# Comparison of Renewable Natural Gas to Other Renewable Energy Technologies

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# Overview

- This presentation compares Catalytic Hydrothermal Gasification of Wet Biomass to a number of other renewable energy technologies
- It should be used in conjunction with the presentation titled “Renewable Natural Gas via Catalytic Hydrothermal Gasification of Aquatic Biomass”

# Compared to Biological (Anaerobic) Digestion

# Biological (Anaerobic) Digestion

- **Process is well known and used for many years**
- **Main disadvantage is digestion time (up to 30 days) and relatively low yield**
  - AD yield = .23 L methane/g biomass; CHG yield = .40 L methane/g biomass
  - Time in catalytic system is minutes
  - Digesters produce large amount of undigested sludge
- **AD facilities are very large compared to CHG**
- **All outputs of CHG are sterile; not with AD**

# Compared to High-Temperature Pyrolysis

# High-Temp Gasification

- Higher temperatures make system design more difficult and expensive
- Less efficient than lower temperature catalytic system
- Feedstock must be dry, and must often be ground or chopped, increasing energy needs
- Product gas is syngas, a combination of carbon monoxide and hydrogen, which is less desirable and flexible than methane

# Compared to Algal Lipids for Diesel Fuel

# Algal Lipids for Diesel Fuel

- **Some species of algae (and some species of diatoms) produce triacylglycerides (TAG's), in varying amounts**
- **These can be converted to a liquid fuel by one of several processes:**
  - Direct hydrogenation (forming a pure alkane)
  - Transesterification (forming a fatty acid ester)

# Lipid Production

- **Under good growing conditions lipid production is app. 25% of cell mass**
- **To increase this to a higher level, the organism must be stressed, often by nitrogen deprivation**
  - The stress increases lipid % by weight, but essentially stops cell growth
- **Result is that high lipid content implies slow cell growth**

# Lipid Production (cont.)

- **Species which produce TAGs are generally small and unicellular—often only a few microns in size**
  - These are hard to harvest
    - Small size jams filters quickly
    - Can be done by centrifugation, but this is expensive
- **Extraction of the useful TAGs is also expensive—supercritical processes or hexane extraction requiring solvent recovery**

# Lipid Production (cont.)

- **Some of the best lipid producers are diatoms, which have other difficulties**
  - Diatom shells are made of silica, which is abrasive to machinery and difficult to work with
- **Whether the chosen species are algae or diatoms, well over half of the biomass must be disposed in some way after oil extraction**
  - With algae, the general consensus is to use the remainder as cattle feed; diatoms are harder to use
  - CHG can gasify these “bottoms” to produce second fuel

# Lipid Production Economics

- The combination of slow growth, expensive harvesting and oil extraction, and relatively low yield (less than half of the mass) makes this an expensive fuel source
- Unlikely to be profitable without subsidies in the foreseeable future (10 years?)

# Compared to Oil Crops

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# Fuel from Oil Crops

- **Many food-type crops produce vegetable oils which can be converted to bio-diesel fuel**
  – Soybeans, canola, peanuts, palm, sunflower, etc.
- **The problem with using food crops is that it creates competition between food and fuel for premium land and water (similar to corn or sugar ethanol)**
- **This competition is not desirable or economic in the long run**

# Compared to
# Corn or Sugar Ethanol

# Corn Ethanol

- In the US, by far the largest volume of current biofuel production is ethanol from corn
- Corn is grown by conventional means, and the grain is processed to remove starch and sugars, which are fermented to alcohol
- The technology is well known, proven, and efficient.

# Sugar Ethanol

- Ethanol from sugar is the dominant biofuel in Brazil, and one of the major biofuel products in the world
- However, it suffers from many of the same problems as corn ethanol
- Sugar ethanol is unlikely to be economically viable in the long run

# Corn Ethanol (cont.)

- **Using corn for fuel has highlighted a number of problems**
  - Corn production is energy intensive (for nitrogen fertilizer and other agricultural requirements)
  - Corn requires abundant water and good land
  - Corn is a basic food grain, and using corn for fuel creates competition between food and fuel
  - The net result is that corn ethanol is only slightly energy positive, and is too expensive in the long run in the absence of government subsidies

# Compared to Cellulosic Ethanol

# Cellulosic Ethanol

- Cellulosic ethanol production is generally assumed to come from terrestrial biomass
- The process involves the thermal, chemical, or biological breakdown of plant material to extract sugars
- The sugars are then fermented into ethanol
- The alcohol can be used as fuel or blended with hydrocarbon fuels such as gasoline
- Not clear how to use remaining material—high in lignin, which is hard to process economically

# Cellulosic Ethanol

- **Cellulosic ethanol is an alternative to fuel production from food crops**
- **Current research focuses on fast-growing grasses which can use marginal (non-crop) land**
  - Examples include miscanthus, switchgrass, etc.
  - Despite massive investments by governments around the world, no commercially viable production yet

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# Cellulosic Ethanol (Problems)

- **Current production is non-economic, primarily because extracting sugars is still technically difficult and expensive**
- **Very high yields (30 tons/acre/yr) are often quoted for crops such as miscanthus or switchgrass, but such yields can only be achieved with water and fertilizer additions.**
- **On marginal land, with no irrigation or fertilizer, the yields are likely to be in the range of 5-7 tons/acre or less**

# Compared to Photovoltaics (Solar Cells)

# Photovoltaic vs. Biological Systems

- **Photovoltaic energy production is similar to growth of biomass in the sense that both depend on capturing photons from sunlight**
- **PV systems produce electricity directly for immediate use, while biological systems store energy in chemical form for later use**
- **Theoretically, both capture similar energy per unit of surface area**
  - However, in practice limits on photosynthesis result in lower energy/area for biological systems

# Photovoltaic vs. Biological (cont.)

- **Both accomplish a quantum conversion of photons to usable energy**
  - PV systems use semiconductor materials to achieve charge separation (electrons and holes)
  - Biological systems use photosynthesis to achieve charge separation as electrons and hydrogen ions (protons)
- **Both systems use a similar portion of the solar spectrum and (with currently practical technology) achieve similar quantum efficiencies**

# Major Differences

- **PV and Biological systems have two major differences:**
  - Energy storage
    - PV energy output is electricity which must be used immediately
    - Biological energy can be harvested, stored, and converted to usable energy day or night
      - After CHG conversion to renewable natural gas, the energy (in the form of fuel) can be stored indefinitely without loss
  - PV systems are vastly more capital intensive—by at least an order of magnitude

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# PV Economics

- The high cost (capital intensity) of PV systems make them uneconomic today
- Typical of semiconductor technology, PV costs are declining
- Some forecasts expect economic viability around 2015, though this projection usually assumes some form of continuing governmental subsidies

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# Major Differences

- **PV systems produce peak output from late morning to mid-afternoon**
- **Renewable natural gas from aquatic biomass can be used on demand, including by conversion to electricity on demand via natural gas turbines**
  - Can be used as "peaking power" when needed
  - Can be used as "base load" power, which is not possible with PV power

# Compared to Wind Turbines

# Wind Turbines

- Wind turbines are usable only in areas of moderate but consistent wind
- Fortunately, the US has a number of such areas
- The problem is that good wind areas are usually in remote locations with no connection to the electrical grid
- High concentrations of wind turbines can also be noisy and unsightly, further driving them to remote locations

# Wind Turbines (cont.)

- Wind turbines are capital intensive compared to biological growth systems—wind is similar to PV systems in capital intensity
- Wind systems achieve relatively low capital utilization—often in the range of 20% to 25%
- Much confusion arises because nameplate capacities are not the same as effective capacities—the only valid measure of wind capacity is total energy produced per year, not nameplate capacity of the turbines

# Compared to Concentrated Solar

# Concentrated Solar

- Concentrated solar uses mirrors to focus sunlight on a thermal collector
- Heat is generally converted to steam to produce electricity with a conventional steam turbine-generator
- Process heat may also be made
- Economics are similar to PV Solar

# Conclusion

# Conclusion

- Wind, PV, Concentrated Solar, and Biomass Gasification all theoretically achieve a similar power density—that is, the amount of power which can be produced per unit of land
- This figure is in the range of 750 MWh/acre/year; in practice, biomass gasification is somewhat less
- Biomass gasification has the lowest capital cost, and is the only one of these technologies which can provide continuous energy output without very expensive intermediate storage technologies

# Conclusion (cont.)

- **At the current stage of development, the production of renewable natural gas via catalytic hydrothermal gasification of wet organic materials is very likely the most economically viable renewable energy process**
- **Genifuel produces renewable natural gas via this process**