Biomass combustion processes

INVENT – Final Meetings
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What is biomass?

- Organic matter in trees, agricultural crops and other living plant materials
- Made up of carbohydrates – organic compounds that are formed in growing plant life
- Biomass is **solar energy** stored in organic matter
- Process of photosynthesis uses energy from the sun to convert carbon dioxide into carbohydrates (sugars, starches and cellulose)
- When plants die, the process of decay releases the energy stored in carbohydrates and discharges carbon dioxide back into the atmosphere

- Biomass is a **renewable energy source** because the growth of new plants and trees replenishes the supply
Significance of biomass combustion

- Use of biomass for energy causes no net increase in carbon dioxide emissions to the atmosphere and does not contribute to the risk of global climate change
- Growing plants remove carbon from the atmosphere through photosynthesis
- If the amount of new biomass growth balances the biomass used for energy, bioenergy is carbon dioxide “neutral”
- Globally, biomass meets about 14 percent of the world’s energy needs

- Origination process of biomass:

\[
6 \text{ CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{+ sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2
\]
Classification of biomass

- **Renewable primary products:**
  forest wood, energy crops (rape, maize, corn), biological raw materials, oil plants

- **Biological residues:**
  straw, matured forest, small dimensioned wood, loppings, abattoir refuse, blackstrap molasses, sewage sludge, landfill gas, biological part of municipal solid waste
Classification of biological solid fuels

Biological solid fuels

- Wood-like biomass
  - Residues
    - Logging remains
    - Industrial wood residual
    - Used and demolition wood
  - Energy crops
    - Fast-growing forest species

- Calm-shaped biomass
  - Residues
    - Straw
  - Energy crops
    - Corn
    - Rape
    - Sunflower
    - Maize

Sizing of biological solid fuels:
1) bulk goods (bale of straw, firewood)
2) bulk solids (straw, wood chips, wood in powder form, pellets)
## Combustion processes

<table>
<thead>
<tr>
<th>Technology</th>
<th>Conversion Process Type</th>
<th>Major Biomass Feedstock</th>
<th>Energy or Fuel Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Combustion</td>
<td>Thermochemical</td>
<td>wood, agricultural waste, municipal solid waste, residential fuels</td>
<td>heat, steam, electricity</td>
</tr>
<tr>
<td>Gasification</td>
<td>Thermochemical</td>
<td>wood, agricultural waste, municipal solid waste</td>
<td>low or medium-Btu producer gas</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>Thermochemical</td>
<td>wood, agricultural waste, municipal solid waste</td>
<td>synthetic fuel oil (bio-crude), charcoal</td>
</tr>
<tr>
<td>Anaerobic Digestion</td>
<td>Biochemical (anaerobic)</td>
<td>animal manure, agricultural waste, landfill, wastewater</td>
<td>medium Btu gas (methane)</td>
</tr>
<tr>
<td>Ethanol Production</td>
<td>Biochemical (aerobic)</td>
<td>sugar or starch crops, wood waste, pulp sludge, grass straw</td>
<td>ethanol</td>
</tr>
<tr>
<td>Biodiesel Production</td>
<td>Chemical</td>
<td>rapeseed, soy beans, waste vegetable oil, animal fats</td>
<td>biodiesel</td>
</tr>
<tr>
<td>Methanol Production</td>
<td>Thermochemical</td>
<td>wood, agricultural waste, municipal solid waste</td>
<td>methanol</td>
</tr>
</tbody>
</table>
Direct combustion

- Combustion technologies convert biomass fuels into several forms of useful energy for commercial or industrial uses: hot air, hot water, steam and electricity

- A furnace is the simplest combustion technology:
  - biomass fuels burns in a combustion chamber
  - converting biomass into heat energy (hot gases contains 85 % of the fuel’s potential energy)
  - either direct or indirect use of heat exchanger to use the hot gases in the form of hot air or hot water
  - combustion of wood can be divided into four phases:
    1) **Drying**: water inside the wood boils off
    2) **Degasification**: gas content is freed from the wood
    3) **Gasification**: the gases emitted mix with atmospheric air and burn at a high temperature
    4) **Combustion**: the rest of the wood (mostly carbon) burns
Direct combustion

- Biomass
- Drying
- Degasification
- Burnout
- Primary air
- Secondary air
- Cooling
- Ash
- Post-combustion
Direct combustion

- **A biomass-fired boiler** is a more adaptable direct combustion technology because a boiler transfers the heat of combustion into steam
  - steam can be used for electricity, mechanical energy and heat
  - boiler’s steam output contains 60 to 85% of the potential energy in biomass fuel
  - major types of biomass combustion boilers: pile burners, stationary or travelling grate combustors, fluidized-bed combustors

Pile burners:
- consist of cells, each having an upper and a lower combustion chamber
- biomass fuel burns on a grate in the lower chamber, releasing volatile gases
- the gases burn in the upper combustion chamber
- operator must shut down pile burners periodically to remove ash
Direct combustion

- **Fluidized-bed combustors:**
  - burn biomass fuel in a hot bed of granular material, such as sand
  - injection of air into the bed creates turbulences resembling a boiling liquid
  - the turbulences distributes and suspends the fuel
  - the design of a fluidized-bed reactor increases heat transfer and allows for operating temperatures below 950 °C, reducing nitrogen oxide emissions
  - fluidized-bed combustors can handle high-ash fuels, agricultural residues and sewage sludge
Direct combustion

- **Cogeneration:**
  - using a boiler to produce **heat** and **electricity** conversion efficiency 85%  
  - for comparison: electricity production from steam-driven turbine-generators 17 to 25% conversion efficiency

- **Direct-Fired Gas Turbine Technology:**
  - fuel pre-treatment reduces biomass to a particle size less than 2 mm and a moisture content of less than 25%  
  - fuel is burned with compressed air turbine **electricity**

- **Co-Firing:**
  - biomass is used as **secondary fuel** e.g. in coal-burning power plants  
  - could help to reduce sulphur dioxide and nitrogen oxide emissions  
  - decreases net carbon dioxide emissions from the power plant (if the biomass fuel comes from a sustainable source)
## Advantages and disadvantages

Advantages and disadvantages of modern firing (bulk goods vs. bulk solids)

<table>
<thead>
<tr>
<th>advantages</th>
<th>disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>firing of wood log</td>
<td></td>
</tr>
<tr>
<td>- low investment costs</td>
<td>- high operating expense</td>
</tr>
<tr>
<td>- low stock requirements for the solid fuels</td>
<td>- buffer storage to avoid light load operation</td>
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<tr>
<td>- high efficiency (up to 90 %)</td>
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<tr>
<td>firing of wood chips</td>
<td></td>
</tr>
<tr>
<td>- user friendly and low-maintenance</td>
<td>- higher costs of investment</td>
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<tr>
<td>- automatic provision of heat</td>
<td>- higher stock requirements for the solid fuels necessary</td>
</tr>
<tr>
<td>- very high efficiency (more than 90 %)</td>
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<tr>
<td>- also weak wood residuals useable</td>
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<tr>
<td>firing of wood pellets</td>
<td></td>
</tr>
<tr>
<td>- user friendly and low-maintenance</td>
<td>- higher costs of investment</td>
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<tr>
<td>- automatic provision of heat</td>
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<tr>
<td>- very high efficiency (up to 95 %)</td>
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<tr>
<td>- low stock requirements for the solid fuels</td>
<td></td>
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<tr>
<td>- necessary</td>
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</table>
Pyrolysis and gasification

• **Gasification of solid biological fuels:**
  - emergence of a gaseous energy sources (lean gas, burnable gas) by conversion of solid biological fuels with the influence of high temperatures
  - scission of solid biological fuels into solid and gaseous components by using heat and $O_2$
  - advantages: less emissions than combustion, ideal for energy recovery
  - disadvantages: lots of dust and organic compounds in the exhaust poorly properties for turbines

• **Pyrolysis: (liquefaction of solid biological fuels)**
  - conversion of the biomass with lack of $O_2$ and influenced by heat
  - emergence of solid, fluid and gaseous products which can use for energy recovery
  - advantages: solid biological fuels can convert into liquid energy sources which are well transportable and have a high energy density
  - currently: stage of development
Thank you for your attention!