Fuels and Chemicals from Biomass and Waste

Esben Taarning, Haldor Topsøe A/S
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Turnover 2008: ~5 mia kr
Catalyst volume: 40,000 tons

2000 employees
- 1700 in Denmark
  - 300 in R&D
- 300 abroad

Headquarter (Lyngby)

Catalyst prod. in Fr.sund
Catalyst prod. in Houston, Tx
Technology to Fuel, Feed and Clean the Planet

- **Hydrotreating**
  \[ C_{12}H_8S + 2H_2 \rightarrow C_{12}H_{10} + H_2S \]

- **Ammonia**
  \[ N_2 + 3H_2 \rightarrow 2NH_3 \]

- **Sulphuric acid**
  \[ S + 1\frac{1}{2}O_2 + H_2O \rightarrow H_2SO_4 \]

- **Hydrogen plants**
  \[ CH_4 + H_2O \rightarrow CO + 3H_2 \]

- **Emission control**
  - Power sector
  - Diesel truck producers
  \[ 4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \]
Conversion Options for Biomass

- Bio-oil
- Thermochemical treatment
- Catalytic conversion
- Fermentation
- Chemicals
- Syn-fuels
- Gasification
- Chemicals
- Fertilizers
- Syn-fuels
- Ethanol
Gasification

30-70 bar

Biomass

1500°C

Gasification

Combustion

Hydrogen

Methanol

Dimethyl ether

Gasoline

Diesel

SNG

~ 1 atm > 25 atm

CO

H2

CO2

Syn-gas

CO

H2

CO2

H2O

NOx

SO2

Ash

C

H

N

S

Syn-gas
Dimethyl ether from Black Liquor

Black liquor → Gasification → Gas Cleaning → DME

- Power generation
- Diesel vehicles
- Fuel cell
- Domestic gas
- Chemical feedstock

DME: \( \text{CH}_3\text{-O-CH}_3 \)
Waste Processing and Biorefinery Integration

Waste / Biomass

Metals / Glass / Plastic

Gasification

O₂

Coal

Gas Cleaning

Max.

Min.

Gas Turbine

Steam Turbine

Power

Heat

Off-gas

Steam

Gasoline Synthesis

Light Ends

Gasoline

Water
Energy Input for the Production of Chemicals

Energy input

Fossil feedstocks

Ethanol platform

Ethyl acetate
Ethylene
Acetic acid

Renewable feedstocks

Ethanol
Acetic acid
Methanol
Ethylene
Syn-gas
Gasoline
Diesel
Fossil feedstocks

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Energy Efficiency: Ethylene and Acetic acid

Energy input

- Steam cracking
  - 2.9 Gcal/ton

Cheap natural gas conversion

Energy input

- Oxidation
  - 1.5 Gcal/ton

Dehydration

Ethanol

Energy input

- Fossil
  - 4.75 Gcal/ton

Energy input

- Ethanol
  - 1.5 Gcal/ton
Economic Evaluation: Ethylene and Acetic acid

Ethanol to ethylene

1000 kg Ethanol to 610 kg Ethylene

Ethanol: 1000 kg, 278 $
Ethylene: 610 kg, 356 $

Ethanol to acetic acid

1000 kg Ethanol to 1300 kg Acetic acid

Ethanol: 1000 kg, 278 $
Acetic acid: 1300 kg, 585 $

HALDOR TOPSOE
Oxidation of Ethanol to Acetic Acid

Tunable parameters
- Temperature
- Pressure
- Catalyst
- Feed composition
- Oxygen amount
Conclusion

- The production of chemicals is in some cases the best use of our limited bio-resources.

- Conversion of waste to energy will become an important aspect of future resource management.

- New business opportunities will emerge as the renewable chemical industry becomes established.
Thank you for your attention!

Everything is possible