reduction, but may still have low levels of pathogens which are expected to rapidly die-off when applied to soils. There are also Exceptional Quality biosolids that are not explicitly defined in the Part 503 rule, but are Class A biosolids that contain lower levels of metals. Most biosolids applied to land in California are Class B.

The use of biosolids as a fertilizer in farms or as a compost in gardens, public parks, and other open spaces is the most common application of biosolids. Benefits from these uses include a reduction in landfill use, better air quality (as biosolids incineration is avoided), and soil quality improvement. Biosolids are not a total replacement for fertilizers since they do not supply a balance of nutrients. However, they contain essential nutrients (nitrogen and phosphorous) and trace elements (such as copper, iron and manganese) that are important for plant growth. Biosolids are also used to improve soil conditions through the establishment of a vegetative cover in land reclamation projects (in gravel quarry waste or mine spoils).

Frequent applications of biosolids to certain soils and crops could have toxic effects on plants, nutrient imbalances, and soil contamination due to high levels of pollutants contained in the biosolids. These effects may lead to lower productivity or cause quality problems in some tree or crop species, depending on the type of soil. Some soils and crops may have high sensitivity to trace element concentrations (iron, zinc, lead, cadmium, etc.). Furthermore, treated biosolids that meet regulatory standards could still contain a wide variety of pathogens excreted by humans, including bacterial, viral, and fungal microorganisms that could affect human and animal health.

The use of biosolids as a soil amendment may also have adverse effects on water sources and groundwater with further implications for public health. For example, areas that do not receive a large amount of fresh water may accumulate nitrates. Water quality can be contaminated through runoff from treated lands and deep percolation of excess irrigation water or precipitation.

There are numerous organic compounds in biosolids, coming from diverse sources such as pharmaceuticals and personal care products, that end up in the waste stream. Although some of these compounds are destroyed during the treatment process, many are found in the discharge resulting from the waste treatment process. Concerns are highest for organic compounds contained in biosolids such as plastic-like compounds, pesticides, detergent additives, PCBs, and other organic compounds that may have negative effects for human health. There are also concerns about effects from radioactive materials that may enter the waste stream.

Animals can be affected by ingesting crops and vegetation grown in contaminated soils due to biosolids application. Humans may eat products grown in contaminated soil, animals contaminated by grazing on land where biosolids were used, or become contaminated through vectors (rats, insects) that have been exposed to biosolids. Adverse effects on humans range from gastroenteritis, flu-like symptoms, salmonella, and other potential unknown diseases. Organic compounds found in biosolids are known to cause some illnesses including cancer and birth defects.

Public health concerns are supported by a variety of anecdotal reports and studies. Some people are concerned that the level of protection provided by regulations is not adequate. Critics question regulators on whether they have obtained enough information on infectious contamination dose and environmental persistence to support current standards. A major problem is that EPA regulations do not establish standards for synthetic organic compounds contents, however, in California state regulations require testing of biosolids for PCBs and semivolatile organic compounds. There are also concerns about potential risks posed by new organic compounds or pollutants that have become known since the promulgation of the 503 regulations. The validity of the methodology used by EPA for risk assessments and the accuracy of the data used to support research is also questioned. A major concern is the level of implementation and enforcement of the regulations controlling biosolids.

Regulators generally believe that new technologies used in wastewater treatment, together with the existing regulations and guidelines, are sufficient to protect public health. To address public concerns U.S. EPA requested the National Research Council to study these issues. The National Council concluded in 2002 that EPA could ensure that the standards are supported by current scientific data and risk assessment methods and that EPA should validate the effectiveness of biosolids-management practices. Currently, the recommendations of the Council's study are in the process of being implemented.

Other public issues related to biosolids concern the aesthetic effects and potential deterioration of the quality of life in the communities where biosolids applications take place due to odors, vector attraction, and increased traffic. Farmers are concerned about the public perceptions of the safety of their product and real estate values for agricultural land and other properties surrounding areas of biosolids application.

The controversy around the safety of biosolids as a soil amendment has led many jurisdictions to enact regulations placing restrictions on biosolids use, including its prohibition. One example is Kern County where a public initiative banning the land application of most biosolids passed in June 2006.

Increasing public opposition obligates communities to find alternatives to a sustainable biosolids management strategy. This paper reviews some potential alternatives that are presented in Section 5. The least expensive is to continue with land application of biosolids while tightening the standards and enforcement for this practice and educating the public to increase their acceptance of this practice. Another option could be supporting compost producers and expanding the market for compost by providing economic incentives to these producers to ameliorate start-up losses and stimulate the expansion of the industry. Finally, a more aggressive management option that may help to save energy and decrease the use of fossil fuels is to support conversion technologies that allow for energy savings in waste treatment plants and/or production of by-products that can be used as biofuels or other applications.

Section 3 presents a detailed description of various technologies that can be used to treat sludge to reduce the use of energy or produce energy during the sewage treatment process. These technologies have already passed the demonstration stage and are ready to be commercialized. To make the use of these technologies widespread, the state could follow a variety of policy actions (discussed in Section 5), in addition to some policies already in place (discussed in Section 3). For example: 1) the state may direct a panel of qualified professionals to conduct a complete and objective evaluation of the costs and benefits of the existing technological processes that use biosolids as an energy source and provide this information to sanitary districts and wastewater treatment plants; 2) the state could help to create a market for these technologies by requiring the use of innovative products derived from biosolids treatment in public construction (such as glass, bricks, and tiles made with by-products from biosolids treatment, etc.); 3) the state could provide incentives for wastewater treatment plants to use biosolids as a source of energy, such as technical assistance, seed funds, tax credits, low-interest loans, and facilitate the formation of a market for energy generated during the treatment of biosolids; and, 4) the state could create a subsidy to support the development of innovative industrial processes that can convert biosolids to energy or other products. A rough estimate of this subsidy is $140 per dry ton, requiring a fund of about $120 million a year to support this subsidy. This could be financed with an average annual contribution of about $10 per housing unit in the state.

INTRODUCTION

The management of human waste has been a concern of societies since the formation of human communities. When population was low, waste was managed by its removal from the immediate area and discarded on the surrounding land or waterways. As populations grew and larger communities formed, human waste began to be discarded in a more organized fashion and often was disposed into large waterways, including streams, rivers, and the ocean.

The earliest known organized sewage systems were constructed in the Orkney Islands of Scotland in 3200 B.C.[1] The first known regulation concerning the proper disposal of human waste was written between 13^{th} to the 16^{th} centuries BC and is contained in the Deuteronomic Code (Deut. 23:13):

> *"And thou shalt have a paddle among thy weapons; and it shall be, when thou sittest down abroad, thou shalt dig therewith, and shalt turn back and cover that which cometh from thee."*

Most ancient sewage collections were somewhat similar to modern systems, but generally constructed for the primary purpose of drainage. The Cloaca Maxima sewer in Rome is perhaps the best known of these systems. Excrement and other wastes were routinely thrown into the streets where they washed into the drains via a street cleaning process. The system met with success until the amounts of water available for the cleaning process were reduced due to pilferage from the aqueducts, limited precipitation or high demand for other uses of the water.

Sanitation became a larger problem beginning in medieval and post-medieval times when cities and towns became more densely populated. In 1349, in response to the high number of deaths caused by a plague, the King of England ordered the streets of London to be cleared of the massive amount of human waste. Piles of human waste became such a problem in Berlin that a law was passed in 1671 requiring every peasant who traveled into town to remove a load of filth when leaving the urban area.

Parisians freely emptied human waste receptacles into their streets causing the passage of a 1531 law requiring the installation of latrines in every house. The law was routinely ignored and by the time of the French Revolution, the terrace of the Tuilleries became heavily contaminated by mounds of human waste.

A "Health of Towns Commission" reported in 1844 that there were massive amounts of human wastes on the streets of English cities.[2] This report caused a movement to address the problems of human waste disposal by the most modern means available. The source of London's cholera outbreaks of the mid 1800's was polluted water from wells and from the River Thames, below the sewage outfall. To reduce pollution of the Thames, "sewage farms" were established to take the discharges from an interceptor built in the north bank of the river to prevent the contaminated sewage materials from entering the river.[3] The practice of utilizing sewage farms to manage sewage wastes quickly spread in

Europe. By 1875, there were about 50 farms following this practice in England, and many similar farms served major cities on the continent.[4]

The construction of the first large scale modern sewage system was begun in Paris in 1850 under the direction of Eugène Belguard. Most of the sewage was pushed through the underground canals downstream via boats (with "wings") to the discharge point of the sewer into the River Seine. At this point, sewage sludge was pushed onto barges and transported to various sewage fields or farms.

In the United States, discharges of raw sewage into waterways continued to be the preferred method of disposal through much of the 19th and 20th centuries. In arid areas of the country, such as the Los Angeles basin, sewage farming, which is a method of slowly irrigating croplands with raw sewage, was a popular disposal method until the beginning of the 20th century.

Water pollution became a public issue in the United States near the turn of the 20th century, which resulted in the promulgation of federal legislation aimed at controlling it. The federal Rivers and Harbors Act of 1899 prohibited the unauthorized disposal of any refuse matter into navigable bodies of water or any tributary to such water. The Water Pollution Control Act, passed in 1948, required the Surgeon General to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. After 1950, thousands of municipal sewage treatment systems, or publicly owned treatment works (POTWs), were built. This process was accelerated by the passage of the Clean Water Act of 1972. In 1992, the ocean disposal of residual solids was banned.

These laws and their subsequent regulations have caused the upgrade of most modern sewage collection systems from a conveyance and discharge system to a conveyance treatment and treated effluent discharge system. The most common methods to treat wastes were drying, or aerobic or anaerobic digestion. The wastes created by these treatment systems consist of a liquid discharge, a gas or gases (such as methane) and a semi-solid nutrient-rich organic material called a "biosolid."

The United States restrictions on ocean disposal of sewage solids and the scarcity of landfill space make land application one attractive option to dispose of biosolids (the solid part resulting from the municipal wastewater treatment). In 1993, EPA promulgated standards for the use and disposal of sewage sludge (Code of Federal Regulations Title 40, Part 503) that established rules for the land application of biosolids.

Nationwide, municipal wastewater is currently generated at an estimated daily rate of more than 180 gallons per person.[5] In California, wastewater treatment yields a daily biosolids generation of about 2,130 dry tons, or nearly 780,000 dry tons a year. About half of this amount is applied to land. As the population expands, the extent of the problem of managing biosolids will become more critical.[6]

The disposal of biosolids to land has not been without controversy. Most controversy stems from a belief that there is a lack of credible scientific studies that verify that the legal disposal of biosolids is protective of public health. The public believes that pathogens and chemicals such as pharmaceuticals, health-care products, and industrial compounds known to be present in raw municipal wastes may continue being present in concentrations sufficient to constitute measurable risks to public health, even after the wastewater treatment process is completed.

The U.S. Environmental Protection Agency (EPA) commissioned a study by the National Research Council (NRC) to examine the public health protection issues relating to the management of biosolids and whether the Part 503 rules were sufficiently stringent. In July 2002, the NRC issued its report entitled "Biosolids Applied to Land: Advancing Standards and Practices." The NRC committee concluded that "there is no documented scientific evidence to indicate that the Part 503 rule has failed to protect human health," but that additional scientific work is needed to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids. The committee recognized that land application of biosolids is a widely used, practical option for managing the large volume of biosolids generated at wastewater treatment plants that otherwise would need to be disposed of at landfills or by incineration.[7]

EPA has identified three main objectives for attaining a better understanding of biosolids and reducing the potential for, or reducing the uncertainty related to, human health impact: (1) update the scientific basis of Part 503 by conducting research in priority areas; (2) strengthen the biosolids program by evaluating results of completed, ongoing, or planned studies both within and outside EPA; and, (3) continue ongoing activities for enhancing communication with outside associations and with the public. Following the recommendations from the study, standards under Part 503 are currently being revised.[8]

Increasing public opposition to the practice of using biosolids as a fertilizer has affected municipalities' current biosolids management programs and prompted them to look for alternative ways to dispose of these materials. The continuation of biosolids' widespread use as a soil amendment will require public education and a concerted effort by regulators to show the public that their concerns are being addressed and that biosolids management is conducted according to the prescribed regulations. Another way to mitigate public opposition is to ensure treatment of biosolids to higher quality standards prior to land use. This would eliminate the potential health threats that may exist either in reality or in public perceptions.

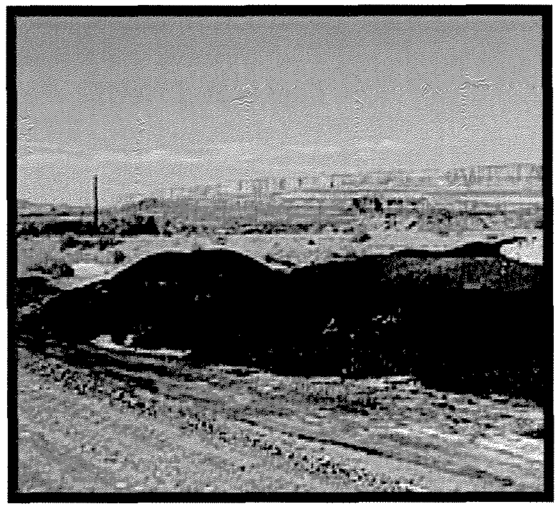
Feasible alternatives to landfilling for the disposal of biosolids include the processing of the wastes for use as road pavement, brick manufacturing, as an ingredient in other construction materials, power and fuel generation, and as an alternative daily cover at municipal solid waste (MSW) landfills.

This paper provides an overview of the production and management of biosolids. Section 1 describes biosolids, their classification, generation, and amounts produced in California. Section 2 presents current alternatives of biosolids management in the state including benefits and costs of these alternatives. Section 3 focuses on the use of biosolids as a source of energy. Section 4 briefly describes the main federal, state, and local policies that encourage and/or regulate biosolids use; and Section 5 summarizes biosolids management alternatives available to municipalities and main policy measures that may support these alternatives.

SECTION 1. BIOSOLIDS PRODUCTION

I. DEFINITION

Figure 1: BIOSOLIDS



Source: U.S. EPA, Region IX.

Virtually all of the raw sewage that is conveyed to a sewage treatment plant in the United States results in the discharge of two waste streams; an effluent and a sewage sludge. Sewage sludge is defined as the solid, semi-solid or liquid residue generated during the treatment of domestic sewage in a treatment work. Biosolids are sewage sludge treated to meet the land application requirements of the Code of Federal Regulations Title 40 (40 [CFR]), Part 503 regulations or any other equivalent land application standards. [*] [9]

Most biosolids resulting from the treatment of municipal sewage have a dry matter content of three to six percent. This type of biosolids is a somewhat viscous fluid (similar to mud) and can be handled hydraulically by pumps, pipelines, and applicators.

Biosolids that are further dewatered by filter or press may contain up to 30 percent dry matter that can be handled by mechanical loading, hauling, and spreading equipment. The advantage of drier biosolids is the reduction in volume and, therefore, handling costs. However, due to the relatively high cost of reducing moisture, most biosolids are handled as a fluid.[10]

After biosolids are treated to varying degrees and tested to meet legal standards, they can be disposed of or reused.[11]

II. BIOSOLIDS PRODUCTION

Sewage treatment (Figure 2) typically involves three stages known as *primary, secondary,* and *tertiary* treatment. Primary treatment consists of physical processes (settling or skimming) that remove a significant percentage of the organic and inorganic solids from wastewater. [†] The secondary treatment involves the reduction of biologicals, including pathogens. Secondary treatment typically utilizes biological treatment processes, in which microorganisms convert nonsettleable solids to settleable solids.[‡] An

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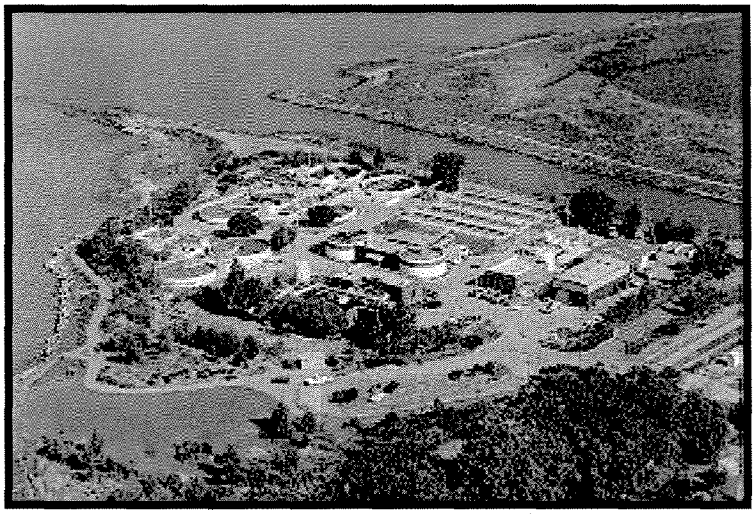
[*] Commonly referred as Biosolids Rule 503. This regulation is discussed in Section 4.

[†] Pathogen is any organism or genetic substance that causes disease, such as bacteria, viruses, parasites, cell substances, and fungi. Some pathogens are sufficiently aggressive that they can invade and infect any healthy individual, while others can only affect people predisposed (with weakened or suppressed immune systems).

[‡] ''Settleable solids'' are solids removed by settling in sedimentation tanks, clarifiers or ponds. "Nonsettleable solids" are suspended solids that remain in suspension, usually for more than 1 hour.

aerobic digestion is generally used to accomplish this process.* Tertiary treatment may include processes to remove nutrients such as nitrogen and phosphorus, and carbon adsorption to remove chemicals, depending on the discharge standards of the plant. Tertiary treatment can involve various physical, biological, or chemical processes to remove pollutants, such as filtration, nutrient removal, or disinfection (see Figure 3).[12]

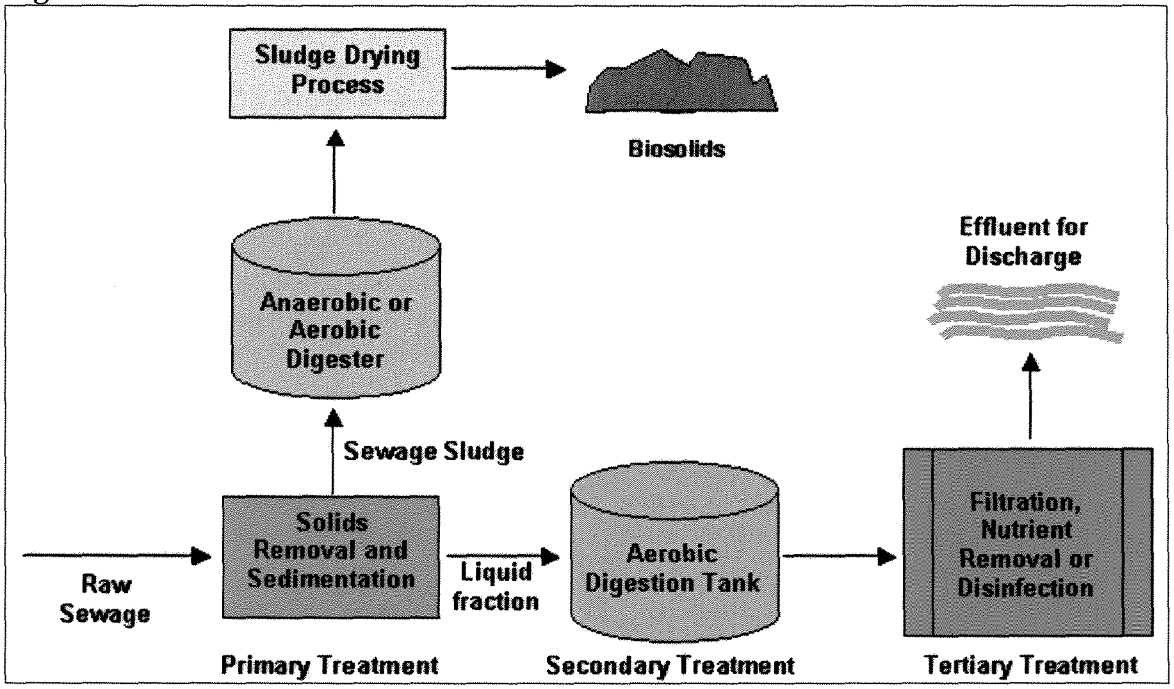
Figure 2: PINOLE/HERCULES WASTEWATER TREATMENT PLANT



Source: Picture from the plant's website at: http://www.ci.pinole.ca.us/publicworks/treat_plant.html.[13]

* Aerobic digestion of waste is the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste.
Source: http://www.biotank.co.uk/aerobic.htm.

Figure 3. SCHEMATIC OF WASTEWATER TREATMENT FACILITY



Source: California Research Bureau.

III. CLASSIFICATION OF BIOSOLIDS

U.S. EPA defines biosolids as "a primarily organic solid product produced by wastewater treatment processes that can be beneficially recycled."[14] EPA developed regulations known as *The Standards for the Use or Disposal of Sewage Sludge* (40 CFR Part 503 referred as the Part 503 rule) that became effective on March 22, 1993. Federal (40 CFR Part 503) regulations contain the requirements for the classification of biosolids into either "Class A" or "Class B":

<u>Class A biosolids</u>. These biosolids have had sufficient treatment to essentially eliminate all pathogens.

- Class A "Exceptional Quality" biosolids (EQ). Although not explicitly defined in the Part 503 rule, Exceptional Quality biosolids are Class A biosolids that meet a reduced level of metals concentration requirements than either Class A or B. EQ biosolids are not subject to most land application requirements and management activities and they may generally be used like any other fertilizer or soil amendment product.

<u>Class B biosolids.</u> These biosolids have been treated for the level of pathogens to be substantially reduced, but not completely removed. Class B biosolids may have low levels of pathogens which are expected to rapidly die-off when applied to soils, essentially becoming pathogen-free soon after application. Most California biosolids are Class B. Land application of biosolids that meet Class B criteria are restricted by a variety of conditions.[15] For example, there are buffer requirements, public access, and

crop harvesting restrictions for virtually all forms of Class B biosolids pursuant to State Water Resources Control Board Water Quality Order No.–2004-0012–DWQ.[16]

- Class B "Pollutant Concentration" biosolids. Pollutant Concentration (PC) biosolids meet the same low pollutant concentration limits as EQ biosolids, but only meet a Class B pathogen reduction. PC biosolids may only be applied to land in bulk and are subject to management practices.* [17]

Other solid or semisolid wastes include unstabilized sewage sludge, septage and wastes that do not meet the Part 503 regulations, and those determined to be hazardous under the federal Resource Conservation and Recovery Act (RCRA) (Title 42 United States Code, Section 6901, et. seq.) or pursuant to the California State Hazardous Waste Management Act (Article 7.7, Division 20, California Health and Safety Code).† [18]

IV. Amount of Biosolids Produced in California

Recent information from U.S. EPA Region IX, based on the annual reports submitted by the publicly owned treatment works (POTWs) for 2003, indicates that approximately 777,500 dry tons of biosolids were produced statewide in 2003.‡ This would yield a daily generation of approximately 2,130 dry tons.[19] About half of the sludge is generated in the Los Angeles region followed in order by the Central Valley, San Francisco, Santa Ana, and San Diego regions.[20] Much of this material is transported by truck for land application and other beneficial uses. Counties supporting the largest amounts of biosolids reuse are Kern, Kings, Merced, San Diego, Riverside, and Solano.[21]

Table 1 shows the ten counties in California that generated the largest amount of biosolids in 2003.

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* 40 CFR 503.9 (t) defines a pollutant as "an organic substance, an inorganic substance, a combination of organic and inorganic substances, or a pathogenic organism that, after discharge and upon exposure, ingestion, inhalation, or assimilation into an organism either directly from the environment or indirectly by ingestion through the food chain, could, on the basis of information available to the Administrator of EPA, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunction in reproduction), or physical deformations in either organisms or offspring of the organisms." http://www.cee.vt.edu/ewr/environmental/teach/gwprimer/group09/503reg.htm.

† Septage is the partially treated waste store in a septic tank. It generally consists of all the household wastes that are disposed of through a homes plumbing system that do not drain out into the soil or converted to gases by the special bacteria in the septage tank. Septage is generally split into three parts in a septic tank: 1) scum which floats to the top and is generally where the bacteria that treat the waste live; 2) effluent, which is the semi-treated liquid that comprises the majority of the material in the septic tank; and, 3) sludge, the solids which collect at the bottom of the tank. http://encyclopedia.thefreedictionary.com/septage.

‡ EPA defines a POTW as a wastewater treatment facility owned by a public entity, such as a city, a county, or a special sanitary district. http://www.epa.gov/owm/mtb/cwns/1996rtc/glossary.htm.

Table 1: COUNTIES WITH THE LARGEST PRODUCTION OF BIOSOLIDS, (2003)

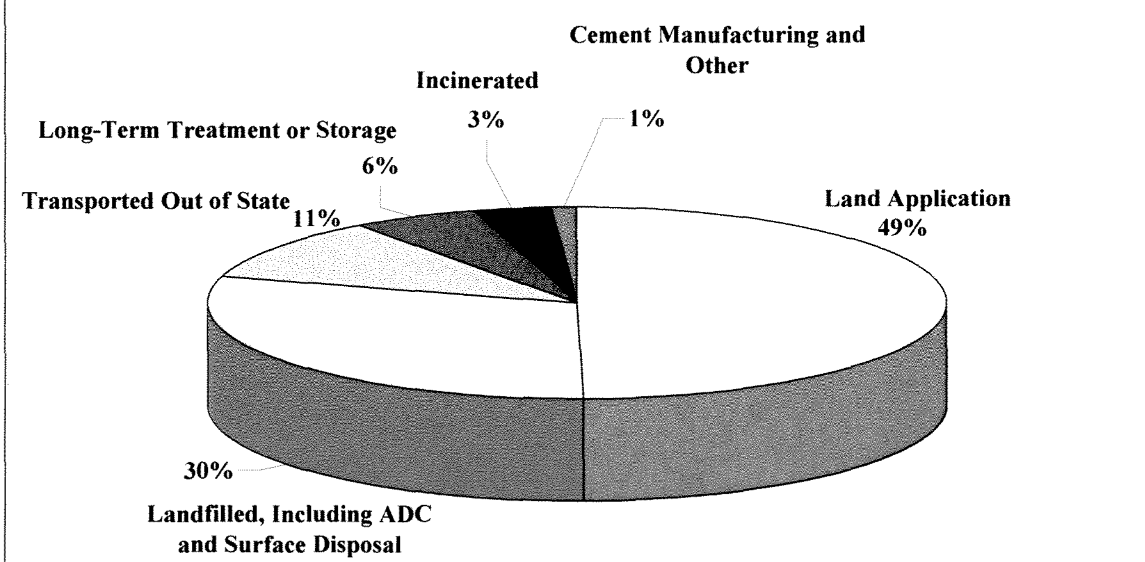
County	Amount of Biosolids Produced (Dry Tons)
Los Angeles	248,600
Santa Clara	81,400
San Diego	62,700
Orange	61,600
Riverside	47,300
Contra Costa	45,100
San Bernardino	34,100
Alameda	29,700
San Francisco	20,900
Ventura	20,900

Source: U.S. EPA, Region IX, Biosolids Coordinator, San Francisco, California, March 2004.[22]

SECTION 2. BIOSOLIDS MANAGEMENT

More than 50 percent of the biosolids generated in the United States are reused through some form of land application.[23] According to U.S. EPA Region IX data, the percentage of biosolids applied to land in California is similar (49 percent). Approximately 30 percent of the biosolids produced in California is placed in solid waste landfills, typically as an alternative daily cover (ADC) over disposed wastes and, occasionally, as a waste within the landfill.* Six percent of the biosolids produced are placed in long-term storage and three percent is incinerated. One percent is diverted to other uses, such as a material in the manufacture of cement and the production of energy (see Figure 4).[24]

Figure 4: MANAGEMENT OF BIOSOLIDS IN CALIFORNIA, 2003



Source: Data from U.S. EPA, Region IX, Biosolids Coordinator, San Francisco, California, March 2004, published in Chapter 3 Final Revisions of Final Statewide EIR Report from the California State Water Resources Control Board. Table 2-1a: http://www.swrcb.ca.gov/hearings/docs/finalbio_chap3.pdf.

I. LAND APPLICATION OF BIOSOLIDS

Land application is the most prevalent use of biosolids in California. EPA defines land application as "the spraying or spreading of sewage sludge onto the land surface; the injection of sewage sludge below the land surface; or the incorporation of sewage sludge into the soil so that the sewage sludge can either condition the soil or fertilize crops or vegetation grown in the soil."[25]

* Alternative daily cover is cover material other than earthen material that is placed on the surface of the active face of a municipal solid waste (MSW) landfill at the end of each operating day to control vectors, fires, odors, blowing litter, and scavenging. Source: www.metrokc.gov/dnrp/swd/construction-recycling/cdl-definitions.asp.

Benefits from land application of biosolids include landfill use reductions, better air quality by avoiding biosolids incineration, and soil quality improvement. Although they are not a total replacement for fertilizers since they do not supply a balance of nutrients, biosolids are used to enrich nutrient-depleted and barren soil because they contain essential nutrients (such as nitrogen and phosphorous) and trace elements (such as copper, iron, and manganese) that are important for plant growth.[26] Silvicultural uses for biosolids, such as applications for commercial tree-growing operations, are common in other parts of the country such as the Pacific Northwest, but less so in California.[27]

Biosolids are valuable as fertilizers for agricultural fields and to improve soil conditions through the establishment of a vegetative cover in land reclamation projects (in gravel-quarry waste or mine spoils).[28] Biosolids improve the soil's ability to absorb and store moisture, reducing the need to irrigate and providing natural drought resistance.[29] Studies have found that soil humic matter, cation exchange capacity, and nitrogen increase after repeated applications of biosolids.[*] [30]

1. Biosolids Application in Agricultural Land

According to the U.S. EPA, in 2003 about 387,000 acres of land fertilized with biosolids grew crops in California.[31] Table 2 shows the amount of biosolids applied as fertilizer by type of crop. Most biosolids are applied to land growing cotton, alfalfa, winter wheat for feed, and sudan grass.

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[*] The relative ability of soils to store one particular group of nutrients, the cations, is referred to as cation exchange capacity. Cation is an atom or group of atoms carrying a positive charge. The charge results because it contains more protons than electrons. The cations used in largest amounts by plants are calcium, potassium, and magnesium.

Table 2: AMOUNT OF BIOSOLIDS APPLIED BY CROP IN CALIFORNIA, 2003

Type of Crop	Amount of Bosolids Applied (Class A, B, and Compost)	Percent
Cotton	80,300	20.8
Landscaping	79,200	20.5
Alfalfa	37,400	9.7
Winter wheat, for feed	36,300	9.4
Sudan grass	35,200	9.1
Silage corn	34,100	8.8
Orchard (fruits and nuts)	23,100	5.9
Winter wheat, green chop	17,600	4.5
Oats, for hay	10,340	2.7
Milo	8,800	2.3
Nursery	6,380	1.6
Pasture	5,500	1.4
Wheat, for food processing	3,960	1.0
Oats, for feed	2,200	0.6
Safflower	2,200	0.6
Clover	2,200	0.6
On-site vegetation (i.e. naturally occurring grasses or other plants)	2,200	0.6
Total	**386,980**	**100**

Source: U.S. EPA, Region IX. Biosolids Coordinator, San Francisco. California, March 2004.[32]

For application in agricultural land, biosolids are usually transported in bottom-dumping trailers from the publicly owned treatment work (POTW) of origin to the agricultural site. Materials may be directly dumped on the site, bottom-dumped into spreaders for immediate application or placed in stockpiles for later use. Biosolids are spread evenly across the fields and subsequently incorporated into the soil through disking or harrowing. In some instances, biosolids with high moisture content may be transferred to liquid tank vehicles and injected into the soil.

The application rate of biosolids depends on the characteristics of the materials, the chemical composition of the soil upon which it will be applied and the loading rate for nutrients for the particular type of crop to be grown in the fertilized soil. Soils may receive one or several loads of biosolids before planting.[33]

2. Composting for Agricultural, Horticultural and Land Reclamation

After further treatment such as lime stabilization or composting (using a bulking agent such as wood chips or co-composted with green waste), biosolids may be used for more specific horticultural uses, such as bulk and bagged sales to the public as a garden soil amendment, bulk land application to public areas (for example, golf courses and parks), and land application for certain agricultural crops.[34] The end product from composting is usually a Class A, humus-like material. The three most commonly used methods for composting wastewater residuals into biosolids are:

Aerated Static Pile: Dewatered biosolids are mechanically mixed with a bulking agent and stacked into long piles over a bed of pipes through which air is transferred to the composting material. As the pile is starting to cool down, the material is moved into a curing pile.[35]

Windrow: Dewatered wastewater solids are mixed with bulking agent and piled in long rows. Because there is no piping to supply air to the piles, the material is aerated mechanically by devices such as drums and belts powered by agricultural equipment. This periodic mixing is essential to move outer surfaces of material inward so they are exposed to the higher temperatures deeper in the pile. After this process, the material is moved into curing piles.

In-Vessel: A mixture of dewatered wastewater solids and bulking agent is fed into a silo, tunnel, channel, or vessel. Augers, conveyors, rams, or other devices are used to aerate, mix, and move the product through the vessel to the discharge point. Air is generally blown into the mixture. After active composting, the finished product is usually stored in a pile for additional curing prior to distribution.

Composting is not a sterilization process. Under some conditions, explosive re-growth of pathogenic microorganisms is possible. Dust and airborne particles from a composting operation may affect air quality.

The length of time biosolids are composted at a specific temperature is important in determining the eventual use of the compost end product. *Standards for the Use and Disposal of Sewage Sludge* (40 CFR Part 503) defines time and temperature requirements for both Class A and Class B biosolids products. Class A biosolids resulting from the use of aerated static pile or in-vessel methods require three days of processing at 55°C (131°F). Class A biosolids resulting from the use of Windrow method is at least 15 days at 55°C (131°F) and with five turns. For Class B regulatory requirements are five days at 40°C (104°F) or higher with at least four hours with temperature exceeding 55°C (131°F). Most compost products are Class A or Exceptional Quality biosolids. Class A biosolids can be used in home gardens with public contact and no site restrictions.

There are currently several biosolids composting operations in California with the majority of them located in Southern California.[36] In California, horticultural use typically involves biosolids that have been composted with various types of green waste.[37]

Composting could be a good alternative to direct land application of biosolids as it becomes more difficult and costly to find farm sites on which to apply the biosolids. In addition, compost can be safely stored for later applications and it is easier to transport, because it has lower moisture content in comparison with sludge.[38]

Biosolids could also be incorporated into surface materials at mining reclamation sites, gravel pits, and other severely disturbed lands. However, application of biosolids for land reclamation is infrequent in California.[39]

3. Controversial Issues Associated with the Land Application of Biosolids

a. Public Concerns about Public Health Effects from Biosolids Use

Some groups, including researchers, are concerned that pollutants contained in biosolids applied to land could contaminate the environment and compromise their health. One concern is that the land application of biosolids could contaminate the ground and also water through leaching from biosolids into water sources and groundwater.

Humans could be contaminated by direct ingestion or adsorption of biosolids; by inhalation of biosolids-derived aerosols or dust; or through the consumption of crops produced in soils amended by biosolids or food chains. Animals can be affected by ingesting crops and vegetation grown in soils amended with biosolids. Health problems could also arise if animals and humans drink from water sources that have become contaminated due to their proximity to land using biosolids.

Horticultural operations may use biosolids to grow turfgrass, cut flowers, and landscape plants for gardens. The health effects associated with these activities are similar to those related to the agricultural use of biosolids as a fertilizer. The principal routes of human exposure to contamination from horticultural operations are through direct contact and inhalation of aerosols.

Public health concerns may be validated by a variety of anecdotal reports and studies.[*] Some studies confirm the link between biosolids and adverse health effects, or at least raise questions on the subject. Below is a discussion of these concerns.

[*] There are several allegations of deaths caused by exposure to biosolids and also anecdotal reports of acute and chronic illnesses, including headaches, respiratory problems, and gastrointestinal illnesses; however, these allegations are not always well substantiated. For example, in October 2003, CBS News reported a story on a Pennsylvania teenager who died from a staph infection and the potential health risks of Staphylococcus aureus (S. aureus) in Class B biosolids. S. aureus is a commonly found strain of staph that resides in the human nose, skin, and gastro-intestinal tract and is present in raw sewage. It can cause a variety of human illnesses, including skin and wound infections, food poisoning, septicemia, pneumonia, and toxic shock syndrome. The parents of the victim believed the teenager death resulted from exposure to neighboring farm fields amended with Class B biosolids. (Quoted in California State Water Resources Control Board. "Covering General Waste Discharge Requirements for Biosolids Land Application." (Chapter 5).

b. Health Risks Due to Biosolids High Trace Metals Content

Biosolids could contain high levels of trace metals (chemical elements that are normally present in the environment in very low concentrations). Some trace metals in biosolids (such as copper, iron, manganese, molybdenum, and zinc) are nutrients for plants and animals; however, some of them are or could become toxic for plants in large amounts. There is research documenting plant accumulation at some biosolids utilization sites of cadmium (the most toxic heavy metal that is likely to accumulate in plants) and zinc.[40]

The level of toxicity due to excess amounts of trace metals varies with the type of soil and crops. Soils and plants have different sensitivities to trace element concentrations and different abilities to absorb them. For example, sandy soils with high acidity can make metals bio-available and leafy vegetables (such as lettuce and spinach) are particularly amenable to heavy metal absorption. In California, however, most soils have a high capacity to bind up additional heavy metals,[41] and research shows that soils must contain a significant amount of metals for plants to increase their metal content.[42]

Trace metals in biosolids could leach into water sources and groundwater. This is especially true in acidic soils or when the metals are exposed to an acidic leachate.

As humans absorb trace metals through the food chain, their health can be affected.[*] The excess ingestion of nutrients and trace metals can have detrimental effects on the health of grazing animals or wildlife. Nutritional deficiency or toxicity problems in animals can occur in many ways and could lead to low reproduction rates and even death.[43] Imbalances of copper and zinc can occur. In the case of some trace metals, such as molybdenum, there is little or no plant toxicity at elevated soil levels, but grazing animals can be adversely affected if plant forage has a high content of this element.

A variety of studies document neurological damage and endocrine system disruption from heavy metals contamination such as lead, cadmium, and mercury. The highest health risk for trace metals contamination is for children directly ingesting biosolids. However, there are no available studies that evaluate biosolids practices in California and their effects on animal and human intake of various trace metals.[44]

c. Health Risks Due to Biosolids High Nitrogen Content

As it is the case for nitrogen fertilizers, to avoid groundwater contamination and nutrient imbalances, the application of biosolids must balance the nitrogen needs for profitable crop production with the amount of irrigation, seasonal rainfall conditions, and the water retention characteristics of the soil.

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[*] Heavy metals are natural components of the Earth's crust. As an element, they cannot be degraded or destroyed. To a small extent they enter human bodies via food, drinking water, and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning.

High carbon-nitrogen ratios may generate nutrient-imbalance problems for plants, and high concentration of nitrogen in the soil could transfer to groundwater. Water quality can be contaminated through runoff from treated lands and deep percolation of excess irrigation water or precipitation. Shallow wells are extremely susceptible to contamination. Areas that do not receive a large amount of fresh water recharge also may act as "sinks," and become more susceptible to accumulate nitrates.[45]

The level of nitrogen contamination depends on the type of crop planted in the field. The crop types most likely to increase nitrate leaching are: 1) those that need heavy nitrogen fertilization together with frequent irrigation; 2) have high economic value, so that the cost of fertilizer is relatively small compared to revenue produced; 3) are not harmed by excess nitrogen; and, 4) take up only a small fraction of the nitrogen applied. Many vegetable, fruit, nut, and nursery crops fit these criteria, and therefore have high potential for nitrate leaching. Crops with lower potential include field crops such as alfalfa, wheat, and sugar beets.[46]

Excess levels of nitrogen in the water may have adverse effects on the environment and public health through nitrate contamination of groundwater used for domestic consumption. Nitrogen may be present as organic nitrogen, ammonium, nitrate, and nitrite ions. Nitrates are relatively nontoxic to humans when ingested with water or food, unless they are converted to nitrite, which can enter the bloodstream and bind with hemoglobin to form methemoglobin, reducing the blood's oxygen-carrying capacity.[47] Another concern is the possibility of nitrate reactions creating N-nitroso compounds that are carcinogens. Extensive epidemiological studies, however, have not yielded a causal association between chronic nitrate exposure and an increased risk of cancer.[48]

According to the Environmental Impact Assessment conducted by the State Water Resources Control Board, no health-related problems related to nitrates in biosolids were found during the literature review or discussions with health officials in California.[49]

d. Health Risks Due to Biosolids Synthetic Organic Compounds Content

Water can be contaminated by numerous organic compounds in biosolids coming from diverse sources such as organic wastes (fecal matter) and products used at home (for example, pharmaceuticals and personal care products) that end up in the waste stream. Some of these compounds are destroyed during the treatment process, but many are found in the discharge resulting from the waste treatment.[50] Although most organic compounds originating from biosolids application degrade in the soil or are absorbed in the surface layer, a primary concern is that they could migrate to drinking water sources. Humans can ingest these compounds by eating crops coated with dust from biosolids sources. Animals could ingest these pollutants by grazing on contaminated land.

Nonvolatile or semivolatile organic compounds are the biggest problem, since volatile compounds are either lost or biodegrade during biosolids treatment or the incorporation of biosolids into the soil.* [51] Nonvolatile or semivolatile organic compounds contained in biosolids include plastic-like compounds (phthalates), pesticides, phenols, detergent additives, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and the group of chlorinated dibenzo-para-dioxin and chlorinated dibenzo-furan compounds.[52] Dioxins, PCBs, furans, hexachlorobenzene, and pentachlorophenol are endocrine disruptors (pollutants reported to have reproductive and endocrine-disrupting effects).[53]

Some of the synthetic organic compounds found in biosolids are known to cause some illnesses, including cancer and birth defects. Endocrine disruptors are linked to the acceleration of breast cancer cell growth at chemical concentrations of parts per trillion, levels at which most chemicals have never been tested.[54]

There is controversy regarding the human health risks posed by dioxins in biosolids. Dioxins are a group of highly toxic persistent compounds formed by the burning of chlorine-based chemical compounds or in other processes such as the bleaching of paper or in the manufacture of chlorinated phenols. Effects of exposure to large amounts of dioxin include chloracne, skin rashes, skin discoloration, excessive body hair, and possibly mild liver damage.[55] A common health effect in people exposed to large amounts of dioxin is chloracne. Chloracne is a severe skin disease with acne-like lesions that occur mainly on the face and upper body.[56] Some studies suggest that long-term exposure to dioxins is related to increased risk of cancer in adults and animals. Dioxins bioaccumulate in fish and other wildlife.

There are few studies on synthetic organic compound accumulation in biosolids and the actual effects on health of these compounds in biosolids are still an area of controversy. Some organic compounds have been demonstrated to be very toxic and may cause cancer and other cardiovascular, immunological, and neurological disorders. However, research has not been able to prove the risk of organic compounds accumulating in the soil or water or plant absorption due to biosolids.[57] Furthermore, in contrast to the large amount of detailed information available on trace elements, little is known about soil accumulation, plant uptake, and concentration mechanisms of synthetic compounds.

Several studies suggest that workers exposed to high levels of dioxins at their workplace over many years have an increased risk of cancer. Animal studies have also shown an increased risk of cancer from long-term exposure to dioxins.[58] However, the U.S. EPA in 2003 made a final decision not to regulate dioxins in land-applied sewage, based on a five-year study that looked at the health risks of dioxins in biosolids. This study determined that dioxins from biosolids do not pose a significant risk to human health or the environment and that the risk for those that apply biosolids on their land and then consume the produce was very low. The risk for the general population was even lower.

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* An organic compound is any member of a large class of chemical compounds whose molecules contain carbon and hydrogen. Volatile and semivolatile organic compounds have somewhat different vapor pressures. Essentially, a volatile pollutant is an organic compound that converts into a gas or vapor state quickly at ambient (natural outside environment) temperatures, and a semivolatile pollutant is an organic compound that converts into gas or vapor slowly.

In addition, the 2001 National Sewage Sludge Survey found that the presence of dioxins in biosolids is insignificant.[59]

EPA regulations (Part 503) do not establish standards for synthetic organic compounds contents, but in California, state regulations require testing of biosolids for PCBs and semivolatile organic compounds. EPA did not establish standards because it estimated that: 1) most of these pollutants are either banned from being used, have restrictions on use, or are not manufactured in the United States; 2) the pollutants were detected in less than five percent of the sludge tested for the 1990 National Sewage Sludge Survey (NSSS); or, 3) the cancer risk was very low.[60]

Critics feel that there is insufficient testing for synthetic organic compounds by EPA regulations.[61] A 2002 study by the National Research Council conducted at the request of EPA supports public concern. This study criticized the EPA's decision of excluding chemicals from regulatory consideration based solely on whether or not those chemicals have been banned from manufacture in the United States (e.g., PCBs) since they are still found in sewage sludge from many wastewater treatment plants.[62] The study also recommended a more comprehensive and consistent survey of municipal wastewater treatment plants to prove that toxic organic compounds are present in biosolids at concentrations too low to pose a risk to human and animal health and to the environment.

Some analysts are also concerned on potential risks posed by new organic compounds such as pharmaceuticals that have emerged after the Rule 503 regulations were established (discussed in Section 4).

e. Health Risks Due to Biosolids Pathogens Content

Sludge contains a wide variety of pathogens excreted by both healthy and ill people that can persist in properly treated biosolids despite meeting regulatory standards. Pathogens are microorganisms such as bacterial, viral, protozoan, fungal, and worms classified as parasites (for example, helminth) that could affect human and animal health. Depending on environmental conditions, some pathogens (bacteria for example) can survive days; others may survive months (viruses) or years (helminth eggs). Primary concern is the transmission of acute diseases such as gastroenteritis or flu-like symptoms and some potential unknown diseases.[63]

After land applications, pathogens present in the biosolids can be deposited on plants, either directly from application operations or indirectly by vectors. Some traditional vectors are insects, flies, and rodents. Rats and mice are vectors for serious illnesses. For example, rodents may drink treated wastewater containing *Salmonella* from a local waterway, and the *Salmonella* could be transferred to chickens that incidentally eat rodent droppings, which then transfer the pathogen to humans when their eggs are consumed. Farm or biosolids workers who become ill could transmit the disease to their families.

Grazing animals can also be vectors.[64] A variety of articles raise uncertainty and questions about the persistence of pathogens and their potential impacts on grazing animal health.[65] Potential bacterial and viral pathogens carried by animals that could be contracted by humans include tuberculosis, salmonella, lysteria, campylobacter, rotovirus, and toxoplasmosis.[66]

Virus particles and small bacteria can be transported through the soil to groundwater. Potential transport of pathogens to local surface waters may occur through wash off into surface waters used for irrigation or stock watering. Coarse sands and other permeable soils are most conducive to pathogen transport to groundwater. The probability of water contamination increases as land application of biosolids takes place in sites close to wells, particularly shallow wells used for drinking water.[67]

There have been few rigorous epidemiological studies of biosolids utilization and many of the researchers who have studied health risks from exposure to biosolids have concentrated on wastewater-treatment plant workers, or workers at composting facilities, where the potential for exposure to pathogens is greatest. For example, the University of Arizona National Science Foundation's Water Quality Center reported in 2003 the results of the analysis of biosolids samples taken from 15 sites across the United States to test the presence of viable S. aureus. Samples included raw, untreated sewage, undigested primary sewage sludge samples, different biosolids samples, and aerosols obtained during the land application of biosolids. Samples were drawn from operating wastewater treatment facilities and agricultural lands amended with biosolids from southwestern and northeastern United States. The analysis found S. aureus in samples of raw (untreated) sewage and undigested primary sewage sludge. However, no S. aureus was found in any of the samples taken from the land application sites, including airborne samples.[68] This research took place after a study by researchers at Cornell's Waste Management Institute on numerous illness reports from people living near biosolids application sites. The authors recommend better tracking of incidents and information before concluding that biosolids may pose a serious risk. However, no testing was done of the sites that originated the complaints.[69]

Bioaerosols, very small and biologically active particles that are transported by air currents from the biosolids, could be a source of potential contamination. A national study conducted by the University of Arizona looked at the impact of biological aerosols on residents living near biosolids land application sites. The study concluded that risk of microbial infection for residents living near biosolids land was very low.[70]

Use of composted biosolids in bulk can pose a health risk. The high populations of many different species of molds and fungi in an active compost process can cause allergic reactions. However, the same effects can be found in gardeners working with composts that are not derived from biosolids.[71]

There have been reported cases of fungal allergies and possible outbreaks of asthma near composting operations that have generated large populations of *Aspergillus fungi,* which thrive in the environment created during composting.[72] Some individuals could be particularly sensitive to some of the organisms in compost. On the other hand, some studies of composting operations and at farms where biosolids have been used show no differences in the incidence of health problems from farms where no biosolids were applied.[73]

f. Health Risks from Potential Radioactive Materials Contained in Biosolids

There are also concerns about effects from radioactive materials that may enter the waste stream that is being treated at a water treatment plant, since in the U.S. there have been a small number of plants where elevated levels of man-made radioactive materials have been detected. Based on that experience, analysts raised the question whether radioactive materials could concentrate in sewage sludge and ash and pose a threat to the health and safety of workers or the public.

Publicly owned treatment work (POTW) workers most likely to receive direct exposure are workers that handle sewage sludge and ash, or work in areas of elevated indoor radon. Farmers and other members of the public who use sewage sludge products or ash from contaminated plants as fertilizer or soil conditioners could receive direct exposure to radiation, particularly gamma radiation, if these materials are present.* The exposure would be from the ground or from concentrations of biosolids in piles, or from contact radiation from dust particles on clothes or skin. Over the long run (50 to 100 years), the application of biosolids containing radioactive materials to fields may lead to impacts on the health of residents and agricultural workers from exposure to radon.[74]

At the request of Congress, the Sewage Sludge Subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS) have conducted studies analyzing samples of sewage sludge and ash to determine whether these concerns are valid and to estimate typical levels of radioactive materials in POTWs around the country.† ISCORS concluded in their final report "ISCORS Assessment of Radioactivity in Sewage Sludge: Recommendations on Management of Radioactive Materials in Sewage Sludge and Ash

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* The three most common types of energy given off by radioactive material are called alpha, beta, and gamma radiation. Alpha and beta radiation are emitted from both natural and man-made radioactive materials while gamma radiation comes almost entirely from man-made materials. Alpha particles have limited ability to penetrate. A single sheet of paper can stop them. Beta particles can penetrate human skin but usually can be stopped by a thin layer of plastic, wood or aluminum. The main hazard to humans from alpha and beta radiation comes from swallowing or breathing radioactive material. Gamma radiation is very penetrating and can pass through the human body and common construction materials. Thick and dense layers of concrete, steel, or lead are used to stop gamma radiation. Gamma emitters are dangerous to humans even when they are not breathed or swallowed. (From Biosolids Radiation Information Sheet, at http://www.biosolids.org/docs/nuclide.pdf.)

† The purpose of ISCORS is to foster early resolution and coordination of regulatory issues associated with radiation standards. Agencies represented on ISCORS include the U.S. Nuclear Regulatory Commission (NRC), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy, the U.S. Department of Defense, the U.S. Department of Transportation, the Occupational Safety and Health Administration of the U.S. Department of Labor, and the U.S. Department of Health and Human Services. The Office of Science and Technology Policy, the Office of Management and Budget, and state representatives may be observers at meetings.

at Publicly Owned Treatment Works,"[75] that: at most POTWs, radiation exposure to workers or to the general public, including from land application of sludge for growing food crops, is very low and, consequently, is not likely to be a concern.[76]

g. *Public Concerns about the Ability of Regulators to Protect the Public*

1) Concerns about How the Standards of Protection Are Determined

Analysts are concerned that the 503 regulations (discussed in Section 4) are inadequate to protect public health from unknown pollutants or unforeseen pollutants pathways not taken into account by regulators. For example:

1) Standards for Class A biosolids only include monitoring of four groups of pathogenic organisms: salmonella, fecal coliform, enteric viruses, and helminth ova.
2) Dioxins are not included in Part 503.
3) A variety of new compounds have not been evaluated.

Scientists have also questioned the accuracy of risk assessments performed by EPA and whether the EPA's assumptions regarding the appropriate level of risk are protective of public health. A great concern is the choice of risk factors used for the establishment of contaminant levels allowed in biosolids under the 503 regulations.[77] Some scientists state that there is no safety factor in the maximum contaminant levels set by Part 503 and that there is not an adequate system to monitor long-term cumulative contamination effects on soil.

Experts indicate that Part 503 used risk assessments that did not take into account synergistic or combined risks from simultaneous exposure to multiple constituents that may be present in biosolids. Biosolids are a mixture of organic and inorganic chemicals and biological agents. Risk-assessment procedures typically quantify risks from single chemicals and add them up to determine the level of risk when multiple chemicals are present. Strategies for considering risks from exposure to complex mixtures with interactive effects are still in development.[78]

Some are concerned that the Part 503 risk assessments on biosolids pollutant effects on public health are based on average conditions such as the quality of soil, type of crop, climate, biosolids content levels, use, and application practices. These factors vary greatly among and within U.S. regions, and the California experience can be quite different from the national norm.[79]

2) Concerns about Implementation and Enforcement

There are also questions on the extent to which the agents handling biosolids implement standards and recommended procedures established by the regulatory agencies, and on the ability of regulators to enforce them. A variety of anecdotal information on improper application of biosolids, inadequate public-access restrictions at Class-B application sites, and violations of the 30-day waiting period before allowing grazing on treated pastures have been reported.

An audit of the national biosolids program by EPA's Office of Inspector General was driven as a response to public raised questions on the implementation and enforcement of Part 503. Auditors felt that EPA cannot assure the public that "land application practices are protective of human health and the environment," and that EPA does not have an effective program for ensuring compliance with the land application requirements. The audit noted that there was a significant lack of oversight and resources committed to the program.[80] The biosolids programs need more resources to assure compliance with the regulations that protect the public and the environment.[81]

3) Regulators' Position

Advocates for land application of biosolids and regulators suggest that the public opposition to biosolids land application is due to misinformation and that there is "no solid scientific evidence" that public health has been threatened. They believe that the new technologies to remove pollutants from wastewater together with the existing regulations and guidelines for the use of reclaimed wastewater and biosolids are adequate to protect human health and the environment, and risks are negligible.

In 2002, however, the National Research Council reassessed 503 standards at the request of U.S. EPA. Their study emphasized the need for a revision of the standards to incorporate the latest scientific knowledge. The study concluded that to reassure the public and to protect human health, there is a critical need to update the scientific basis of the Part 503 rule to:

1) Ensure that the chemical and pathogen standards are supported by current and better scientific data and risk assessment methods;
2) Demonstrate effective enforcement of the Part 503 rule; and,
3) Validate the effectiveness of biosolids-management practices.

The Committee convened by the National Research Council to prepare the 2002 report also noted that EPA had not, at that point, addressed certain recommendations of a 1996 National Research Council report, which reviewed the practice of using wastewater and biosolids for agricultural purposes. Currently, EPA has outlined fourteen projects in response to the recommendations from this report. In December 2003 (Federal Register Notice 68 FR 75531) EPA published the results of its most recent biennial review (Biennial Review Cycle 2003), and identified fifteen pollutants that have health and environmental potential hazards. Among other additional projects are: 1) plans for conducting a survey on these and other pollutants; 2) plans for improving methods for detecting viruses in sewage sludge; and, 3) the development and application of analytical methods for detecting pharmaceutical and personal care products in sewage sludge.[82]

h. Other Concerns Related to the Land Use of Biosolids

1) Effects on Fish and Wildlife

Pollutants in biosolids may adversely affect the habitat and health of wildlife and endangered species. Fish, amphibians and other species can become contaminated as biosolids pollutants are transferred to ponds, groundwater, and other water sources, including wetlands and vernal pools. Small water bodies with no external drainage that are a habitat for protected fish species (such as pupfish) could be adversely affected. Toxics could leach and travel long distances (more than 1,000 feet) in sandy areas.[83]

2) Deterioration of the Quality of Life in the Communities Where Biosolids Are Used

A variety of effects from biosolids utilization reduce the quality of life of the localities where land application takes place.[84] These include:

- Odors. Biosolids odors are typically the primary cause of complaints from those living near land-spreading sites. The public describes these odors as "noxious," "horrible," "putrid," "nauseating," "eye-watering," and "sickening."
- Traffic Problems. Increased truck traffic on local roads and the danger of contamination from potential spills of the biosolids materials when they are being transported.
- Blowing dust from agitated farm lands during biosolids application.
- A perceived increase in the number of flies and mosquitoes attracted by the biosolids.

There are concerns about decreases in real estate values in the communities near land using biosolids due to these quality-of-life effects. Studies documenting this effect have not been found.*

3) Decrease in Farm Land Values

Farmers and the food industry have expressed their concerns that the agricultural use of sludge may affect the safety of food products and the sustainability of agricultural land, with the consequent economic and liability risks. They also worry that public perceptions on the potential adverse consequences of applying biosolids may decrease the value of their land and products.

Land application of biosolids with high concentrations of some nutrients, trace elements, and heavy metals could decrease soil productivity by reducing crop yields and affecting

* According to the Department of Environmental Protection, Commonwealth of Pennsylvania, although there are no studies documenting the allegation of lower real estate prices due to biosolids application, there are data indicating that successful land reclamation projects using biosolids recycling have raised land values at and around surface mine sites. (Department of Environmental Protection, Commonwealth of Pennsylvania Fact sheet, "Common Questions about Biosolids." At: http://164.156.71.80/VWRQ.asp?docid=0442d740780d000000000b5b00000b5b&context=2&backlink=WXOD.aspx%3ffs%3d0442d740780d0000800004220000422%26ft%3d1.

crop quality and appearance. For example, frequent applications of biosolids to certain soils and crops could lead to significant plant toxicity problems and/or nutrient imbalances. Long-term additions of biosolids with high carbon-nitrogen ratios or with lime-stabilized, low-bioavailable phosphorus could decrease land productivity. High levels of pollutants (undesired contaminants) contained in biosolids may affect plant nutrition by reducing the amount of useful organisms and microorganisms in the soil (for example, earthworms or bacteria). These microorganisms carry out the biochemical processes that facilitate the absorption of nutrients by plant roots.[85] High carbon-nitrogen ratios may decrease land productivity and generate nutrient imbalance problems for plants.

Changes in productivity and/or quality of land and products due to high pollutant content devalue land market values, as farms become more unsuitable for grazing or crop yields reduce. In addition, farmers using biosolids are also concerned with losing commodity markets and market value of their land as the public reacts adversely to the land application of biosolids. For example, their access to certain markets (such as organic produce and food processing markets) could become difficult, as consumers or wholesale produce buyers perceive that crops may be contaminated and have the potential to adversely affect public health. The reduction of farmers' ability to market their products also reduces the value of their land. This effect could be significant.[86]

II. BIOSOLIDS EXPORTED TO OTHER STATES

Exporting biosolids to other states is another alternative for biosolids management. According to annual reports from biosolids generators collected by U.S. EPA, Region IX, in 2003, 81,400 dry tons of biosolids were transported from California to Arizona and Nevada. This is a lower estimate than data from a California Association of Sanitation Agencies' (CASA) survey, which indicates that over 105,000 dry tons of biosolids produced by Southern California sanitation agencies were transported to and managed in both Nevada and Arizona in 2003.

Data from the Arizona Department of Environmental Quality reports even higher amounts of California biosolids exported out-of-state. In 2003, the Arizona Department of Environmental Quality estimates that approximately 105,860 dry tons of biosolids were delivered to Arizona sites. According to this Department, the amount of biosolids transported to Arizona from California (primarily from Southern California) has increased significantly. In 2001 about 1,014 dry tons of biosolids were transported, in 2002 this amount was 59,906 dry tons, while in 2003 approximately 105,860 dry tons of biosolids were delivered to Arizona sites. Of these 105,860 dry tons, the Department estimates that 70,675 were applied to land, 3,013 were composted, 32,172 were processed further and none was landfilled.[87]

Data from the Orange County Sanitation District (OCSD) indicates that the District has used biosolids on farming sites in San Bernardino, San Diego, Riverside, Kern and Kings Counties, and Tribal Lands of the Mohave Indian Reservation.[88]

However, the biosolids export option is fading away as public concerns about odor and environmental and health issues related to biosolids land application increase. For example, in Nye County, Nevada (where OCSD's vendor obtained a five-year permit to land-apply Class B biosolids in May 2003), complaints from affected neighbors resulted in cessation of operations in March 2004.[89]

III. Storage of Biosolids

Approximately six percent of the biosolids generated in California are stored temporarily in onsite facilities, such as lagoons. The biosolids are dried and further treated while in storage. Stored biosolids are finally disposed or reused using one or a combination of management options discussed in this section.[90]

Lagoons are a common type of storage structure for biosolids because this method is typically less expensive than other alternatives. For short-term storage of biosolids, smaller municipalities use steel and concrete tanks.[91]

IV. Transfers to Landfills and Disposal Surface Impoundments

1. Final Surface Disposal

According to California law, surface impoundment refers to waste management units such as natural topographic depressions, excavations or diked areas that are designed to contain liquid wastes or wastes containing free liquids. Surface impoundments do not include injection wells (California Code of Regulations [CCR], Title 27, Section 20164). Surface disposal methods account for four percent of the biosolids managed in California. These methods require large amounts of vacant land, which is lined with an impermeable material prior to the implementation of final disposal of biosolids. Since biosolids are applied for final disposal, applications can be frequent and more intense than they would be when biosolids are applied to agricultural lands.[92]

Surface disposal operations are individually permitted and monitored by the California Regional Water Quality Control Board. Surface disposal is used on a limited basis by several wastewater treatment agencies.[93]

2. Landfill Disposal

Biosolids can be disposed in permitted landfills, which are defined by California law as waste management units at which waste is discharged in or on land for disposal. Landfill disposal does not include surface impoundment, waste pile, land treatment unit, injection well, or soil amendments (CCR Title 27, Section 20164). Landfill disposal is not a widespread management option because beneficial uses of biosolids are preferred and landfill availability is limited. In 2000, approximately ten percent of the biosolids produced in California were buried in permitted landfills. Biosolids buried in landfills are simply treated as a solid waste. More than one third of the 161 landfills in California are permitted to accept biosolids for disposal, but only a portion of these landfills actually accept them.[94]

3. Alternative Daily Cover (ADC)

Alternative daily cover is material used to cover and contain landfilled materials at the end of each day and is a critical part of vector control at many landfill facilities. In 2000, approximately 13 percent of the biosolids produced in California was used for landfill cover.[95] California Integrated Waste Management Board (CIWMB) regulations allow the use of biosolids as a compacted alternative daily cover material provided that: 1) the biosolids meet the performance standards for cover material; 2) they do not exceed 25 percent of the total landfill cover material; and, 3) there is no public contact with the biosolids. As an alternative daily cover material, Class A and Class B biosolids may be used alone or blended with soil, processed green material, or stabilization agents (for example, lime, lime kiln dust, or cement kiln dust).[96]

Of the 161 active landfills in California, three routinely accept biosolids for use as ADC. As of 2004, only 15 of the state's landfills ever accepted biosolids as an alternative daily cover.[97]

A variety of factors explain the low proportion of landfills using biosolids as ADC. For example, some landfills are concerned about the effect on land and the environmental impacts from toxic substances contained in biosolids. The nature of the material makes it difficult to spread and compact over waste as cover, given the typical moisture content. The application of biosolids as ADC needs to follow strict landfill operational controls, including biosolids acceptance procedures, pre-acceptance testing, and scheduling. There are limits to the amount of biosolids that can reasonably be used within a specified period, so that biosolids do not stockpile in the facility. There are also limits to the amount of biosolids to be used depending on climate. Some landfills do not accept biosolids because of concerns regarding odor. Landfills located in residential areas are concerned with residents' reactions to biosolids application and on the potential adverse effects of traffic, dust, and odors of transporting the materials.

The distance to the source of ADC is important because landfills need a sustainable supply of ADC at a low cost. The size of the landfill is another factor. Smaller landfill areas prefer to use tarp and dirt since this practice does not use scarce space. Concerns about the effect of biosolids on worker health and safety are also a factor. However, certain landfill operators see biosolids as a desired waste stream if they can get a profitable fee.[98]

V. Incineration

Approximately three percent of the biosolids generated in California are incinerated.[99] Incineration involves the high temperature burning of biosolids using a fuel supply such as natural gas or diesel fuel. The resultant ash has a higher metal content because incineration concentrates the trace elements in the biosolids. Thus, the ash is generally landfilled.

Incinerators require significant capital investment and have high operating costs. As of 2004, there are three operating facilities statewide, each with a very limited capacity relative to the total amount of biosolids produced statewide. Because of existing and increasing air quality regulations, permitting of additional facilities is not considered likely and thus incineration is not considered a widespread management option.[100]

VI. Innovative Uses of Biosolids

1. As a Fertilizer of Energy-Dedicated Crops

There are some efforts to use biosolids to fertilize energy-dedicated crops as an indirect way to support renewable energy production. Recently, a Scottish sewage recycling company teamed up with farmers in a pilot project to produce biofuel from crops fertilized from Edinburgh's waste output. Terra Eco Systems, with a contract to dispose of Edinburgh's waste, will provide farmers with sewage sludge to be used as fertilizer for growing rapeseed, wheat, and barley that the company will then buy and process into biofuel. The company is looking initially for about 2,500 acres of land, which should produce about 1.3 million gallons of ethanol and biodiesel, enough to fuel about 5,000 cars for a year. Terra Eco Systems, working with Harlow Agricultural Merchants, would like to expand the biofuel project throughout Scotland and has asked Scottish Water, a state-owned company in Scotland that provides water and sewerage services, for access to more sewage waste.[101]

2. In Cement Industries

Using biosolids as a source of energy is being explored by the cement industry. Fossil fuel accounts for a significant share of the cost in this industry. Representatives of the cement industry are considering the use of biosolids as an alternative fuel that would allow them to decrease costs and assure a secondary fuel supply.*

Biosolids have been used for nitrogen oxides control in cement manufacturing where biosolids injection technology is being used. Mitsubishi Cement Corporation (located in Southern California) is using this technology with significant savings in costs, compared to alternative techniques.[102]

3. In Construction Materials

a. For Bricks

Research into the use of dried sludge as a component of brick manufacture is currently underway. For example, Melbourne Water, owned by the Province of Victoria, Australia, is participating in a pilot project by Re-Brick Pty. Ltd. (as part of the Australia's Smart Water Fund program) and three retail water businesses.[103] Melbourne

* In early November 2006, the Cement Industry Environmental Consortium (CIEC), the Air and Waste Management Association, and the Mohave Valley Air Quality Management District co-sponsored a conference on biosolids utilization in the cement industry. The purpose of the conference was to initiate dialogue between the cement industry and biosolids profession and share information on the potential for using biosolids as an alternative fuel source in cement kilns.

Water is also looking for other applications, such as using the biosolids as a material to pave roads.

b. For Glass and Other Materials

Through vitrification (a process of converting materials into a glass-like aggregate), the inorganic minerals in biosolids can be used beneficially in products that include glass aggregate (which can be used in lightweight concrete or as an industrial abrasive) and pozzolan, which can be used in sandblasting grit, abrasives, roofing shingle granules, and cement additive. Ash from oxidation or combustion can be used to manufacture cement. The next section discusses in more detail the vitrification process using the technology "GlassPack" developed by a company called Minergy. This technology has been implemented in Wisconsin and other places in the United States.[104]

c. As a Source of Energy

The energy in biosolids can be converted using pyrolysis and/or gasification technologies into three fuel products (char, bio-oil, and syngas), or biosolids can be completely combusted or oxidized to produce heat and power.* Char is a solid material that consists primarily of reduced carbon and hydrogen compounds that have heating value. Bio-oil consists of the reduced organic content of biosolids and some water. Synthesis gas or syngas consists of carbon monoxide and hydrogen gas that have heating value, and carbon dioxide which does not. Char, bio-oil, and syngas can be used at a biosolids processing facility to produce power and heat, or the fuel can be sold to consumers such as cement kiln operators. Thermally-dried, granular biosolids can also be used as fuel. The next section discusses the processes and state of the art technologies that can help the conversion of biosolids to energy.

* Pyrolysis is the conversion or cracking of biomass or biosolids at high temperatures in the absence of oxygen. Gasification is a process that converts the energy contained in biomass or biosolids into a combustible gas in an environment that has less oxygen content than the air.

SECTION 3. USE OF BIOSOLIDS AS A SOURCE OF ENERGY

Generally, biosolids processing by wastewater treatment plants include stabilization through conventional anaerobic digestion (a bacterial fermentation process) and dewatering (by using solar drying beds or mechanical dewatering using belt filter presses or centrifuges). Anerobic digestion produces biogas, a fuel gas.*

There are also various processes that can convert the energy contained in biosolids into fuels, heat, and power, while controlling odors and minimizing biosolids volume and amount of residuals. These processes can also produce inert inorganic minerals that can be used in cement kiln operations or as a component of construction materials. Below is a brief discussion of various processing technologies that generate energy and their application.

I. THE ANAEROBIC DIGESTION PROCESS

This bacterial fermentation process that is used for sludge degradation and stabilization operates without free oxygen and results in a fuel gas called biogas. Biogas consists of methane (typically in concentrations of 55 to 75 percent), carbon dioxide, and other gases.

Anaerobic digestion occurs over a wide temperature range from 50°F to 160°F. This process requires attention to the nutritional needs and the maintenance of appropriate temperatures for the bacteria to degrade the waste materials.† The biogas generated can be used after some refinement as a fuel and for the manufacturing of chemicals. Anaerobic digestion is also being explored as a route for direct conversion to hydrogen.

Biogas' high methane content makes it an excellent source of renewable energy to replace natural gas and other fossil fuels. Biogas is typically used in factory boilers and in engine generator sets to produce electricity and heat. Biogas can also fuel an internal combustion engine to produce electricity and the heat generated from the engine exhaust can be used for space heating, drying, and pre-heating process materials.

Many wastewater treatment plants (WWTPs) produce sufficient methane to justify converting it to heat or power. Biogas can be recovered from a wastewater treatment plant by the installation of an on-site digester. Using this fuel requires a nearby terminal for distributed generation or a combined heat and power plant. WWTPs are particularly

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* Anaerobic digestion is the biological degradation of organic material without oxygen present. Digestion bacteria have a temperature range in which they are most productive in terms of production rates, growth rates and substrate degradation performance. The several groups of bacteria involved in anaerobic digestion all have (slightly) different temperature optimums. This results in two main temperature ranges in which digestion usually can be performed optimally and most economically. These ranges are: 77°F to 100.4°F called the mesophilic range, and 122°F to 158°F called the thermophilic range.

† Bacteria give off methane gas as a by-product of their metabolism, and are common in sewage treatment plants and hot springs, where the temperature is high and oxygen is absent.

appealing hosts, because the heat they generate can be used to maintain the temperature of the digestion process.[105]

According to the federal government, 3,500 of the nation's 16,000 WWTPs already employ anaerobic digesters, but only two percent use digester methane to produce electricity. In California, use of biogas is still at a very early stage of development.*

WWTP methane is an untapped potential source of electricity. The total biogas resource from wastewater treatment in California is currently 16 billion cubic feet per year for a methane concentration of 60 percent, or 9.6 billion cubic feet per year methane equivalent. If biogas from wastewater treatment plants was converted to electricity, 578 Gigawatts per hour (GWh) of electricity could be generated.† This could power more than 80,000 homes.‡ Currently existing or planned electricity generation from biogas from wastewater treatment plants in California is 460 GWh.[106]

Some examples of power generation by wastewater treatment plants from sewage sludge are:

- The second largest wastewater treatment facility in the U.S., the Deer Island Treatment Plant (operated by the Massachusetts Water Resources Authority in Boston) recovers methane from its twelve three-million gallon digesters and uses it to fuel boilers. High-pressure steam from the boilers goes through an 18-megawatt-steam turbine generator. The turbine generates electricity while the low-pressure exiting steam is used in the plant heating.

- In California, at least ten WWTPs have grid connected power generation capability and provide a combined gross electrical capacity of 39 megawatts. The two largest, in Los Angeles County, provide a combined 24 megawatts of electricity derived from processing 770 million gallons of wastewater per day.[107]

- The Point Loma Wastewater Treatment Plant, in San Diego, uses sewage sludge as a source of energy. This facility fuels two continuously running generators that can produce up to 4.5 megawatts of electricity from methane. In addition, the plant operates new technology that allows a diesel-powered generator to burn

* Existing and near-term planned biomass grid generating capacity in California in 2005 was 969 megawatts of electricity, including solid-fueled combustion power plants and engines, boilers, and turbines operating on landfill gas, sewage digester gas, and biogas from animal manures. Source: California Energy Commission (CEC). Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development. PIER Collaborative Report. California Biomass Collaborative. CEC: Sacramento, June 2005. http://biomass.ucdavis.edu/pages/reports/CBC_BiomassInCA_v0605.pdf.

† A Gigawatt is equivalent to one billion watts. This estimate takes into account that not all biogas can or will be used for power generation.

‡ The state uses 283,000 GWh of electricity, and about 31 percent is used for residential consumption. Since there are 12,097,894 households in California, biogas from wastewater treatment plants could power about 80,000 homes. Based on California Energy Commission (CEC). Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development. PIER Collaborative Report. California Biomass Collaborative. CEC: Sacramento, June 2005.

methane and produce an additional 1.2 megawatts.[108] Using the methane produced on site, the plant has not only become energy self sufficient, but the facility is also able to sell excess power it generates to the local energy grid.

The use of sewage sludge as a generator of methane gas does not significantly reduce the volume of solid materials. However, the production method increases the digestion of pathogens that will generally make the residual solid a better candidate for land application.

Digested biosolids have a heating value of around 6,500 Btu[*] per pound of dry solids and undigested biosolids have a heating value of about 9,000 Btu per pound of dry solids. This value is lower than the heating value of kiln-dried wood (8,000 to 10,000 Btu per pound) and much lower than the heating value of high-quality coal (11,000 to 13,000 Btu per pound).

A variety of demonstration projects have used biosolids as a fuel for power plants. For example, a project funded by the Public Interest Energy Research Program of the California Energy Commission (PIER) focused on the feasibility of using biosolids to fuel Gas Turbine Combined Cycle (GTCC) power generation plants,[†] by converting compost made from sewage sludge to clean energetic gases. The project was important since most new power plants installed in California are GTCC plants. GTCC plants are more efficient than other technologies, but consume expensive natural gas and oil to produce electricity. The project showed the feasibility of using biosolids as a cheap fuel source for GTCC and existing steam power plants. No toxic materials were produced that would limit disposal of the residue in a landfill.[109]

The technologies discussed below can use the energy contained in digested biosolids. There are several demonstration plants operating in the U.S. and Europe applying these and other technologies.[110]

II. THERMAL DRYING

Thermal drying is usually used as the last stage in processing of solids at municipal WWTPs. Typically, dewatered solids (at approximately 18 to 35 percent dry solids content) are delivered to a thermal drying system, where most of the water is removed via evaporation. The resulting product are granules or a soil-like material containing approximately 90 to 96 percent solids that can be used either as fertilizers or as a fuel for generating heat and power.[111]

Most heat dryers can be classified into two main categories: direct and indirect. A third category that is less common uses heated soil that is mixed with the biosolids during the

[*] Btu or a British thermal unit is the amount of heat required to increase the temperature of a pint of water (which weighs exactly 16 ounces) by one degree Fahrenheit.
[†] In a GTCC plant, a gas turbine generator generates electricity and the waste heat from the gas turbine is used to make steam to generate additional electricity via a steam turbine.

drying process. Each of these alternatives requires several support systems to provide a complete and safe heat-drying system.

One advantage of thermal drying is that the process results in a significant reduction in both volume and mass of the biosolids. However, thermal drying systems consume substantial amounts of energy and, consequently, the cost of fuel is one of the largest operating costs for any thermal drying system (25 to 55 percent of the operating cost). The most common energy sources used by the process are natural gas, biogas from digesters, and fuel oil. If biogas from digesters or another waste heat source is available, there could be considerable savings in fuel costs.

The historical cost data for thermal drying facilities in the 20 to 100 dry ton per day size range are: 1) Equipment cost between $110,000 to $180,000 per dry ton; 2) Capital cost approximately $220,000 to $300,000 per dry ton; and, 3) Operating and maintenance costs of thermal drying systems range from $180 to $300 per dry ton of material processed.

Once energy generation is incorporated, costs may decrease significantly depending on the process and scale of operation.[112]

III. PYROLYSIS

Pyrolysis is the conversion or cracking of biomass or biosolids at high temperatures in the absence of oxygen. Pyrolysis usually produces synthesis gas or syngas (primarily carbon monoxide, hydrogen gas, carbon dioxide, and a small amount of hydrocarbons), char (common charcoal), and sometimes oil that have heating value.* The products depend on the temperature at which the process is conducted. This technology may require the use of natural gas or other fuel source if biogas is not available.

Pyrolysis technologies have not yet been widely used for biosolids management, largely because the technologies have not been proven on a large scale, costs have historically been considerably higher than land application options, and the process is complex and not well understood. However, with the increasing restrictions on land application and improvements in the technical development, there is growing interest in pyrolysis.

This process has the advantage of converting most of the organic waste stream so that only a very small portion of it would need to be landfilled. It also has a significant potential for energy production. However, it is difficult to verify operating cost estimates, emissions projections, and end product markets for these technologies because they have not been widely used commercially.

* Syngas consists primarily of carbon monoxide, carbon dioxide, and hydrogen, and has less than half the energy density of natural gas. Syngas is combustible and often used as a fuel source or as an intermediate for the production of other chemicals. Syngas is also used as an intermediate in producing synthetic petroleum for use as a fuel or lubricant via Fischer-Tropsch synthesis.

1. Low-Temperature Pyrolysis

Low-temperature pyrolysis takes place at temperatures below 600°F and produces char that has a heating value, an effluent stream from post-pyrolysis dewatering that is high in ammonia and organics, and air emissions that consist primarily of carbon dioxide with some volatile organic and other compounds.

There are two companies that have been promoting this technology in the U.S.: EnerTech and ThermoEnergy Corporation.

EnerTech Environmental, Inc. (EnerTech) technology converts biosolids into a fuel. The technology has passed the demonstration stage.

In May 2006, Orange County Sanitation District (OCSD) in California announced signing a long-term agreement with EnerTech to convert biosolids into renewable fuel (E-Fuel).* EnerTech is finalizing financing on their first commercial facility in Rialto, California that will have the capability of converting 675 wet tons per day of biosolids to renewable fuel. According to the Vice President of Biosolids Project (Mr. Raymond Kearney), the technological challenge has been to commercialize the technology since most WWTPs are reluctant to try new technologies unless they have been running successfully at a commercial scale for several years. Another challenge was raising capital to build a commercial facility.

During the pyrolysis reaction, the organics in the biosolids are broken down and carbon dioxide gas is separated from the solids. At the same time, this process removes chlorine before it can be converted into dioxin. The resulting product (char) has a heating value of around 9,000 Btu per dry pound when undigested biosolids are processed and of 6,500 Btu per pound of digested dry solids. E-Fuel has a heating value equivalent to a low-grade coal and EnerTech will be supplying its E-Fuel to a nearby cement plant (owned by Mitsubishi Cement) to augment the plant's power supply. EnerTech also plans to market its fuel to other interested facilities. EnerTech's process is a net producer of power, generating 1.25 to 1.5 times the energy required to operate the facility.[113] The ash from the E-Fuel will be used as a cement additive, resulting in zero solid waste. The Rialto facility is scheduled to begin operations in 2008.

The process does produce an effluent waste stream that is high in ammonia and organics. However, the facility in Rialto will include a membrane filtration process to treat the effluent prior to discharging the stream back to the Rialto WWTP. The vent air from the process will be returned to the process heater (which operates at a temperature of 1,800°F) to oxidize volatile organic compounds in the air stream. Tests conducted by General Electric show that the nitrogen oxides emissions from the char are similar to coal and that other emissions are lower, providing a cleaner burning fuel overall.[114]

* A renewable fuel captures their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, wave power, flowing water (hydropower), biological processes such as anaerobic digestion, and geothermal heat flow.

The average variable cost of the new facility will be about $85 per wet ton. The smallest operation that can still be economical is 300 wet tons per day. This compares to a range in cost from $90 to $120 per wet ton for the currently used technologies. Furthermore, the technology can dry biosolids using 50 to 60 percent less energy than conventional drying technologies.[115]

ThermoEnergy. This company is marketing a pyrolysis process called the Sludge-to-Oil Reactor System (STORS), which can be coupled with the company's Ammonia Recovery Process (ARP). The ThermoEnergy process is similar to the EnerTech process, although some of the equipment is different. This process produces char with heating value similar to the EnerTech product.[116]

The STORS/ARP process can produce oil that has heating value, or the resultant oil can be dewatered and dried to produce char. ThermoEnergy has developed an ammonia recovery process that uses a resin to absorb the ammonia. Recovered ammonium sulfate crystals are dried, bagged, and used as fertilizer. The char has about one-tenth the volume of the original dewatered sludge and has a heating value similar to medium-grade coal (between 5,000 and 10,000 Btu per pound). According to ThermoEnergy, the oil has 90 percent of the heating value of diesel fuel.

ThermoEnergy installed a demonstration facility at the Colton WWTP in southern California sponsored by the United States Environmental Protection Agency. According to the company, this $3 million project confirmed the ability of the STORS process to convert raw sewage sludge into a high-energy fuel (char) known as "biofuel." In turn, this biofuel can be converted into electricity on-site and sold to the local electricity power market.[117] According to ThermoEnergy, this system significantly reduces the cost of operating a wastewater treatment plant.[118]

2. Mid-Temperature Pyrolysis

Mid-temperature pyrolysis processes are conducted at temperatures of 800°F to 1,000°F, and typically produce oil and char. Environmental Solutions International Ltd. (ESI) commercially used this process in Australia.

ESI Enersludge had one full-scale biosolids processing facility located at the Subiaco WWTP in Perth, Australia. This plant treated undigested sludge and had a capacity of 25 dry tons per day.

The first step of the Enersludge process involves thermally drying the feed to 90 percent solids, rather than carrying out pyrolysis on slurried biosolids as in the case of the low-temperature processes described above. The biosolids are then passed into a conversion reactor where they are maintained at a temperature of 850°F for 30 minutes.

Four by-products are formed in this process: oil, reaction water (condensate from the vapor stream), syngas, and a solid char. When anaerobically digested biosolids are processed, the product yields are about 20 percent oil, 60 percent char, 10 percent syngas, and 10 percent reaction water.[119]

The oil stream, once separated from the condensate stream, can be used for heat and power generation. A 100-dry-ton-per-day plant would produce around 4,700 gallons of oil, or one tanker-truck load per day with a heating value of 130,000 Btu per gallon. The char and syngas are used for energy generation in a hot gas generator that is added to the process. The reaction water is also used in the hot gas generator. When heat available is converted to electricity via a steam turbine, it could produce about 700 kWh per ton. The ash produced from the combustion of the char and biogas can be sent to a landfill for disposal or can be used to manufacture products such as cement. Metals are bound in the ash in the form of non-leachable silicates and oxides and can therefore be classified as non-hazardous.[120]

The original process has been complex, since it includes thermal drying, pyrolysis, and incineration. There were also concerns about the quality of air emissions from the hot gas generator, which is essentially an incinerator, and the disposal of hazardous mercury sulfide scum, a by-product from the process.[121]

The plant operated for about 18 months. Following this demonstration period that ended in 2001, the Water Corporation, owners of the Subiaco WWTP took over the operation of the system. However, they reported that the system was taken out of service because it is more cost effective to use a lime-amended process and then applying the biosolids to land. In December 2004, ESI was sold to Tenix Alliance, who is currently seeking offers for the Enersludge technology. The technology was further developed in Germany to overcome some problems experienced in Subiaco, resulting in a new technology patent. The new patent is in a demonstration stage, since the improvements have not been tested at full-scale.[122] The system in Germany is generating a char product for re-use in brick manufacturing or as a phosphate fertilizer. Heat recovered from the conversion process meets about half the energy requirements of the process.[123]

The cost of processing biosolids using this technology depends on local cost factors. The improved system may cost less than currently used systems. Operating costs for a 101.6 dry tons per day plant are about $41 per dry ton, including the drying stage. Capital investment is estimated at about $9 million a 100-dry-ton-per-day module.[124]

3. High-Temperature Pyrolysis

High-temperature pyrolysis occurs in the absence of oxygen at temperatures similar to incineration. International Environmental Solutions (IES), a company in partnership with Neoteric Environmental Technologies, is developing a facility at Romoland, Riverside County, California that will be used as the basis for evaluating the technology.

International Environmental Solutions (IES). IES has patented a high-temperature pyrolysis system called Advanced Pyrolytic System (APS). This process has an operating temperature of 1,200°F to 1,800°F and was designed primarily as a waste-to-energy process using municipal solid waste. The system can be used to treat other wastes including tires, oil wastes, medical waste, and hazardous waste, and to reactivate carbon.

A 50-dry-ton-per-day unit has been installed and tested with biosolids and other wastes. The Romoland project has a number of units to treat different waste streams, with a capacity of 250 dry tons per day. The IES facility obtained an operating permit from the South Coast Air Quality Management District and is performing tests necessary to show that it meets environmental requirements. Testing includes a variety of waste streams including biosolids, MSW, fireworks, infested forest trees, and tires.[125] Future IES systems are expected to be larger and will provide electricity for off-site sale or use.[126]

Waste heat at the Romoland facility will be used to generate electricity for use on-site as well as to power a wastewater treatment facility constructed at the site. The process is expected to be a net producer of energy, with the excess power generation dependent on the types of waste being treated. At a capacity of 250 dry tons per day, IES claims that the facility will be able to generate a net of around five megawatts of excess power. In comparison, a facility designed to process an equal weight of municipal solid waste would generate 7.2 megawatts and would not require thermal drying.

The system uses thermal heat drying to achieve 90 percent solids. The vapor stream is separated from the solids and the hot vapor stream is sent to a waste heat boiler to recover heat that can be used for drying biosolids or generating electricity in a steam turbine. The process also produces char that has some heating value and can be used as a fuel source. It is estimated that 100 dry tons of biosolids will produce eight dry tons of char. Final emissions are primarily carbon dioxide. IES is developing a carbon dioxide removal system that will result in a zero-emissions process at the Romoland site.[127] The company did not pass test burns conducted in 2004 on sewage sludge and fireworks. IES declared tests using municipal solid waste conducted in 2005 a success, but analysis by the South Coast Air Quality Management District determined that test results for multiple metals were invalid. Currently, the company is waiting for approval of the latest tests on solid waste and it will continue testing for emissions from different waste streams such as biosolids and industrial waste. IES is also planning to open operations in Minnesota, Nevada, Connecticut, South Carolina, and Florida. The company in Romoland may start operations in 2008.[128]

IV. SUPERCRITICAL WATER OXIDATION (SCWO)

Supercritical Water Oxidation (SCWO) is a high-efficiency, thermal oxidation process capable of treating a wide variety of hazardous and non-hazardous wastes. This process is also known as wet oxidation or wet combustion. It involves oxidation of organics above supercritical pressure and temperature in a liquid state.* The terms supercritical

* The Critical Point of water occurs at 705 degrees Fahrenheit under pressure of 3,208 pounds per square inch (psia). At the Critical Point, the bubbling formation associated with boiling no longer occurs. Instead, with the addition of heat or increase in pressure the fluid experiences a continuous transition from water-like to steam-like characteristics. Pressure is said to be "supercritical" when the pressure exceeds 3,208 psia. Absolute pressure (psia) is the pressure measured above a perfect vacuum (14.7 at sea level). Absolute pressure is equal atmospheric pressure (psi) plus gauge pressure reading (psig). In other words, Psig is the pressure read from a gage, which reads the difference between the pressure in the pipe and the pressure of the atmosphere. A conventional supercritical unit operates at a steam pressure of 3,500 psi or

and ultra-supercritical are derived from the definition of the temperature and pressure at which water vapor and liquid water are indistinguishable—known as the critical point.

SCWO processes generally operate at temperatures in the range of 700°F to 1,000°F and pressures in the range of 3,200 to 4,000 psig (pounds per square inch gauge (gage) pressure reading).* Compressed air or oxygen is added to the pressure vessel to provide an oxidant. The degree of oxidation is dependent on the reaction time, temperature, and pressure.[129]

This technology is considered a new process and may be subject to continued testing. Overall economics may vary depending on the composition of the sludge to be processed, and whether the facility chooses to make use of the by-product energy or electricity production credits from steam generated at the facility.

SCWO systems can be configured as below-ground deep-well systems or above-ground pressure vessel systems. Both processes produce water, carbon dioxide, elemental nitrogen, and an inert, silty material that settles out of the liquid stream. The volume of solids is significantly reduced as the organics are destroyed in the process. Metals are bound in a non-leachable form. Air emissions are anticipated to be primarily carbon dioxide, oxygen, and nitrogen, with no nitrogen oxides, or volatile organic compounds, and minimal odor.[130]

One example of this type of technology is the **HydroProcessing, L.L.C.'s** hydroSolids process installed at Harlingen, Texas to process up to 9.8 dry tons per day of sludge. The system began operation in April 2001. The process can be a net producer of energy and HydroProcessing calculates that the energy captured by it is two to three times the total energy input from electricity, natural gas, and oxygen. The project in Harlingen Waterworks Systems is intended to generate income from the sale of energy in the form of hot water and from the use of carbon dioxide from the HydroSolids process for neutralization of high pH industrial effluent, as well as from the treatment of septage and grease trap wastes.[131] However, due to problems with the grit and trash in the sludge causing pumping problems, the facility shut down. HydroProcessing claims that the problems can be overcome with appropriate pretreatment of the feed solids.

At Harlingen, saleable by-products (steam energy and carbon dioxide) are produced and used by a neighboring textile facility with the carbon dioxide providing a neutralizing agent for any caustic effluent. In this case, the capital cost of the sludge processing facility was $8 million and the operating cost including maintenance, labor, and biosolids disposal is approximately $180 per dry ton, versus about $275 per dry ton for the cost of sludge disposal by land applications. Harlingen's waste heat recovery credit plus its carbon dioxide credit amounts to $120 per dry ton, which reduces the net operating costs to about $60 per dry ton.[132]

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higher and steam temperatures of 1,000°F to 1,050°F. By contrast, a subcritical unit operates below the critical pressure, typically 2,400 psi at similar temperatures.

* Gage, gauge is an instrument or standard of measuring or testing.

V. GASIFICATION

Biosolids drying requires thermal energy provided by conventional fuels such as natural gas, propane, or fuel oil. As an alternative, all of the thermal energy requirements can be satisfied by the conversion of the dried sludge into thermal energy, eliminating the need for and cost of, auxiliary fossil fuel. However, dried biosolids have not been used as a fuel source because when burned in a conventional fashion, biosolids form gas and contaminant emissions, requiring expensive air pollution control equipment. Through gasification, biosolids energy can be released and recovered, while air pollutants, particularly nitrogen oxides and oxides of sulfur, are reduced.

Gasification is a process that converts the energy contained in biomass or biosolids into a combustible gas in an environment that has less oxygen content than the air. The products from gasification are syngas (which usually has a fairly low heating value), tar, oil, and char that have a moderate heating value. The process dynamics and products vary considerably depending on the type of feed, operating temperatures, and pressure.

In addition to the surplus heat and power recovered by the process, the advantage of gasification is the ability to control air emissions at a higher standard compared to other processes. Also, because the products have energy value, the process can be used to recover surplus heat and power. Gasification systems processes have been used more widely with biomass such as wood waste and rice hulls that have higher heating values than biosolids. The experience of these systems with biosolids is limited. Gasification of biosolids has proven to be expensive and typically the economics of energy recovery are not favorable due to the low heating value content of the char and oils produced by this process.[133]

Primenergy, LLC. Primenergy, L.L.C. is a Tulsa, Oklahoma based company that has a proprietary method of biomass gasification. Primenergy has 25 operational biomass gasification facilities around the world. Although Primenergy lists dried biosolids as a feedstock material, they had only one commercial facility using biosolids operating in Philadelphia. The private company that purchased and operated the equipment is no longer in business and the equipment is currently shut down.[134]

The Primenergy process reduces the sludge feed to approximately one tenth of the weight of the input. According to Primenergy, the system is energy self-sufficient and generates dry ash (odor and pathogen free), which is returned to the host sludge plant to be blended with a compost product.[135] Ash contains significant amounts of nutrients (potash, phosphorous) that could possibly be used for land application. The gasifier can handle biosolids at nominal 6,800 Btu/lb containing up to 25 percent moisture content. When combined with a drying system, wet digested cake at 75 percent moisture content usually contains sufficient energy content (no excess energy) for the drying process. For example, wet cake is fed into the dryer, dried biosolids go into the gasifier, heat energy goes back to the dryer, and ash vacates from the gasifier.[136]

Average cost per dry ton is calculated at about $140. The operation has a modular configuration. A single "train" (module) is designed to dispose of ten wet tons per hour (2.5 dry tons per hour), or 25 dry tons per day. A system could consist of multiple trains. The installed cost for a single 960 dry ton per day system is approximately $10,000,000. For a stand-alone facility, operating costs (including maintenance and plant turnaround costs) are estimated to be $650,000 per year.[137]

VI. DEEP WELL INJECTION AND ENERGY RECOVERY

Deep-well injection and energy recovery involves pumping of liquid biosolids at solids concentrations of three to five percent solids and pressures of around 3,000 psig through wells into depleted oil fields at depths of 4,000 to 6,000 feet. Energy recovery from depleted wells is not a new process and has been conducted in southern California for over 50 years as a means of disposal of oil field brines, slurries, and other wastes.[138]

This process requires that injection wells be located adjacent to existing wastewater treatment plants so the dilute biosolids can be delivered by pumping instead of trucking, or dewatered biosolids could be hauled to a well site where water could be added to produce a slurry that can be injected.

The complete process involves injecting biosolids slurry into a deep unconsolidated sand formation, displacing oil and gas that remains in the formation, and potentially producing methane through further decomposition of the biosolids. The oil and gas can then be recovered from other recovery wells.

Terralog Technologies is a company that supplies services in the oil and gas markets and has been involved in deep-well energy recovery projects for disposal of oil-contaminated soils and drilling slurries. Terralog Technologies and the City of Los Angeles, working in coordination with the U.S. Environmental Protection Agency Region 9, will demonstrate the technology of biosolids injection through a five-year plan in Los Angeles County.[139] New wells for the project would be drilled to a depth of about 5,600 feet in an isolated fault block near the Wilmington Oil Field in Long Beach. Reservoirs are on the order of 125°F to 145°F. Extensive monitoring, sampling, and parallel laboratory research would be conducted to better quantify biodegradation rates, long-term carbon sequestration, and optimum injection parameters for enhanced methane generation.[140]

Injected biosolids are expected to continue degrading in the oil reservoir, and the carbon dioxide gas produced is expected to dissolve into water contained in the formation due to the high pressure in the formation, a form of carbon sequestration. The methane gas produced is less soluble, and it is anticipated that it could be extracted from gas recovery wells. The California EPA has been reviewing the process, and its key concerns have been with regard to the suitability of existing wells (as some older or lower-class wells may not be able to withstand the high pressures). Resistance to earthquakes must be engineered into the design.

The system is expected to cost $3 to $4 million to build, it will be implemented in phases, starting spring of 2008. When fully operational in three years, the system is expected to produce 3.5 megawatts of electricity a year worth about $2.4 million a year.[141]

VII. VITRIFICATION

Vitrification involves production of glass-like material from the inert, inorganic material in biosolids. Organic material is oxidized and removed during the process. The process can be used to produce materials used in construction, such as glass aggregate or bricks. In the United States, Minergy Corporation, a subsidiary of Wisconsin Energy Corporation, has one glass aggregate plant that processes biosolids. Vitrification has also been developed in Japan where land application of biosolids is less prevalent due to space constraints.

Minergy.[142] The company indicates that the technology is at the commercial stage. The Minergy vitrification process is based on the patented "GlassPack" system. It requires biosolids to be pre-dried to a minimum of more than 85 percent solids, which can be conducted using waste heat recovery from the vitrification process. The process can produce sufficient heat for the drying and vitrification process, as long as the heating value of the dried biosolids is 6,000 to 8,000 Btu per pound. The vitrification procedure uses oxygen-enriched air to reduce the volume of air emissions and is conducted at temperatures of 2,600°F to 2,900°F. The organics in the biosolids are combusted to provide the primary source of heat to melt the inorganic mineral fraction (ash). The melted solids are cooled to form an inert glass aggregate product, which is dark and angular. The glass can also be ground to form pozzolan, which can be used as an additive in cement.

The glass aggregate product can be used as raw material in a number of applications. The company states that the construction industry has a demand for aggregate of over one billion tons per year, for pavement and construction fill uses. Other markets include cement and tile manufacturers. Glass can be marketed at a value from $2 to $15 per ton, depending on the market.

The product yield is around 25 percent of the feed solids on a dry weight basis, so a 100 dry tons per day plant would provide 25 dry tons per day of glass product containing less than two percent moisture.

According to the company, their main challenge is to convince sanitary districts and their customers that this technology is quite different from traditional incineration. The first commercial GlassPack application on municipal sewage sludge is in the North Shore Sanitary District's new Sludge Recycling Facility in Zion, Illinois. Costs are size dependent and lower than thermal drying processes. A 35 dry ton per day unit costs about $38 per wet ton and 100 dry ton per day unit costs approximately $28 per wet ton.[143]

VIII. USE OF BIOSOLIDS AS FEEDSTOCK TO PRODUCE ETHANOL AND BIODIESEL

1. Ethanol

Ethanol (or ethyl alcohol) can be used as a fuel in internal combustion engines either alone (known as E-100) or when blended with another fuel, such as gasoline. In California, most of the gasoline currently sold for retail consumption contains 5.7 percent ethanol that is added as an air pollution-fighting additive. Ethanol is also marketed as a blended fuel as E-10 Unleaded (a blend of ten percent ethanol and 90 percent unleaded gasoline) and E-85 (85 percent ethanol and 15 percent unleaded gasoline).

Ethanol is produced via a fermentation and distillation process utilizing a feedstock (traditionally corn) that is high in sugar. Cellulose and hemicellulose are carbohydrates that can be broken down by enzymes, acids, or other compounds to simple sugars, and then fermented to produce ethanol. Biosolids are cellulosic materials that can be converted into sugar and thus, ethanol.* The cellulose content in biosolids ranges between 15 to 30 percent. Although this content is low compared to other types of biomass, biosolids can be used as feedstock to produce ethanol, particularly if integrated with other biomass materials. The conversion from cellulose to sugar can be accomplished via the following methods.

a. Hydrolysis Processes

The hydrolysis of biosolids is a chemical decomposition process in which water reacts with the cellulose to form a starch and, ultimately, a sugar (glucose). There are two specific hydrolytic processes to accomplish this conversion:

- **Chemical hydrolysis**. Chemical hydrolysis to a sugar is achieved by exposing the cellulose to an acid under high temperature and pressure conditions. The sugar is introduced into a fermenter, yeast is added, and ethyl alcohol and water is produced. A subsequent distillation process separates the water from the alcohol, thus producing ethanol.

- **Enzymatic hydrolysis.** The cellulose chains contained in biosolids can be broken into beta glucose molecules via a reaction caused by the addition of enzymes. This is the same process that is used in the stomach of animals, such as cows and sheep that subsist on a high cellulose diet. The fermentation and distillation processes that transform beta glucose into ethanol are similar to those utilized for sugars derived via chemical hydrolysis. According to the National Renewable Energy Laboratory, this process is the most promising for reducing the cost of

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* Biomass (or cellulosic materials) is defined as matter produced through photosynthesis. It includes plant materials; agricultural, industrial, and municipal wastes, and residues derived from there (such as switch grass, rice straw, sugar cane (bagasse), trees, paper waste, plastics, plant and tree clippings, and cardboard). Biomass contains three primary constituents: cellulose, hemicellulose, and lignin, and can contain other compounds (for example, extractives).

producing fuel ethanol and enabling biorefinery development. The success of this process depends on the development of effective enzymes at low costs.

In Orange County, New York, the Masada Corporation (Masada) is developing a facility to process municipal solid waste and sludge that will produce ethanol as one of its products. Masada plans to use municipal solid waste and sludge to produce ethanol, lignin (a chemical compound that can be burned for energy or used in several industrial processes), and gypsum using a concentrated acid hydrolysis technology. The major sources of operating income are tipping fees for sewage sludge disposal, tipping fees for municipal solid wastes (MSW) disposal, and the sale of ethanol and co-products. This first project is located in New York State, partially because of the state's large waste disposal problem (with high tipping fees), but Masada believes that a similar business model will work in California. The original design capacity for the facility is 800 tons per day of MSW and produces ten million gallons of ethanol. The total capital cost of the facility was approximately $287 million. The firm expects to begin accepting waste from Middletown and surrounding municipalities by early December of 2008. Facility construction was planned for early 2007.[144]

The Harris Group, the company's process engineers, is also studying the feasibility of initially constructing and operating a smaller facility. A smaller facility has the advantages of quicker construction and lower capital costs. A smaller facility can be constructed in other parts of the country and assembled in modules at the Middletown facility site. Additionally, a small facility could be expanded and enhanced, once the process is launched in a successful commercial setting, to increase the amount of MSW treated.[145]

b. Gasification Process

Instead of relying on a chemical or biological digestion of the cellulose chains to create a sugar, the gasification process converts the carbon in biosolids into carbon monoxide via a process that amounts to a partial combustion. The carbon monoxide is fed into a special fermenter that utilizes a microorganism to convert the carbon monoxide into ethyl alcohol.[146] Syngas platforms require a supply of uniform feedstock and reliable feed preparation, storage, and handling systems.* Commercial operators must have quality control procedures to ensure uniformity in biomass feedstocks and for long-term fuel supply contracts.

Bioengineering Resources, Inc. (BRI) has developed a syngas fermentation technology that can be used to produce ethanol from cellulosic wastes (including biosolids) with high yields and rates. The process of combined gasification/fermentation has been under development by BRI for several years. According to the National Renewable Energy Laboratory, the feasibility of the technology has been demonstrated and plans are under way to pilot the technology as a first step toward commercialization. All of the

* Syngas is primarily carbon monoxide, hydrogen gas and carbon dioxide and a small amount of hydrocarbons.

feedstock, except ash and metal, is converted to ethanol. BRI has developed bioreactor systems for fermentation with retention times that lower equipment costs.

The company has been producing ethanol for the past four years at their pilot plant in Fayetteville, Arkansas. The technology is at the point of commercialization and the first commercial plants are expected to begin construction in 2007. Biosolids can be processed since the gasification system only needs any blend of carbon-based materials with average moisture content below 40 percent (by weight). The BRI process will gasify any mixture of municipal solid wastes, biosolids, plastics, tires, animal wastes, paper or yard wastes, construction debris, hazardous wastes, crop residues, timber slash, etc., converting them into syngas, and then to ethanol.[147]

BRI's plants will be modular. BRI is designing a standard plant module that can handle any combination of feedstocks and can be put down anywhere in the world and by adding modules, their capacities can be readily expanded. Annually, a single module will process up to 100,000 tons of biomass and, depending upon the Btu content of the feedstock, will produce approximately six to eight million gallons of ethanol and generate five to six megawatts of power, approximately half of which could be available for sale into the grid. The amount of ethanol and electricity to be produced by any module can be varied according to energy demand.[148]

According to BRI representatives, BRI technology can produce ethanol from any organic wastes or hydrocarbons less expensively than traditional ethanol processes (for example sugar fermentation) and very competitively with gasoline, without state or federal subsidies. The gasification process can produce ethanol at about one-third of the current average retail cost of gasoline in California and can deliver electricity (green power) in the range of five to ten cents per kilowatt per hour (kWh).[149]

In addition to tipping fees from waste disposal, the process could generate revenue from a variety of by-products besides ethanol and electricity generation, such as steam, excess hydrogen, the production of ammonia for fertilizer, protein for animal feed (from the bioreactor purge), and ash for use in strengthening concrete or paving.[150]

Other benefits from this technology include a reduction of sewage treatment facilities' capital expenditures, since biosolids need only to be dewatered rather than digested or treated. The process could also reduce significantly the need for the trucking of biosolids if the modules are located at a wastewater treatment plant.[151]

Table 3: SUMMARY TABLE OF SELECTED TECHNOLOGIES FOR BIOSOLIDS PROCESSING					
TECHNOLOGY	**Type of Process**	**Use Biosolids Organic Materials and Nutrients**	**Use Energy in Biosolids**	**Use Inert Inorganic Materials in Biosolids**	**Marketable Products**
ANAEROBIC DIGESTION Sludge Degradation and Stabilization	Bacterial fermentation	Yes			Biosolids
THERMAL DRYING Dewatering of Biosolids	Heat	Yes	Yes		Biosolids Energy
PYROLYSIS	High heat and no oxygen				
EnerTech Low-Temperature Pyrolysis	<600°F		Yes	Yes	Chart, Heat, and Power
ThermoEnergy Low-Temperature. Pyrolysis (STORS)	<600°F		Yes	Yes	Chart Heat, Power, and Ammonia Fertilizer
ESI Enersludge Medium-Temperature. Pyrolysis	Range 800°F to 1,000°F		Yes	Yes	Bio-oil and Ash
IES High-Temperature Pyrolysis (Advanced Pyrolytic System)	1,200°F to 1,800°F		Yes	Yes	Heat, Power, and Ash
SUPERCRITICAL WATER OXIDATION	Oxidation of organics above supercritical pressure and temperature in liquid state				
HydroProcessing, LLC			Yes	Yes	Heat, Power and Ash
GASIFICATION	Heat converts energy in biosolids into syngas in an environment with less oxygen than the air				
Primenergy, LLC		Yes			Ash
Bioengineering Resources Inc.	Combined fermentation/ Gasification		Yes		Ethanol
VITRIFICATION	Produces glass like material from the inert material in biosolids. Organic material is oxidized and removed				
Minergy GlassPack			Yes	Yes	Glass Aggregate
HYDROLISIS	Can be acid or enzymatic				
Masada Group (Oxynol Facility)	Exposes the cellulose material to an acid under high temperature	Yes			Ethanol, Gypsum

2. Biodiesel

Biodiesel fuel can be made from thermal conversion processes (TCPs) using a broad range of feedstock, including biosolids. The thermal conversion process emulates the earth's natural geothermal process, whereby organic material is converted into fossil fuel under conditions of extreme heat and pressure over millions of years, by using pipes and controlling temperature and pressure. Three separate product streams are produced from the feedstocks: fuel gas, light organic liquid (oil), and a solid product (carbon or minerals). TCP produces no secondary hazardous waste stream.[152]

IX. Remarks on the Effects of Biosolids Management on Global Warming

The selection of biosolids processing technologies not only includes cost efficiency considerations, but also environmental effects, particularly, air pollutants and greenhouse emissions.

Greenhouse gases are gases that trap heat in the atmosphere and lead to "global warming." Some of them (such as carbon dioxide) are emitted to the atmosphere through both natural processes and human activities while others (e.g., fluorinated gases) are solely the result of human activities. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide, methane, nitrous oxide, and fluorinated gases.[153]

Carbon dioxide (CO_2) is produced by the burning of fossil fuels (oil, natural gas, and coal) and other materials and is also generated from chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") by plant absorption.

Methane (CH_4) emissions are generated during the production and transport of coal, natural gas, oil, and also result from livestock and other agricultural practices and from the decay of organic waste in landfills.

Nitrous Oxide (N_2O) is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

Fluorinated Gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as "high global warming potential gases."

Technologies used in biosolids processing must meet the federal and California Air Resource Board air emissions standards before starting operations. However, carbon dioxide and other greenhouse emissions considerations, not currently subject to emission standards, have become increasingly important as evidence of global warming is building up. In April 2007, the U.S. Supreme Court decided on a case brought about by twelve states including California and most major environmental organizations against the U.S. Environmental Protection Agency (Massachusetts versus EPA, 05-1120). EPA had denied a petition by a group of private organizations to begin regulating greenhouse emissions reasoning that: 1) the 1970 Clean Air Act does not authorize it to issue mandatory regulations to address global climate change; 2) a causal link between greenhouse gases and global warming was not unequivocally established; and, 3) that any EPA regulation of motor-vehicle emissions as a piecemeal approach to climate change would conflict with the President's comprehensive approach to support innovation, while increasing research on climate change. The Court concluded that the U.S. Environmental Protection Agency has authority under the 1970 Clean Air Act to limit vehicle emissions of carbon dioxide and other greenhouse gases and that the decision to regulate must be based entirely on scientific evidence of whether the emissions contribute to climate change that endangers the public health or welfare.[154]

In California, Governor Schwarzenegger signed Executive Order # S-3-05 on June 1, 2005 that established greenhouse gas targets and directed California state agencies to form a Climate Action Team to discuss strategies to meet those targets. The passage of Assembly Bill 32, Chapter 488, Statutes of 2006, "The California Global Warming Solutions Act of 2006" created a comprehensive, multi-year program to reduce greenhouse emissions in California. In this context, biosolids management strategies that have lower emissions of greenhouse gases have an advantage when considering various alternatives.[155]

All wastewater treatment and biosolids management processes release carbon dioxide gas.[156] If biosolids are landfilled, their bacterial decomposition produces significant quantities of "landfill gas." Unless landfill gas is recovered and utilized as a source of energy, it is a source of global warming. The methane emissions from landfills are particularly important, since methane is 21 times more potent as a greenhouse gas than carbon dioxide and since landfills represent the second largest source of anthropogenic methane emissions behind the energy industry. Methane currently causes one third of carbon dioxide's global warming production.

Biosolids incineration releases significant amounts of carbon dioxide. However, incineration processes have improved significantly. A study by Guibelin conducted in 2002 cites three cases where incineration can be combined with heat and power systems that recover energy. This practice will produce less carbon dioxide than will land spreading of biosolids.[157]

Several research articles show that the land application of biosolids compared to inorganic fertilizers can help reduce greenhouse gas emissions by sequestering carbon in soils and in crops, avoiding the use of fossil fuels needed for the production of inorganic fertilizer, avoiding the production of unused methane in landfills, and even more if applied in fields producing crops used for biofuel production.[158] On the other hand, the transport and application of biosolids also generates greenhouse gases, particularly carbon dioxide emissions.

A study published in the Journal of Industrial Econology compared the greenhouse effects of thermal drying versus lime-amendment technologies for biosolids treatment as implemented in wastewater plants in Sydney, Australia. The authors found: 1) Lime amendment generates more greenhouse emissions than drying the biosolids; 2) The drying option (45 percent better than the lime-amendment option in terms of greenhouse emissions) requires more energy in the processing but significantly less energy for transportation, which it makes it superior; and, 3) Selection of renewable energy sources such as biogas reduces carbon intensity and toxicity of emission by-products.*

Converting biosolids to fuel and using renewable energy generated from wastewater/biosolids treatment instead of nonrenewable fuels such as natural gas, reduces greenhouse effects by conserving energy. The Climate Action Team created to implement global warming emission reduction programs in California promotes the production and use of renewable energy as a way to meet greenhouse gas reductions.[159]

All conversion technologies that use biosolids as a source of energy help greenhouse emissions reductions. Most of these processes not only recover energy from biosolids but recycle steam heat. While processing technologies generate carbon dioxide and other global warming gases in the process, these emissions have to be compared with the amount of greenhouse gases that are not released by using renewables produced in the operation.

Processes that generate biogas can contribute to reduction of greenhouse gases and other harmful emissions by replacing fossil fuels. Methane, the main component of biogas, is itself a greenhouse gas with a much higher "greenhouse potential" than carbon dioxide. Converting methane to carbon dioxide through combustion is another contribution of biogas technology to the mitigation of global warming. However, methane leaking from biogas plants without being burned contributes to the greenhouse effect. Of course, burning biogas also releases carbon dioxide. But this, according to scientists, is similar to the sustainable use of firewood in that it returns carbon dioxide which has been assimilated from the atmosphere by growing plants in an earlier period. Hence, there appears to be no net increase of carbon dioxide in the atmosphere from biogas burning, as is the case when burning fossil fuels.[160]

This section has discussed gasification, supercritical water oxidation, pyrolysis, and other technologies that can process biosolids and use them as a source of energy. Compared to traditional methods of biosolids treatment, all these technologies have a less negative

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* Peters, Gregory M. and Sven Lundie. "Life-Cycle Assessment of Biosolids Processing Options." Journal of Industrial Ecology. Volume 5, N. 2, 2002. http://mitpress.mit.edu/JIE. The authors excluded from their calculation carbon dioxide and nitrous oxide emissions resulting from the microbial degradation of biosolids or the combustion of biogas resulting from the metabolizing of biosolids because these emissions complete a biological cycle that begins with the conversion of atmospheric carbon dioxide to biomass by photosynthesis in crops. Authors followed environmental life-cycle assessment method according to approach used by others. See U.S. EPA "Greenhouse Gas Emissions From Municipal Waste Management. EPA contract 68-W6-0029. Washington D.C. U.S. Environmental Protection Agency, Office of Solid Waste and Office of Policy, Planning, and Evaluation. 1997.

effect on greenhouse emissions. Although some of these processes result in carbon emissions, they also generate energy such as biogas, synthesis gas, and heat that can be converted to steam and power and, therefore, significantly reduce overall greenhouse emissions.

Furthermore, some of these processes have various mechanisms to reduce their carbon dioxide emissions.[161] International Environmental Solutions (IES), which uses a high-temperature pyrolysis process for biosolids treatment, is developing a carbon dioxide removal system. They expect to have zero-carbon dioxide emissions when processing biosolids at their Romoland site in California. Another example is the super critical water oxidation process used by HydroProcessing, where emissions contain 75 percent carbon dioxide. The company uses carbon dioxide as a sulfuric acid replacement for pH adjustment at an adjacent plant. HydroProcessing claims that the facility is a net producer of energy, stating that the energy captured is two to three times the total energy used from electricity, natural gas, and oxygen.

The use of deep-well injection and energy recovery technologies for biosolids treatment like the one used by Terralog Technologies in their demonstration project in Los Angeles is another process that has a variety of air quality advantages compared to traditional technologies and biosolids land application. These benefits are derived from reduced truck traffic and associated emissions; lower amounts of carbon dioxide and methane released to the atmosphere, and the potential recovery and beneficial use of generated methane as a clean fuel.

The merit of the various technologies to reduce greenhouse effects requires a detailed analysis of many factors including: the technology and configuration of the system; the amount of generation and/or recycling of energy during the process, the type of products and by-products resulting from the process, transportation distances and methods of biosolids transport; end uses of biosolids; and the standard of comparison one chooses (for example, land application versus alternative energy generation processes or one conversion technology versus the other). Such a comparison is beyond the scope of this paper.

X. PROGRAMS THAT PROVIDE SUPPORT FOR BIOSOLIDS ENERGY CONVERSION

1. Federal Policies Supporting the Conversion of Biosolids to Alternative Fuels

a. The Biomass Research and Development Act of 2000[162]

This Act calls for the development of a comprehensive national strategy to stimulate the development and use of bioenergy and bioproducts through research, development, and private sector incentives. The Act directed the departments of Energy and Agriculture to integrate their biomass research and development and established the Office of Biomass Programs (Department of Energy), the Biomass Research and Development Technical

Advisory Committee and the Biomass Research and Development Initiative (Department of Energy) to promote bioenergy and bioproduct research, development, demonstration, and deployment.* [163] The Biomass Research and Development Technical Advisory Committee (BTAC) advises the Secretary of Energy and the Secretary of Agriculture on strategic planning for biomass research and development.

The 2002 federal vision for 2030 was to double the biomass share of electricity and heat used by utilities and industry, increase transportation biofuels by 65 times, and expand the share of bioproducts by five times over current levels.[164] The term "biomass" means any organic matter that is available on a renewable or recurring basis (including dedicated energy crops and trees, agricultural food and feed crop residues, animal wastes and other waste materials). The term "biobased fuel" means any transportation fuel produced from biomass. A "biobased product" is any product produced from biomass.

Subtitle D, Section 941 of The Energy Policy Act of 2005 amended various sections of this Act (Sections 303 though 311) expanding the technical areas and research activities to include biobased fuels, biobased products, and practices and technologies for their production.[165]

b. Executive Order 13134

This order aimed at "developing and promoting biobased products and bioenergy" to further the development of a comprehensive national strategy that includes research, development and private sector incentives to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in national and international markets.[166]

c. The Renewable Energy Production Incentive (REPI)

REPI was part of an integrated strategy in the Energy Policy Act of 1992 to promote increases in the generation and utilization of electricity from renewable energy sources and to further the advances of renewable energy technologies. This program was authorized under Section 1212 of the Energy Policy Act of 1992, and renewed on August 8, 2005 under Title II Section 202 of the Energy Policy Act of 2005 (Pub. Law 109-58) and it is administered by the Department of Energy.[167] The REPI program provides financial incentive payments for electricity produced and sold by new qualifying renewable energy generation facilities. Eligible electric production facilities are those owned by state and local government entities. Qualifying facilities are eligible for annual incentive payments per kilowatt hour for the first ten-year period of their operation, subject to the availability of annual appropriations in each federal fiscal year of operation. Criteria for qualifying facilities and application procedures are contained in the rulemaking for this program.[168]

* "Biomass" includes those living and recently-living organic material that can be used for industrial production or for fuel. "Biosolids" are a subset of the term "biomass."

The 2005 Act included use of landfill gas for electricity production[169] and extended the eligibility period to October 1, 2016.[170] This means a facility generating electricity from landfill gas: 1) must be operational by October 1, 2016; and, 2) can receive payments for the first 10 years of operation, until 2026, if federal funds are available. Appropriations are extended for fiscal years 2006 through 2026 although no annual amount is set forth in the Act.[171] If appropriated funds are insufficient to make full payments, 60 percent of funds will be assigned to facilities that use solar, wind, ocean, geothermal, or closed-loop biomass technologies, and the remaining 40 percent will be assigned to other projects, including those that use landfill gas.[172]

d. The Energy Policy Act of 2005

The Energy Policy Act was signed into law on August 8, 2005. Among other things, this Act amends the Clean Air Act and introduces a series of measures intended to reduce petroleum dependency and encourage the development of renewable fuels markets. The Act intends to establish a comprehensive, long-range national energy policy, providing incentives for production of traditional energy sources and also for newer, more efficient energy technologies. The law also provides incentives for energy conservation. It contains many new research and development programs and also makes changes to current energy policy. Biomass definitions throughout sections in this Act vary, and biosolids are not always explicitly included in the biomass definition (one example is Section 203: Federal Purchase Requirements).

Important sections of this Act that provide incentives for biosolids use as an energy source are:

- Revised the credit for producing fuel from a nonconventional source.
- The Act creates Clean Renewable Energy Bonds. The owners of the bond receive federal tax credits instead of tax-free interest payments from the bond issuer.[173]
- Section 1701 of the Act authorizes loan guarantees for up to 80 percent of the cost of an eligible project. Eligible projects include projects that both reduce greenhouse gas emissions and employ significantly improved technologies. Projects include renewable energy systems.
- Title XV of the Act includes a variety of incentives for waste-derived ethanol, including from municipal waste and sludge. For example:
    - The Act includes incentives for the production of renewable fuel from these "non-traditional" sources, allowing greater credits for ethanol derived from cellulosic biomass or waste. Every gallon of cellulosic or waste derived ethanol counts as 2.5 gallons towards the renewable fuel program requirements.
    - Amends the Clean Air Act to provide grants to merchant producers of cellulosic biomass ethanol, waste-derived ethanol, and approved renewable fuels to assist with building of production facilities. It

authorizes $100 million in fiscal year 2006, $250 million in fiscal year 2007, and $400 million in fiscal year 2008 for these grants.

- Creates an Advanced Biofuels Technologies Program to be established by EPA in consultation with the Department of Energy (DOE) and the Biomass Research and Development Technical Advisory Committee. This program funds demonstrations of advanced technologies for the production of alternative transportation fuels including the development of no less than four different conversion technologies for producing cellulosic biomass ethanol and for developing no less than five technologies for co-producing value-added bioproducts. The program authorizes $550 million per year for fiscal years 2005 through 2009.
- Section 941 amends and updates wording in the Biomass Research and Development Act of 2000. One important amendment introduces four new technical areas for research and development activities: 1) develop crops and systems that improve feedstock production and processing; 2) convert recalcitrant cellulosic biomass into intermediates that can be used to produce biobased fuels and products; 3) develop technologies that yield a wide range of biobased products that increase the feasibility of fuel production in a biorefinery; and, 4) analyze biomass technologies for their impact on sustainability and environmental quality, security, and rural economic development.[174]

e. American Jobs Creation Act of 2004

The Act contains two provisions that provide tax exemptions for three renewable fuels: ethanol, biodiesel, and wind energy. This bill provides, for the first time, a federal biodiesel tax incentive (a tax credit of $1.00 per gallon of agri-biodiesel) that is used in blending with petroleum diesel, and a 50-cent credit for every gallon of non-agri-biodiesel (recycled oils).[175] This bill established the Volumetric Ethanol Excise Tax Credit (VEETC) extending the ethanol tax incentive of 51 cents a gallon until 2010 and basically replacing the excise tax exemption with an equivalent immediate tax credit.*

Although a number of incentives have been established, few at the state level are targeted specifically at biomass and there is no specific policy identifying the need for increased and improved utilization or to comprehensively address biomass as a resource.

* The primary mechanism of the federal ethanol incentive is a reduction in the federal excise tax collected on sales of gasoline when gasoline is blended with ethanol. This incentive was originally authorized through 2007, but decreased from 52 cents for each gallon of ethanol to 51 cents starting in 2005.

2. State Policies Supporting the Use of Biosolids as a Source of Energy

Below is a description of available state programs that provide incentives and financing for the conversion of biomass (including biosolids) to energy that could be utilized by biosolids-to-energy processors.*

a. Renewable Portfolio Standard

Established by California Senate Bill 1078 (Sher), Chapter 516, Statutes of 2002, the law mandates 20 percent of retail electricity sales to come from renewable resources by the year 2017. California's current energy policy accelerates the RPS target to 20 percent renewables by 2010 and the Governor expanded the goal to achieve 33 percent by 2020. As of June 30, 2006, the Energy Commission has certified 503 facilities as eligible for the RPS, representing 8,170 megawatts (MW).[176] Eligible renewable resources include biomass, solar thermal, photovoltaics, wind, geothermal, fuel cells using renewable fuels, small hydropower of 30 megawatts or less, digester gas, landfill gas, ocean wave, ocean thermal, and tidal current. Municipal solid waste is generally eligible only if it is converted to a clean-burning fuel using a noncombustion thermal process. Electricity produced from biosolids can qualify for the RPS. Although the RPS stimulates renewable energy development, it does not guarantee an increasing use of biomass in competition with other renewables, such as wind and geothermal.[177]

b. The Renewable Energy Program

Assembly Bill (AB) 1890 (Brulte), Chapter 854, Statutes of 1996, and Senate Bill (SB) 90 (Sher), Chapter 905, Statutes of 1997, the California Legislature directed that a portion of the funds collected from the ratepayers of the three major investor-owned utilities (San Diego Gas & Electric, Southern California Edison, and Pacific Gas & Electric Company) be used for statewide public benefit programs. As one of these important public purpose programs, the Renewable Energy Program (REP) began in 1998, with the goal of fostering the growth of renewable energy generation in California. SB 90 created the Renewable Resources Trust Fund (RRTF) as a depository for funds collected under AB 1890 and authorized the Renewable Energy Program to distribute the funds consistent with the Energy Commission's 1997 renewable energy investment plan. The REP continued through 2002, providing financial incentives to support existing, new, and emerging renewable resources in a market environment. Projects administered under the REP include energy generation from biomass and solar thermal, wind, geothermal, small

* However, personal communications with representatives of conversion technologies used to process biosolids indicate that their main problem to start operations is not that much financing as it is the permitting process to build a plant and start operations. According to the industry, the existing regulations and lack of understanding of these technologies make the building of these plants a very long and expensive process.

hydro, digester gas, landfill gas, and municipal solid waste.* Electricity produced from biosolids can qualify under this program.[178]

With the passage of SB 1038 (Sher), Chapter 515, Statutes of 2002, the Renewable Energy Program was reauthorized through 2006. Although the program basically remained the same, it redefined its goals to encourage the renewable energy projects that would allow meeting the state's renewable portfolio standards (RPS).† The enactment of SB 1250 (Perata), Chapter 512, Statutes of 2006, provided new authority to use funds collected over the following five years to support the Renewable Energy Program.[179]

Two important elements of the Renewable Energy Program are the Existing Renewable Facilities Program and the New Renewable Facilities Program.

1) Existing Renewable Facilities Program (ERFP)

The ERFP pays production incentives to eligible biomass, solar thermal, and wind energy facilities to help them while they move to a competitive market position. This program supports the development and maintenance of existing renewable energy projects (that is, renewable projects that have already been constructed). This account uses a production credit mechanism based on the kilowatt hours generated by a project. From January 1998 through December 2005, payments totaling about $225.5 million have been made to existing facilities for generation.

To qualify for the Existing Renewable Resources Account, only solid fuel biomass combusted at an existing facility could produce electricity that is eligible for funding. Consequently, electricity produced from digester gas does not qualify for funding from the Existing Renewable Resources Account. If biosolids are combusted at an existing facility, then the electric generator could apply for funding from the Existing Renewable Resources Account for the electricity it produces. Although some biomass facilities have received funding from the Existing Renewable Resources Account, there are no facilities that use biosolids derived fuels.[180]

2) New Renewables Facilities Program

This program consists of two components. Under the first, production incentives provide support to potential new renewable energy projects that generate electricity. Once they come on line, the new facilities receive payments for the first five years of generation. Secondly, under the RPS, the New Renewable Facilities Program will provide supplemental energy payments (SEP) for up to ten years to eligible projects for the above-market costs of meeting RPS requirements. Since its inception in June 1998, this

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* Biomass as defined in the Overall Program Guidebook (March 2007, CEC-300-2007-003-CMF) includes "any organic material not derived from fossil fuels, including agricultural crops, agricultural wastes and residues, waste pallets, crates, dunnage, manufacturing, construction wood wastes, landscape and right-of-way tree trimmings, mill residues that result from milling lumber, rangeland maintenance residues, sludge derived from organic matter, and wood and wood waste from timbering operations."

† California's move to a restructured electricity market and the resultant energy crisis prompted policy makers to pursue a new method to encourage the development of renewable power: the RPS.

program has paid a total of over $60 million in production incentives to 46 new renewable generating facilities for 6,244 gigawatt hours (GWh) of generation.[181]

To date, no projects using biosolids has been awarded funding or reviewed for funding from this program.[182]

3) Supplemental Energy Payments (SEPs)

This program provides production incentives to eligible renewable generators for the above-market costs of eligible procurement by California's three largest investor-owned utilities to fulfill their Renewable Portfolio Standard (RPS) obligations. SB 1038 and SB 1078 of 2002 established these payments with funding availability of approximately $70 million per year collected for five years from the Renewable Resources Trust Fund.

To qualify for funding, applicants must show that their proposed renewable facility meets a number of requirements, such as: 1) Facilities must be certified by the Energy Commission as an eligible renewable energy resource for purposes of meeting the state's RPS; 2) Facilities must begin commercial operations or be re-powered on or after January 1, 2002, or such later date as determined by the Energy Commission; 3) Facilities must not be owned by a retail seller or local, publicly-owned electric utility, and; 4) The electricity generated must not be sold under certain long-term contracts with an in-state retail seller, used on-site, or sold in a manner avoiding competitive transition charge payments.[183]

Applicants for eligible renewable facilities must compete for funding by participating in competitive RPS solicitations held by the largest investor-owned utilities.

Under the RPS program, renewable generators will be paid the full value of the "market price referent" (a proxy for the cost of a conventional new power plant) that is developed (up to their bid price) through contract payments made by the utilities. Thus, the deemed market price for a conventional energy source will be paid by the utility, and any above-market increment for the renewable project will be paid through a long-term SEP award.[184] As of June 30, 2006, the Energy Commission had not received any complete applications for SEPs. However, staff expected to receive at least two applications in the near future.[185]

c. The Public Interest Energy Research (PIER) Program

The California Energy Commission's Public Interest Energy Research (PIER) Program supports energy research, development and demonstration (RD&D) projects that will bring environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program annually awards up to $62 million to conduct the most promising public interest electricity research by partnering with RD&D organizations including individuals, businesses, utilities, and public or private research institutions. This program spent about $47 million in FY 2005-06, and more than $106 million in FY 2006-07.[186]

The Energy Innovations Small Grant (EISG) Program (AB 1890, 1996) is part of the California Energy Commission's PIER program. It provides up to $95,000 for hardware projects and $50,000 for modeling projects to small businesses, non-profits, individuals, and academic institutions to conduct research that establishes the feasibility of new, innovative energy concepts. Qualifying renewable energy sources include solar radiation, geothermal fluids, biomass, water, and wind. Technology applications include, but are not limited to: photovoltaic systems; solar thermal; wind turbines; hydropower; geothermal energy; and, biomass energy. The maximum term of each grant project is 12 months. About $3 to $3.5 million have been available annually. From FY 2001-02 through FY 2005-06 EISG has spent $15 million.[187]

The Energy Innovations Small Grant (EISG) Program does and has funded 17 projects using bio-solids processing technologies, such as the projects "Innovative Design of High Solids Digestion Plants for Economic and Renewable Energy Production," and "Energy Production from Bulk Wastewater Using Optimized Super-synthetic Bacteria."[188]

d. Low Interest Loans

Tax-exempt bond financing provides qualified borrowers with lower interest costs than are available through conventional financing mechanisms. The California State Treasurer's Office has bond-financing programs that could be available to renewable fuel producers. The California Pollution Control Financing Authority provides low-interest loans to small businesses from a minimum of $1 million up to $20 million for waste-to-energy, resource recovery, and landfill projects through the Small Business Assistance Fund's tax-exempt bond program. In FY 2005-06, eight small businesses benefited from this program totaling more than $68 million. The previous fiscal year five businesses received a comparable amount from bond issues, while in FY 2003-04, twelve small businesses participated in this program receiving a total of $53 million.[189]

In total, the California Pollution Control Financing Authority issued $236 million in bonds in the FY 2005-06, a lower amount than in FY 2003-04 when $506 million in bonds were issued, but an increase from the $178 million issued in FY 2004-05.

The California Integrated Waste Management Board manages the Recycling Market Development Zone (RMDZ) Loan Program. This program provides direct loans to private businesses that use recycled materials to manufacture new products or that undertake manufacturing projects that result in waste reduction in designated zones. Some composting projects have been financed under this program and some ventures converting biosolids to construction materials or other transformations that reduce landfill waste could qualify for these loans under certain conditions.[190]

As of July 2006, $18 million was available. The maximum loan amount is $2 million. According to the program's supervisor "the first loans were funded in the second half of

FY 2003-04 and in subsequent years the total loans made have varied from a low of $2.2 million (two loans) to a high of $11.5 million (18 loans). In FY 2005-06, 11 loans were funded for a total of $11.2 million. Five years ago (FY 2001-02) eight loans were made for $4.8 million."[191]

e. California's Participation in the Western Governor's Association's Energy Efficiency and Renewable Energy Generation Strategy

The Western Governors' Association is an independent organization of Governors representing 18 Western states, and three Pacific islands territories or commonwealths (Guam, American Samoa, and Northern Mariana Islands). Through this Association, Governors identify and address key policy and governance issues in natural resources, the environment, human services, economic development, international relations, and public management. The Association helps the Governors develop short term and long-term strategies for these issues and to develop and advocate policies that reflect regional interests.

There is broad agreement among Western Governors on the need to utilize regional resources to produce affordable, sustainable, and environmentally responsible energy, and decrease reliance on foreign energy sources. Under the leadership of Governors Bill Richardson (New Mexico), Arnold Schwarzenegger (California), Dave Freudenthal (Wyoming) and John Hoeven (North Dakota), Governors created the Clean and Diversified Energy Advisory Committee (CDEAC) in 2004 to develop recommendations for a future energy strategy for the West. The Governors passed a resolution at their 2006 Annual Meeting based on the CDEAC's report, which identified the necessary policy actions to achieve an additional 30,000 megawatts of clean and diverse energy by 2015; a 20 percent increase in energy efficiency by 2020; and, a plan for safely and reliably meeting transmission needs over the next 25 years.[192]

Policies recommended by the CDEAC include the implementation of long-term programs in support of biomass, such as long-term power purchase contracts, fuel supply incentives, tax credits, and other measures that would help provide the investment environment needed for infrastructure growth. The implementation of this type of policies would benefit ventures using biosolids as a source of energy since biosolids are a type of biomass.

SECTION 4. THE REGULATION OF BIOSOLIDS

Federal, state, and local regulations control the use and disposal of biosolids. The U.S. Environmental Protection Agency (EPA) has encouraged the proper use and management of biosolids for many years by promulgating federal regulations that are implemented by state and local governments. In California, the state and local governments have additional ordinances and criteria for biosolids management.[193]

I. FEDERAL REGULATIONS

Several federal laws directly or indirectly encourage biosolids recycling and regulate various aspects of biosolids disposal, including the following:

1. The Marine Protection, Research and Sanctuaries Act (MPRSA)

Enacted in 1972, the Act declared that the policy of the United States is to regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities. MPRSA is sometimes referred to as the Ocean Dumping Act (ODA), after an amendment enacted in 1988. This amendment banned ocean dumping of industrial waste and sewage sludge.

2. The Federal Water Pollution Control Act Amendments of 1972

Concerns for controlling water pollution led to enactment of this Act. This law became known as the Clean Water Act after being amended in 1977. The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by nonpoint source pollution (pollution coming from diffuse sources such as rainfall or snowmelt). The 1977 amendments required the promulgation of the first regulations governing biosolids management practices. These regulations established standards for cadmium, PCBs, and pathogens in biosolids applied to land and established general management standards for solid waste landfills. These provisions apply for biosolids not regulated by 40 CFR 503 (explained later in this section).*

3. The Resource Conservation and Recovery Act (RCRA)

Enacted in 1976, this act amended the Solid Waste Disposal Act. The Act established a system for managing non-hazardous and hazardous solid wastes in an environmentally sound manner. Specifically, it provides for the management of hazardous wastes from

* Note: 40 CFR refers to Code of Federal Regulations (CFR), Title 40.

the point of origin to the point of final disposal. RCRA also promotes resource recovery and waste minimization and regulates all solid waste as either hazardous or nonhazardous. Subtitle C regulates hazardous waste and Subtitle D is concerned with nonhazardous solid waste. Under the hazardous waste provisions of RCRA, municipal wastewater biosolids are neither excluded nor specifically listed as hazardous waste. However, biosolids from POTWs with highly industrialized areas may need to be evaluated for characteristics that designate hazardous waste. The test most appropriate for municipal biosolids is the toxicity characteristic leaching procedure (TCLP) that measures the leachability of persistent and bioaccumulative substances in an acidic environment. If the leachate derived from a TCLP test exceeds a regulatory threshold, the waste must be classified and managed as a hazardous waste.

In 1984, the Hazardous and Solid Waste Amendments (HSWA) expanded the scope of the RCRA Program. Regulations affecting biosolids are contained in 40 CFR Parts 261-268 and 271. HSWA initiatives were especially important in preventing or addressing hazardous waste/constituent releases.

Congress directed EPA to develop what is now known as the Land Disposal Restrictions (LDR) Program [Section 3004(d) of RCRA]. Under the LDR Program, the land disposal of untreated wastes is prohibited. This program's disposal prohibition establishes treatment standards, variances, and notification requirements. EPA must establish treatment standards for all listed and characteristic hazardous wastes destined for land disposal. Treatment standards are either concentration levels for hazardous constituents or treatment technologies that must be applied to the waste in order to substantially diminish the toxicity of wastes and/or reduce the likelihood that wastes will migrate from the disposal site. The regulatory requirements of the LDR Program can be found in 40 CFR, Parts 261 and 268.

Facilities were required to satisfy minimum technology requirements (for example, liners and leachate collection systems) for surface impoundments, waste piles, land treatment units, and landfills (40 CFR 264/265, Subparts K-N) to prevent hazardous wastes and/or constituents from migrating into the groundwater and to allow releases to be detected when they occur [Section 3004(o)].[194]

4. The Clean Air Act

This Act regulates air emissions from stationary and mobile sources. This law authorizes the U.S. Environmental Protection Agency to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. Biosolids treatment, processing, handling, and transporting must conform to air emission requirements.

5. Water Quality Act of 1987

With the passage of the Water Quality Act of 1987 (P.L. 100-4) (WQA), the Environmental Protection Agency became the responsible agency to regulate biosolids management. The Act required the establishment of technical standards for the identification and control of toxic pollutants in biosolids that may adversely affect public health and the environment. EPA implemented the technical standards through National Pollutant Discharge Elimination System (NPDES) permits issued to publicly owned treatment works (POTWs), unless a permit issued under other federal or state programs ensured compliance of these technical standards.

The Clean Water Act requires that wastewater treatment plants (WWTPs) that discharge to surface waters obtain a NPDES permit (40 CFR). Although the NPDES permit process provides standards for liquid discharge, the standards can also regulate biosolids treatment and disposal.* These standards set parameters for various chemical, physical, and biological characteristics (such as temperature, dissolved oxygen, coliform bacteria, and ammonia content, among others).

To accomplish its role, EPA:

- Set requirements and procedures for including biosolids conditions in NPDES permits (40 CFR Parts 122, 123, and 124).
- Set requirements and procedures for approving state biosolids management programs to operate in lieu of federal programs, or if a state prefers it, for federal programs to implement biosolids permits. (40 CFR Part 501).
- Set technical standards for biosolids use and disposal (40 CFR Part 503), effective on February 19, 1994).

6. The Standards for the Use and Disposal of Sewage Sludge 40 CFR 503

For land application, biosolids must satisfy the requirements for pathogen reduction, pollutant limitations, and vector-attraction reduction established in 40 CFR, Part 503. Part 503 regulations apply to the generator of the biosolids, not the applier.

a. Pathogen Reduction Standards

The regulation establishes two pathogen-reduction standards for land-applied biosolids: Class A and B biosolids. Class A biosolids must be monitored for bacteria growth at the time of use. The use of Class B biosolids is subject to several site restrictions concerning public access, animal grazing, and crop harvesting; for example: 1) public access to land shall be restricted for one year after the application; 2) animals shall not graze on a site for 30 days after the application; and, 3) food crops with harvested parts that touch the biosolids/soil mixture (such as melons, cucumbers, squash) shall not be harvested for 14 months after application of biosolids. General management practices specified for biosolids Class A or B include the prohibition of biosolids application: 1) where threatened or endangered species or their habitat could be affected; 2) on frozen, snow-covered, or flooded ground; or, 3) on land within 10 meters (33 feet) of surface water.

* Biosolids treatment and disposal regulations can also be covered under separate water discharge requirements (WDRs)

b. Ceilings on Pollutant Concentration

The regulation sets standards for pollutant concentration and ceilings. Biosolids with pollutant levels below the ceiling concentrations, but above pollutant concentration standards, can be applied to land subject to restrictions on the frequency or cumulative loading. Pollutant levels below the standards can be applied without restrictions. Those with pollutant concentrations above the established ceilings cannot be applied to land.

c. Vector-Attraction Reduction

The regulation specifies ten alternatives for meeting the vector-attraction reduction requirement. Vectors are insects or animals that can transport and transmit infectious agents (for example, flies, mosquitoes, and rodents).

d. Other Aspects

The regulation also specifies several standards for site management: distribution, marketing, monitoring, record keeping, and reporting procedures of biosolids products.

Implementation of Part 503

Each state has the responsibility to develop programs to implement the rules and guidelines established by EPA. EPA's regional offices verify state compliance with the EPA's regulatory programs.

In California, discharges of waste to surface water bodies, including discharges from wastewater treatment plants (WWTPs), are regulated through the National Pollutant Discharge Elimination System (NPDES) federal permitting process, which typically imposes various chemical, physical, and biological standards on both the effluent and receiving water body. Part 503 restrictions and conditions are typically included in the NPDES permits issued by the Regional Water Quality Control Boards. Generally, NPDES permits focus mainly on the liquid discharge, whereas waste discharge requirements permits (WDRs) issued by the state focus on the solids generated at the facility. Biosolids treatment and disposal regulations can be included in the NPDES permit or in separate WDRs.[195]

Each NPDES permit contains a monitoring and reporting program that identifies the volume of solid material removed from the wastewater (including biosolids) and the locations where this material was taken. The NPDES permit also requires periodic sampling of biosolids for pollutants and other constituents of concern in accordance with the provisions of the EPA Part 503 regulations.[196]

II. CALIFORNIA LAWS AND REGULATIONS

1. The Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act (California Water Code, Division 7) gives the State Water Resources Control Board (SWRCB) the ultimate authority over the state's water rights and water quality policy. The Board policies are implemented through nine Regional Water Quality Control Boards (RWQCB) also established by the Porter-Cologne Water Quality Control Act. The Regional Boards engage in a number of water quality functions in their respective regions. One of the most important is preparing and periodically updating Basin Plans (water quality control plans).[197] Each regional Basin Plan establishes:

1) Beneficial uses of water designated for each water body to be protected. California recognizes 23 designated or beneficial uses for water bodies (for example, agricultural use, groundwater recharge, industrial process supply, municipal and domestic supply, etc.).[198]

2) Water quality standards, known as water quality objectives, for both surface water and groundwater.

3) Actions necessary to maintain these standards in order to control non-point and point sources of pollution to the state's waters.

The RWQCBs regulate all pollutant or nuisance discharges that may affect either surface water or groundwater. Any person proposing to discharge waste within any region must file a report of waste discharge with the appropriate regional board. RWQCBs issue permits or waivers for land application sites, inspect and monitor those sites, and enforce the regulations, when needed.

The RWQCBs administer two principal permitting processes for water quality protection:

- Waste discharge requirements (WDRs) for discharge of waste to land (or discharges affecting surface, coastal, or groundwater); and,

- Permits for discharges to surface waters, issued under the NPDES, mandated under the federal Clean Water Act.

Land application of biosolids by individuals or parties not involved in biosolids generation is primarily regulated through the issuance of WDRs (in accordance to Section 13260 of the Porter-Cologne Water Quality Control Act). The WDR process requires a potential discharger of biosolids to prepare a Report of Waste Discharge describing the biosolids application project. The RWQCB evaluates the project and prepares WDRs including discharge conditions, prohibitions, monitoring, and reporting requirements for the project. The RWQCBs often make the WDR process contingent on the project's adherence to the federal Part 503 regulations. Several RWQCBs waive the WDR preparation for applications involving biosolids with low pollutant and pathogen concentrations, as specified in the Part 503 regulations.

2. California Environmental Quality Act

The California Environmental Quality Act (CEQA) (Public Resources Code [PRC] Section 21000 et seq.) was enacted in 1970 as a system of checks and balances for land-use development and management decisions in California. CEQA requires that state and local government agencies consider the environmental consequences of projects over which they have discretionary authority before taking action on those projects. All projects undertaken by a public agency are subject to CEQA. This includes projects undertaken by any state or local agency, any special district (for example a school district), and any public college or university.

CEQA also applies to discretionary projects undertaken by private parties. A discretionary project is one that requires the exercise of judgment or deliberation by a public agency in determining whether the project will be approved, or if a permit will be issued. Some common discretionary decisions include placing conditions on the issuance of a permit, delaying demolition to explore alternatives, or reviewing the design of a proposed project. CEQA not only applies to projects that have a direct physical impact on the environment, but to decisions that could lead to indirect impacts, such as making changes to local codes, policies, and general and specific plans. Judgment or deliberation may be exercised by the staff of a permitting agency or by a board, commission, or elected body.[199]

The environmental review is described in an Environmental Impact Report (EIR), which records the scope of the applicant's proposal and analyzes all its known and potential environmental effects. This information is used by state and local permitting agencies in their evaluation of the proposed project. The SWRCB's discretionary action on land application of biosolids requires compliance with CEQA. Before the establishment of regulations on this practice, its potential environmental impacts must be addressed in an EIR report prepared in accordance with California Environmental Quality Act and state CEQA guidelines. These potential effects include impacts on land productivity, public health, land use and aesthetics, biological resources, traffic, noise, air quality, and cultural resources.

3. Inclusion of Biosolids in the Definition of Solid Waste

PRC Section 40191 includes dewatered, treated, or chemically fixed sewage sludge in the definition of "solid wastes." Since biosolids are included in this classification, the California Integrated Waste Management Board (CIWMB) exercises jurisdiction over the use and disposal of biosolids. CIWMB is responsible for overseeing solid waste management, reduction, and recycling efforts of jurisdictions throughout California, according to PRC Section 40000.

4. City Source Reduction and Recycling Element

Section 41000 et seq., of the Public Resources Code (PRC) mandates the use of source reduction, source separation, diversion, recycling, reuse, composting, and co-composting of solid waste to the maximum extent feasible to conserve water, energy, and other natural resources and to protect the environment.

5. Waste Diversion Credit

PRC Section 41780 requires jurisdictions to divert 25 percent of their generated waste for landfill disposal by 1995, through source reduction, recycling, and composting activities. Section 41781 requires that the CIWMB "determine that each sludge diversion, for which diversion credit is sought, meets all applicable requirements of state and federal law, and thereby provides for maximum protection of the public health and safety and the environment." In 2000 the diversion proportion increased to 50 percent. For many jurisdictions in California, land application of biosolids serves as a means of achieving these diversion rates. In 2004, more than 180 jurisdictions ran a biosolid diversion program (Sludge recycling program), out of 421 jurisdictions running diversion programs.* [200]

6. Exemption from Requirements Under PRC Section 50002 (b)

PRC Section 50002(b) exempts the application to land of biosolids that, according to the California Integrated Waste Management Board, poses no threat to public health or the environment from requirements established in Sections 50000 and 50000.5, which regulates increases in solid waste at solid waste facilities.[201]

7. Safe Drinking Water and Toxic Enforcement Act

Safe Drinking Water and Toxic Enforcement Act (Health and Safety Code, Section 25249.5) prohibits a person in the course of doing business from knowingly and intentionally discharge or release a chemical known to the state to cause cancer or reproductive toxicity into water or onto or into land, where such chemical contaminates or could contaminate any source of drinking water, notwithstanding any other provision or authorization of law except as provided in Section 25249.9.[202] Land application of biosolids that would cause a violation of Section 25249.5 is not permitted.

8. California Food and Agricultural Code Regulations on the Use of Biosolids in Farming Operations

The California Food and Agricultural Code contains numerous provisions related to public health and safety that apply to farming operations using biosolids. These provisions relate to water supply protection, sanitation, sewerage, and general sanitation and crop harvesting, as well as to pesticide residues and handling of toxic materials.

* Jurisdiction refer to a city, county, a combined city and county, or a regional agency with the responsibility for meeting Integrated Waste Management Act requirements.

California Food and Agricultural Code, Section 14505 regulates biosolids as a fertilizer. It establishes that "agricultural products derived from municipal sewage sludge shall be regulated as a fertilizing material…and when used in general commerce, these products are not subject to regulation as a hazardous substance pursuant to Section 108130 of the Health and Safety Code and are not subject to regulation as a waste under Chapter 6.5 (commencing with Section 25100) of Division 20 of the Health and Safety Code."

9. State Laws on Emissions and Pollution Control in the Health and Safety Code

Air quality impacts associated with biosolids occur during the treatment (including composting), hauling, and land application of biosolids. Emissions resulting from these operations include inhalable particulates (PM_{10} and $PM_{2.5}$) and toxic air pollutants, such as carbon monoxide (CO) and the ozone precursors (oxides of nitrogen [NOx] and reactive organic gases [ROG]). The State Water Resources Control Board General Order (GO) regulating biosolids (Water Quality Order No 2004-0012–DWQ) includes various measures to control these effects. The major concern from the effect of land application of biosolids on air quality relates to whether federal and state standards for fine particulates (PM_{10}) are violated. In addition, there are numerous state and local air quality regulations that control toxic emissions from transportation, hauling, and agricultural equipment. The anticipated tightening of air particulate standards is expected to increase regulatory control of agriculture, particularly the application of biosolids products such as compost at agricultural sites, which could increase the costs of applying biosolids products.[203] Industrial operations transforming biosolids to energy, fuels, or construction materials must comply with California regulations on emissions and pollution control.

10. Discharges of Waste to Land

The SWRCB administers Title 23 and Title 27 (Discharges of Waste to Land) of the California Code of Regulations (CCR), which govern the disposal of wastes in a landfill or on dedicated land disposal sites. CCR Title 23, Sections 2510-2601 apply to all waste disposals to land, including hazardous and non-hazardous materials, into landfills and surface impoundments. Combined SWRCB/CIWMB regulations, Division 2, Title 27 are promulgated by the SWRCB and pertain to water quality aspects of discharges of solid waste to land for treatment, storage, or disposal. The SWRCB-promulgated regulations in this subdivision establish waste and site classifications and waste management requirements for solid waste treatment, storage, or disposal in landfills, surface impoundments, waste piles, and land treatment units.

Discharges of Waste to Land regulations require that all wastes be classified to determine the appropriate type of waste management strategy to be used. The Department of Toxic Substances Control (DTSC) is the responsible agency for classification of materials as hazardous or nonhazardous, while SWRCB may further classify DTSC nonhazardous waste, such as wastewater sludge, as a designated toxic waste. If a sludge or biosolids product is hazardous, its application to land is prohibited and could be disposed subject to provisions of Title 27, or further treated, which involves the compliance with additional requirements, such as those established for composting operations.

11. State General Order (GO) Regulating Biosolids Land Application

On July 22, 2004, Water Quality Order No 2004-0012 – DWQ was approved, regulating the general waste discharge requirements for the discharge of biosolids to land for use as a soil amendment in agricultural, silvicultural, horticultural, and land-reclamation activities. Section 13274 of the California Water Code (CWC) requires the SWRCB or RWQCBs to prescribe general WDRs for the discharge of biosolids used as a soil amendment. This GO intends to satisfy these requirements. It assists in streamlining the regulatory process for such discharges, but may not be appropriate for all sites using biosolids due to particular site-specific conditions or locations. In that case, sites can obtain individual WDRs.

The GO is, in some aspects, more stringent than the 40 CFR Part 503 regulations. For example, it establishes limits for molybdenum and requires lifetime tracking of cumulative loadings for metals in biosolids, including "high quality" metals.

Monitoring and reporting include pre-application reporting, semi-annual monitoring, and post-application reporting. Individual property owners and managers responsible for site operations have primary responsibility for compliance, including monitoring. The discharger (owner/operator of the land-spreading operation) must submit a Notice of Intent (NOI) and fee to the Regional Board, and copies to the Department of Fish and Game and the County Health Department. The Regional Board reviews the NOI for completeness.

The discharger must submit a pre-application report describing how the project will comply with the GO. The Regional Board must review and approve the pre-application report prior to the application of biosolids.

The discharge of biosolids is prohibited unless the discharger has submitted an NOI, filing fee, and a pre-application report. In response to these submittals, the RWQCB will issue a Notice of Applicability, individual WDRs, or a waiver of WDRs for the discharge.

The general order does not apply to areas that are unique or valuable public resources, jurisdictional waters or preserves, or state-designated management areas, where biosolids application cannot be permitted. Among the areas excluded from the GO are:

- The Lake Tahoe Basin;
- The Santa Monica Mountains Zone;
- The California Coastal Zone;
- The area within 0.25 mile of a wild and scenic river;
- The jurisdictional Sacramento-San Joaquin River Delta;

- Suisun Marsh; and,
- The area under the jurisdiction of the San Francisco Bay Conservation and Development Commission; and several specific areas within the jurisdiction of the Lahontan RWQCB, including the Antelope Hydrologic Unit above 3,500 feet, areas in the Mojave River Planning Area, the Hilton Creek/Crowley Lake areas, and areas of the Mono-Owens Planning Area.

12. Classification of Municipal Biosolids as Hazardous/Nonhazardous Waste

In accordance with the California Hazardous Waste Control Act (HWCA,* DTSC is responsible for determining whether sewage sludge/biosolids are a hazardous or nonhazardous material (CCR, Title 22, Division 4.5, Chapter 11, pursuant: Health and Safety Code, Sections 25141 and 25159).

DTSC uses various adopted criteria to determine whether sludge is classified as a hazardous waste including testing for toxicity, persistent and bio-accumulative toxic substances, ignitability, reactivity, and corrosivity. Any waste containing a substance exceeding listed threshold limit concentrations or criteria is classified as a hazardous waste. Most municipal biosolids are classified as nonhazardous.[204]

13. Compostable Materials Handling Operations and Facilities Regulatory Requirements

The California Integrated Waste Management Board (CIWMB) is responsible for regulating biosolids composting practices (CCR Title 14). CIWMB regulations require recycling agencies to submit a permit application under the CIWMB tiered-permitting program. The CIWMB designates a local agency in each county as the local enforcement agency (LEA), which sets standards and enforces solid waste regulations. LEAs issue solid waste facilities permits (SWFPs) for composting and dedicated disposal sites.

In April 2003, CIWMB introduced a regulation limiting selenium concentration in compost to 36 mg/kg. This is a more stringent standard than that established by federal regulations under Part 503, which is 100 mg/kg.[205]

* The California Hazardous Waste Control Act (HWCA) is the state's equivalent to the federal Resource, Conservation and Recovery Act (RCRA), and closely parallels RCRA by regulating the generation, storage, transportation, treatment, and disposal of hazardous waste in the state. The primary authority for enforcement of HWCA and RCRA itself lies with the State Department of Toxic Substances Control, which is a department of the California Environmental Protection Agency. The State of California has been granted authorization by the United States EPA to administer all regulations under both RCRA and the State's Hazardous Waste Control laws. http://72.14.253.104/search?q=cache:mdKlr5fT4vIJ:www.rutan.com/sitecontent.cfm%3Fsection%3Dpractices%26page%3Dpractice_detail%26itemID%3D12+%22California+Hazardous+Waste+Control%22&hl=en&gl=us&ct=clnk&cd=1.

14. Advisory Guidelines by Office of Environmental Health Hazard Assessment (OEHHA)

OEHHA has general authority to protect public health, including the responsibility of regulating the land utilization and land disposal of biosolids. In 1983 OEHHA's Sanitary Engineering Branch published a manual on effective and safe practices to use sewage biosolids (Manual of Good Practice for Land Spreading of Sewage Sludge). OEHHA's advisory guidelines and recommendations are not regulations. However, they often are incorporated in the RWQCB's orders (WDR's).

III. LOCAL PROGRAMS - COUNTY ORDINANCES

Several California counties have local ordinances that directly regulate biosolids reuse and disposal practices or indirectly affect biosolids management by requiring conditional use permits for certain activities.

Of the 58 counties in California, at least 16 currently have ordinances that relate directly to land application of biosolids. Local ordinances restrict the areas within the state that can currently accommodate land application of biosolids and they supersede the federal and state regulations when they are more restrictive.

Sutter, San Joaquin, Stanislaus, and Kern Counties have full or partial bans on the land application of biosolids for areas within their jurisdiction. Other counties have issued ordinances that effectively ban the use of them or issued ordinances regulating the land application of biosolids. For example:

- In Tulare County there are additional requirements on monitoring and testing for dioxins, furans, PCBs, and other organic pollutants.
- Kings County banned land application of Class B biosolids starting in February 2003. The use of Class A and Exceptional Quality (EQ) biosolids were allowed until February 2006. The current ordinance only allows land application of composted Class A and EQ biosolids.
- In response to complaints and local demonstrations during biosolids land application at some sites, Riverside County decided to evaluate revisions to their ordinance that would ban Class B biosolids. In November 2001, a final ordinance was enacted that effectively implemented a ban on application on all but 600 acres in the County. Land application in the County has ceased except for some Class A solar dried biosolids.

The remaining 42 counties without ordinances rely on the RWQCBs to regulate land application through the WDR process.

Recently, Kern County tried to ban biosolids application. This County had adopted in 1999 an ordinance that banned land application of biosolids with the exception of exceptional quality biosolids (EQ). After various attempts to prohibit biosolids import from other counties, Measure E, which prohibited the application of biosolids in the unincorporated area of Kern County was placed on the June 2006 ballot and approved by the voters. Los Angeles and other Southern California municipalities are challenging this measure and a federal judge is expected to rule on the final decision. The fate of Measure E could set a precedent and influence other counties' decisions on biosolids management. If the Measure is enforced, other counties may place the same or similar biosolids restrictions.

Kern County Resistance to Biosolids Land Application

More than one million wet tons of biosolids were transported into Kern County each year from Southern California Cities (Los Angeles, Orange County). Kern residents became increasingly concerned that toxins and pathogens contained in the sludge could contaminate their environment, even after biosolids were treated under federal and state regulations. Kern residents also felt that biosolids application could cause loss of confidence in agricultural products from the County, lowering the value of their land and agricultural products. They also complained of odors, insects, and other adverse effects from biosolids application.

In 1999, Kern County adopted an ordinance that banned land application of all except the exceptional quality biosolids (EQ) and established extensive monitoring requirements. In an attempt to keep the option of applying Class B biosolids, Orange County Sanitation District and others filed suit to vacate the ordinance, but in 2002, the Tulare County Superior Court upheld Kern County's right to control biosolids use.

Senator Dean Florez introduced legislation in 2005 that would have prohibited importation of biosolids. This legislation was strongly opposed by Southern California biosolid generators and by municipal governments throughout the state. As a response, Senator Florez sponsored the signature collection that led to the placement of Measure E "Keep Kern Clean Ordinance of 2006" on the June 2006 ballot, which prohibited the application of biosolids in the unincorporated area of Kern County, which was approved by 83 percent of voters. Existing permit holders got six months to discontinue the land application of biosolids.

On August 15, 2006, Los Angeles and Orange Counties and others filed suit against Kern County alleging that the County is violating state and federal laws by banning the legal application of an organic fertilizer. The case went to the United States District Court for the Central District of California, and the Kern County ban was suspended until a federal judge rules on the case. On August 10, 2007, the U.S. District Court Judge overturned Kern County's ban. The judge ruled the measure is discriminatory in prohibiting sludge from Southern California from being dumped locally while not requiring the same of cities and towns in Kern, which use their own sewage sludge as farmland fertilizer. Furthermore, the judge ruled the measure also violates state law promoting the recycling of biosolids. Kern County is considering appealing the decision to a higher court, such as the Ninth Circuit in San Francisco. If that is the case, it could take two more years for this case to be resolved.

SECTION 5: ALTERNATIVES FOR BIOSOLIDS MANAGEMENT AND POLICY OPTIONS TO SUPPORT THEM

Communities are facing the challenge of what to do with the growing amount of biosolids that they produce. They must look for ways to beneficially use these materials while protecting environmental and human health.

Currently, more than half of all biosolids produced in California are used in land applications. However, the previous sections have illustrated how this practice is becoming less popular as a result of continued uncertainty over its environmental and public health effects, and the annoyance associated with biosolids applications (increased traffic, dust, and odor). Many people, including agricultural scientists and environmentalists, question the efficacy of government regulations and enforcement to prevent cumulative effects of toxic materials and pollutants on the soil, water sources, and consequently, animals and humans. Both groups, regulators and scientists, acknowledge the need for additional study on the risks posed by biosolids pollutants and for stronger monitoring and enforcement of the regulations.

As opposition to biosolids land use grows and landfill space becomes more scarce, communities will have to find alternatives for a sustainable biosolids management strategy. Below are several management options.

I. Continuation of the Current Programs of Biosolids Application on Farmland

This alternative is one of the least expensive. To continue with this practice, several policy measures could be required to convince the public to accept it. The success of these actions will depend on new scientific evidence brought about by research based on more accurate data and modern research techniques. The following are some suggested strategies to curb public opposition.

1. Implementing a System of Effective Tracking and Response of Complaints on Problems Associated with Biosolids

Regulators could create an incident-tracking program available to the public as a way of demonstrating commitment to public health protection and addressing nuisance issues. The program could have a database including: 1) complaints addressed to regulators, land-owner/appliers, haulers, health officials, and government representatives; 2) reports from regulators and site inspectors; 3) information collected from residents living or working in the nearby area of biosolids application; and, 4) the responses to the alleged problems by stakeholders and experts.

2. Restricting the Land Application of Biosolids to Only Exceptional Quality or Class A Biosolids

Some counties restricted land applications to only biosolids Class A or EQ, a measure that addresses partially health public issues and increases the costs of biosolids management. Since biosolids Class A and EQ meet higher standards, the use of these types of biosolids is safer than Class B. However, this type of policy is a partial solution since it does not address other public fears such as the effects on the environment and public health of new pollutants that have not been included on the list of Part 503 requirements.

3. Restricting the Application of Biosolids for Growing Dedicated Biomass Crops

Nationally, dedicated biomass herbaceous and woody crops are expanding to supply large amounts of biomass for new biobased products and energy. Dedicated crop production in California is not a large scale agricultural enterprise, however, there is increasing interest and opportunity for the development of this activity as a result of increasing attention on renewable energy and biobased products markets (such as ethanol and biodiesel). Using biosolids as a fertilizer in dedicated crop fields would reduce public health concerns as long as those fields are used only for energy purposes.

4. Demonstrating Enforcement and Monitoring by Responding to Concerns Raised by Affected Parties

The state in partnership with regional stakeholders could implement field investigations at selected sites to determine whether standards for biosolids land use are being met. This would help restore public confidence in the efficacy of the regulatory process. Regulators could also perform more analytical tests to assure efficacy of waste-treatment processes.

Conversely, if new studies continue yielding inconclusive or negative results regarding the effects of land application of biosolids on the environment and human health, communities will have to look for alternative ways to dispose of them. It is possible that the negative public perception of biosolids could continue even if additional scientific data corroborates their safety. This could occur as a result of public psychological reaction to these materials. In this case, there could be a large proportion of biosolids that need to be reallocated.

This problem could become more acute if the costs of treatment by processors are not compensated by financial returns from the sale of products (biosolids) or service because of this decrease in demand. A higher volume of materials that need to be disposed of (sludge rather than biosolids) could be created.

II. Composting

The composting process reduces the pathogens in biosolids. It is possible that the public will become more tolerant of using biosolids with other materials to produce a finished compost product that could be applied to land. The compost is a higher-quality soil amendment in addition to being a safer product.

The composting market may not be able to process a large amount of materials since the current composting industry is relatively small. A problem for the compost industry is that compost facilities are generally located in districts with more stringent emission standards. Technologies needed to comply with those standards are expensive.
To promote the use of biosolids in compost, the state and localities could consider providing production or tax incentives to the composting industry to ameliorate start-up losses and to stimulate its expansion. These incentives may include:

- Low-interest loans to meet emission standards.
- Establishment of tax reductions for these companies.
- Payment of a tipping fee (the charge for levied upon a given quantity of waste received at a waste processing facility).

III. Use of Biosolids as a Source of Energy or Other Products

According to the Energy Commission, California produces approximately 400 megawatts of biomass-generated electricity from sources such as landfill gas, biogas from wastewater treatment, direct burning of municipal solid waste, and anaerobic digestion of livestock manure. Using biosolids to produce fuels and other products or to generate electricity is an attractive alternative for biosolids management since it would solve the problem of what to do with the biosolids at the same time of reducing fossil energy consumption. However, this option may require state financial support because most of the technologies that recover and use the energy from biosolids are still in an early stage. As discussed in an earlier section, there are already a variety of policies to encourage the use of biomass to generate energy; however, the state could expand its support in many ways, for example:

1. Stimulating Demand for New Products Derived from Biosolids Processing

- The state could require the use of innovative products such as cement and other construction materials derived from biosolids processing in public construction.
- California could establish a statewide policy on biosolids treatment, disposal, and recycling that would promote the conversion of biosolids into energy or other products.
- The state could sponsor workshops throughout California and invite representatives of the biomass conversion technology industry to present their

technology to Sanitary Districts, cities and agencies involved in biosolids processing.

- The state could provide incentives for water waste treatment plants to use biosolids as a source of energy. For example, existing rules do not allow water or wastewater utilities to credit the electricity they generate to their energy bills. Therefore, if this electricity cannot be directly connected to an existing load, it must be sold into the wholesale bulk power market. The cost and complexity of selling into the wholesale bulk power and transmission markets are prohibitive, particularly for very small generators. The Energy Commission recommends "expediting and reducing the cost of utility interconnection, eliminating economic penalties including standby charges, removing size limitations for net metering, and allowing water and wastewater utilities to self generate and provide power within their own systems."[206]
- Amending Diversion Credits Policies. The state could consider changing the diversion credit policies by assigning a higher credit to projects transforming biosolids to energy or other useful by-products.

2. Stimulating Supply of Energy and New Products Derived from Biosolids Processing

The state could direct a panel of qualified professionals to conduct a complete and objective evaluation of the costs and benefits of all the technological processes that can use energy contained in biosolids, their applicability, economic and environmental costs and benefits, and energy generation efficiency. Representatives of various technologies discussed in this paper feel that interested agencies or sanitary districts should hire consultants to evaluate their technologies before taking the decision to use them. According to them, these consultants are not always qualified or have biases acquired from their professional experiences that prevent objective assessments of the benefits of these conversion technologies.

California policymakers could establish a statewide policy on biosolids treatment, disposal, and recycling that would promote the conversion of biosolids into energy or other useful products.

The state could create a subsidy to support the development of technologies that can convert biosolids into energy or other products, as well as those that are energy efficient. This subsidy could be a direct payment to producers or tax reductions for qualifying firms or individuals who have undertaken particular actions, such as saving a certain amount of energy in the processing of biosolids or recycled biosolids in other useful products.

According to information collected in this study, the average cost of processing biosolids is about $110 per dry ton. The cost of innovative conversion processes is estimated roughly around $250 per dry ton. Net costs vary depending on the geographic area, scale of production, and the value of by-products generated in the process. According to these figures, these producers may need a direct subsidy of approximately $140 dollars per dry ton.* Based on information provided by the industry, conversion technologies such as the syngas fermentation technology developed by Bioengineering Resources, Inc. (BRI) to produce ethanol from biomass are already profitable. However, an extensive program using this technology may require a complicated system of collection materials, since the BRI process includes forest materials and other biomass in addition to biosolids.

Taking into account population growth, by 2008 the total volume of biosolids processed could be around 853,000 dry tons, requiring an annual fund of around $120 million to cover this monetary support. This subsidy could be financed with an *average* contribution of about $10 per housing unit. Fairness would require that the contribution (user fee) collected to support innovative technologies for biosolids processing is related to the value and location of the property.[207]

Other measures that could help the use of biosolids as a source of energy include:

- The state could direct funds and leverage federal funds for research and development and demonstration projects on the use of biosolids for unconventional uses.
- The state could provide grants or other incentives (tax credits, low-interest loans) to companies for the creation of new technologies that allow alternative applications of biosolids and other biomass with processes resulting in a substantial reduction of waste. The state could provide additional funds and technical assistance to support short-term demonstration efforts to develop biosolids-based fuel production and power generation.
- The state could provide funding to support investments to manufacture products from biomass and/or biosolids processing. Seed funds, capital tax credits, and capital gains tax cuts could also be provided to innovative plants that use biosolids to produce materials through processes that reduce solid waste.†
- The state could provide funding to support investment in fuel-generation plants.
- The state could consider establishing a California seed fund and/or seed capital tax credit for renewable energy production from biomass, including biosolids. Investments in biofuel processing can also be promoted through capital gains tax cuts, targeting individuals and institutions making venture capital investment in early stage technologies.

Personal communications with representatives of conversion technologies used to process biosolids indicate that their problem is not that much financing, as it is the permitting process to build a plant and start operations. According to the industry, the existing regulations and lack of understanding of these technologies make the building of these plants a very long and expensive process. The state may find ways to accelerate or create a separate permitting process for the installation of plants using these conversion technologies.

* This is a gross approximation. Some of the processes are significantly less expensive.

† Seed financing is the small amount of capital needed to prove a concept and build a management team.

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