BIOMASS ENERGY TRAINING CURRICULUM

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This curriculum was developed through a Southern SARE grant and collaboration between Tennessee State University, the University of Tennessee, eXtension.org, and USDA-Rural Development.

The objective of this curriculum is to provide training on biomass energy to extension agents and local officials so that they may deliver this information to their stakeholders.

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Biomass Energy Training Curriculum

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Part I: Introduction to Biomass Energy

Anaerobic digestion

Learning objectives:

- Participants will be able to explain the process of anaerobic digestion
- Participants will be able to explain how anaerobic digestion can be used on the farm to produce energy

Materials:

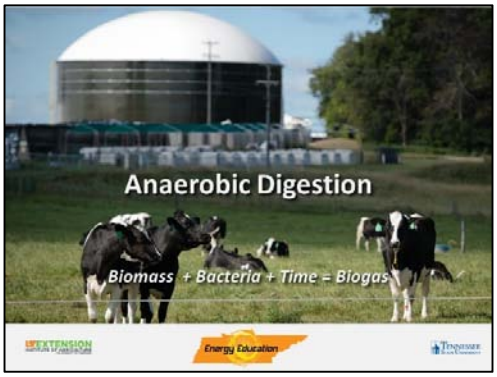
- PowerPoint® slides "Anaerobic digestion"
- Lesson guide: Use the notes in this lesson guide to present information for each presentation slide.
- Questions found at the end of this lesson guide can be used to test participants' knowledge at the end of the presentation. This can be combined with clickers to improve audience engagement and create discussion.
- An evaluation of the presentation can be found in this lesson guide following the lesson questions.

Topics:

Definition and process
Feedstocks for anaerobic digestion
Components of anaerobic digestion systems
Producing energy from anaerobic digestion
How to build a system
Uses of biogas from anaerobic digestion

Slide 1

This presentation will focus on the use of anaerobic digestion to turn wastes, like manure, into energy. The animal requirements and systems used will be discussed in detail.



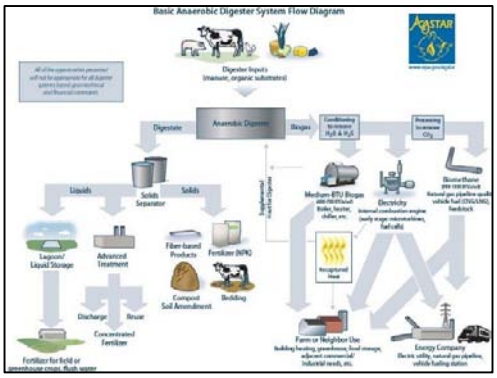
Slide 1

Slide 2

Anaerobic digesters use bacteria in an oxygen-free environment to break down biomass into usable methane gas and other products.

This diagram depicts the various types of anaerobic digester systems and ways to utilize the biogas (methane) and digestate (solids and liquids) from the digesters.

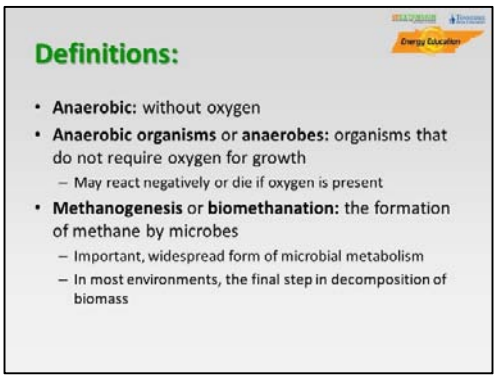
The system you might use will depend on the feedstock type and daily volume, as well as ways you can utilize the methane and other products.



Slide 2

Slide 3

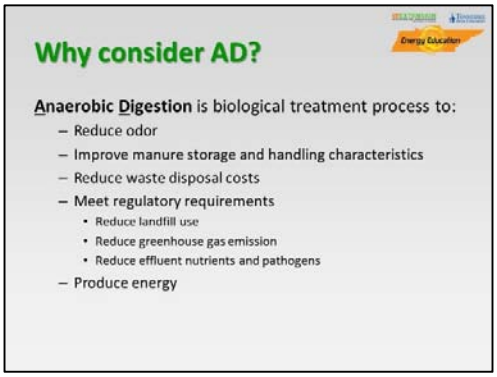
Anaerobic digestion is a natural process that takes place in an oxygen-free environment.



Slide 3

Slide 4

Anaerobes (bacteria that live without oxygen) consume and digest biological materials, giving off methane, carbon dioxide, hydrogen sulfide and other gases. The digestate that remains is a mixture of liquids and solids with a reduced nutrient value, making it less damaging to the environment than the original feedstock might be.



Slide 4

The main reasons to use anaerobic digestion are to reduce odor and disposal costs of wastes such as manure and food processing wastes. This can also help meet regulatory requirements for things like reducing landfill space and greenhouse gas emissions. As a bonus, the biogas produced can be used as an energy source for heating, electricity production and transportation fuel.

Slide 5

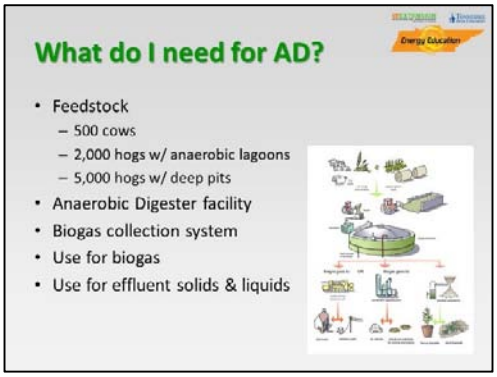
Any biological material can be digested. However, materials with high energy or nutrient value yield higher gas production.

An important need is a steady and consistent supply of feedstock for the digester. For that reason, operations like dairies, food processing plants and municipal waste water treatment plants work well.

Slide 5

Slide 6

Anaerobic digesters on farms are typically found on large operations, with 500 or more cows. While smaller systems will certainly work, and you can find small home-built digesters on the Internet, the economics of scale favor larger systems.

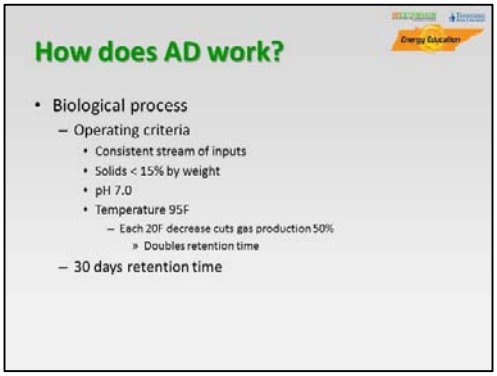


Slide 6

Slide 7

As mentioned earlier, anaerobic digestion is a natural biological process for breaking down wastes into useful products.

The process works best with a steady, consistent feedstock and consistent operating conditions. For example, allowing the digester to cool from 90F to 70F can cut gas production in half. The process needs about 30 days to complete, so allowing the system to cool by 20 degrees can double retention time.

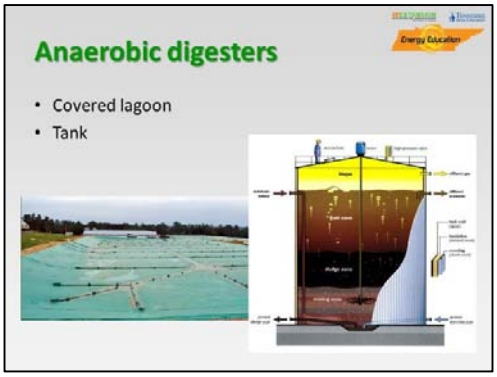


Slide 7

Slide 8

Two basic types of construction are covered lagoons and tanks. Each has its advantages and disadvantages.

Lagoons are simple and can be built large enough to handle large waste streams. However, the lagoon must be lined to prevent seepage of wastes into groundwater, and membrane covers must be maintained. Lagoons will also cool during winter and have reduced gas production and longer retention times.



Slide 8

Insulated tanks can be used on smaller land areas, and the temperature can be maintained for optimum performance. Leaks can be easily identified before environmental damage occurs. But, tank digesters must be insulated and maintained to prevent corrosion damage and insulation damage. Entering a tank is also a deadly confined space job requiring special training, safety harnesses, and at least 2 supplied-air respirators (1 for the person entering the tank, and one for the required assistant at the opening to monitor the job and provide emergency assistance).

Slide 9

The wastes fed into the digester as a slurry are broken down to liquids and solids that can be used in a variety of ways.

Slide 9

In agricultural settings, the liquid is normally applied to land as irrigation water containing nutrients, reducing the need for commercial fertilizer.

Note that if you are using an anaerobic digester, your operation is probably large enough to be considered a confined animal feeding operation (CAFO) which will require an approved comprehensive nutrient management plan (CNMP). This will require testing the liquid for its nutrient value and making applications that do not exceed the soil test recommendations, and it must not create runoff.

Another use of the liquid might be as flush water in the manure handling system, reducing the need for fresh water.

In some cases, such as food processing plants, the waste liquid is may be sent to the minucipal sanitary sewers. But, because the levels of biological materials and nutrients in the water is reduced, the disposal costs are reduced.

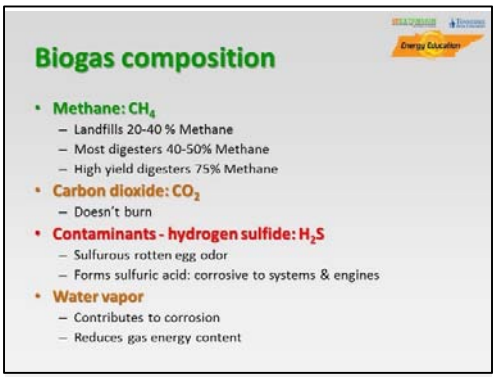
Slide 10

Solids may be used as a soil amendment, dried and used as bedding or used to manufacture products such as seed germination pots, etc.

Slide 10

Slide 11

The gas of most interest from anaerobic digesters is methane (CH_4), which is the same as natural gas. However, the gas is a mixture of useful methane, water vapor (H_2O), corrosive hydrogen sulfide (H_2) and nonflamamble carbon dioxide (CO_2). Depending on your feedstock, there may also be other harmful compounds in the gas.

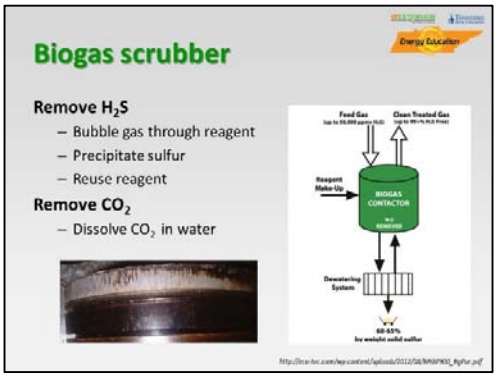


Slide 11

While you can burn the gas as-is, removal of H_2S, CO_2 and H_2O will improve performance of the engine, boiler or other devices utilizing the gas.

Slide 12

Hydrogen sulfide is a toxic gas with a rotten egg odor. When burned in an engine, it can form acids that break down the lubricants and lead to serious engine damage.



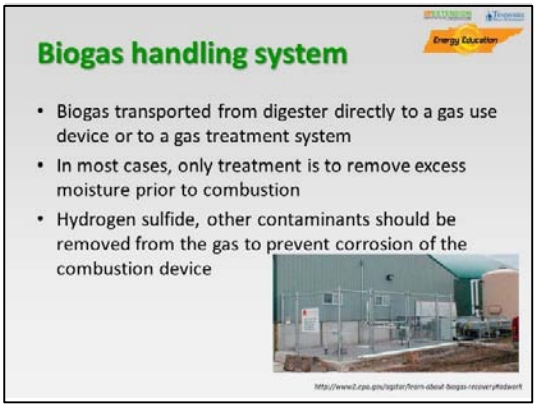
Slide 12

Carbon dioxide simply reduces boiler or engine efficiency because it displaces methane in the fuel system, and it is nonflammable. Removing CO2 produces a more energy dense fuel supply.

Fortunately, both of these gases are relatively simple to scrub from the biogas, and the sulfur captured from the system can be used as a fertilizer ingredient or other uses.

Slide 13

Gas scrubbing / treatment systems are designed for the intended uses of the biogas.



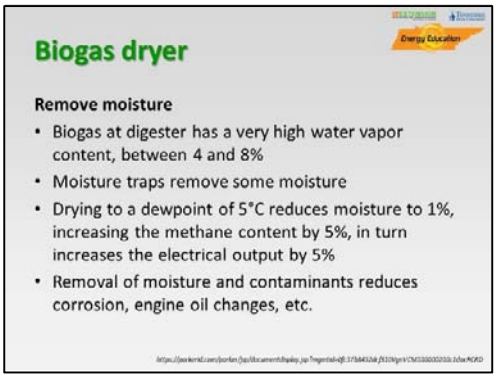
Slide 13

Slide 14

Water vapor in the biogas reduces it energy density, and water also contributes to corrosion in the biogas pipes and tanks.

Cooling the biogas will condense some of the water vapor to liquid that can be drained from the system.

If the biogas can be cooled to 40F, it will reduce moisture to 1% and increase generator output by 5%.



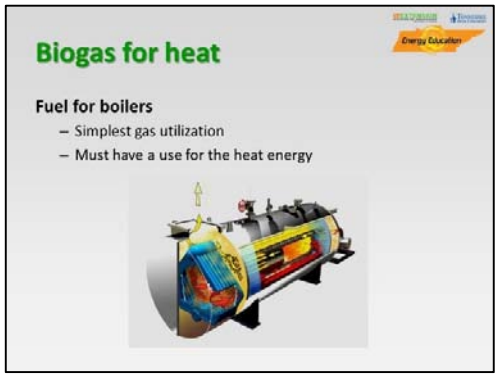
Slide 14

Slide 15

The simplest use of biogas is to fire a boiler for heating water or structures.

Scrubbing the moisture and contaminants from the biogas will improve boiler efficiency, and increase the service life by reducing corrosion.

But, burning biogas for heat may not be a viable option for most users, because you must have a need for large amounts of heat year-round.

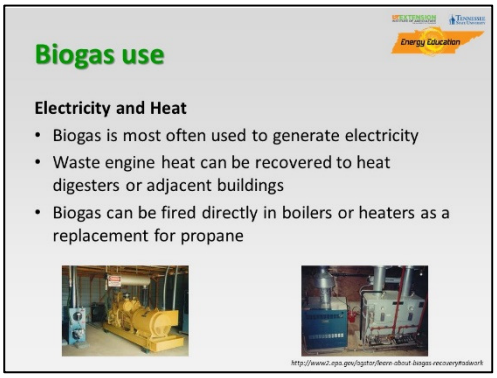


Slide 15

Generating electricity is often a better choice, because electricity can be sold onto the utility grid and used 24/7.

Slide 16

Follow material on presentation slide.



Slide 16

Slide 17

Biogas can also be used to power generators, producing both electricity and heat. These pictures depict small to very large Caterpillar generator sets designed for biogas fuels. For perspective, the 4,300 kW generator set has an engine of over 6,000 horsepower and can power more than 3,000 homes (assuming 1,000 kWh per month per home, typical for Tennessee).

Slide 17

Electricity would typically be sold directly onto the utility grid, the same as for solar photovoltaic energy, with a power production agreement through the electric utility. Assuming a wholesale power rate of $0.04 per kilowatt-hour, a 100 kW generator would produce $4.50 per hour in electricity sales, or about $2,880 per month. The two 250kW generators running at one biomass to energy facility might generate about $14,400 per month in electricity sales.

The waste heat from the engine coolant can be used to heat water and structures, or to heat the digesters in cold weather.

Slide 18

Another logical use of the gas is to scrub it and compress it for use in vehicles. Compressed natural gas (CNG) can be 3,000 to 6,000 psi, so specialized equipment is needed. But, this will become easier as more vehicles and fueling systems are introduced.

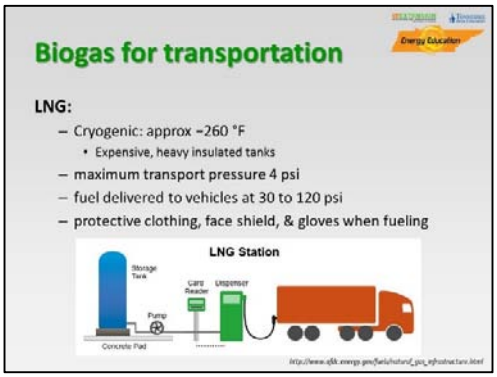
Slide 18

A recent introduction is the New Holland biogas-powered tractor. The diesel engine has been modified with a spark ignition system and natural gas fuel system configured for biogas, and the machine delivers the same performance as the diesel version.

Slide 19

Liquid natural gas (LNG) is a cryogenic liquid at about -260F temperature, requiring expensive, heavy insulated tanks. Equipment to produce LNG from biogas will be very expensive and not likely to be found at farms and homes.

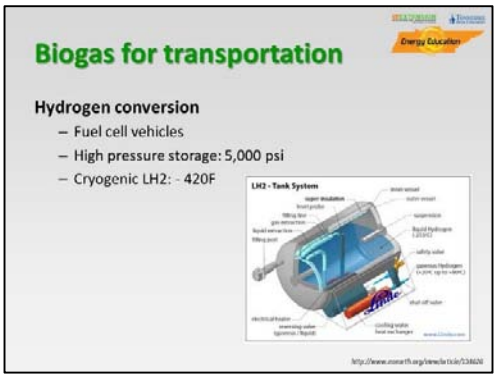
Larger users may be able to justify the cost of the equipment and vehicle conversions. For example, UPS is using LNG to power many of the over-the-road tractor-trailer rigs.



Slide 19

Slide 20

Another possible use of methane is to convert it to hydrogen gas than can be used to power hydrogen fuel cells. This is another technology that is not likely to be adopted on a small scale due to complexcity and costs. Hydrogen storage requires very high pressure cylinders or cryogenic storage at 160 degrees colder than LNG.



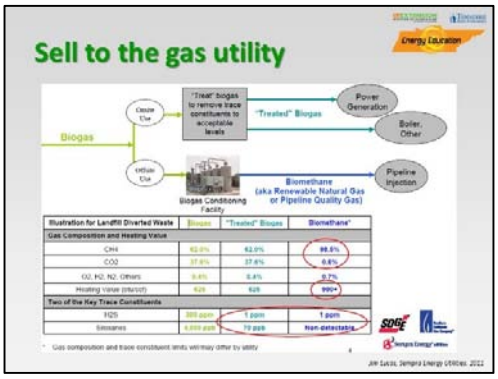
Slide 20

Slide 21

Another use biogas is to scrub it sell it to the local natural gas utility.

This is an option only if there is a natural gas distribution very near the digester system.

Utility gas requires a much greater level of gas treatment or conditioning than is necessary for on-site uses. It will also require a means of injecting the odorants to make gas leaks detectable by smell, and routine sampling to assure proper gas quality.



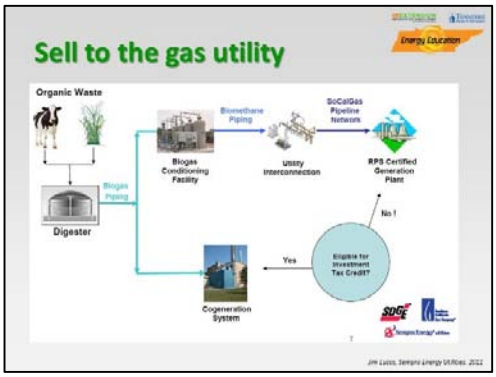
Slide 21

In this example of landfill gas, notice that the levels of CO_2, H_2S and siloxanes for utility gas are reduced by more than 98% from the levels acceptable for treated gas used on-site.

Slide 22

The tax incentives are another consideration for renewable fuels utilization.

Use of biogas to power generators is eligible for tax incentives, grants and loans, while utility use does not qualify.

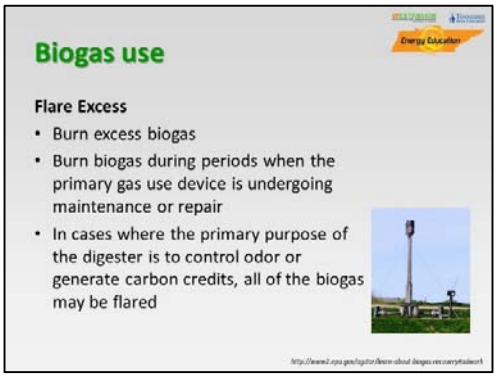


Slide 22

Slide 23

Flaring excess gas is undesirable because it generates no revenue. However, flaring may be required when excess gas is produced or when generators are offline for maintenance and repair.

Do not simple vent biogas to the atmosphere, though, because methane is a more potent greenhouse gas than carbon dioxide.



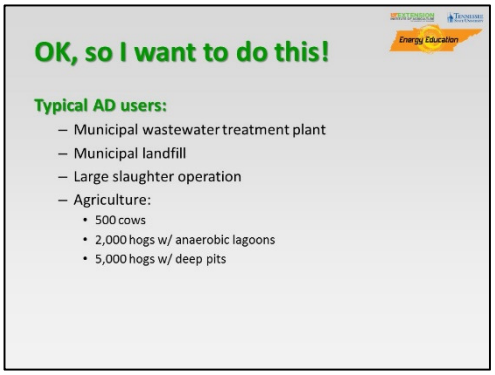
Slide 23

Slide 24

OK, so you want to install an anaerobic digester system?
First, ask yourself if you have enough waste feedstock every day to feed the system.

It is reported that at least 500 cows is needed for a system to be economically viable, but some suggest as many as 2,000 cows might be needed.

Based on these numbers, there are very few farms in Tennessee that might be able to consider anaerobic digestions for manure management.



Slide 24

Slide 25

Is your manure handling system compatible with anaerobic digestion?

A slurry or semi-solid manure mixture with 5-20% solids is most compatible.

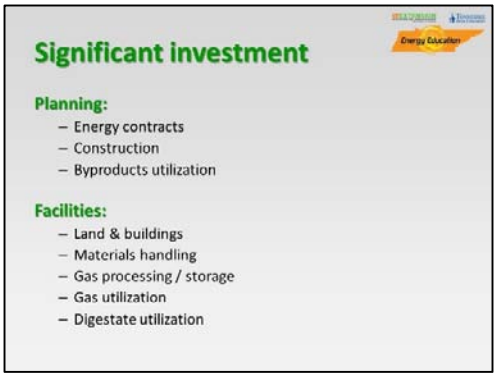
Thinner or mixtures and manure that has been dried are not as suitable for biogas production.

Slide 25

Slide 26

Next, consult with engineers that have installed successful systems similar in size to your proposed system.

This will require a lot of planning and engineering design work. You should not even think about moving ahead until you have all these aspects of the system resolved.



Slide 26

Slide 27

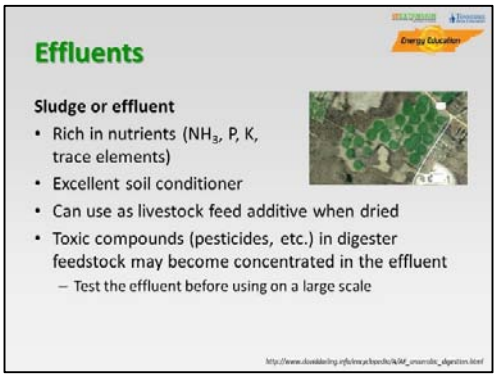
In addition to the planning and engineering, you must make a commitment to provide daily management of the system to monitor performance, maintain system components (digester hardware, gas scrubbers and compressors, engines, digestate management equipment, etc.).

You must also maintain regular communications with your partners (electric utility, equipment providers, digestate users, regulators, etc.).

Slide 27

Slide 28

Use of the digestate liguids and solids also required planning, because they are rich in nutirents and must be used correctly to minimize negative environmental impacts. As mentioned earlier, you may be required to have an approved CNMP and test the liquids and solids in order to calculate application rates in compliance with soil test recommendations and regulations.



Slide 28

Slide 29

We've mentioned this several times already, but it is worth repeating again.

Anaerobic digestion works best in a continuous, steady-state. You need a steady supply of wastes every day that is consistent in quality and consistency.

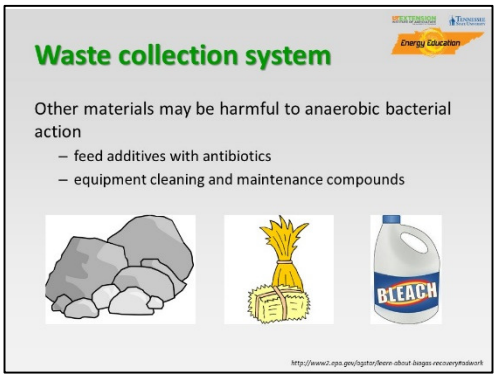
In cold or winter conditions, it may be necessary to preheat the waste before it enters the digester.

Slide 29

Slide 30

You must take care to not introduce contaminants that can clog the system, damage equipment or poison the system. Make sure wash water for dairy tanks and pipelines containing acid and disinfectants is disposed of through other means.

Killing off the bacteria with disinfectants can result in poor waste treatment and little gas production.



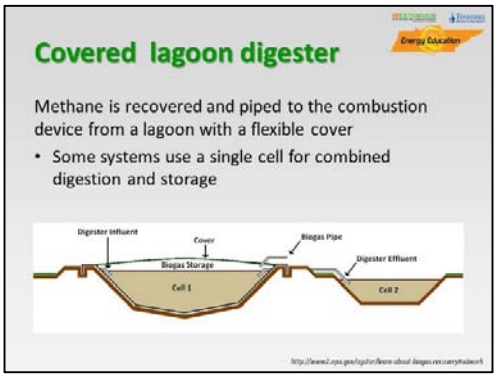
Slide 30

If your system budget depends on electric power sales to the utility, a dead system will produce no income. In addition to reduced power sales income, you might also compromise the power sales agreement with the utility and incur penalties.

Slide 31

Now, let's take a quick look at lagoon digesters.

In the simplest form, the lagoon is a lined pond or reservoir with an airtight cover. Wastes are fed into one end and digestates flow out the other end, with the biogas being trapped by the cover and piped to wherever it will be used.



Slide 31

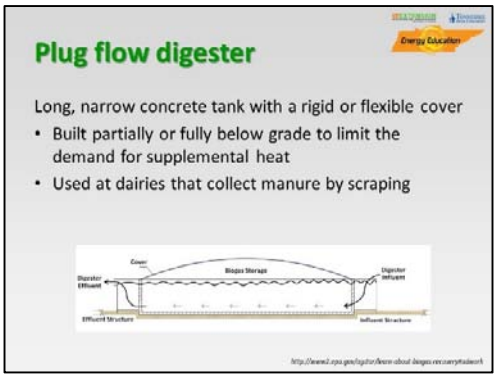
In this example, the second cell stores the digester effluent and some additional treatment can take place there.

Some systems may use a single, covered cell for both digestion and storage.

Slide 32

A plug flow digester is similar to a lagoon, except it consists of long, narrow channels so that the material flows through the digester without mixing fresh feedstock with older, treated material.

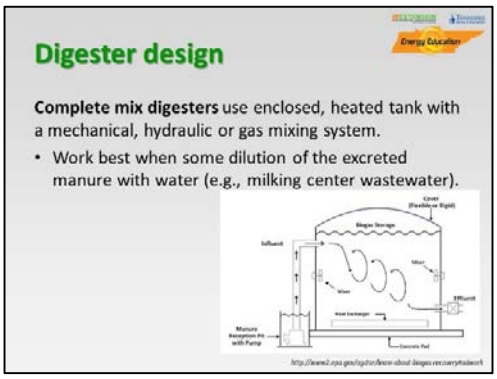
Plug flow digesters might be a back and forth path of channels, similar to the lines for theme park rides, in order to minimize land required for the system.



Slide 32

Slide 33

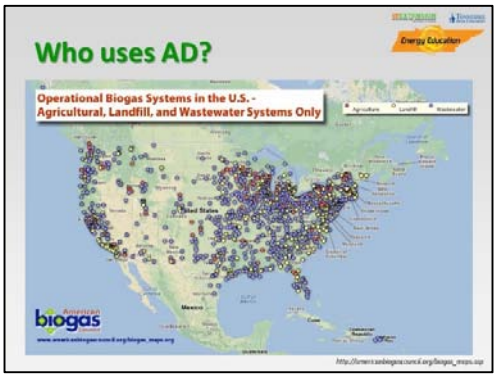
Complete mixing digesters work best for wastes that are fluid enough to stir well. In a dairy or other manure system, some dilution will be needed to thin the mixture.



Slide 33

Slide 34

This map from the American Biogas Council in 2015 shows known biogas systems in the United States.
Red = agricultural systems
Yellow = landfills
Blue = waste water treatment plants



Slide 34

Slide 35

Looking at only the agricultural systems, notice there are only a few in the South, and none in Tennessee.

Slide 35

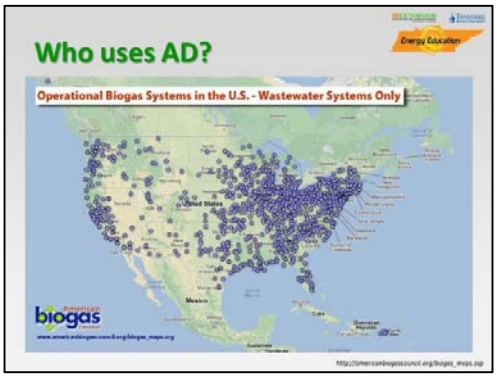
Slide 36

There are a number of landfill gas collection systems in place, and some in Tennessee. The landfill gas is typically used to run generators and the electricity is sold onto the power grid.

Slide 36

Slide 37

Waste water treatment facilities also capture methane. In some cases it is simply flared, but is of much greater value to burn in commercial power plants, power generators, or to pre-heat sewage entering the plant for faster treatment in winter.



Slide 37

Slide 38

Zooming in, we can see several landfill and waste water plant biogas facilities in Tennessee, but notice there are no agricultural installations at this time.

Slide 38

Slide 39

Perdue Farms in Cromwell Kentucky has installed anaerobic digestion to pre-treat waste water before final treatment and disposal.

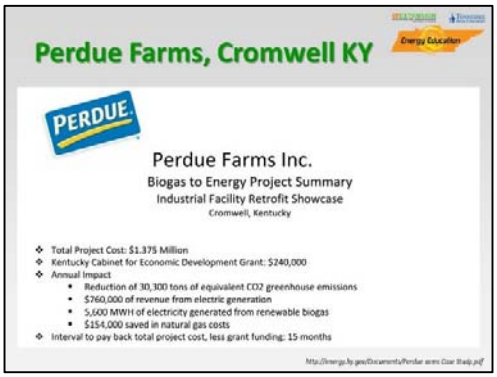
The digester is approximately 137,000 sf or 3.14 acres

Slide 39

Slide 40

This project summary describes the annual impact of this project.

Notice the value of the energy produced and natural gas savings; and the 15-month payback period.



Slide 40

Slide 41

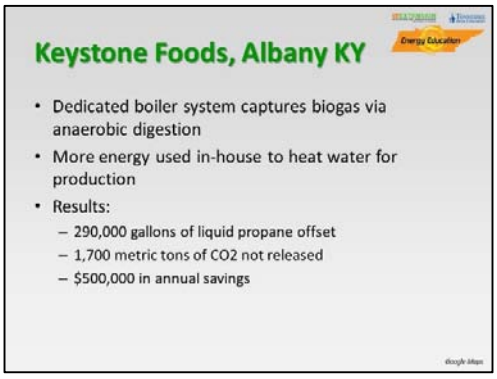
Keystone Foods, at Albany, Kentucky installed anaerobic digestion to treat processing waste water and reduce disposal costs.

The system covers approximately 256,000 sf or 5.9 acres.
In this aerial photo you can see that the liquid effluents are irrigated onto surrounding land. Looking close, you can also see evidence of runoff from the irrigated areas onto down-slope land.

Slide 41

Slide 42

Keystone Foods uses the biogas to heat water for the processing plant, and offsets almost 300,000 gallons of propane annually.



Slide 42

Slide 43

One Memphis, Tennessee waste water treatment plant captures methane and pipes it to the adjacent Tennessee valley Authority power plant.

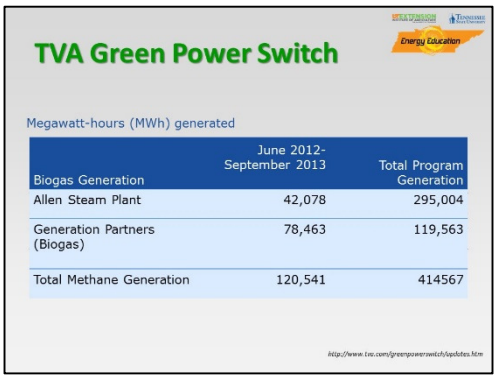
The biogas offsets about 20,000 tons (200 rail car loads) of coal annually.

Slide 43

Slide 44

This table from TVA shows the impact of the Allen Fossil Plant (Memphis) and other biogas energy projects in the TVA system, The other biogas projects include landfill gas and waste water treatment systems.

I am sure the numbers are higher today than when this report was released.



Biogas Generation	June 2012-September 2013	Total Program Generation
Allen Steam Plant	42,078	295,004
Generation Partners (Biogas)	78,463	119,563
Total Methane Generation	120,541	414567

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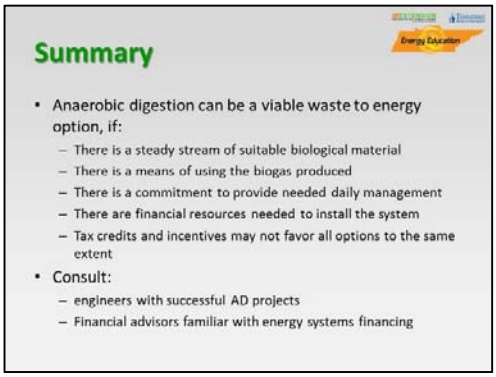
Slide 45

In summary, anaerobic digestion is a viable option for some farmers and businesses to convert was biological materials into useful biogas.

But, AD systems are not economically feasible for small operations, and the systems will require a long-term commitment to provide daily management.

There must also be a use for the biogas that can offset other energy sources or that can be marketed to recover the system installation costs.



Slide 45

And, the various tax credits and financial incentives may not favor all system options to the same extent. Anyone considering AD systems must consult experienced engineers and financial advisors with experience in renewable energy systems.

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You can find more information on anaerobic digestion systems from a variety of sources, including these US government agencies

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Test their Knowledge - Questions for the audience

Q: What is anaerobic digestion?
A: A process using microbes that live without oxygen to reduce waste (like manure) and produce methane which can be burned for energy.

Q: How many animals does a producer need to make an anaerobic digestion system worthwhile?
A: 500 cows
2,000 hogs with anaerobic lagoons
5,000 hogs with deep pits

Q: What can the digested solids be used for?
A: Bedding material, soil amendment, biodegradable plant pots, structural building materials

Q: How can the methane be used?
A: It can be burned to create electricity, it can be burned directly in boilers in place of propane and it can be further processed and converted into compressed natural gas to run vehicles.

Q: What local production exists?
A: Perdue Farms, Cromwell, KY
Keystone Foods, Albany, KY
Memphis Waste Water Plant, Memphis, TN

Evaluation

Please give us your feedback regarding this activity. Your feedback will help us improve the activities you attend in the future.

Name of Activity: Anaerobic digestion	Date of Activity:

A. Instruction	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. The specialist was well prepared.	①	②	③	④	⑤	⑥
2. The specialist presented the subject matter clearly.	①	②	③	④	⑤	⑥

B. General Learning and Change	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. I have a deeper understanding of the subject matter as a result of this session.	①	②	③	④	⑤	⑥
2. I have situations in which I can use what I have learned in this session.	①	②	③	④	⑤	⑥
3. I will change my practices based on what I learned from this session.	①	②	③	④	⑤	⑥

C. Specific Learning How much ***did you / do you*** know about these subjects?	***Before this program I knew…***					***Now I know….***				
	Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1. *The process involved in anaerobic digestion*	①	②	③	④	⑤	①	②	③	④	⑤
2. *How anaerobic digestion can be used to produce energy on the farm*	①	②	③	④	⑤	①	②	③	④	⑤

D. Specific Practices To what degree ***did you / will you*** do the following?	***Before this program I did…***					***In the future I will realistically do….***				
	Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1. *Seek information related to anaerobic digestion*	①	②	③	④	⑤	①	②	③	④	⑤
2. *Produce energy using anaerobic digestion*	①	②	③	④	⑤	①	②	③	④	⑤
3. *Tell others about anaerobic digestion*	①	②	③	④	⑤	①	②	③	④	⑤

E. Satisfaction with Activity	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. *I would recommend this program to others.*	①	②	③	④	⑤	⑥

F. Other comments?

Thank you for completing this survey!