“Poop To Power Or How To Learn To Love Manure”

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Manure (Feces And Urine), IS NOT Solely A Waste, But IS A Valuable Fuel Resource

Manure, traditionally has been used as a fertilizer or a composting ingredient and is largely regarded as a potential and sometimes real pollutant.

To handle potential problems, while using it directly or converting it into a fuel:

- Lagoons can be reduced in size or eliminated,

  - It can be de-watered and the water recycled,

  - Pathogens and toxins can be eliminated, while reducing or eliminating disease vectors, pests and odors,

  - Solid or liquid fertilizers can be produced, along with oil of different grades, syngas, liquid fuels,
    hydrogen, methane, carbon dioxide, waste heat, and other commodities can be captured,

  - It can be directly composted or land applied, according to agronomic rates, or leftover sludge can be land applied or composted (resulting compost can be used to absorb mine or other waste runoff, used as a soil amendment, to halt erosion or for soil-water retention and for animal bedding),

- And, most promising, if the process is well planned, absolutely no wastestream should leave the site.

Various Ways Manure Can Be Treated/Utilized

Manure, converted to fuel (generally methane) and other byproducts, can replace other fuels, including coal, natural gas, propane and other petrofuels and provide a significant revenue stream.

- Manure can be directly burned for power/heat/cooling; or to destroy it
- Manure can be anaerobically or aerobically digested to produce methane to bottle, transport or to use real-time on-site
- Methane can be scrubbed to remove H2S, Ammonia, water and other contaminants or commodities or can be used to directly produce power/heat/cooling
- Manure can be thermally depolymerized, hydrolyzed, pyrolyzed or gasified to produce syngas, oil, liquid fuels, solid fertilizers, hydrogen, etc.
- Excess power can be sold to others nearby or to the grid, and gas or other byproducts can be sold
- Power production credits can be sold as Renewable Energy Credits (RECs), Carbon Credits, Methane Reduction Credits (Methane is 24 times more potent, as a greenhouse gas, than carbon dioxide)
- Exhaust emissions produced on-site can be sequestered and credits can be taken for trade or to sell

Electrical Output From Manure

- A chicken yields ~ 9/10th pound of manure per day; a hog yields ~ 9 pounds; a feedlot cow yields ~ 90 pounds; a dairy cow yields ~ 140 pounds; and a human produces ~ 2.5 pounds

- ~ 9/10th pound of manure yields one watt of power for a day - therefore, 900 pounds of any manure source yields one kilowatt (kW, = 1000 watts) of power for a day to provide 24 kWh. One chicken, then, = 1 watt; one hog = 10 watts; one feedlot cow = 100 watts; one dairy cow = 162 watts; and one human ~ 3 watts

- That means, a 5000 head: chicken farm yields ~ 5 kW; hog farm yields ~ 50 kW; feedlot operation yields ~ 500 kW; dairy farm yields ~ 810 kW; and 5,000 people yield ~ 15 kW.

Electrical Output From Manure

- Estimates of total manure produced in the US, per year, on animal farms range from 1.5 to 2 trillion pounds PER YEAR
- Theoretically, this amount could produce 4.7 to 6.3 Gigawatts (GW) from US CAFOs (The world-wide yield ?)
- These estimates don't include animal mortalities, slaughter byproducts and waste bio-greases/bio-oils which, pound for pound, can produce up to four times as many watts as manure
- Current US human population could theoretically produce ~ 900 Megawatts (MW) and the world population could produce ~18 GW from ~5.75 trillion pounds/yr. of manure

Of Houses That Can Be Powered From Manure

- Average size home (~2200 square feet) uses about (for ease of computations) 720 kWh/month or, on average, across time, 1kWh each hour.
- Therefore, a generator **consistently** producing one MW (one thousand kilowatts) of power can supply 1,000 homes; a GW (one million kilowatts) of power will supply power to one million homes and a Terawatt (TW, one billion kilowatts) will supply one billion homes

Here, we're talking about power for homes only, but Office buildings, office equipment, foundries, etc., also require more, and also enormous, amounts of power.

Comparative Energy Consumption

- 20-40 W*:* human brain's approximate power use
- 100 W*:* human body's approximate average power use
- 745.7 W: equals one horsepower
- 750 W*:* amount of sunshine falling on a square meter of the Earth's surface on a clear day
- up to 2 kW*:* a sprinting professional cyclist's approximate short time power output
- 2.2 kW*:* world's per capita average power use in 2001; means a need for ~4 more TW of power when world pop. hits, e.g., 8B
- 3.3-6.6 kW*:* average photosynthetic power output per square kilometer of ocean
- 11.4 kW: US' per capita average power use in 2001; would mean a need for more than 5 times the current world use if all world inhabitants used power at our individual level
- 959 MW*:* Zimbabwe's average electrical power consumption in 1998 (Pop. = ~ 10M then)
- 11.1 GW: Colorado's current electrical power capacity

Comparative Energy Consumption (Cont'd)

- 1.7 TW*:* world's average electrical power consumption in 2001
- 3.327 TW*:* US' average total (gas, electricity, etc) power consumption in 2001
- 3.6-7.2 TW*:* global photosynthetic energy production
- 13.5 TW*:* world's average total power consumption in 2001
- 44 TW*:* average total heat flow from earth's interior
- 50 to 200 TW*:* heat energy released by a hurricane
- 4 PW*:* estimated total heat flow transported by Earth's atmosphere and oceans; from the equator towards the poles.
- 174 PW*:* total power received by the Earth from the Sun

Note: One Petawatt (PW) = one quadrillion watts or one trillion kW

Other Organic Waste That Could Be Blended With Manure

- Forest thinnings and logging wastes
- Other agriculture waste: e.g., cellulosic
- Land-filled bio-based materials (paper, plastics, wood)
- Fish (fin and shell) processing waste
- Paper mill wastes
- Some wastes from chemical plants
- All food processing wastes
- Other biofuel processing wastes
- Anything carbonaceous

Colorado’s Only Active On-Farm Anaerobic Digester

STM Power Stirling Engine 55 kW

Vestas Wind Turbine 65 kW

Colorado Pork Generation Devices

Caterpillar Recip, IC Engine

Capstone MT 30 kW

Biorefinery Types:

Thermal Depolymerization (Renewable Environmental Solutions)

As shown: an approx. 7 tons/day pilot plant using turkey waste.

A scaled up plant in Carthage, MO was treating 200 tons/day

An approx. 1,000 tons/day plant was planned for Weld County, CO (ON HOLD)

Rendering of Biorefinex Refinery

Other Planned Colorado Biomass Operations

- **Leadville Institute of Science and Technology** is considering a pyrolysis gasification process to treat forest waste to make gas, activated carbon, ethanol and hydrogen. They will consider in-forest or site-specific plants.
- **Power Energy Fuels** uses a catalyst to make, from carbon-based items, a fuel trademarked as Ecalene which is said to be a higher alcohol. Has been pilot tested under contract with DOE and others and is ready for scale up.
- **Advanced Concept Technologies** uses any carbonaceous material to make super-clean natural gas for power. The one megawatt pilot scale plant will soon be tested at the USAFA, using on-site forest thinnings.
- **Agriquatics** will use duck weed to test its ability to filter out salts creating salt-laden soils and drinking water and interstate water compact problems. This application will test whether it can replace of supplement the existing municipal wastewater treatment plant while providing electrical power from methane created by AD of pig manure and that from the town's populace; producing animal feed by harvesting the duck weed; and improving tourism by providing hiking, fishing and general recreation within a park-like setting.

Conclusions

- Residues that are carbonaceous in nature should not be called waste – they should be valued, energy-rich resources
- Current and potential pollution problems can be ameliorated, mitigated, or eliminated and the solution is the way biomass is utilized Every project, designed correctly, can have zero off-site waste or odor emissions. There need be no lagoons and essentially no toxins or pathogens produced
- Manure from billions of people and billions of animals can provide very large amounts of power/heat/cooling. But:

  - it is difficult to capture large supplies inexpensively, especially in developing and underdeveloped parts of the world;

  - farmers generally operate on thin margins and don't like to deal with new requirements, particularly specialized labor;

  - it's easier to build manure treatment and power production facilities when constructing a new CAFO

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