Anaerobic Digestion: Greenhouse Gas Emission Reduction and Energy Generation

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Summary

Anaerobic digestion technology may help to address two congressional concerns that have some measure of interdependence: development of clean energy sources and reduction of greenhouse gas emissions. Anaerobic digestion technology breaks down a feedstock—usually manure from livestock operations—to produce a variety of outputs including methane. An anaerobic digestion system may reduce greenhouse gas emissions because it captures the methane from manure that might otherwise be released into the atmosphere as a potent greenhouse gas. The technology may contribute to the development of clean energy because the captured methane can be used as an energy source to produce heat or generate electricity.

Anaerobic digestion technology has been implemented sparingly, with 151 anaerobic digestion systems operating nationwide. Some barriers to adoption include high capital costs, questions about reliability, and varying payment rates for the electricity generated by anaerobic digestion systems. Two sources of federal financial assistance that may make the technology more attractive are the Section 9007 Rural Energy for America Program of the Food, Conservation, and Energy Act of 2008 (2008 farm bill, P.L. 110-246), and the Renewable Electricity Production Tax Credit (26 U.S.C. §45).

Congress could decide to encourage development and use of the technology by (1) identifying the primary technology benefit, so as to determine whether it should be pursued in the framework of greenhouse gas emission reduction or clean energy development; (2) determining if the captured methane will count as a carbon offset; and (3) considering additional financing options for the technology.

This report provides information on anaerobic digestion systems, technology adoption, challenges to widespread implementation, and policy interventions that could affect adoption of the technology.

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Introduction

An anaerobic digestion system (AD system) captures the methane that may otherwise be released from conventional manure handling methods, and has the potential to reduce greenhouse gas emissions and produce clean energy. Absent such technology, confined animal feeding operations typically collect and store manure (e.g., in a waste storage facility) under anaerobic conditions, which produces the potent greenhouse gas methane. The methane is released into the atmosphere as the manure decomposes while being stored. Livestock producers handle large quantities of manure on a daily basis that emit methane.[1] Some estimate that livestock operations produce more than a billion tons of manure yearly[2] and that 0.7% of total U.S. methane emissions are from managed manure.[3] Through methane capture, anaerobic digestion has the potential to reduce these emissions.

In addition, anaerobic digestion of manure produces biogas—a combination of methane, carbon dioxide, and trace amounts of other gases that can be used for renewable energy purposes or flared.[4] Recent legislation pertaining to agricultural sources of renewable energy has focused primarily on corn-based ethanol and cellulosic ethanol for liquid fuel purposes, and not biogas.[5] The economic environment is not currently favorable to profit from the investment required to compress biogas[6] produced from an AD system into a liquid fuel. There are, however, several successful cases where an engine-generator set has been used to generate electricity from the biogas or the biogas is burned in a boiler to produce heat. Biogas from an AD system could be used to assist livestock producers in an effort to have an energy self-sufficient operation as well as, potentially, to sell electricity to the local utility.

There are 151 AD systems operating nationally (see **Figure 1**). Some factors that may be responsible for the low technology adoption rates are high capital costs, reliability concerns, and payment rates for the electricity generated. Congress may consider encouraging increased adoption of the technology by (1) identifying the primary technology benefit, so as to determine whether AD should be pursued in the framework of greenhouse gas emission reduction or clean energy development; (2) determining if the captured methane will count as a carbon offset; and (3) considering additional financing options for the technology. Moreover, Congress may receive insight on collaborative techniques by monitoring the first public-private partnership agreement between the U.S. Department of Agriculture and the Innovation Center for U.S. Dairy to reduce

[1] For example, the amount of manure excreted from one lactating dairy cow is estimated at 150 pounds per day based on the American Society of Agricultural and Biological Engineers (ASABE) Manure Production and Characteristics Standard D384.2, March 2005.

[2] Amanda D. Cuellar and Michael E. Webber, "Cow Power: The Energy and Emissions Benefits of Converting Manure to Biogas," *Environmental Research Letters*, vol. 3 (2008).

[3] The agriculture sector was responsible for roughly 6% of all U.S. greenhouse gas emissions in 2008, approximately 11% of which is attributable to methane emissions from managed manure. U.S. Environmental Protection Agency, *2010 U.S. Greenhouse Gas Inventory Report*, EPA 430-R-10-006, April 2010, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

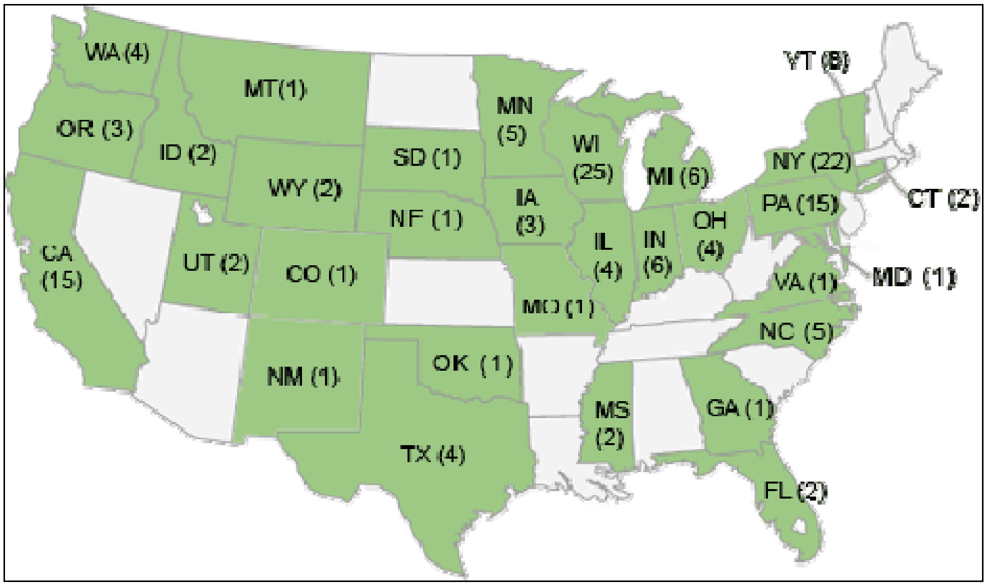
[4] Flaring is the combustion of gas without commercial purposes. Flaring emits fewer greenhouse gases than simply releasing the biogas as is into the atmosphere. See the "Biogas Quality and Use" section for additional details.

[5] For more information on agriculture-based renewable energy, see CRS Report RL34130, *Renewable Energy Programs in the 2008 Farm Bill*, by Megan Stubbs, CRS Report RL34738, *Cellulosic Biofuels: Analysis of Policy Issues for Congress*, by Kelsi Bracmort et al., and CRS Report RL32712, *Agriculture-Based Renewable Energy Production*, by Randy Schnepf.

[6] Biogas consists of 60%-70% methane, 30%-40% carbon dioxide, and trace amounts of other gases.

greenhouse gas emissions from dairy operations by 25% by 2020.[7] One goal of the agreement is to "accelerate and streamline the process for adopting anaerobic digesters by the United States dairy farm operators through various USDA programs."[8]

Figure 1. Operational Anaerobic Digesters



Source: Environmental Protection Agency, 2010. The AgSTAR Program. http://www.epa.gov/agstar/accomplish.html.

Notes: The AgSTAR Program is a voluntary effort jointly sponsored by the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, and the U.S. Department of Energy. The program encourages biogas capture and utilization at animal feeding operations that manage manures as liquids and slurries.

This report provides information on AD systems, technology adoption, and challenges to widespread technology implementation, and explores the issues facing Congress concerning adoption of the technology.

What Is an Anaerobic Digestion System?

Most manure management systems used on livestock operations store the manure in an open facility, allowing the manure to decompose naturally, which releases the potent greenhouse gas methane into the atmosphere. By contrast, an AD system feeds manure into a digester that breaks it down in a closed facility in the absence of oxygen (see **Figure 2**). The digested feedstock[9] is contained for a period of time[10] as anaerobic bacteria decompose the manure to produce several

[7] U.S. Department of Agriculture, "Agriculture Secretary Vilsack, Dairy Producers Sign Historic Agreement to Cut Greenhouse Gas Emissions by 25% by 2020," press release, December 15, 2009, http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2009/12/0613.xml.

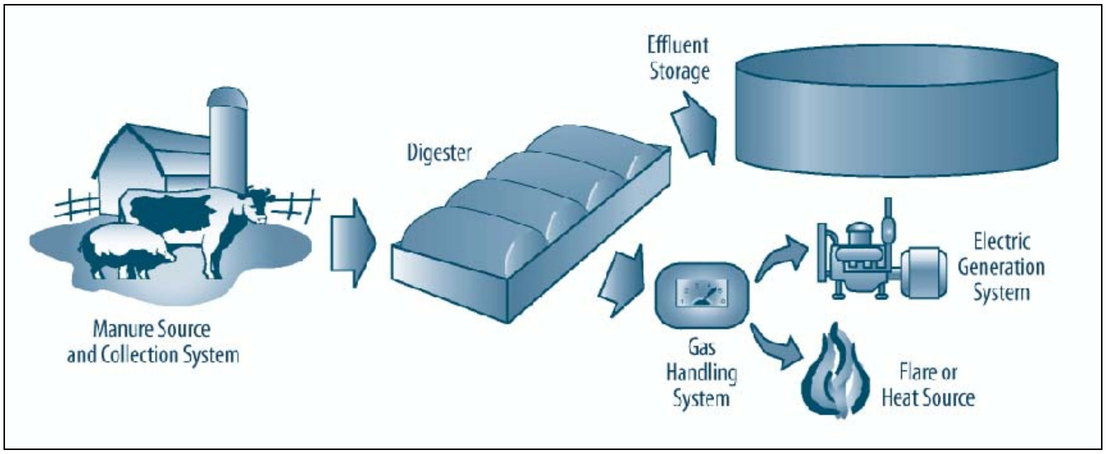
[8] *Memorandum of Understanding between the United States Department of Agriculture and The Innovation Center for U.S. Dairy*, December 15, 2009, http://www.usda.gov/documents/FINAL_USDA_DAIRY_GHG_AGREEMENT.pdf.

[9] The feedstock is usually manure, but can also include other organic matter. The digestion of two or more types of organic matter is referred to as co-digestion.

[10] The time required for the manure to be treated is referred to as the hydraulic retention time (HRT). HRT is normally expressed in days.

outputs, including biogas, liquid effluent, and dry matter. The captured biogas is flared (see footnote 4) or used for energy. The liquid effluent may be applied to the land as a fertilizer. The digested dry matter may be sold as a soil amendment product or used for animal bedding. AD systems have other benefits (e.g., odor reduction) that may curb negative impacts of livestock operations, including environmental pollution.[11]

Figure 2. Anaerobic Digestion System Schematic



Source: U.S. EPA, The AgSTAR Program.

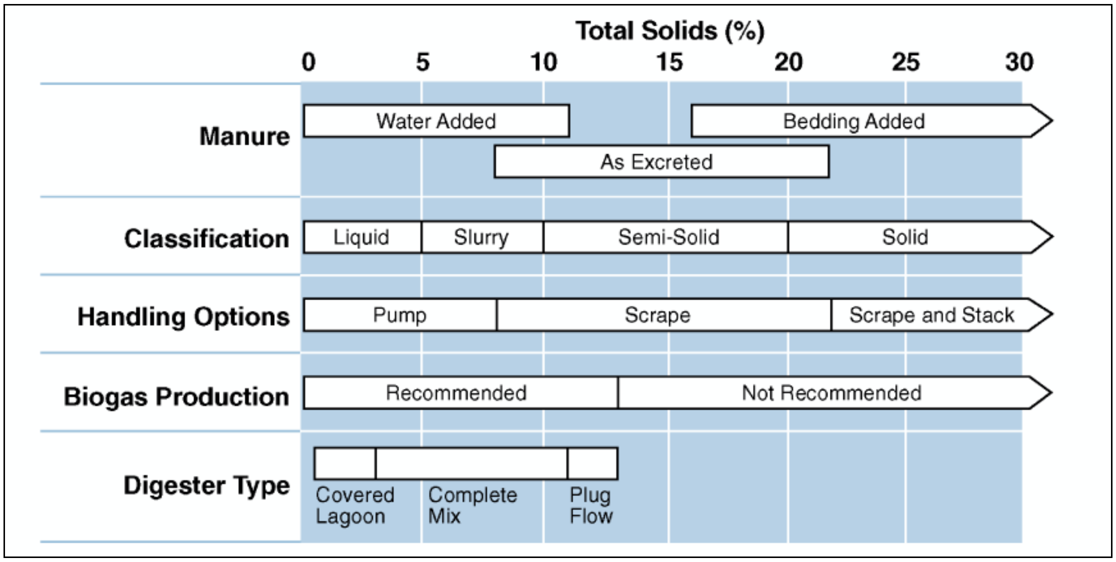
An AD system is designed and constructed to suit the needs of an individual livestock operation and is typically selected based on the total solids (TS) content[12] of the manure and the manure handling system (see **Figure 3**). Other criteria taken into consideration when building an AD system include the feedstock quantity, feedstock quality, feedstock availability, feedstock handling, demand for effluent, use of captured biogas, and transportation logistics (e.g., feedstock may be transported to an AD system if it is not available on-site, or effluent transported to a receiving entity if not used on-site).

AD systems in the United States are in use on dairy cow, swine, and poultry operations. More than 80% of the operating AD systems are located on dairy cow operations. Some argue that less complex AD systems could be constructed on dairy cow operations at a lower cost and that the manure could be easily transported to the AD system, thus making them more economically appealing. Others contend that fewer AD systems are installed on swine operations because many swine operations currently store liquid manure in pits beneath the livestock; the producer would need to redesign the swine operation to incorporate an AD system. Installation of an AD system on a swine operation may also be more expensive if a storage facility must be constructed to contain the digested feedstock. Some assert that AD systems are not a favorable addition to a poultry operation partly because the litter is dry and may require more resources for transport to an AD system and additional inputs to digest.

[11] For more information on environmental issues facing the livestock community, see CRS Report RL32948, *Air Quality Issues and Animal Agriculture: A Primer*, by Claudia Copeland, and CRS Report RL33691, *Animal Waste and Hazardous Substances: Current Laws and Legislative Issues*, by Claudia Copeland.

[12] Total solids content for manure is the amount of solid material remaining after all moisture has been removed from a sample.

Figure 3. Manure Characteristics and Handling Systems for Specific Types of Anaerobic Digestion Systems



Source: U.S. Environmental Protection Agency, *Managing Manure with Biogas Recovery Systems: Improved Performance at Competitive Costs*, EPA-430-F-02-004, 2002, http://www.epa.gov/agstar/pdf/manage.pdf.

Three Common AD System Types Found in the United States

Covered lagoon AD system:

- Usually an earthen structure containing manure affixed with a flexible geosynthetic cover (e.g., high density polyethylene).
- Typically operated at ambient temperature.
- Biogas production may occur seasonally when weather is warmer.
- Ideal for manure with 0.5%-2% TS content.
- Time required to treat manure ranges from approximately 30 to 60 days.
- Low capital costs.

Plug flow AD system (see **Figure 4**):

- Usually a rectangular concrete tank affixed with a flexible geosynthetic cover.
- Digestion occurs in a plug fashion where the digested manure exits the system as raw manure enters the system.
- Heated structure.
- Ideal for manure with 11%-13% TS content.
- Time required to treat manure ranges from approximately 18 to 20 days.

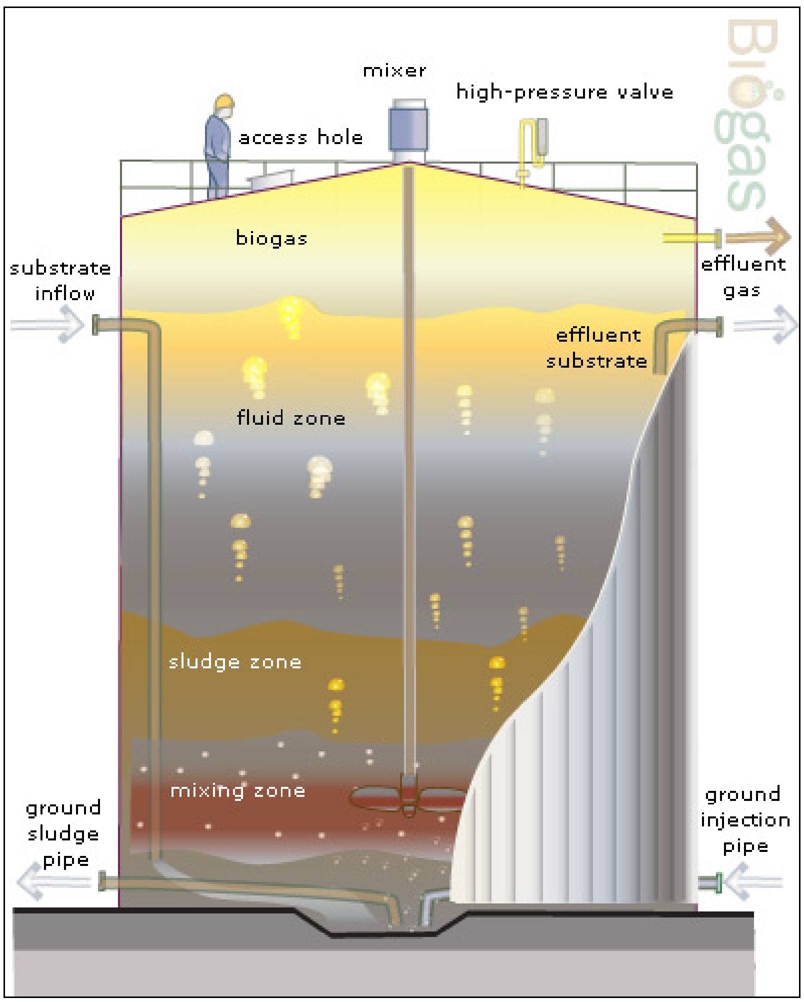
Complete mix AD system (see **Figure 5**):

- Usually a round concrete or steel tank.
- Heated structure.
- Capable of digesting a range of feedstock with varying total solids content.
- Ideal for manure with 3%-10% TS content.
- Time required to treat manure ranges from approximately 5 to 20 days.
- High capital costs.

Figure 4. Plug Flow AD System

Source: EPA, The AgSTAR Program.

Figure 5. Complete Mix AD System Schematic



Source: Renewable Energy Association.

Characteristics of Anaerobic Digestion Systems

Methane Capture

Methane (CH_4) is one of the primary greenhouse gases associated with the agricultural sector.[13] The odorless, colorless, flammable gas is potent because it is 21 times more effective at trapping heat in the atmosphere than carbon dioxide (CO_2) over a 100-year timeframe.[14] In other words, it takes 21 tons of CO_2 to equal the effect of 1 ton of CH_4. Methane has a relatively short atmospheric lifetime (approximately 12 years) when compared to the atmospheric lifetime for carbon dioxide, which has a half-life of roughly 100 years; thus some argue that efforts to capture methane from anthropogenic sources may provide near-term climate change abatement.

Major sources of methane emissions from animal agriculture are enteric fermentation[15] and manure management (see **Table 1**). While enteric fermentation emissions are much larger than manure management emissions, they are also much more difficult (nearly impossible) to control. Emission factors[16] affiliated with methane released from enteric fermentation, and conversion factors[17] affiliated with methane released from a manure management system, are used to estimate overall methane emissions from animal agriculture. Estimation incorporates a multi-step process that takes into account livestock population data, waste characteristics, waste management system data, and other variables.

Table 1. Methane Emissions from Animal Agriculture (Tg CO_2e)

Source	2006	2007	2008
Enteric fermentation	139.0	141.2	140.8
Manure management	42.3	45.9	45.0

Source: Environmental Protection Agency, 2010 U.S. Greenhouse Gas Inventory Report.

Notes: Select values obtained from EPA, 2010 U.S. Greenhouse Gas Inventory Report, Table 6-1. A teragram (Tg) is equivalent to 1 trillion grams. A Tg CO_2e (teragram of carbon dioxide equivalent) is a principal unit of measurement across greenhouse gases. Agricultural activities and livestock emit an assortment of greenhouse gases in various quantities given numerous factors. CO_2e is used to compare greenhouse gases emitted from different sources on the same basis.

Capturing methane with an AD system is beneficial because it reduces emissions of a harmful greenhouse gas from an agricultural source of methane: managed manure (e.g., manure stored in pit storage, an anaerobic lagoon, or a storage facility).[18] Swine and dairy cattle are the two

[13] For additional information on agricultural greenhouse gas emissions, see CRS Report RL33898, *Climate Change: The Role of the U.S. Agriculture Sector*, by Renée Johnson. For more information on methane capture, see CRS Report R40813, *Methane Capture: Options for Greenhouse Gas Emission Reduction*, by Kelsi Bracmort et al.

[14] The IPCC Second Assessment Report issued in 1996 assigned methane a Global Warming Potential of 21. Global Warming Potential is an estimate of how much a greenhouse gas affects climate change over a quantity of time relative to CO_2, which has a GWP value of 1.

[15] Enteric fermentation is the production and release of methane via eructation (burping) and flatulence as ruminant animals digest their feed.

[16] The amount of methane produced by an animal expressed per mass unit for one year (kg CH_4/head/year).

[17] The potential amount of methane produced from a manure management system for a given animal expressed in percent. The factor for dry manure management systems may vary according to climate.

[18] Manure that is not managed (e.g., manure deposited in a pasture from livestock grazing) has low methane emissions, but relatively high nitrous oxide emissions. The greenhouse gas nitrous oxide is 310 times more effective at trapping heat in the atmosphere than carbon dioxide over a 100-year timeframe.

dominant livestock emitters of methane for managed manure (see **Table 2**). Emissions from managed manure vary on a statewide basis depending on the livestock population and the manure handling systems in place (see **Figure 6**).

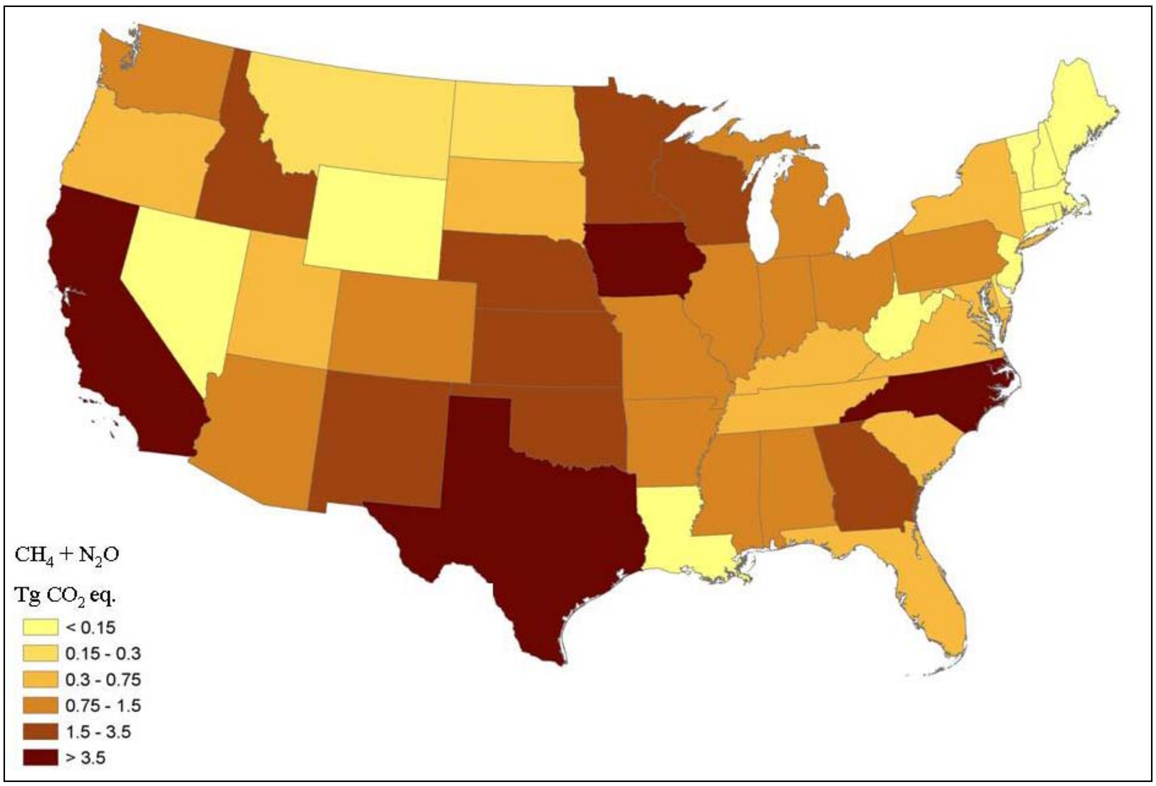
Table 2. Methane Emissions from Manure Management (Tg CO_2e)

Animal Type	2006	2007	2008
Swine	18.5	20.1	19.6
Dairy cattle	17.5	19.5	19.4
Poultry	2.7	2.7	2.6
Beef cattle	2.6	2.6	2.5
Horses	0.9	0.9	0.8
Sheep	0.1	0.1	0.1
Goats	+	+	+

Source: Environmental Protection Agency, 2010 U.S. Greenhouse Gas Inventory Report.

Notes: Select values obtained from EPA, 2010 U.S. Greenhouse Gas Inventory Report, Table 6-6. The + symbol denotes a value that does not exceed 0.05 Tg CO_2e. A Tg CO_2e (teragram of carbon dioxide equivalent) is a principal unit of measurement across greenhouse gases. Agricultural activities and livestock emit an assortment of greenhouse gases in various quantities given numerous factors. CO_2e is used to compare greenhouse gases emitted from different sources on the same basis.

Figure 6. Greenhouse Gas Emissions (Methane and Nitrous Oxide) from Managed Waste in 2005



Source: USDA, U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005.

Captured methane may qualify as a carbon offset because the methane would no longer be released directly into the atmosphere. Carbon offsets[19] are a facet of the climate change cap-and-trade program debate currently underway in the 111th Congress. Accurate quantification and verification of the methane captured from an AD system requires robust data, observed or inferred, to ensure that actual reductions are occurring as projected.

Biogas Quality and Use

Another AD system benefit is the production of biogas, which can be used as a renewable energy source. Biogas consists of 60%-70% methane, 30%-40% carbon dioxide, and trace amounts of other gases (e.g., hydrogen sulfide, ammonia, hydrogen, nitrogen gas, carbon monoxide). Biogas can be explosive if exposed to air, depending on the concentration of methane in a confined space. The quality (i.e., heat value) and amount of biogas produced varies based on the hydraulic retention time of the AD system, the manure total solids content, and temperature.

Biogas can be used to produce heat or generate electricity. The biogas may be burned in a boiler for space heating or water heating on-site. Another option is to use an engine-generator set to create electricity from the biogas. Biogas that is upgraded to pipeline quality[20] may be sold to a natural gas utility. Typically a producer will decide on only one use for the biogas—either generating electricity or producing heat—due to the expense associated with energy generation and boiler equipment. Few choose to sell the biogas to a natural gas utility.[21]

If electricity is generated from the captured biogas, it may be sold to a utility in addition to its on-site use.[22] A rule of thumb is that manure from approximately five Holstein milking cows supplies fuel for 1 kilowatt capacity.[23] Sales to a utility require a contractual agreement between the producer and the local utility provider that typically outlines safety, reliability, and performance standards. Additionally, any federal and state environmental requirements must be met (e.g., AD system generators may have to meet Best Available Control Technology[24] requirements). Net metering,[25] a preferred form of billing for many renewable electricity generators, is an option for producers selling the electricity generated to electric utilities in 43 states.[26]

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[19] A carbon offset is a measurable reduction, avoidance, or sequestration of GHG emissions from a source not covered by an emission reduction program. For more information on carbon offsets, see CRS Report RL34705, *Estimating Offset Supply in a Cap-and-Trade Program*, by Jonathan L. Ramseur, and CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns*, by Jonathan L. Ramseur.

[20] Pipeline quality is achieved by the removal of carbon dioxide and other contaminants so that only the methane is sold to the natural gas utility.

[21] Elizabeth R. Leuer, Jeffrey Hyde, and Tom L. Richard, "Investing in Methane Digesters on Pennsylvania Dairy Farms: Implications of Scale Economics and Environmental Programs," *Agricultural and Resources Economics Review*, vol. 37, no. 2 (October 2008), pp. 188-203.

[22] The quality of the biogas, measured by its Btu value, necessary to generate electricity varies depending on the engine.

[23] Wisconsin Focus on Energy, *Farm Anaerobic Digesters: Producing Energy from Waste*, REN2003-0709, 2009, http://www.focusonenergy.com/files/document_management_system/renewables/farmenergyfrommanure_factsheet.pdf.

[24] Best Available Control Technology (BACT) is a pollution control standard mandated by the Clean Air Act.

[25] Net metering is an energy metering method that uses a bidirectional meter, thus allowing the meter to run backwards if a customer generates more electricity than being consumed.

[26] Interstate Renewable Energy Council , *Map of state net metering rules*, 2010, http://www.dsireusa.org.

Biogas may be used as a fuel if it contains at a minimum a 50% concentration of methane (CH_4).[27] The biogas must be cleaned, upgraded, and compressed if it is to be used in a mobile engine. Cleaning biogas removes hydrogen sulfide. Removing any moisture and carbon dioxide upgrades the biogas and increases the British thermal unit (Btu) value.[28] With an energy content of 600 Btu/ft^3 for biogas with approximately a 60% methane concentration, biogas is a low-Btu fuel compared to other fuels (see **Table 3**). A high-Btu fuel is necessary for energy applications requiring greater amounts of power.

Table 3. Energy Content for Select Fuels

Fuel	Energy Content
Biogas[a]	600 Btu/ft^3
Natural gas	1,000 Btu/ft^3
Propane	92,000 Btu/gallon
Diesel fuel	138,000 Btu/gallon
Coal	25,000,000 Btu/ton

Source: James C. Barker. *Methane Fuel Gas from Livestock Wastes: A Summary*. North Carolina State University Cooperative Extension Service, EBAE 071-80, 2001.

a. Assumes a 60% methane concentration.

Biogas is flared if not used for energy purposes. Flaring the biogas destroys the methane and yields the greenhouse gas carbon dioxide (CO_2) and water.[29] Carbon dioxide has a longer atmospheric lifetime (~100 years) and is less effective at trapping heat in the atmosphere when compared to methane, which has an approximate atmospheric lifetime of 12 years. Some view the release of the carbon dioxide due to biogas flaring as more environmentally acceptable than releasing unused biogas into the atmosphere.[30] Environmental impacts of flaring methane require further investigation to determine flare efficiency under varying wind speeds and various biogas compositions.

U.S. Adoption of Anaerobic Digestion Technology

Federal funding (discussed in the following section) has supported the installation of 151 AD systems nationwide, operating with a total energy production of approximately 374,000 megawatt-hours (MWh) in 2009.[31] These AD systems restricted roughly 900,000 metric tons of

[27] Jenifer Beddoes, Kelsi Bracmort, and Robert Burns et al., *An analysis of energy production costs from anaerobic digestion systems on U.S. livestock production facilities*, USDA Natural Resources Conservation Service, October 2007.

[28] A Btu (British thermal unit) is a unit of energy used to express the heating value of fuels.

[29] Stoichiometric equation for biogas combustion: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

[30] According to the California Climate Action Registry, *Livestock Project Reporting Protocol Version 2.1*, August 2008, the CO_2 released from flaring the biogas is considered biogenic and therefore more environmentally acceptable. See http://www.climateregistry.org/resources/docs/protocols/project/livestock/CCARLivestockProjectReportingProtocol2.1.pdf.

[31] U.S. Environmental Protection Agency, The AgSTAR Program, online *AgSTAR Digest*, spring 2009. One megawatt-hour (MWh) is equivalent to 1,000 kWh. The energy generated could provide approximately 33,887 average homes with electricity for one year assuming the average residential home uses 11,040 kWh on a monthly basis. EIA estimates (continued...)

carbon dioxide equivalent (CO_2e) in direct emissions from entering the atmosphere, which is comparable to the annual greenhouse gas emissions from approximately 172,000 passenger vehicles.[32]

Startup Financing

Congress as well as states have enacted legislation that provides financial assistance for AD system installation. Loans, grants, tax credits, tax exemptions, and production incentives are common financial assistance tools available at the federal and state levels.[33] One principal source of federal funding is the Section 9007 Rural Energy for America Program (REAP) of the Food, Conservation, and Energy Act of 2008 (2008 farm bill, P.L. 110-246).[34] Section 9007 authorizes $255 million in mandatory funding for 2009-2012, with an additional $25 million per year in discretionary funding. For FY2009, $55 million is available, part of which is to be distributed to eligible applicants for AD system projects. Grants dispensed to applicants are not to exceed 25% of the cost of the activity. Loan guarantees dispensed to applicants are not to exceed $25 million. The maximum amount of a combined loan and grant can be no more than 75% of the cost of the activity. Approximately $40 million in loans and grants from Section 9006 of the 2002 farm bill was allocated for the construction of AD systems.

Another source of financial assistance offered for anaerobic digestion projects is the Renewable Electricity Production Tax Credit (REPTC; 26 U.S.C. §45).[35] The REPTC grants a one cent per kilowatt-hour tax credit for electricity generated from open-loop biomass (e.g., agricultural livestock waste nutrients).[36] The tax credit period is five years for an open-loop biomass facility using agricultural livestock waste placed in service after October 22, 2004, and before August 9, 2005. The tax credit period is 10 years for a facility placed in service after August 8, 2005.

Anaerobic Digestion Obstacles

Some technology deployment and adoption barriers exist because of the complexity involved in designing and operating an AD system. Thus far, a significant number of successful AD systems

(...continued)

that the average annual electricity consumption for a U.S. residential utility customer in 2008 was 11,040 kWh.

[32] Passenger vehicle estimate computed using the EPA Greenhouse Gas Equivalencies Calculator available at http://www.epa.gov/rdee/energy-resources/calculator.html#resultshttp://www.epa.gov/solar/energy-resources/calculator.html. Calculation based on 2007 average fuel economy assumptions and average vehicle miles traveled at 20.4 mpg and 11,720 miles per year, respectively. Additional information on passenger vehicle calculation available at website provided.

[33] For a comprehensive list of AD system financing tools, visit the EPA AgSTAR Program Federal Incentives for Developing Anaerobic Digester Systems, at http://www.epa.gov/agstar/pdf/agstar_federal_incentives.pdf; and consult the EPA AgSTAR Funding Database website at http://www.epa.gov/agstar/resources/funding.html document.

[34] REAP is an extension of the Farm Security and Rural Investment Act of 2002 (2002 farm bill, P.L. 107-171).

[35] For more information on renewable energy policy, see CRS Report R40999, *Energy Tax Policy: Issues in the 111th Congress*, by Donald J. Marples and Molly F. Sherlock, and CRS Report R40412, *Energy Provisions in the American Recovery and Reinvestment Act of 2009 (P.L. 111-5)*, coordinated by Fred Sissine.

[36] For more information about the Renewable Electricity, Refined Coal, and Indian Coal production credit visit http://www.irs.gov/pub/irs-pdf/f8835.pdf

are operated by producers who have sophisticated anaerobic digestion technology knowledge. Some assert that the technology will reach its full potential when an array of concerns are addressed. Some challenges include:[37]

- *Lack of economic return*. AD systems are capital-intensive.[38] The cost fluctuates depending upon the system type, system size, livestock operation type, and factors specific to the site. Capital costs generally include the AD system cost, the engine-generator set, the engineering design process, and installation. Extra costs are incurred for additional elements (e.g., a post-digestion solids separator, utility and interconnection fees). System costs range from a few hundred thousand dollars to a few million dollars.[39] A covered lagoon AD system could cost at a minimum a few hundred thousand dollars.[40] A complete mix AD system or plug flow AD system can cost a few million dollars. An analysis of 38 AD systems indicates that approximately one-third of the total system cost is estimated to be spent on the electrical generation equipment.[41] A producer may find it feasible to forgo producing electricity to save money and to use the biogas produced on-site for heating purposes, which still requires a boiler. A general approximation is that 300-500 head for a dairy cow operation and 2,000 head for a swine operation is the minimum number of head necessary to produce electricity with an AD system at a possible profit.[42]
- *Reliability*. Some argue that producers hesitate to adopt anaerobic digestion technology due to the poor performance rate observed in the 1970s. AD system performance has improved over time due to better engineering, construction materials, and management. Communicating current performance rates may provide producers with the information needed to gain more confidence in the improved technology. AD system performance data may be expanded with mandatory reporting on a periodic basis by an independent third party, which might bolster performance claims made by some AD system construction companies. Information (e.g., demonstration projects, long-term performance records) that communicates recent performance may mitigate producers' doubts about technology reliability and may verify energy generation and greenhouse gas emission reduction data reported.[43] Some producers and construction

[37] No relative importance is intended by the order in which challenges are listed.

[38] William F. Lazarus, *Farm-Based Anaerobic Digesters as an Energy and Odor Control Technology: Background and Policy Issues*, USDA Office of the Chief Economist Office of Energy Policy and New Uses, Agricultural Economic Report Number 843, February 2008, http://www.usda.gov/oce/reports/energy/AnerobicDigesters0308.pdf.

[39] AgSTAR Program, *Estimating Anaerobic Digestion Capital Costs for Dairy Farms*, February 2009, http://www.epa.gov/agstar/pdf/conf09/crenshaw_digester_cost.pdf.

[40] Assuming the producer is only purchasing the cover and the biogas recovery equipment to add to an existing lagoon.

[41] Jenifer Beddoes, Kelsi Bracmort, and Robert Burns et al., *An analysis of energy production costs from anaerobic digestion systems on U.S. livestock production facilities*, USDA Natural Resources Conservation Service, October 2007.

[42] U.S. Environmental Protection Agency, *Market Opportunities for Biogas Recovery Systems*, EPA-430-8-06-004; The Minnesota Project, *Profits from Manure Power*, http://www.mnproject.org/pdf/AD%20economics.pdf; Wisconsin Focus on Energy, Farm anaerobic digesters: producing energy from waste, REN2003-0709, 2009, http://www.focusonenergy.com/files/document_management_system/renewables/farmenergyfrommanure_factsheet.pdf.

[43] For an example of reporting criteria to communicate technology performance, see John H. Martin, *A Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures*, January 2007.

companies are opposed to a national reporting program because of the release of potentially proprietary information.

- *Lack of an engineering practice standard.* A national practice standard that lists performance criteria, safety precautions, technical components, and design elements and has undergone review from a standards developing organization is not available for anaerobic digestion technology. Some producers may be reluctant to make a financial investment in a technology that may or may not meet future environmental and technical requisites. The USDA Natural Resources Conservation Service (NRCS) issued a revised anaerobic digester conservation practice standard in 2009.[44]
- *Utility collaboration.* Rates paid by utilities for the electricity generated from AD systems vary by state and within each utility. It may not be economically attractive for a producer to sell the renewable energy generated depending on the cost per kilowatt-hour offered. Some net-metering agreements pay wholesale rates instead of retail rates for the electricity generated, thus limiting potential profitability. Some gas utility companies may be reluctant to accept a renewable energy fuel originating from a technology with no official standard that may contaminate an otherwise clean energy source.
- *Unquantifiable co-benefits.* Certain benefits (e.g., odor reduction) may not be quantifiable in dollar terms but may add to the value of an AD system.
- *Operation and maintenance.* AD systems perform optimally when they are well maintained. Some estimate that daily AD system operation and maintenance may require 30 minutes to an hour. The producer may have to acquire a level of technical expertise not previously necessary.

Issues for Congress

The 111th Congress is faced with proposed legislation centered on clean energy and climate change mitigation. There may be an opportunity for the agricultural community, particularly the livestock industry, to participate in forthcoming efforts for energy generation and greenhouse gas emission reduction with anaerobic digestion technology. Prior to incorporating anaerobic digestion technology into legislation, Congress may choose to consider:

- *Identifying the primary benefit offered by an AD system.* Selecting a primary benefit (renewable energy generation or greenhouse gas emission reduction) may assist with determining which policy vehicle could support technology deployment (e.g. energy legislation, climate change legislation, agricultural legislation). A single message regarding the technology benefit may encourage producers to adopt the technology to achieve the policy goal.
- *Determining if the methane captured from the technology will be included as a carbon offset.* The climate change debate underway in the 111th Congress includes carbon offsets as a potential greenhouse gas emission reduction strategy.

[44] The conservation practice standard must be adhered to for AD systems that will be constructed with financial or technical support from USDA NRCS. Conservation practice standards are provided at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Producers may find it economically worthwhile to invest in AD technology if it produces an additional revenue source in the form of carbon offsets. If the methane captured and combusted is not treated as a carbon offset, will the 111th Congress consider regulating the methane captured as a pollutant?

- *Identifying whether alternate sources of financial support for technology implementation are appropriate.* Most of the federal financial assistance available comes in loans and grants for AD system construction. A shorter payback period for an AD system may occur if producers receive a more substantial monetary sum for the energy generated and transferred to a utility company via a federal electricity rate premium. Additional tax credits may also improve the economic return for AD technology (e.g., raising the tax credit value for agricultural livestock waste nutrients to that of closed-loop biomass for the Renewable Electricity, Refined Coal, and Indian Coal Production Credit).

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