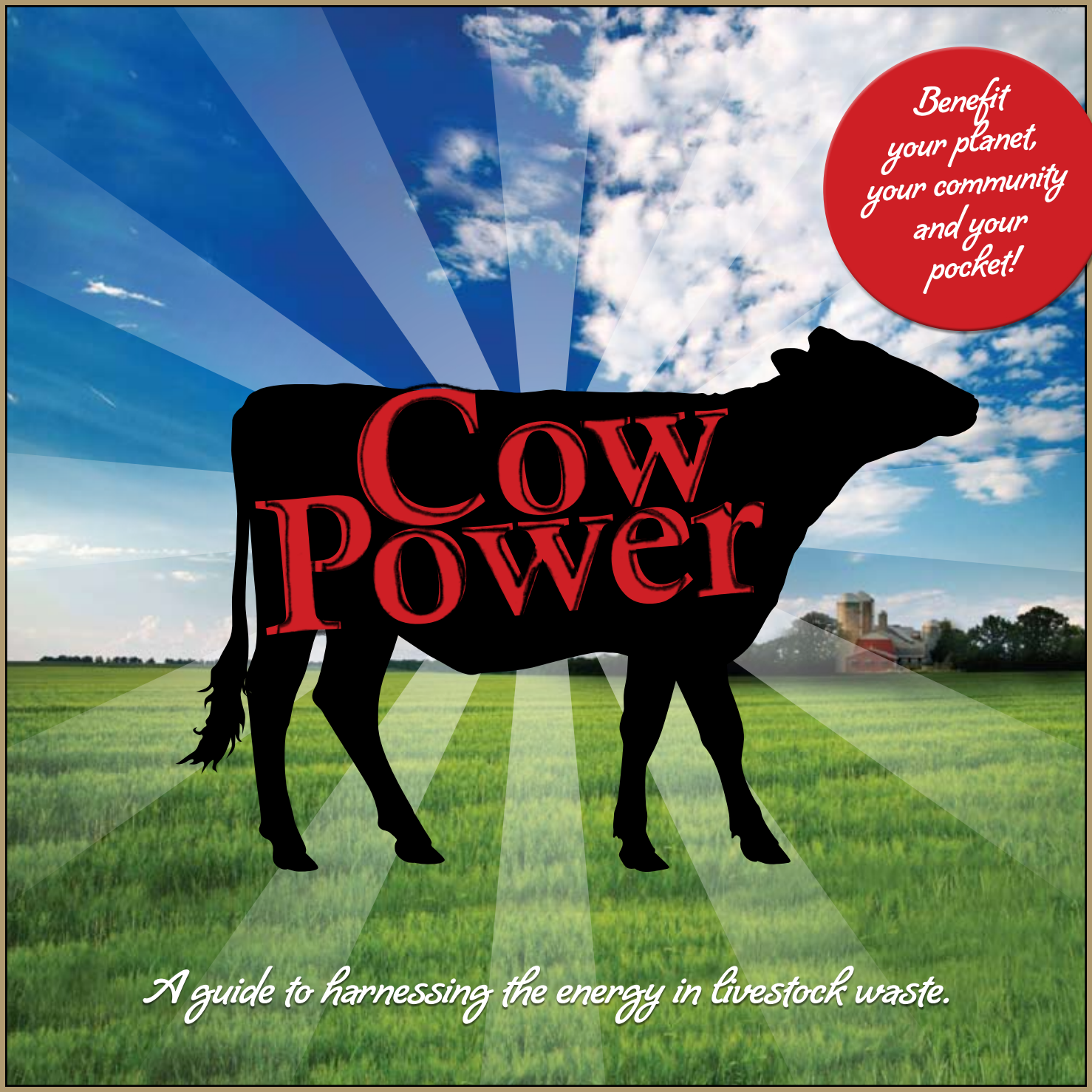
Benefit your planet, your community and your pocket!
Cow Power
A guide to harnessing the energy in livestock waste.

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Waste to energy, are you kidding me?

You've probably heard this before, but we'll tell you again: you can convert all the manure in your farm or feedlot into energy, killing two birds with one stone. **One, you're going to get rid of the manure; two, your energy bills will be reduced.** Of course, this is an oversimplification, but if you keep reading, we'll show you the ins and outs of manure to energy conversion.

How is this possible?

In as few words as possible: plants store the energy of the sun, the cows eat that but they're not able to extract all the energy stored. While the biomass decomposes, some of that energy escapes in the form of biogas, the rest remains in the solids, which can be burned.

What is biomass?

When organic material decomposes, it emits gases like methane and carbon dioxide. The combination of these gases is flammable and is called biogas.

What are greenhouse gases and why are they important to me?

Green house gases (GHG) are carbon dioxide, methane, and other gases which trap heat in the atmosphere, thus contributing to climate change. Methane, produced by cattle, is 23 times more powerful than carbon dioxide and is responsible for 14% of the total GHG concentration in the atmosphere. The Colorado Climate Action Plan will lead the establishment of a carbon credit market through which farmers and ranchers may receive revenue for reducing GHG emissions.

Understanding How to Turn Waste into Watts

The sweet smell of our bovine friends and it isn't the smell of steaks on the grill. Is there a future without worrying about what to do with all the manure?

Yes. Imagine in the near future a day when the waste of so many cows will be transformed into energy to run your farm or even power rural Colorado. Envision a time when cows will become something more than "what's for dinner." Farmers and their cows have the potential to become the future of clean energy through—who would've guessed it!—manure.

This resource guide will provide you information on ways to turn cattle's waste into energy you can use or sell: electricity, biogas, steam, liquid fuel, and heat. We will provide a summary of the various biomass technologies available to you.

The intent of this guide is not to showcase every technology available, but to introduce you to the concepts and ideas needed to better understand waste to energy processes applicable to your farm. Our purpose is to equip you with a basic understanding of the different technologies and the benefits of converting manure into energy.

Envision a future when waste management is not a problem, but the solution to rising energy prices and, with a little bit of luck, one extra source of income.

A Brief Background on Biomass to Energy Conversion

Using manure for energy has been around for many years. People throughout history have used manure to burn for fires when no trees or wood could be found. Bison manure was regularly collected by pioneers on their long trek across the Great Plains to fuel their campfires.

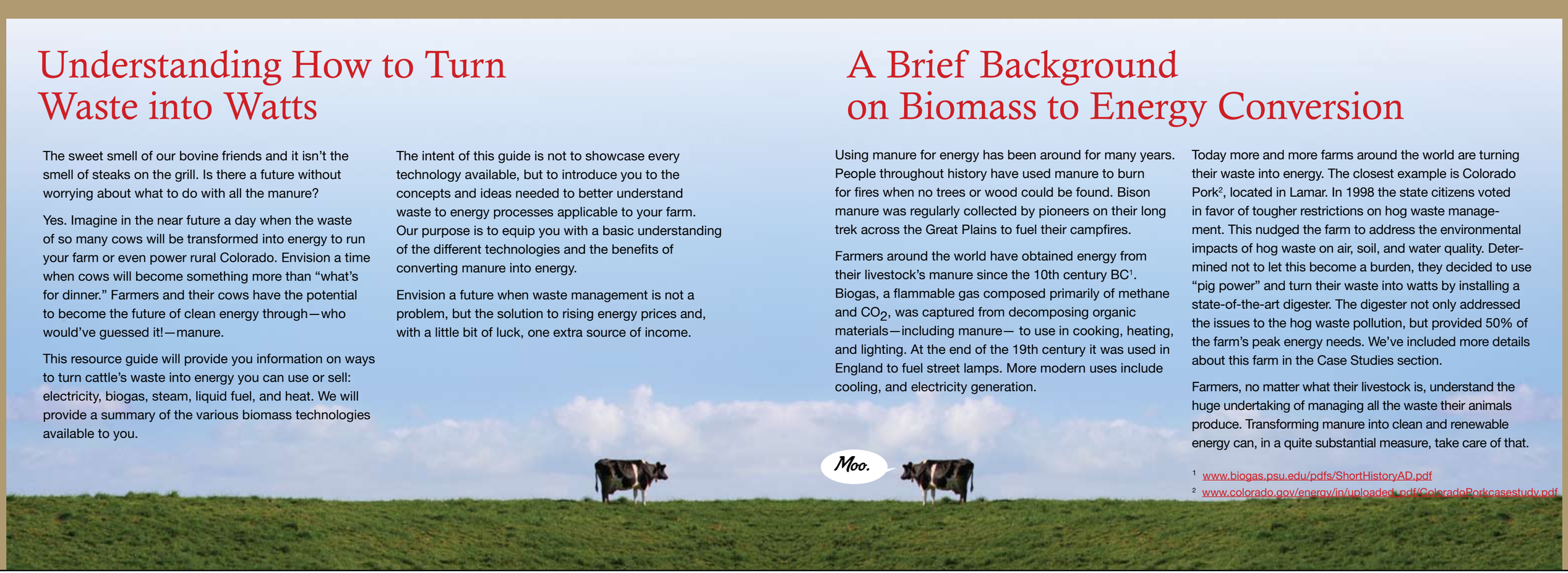
Farmers around the world have obtained energy from their livestock's manure since the 10th century BC[1]. Biogas, a flammable gas composed primarily of methane and CO_2, was captured from decomposing organic materials—including manure— to use in cooking, heating, and lighting. At the end of the 19th century it was used in England to fuel street lamps. More modern uses include cooling, and electricity generation.

Today more and more farms around the world are turning their waste into energy. The closest example is Colorado Pork[2], located in Lamar. In 1998 the state citizens voted in favor of tougher restrictions on hog waste management. This nudged the farm to address the environmental impacts of hog waste on air, soil, and water quality. Determined not to let this become a burden, they decided to use "pig power" and turn their waste into watts by installing a state-of-the-art digester. The digester not only addressed the issues to the hog waste pollution, but provided 50% of the farm's peak energy needs. We've included more details about this farm in the Case Studies section.

Farmers, no matter what their livestock is, understand the huge undertaking of managing all the waste their animals produce. Transforming manure into clean and renewable energy can, in a quite substantial measure, take care of that.

[1] www.biogas.psu.edu/pdfs/ShortHistoryAD.pdf

[2] www.colorado.gov/energy/in/uploaded_pdf/ColoradoPorkcasestudy.pdf



What's in it for us?

Taking everyone's perspective into account

According to the Colorado Department of Agriculture, "livestock industry represents the backbone of the state's $16 billion agriculture industry." On the flipside, manure from large scale operations has become a major source of pollution and unpleasant smells. What can farmers do to help the communities that surround them, the environment, and their pockets?

Additionally, scientists with the EPA and the U.N., amongst many others in the scientific community, have studied how greenhouse gases (GHG) affect climate. The U.N. notes that livestock contributes more GHG than automobiles do globally. Why not take that headache and use it to power your farm?

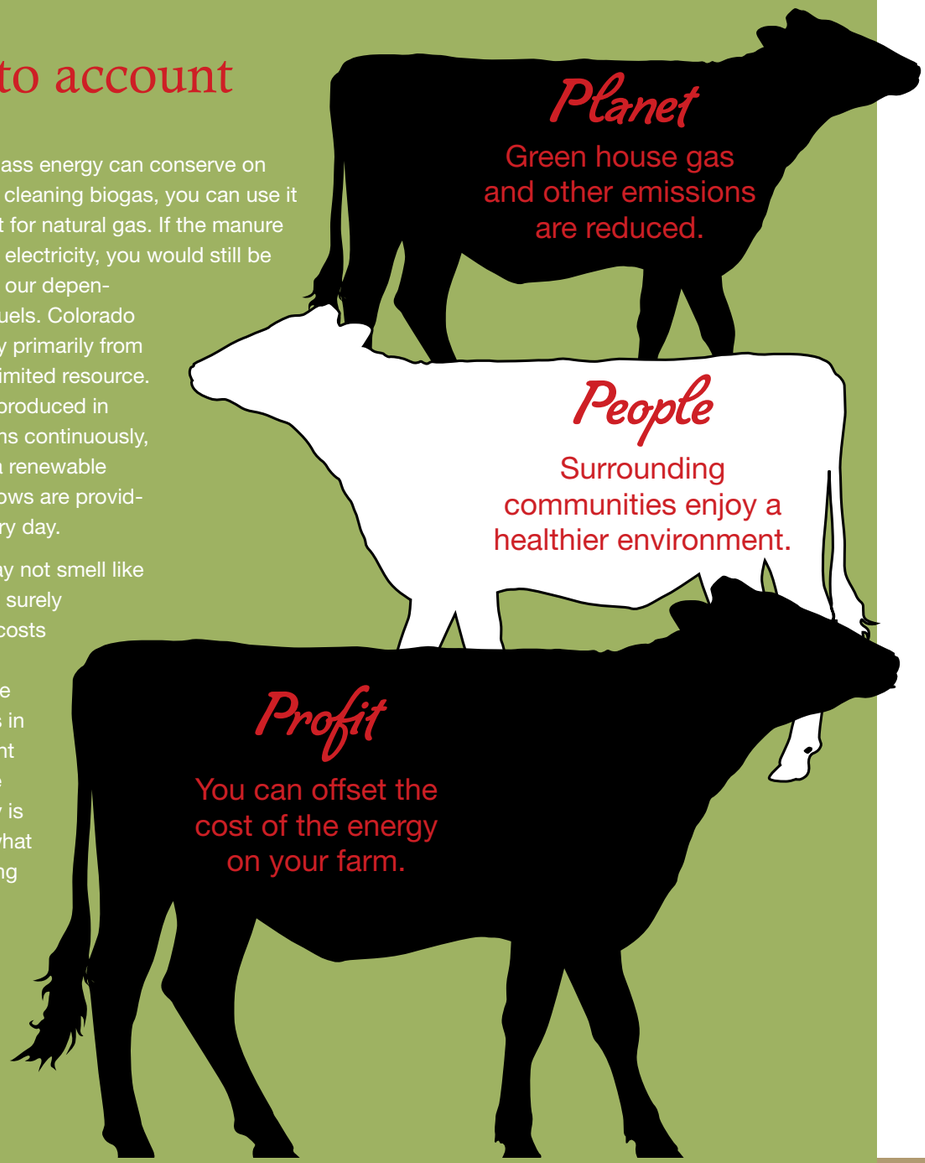
There are many benefits to converting manure into energy. As we discussed in the previous section, the law on livestock waste management will turn much more stringent over time. The demand for food will continue to increase and the cost of energy will also increase. The manure will continue to pile up.

Converting manure into energy helps reduce the amount of pollutants released into the local environment, cuts down on greenhouse gas emissions, and provides farmers with a reliable source of energy.

Your neighbors will enjoy a cleaner atmosphere and, with the proper design, the smell will be significantly reduced.

In addition, biomass energy can conserve on fossil fuels. After cleaning biogas, you can use it as a replacement for natural gas. If the manure is converted into electricity, you would still be helping reducing our dependence on fossil fuels. Colorado gets its electricity primarily from coal, which is a limited resource. Animal waste is produced in feedlots and farms continuously, that means it is a renewable resource. Your cows are providing tons of it every day.

Animal waste may not smell like money, but it will surely cut your energy costs considerably. Depending on the number of heads in your farm, it might even be possible that more energy is produced than what you need, opening the possibility of profit.



How Biomass to Energy Conversion Works

Humans have been using biomass as a fuel since we discovered fire. Biogas is created by capturing the gas emitted from decomposing organic materials or by burning organic materials under high temperatures. For instance, you may have heard of swamp gas in the southern U.S. This is created by bacteria breaking down organic materials in an oxygen deprived environment, like under the mud. Organic material can be vegetation, food waste, animal excretions, etc.

In this guide we will focus on three different ways to transform manure into energy. These are anaerobic digestion, incineration, and gasification.

The next section will discuss a number of different technologies. While fossil fuels are a limited resource and need to be conserved, farmers are also concerned about conserving water for their cattle and our future. We will provide some examples of different ways to release the energy trapped in animal waste and allow you to make an informed decision on what technology would work best on your feed lot or farm.

Anaerobic Digesters and Feedlots!

Usually feedlot manure is full of straw and grit. This makes it really hard to use a digester to convert it into energy. However, recent developments are looking very promising, so don't discard digesters if you have a feedlot!

1. Anaerobic Digestion

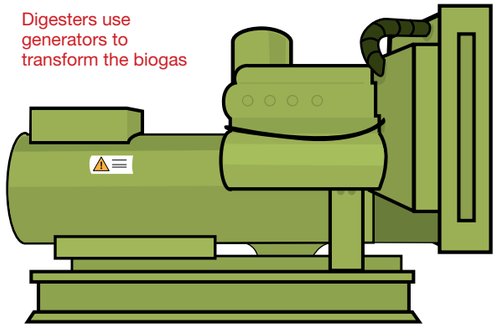
Mix manure with liquid (which doesn't necessarily mean water) and let the bacteria feast begin. The anaerobic digestion method is the most popular method used in the livestock industry in the U.S. and especially in Europe. There are more than one hundred farms[3] in the U.S. using this technology: Colorado Pork (see Case Studies section), Huckabay Ridge Dairy (Texas)[4], Vintage Dairy (California)[5], and Gordondale Farms (Wisconsin)[6], just to name a few.

[3] www.epa.gov/agstar/operational.html
[4] www.window.state.tx.us/specialrpt/energy/renewable/feedlot.php
[5] www.theregister.co.uk/2008/03/05/bovine_biogas_plant/
[6] www.epa.gov/agstar/pdf/gordondale_report_final.pdf

There are three types of digesters:

A. COVERED–LAGOON

This method is quite simple and can work from the septic/waste management system most dairies and other livestock farmers already have in place. Waste is mixed with liquid and piped into an anaerobic covered pond. The pond must be covered to keep oxygen from entering—which inhibits biogas production—and the biogas from escaping. This method provides an added benefit that eliminates the odor of the manure from getting into the air or into the ground water. This is true for all three anaerobic digester types.



Digesters use generators to transform the biogas

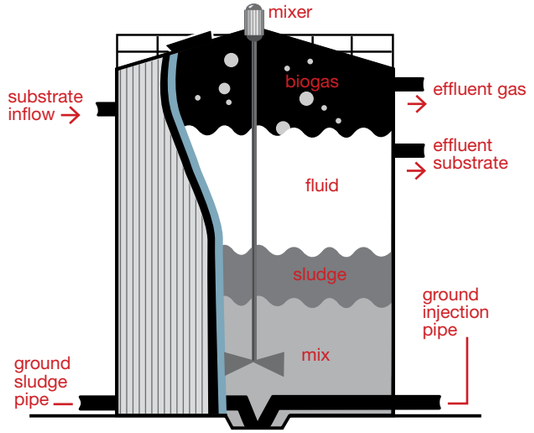
Waste

Additionally to the biogas, anaerobic digesters produce solid remnants—which are also known as digestate—and wastewater. After an additional maturation process, digestate can be turned into a high quality soil conditioner that has the potential to reduce the need for inorganic fertilizers. Wastewater can be used to increase the moisture content of the manure entering the process. However, not all wastewater can be used this way, and further treatment is often required.

Covered lagoons are particularly well suited for dairies.

Generally the warmer the air the faster the digester will produce methane (within certain limits, of course.) Therefore, in the warmer months farmers will be producing more energy from the waste.

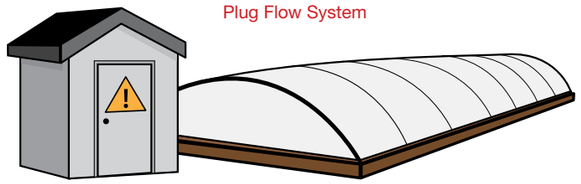
This system requires 97% or more liquid to process the manure effectively into methane. The cost is between $150 and $400 per Animal Unit (AU). While this technology is one of the least expensive, it works best in wetter and warmer climates.



B. COMPLETE MIX FLOW

This method uses an air-tight and heated tank. The tank uses a motor-driven propeller to mix manure and liquid together. Heat can come from a number of sources. A mixing device is required for this specific system.

While this technology requires more upfront cost for installation, it requires less water and has a faster turnaround transforming manure into power. It requires 90-97% liquid and can produce power all year round. The complete “gas flow” transformation takes place in as little as 5-20 days. The cost is $200 to $400 per AU.



C.PLUG FLOW

Fresh manure is piped into one end of a cylindrical air tight tube and exits out the other end as cow power gas.

This tank is also heated and requires the same type of heating equipment, storage, and “gas handling system” as the complete mix system. However, unlike the other two anaerobic systems we have discussed, this system requires the least amount of liquid and works below ground level. In addition, the heating system is narrower, which takes up less space.

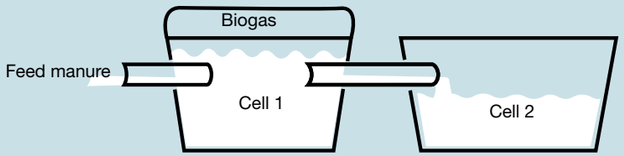
The amount of liquid required for the plug flow system is between 87-89% and will provide a steady gas flow all year round. The cost is $200-400 per AU.

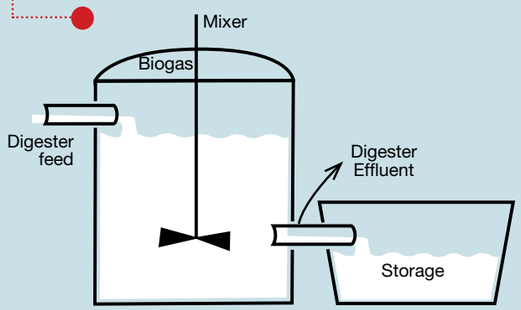
Furthermore, the EPA reports that the plug flow models are the most efficient and cost effective of all the anaerobic designs.

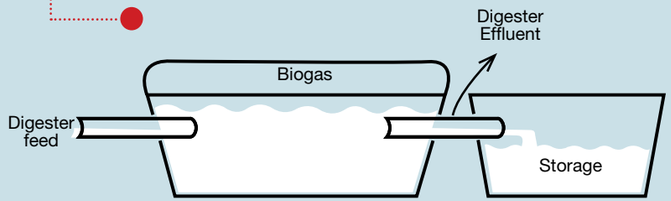
What is an animal unit (AU)?

An animal unit is 1,000 pounds of live weight.

Anaerobic digestive systems





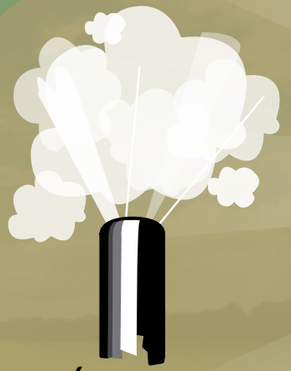


Considerations

Outputs

water needs
(see pages 5 & 11)

system size
(see page 11)



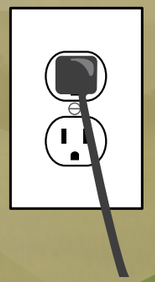
steam
(see page 10)

Cow Power

gas
(see page 10)

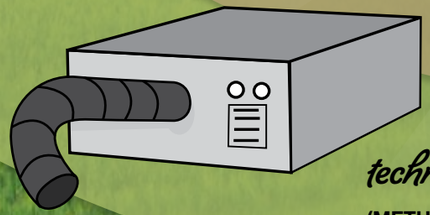
government grants
(see pages 14 - 16)

electricity
(see pages 6,7,10,11)



unbiased expert
(see page 15)

briquettes
(see pages 10,11)



technology
(METHODS OF CONVERSION)
(see pages 5-7,10,11)

business model
(see pages 12,15)

2. Incineration

Throw a few cow pies on the fire! This is what the incineration technology entails. It is the direct burning of biomass. In fact, many farms in rural India make manure cakes to use in cooking. While this is an inexpensive method, it will have some pollution issues.

However, there are newer and cleaner incineration systems available. The process, which is at the same time cutting edge and the oldest one available, involves four stages: collection, drying, burning, and cogeneration of heat and electricity.

First, manure is collected and dried. What happens is that moisture lowers the energy content of manure. Excessive heat produced by the next step, incineration, can be used to dry the manure.

The incineration process is very similar to what happens inside an engine that burns coal to run, like in old trains. The coal was burned in a stove, which heated a boiler with water, which in turn powered the locomotive's engine. In this case, the steam is used to run a cogenerator that produces electricity and heat with a high efficiency ratio.

One benefit of the incinerator is that the waste heat can be used in other ways as well. Also, the payback on investment can be in less than with other methods, but that depends on the energy consumption of your farm, and the quality of the available manure. The remaining ashes can be used as fertilizer, which makes waste disposal really easy and a potential source of income.

3. Gasification

Gasification has been around since the 19th century. Before electricity and natural gas were as popular as they are today, this process was used to produce gas for lighting and cooking. Through gasification, animal waste is converted into syngas, which can be used as a fuel to generate steam, electricity, and heat.

Syngas is produced in a system where little oxygen is present and the waste material is heated to a high temperature. One example would be what many people around the world have done with wood for centuries. Wood is burnt at a high temperature or superheated, this is called pyrolysis, which is just basically super heating organic matter. Some of the wood turns to ash/soot (tars). The rest is turned into charcoal. This charcoal is much more efficient than the wood or just incinerating manure. Char, as it is called, is light weight and is a concentrated potential energy source. The tar can be used as a fertilizer, and char is combusted to form syngas.

4. Pressing Poo into Power

If you plan to use the gasification or incineration technology you may want to consider pressing the manure into briquettes. This might interest you for several reasons:

Briquettes, or pellets, can be easily transported and have a high energy content relative to their size. If you believe your local community could be a good market for them, then briquetting could be a profitable option for you.

Briquetting is one of the least expensive solutions, and is easily scalable. You can start with one briquette press and grow as the market for it expands. Presses can be simple or complex depending on your budget, amount of manure being processed, and time.

You can use briquettes in your farm as fuel for furnaces and stoves purposely design for this source of energy. Briquettes, due to their high energy content, will burn for extended periods to generate more energy.

Pros and Cons of Biomass Energy Options

Which option works best for your business?

ANAEROBIC DIGESTION

\+ Relatively low upfront investment. Simple technology. Relatively easy operation.

\− High use of water. Somewhat fragile biological balance. Longer processing periods. Wastewater is not easy to dispose of.

\= Most suitable for wet manure, and small to large-scale operations.

INCINERATION

\+ Less water required than in anaerobic methods. Plumbing of manure not required. Clean handling and storage. No waste: ash can be used as fertilizer.

\− Expensive pollution control equipment and can have excessive energy losses. Higher upfront investment. More sophisticated technology may lead to higher operation and maintenance costs.

\= Most suitable for dry manure, and large-scale operations.

GASIFICATION/SYNGAS

\+ Can produce different forms of energy, such as biogas, steam, and electricity, more efficiently. Plumbing of manure not required. Waste can be reused.

\− Higher upfront investment. More sophisticated technology may lead to higher operation and maintenance costs.

\= Most suitable for dry manure, and large-scale operations.

BRIQUETTING / PRESSING

\+ Pellets can be transported easily. Fuel suitable for different devices. Simple technology. Easy operation. Low investment. Easily scalable.

\− Not presently suitable for high volumes. You would need to either use all the briquettes or develop a market on your community.

\= Most suitable for dry manure, and small to medium-scale operations.

Case Studies

There are a number of case studies that have used many of the technologies mentioned in the guide: Colorado Pork (covered lagoon digester), Five Star Dairy (WI) (complete mix digester), and Emerald Dairy (WI) (mixed plug flow). We provide you these real life examples so you can learn from their experiences.

Colorado Pork

This farm located in Lamar, Colorado decided to address the issues of their wastes after stringent regulations on hog waste management were passed into law in 1998.

Colorado Pork has one of the earliest covered lagoon digester systems in the state. It is used to generate electricity from the waste. They compress the biogas collected from the lagoon to power a combined heat and power system (CHP) that generates 80 kW. This system then recaptures excessive heat, water, and exhaust from the engine and places it back into the digester. They have since added a 30 kW microturbine to their system for more efficiency.

Colorado Pork is tied to Southeastern Colorado Rural Electric, where they produce approximately 43,000 kWh (kilowatt hours) of electricity a month. The farm has 5600-6300 sows that produce 15,000-18,000 gallons of manure a day. That pig power saves the farm $38,700 in electricity and $10,000 for lagoon clean-outs every year.

The total cost of the system was $338,000. Colorado Pork received a $75,000 grant from the EPA AgSTAR program, so the system will pay for itself in around 6 to 9 years, possibly earlier if the energy prices continue to rise.

Five Star Dairy

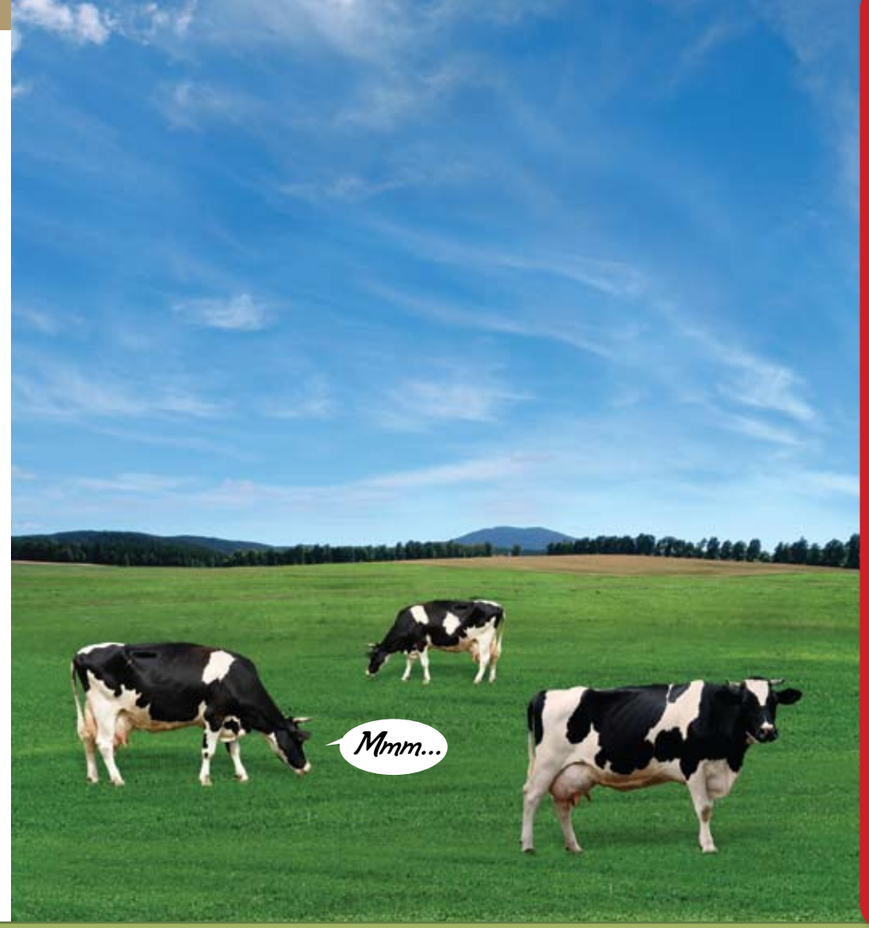
Five Star uses a complete mix digester which is developed by Microgy, Inc. They have approximately 850 head of cattle that produce about 100,000 kWh per month, which has been in operation since 2005.

Microgy operates and maintains the digester to create methane. The methane is sold to Dairyland Power Cooperative, who generates electricity from the gas and sells it to coop members. The money raised is then used by the farm to pay down the debt on the digester.

Emerald Dairy

In this case Emerald uses a mixed plug-flow system that was designed by GHD, Inc., which has been in operation since 2005. This dairy is twice the size of Five Star and has approximately 1,600 head of dairy cows, which produce 45,000 gallons of waste a day.

The dairy owns the system and compresses the methane, which is then hauled to a facility where St. Croix Electric Coop sells it to their customers as natural gas.



How can waste be managed?

These biomass methods will decrease waste disposal, but will waste be eliminated entirely?

All of the technologies shared in this guide will have some waste, but much less than dealing with your manure.

The waste that is leftover is a “cleaner” waste, since the bacteria that was present is now gone. What you have left is a concentrated fertilizer in either a liquid, dried or ash form. This can be safely placed back into the soil, sold on the market, or the ash could be used in concrete production.

Some methods, however, may produce waste that is still full of noxious substances. Make sure you ask your provider what kind of waste and byproducts are produced by their technology.

Excess Energy: Sell or Store

What will you do with the energy you don't use?

There are several different reasons why it's important to think about the excess energy. Even if the system is sized to provide, say, 50% of your yearly average consumption, there will be times when the system is running and you are just not consuming that much energy. What are your options? It depends on what your system is producing.

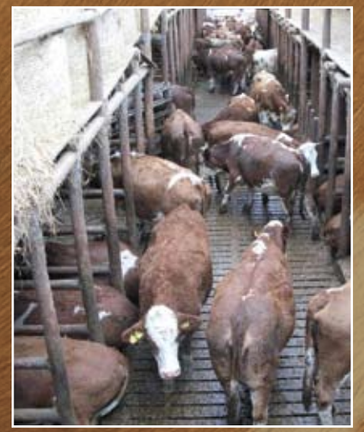
Electricity can sometimes be sent back into the grid. Power utilities are working with their customers on ways to place power to the grid. However, it is key to understand the implications of this, since it might mean that you need to install extra equipment. Additionally, you'll need to negotiate a profitable utility contract. Currently, storage of electricity is expensive and not very efficient.

Unused biogas can either be stored in a storage tank or can be piped or hauled to a local natural gas provider, as long as it meets the standards of quality.

Some systems have a built-in system to use excess energy in their own processes. For example, a gasifier might be able to use the extra heat generated to dry the manure before it enters the gasifier.

Solid wastes that are rich in nutrients may constitute a good fertilizer. If this is the case, the possibilities of marketing need to be considered during the feasibility analysis.

Independently from the system you are planning to use, an intelligent design will always include a smart strategy to deal with excess energy.



A hand from the government

AgStar, which is part of the EPA, offers a great deal of funding for farmers using biofuels and renewable energy. These include low interest loans, grants, and tax incentives. Producing cow power is easier than ever before and farmers can become not only energy producers but stewards for the environment. Check the Resource Section at the end of this guide.

Successful Projects, One Step at a Time

Naturally, one of the biggest considerations are the costs to purchase, install, and maintain systems, as described in this guide. However, keep in mind that there are more funding opportunities out there than ever before for farmers considering animal waste to power technologies.

The Colorado Governor's has recently added an Anaerobic Digestion section to their website. Learn more at: www.colorado.gov/energy/renewables/biomass-anaerobic-digestion.asp

In addition, the federal government has even more funding opportunities for farmers. Check out the programs from the USDA found at: www.rurdev.usda.gov/rbs/busp/bprogs.htm

Remember the steps for a successful project:

1. Shop around.

Find out who has the best prices and the best systems. Talk to your neighbors, county officials and unbiased experts, like the folks at CSU Extension, or iCAST.

2. Plan ahead.

A feasibility analysis and business plan will help you compare your different options, forecast possible earnings, and identify potential weaknesses and challenges that you haven't considered. Examples of points to take into account are:

- Who will own the system? What if you and other farmers get together? The provider could own the system and then sell you energy back at a discounted rate.
- Will other sources of waste increase the efficiency? Are they readily available?
- Tax credits and other government incentives.
- Negotiate a profitable utility contract to sell the excess energy.
- Potential markets for your by-products: liquids, solids, fertilizers.
- Etc.

3. Search for government grants, and other sources of cash.

If you don't find any, talk to your county officials, they might be able to steer you in the right direction.

4. Design.

Work together with your technology provider to ensure you understand the benefits, and other implications of your new waste to energy system. Again, you don't have to know it all, seek the help of unbiased experts.

5. Construction.

Understand what's going to happen once the system is running. What if there's a malfunction?

GLOSSARY OF TERMS

Anaerobic digestion: decomposition of organic materials in an environment deprived of oxygen.

Animal unit (AU): 1,000 pounds of live weight

Biogas: The combination of mostly methane and carbon dioxide that results from organic decomposition.

Biomass: Organic waste used as an energy source.

Gasification: Any process to transform biomass into syngas.

Incineration: The process of burning any material, particularly biomass in the context of this guide.

Methane: A flammable gas; one of the by-products of organic decomposition.

Syngas: A flammable gas with half the energy density of natural gas.

SOURCES

A short history of Anaerobic Digestion:
www.biogas.psu.edu/pdfs/ShortHistoryAD.pdf

Greenhouse gas emissions, EPA
www.epa.gov/climatechange/emissions

Ruminant Livestock contribution to Climate Change, Frequently Asked Questions, EPA
www.epa.gov/rlep/faq.html

Cuéllar, A., & Webber, M. (2008). *Cow power: the energy and emissions benefits of converting manure to biogas* (Department of Chemical Engineering, The University of Texas at Austin, USA)

AgSTAR Guide to Anaerobic Digesters:
www.epa.gov/agstar/operational.html

Frequently Asked Questions: www.epa.gov/agstar/faq.html

Srivastav, R., & Bielefeldt, A. (2008). *Biomass to Energy: A Farm Biomass Management Resource Guide*. (Department of Civil, Arch. and Environmental Engineering, University of Colorado at Boulder, USA)

Briquette presses for alternate use:
www.echotech.org/technical/technotes/Briquete.pdf

An Assessment of Technologies for Management and Treatment of Dairy Manure in California's San Joaquin Valley, Prepared by the San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel, December 2005
www.arb.ca.gov/ag/caf/dairypnl/dmtfaprprt.pdf

RESOURCES

Colorado Department of Agriculture
Advancing Colorado's Renewable Energy Program
www.colorado.gov/ag/energy

National Renewable Energy Laboratory
Renewable Energy Basics
Biomass: www.nrel.gov/learning/re_biomass.html
Biopower: www.nrel.gov/learning/re_biopower.html

Basics of Anaerobic Digestion, Department of Agricultural and Biological Engineering, Penn State University:
www.biogas.psu.edu

Governors Energy Office
Anaerobic Digestion:
www.colorado.gov/energy/renewables/biomass-anaerobic-digestion.asp

Support for AD feasibility study:
www.colorado.gov/energy/resources/funding-opportunities.asp#AD

CSU Extension, Animal Manure Management:
www.extension.org/animal+manure+management

The Intermountain CHP Center
www.intermountainchp.org

iCAST - International Center for Appropriate and Sustainable Technology
www.icastusa.org

AgSTAR Loans and Grants for farmers:
www.epa.gov/agstar/resources/funding.html

ABOUT ICAST

iCAST, International Center for Appropriate & Sustainable Technology, is a non-profit 501(c) (3) organization located in Lakewood, Colorado. We began as an initiative from the Engineering College at the University of Colorado at Boulder and later became registered as an individual organization in 2002.

We are dedicated in establishing relationships with local organizations to develop sustainable solutions for underserved populations. Our mission is to promote environmental health, economic viability, and social responsibility. iCAST projects are designed to encourage self-sufficiency based on the development, application and commercialization of appropriate and sustainable technologies.

iCAST also provides opportunities for university students to learn how academic studies and concepts such as sustainable development can be practically applied to the real-life problems facing disadvantaged communities. Through participation in service learning projects, students enhance technical and business skills while learning valuable lessons in teamwork, communications and ethics that will help create more valuable professionals.

iCAST projects bring together a variety of partners representing industry, government agencies, re-search facilities and educational institutions to serve the needs of local communities. By leveraging available technical, financial and intellectual resources, iCAST helps meet the challenges of the future by building stronger communities and a well-prepared workforce.

iCAST has partnered in a number of projects in Colorado and New Mexico: Rialto Theater Adaptive Reuse Feasibility Study in Alamosa, Jemez-Pueblo Waste Water Treatment Project, Affordable Arsenic Filters for drinking water in the San Luis Valley, among many others.

To learn more about current or future iCAST projects or if you have questions about any of the technologies mentioned in this guide, please visit our web site at **www.icastusa.org**
Contact iCAST directly:

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Email: **ravim@icastusa.org**
Phone: **(303) 462-4100 x801**

ABOUT THE AUTHORS

Michele Melio grew up on a small farm in Northern California and her early experience includes working with a variety of livestock, poultry, and growing fruits and vegetables. Her family's farm had to deal with severe drought in the 1970's and found creative ways to conserve water.

She has lived in Colorado for nearly 20 years. Her educational background is in education and received a B.A. in English from Metropolitan State College of Denver and an M.A.in education from the University of Colorado at Denver.

Michele has been an independent writer for many years and maintains a blog, online newsletter, and is a green reporter for Examiner.com.

Francisco Flores believes creativity, respect for the environment and one another, and immediate action is what we need to bring us closer to a sustainable world.

After seven years in the telecommunication industry, he realized something very important was missing in the picture: a purpose. Various experiences showed him that what he wanted to do the most is to contribute to make this a better world, both socially and environmentally. At iCAST he found a place to work for social empowerment and environmental conservation while having fun as an engineer.

He has a B.S. in Telecommunications Engineering from the Instituto Tecnológico y de Estudios Superiores de Monterrey.

Gillian Hickie was raised on an organic grain farm in Saskatchewan, Canada. Now a big-city gal, she thanks her prairie roots for helping her develop a sense of creativity, curiousity and consequence that influences her work daily.

She holds a degree in Visual Communications from the Alberta College of Art & Design and has now worked for design firms and independently nearly seven years.

Gillian believes that good design can create a positive impact on society. It is her hope that her graphic design work will help people understand an important message, feel inspired by what they learn, or even act – and create positive change.

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Anaerobic Digesters, Cesar Harada: http://cesarharada.com/
Pages 14: The cows, whose manure produces the biogas, ECOSAN: www.ecosan.nl/

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