Renewable Natural Gas
via
Catalytic Hydrothermal Gasification
of Aquatic Biomass

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Photosynthesis Captures Solar Energy

- All photosynthetic organisms capture energy from the sun
- This energy is stored in the cells in chemical form, mostly carbohydrates and proteins
- The energy can be harvested in various ways:
  - Direct burning (e.g. wood fires)
  - Gasification to methane or syngas (carbon monoxide plus hydrogen)
  - Fermentation to alcohol
  - Extraction of lipids with conversion to fuel oils
Photosynthetic Efficiency

• While all photosynthetic organisms capture solar energy, not all are equally efficient
  – Efficiencies of utilizing sunlight to store energy vary but average about 7% for an individual species

• In an intact ecosystem of many species total efficiency of solar capture can be as high as 14%

• Photosynthetic aquatic species can include algae, cyanobacteria, diatoms, and certain protozoa
Advantages of Aquatic Biomass

• Aquatic Biomass, under optimal conditions, can grow very fast—often called “blooms”
• Growth may be substantially faster than terrestrial species
• In temperate climates, plants generally die off and stop growing during winter, but aquatic species can grow all year if water temperature is maintained suitably
Advantages of Aquatic Biomass (cont.)

• Because of its higher growth rate, aquatic biomass can produce greater biomass per unit of area compared to terrestrial plants
• If growing in ponds or troughs on land, this means less land area
• The land itself can be poor land—does not need to be fertile cropland
Advantages of Aquatic Biomass (cont.)

- The water can be of poor quality
  - Treated wastewater
  - Brackish or alkaline water
  - Salt water
- Less water is lost to evaporation compared to irrigated terrestrial crops
- Can be grown almost anywhere, though areas of high sunlight and warm temperature do best
Advantages of Aquatic Biomass (cont.)

• The aquatic species used are small but not too small
  – Large enough to be efficiently harvested
  – Small enough to be easily prepared for gasification, requiring little pre-processing
• Are already in water, which is needed for the hydrothermal gasification process
• Drying not needed
Advantages of Gasification

• Since the entire biomass is efficiently gasified, the only objective of the growth process is to achieve the fastest possible growth and production of mass

• Species are chosen to be fast-growing indigenous species, so they are adapted to the location, and there is no risk of a foreign or invasive species which is not already present in the environment
Gasification of Biomass

- Biomass can be gasified in a number of ways, yielding different gas compositions and efficiencies, for example:
  - Dry thermal pyrolysis
  - Supercritical pyrolysis
  - Biological digestion (landfills and digesters)
  - Catalytic gasification (low-temperature wet catalytic gasification, also known as catalytic hydrothermal gasification)
- Of these, the catalytic method is most efficient
Advantages of Catalytic Gasification

• Temperatures of 350°C, pressures of 20-22MPa
  – Compared to other techniques, which may require up to 1000°C

• Biomass is processed wet (80-85% moisture), so energy is not lost in drying

• The gas stream is mostly steam, so heat is easily recovered in a heat exchanger to greatly improve efficiency
Advantages (cont.)

• Conversion efficiency is very high, with >99% of the biomass converted to the output stream
• Gas output is clean with no residual tars and <1% ash
• Typical gas stream composition by volume:
  – 62% methane
  – 35% carbon dioxide
  – Small amount of hydrogen, ethane, and propane
Resource Recovery

• Heat is recovered to heat incoming feedstock
• CO$_2$ is separated from product gas leaving product gas very similar to natural gas
• CO$_2$ dissolved in the condensate is recycled to the aquatic growth medium, accelerating growth of the biomass and reducing emissions to nearly zero
Favorable Economics

• Overall process is very efficient
• Yield higher than any other biomass processes
• CO2 recovery is critical
  – Prevent GHG emissions
  – Recycle to growth ponds to accelerate growth
  – Reduces cost for growing aquatic biomass
• Low temperature and pressure regime reduces capital cost of the gasifier