Biofuels: Social, environmental and economic concerns

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Introductory lecture – Energy commodities and technologies

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Global trends

- Biofuels: overview
- Economic concerns
- Environmental concerns
- Social concerns
Biofuels: overview

- **First generation biofuels (1G)** – produced from food-grade biomass by natural microbiological processes.
  - Example: vegetable oils, ethanol, biogas from crops.

- **1G non-food biofuels** – produced by natural processes but from non-edible biomass, i.e. from organic residues, sewage sludge or garbage.
  - Example: biogas.

- **Second generation biofuels (2G)** – produced by advanced thermochemical conversion methods from non-edible biomass feedstocks.
  - Example: alcohols or biosynthetic fuels from wood or from another lignocellulosic material!

- **Third generation biofuels (3G)** – based on more productive, special grown non-food biomass feedstocks.
  - Example: algae, genetically modified or hybrid crops, artificial photosynthesis.
Utilized in thermal power plants, boilers and suitable vehicles
- Thermal efficiency 35-40% of ICE, up to 90% in the case of cogeneration
- Base load supply
- Power plant cost comparable to fossil fuels
- Biofuel production cost depends on the fuel type
Susceptible to aging and freezing

Difficult to maintain the production process in small scales

Existing infrastructure can sometimes handle biofuels but in many cases modification or equipment replacement is required
Biofuels: environmental concerns

- Deforestation
- Reduction in biological diversity
- Erosion
- Typically high input of energy required (fertilisers, harvesting processing)
- New agricultural land, less retention of water in soil, desertification (higher evapotranspiration)
- Improper irrigation of energy crops => soil salinity
- Ground water pollution due to fertilisers
- H2O for biogas production and distilleries =>
  - Production of waste water rich in N2, phosphorous and potassium.
Biofuels: social concerns

- Biofuel production requires significant amounts of water (often scarce). This leads to a clear trade-off in water allocation.

- Land use conflict. Biomass alone can NOT be a single source of both fuel and food for the growing population on planet Earth. Efficient production/conversion/utilisation methods should be sought.

- Visual impact on land.
Technologies in the biofuels chain

- Biomass production
- Biogas and bio-synthetic gas production
- Biomass for heat and power
Import / Production of biomass

Biomass

Combustion-based power plant

Bio-synthetic gas

Biogas

Electricity

Electricity transmission and distribution

Decentralised energy supply

Heat

Energy demand

Residential sector

Commercial sector

Industrial sector

Transportation sector
Processes for bioenergy conversion

Biomass

- Gasification: H₂, Alcohols, FT, Gasoline & Diesel Olefines, Oxochemicals NH₃ and SNG
- Pyrolysis: H₂, Olefins, oil & chemicals
- Anaerobic Digestion: Biogas (Hydrogen)
- Fermentation: Alcohols (Hydrogen)
- Other: H₂, CH₄, Oils & Chemicals
Biomass Production

- Biomass comes from agriculture/forest products/residues as well as waste.
- Various harvesting or collection methods are applied.
- Treatment includes chipping, drying, pelleting and torrefaction.
- Transport is done by truck, train and ship.
- It can be either used in solid form (e.g. chips or pellets) or converted into liquid fuels (ethanol, biodiesel, etc.), or gas (syngas, biogas).

### Key characteristics

**Pellet Production Plant (40,000 t/yr capacity)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>4866 k$</td>
</tr>
<tr>
<td>FOM cost</td>
<td>225 k$/a</td>
</tr>
<tr>
<td>Energy use</td>
<td>0.410 GJ/t pellets</td>
</tr>
<tr>
<td>Utilization factor</td>
<td>91%</td>
</tr>
</tbody>
</table>
Biogas and bio-synthetic gas production

- Biogas usually produced by anaerobic digestion. Applications also in developing countries and rural contexts.

- Bio-syngas production less mature. Gasification technologies work on same principles as those for coal. Potentially higher production rates.

**Key characteristics**

<table>
<thead>
<tr>
<th>Anaerobic digester</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>5000-7500 USD / Nm3/h</td>
</tr>
<tr>
<td>FOM cost</td>
<td>2-7% of capital</td>
</tr>
<tr>
<td>Energy use</td>
<td>Up to 15% of feed</td>
</tr>
<tr>
<td>CO2 emission factor</td>
<td>11-20 gCO2/MJ</td>
</tr>
</tbody>
</table>
Biomass for Heat and Power

- The most common application of biomass in the energy sector is combined heat and power (CHP) generation.
- CHP (if not for industrial use) is coupled with district heating.
- Co-firing of biomass/biogas with coal/natural gas respectively is possible with a few adjustments.

<table>
<thead>
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<tbody>
<tr>
<td><strong>Biomass CHP plant</strong></td>
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<tr>
<td>Capital cost</td>
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<td>FOM cost</td>
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<tr>
<td>Fuel cost</td>
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<tr>
<td>Electric Efficiency</td>
</tr>
<tr>
<td>Total Efficiency</td>
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</table>
References and reading material
IEA, World Energy Outlook 2016;


IEA-ETSAP, Energy Technology Data Source. Available at: https://iea-etsap.org/index.php/energy-technology-data;
Gasification: http://www.gbgasified.com/model.html
Biomass: http://inhabitat.com/tag/biomass/
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Transportation of oil products: http://www.picquery.com/gasoline-truck_WXRZapIkZ2eaRVifu*zjgPAvrMnnxmBsTsgdn*BBBKk/
Sources for the RES pictures

Biogas and bio-synthetic gas production: https://ehp.niehs.nih.gov/123-a180/
Onshore wind: https://www.mitchelltech.edu/programs/on-campus/energy-production-transmission/wind-turbine-technology
Offshore wind: http://inhabitat.com/tag/offshore-wind-farm/
PV panels: https://dir.indiamart.com/coimbatore/solar-pv-panel.html
Bioenergy conversion:
## Changelog and attribution

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<th>Reviser</th>
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<tr>
<td>2017-09-26</td>
<td>Georgios Avgerinopoulos</td>
<td>Mark Howells</td>
<td>Georgios Avgerinopoulos</td>
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