Energy and Greenhouse Gas Analysis for Biogas Power Plants

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Basic Operation

- Plants convert solar radiation, ground water, and atmospheric CO₂ into biomass
- Fermenting the shredded plants releases methane, which is burned to liberate some of the original solar energy
- **CARBON - NEUTRAL** energy “production”
Energy Crop: Corn (whole plant)
Biomass Consumption / Day

- 25 tons of shredded corn silage
- 11 tons of cow dung
Fermenter

• Annual residue production:
  – 10,000 cubic yards of solid/liquid mixture
  – High quality (non-smelly!!!) organic fertilizer

• Farming cycle sustainable without artificial fertilizer purchase (no soil deterioration)
Gas Storage

- 7,100 cubic yards of gas/day
- 60% methane
- Equivalent energy content of 4,500 cubic yards of natural gas
Generators (82% efficient)

- 2 engines rated at 526 kW electric power each (=705 horsepower)
- Another 540 kW of heat
• Initial investment: ~ $3-5 million
• Land required to grow biomass: 150 hectares
• 6.2 million kWh of electrical energy/year
• 6.5 million kWh of thermal energy
• Payoff time (@10¢/kWh): 3-4 years
Energy Balance

Factor 8 more electricity output than total energy input!
Net Energy Ratio

\[ R_E = \frac{\text{Net Energy Output}}{\langle \text{Fossil Energy Input} \rangle_{\text{Life Cycle}}} \]


Figure of Merit

- Solar constant: 1.37 kW/m²
- Real average value for Germany: ~75 W/m² (\(\cos \theta\), day/night, clouds, growing season…).
- 150 hectares = 1.5 \(\times\) 10⁶ m²
- Maximum possible power capture: \(\sim 1.1 \times 10^8\) W
- Present efficiency = 0.7 MW / 0.11 GW = 0.6%
- Room for improvement!
  - Research on better microbes, better energy crops, better conversion processes
- (But already much better than covering 7 ha of land with 15% efficient photovoltaic cells)
Transportation Fuel

- Could produce 0.68 M liter of ethanol / year
  - Industry standard output from our corn yield on 150 ha
- Are producing 2.6 M liter of (liquid) CH₄ / year
- Factor of 3.8 better yield!
  (heat of combustion per liter almost identical for ethanol and methane, ~ 2/3 of gasoline)

Driving distance per hectare (numbers for Chevy Volt)

- Bioethanol: 5,000 km
- Biogas, methane: 19,000 km
- Biogas, electric: 23,000 km
methane
2015 projected bioethanol yield: 50 billion liters

Proposal: Convert to biogas reactors
Make 190 billion liters methane
More than $100 billion/year profit!
Greenhouse Gas Balance

Methane is ~25 times more powerful greenhouse gas than CO₂ - our process prevents methane from cow dung to escape.
Food vs. Fuel?

Conservation Reserve Program

10 M hectare
Marginal land(?)

USDA 2008

~100 GW potential
Summary (yes, we can ...)

• We can produce lots of “green” energy
• We can build environmentally friendly power plants
  – High net energy ratio (~ 4-8 x that of corn-ethanol)
  – High transportation fuel yield (> 3 x that of corn-ethanol)
  – Negative carbon emissions (~ -100g CO₂/kWh)
  – No intermittency / excellent power quality
• We can make lots of small farms very profitable
• We can make $$, £££, €€€, … from our waste
• We can create lots of great jobs in the process
  – Distributed ownership of energy resources
Final Word

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