

To our teachers:

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Name: * _____



Date: * ____ / ____ / ____ Class Hour: * ____



**Wisconsin Public Service
SolarWise for Schools
and the
Center for Renewable Energy
Advanced Technological Education**



Dairy Waste To Power

Instructor's Answer Key

1. What is this?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Cow Waste

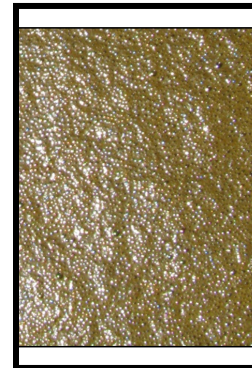


2. What is this (the bubbles)?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Biogas



3. Each of these is a(n)?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Anaerobic Digester



4. Each of these is a(n)?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Electrical Generator



5. Each of these is a(n)?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Solids Separator

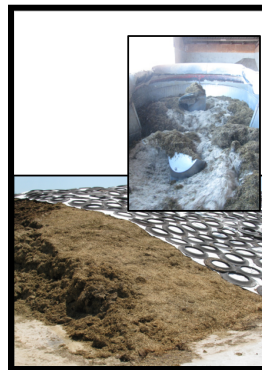


6. What is this?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Cow Feed



7. What is this?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Lagoon Storage

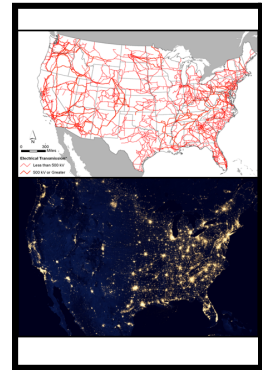


8. What is this?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Electrical Grid

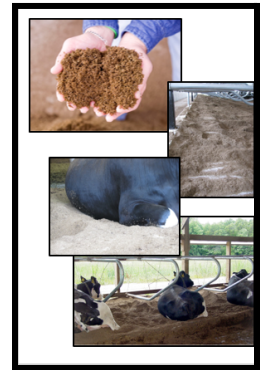


9. Each of these depicts?

Choices:

anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Biosolids



10. What is this?

Choices:

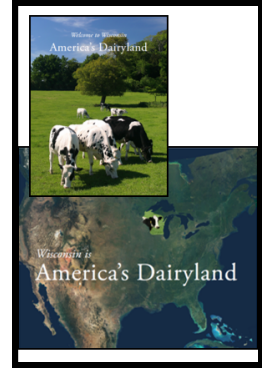
anaerobic digester, biogas, biosolids, cow feed,
cow waste, digested liquid fertilizer, electrical generator,
electrical grid, lagoon storage, solids separator

Answer: Digested Liquid Fertilizer



11. Name one popular industry from another state that Wisconsin's dairy industry easily surpasses economically:

Answer: Washington Apples or California Apples or Florida Citrus or Idaho Potatoes

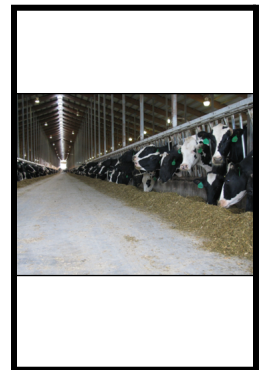


12. Which product segment in Wisconsin's dairy industry is growing the fastest (it's almost doubled in the last 20 years)?

Answer: Cheese



13. Wisconsin has roughly **Answer: 1.25million** dairy cows on about **Answer: 10,000** dairy farms.



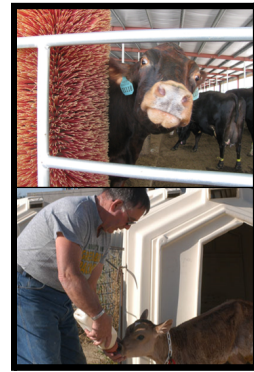
14. Each cow in Wisconsin generates more than **Answer: \$21,000** of economic activity every year.



15. Describe at least three ways dairy cows are well cared for.

Answer:

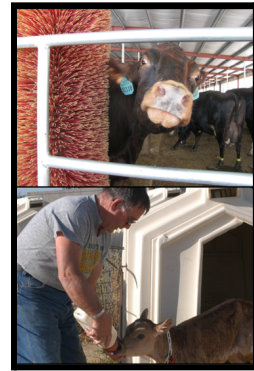
- Nutritious diet
- Plenty of clean, fresh water
- Routine veterinary care
- Barns and bedding regularly cleaned
- Kept warm in winter, cool in summer
- Treated well
- Milked regularly
- There are probably other very good answers



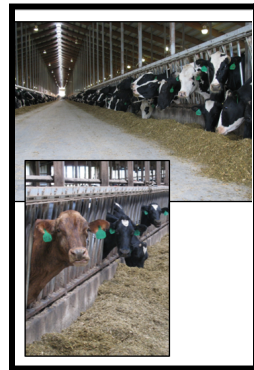
16. Explain: Besides keeping milk production up, why is it in a dairy farmer's best interest to keep cows healthy?

Answer:

- Keeping cows healthy keeps costs, like veterinary care, down.
- Healthier cows also give better quality milk.
- Like any other business, dairy farmers have their good reputation to maintain.



17. Cows typically consume over **Answer: 100** pounds of food each day.



18. Cows are mammals called “ruminants” that **Answer: chew the cud**. This is when the food a cow consumes is later returned to its mouth where it is chewed a second time.



19. The three most important nutrients needed for plant growth are

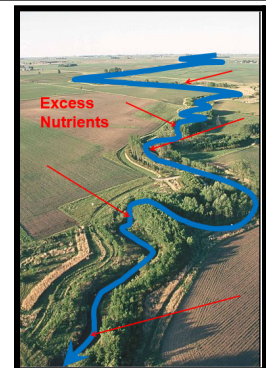
Answer: nitrogen, phosphorus, and potassium



20. A **Answer: nutrient management plan** will track which nutrients are already in the soil, which nutrients are applied to the soil, when, where, and how they are applied, and in what form they are applied.



21. Streams that are close to fertilized fields can be seriously affected by excess nutrient **Answer: runoff** when the snow melts or when it rains.



22. **Answer: Eutrophication** is the environmental response of a waterway to the addition of excess nutrients from fertilizer.



23. Explain: What is eutrophication? What are the steps that lead to eutrophication?

Answer:

- Eutrophication is the environmental response of a waterway to the addition of excess nutrients—usually nitrogen or phosphorus from fertilizer.
- Eutrophication begins with the application of excess nutrients.
- When it rains or snows running water can carry those nutrients away to streams, rivers, or lakes. Then:
- Excess nutrients in the water promote the growth of excess algae. This is called an algae bloom.
- When the nutrients are all used up, the algae die.
- Microbes in the water decompose the dead algae, using up oxygen in the water in the process.
- The waterway suffers from too little oxygen; fish and other creatures in the water die from lack of available oxygen



24. Explain: How can urban, city dwellers cause the same kind of eutrophication that happens from agricultural runoff?

Answer:

- Eutrophication can result if improperly treated wastewater is discharged into a stream from a city or one of its industries.
- Eutrophication can result from improper use (typically overuse and overspray) of residential fertilizer.



25. Explain: What general information is contained in a dairy farm's nutrient management plan?

Answer:

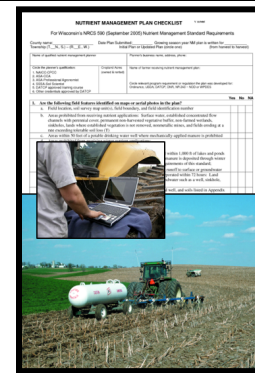
A nutrient management plan will track the nutrients that are applied to the soil, when, where, and how they are applied, and in what form they are applied. These factors are carefully considered to promote the best plant growth. But they are also managed to prevent (or strictly limit) environmental damage from nutrient runoff.



26. Explain: Why is it important for a dairy farm to have a nutrient management plan?

Answer:

A nutrient management plan will track the nutrients that are applied to the soil, when, where, and how they are applied, and in what form they are applied. These factors are carefully considered to promote the best plant growth. But they are also managed to prevent (or strictly limit) environmental damage from nutrient runoff.



27. Describe at least three qualities that good cow bedding material must possess.

Answer:

Comfort, cleanliness, and moisture control. Low cost could also be included.



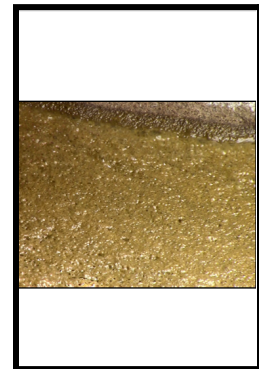
28. The average cow in Wisconsin, when milking, produces about **Answer: 60** pounds of milk each day, which is about **Answer: 70** gallons.



29. A typical milk cow will eliminate over **Answer: 100** pounds of waste in a day.



30. **Answer: Anaerobic digestion** can be defined as the breakdown of organic material by microorganisms in the absence of oxygen.



31. You may think of an anaerobic digester as a really big **Answer: stomach**.



32. The price for building a “small” anaerobic digester will start somewhere near **Answer: one million dollars.**



33. While it passes through the digester cow waste is kept at a temperature of about **Answer: 100 °F.**



34. Explain: Where does the heat required for the anaerobic digester come from?

Answer:
So called "waste heat" from the electrical generator is used to deliver the heat that is needed in the anaerobic digester.



35. A liquid storage lagoon will always be lined. A liner is used to protect **Answer: groundwater** supplies beneath the lagoon from any kind of contamination from above.



36. For lagoon liquid storage, a liner of **Answer: compressed clay** will always be used. If conditions require it, a second lining of thick **Answer: plastic** may be applied over the top of the first liner.



37. Explain: What are the differences between what is stored in a lagoon on a dairy farm with a digester compared with what is stored in a lagoon on a dairy farm without an anaerobic digester.

Answer:

Dairy farm with no digester:

- Stores all of the raw cow waste from the farm—both solid and liquid
- Stored waste has high bacteria content
- Stored waste has a strong odor
- Stored waste gives off methane to the air as it slowly decomposes

Dairy farm with an anaerobic digester:

- Stores only digested liquid cow waste from the farm
- Stored liquid has low bacteria content
- Stored liquid has low or no odor
- Stored liquid gives off little methane to the air since the waste was broken down in the digester



38. Explain: Why is digested liquid fertilizer easier for plants to use and safer for the environment than fertilizing with raw cow waste?

Answer:

Organic nutrients in cow waste were broken down and put into an inorganic form in the digester. This makes the nitrogen, phosphorus, and potassium much easier for growing plants to take up and use from digested liquid fertilizer. This is not the case with raw cow waste fertilizer.



39. Crops can take up and use nutrients from a synthetic fertilizer about as easily as they can take up and use nutrients from digested liquid fertilizer. Why is digested liquid fertilizer looked at as a better, more sustainable, “green” fertilizer?

Answer:

Petroleum and natural gas compounds—nonrenewable resources—are used in the production of synthetic fertilizers.



40. As you know, anaerobically digested liquid cow waste is used as a liquid crop fertilizer. Raw cow waste is also applied to crops as a fertilizer. Explain: What are the three important differences between digested liquid fertilizer and raw cow waste that is used as a fertilizer?

Answer:

Anaerobically digested cow waste:

- **Nutrients have been mineralized (broken down from an organic to an inorganic form) making them easier for growing plants to use**
- **Low bacteria content**
- **Low or no odor**

Raw cow waste:

- **Nutrients have not been mineralized and are still in organic form. They are not readily available for growing plants to use. They will slowly decompose in the field after application**
- **High bacteria content**
- **Strong odor**



41. Explain: What characteristics do biosolids possess that make them an excellent soil amendment? What characteristics do biosolids possess that make them an excellent cow bedding material?

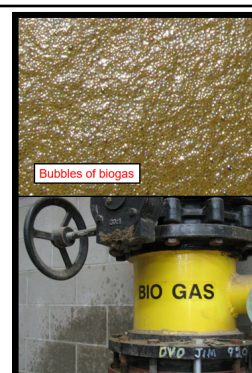
Answer:

Biosolids contain all of the nutrients found in the digested liquid fertilizer, but in solid form. For these reasons biosolids make an excellent soil amendment and fertilizer. The plant-accessible nutrients in the biosolids effectively fertilize the soil. But biosolid nutrients are even less likely to runoff even when surface-applied. And just like the digested liquids, biosolids have low odor and are low in bacteria levels.

But biosolids also make an excellent cow bedding material. Biosolids fit the criteria for a cow bedding material nicely by promoting cow health, comfort, and milk production economically.



42. Anaerobic bacteria perform natural decomposition within the digester. In the end the gaseous product, called biogas, is a mixture of mostly **Answer: methane (CH₄)** and some carbon dioxide (CO₂).



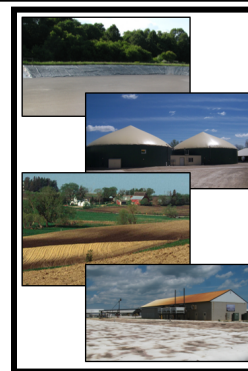
43. As you know, biogas is also produced from raw, undigested cow waste. However, this biogas is produced as the raw cow waste breaks down in the storage lagoon or as it breaks down after it is applied on a field. The biogas produced in this way is released to the **Answer: air or atmosphere.**



44. Explain: On a farm without an anaerobic digester, where does the methane that's produced go? On a farm with an anaerobic digester, where does the methane that's produced go?

Answer:

On a farm without an anaerobic digester, the methane that's produced goes into the air (atmosphere). On a farm with an anaerobic digester, the methane that's produced is kept out of the air and used to produce renewable electricity.



45. As you know, methane biogas is produced in the anaerobic digester. Explain how the production of methane biogas can be looked at as a positive result. Also explain how the production of methane biogas can be looked at as a avoiding a negative result.

Answer:

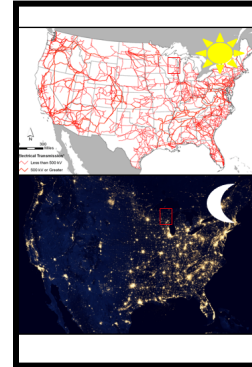
On a farm with an anaerobic digester, the methane that's produced is kept out of the air and used to produce electricity. This is a positive result because the methane is used to produce renewable electricity. This is avoiding a negative result because the methane is not released to the air where it would contribute to the greenhouse effect.



46. Biogas that has been produced in an anaerobic digester is pumped here and burned to produce **Answer: electricity.**



47. Unlike renewables like wind and solar, electricity production from renewable biogas can be depended on **Answer: 24** hours a day, **Answer: 7** days a week.



48. The waste from a dairy farm of 2750 cows can be used to make enough electricity to power **Answer: 550** average homes.



49. Name three common nonrenewable natural resources used to produce electricity in Wisconsin:

Answer:
coal, natural gas, uranium



50. Name three common renewable natural resources used to produce electricity in Wisconsin:

Answer:
water (hydroelectric), wind, solar photovoltaic



51. Explain: Why is it a disadvantage for Wisconsin to use energy resources that are brought in from out of state? Why is it an advantage for Wisconsin to use energy resources that are found within our state borders?

Answer:

The energy resources used most in Wisconsin are coal, oil, natural gas, and uranium. Wisconsin doesn't have any of these resources inside its borders—at least not in amounts that make sense to develop. Those resources must all be brought into Wisconsin from other places.

Disadvantage: The billions of dollars that Wisconsinites pay for coal, oil, natural gas, and uranium flow out of the state and provide further economic benefit somewhere else.

Renewable energy resources like anaerobically digested cow waste is an energy source that is both produced and used right here, within Wisconsin's borders.

Advantage: The economic benefit for producing and using the resource stays right here in Wisconsin.



52. Describe at least two important advantages of using renewable energy resources over using nonrenewable energy resources.

Answer:

Once constructed and running, renewable energy resources are relatively "clean" and environmentally friendly to use.

Renewable energy resources, by definition, are resources that will not run out—they are being renewed, or replaced each day by natural processes. This is not the case with nonrenewable energy resources, supplies of which are eventually limited.



53. Describe the most important advantage of using digester-produced biogas over most other renewable energy resources.

Answer:

Digester-produced biogas has the capacity to produce electricity 24/7. This is similar to water-produced hydroelectricity. But it is much better than wind (which only produces electricity when the wind is blowing) and solar PV (which produces electricity well only in good sunshine).



54. In the end, the anaerobic digester produces a solid, a liquid, and a gaseous product. Describe these three end products in detail. Explain what each product is used for.

Answer:

After anaerobic digestion, cow waste can be viewed as a remarkably sustainable resource from which these especially beneficial and valuable assets are produced:

- **methane biogas**—collected and kept out of the air, it is used as fuel on a scale that can serve hundreds of homes
- **liquid fertilizer**—broken down much further than raw cow waste, it now holds nutrients in a form that can be more safely managed and applied to croplands
- **biosolids**—that can be sold as a soil additive or used as cow bedding



55. A dairy farmer who puts in an anaerobic digester expects to make money from the investment. Spend some time talking to such a farmer though, and you will hear plenty of other reasons for putting in a digester. Explain why such a farmer would give each of these as a reason for putting in a digester:

55a. "I want to be thought of as a good neighbor by those who live close by me."

Answer:

Anaerobically digested cow waste has very little or no odor in comparison to raw cow waste.



55b. "I want to do a good job when it comes to keeping our local water supplies healthy."

Answer:

Anaerobically digested cow waste is much safer to apply to crops as a liquid fertilizer. Most of the bacteria in the waste has been destroyed. In addition, the nutrients in the cow waste have been "demineralized." This means they have been broken down from their organic form in the raw cow waste. They have been put into an inorganic form which is much easier for plants to take up and use.



55c. "I want my children and their children to breathe healthier air."

Answer:

Anaerobically digested cow waste produces a renewable resource—methane biogas—which is captured and burned to produce electricity. Not only is renewable electricity produced, but it is produced by a relatively clean-burning fuel—methane biogas. Methane biogas burns much cleaner than coal.



55d. "I want Wisconsin to be more self-sufficient."

Answer:

Anaerobically digested cow waste is an energy source that is both produced and used right here, within Wisconsin's borders. The economic benefit for producing and using the resource stays right here in Wisconsin. [The energy resources used most in Wisconsin are coal, oil, natural gas, and uranium. Wisconsin doesn't have any of these resources inside its borders—at least not in amounts that make sense to develop. Those resources must all be brought into Wisconsin from other places. The billions of dollars that Wisconsinites pay for coal, oil, natural gas, and uranium flow out of the state and provide further economic benefit somewhere else.]

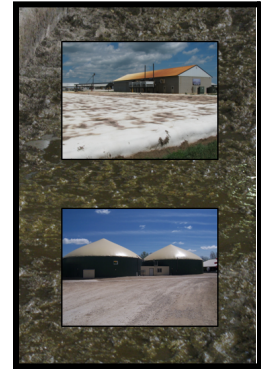


56. Name two other substrates (what you would probably think of as wastes) that when digested, produce more energy for their weight than cow waste.

Answer:

The whole list from the PowerPoint follows. They are given in order from most-to-least in their energy density:

- Fats and grease
- Food scraps
- Grass silage
- Brewery waste
- Potato waste
- Bakery waste
- Corn silage
- Green clippings
- Chicken manure
- Pig manure



57. Describe one other way the methane biogas produced from anaerobic digestion can be put to good use.

Answer:

If the methane is concentrated further and compressed, we would have CNG (compressed natural gas) . This can be used as a transportation fuel (in place of gasoline) in vehicles that are set up to use it. It is a cleaner burning fuel than gasoline.

If the methane is concentrated further but not compressed, it can be used in most of the ways that utility provided natural gas is used: space heating and water heating.



58. Biosolids are currently used as a soil amendment or recycled as cow bedding. Name one other purpose to which they can be put—one other thing they can be used for.

Answer:

The fiber present in the biosolid material can be used to make fiber board.



59. List at least ten professions / trades / jobs that are likely to be needed on a farm with an anaerobic digester.

Answer:

There are many more possible than can be listed here. Also some of the jobs are called upon only when needed. Here are some of the more obvious possibilities:

- Trucker
- Veterinarian
- Nutritionist
- A variety of jobs in the milking parlor
- A variety of jobs in the feed storage, feed mixing, and cow feeding process
- A variety of jobs in the tending and cleaning of barns
- A variety of tractor drivers
- Digested fertilizer spreader
- Mechanic
- Electrician
- A variety of traditional farming jobs involving planting, harvesting, etc.
- Bookkeeper/accountant
- Supervisors
- Owner



60. Energy from the sun comes to us from every energy resource we use. Describe how the electricity we get through the process of anaerobic digestion originates from the sun.

Answer:

There are many ways to describe this in an academically honest way. Here is one:

1. Nuclear energy is converted to light energy in the sun.
2. Light energy is converted into chemical energy in the process of photosynthesis.
3. Chemical energy is converted to electrical energy in the electrical generating process.

It is important to note that anaerobic digestion (in both cows and the digester) is needed between steps 2 and 3 to produce a type of molecule (methane) with chemical energy that can be effectively used to make electricity.



