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

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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**

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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**