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Anaerobic Digestion as a Renewable Energy Source and Waste Management Technology: What Must be Done for This Technology to Realize Success in the United States?

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ABSTRACT

Anaerobic digestion technology uses microorganisms to consume waste and produce methane gas, which serves as a source of clean renewable energy. Although anaerobic digestion is widely used for both purposes throughout the rest of the world, it is rarely applied in the United States. This Article explains the scientific processes of anaerobic digestion. It then discusses how anaerobic digestion has been used throughout history and among societies as a waste management technology and a source of renewable energy. The Article continues by addressing the legal aspects of anaerobic digestion, examining the reasons why it is not widely used in the United States. The Article concludes with solutions that may allow anaerobic digestion to become more widely adopted throughout the United States.

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I. INTRODUCTION

Anaerobic digestion technology uses microorganisms to consume organic waste,[1] producing a clean source of methane gas with limited contributions to global warming.[2] This technology is widely used throughout the world as a waste management tool and a source of local, renewable energy. Currently, Germany has approximately 7,000 large-scale anaerobic digestion centers, Nepal has 50,000 anaerobic digestion units, and China has 8 million anaerobic digesters, all of which provide clean energy while disposing of waste.[3]

Despite its many benefits, anaerobic digestion remains underutilized in the United States.[4] Most of the waste produced in the

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1 T. Amani et al., *Anaerobic Digestion from the Viewpoint of Microbiological, Chemical, and Operational Aspects – a Review*, 18 ENVTL. REV. 255, 255 (2010). The process can be used to treat diverse waste products including municipal solid waste, petrochemical waste, agricultural waste, food production waste, household waste, wastewater, and other kinds of biosolids. *Id.*

2 *See* David P.Chynoweth et al., *Renewable Methane From Anaerobic Digestion of Biomass*, 22 RENEWABLE ENERGY 1, 2 (2001) ("Compared to other fossil fuels, methane produces few atmospheric pollutants and generates less carbon dioxide per unit energy."). *But see* Mark Bittman, *Is Natural Gas 'Clean'*, N.Y. TIMES: OPINIONATOR (Sept. 24, 2013, 9:05 PM), http://opinionator.blogs.nytimes.com/2013/09/24/is-natural-gas-clean/ ("One reason natural gas is called 'clean' is because it emits 50 percent less carbon dioxide than coal when you burn it. Thus it's seen by some as a 'bridge' fuel until zero-carbon-producing renewables can take over.").

3 PEW CTR. ON GLOBAL CLIMATE CHANGE, ANAEROBIC DIGESTERS CLIMATE TECHBOOK 1-2 (2011), http://www.c2es.org/docUploads/AnaerobicDigesters.pdf.

4 Clark P. Bishop & C. Richard Shumway, *The Economics of Dairy Anaerobic Digestion with Coproduct Marketing*, 31 REV. AGRIC. ECON. 394, 394 (2009). According to the Environmental Protection Agency (EPA), the United States produced approximately 250 million tons of waste in 2010. E.P.A, MUNICIPAL SOLID WASTE GENERATION, RECYCLING, AND DISPOSAL IN THE UNITED STATES: FACTS AND FIGURES FOR 2010 1 (December 2011) [hereinafter EPA 2010 FACTS], http://www.epa.gov/osw/nonhaz/municipal/pubs/msw_2010_rev_factsheet.pdf. The United States produced approximately 1.35 billion pounds of garbage every day and on average, each American citizen generates 4.43 pounds of waste every day. Planet Green, *How much Trash does America Produce?*,

United States is "municipal solid waste," an ideal candidate for disposal through anaerobic digestion.[5] Yet, presently, there are fewer than 200 anaerobic digestion units operating in the United States.[6] American landfills bury nearly 140 million tons of waste on an annual basis,[7] and newly constructed landfills have steadily increased in size throughout the country.[8]

Anaerobic digestion has the potential to benefit American communities by generating renewable energy and reducing the amount of waste buried in landfills.[9] Before anaerobic digestion can achieve the same level of success and widespread adoption in the United States as realized elsewhere in the world, the United States must accept considerable changes in the way it obtains energy and manages its waste.[10]

Perhaps the most significant reason why anaerobic digestion has failed to become widely adopted in the United States is financial infeasibility.[11] American legislation generally does not provide anaerobic digestion facilities with favorable energy statuses and other financial benefits that make the process more efficient in other countries. Americans appear more likely to choose less expensive methods of waste disposal, even if such methods ultimately shift the cost from the consumer to society and pose greater risks to the environment.[12]

CURIOSITY.COM, http://curiosity.discovery.com/question/america-produce-trash (last visited May 25, 2013).

5 *See* Shefali Verma, Anaerobic Digestion of Biodegradable Organics in Municipal Solid Wastes 1 (May 2002) (unpublished Master's thesis, Columbia University), http://www.seas.columbia.edu/earth/vermathesis.pdf.

6 PEW CTR. ON GLOBAL CLIMATE CHANGE, ANAEROBIC DIGESTERS CLIMATE TECHBOOK, *supra* note 3, at 1.

7 EPA 2010 FACTS, *supra* note 4, at 2.

8 *Id.* at 10. Although waste is relatively light, it takes up large amounts of space because of its disproportionately high ratio of volume-to-weight. *See* Planet Green, *supra* note 4.

9 EPA 2010 FACTS, *supra* note 4, at 2.

10 *See* E-mail from Eugene L. Smith, Sales Application Engineer, SUMA America, Inc., to Blake Anthony Klinkner (May 28, 2013, 12:59 MST) (on file with author) (discussing how greater restrictions on what can and cannot be placed in landfills would be a big step but would require a major cultural shift).

11 Bishop & Shumway, *supra* note 4, at 394.

12 *See, e.g.*, Jonathan Cannon, *Environmentalism and the Supreme Court: A Cultural Analysis*, 33 ECOLOGY L.Q. 363, 396–97 (2006) (citing Fort Gratiot

One way to encourage the adoption of anaerobic digestion may be to create feed-in-tariffs. These tariffs typically require utilities to purchase energy from designated sources at a favorable rate.[13] Many countries use preferred status and financial incentives to promote anaerobic digestion and other alternative energy sources.[14] In addition to tariffs, a well-developed and reliable market for anaerobic digestion's co-products could prevent the financial failure of anaerobic digestion systems in the United States.[15]

This Article seeks to expand the body of existing literature on anaerobic digestion by incorporating the results of survey research that the author recently conducted of experts across professions and around the world. The author has also worked as an environmental consultant on waste management and energy technologies and has drawn upon his years of experience in writing this Article. The author is hopeful that this Article will inspire American industry, policymakers, and the general public to explore the benefits of a technology that is used extensively throughout the world.

Part II discusses the science behind anaerobic digestion, demonstrating how it generates reliable, local, and clean energy through the processing and disposal of waste. Part III provides a historical overview of anaerobic digestion's use throughout the world.

Sanitary Landfill v. Michigan Dep't of Natural Res., 504 U.S. 353, 368 (1992) (Rehnquist, J., dissenting) (stating that America's current "unrestrained" economic system for managing wastes relies upon the "cheapest" methods for disposal and poses a number of risks to human health and the environment); Ann E. Carlson, *Recycling Norms*, 89 CAL. L. REV. 1231, 1257 (2001) (discussing how the rise of the modern landfill displaced recycling in America because it allows for "cheap" waste disposal); Michael D. Diederich, Jr., *Does Garbage Have Standing?: Democracy, Flow Control and a Principled Constitutional Approach to Municipal Solid Waste Management*, 11 PACE ENVTL. L. REV. 157, 255 (1993) (noting that waste disposal methods, like landfilling, are "cheaper," but are less environmentally friendly and are not as technologically sound as "progressive" methods, like recycling).

13 PEW CTR. ON GLOBAL CLIMATE CHANGE, ANAEROBIC DIGESTERS CLIMATE TECHBOOK, *supra* note 3, at 9 (defining a feed-in tariff as one that mandates the purchase of biogas energy from anaerobic digesters and provides a financial return to digester projects that could catalyze their development).

14 *See id.* (noting that Germany uses a feed-in-tariff mandating the purchase of biogas from anaerobic digesters); E-mail from Clare Riepma, President, Riepma Consultants Inc., to author (May 26, 2013, 7:54 MST) (on file with author).

15 *See generally* Bishop & Shumway, *supra* note 4 (discussing the possibility that the key to financial feasibility lies in co-product marketing).

Part IV considers the history of anaerobic digestion in the United States, with particular focus on the reasons for its widespread failure in the 1970s and 1980s. Part V offers policy and regulatory recommendations to facilitate anaerobic digestion's expansion and adoption throughout the United States as a waste management tool and source of renewable energy.

II. UNDERSTANDING THE SCIENCE: WHAT EXACTLY IS ANAEROBIC DIGESTION?

Anaerobic digestion is a biochemical process in which microorganisms consume organic waste materials in the absence of oxygen.[16] This process results in three primary end products: methane, carbon dioxide, and "digestate," a solid residue similar in form to soil or compost.[17] Waste designated to undergo anaerobic digestion is commonly referred to as "feedstock."[18] The following is a general description of the steps involved in anaerobic digestion in small community digesters and larger industrial facilities.

A. Pretreatment of the Feedstock

To produce energy most efficiently, feedstock should be pretreated before undergoing anaerobic digestion.[19] "Municipal solid waste" is a general term describing the overall waste stream produced by a typical community.[20] Subcategories of municipal solid waste include the following: residential waste, generated by households; institutional waste, generated by facilities such as hospitals and universities; and commercial waste, generated by stores, tourism, and markets.[21] The fraction of municipal solid waste best suited for anaerobic digestion is identified broadly as "organic waste," which includes materials such as

16 Deshai Botheju & Rune Bakke, *Oxygen Effects in Anaerobic Digestion – A Review*, 4 OPEN WASTE MGMT. J. 1, 1 (2011).

17 *See* Clare Lukehurst et al., *Utilization of Digestate from Biogas Plants as Biofertiliser*, IEA BIOENERGY, 5–7 (June 2010), http://www.biogas.org.nz/Publications/Resources/utilisation-of-digestate-biogas-to-biofertiliser.pdf.

18 *Id.* at 6–7.

19 *See* PEW CTR. ON GLOBAL CLIMATE CHANGE, ANAEROBIC DIGESTERS CLIMATE TECHBOOK, *supra* note 3, at 2; Verma, *supra* note 5, at 4.

20 Amani et al., *supra* note 1, at 264.

21 *Id.*

food waste, garden waste, and paper products.[22] Organic waste accounts for over half of all municipal solid waste produced by the United States.[23]

Pretreatment of feedstock consists of separating nonorganic materials from organic waste.[24] Nonorganic materials commonly found in municipal solid waste include metal, glass, plastic, and rock-like debris such as stones, concrete, and sand.[25] Anaerobic digestion facilities employ, to varying extents, mechanical sorting technologies that physically remove nonorganic materials from the waste stream.[26] This process may involve the use of magnets, passable screens, or conveyor systems staffed by personnel who visually identify nonorganic materials and remove them manually.[27]

Once nonorganic materials have been removed, the remaining waste is ground or shredded to reduce the size of the feedstock that will be fed into the anaerobic digester.[28] Reduction in the size of the feedstock increases the surface area of waste and speeds the ability of the anaerobic bacteria to digest the incoming feedstock.[29]

After reduction, the feedstock enters an anaerobic digester—a silo-like container made of metal or concrete.[30] Inside the digester, the feedstock is mixed and diluted with water.[31] Different types of water

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[22] *Id.*

[23] *Id.*

[24] *See* Lukehurst, *supra* note 17, at 18.

[25] Verma, *supra* note 5, at 4.

[26] *See* Lukehurst, *supra* note 17, at 18. Although agricultural waste is not included within the definition of municipal solid waste, agricultural waste is also highly conducive to anaerobic digestion. For the purposes of analyzing the processes and economic feasibility of anaerobic digestion systems, municipal solid waste and agricultural waste may be analyzed interchangeably. It is generally recommended that one mix municipal solid waste and agricultural waste into a uniform feedstock whenever possible in order to maximize the production of biogas and the quality of the digestate. *See* Verma, *supra* note 5, at 1.

[27] *See, e.g.*, Verma, *supra* note 5, at 41.

[28] *Id.* at 4.

[29] *See Anaerobic Digestion*, WIS. BIOREF. INITIATIVE 2 (Sept. 25, 2013), *available at* http://www.biorefine.org/proc/anaerobic.pdf.

[30] *See* Catherine M. H. Keske, *Anaerobic Digestion Technology: How Agricultural Producers and the Environment Might Profit from Nuisance Lawsuits*, 52 NATURAL RES. J. 315, 318 (2012).

[31] *See* Verma, *supra* note 5, at 4.

may be used, including fresh water, sewage water, or "effluent."[32] The primary benefit of using sewage water or effluent is that the liquids already harbor colonies of anaerobic microorganisms that may immediately begin digesting the feedstock.[33]

"Slurry" is the industry term for a mixture of water and feedstock. The "total solids content" of slurry refers to the percentage of the slurry comprised of waste material.[34] Total solids content can range from 10% to 40% depending upon the design of the digester.[35]

B. Temperatures Inside the Anaerobic Digester

Perhaps the most important parameter to control within an anaerobic digester is temperature.[36] Different strains of microorganisms perform optimally in different temperature ranges.[37] Variations in temperature of only a few degrees can have devastating effects on the colonies of anaerobic bacteria, their ability to digest the feedstock, and their production of methane.[38] To produce methane most efficiently, digester operators need to maintain optimal temperature levels for the particular kind of microorganism employed.[39]

Generally, reactor operators use one of two types of bacteria.[40] A "mesophilic" bacterium is a microorganism that performs best between 95° F and 105° F.[41] A "thermophilic" bacterium is a microorganism that

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32 Effluent is water that has been reused and re-circulated from previous anaerobically-digested batches. *Id.*

33 *Id.*

34 *Id.* at 5.

35 *Id.*

36 *Anaerobic Digestion*, OFF. OF ENERGY EFFICIENCY & RENEWABLE ENERGY (Aug. 14, 2013, 1:07 PM), http://energy.gov/energybasics/articles/anaerobic-digestion.

37 *Id.*

38 Amani, *supra* note 1, at 264.

39 *See id.*

40 *See Anaerobic Digestion*, *supra* note 36.

41 *See, e.g.*, MICH. ADMIN. CODE r. 287.651(k) (2013) (defining "mesophilic" to mean "operating the anaerobic digester in the temperature range of 95 degrees Fahrenheit to 105 degrees Fahrenheit"); *see also* Man-Chang Wu et al., *Influence of Temperature Fluctuation on Thermophilic Anaerobic Digestion of Municipal Organic Solid Waste,* 7(3) J. ZHEJIANG U. SCI. B 180 (2006), *available at* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1419061/.

performs best between 125° F and 135° F.[42] Mesophilic bacteria and thermophilic bacteria bring distinct benefits and detriments to the anaerobic process. Reactor operators need to be mindful of these differences when deciding which strains of bacteria to employ.

Thermophilic bacteria allow a more efficient and complete digestion of the feedstock, and reduce the number of harmful pathogens that survive digestion.[43] Some operators, however, disfavor thermophilic bacteria because they are more sensitive to temperature deviations.[44] Minute temperature shifts can result in major disruptions to methane production and significant deaths of thermophilic bacterial colonies.[45]

Mesophilic bacteria are much more tolerant of temperature shifts than thermophilic bacteria.[46] However, the mesophilic bacteria do not digest feedstock as efficiently as thermophilic bacteria.[47] Furthermore, the optimal temperature level for mesophilic bacteria is not high enough to destroy all of the harmful pathogens.[48]

C. Slurry Retention Time and Mixing

After digester operators introduce feedstock into the anaerobic digestion vessel and mix it with water, the slurry remains within the vessel for a period of days.[49] The retention time for an anaerobic digester varies based on numerous factors including the type of bacteria used, the specifications for the particular digester technology utilized,[50] and the preferences of management.

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42 *See, e.g.*, MICH. ADMIN. CODE r. 287.651(r) (2013) (defining "thermophilic" to mean "operating in the temperature range of 125 degrees Fahrenheit to 135 degrees Fahrenheit"); *see also* Wu, *supra* note 41, at 180.

43 Amani et al., *supra* note 1, at 264.

44 *Id.*

45 *Id.*

46 *See* Wu, *supra* note 41, at 180–81 (2006).

47 *Id.* at 180.

48 *See, e.g.*, N. J. Horan et al., *Die-off of Enteric Bacterial Pathogens During Mesophilic Digestion*, 38 WATER RESEARCH 1113, 1119 (2004).

49 *See* Verma, *supra* note 5, at 9.

50 Anaerobic digestion technology is highly proprietary, and retention times may vary considerably among the different manufacturers of anaerobic digesters, and even among different models made by the same manufacturers. *See, e.g.*, Joshua Rapport et al., Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste 20, 23, 34, 35 (Mar. 2008), http://www

Some anaerobic digesters mix slurry with paddle devices[51] that increase the rate of bacterial digestion.[52] Paddles, however, are prone to mechanical breakdowns.[53] Other anaerobic digesters employ gas jets that use compressed oxygen or biogas injected into the slurry to provide a mixing action.[54] Like the paddle, these jets help to increase the rate of bacterial activity.[55]

Finally, some anaerobic digesters do not use any form of mechanical mixing, but rely instead upon gravity to slowly pull solid particles through the reactor from top to bottom, enabling the complete digestion of particles along the way.[56] Such "gravity" or "plug flow" models produce less overall biogas than reactors using mechanical mixing, but are less technologically complex and, therefore, less expensive to build and maintain.[57]

.calrecycle.ca.gov/Publications/Documents/Organics%5C2008011.pdf. (discussing how Dranco digesters have a retention time of 14 days, Valorga digesters have a retention time of 18 to 23 days, Biocel digesters have a retention time of 21 days, and how SEBAC digesters have retention times ranging from 21 to 42 days).

51 *See, e.g.*, MICH. ADMIN. CODE r. 287.657(7)(8)(b) (2013) ("[Complete mix anaerobic digesters consist of] an enclosed heated tank with a mechanical [or] hydraulic . . . mixing system. Complete anaerobic mix digesters are intended for slurry or liquid feedstocks. Mixing ranges from intermittent to continuous.").

52 *See* J. Sanchez Rubal et al., *Influence of Temperature, Agitation, Sludge Concentration and Solids Retention Time on Primary Sludge Fermentation*, 2012 INTERNATIONAL JOURNAL OF CHEMICAL ENGINEERING 1, 8, http://www.hindawi.com/journals/ijce/2012/861467/.

53 If a digester will rely upon mechanical stirrers, it becomes even more imperative that pretreatment processing is able to remove non-digestible, inert materials such as rocks, metals, glass, and sand, as these materials frequently cause wear and breakdowns in mechanical mixing systems. *See* Verma, *supra* note 5, at 6.

54 *See, e.g.*, MICH. ADMIN. CODE r. 287.657(7)(8)(b).

55 *See, e.g.*, *id.* (describing how a "complete mix anaerobic digester" may employ a "gas mixing system"). This stirring of the slurry prevents inadequate mixing, which leads to the non-uniform distribution of substrates, enzymes and microorganism, incomplete stabilization of waste, a decrease of methane production and less efficient pathogen destruction. *See* Amani et al., *supra* note 1, at 265.

56 *See, e.g.*, MICH. ADMIN. CODE r. 287.657(7)(8)(a) (describing a plug flow anaerobic digester).

57 *Id. See also Plug Flow*, PENN STATE EXTENSION, http://extension.psu.edu/natural-resources/energy/waste-to-energy/biogas/types-of-anaerobic-digesters/plug-flow (last visited May 26, 2013).

D. Biogas Production

As anaerobic bacteria digest organic waste, they produce a mixture comprised mostly of carbon dioxide and methane called "biogas."[58] The percentage of methane contained within biogas can vary dramatically based on a myriad of factors including the type of feedstock digested, the type of bacteria used, the design of the digesters, and the retention time for the slurry.[59] The amount typically ranges between 50–70%.[60] Average biogas production at an anaerobic digestion facility falls between 3.2 and 4.8 standard cubic feet per wet pound of waste.[61]

The methane produced by anaerobic digestion may be used as an energy source in several ways. Historically, anaerobic digesters burned biogas in electrical generators onsite or nearby with only minimal treatment of the biogas to remove impurities.[62] Due to the high costs of maintaining generators, digester operators have moved away from burning biogas in recent years and towards refining biogas for sale on the natural gas market.[63] Before it can be sold on the natural gas grid, biogas must undergo sufficient purification to remove all impurities except for methane.[64] Many facilities divert biogas for onsite energy usage.[65]

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58 David P. M. Zaks et al., *Contribution of Anaerobic Digesters to Emissions Mitigation and Electricity Generation Under U.S. Climate Policy,* 45 ENVTL. SCI. TECH. 6735, 6736 (2011).

59 *Anaerobic Digestion*, supra note 36, at 1–2.

60 Rapport et al., *supra* note 50, at 50.

61 *Id.*

62 *See* Catherine M.H. Keske, *Anaerobic Digestion Technology: How Agricultural Producers and the Environment Might Profit from Nuisance Lawsuits*, 52 NAT. RESOURCES J. 315, 318 (2012).

63 *Id.*

64 *Id.*

65 *See id.* (explaining that many small anaerobic digestion operations, such as farm-scale digesters that process the waste from a single client, will primarily utilize biogas for onsite purposes and do not intend to sell most, if any, of the energy produced).

E. Digestate Production

After the anaerobic bacteria finish digesting feedstock, a physical bi-product remains called digestate.[66] Digestate is rich in nutrients and can be used as an odor free fertilizer [67] or soil enhancer.[68] Unlike typical fertilizers, digestate is nearly free of pathogens, including those that may be harmful to plants, animals, and humans.[69]

III. HISTORICAL APPLICATION OF ANAEROBIC DIGESTION AS A WASTE MANAGEMENT TECHNOLOGY AND A SOURCE OF RENEWABLE ENERGY

Anaerobic digestion has been used in differing forms for thousands of years.[70] In the tenth century BCE, anaerobic digestion was used to heat bath water throughout the Middle East.[71] During the seventeenth, eighteenth, and nineteenth centuries, scientists investigated the decay of organic matter and came to a better understanding of how microorganisms produced methane.[72] In the mid-to-late 1800s, parts of Asia and Europe opened anaerobic digestion facilities that produced methane for municipal purposes such as fueling streetlights.[73]

During the late nineteenth century and early twentieth century, anaerobic digestion technology became more sophisticated.[74] Anaerobic activities were concentrated in closed, airtight tanks where waste was independently heated and mixed.[75] Worldwide interest in

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66 Lukehurst, *supra* note 17, at 4; Verma, *supra* note 5, at 9. Digestate is discussed in greater detail *infra* Part V.A.

67 *See* Cezary Andrzej Pieńkowski, *The Possibilities of Using Renewable Sources of Energy in Podlaskie Province*, 19 POLISH J. OF ENVTL. STUD. 537, 542 (2010).

68 Lukehurst, *supra* note 17, at 6.

69 *Id.*

70 Arthur Wellinger, Process Design of Agricultural Digesters 3 (Nov. 1, 1999) (unpublished manuscript), http://homepage2.nifty.com/biogas/cnt/refdoc/whrefdoc/d14prdgn.pdf.

71 *Id.*

72 *Id.*

73 IRISH EPA, VIEWPOINT, *Anaerobic Digestion*, 3 (September 2006).

74 *See* Wellinger, *supra* note 70, at 3–4.

75 Verma, *supra* note 5, at 12.

anaerobic digestion continued to increase as the technology became more efficient and productive.[76]

As fossil fuels became more plentiful and affordable, however, interest in developing large-scale anaerobic digestion facilities began to wane.[77] During World War II, interest in anaerobic digestion as a source of energy experienced a resurgence, particularly for farms and smaller-scale operations, when shortages in fossil fuels occurred due to the war.[78] Nevertheless, anaerobic digestion again fell out of the public's interest following the conclusion of World War II when coal and oil became more available.[79]

Interest in anaerobic digestion peaked again in the middle of the twentieth century as numerous countries saw an increasing need for the sound management of growing waste production.[80] Worldwide, landfill space became increasingly scarce, and populations became more aware of the hazards associated with the burial and incineration of waste.[81] As awareness of air pollution increased and became associated with fossil fuels, anaerobic digestion remerged as an attractive technology for the production of clean energy.[82]

Asia developed anaerobic digestion facilities at a considerable pace. This was particularly true in regions where population density, public health and hygiene, and environmental conservation necessitated alternatives to traditional waste management practices, such as landfilling and incineration.[83] China, India, and the nations of Southeast Asia experienced an accelerated growth of small-scale, "community" anaerobic digestion facilities designed to process

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76 *Id.*

77 *Id.*

78 Wellinger, *supra* note 70, at 4.

79 *Id.*

80 *See* TASNEEM ABBASI ET AL., BIOGAS ENERGY 14, 18 (2011).

81 *See generally* Daniel Weisberg, Comment, *Taking out the Trash – Where will we put all This Garbage?*, 10 PACE ENVTL. L. REV. 925 (1993) (discussing the rapid decline of space for landfills).

82 *See, e.g.*, *Briefing Anaerobic Digestion*, FRIENDS OF THE EARTH, 4-5 (Sept. 2007), http://www.foe.co.uk/resource/briefings/anaerobic_digestion.pdf (discussing benefits of anaerobic digestion as opposed to traditional energy sources).

83 *See* Verma, *supra* note 5, at 12.

municipal solid waste, animal and agricultural wastes, and food production wastes.[84]

These community-based digesters allowed citizens and farm cooperatives to manage waste in an organized and sanitary manner. This led to improved public hygiene and created a local, dependable source of energy. In fact, many villages in developing countries structured municipal electricity generation around the production of large quantities of biogas from anaerobic digestion facilities.[85]

While anaerobic digestion technology developed in Europe following World War II, it developed more slowly in the United States.[86] At the time, fossil fuels met the national energy need relatively easily and inexpensively.[87] In addition, engineering advancements in landfill design led to the development of landfills that created less pollution.[88] Landfills became larger and able to accommodate higher volumes of waste, making them more cost effective.[89] Because landfilling was inexpensive and convenient, European nations and the United States embraced landfills as a means of addressing increasing societal waste production.[90] This trend was especially pronounced in the United States where massive landfills were built capable of accepting tens of thousands of tons of municipal solid waste on a daily basis.[91]

Although advances in landfill technology made the burial of waste safer and more hygienic, landfilling began to fall out of favor during

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84 *Id.*

85 *Id.*

86 *Id.*

87 *See id.*

88 *See, e.g.*, Fresno Sanitary Landfill, http://historicfresno.org/nrhp/landfill.htm (last visited November 17, 2013) (discussing how post-war engineering improvements in landfill design, which included the construction of trenches and coverings that better contain waste and contaminants, resulted in landfills that were more sanitary and friendly to the environment).

89 *See id.* (noting that new techniques in landfill design and management, such as compaction, allowed landfills to accept more waste and become larger-scale operations).

90 *Id.*

91 *See, e.g.*, Thelma Gutierrez & George Webster, *Trash city: Inside America's largest landfill site*, CNN (Apr. 28, 2012, 11:10 AM), http://www.cnn.com/2012/04/26/us/la-trash-puente-landfill (discussing California's Puente Hills Landfill, which has operated since 1957 and receives 12,000 tons of waste daily).

the 1960s and 1970s.[92] Increased environmentalism and a growing awareness of the effects of pollution on public health led to a reassessment of industrial practices, and waste management was no exception.[93]

Europe and the United States began to look again at anaerobic digestion to avoid the hazards of landfilling, which included groundwater contamination, air pollution, and the harboring of disease and vectors.[94] Waste incineration also became less popular in Europe and the United States as awareness of acid rain and pollution-related illnesses increased.[95] Shortages of fossil fuels during the 1970s also created interest in the ability of anaerobic digestion to provide a reliable source of locally produced renewable energy.[96]

In Europe, per capita waste management through environmentally-friendly technologies such as anaerobic digestion, composting, and recycling has roughly doubled since 1995.[97] In 1999, the Council of the European Union adopted the Landfill Directive, which set landfill diversion milestones for member states over the course of fifteen years.[98] In particular, the Landfill Directive set 1995 as a benchmark year, requiring that European Union members reduce the organic fraction of waste that is landfilled by 25% within five years, 50% within eight years, and 65% within fifteen years.[99]

A number of European Union countries reached Landfill Directive milestones ahead of schedule and accepted organic diversion programs that were even more stringent.[100] For example, Germany capped the

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92 *See, e.g.*, ENG'G & ENVTL SERVS. SOLID WASTE & RECYCLING DEP'T, OUR LANDFILL LEGACY 3 (2004), http://library.oregonmetro.gov/files/landfill_legacy.pdf.

93 *See id.*

94 *See id.*

95 *Id.*

96 *See, e.g.*, Verma, *supra* note 5, at 12 (discussing how the energy crisis that occurred in the 1970s triggered a renewed interest in anaerobic digestion systems and how countries like India, China, and Southeast Asia responded to the crisis with marked expansion of anaerobic digestion systems).

97 Rapport et al., *supra* note 50, at 6. During this same time period, per capita waste production for Europeans actually increased, although landfill disposal rates nonetheless decreased. *See id.*

98 *See id.* (citing Council Directive, 1999/31/EC, 1999 O.J. (L 182) (EU)).

99 *Id.*

100 *Id.*

percentage of organic waste that may be buried by landfill at 18%.[101] Many European Union members also used the Landfill Directive as an opportunity to support research in anaerobic digestion technology.[102] As a result, anaerobic digestion technology improved considerably and became more economical throughout Europe.[103] Today, more than four million tons of organic waste are anaerobically digested in Europe on an annual basis.[104]

IV. THE MODERN HISTORY AND CURRENT STATUS OF ANAEROBIC DIGESTION IN THE UNITED STATES

In the United States, interest in anaerobic digestion, and an attendant optimism in its potential as a renewable energy source and waste management tool, peaked during the 1970s.[105] In the early 1970s, the United States experienced a severe energy crisis, marked by fuel shortages and uncertainty.[106] This crisis inspired Americans to seek energy sources beyond fossil fuels.[107] In particular, many farms became optimistic that local anaerobic digesters could be used to manage manure and other agricultural wastes while producing energy that could be used to power agricultural operations.[108] Many, if not most, of the anaerobic digesters constructed in the United States during the 1970s were built to serve agricultural waste producers.[109]

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101 *Id.* at 7 (citation omitted).

102 *See, e.g.*, DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS, ANAEROBIC DIGESTION STRATEGY AND ACTION PLAN 17 (2011) (Eng.).

103 *See* Rapport et al., *supra* note 60, 6–7 (discussing the impact of the Landfill directive on various countries).

104 Rapport et al., *supra* note 60, at 7. Spain alone processes over half of its organic waste through anaerobic digestion, much of which is processed at several large-scale anaerobic digestion centers. *Id.*

105 *See* Jennifer C. Fiser, *Legal and Policy Issues Related to Anaerobic Digestion at United States Livestock Facilities*, 3 KY. J. EQUINE, AGRIC. & NAT. RESOURCES L. 221, 225–26 (2011).

106 *Id.*

107 *Id.*

108 *Id.*

109 *See* Allison N. Hatchett, *Bovines and Global Warming: How the Cows Are Heating Things Up and What Can Be Done to Cool Them Down*, 29 WM. & MARY ENVTL. L. & POL'Y REV. 767, 803 (2005) (demonstrating that digesters could "kill two birds with one stone" by providing farmers with a cost-effective and efficient method to comply with regulations).

In 1978, to assist the fledgling renewable energy market, Congress enacted the Public Utility Regulatory Policies Act (PURPA).[110] PURPA required utility companies to purchase energy from qualifying producers, such as anaerobic digestion facilities, at rates that were "just and reasonable . . . [and] in the public interest."[111] PURPA also sought to prevent utility companies from discriminating against small energy producers such as anaerobic digestion facilities.[112] During the 1970s, approximately 140 anaerobic digestion facilities became operational throughout the United States.[113]

During the 1980s, anaerobic digestion declined in popularity for several reasons.[114] Anaerobic digestion facilities require considerable capital and operating costs, and for many facilities, these costs became insurmountable.[115] Many of the anaerobic digesters developed during the decade were intended to process agricultural wastes, and these digesters experienced economic infeasibilities due to economy of scale limitations.[116]

Another significant factor in anaerobic digestion's decline in popularity was the absence of an energy crisis.[117] As the price of fossil fuels dropped between the 1970s and 1980s, so too did the American public's interest in energy derived from anaerobic digestion.[118]

Perhaps the greatest contributing factor to anaerobic digestion's decline in the 1980s was the high rate of failure among anaerobic digestion facilities.[119] Poor technological designs, bad business management, and a lack of scientific and engineering knowledge among facility operators all contributed to the failure of anaerobic

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110 Fiser, *supra* note 105, at 225.

111 *Id.* (citing 16 U.S.C. § 824a-3(b) (2008)).

112 *Id.*

113 Hatchett, *supra* note 109, at 803.

114 *See* Fiser, *supra* note 105, at 225.

115 *Id.*

116 *Id.* (noting that economies of scale particularly impacted farm-scale digesters).

117 *Id.* at 226.

118 *Id.* The end of worldwide energy crises and subsequent drop in energy prices coincided with a diminished interest on the part of policymakers and utilities to guarantee minimum prices or favorable treatment for renewable energy and anaerobic digesters, which further discouraged expanding anaerobic digestion operations. *See id.*

119 *Id.*

digestion facilities.[120] A lack of governmental oversight on grant applications for anaerobic digestion projects exacerbated these problems; projects were generally not screened for economic feasibility or site suitability. Considerable tax money was invested in facilities doomed from the beginning—causing further erosion in support for anaerobic digestion among taxpayers and public officials.[121]

As a result of the numerous problems that the anaerobic digestion industry faced in the 1980s, approximately 85% of anaerobic digestion facilities in the United States were shut down or abandoned.[122] The construction of new anaerobic digestion facilities ground to a halt from the mid-1980s into the first half of the next decade.[123] By 1994, only 25 commercial anaerobic digestion systems were operating in the United States.[124]

During the second half of the 1990s, interest in anaerobic digestion reemerged in the United States for several reasons. At the outset, there was increased awareness of global warming and air emissions from intensive industries like agricultural producers and the energy sector, which contribute towards climate change.[125] There were also increased tensions between agricultural producers and neighboring landowners over agricultural odors, waste management, vector management, and hygiene.[126] The agricultural industry turned to anaerobic digestion to manage onsite odors and wastes to reduce conflicts with encroaching communities.[127]

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120 *Id.*

121 *See id.* at 226 n.44 (citing EPA, AGSTAR HANDBOOK: A MANUAL FOR DEVELOPING BIOGAS SYSTEMS AT COMMERCIAL FARMS IN THE UNITED STATES 1–6 (2004)); David Riggle, *Anaerobic Digestion Gets New Life on Farms*, EPA.GOV (Nov. 26, 2007), http://www.epa.gov/agstar/documents/Riggle_11_26_07.pdf.

122 Fiser, *supra* note 105, at 226.

123 *Id.*

124 Hatchett, *supra* note 109, at 803.

125 *Id.*

126 *See id.* at 229–30 (noting that anaerobic digestion is likely to become even more attractive to agricultural operations as they become more intensive—i.e. managing more numbers of livestock on less land—while simultaneously, surrounding lands become more urbanized and neighboring land owners become less tolerant of the odors and vectors associated with such industries).

127 *See id.*

Another reason for renewed interest in anaerobic digestion was the limitations in traditional waste management operations.[128] As increasing amounts of municipal solid waste were met by decreasing landfill space, Americans came to realize that the United States had a "solid waste crisis" on its hands.[129] Despite the growing amounts of waste, states faced "vocal citizen opposition [that] paralyzed the solid waste landfill siting process" and prevented the construction of new landfills.[130] In the 1990s, waste incinerators also fell out of public favor due to their adverse impact on local air quality.[131] Opposition to landfills and incinerators became so common during the 1990s that the acronym "NIMBY"—Not In My Backyard—became synonymous with local waste management planning.[132]

Perhaps the straw that broke the back of traditional waste management was a series of high profile United States Supreme Court cases holding that a variety of conservation-minded, environmentally-friendly waste management policies ran afoul of the Dormant Commerce Clause.[133] As one public administrator lamented in the aftermath of these decisions:

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[128] *Id.*

[129] Richard V. Houpt et al., *Report of the Subcommittee on Land Use and Solid Waste*, 23 URB. LAW. 753, 753–54 (1991).

[130] *Id.* at 754.

[131] *See id.* at 756 (referencing a National Governors Association task force report, issued in February 1990, stating that "many communities will no longer tolerate the construction of . . . incinerators" as a waste management option).

[132] *See* Jonathan P. Meyers, *Confronting the Garbage Crisis: Increased Federal Involvement As A Means of Addressing Municipal Solid Waste Disposal*, 79 GEO L.J. 567, 572 (1991).

[133] *See* Chem. Waste Mgmt., Inc. v. Hunt, 504 U.S. 334, 336–37 (1992) (invalidating Alabama's state law that imposed an extra per-ton surcharge on hazardous waste that entered Alabama for disposal); Fort Gratiot Sanitary Landfill v. Michigan Dep't of Natural Res., 504 U.S. 353, 355 (1992) (striking down a Michigan law that prevented a landfill from accepting waste shipments that originated outside of the county in which the landfill is located, unless the landfill were granted special permission to import waste by the county government); Oregon Waste Sys., Inc. v. Dep't of Envtl. Quality of the State of Oregon, 511 U.S. 93, 108 (1994) (holding that Oregon violated the "negative Commerce Clause" when it charged an extra $2.25 surcharge onto each ton of waste that was imported into the state for disposal); C & A Carbone, Inc. v. Town of Clarkstown, New York, 511 U.S. 383, 386 (1994) (holding that a town violated the Dormant Commerce Clause by having a "flow control" ordinance that directed all town waste to be processed at a single, private, designated

> Taken together, [these] Supreme Court cases . . . pose an immense challenge for public administrators, and reflect a fundamental paradox in U.S. waste policy: what is considered good law by the courts is not good public policy . . . . From a policy perspective, [] it is unwise, and severely ties the hands of local and state public administrators to implement prudent waste policy.[134]

Considering the problems caused by landfilling and the incineration of waste, it is not surprising that anaerobic digestion would pique the interest of waste managers, policymakers, and the general public.

The EPA's AgSTAR Program has also contributed to the interest and success of anaerobic digestion in recent years. AgSTAR is an outreach program that provides information and tools to help the nation's agricultural sector recover energy and manage wastes.[135] AgSTAR estimates that there are presently less than 200 anaerobic digestion facilities operating in the United States, and many of these facilities are farm-scale operations of severely limited scope.[136] AgSTAR estimates that anaerobic digestion could be successfully implemented at over 8,000 farms throughout the United States.[137] AgSTAR attributes "the low number of digesters actually in operation" to technical infeasibility at many sites, and financial infeasibility at many more locations.[138]

In the United States today, there is renewed interest in anaerobic digestion as a source of local, clean energy and as a waste

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facility before leaving the municipality). *See also* Philadelphia v. New Jersey, 437 U.S. 617, 629 (1978) (holding that flow control laws, which are laws that restrict the import or export of waste and recyclables within local governmental jurisdictions, violate the Dormant Commerce Clause). *But see* United Haulers Ass'n, Inc. v. Oneida-Herkimer Solid Waste Mgmt. Auth., 550 U.S. 330, 334 (2007) (ruling that the Dormant Commerce Clause was not violated when county governments sought to increase local recycling efforts by requiring that all county waste streams be processed at a local, public facility).

134 Rosemary O'Leary, *Trash Talk: The Supreme Court and the Interstate Transportation of Waste*, 57 PUB. ADMIN. REV. 281, 284 (1997).

135 *See AgSTAR Program*, U.S. ENVTL. PROT. AGENCY, http://www.epa.gov/agstar/about-us/index.html (last visited May 28, 2013).

136 *AgSTAR Program*, http://www.epa.gov/agstar/projects/index.html (last visited May 28, 2013).

137 *AgSTAR Program*, http://www.epa.gov/agstar/anaerobic/faq.html#q14 (last visited May 28, 2013).

138 *AgSTAR Program*, *supra* note 135.

management tool, although the current infrastructure of anaerobic digestion technology is significantly less than its potential.

V. Recommendations for Promoting and Increasing Anaerobic Digestion Technology in the United States

The United States would benefit considerably in terms of renewable energy production and environmentally-conscientious waste management if anaerobic digestion technology was more widely utilized. There are a number of hurdles, however, that the American anaerobic digestion industry must overcome before this technology can approach the levels of utilization present in Europe and Asia.

A review of literature on anaerobic digestion and recent surveys of anaerobic digestion professionals conducted by the author suggest that there is no single, "silver bullet" policy solution that would make anaerobic digestion technology successful in the United States. Rather, there are a number of impediments that cause anaerobic digestion to stumble as a viable waste management and energy production technology. If these stumbling blocks were removed, anaerobic digestion could pick up the pace and reach greater levels of utilization throughout the United States.

A. Requiring Source Separation at the Consumer Level

Perhaps the easiest, cheapest, and least controversial mandate that local governments could adopt to support anaerobic digestion technology is to require consumers to perform "source separation" of their wastes. "Source separation" is a simple requirement that households, businesses, and other consumers separate waste materials from recyclables before placing them out for collection.[139] More specifically, source separation requires organic waste to be separated from nonorganic waste by end-consumers before it is collected by waste services.[140]

Source separation provides several key advantages for anaerobic digestion programs that mixed-waste collection programs do not. First, mixed-waste collection requires that considerable pretreatment of the waste takes place at the anaerobic digestion facility, such as through

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139 Rapport et al., *supra* note 50, at xii (for example, residences and businesses could be required to place food wastes and yard wastes in separate containers away from nonorganic wastes such as glass, plastics, or metals).

140 *Id.*

the use of pass-through screens, magnetic sorters, or even through using personnel to hand-remove materials from a conveyor line.[141] Such pretreatment procedures create a considerable cost for the anaerobic digestion facility. Additionally, sorting equipment is prone to mechanical failure, and opportunities for mechanical failure lead to increased operational downtime for repair.[142] Source separation can minimize these costs.

Source separation is often more effective than what can be done at a plant. Even with sophisticated sorting equipment, a considerable amount of non-organic waste will pass through sorting and end up in the feedstock fed into the digester.[143] Such non-organic materials contribute toward the wear of anaerobic digester equipment and increase maintenance expenses. Inorganic materials also contribute to mechanical failures. Hence, source separation is an effective method for reducing the likelihood of breakdowns in anaerobic digestion technology.[144]

Perhaps the most underappreciated benefit that source separation provides for the financial viability of anaerobic digestion facilities has to do with digestate.[145] Digestate sales are an important component of a successful anaerobic digestion operation. Without markets for the sale of digestate, anaerobic facilities face difficulty remaining economically viable. Digestate contaminated by inorganic debris such as pieces of plastic or shards of glass is less marketable than manure, fertilizer, and other sources of nutrients. Furthermore, some states have strict regulations that proscribe contaminant values for land-applied nutrients, such as for compost, and these regulations may restrict the application of digestate that is contaminated with inorganic debris.[146]

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141 *Id.* at 66.

142 *See id.* at 6.

143 *See id.* at xii, 66.

144 *Id.*

145 *See* PEW CTR. ON GLOBAL CLIMATE CHANGE, ANAEROBIC DIGESTERS CLIMATE TECHBOOK, *supra* note 3, 8–9 (2011); *see also* E-mail from Earl Brubacher, Manager of Operations, Bio-en Power Inc., to author (May 27, 2013, 5:48 MST) (on file with author).

146 *See, e.g.*, WASH. ADMIN. CODE § 173-350-250 (Table 250-A(2)(b)(i)) ("[Facilities that distribute digestate must] sample and test digestate solids every 5,000 cubic yards or once per year, whichever is more frequent, to demonstrate it meets compost quality standards of WAC 173-350-220(4) (Table 220-B) before it is distributed for off-site use").

Without local requirements for source separation, even the most environmentally conscientious consumers will still see large quantities of their organic wastes sent for burial in a landfill because of the lack of options for collecting and processing wastes through anaerobic digestion. Furthermore, source separation ordinances may serve as an additional motivational factor that encourages consumers to take the extra step of separating organic wastes from inorganic materials as they prepare their trash for curbside collection.[147] Local source separation mandates are inexpensive for the consumer, not controversial, and would be an excellent first step in preparing communities for the eventual adoption of anaerobic digestion.

B. Bans on the Landfilling of Organic Wastes

Another policy that governments could implement to boost the local adoption of anaerobic digestion technology is to ban landfilling of organic wastes.[148] Several countries have implemented laws that prohibit the landfilling of organic waste, or laws that place a limit on the percentage of landfill-buried waste that is organic in nature.[149] These laws successfully direct disposal of wastes that would otherwise be landfilled towards anaerobic processing.[150] One industry professional has stated that greater restrictions on landfilling organic wastes would be a "big step" in the right direction, but would "require a major cultural shift in [America's] 'disposable culture.'"[151]

C. Improved Training and Certification Requirements for Anaerobic Digestion Operators

One of the main reasons why the United States experienced a wave of anaerobic digestion failures in the 1970s and 1980s was because

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147 In Germany, for example, citizens actively participate in their recycling and source separation efforts. *See* Marie Look, *Trash Planet: Germany*, EARTH 911, Jul. 13, 2009, http://earth911.com/news/2009/07/13/trash-planet-germany/ (citing the creation of the Duales System Deutschland GmbH, a non-profit organization in which companies purchase a membership so that all wastes produced having a "green dot" will be accepted, recycled and reclaimed by the member companies).

148 *See, e.g.*, Rachel Balsley, *Alameda County Bans Green Waste from Landfill*, STOPWASTE.ORG (Sep. 2009), http://www.stopwaste.org/docs/swp-pressarch/Green_Waste_ban_BOMA_nwsltr_Sep09.pdf.

149 E-mail from Eugene L. Smith, *supra* note 10.

150 *Id.*

151 *Id.*

facility operators were often uneducated in the requirements of anaerobic digestion technology, and therefore did not know how to properly manage anaerobic digestion systems.[152] Many of the failed anaerobic digestion systems in the United States were farm-scale operations managed by the farmers themselves. These farmers were not adequately trained in the operating parameters of the anaerobic digestion technology.[153]

In addition, many of these farmers treated their anaerobic digestion systems more as a repository for waste than as a technology for generating energy through the processing of organic wastes.[154] They did not place much priority on the around-the-clock management of the anaerobic digesters, ultimately leading to their financial collapse.[155] As one industry expert commented, “anaerobic digestion is a complicated biological process and needs to be supervised by professional people,” rather than by casual owners or operators, in order to be economically successful.[156]

In order to prevent another wave of anaerobic digestion system failures, policymakers should require training for anaerobic digestion facility managers and certification programs in anaerobic digestion technology. Such training and certification requirements for facility operators and managers would not be unique to the waste management industry.[157] This would ensure that anaerobic digestion system owners manage their facilities safely, correctly, and economically, ultimately reducing the likelihood of system failure.

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152 *See* E-mail from Poul Ejner Rasmussen, Managing Director and CEO, Renew Energy A/S, to author (May 27, 2013, 6:15 MST) (on file with author).

153 *Id.*

154 *Id.*

155 *Id.*

156 *Id.*

157 *See, e.g.*, John H. Turner, *Off to a Good Start: The RCRA Subtitle D Program for Municipal Solid Waste Landfills*, 15 TEMP. ENVTL. L. & TECH. J. 1 (1996) (discussing requirements for landfill operator and manager certifications); IOWA CODE § 455B.304 (2013) (promulgating rules for the training, testing, and certification for landfill and waste incinerator operators); Illinois Solid Waste Site Operator Certification Law, 225 ILL. COMP. STAT. 230/1007 (2012) (discussing educational and training requirements for operators of waste management facilities); Tennessee Solid Waste Management Act of 1991, TENN. CODE ANN. § 68-211-853 (2008) (discussing certification requirements for landfill personnel).

D. Direct Economic Assistance and Incentives for Energy Derived from Anaerobic Digestion

Perhaps the most important, but also the most controversial solution that American policymakers could implement to support anaerobic digestion is the provision of direct economic assistance and the creation of market incentives for energy derived from anaerobic digestion. Such programs are likely to be controversial and face resistance, at least in the short-term, because they may result in increased costs to energy producers and consumers upon implementation.[158] It is paramount to recognize that such "increased costs" are actually just an exposure and a realization of the hidden costs of using fossil fuels and other non-environmentally-friendly methods for producing energy.[159] Regardless of which form of governmental assistance or incentives for anaerobically-produced energy are adopted, the conventional wisdom of renewable energy economics suggests that anaerobic digestion will not get a foothold in the United States until policymakers become more involved in implementing programs for assistance.[160]

Many European governments provide direct financial assistance to renewable energy producers, including owners and operators of anaerobic digestion facilities, or have passed laws that otherwise create

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158 *See* W. Kip Viscusi, *Using Economics to Fuel Responsible Energy Consumption Decisions*, 38 ENVTL. L. REP. NEWS & ANALYSIS 10842, 10844 (2008) (arguing that the American public is generally opposed to increases in energy costs, even where such costs are related to reductions in environmental externalities); Karl S. Coplan, *Public Trust Limits on Greenhouse Gas Trading Schemes: A Sustainable Middle Ground?*, 35 COLUM. J. ENVTL. L. 287, 302 (2010) (noting that increased taxes or other costs enacted to mitigate carbon emissions remain unpopular).

159 *See* Viscusi, *supra* note 158, at 10844 (describing the societal externalities of pollution).

160 *See, e.g.*, Hilary Kao, *Beyond Solyndra: Examining the Department of Energy's Loan Guarantee Program*, 37 WM. & MARY ENVTL. L. & POL'Y REV. 425, 507 n.114 (2013) (discussing how renewable energy programs, such as those involving wind energy, have benefitted from loan programs where the government provides capital and shares in some of the financial risks that the private sector is unwilling to accept because the renewable energy technologies are too new, novel, or unproven); Heidi Willers, *Grounding the Cape Wind Project: How the FAA Played into the Hands of Wind Farm Opponents and What We Can Learn from It*, 77 J. AIR L. & COM. 605, 620 (2012) (discussing how wind energy programs in the United Kingdom required the assistance of governmental policies and funding in order to be successful).

incentives for the production of clean energy.[161] Such governmental involvement in the energy market has proven to be imperative to the success of anaerobic digestion in Europe.[162] For example, Germany provides renewable energy producers with guaranteed retail electricity rates.[163] Regulations in Europe have also required utilities to provide renewable energy producers with connections to the energy grid.[164] A number of European Union member states also provide subsidies, favorable loans, and other direct financial assistance to anaerobic digestion facilities.[165] European anaerobic digesters are also allowed to sell carbon credits and green certificates.[166]

Many anaerobic digestion experts believe that anaerobic digestion will not achieve success in the United States unless it can benefit from feed-in-tariffs.[167] Feed-in-tariffs are "legislatively mandated rates that an electric utility must pay renewable energy producers over a guaranteed period of time to cover the cost of energy production and

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161 *See, e.g.*, Willers, *supra* note 160 (discussing how the British government enacted policies and provided financial support in order to help the development of renewable energy projects); Anatole Boute, *Combating Climate Change Through Investment Arbitration*, 35 FORDHAM INT'L L.J. 613, 624 (2012) (discussing how the "European experience" shows that the success of renewable energy programs depends upon the commitment of the public sector to support such programs, and further explaining that the level of private sector investment in renewable energy is influenced by the level of public sector commitment to renewable energy development).

162 *See generally* Luc De Baere & Bruno Mattheeuws, *Anaerobic Digestion of the Organic Fraction of Municipal Solid Waste in Europe – Status, Experience and Prospects*, *in* WASTE MANAGEMENT: RECYCLING AND RECOVERY, VOL. 3 517–526 (2012).

163 Rapport et al., *supra* note 60, at 7.

164 *Id.*

165 *Id.*

166 *Id.* "Green certificate is an incentive scheme put in place by the European Union. It is made to incentive the market of renewable energies and is made to compensate the difference of investment costs of those technologies." Didier Varlot, *Are Green Certificate the Same Thing Than Carbon Credit*, Smart Energies (Mar. 17, 2012), http://smartenergies.wordpress.com/2012/03/17/are-green-certificate-the-same-thing-than-carbon-credit/. "Carbon credits are related to Kyoto agreement and all the mechanisms put in place to incentive the reduction of carbon emissions." *Id.*

167 Bradley Motl, Comment, *Reconciling German-Style Feed-in-Tariffs with PURPA*, 28 WIS. INT'L L.J. 742, 745–46 (2011).

provide a reasonable profit."[168] Under a basic feed-in-tariff framework, a renewable energy producer has the right and ability to connect to the electrical grid, and will then be guaranteed a modest profit that is location and technology specific, with premium rates being provided to specially-promoted energy projects.[169] Feed-in-tariffs also provide long-term contracts and assurances for green energy sales in order to promote confidence and predictability for the renewable energy producers and lenders, which are periodically reviewed in order to ensure that the rates are fair to both the green energy producers and the electricity ratepayers.[170]

An American feed-in-tariff program for anaerobic digestion could dramatically improve the viability of anaerobic digestion in the United States, primarily because it would provide stability and predictability in guaranteeing sufficient returns on investment.[171] In fact, experts have opined that feed-in-tariffs are a superior form of assistance over one-time grants and other short-term financial aid, because these latter programs do not provide investors with the long-term guarantees and predictability that anaerobic digestion operations require.[172] For feed-in-tariff programs to successfully work in the anaerobic digestion arena, their rules need to be clear, consistent, and not prone to governmental tinkering or frequent changes.[173]

Supporters of anaerobic digestion should also encourage lawmakers to enact policies that will allow anaerobic digestion technology to "compete successfully with conventional energy," which includes "forcing the consumer to pay the true and full cost of

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168 *Id.* at 745.

169 *Id.*

170 *Id.* at 745–46.

171 *See, e.g.*, E-mail from Dr. Largus Angenent, Associate Professor of Biological and Environmental Engineering, Cornell University, to author (May 26, 2013, 6:23 MST) (on file with author) (stating that feed-in-tariffs are the "answer" to all questions about the financial viability of anaerobic digestion in the United States); E-mail from Torsten Fischer, Business Director, Krieg & Fischer Engineering LLC, to author (May 25, 2013, 21:47 MST) (on file with author) (stating that the enactment of a renewable energy law which would guarantee a sufficient energy price for biogas producers is the only way to advance anaerobic digestion in the United States).

172 E-mail from Clare Riepma, *supra* note 14.

173 *Id.*

electricity."[174] If American consumers became fully aware of the externalities that polluting sources of energy caused, such as in the form of increased healthcare costs and damage to infrastructure—i.e. corrosion from acid rain—then "normal market forces would [come into] play" and anaerobic digestion could take its place in the market.[175] Many other forms of energy are highly subsidized—unbeknownst to the general public—such as ethanol,[176] and anaerobic digestion supporters could lobby their officials to subsidize anaerobic digestion in similar manners.

E. Simplifying the Regulatory Landscape

A frequent criticism from anaerobic digestion professionals is that regulations in the United States are unclear, and regulatory approval processes are cumbersome.[177] Making anaerobic digestion regulations more straightforward—and perhaps more in line with similar, more established programs such as composting[178]—would help to encourage anaerobic digestion in the United States.

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174 *Id.*

175 *Id.* One excellent example of externalities and "hidden" or "unknown" costs to the public involves nuclear energy. Although nuclear energy has enjoyed increasing popularity as of late as a comparatively cheap energy source that produces little, if any, greenhouse gases, the true, long-term costs of the energy are difficult to fully calculate and very likely will create externalities that must be borne by future generations. If Americans today realized the "full" costs of nuclear energy, they might not be as supportive of this energy source, which would then open the door for more understood and predictable sources of renewable energy such as anaerobic digestion. *See, e.g.*, David H. Topol, *Rethinking Who Is Left Holding the Nation's Nuclear Garbage Bag: The Legal and Policy Implications of Nevada v. Watkins*, 1991 UTAH L. REV. 791, 833–35 (1991) (discussing how it is difficult to calculate and compensate for the various costs associated with nuclear energy, such as those involving the long-term storage of spent fuel).

176 *See, e.g.*, Zachary M. Wallen, Note, *Far From a Can of Corn: A Case for Reforming Ethanol Policy*, 52 ARIZ. L. REV. 129, 134–142 (2010). *See also* E-mail from Poul Ejner Rasmussen, *supra* note 127. It should be noted that although ethanol is highly subsidized and more relied-upon in American energy production than anaerobic digestion, "it is much more efficient and also less expensive to produce the same energy volume" through biogas derived from the anaerobic digestion process. *Id.*

177 E-mail from Earl Brubacher, Manager of Operations, Bio-en Power Inc., to author (May 27, 2013, 5:48 MST) (on file with author).

178 *Compare* CAL. CODE REGS. tit. 14, §§ 17850–95 (2013) (regulating California residential and commercial composting), *with* CAL. INTEGRATED WASTE MGMT.

The anaerobic digestion industry is not entirely innocent in the matter. It has not engaged in the same degree of lobbying activities with lawmakers to the extent of other energy sectors, most notably fossil fuels and other renewable energies like wind power and solar power. It is imperative that anaerobic digestion supporters engage in more lobbying to prevent their industry from going unnoticed.[179]

VI. CONCLUSION

Anaerobic digestion is a technology that provides local, reliable, renewable energy through a process that disposes of the abundant trash produced by society each day. Anaerobic digestion is widely-used throughout the world, yet remains relatively unknown and underutilized in the United States. The author hopes that this Article has stimulated interest in developing an American market for anaerobic digestion by providing industry, policymakers, and the public with information on how anaerobic digestion works and its benefits to the environment and the economy. By analyzing the problems that have historically stymied anaerobic digestion's adoption in the United States, and providing recommendations for improvement, this Article has shown how to remove the hurdles faced by anaerobic digestion in the United States so that it can flourish into a viable and stable source of clean energy.

BD., HOW ANAEROBIC DIGESTION FITS CURRENT BOARD REGULATORY STRUCTURE iii, 12–17 (2009), http://www.calrecycle.ca.gov/Publications/Documents/Organics/2009021.pdf (discussing additional regulatory requirements for California anaerobic digesters including those of the Regional Water Quality Control Board and requirements of local air pollution agencies).

179 E-mail from Eugene L. Smith, *supra* note 10.