Second generation biofuels; Fast pyrolysis liquids

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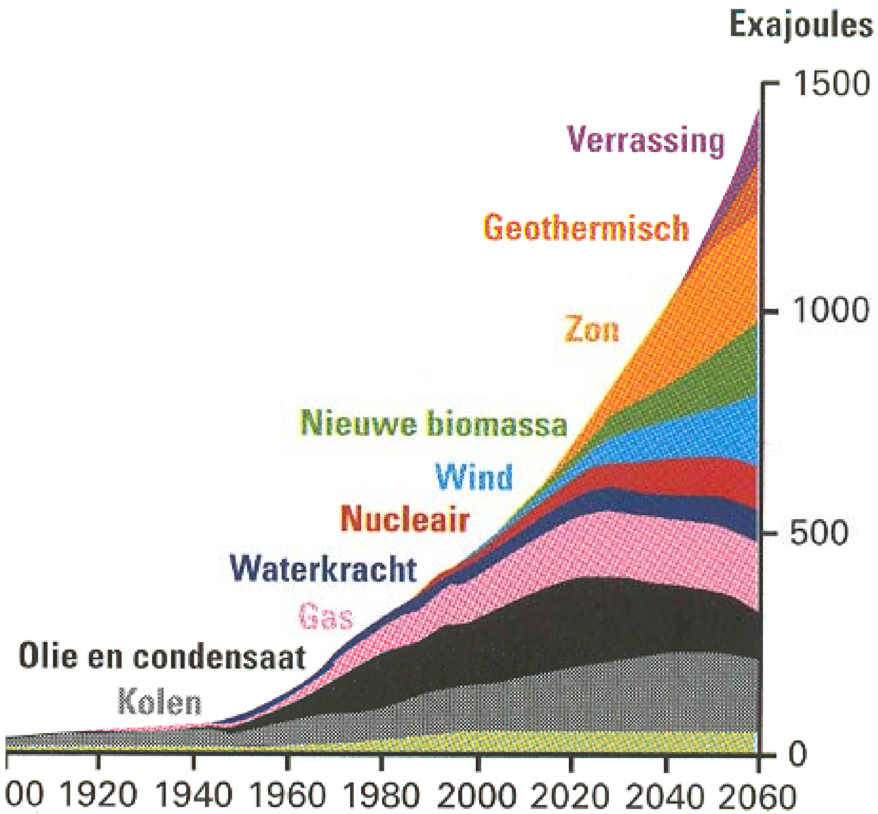
Outline

- Introduction
  - Role of biomass
  - Biomass conversion technology
  - Second generation biofuels
- Fast pyrolysis oil
  - Properties
  - Processes
  - Potential
- Research example
- Conclusions

Role of biomass in energy transitions



Source:
Shell Sustained Growth scenario

Biomass conversion technology

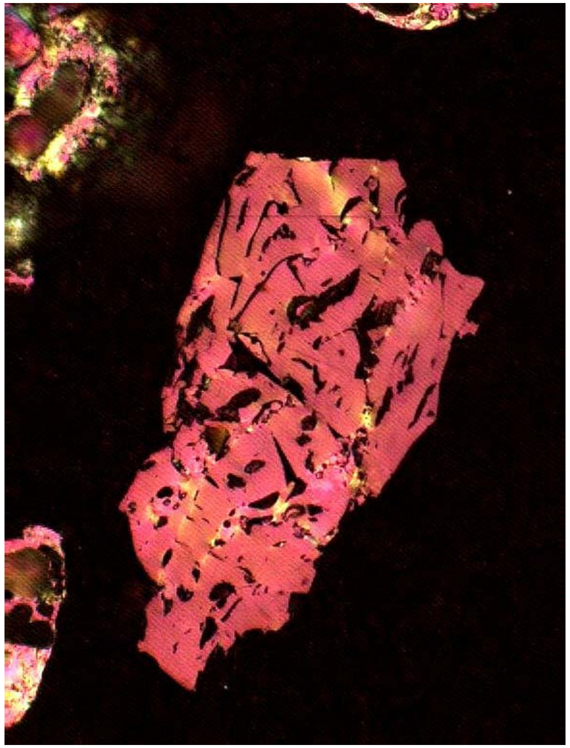
- Combustion
- Gasification
- Liquefaction
  - Pyrolysis
  - HTU
- Fermentation
- Extraction

Second generation biofuels

- Bioethanol from lignocellulosic biomass
- Pyrolysis oil
- HTU (hydrothermal upgrading)
- Syn-gas conversions to FT-diesel, DME, Hydrogen
- Hydrocarbons/plant oils from Algea

- Application of cheap, non-food lignocellulosic biomass

Fast Pyrolysis



Combustion in the absence of oxygen

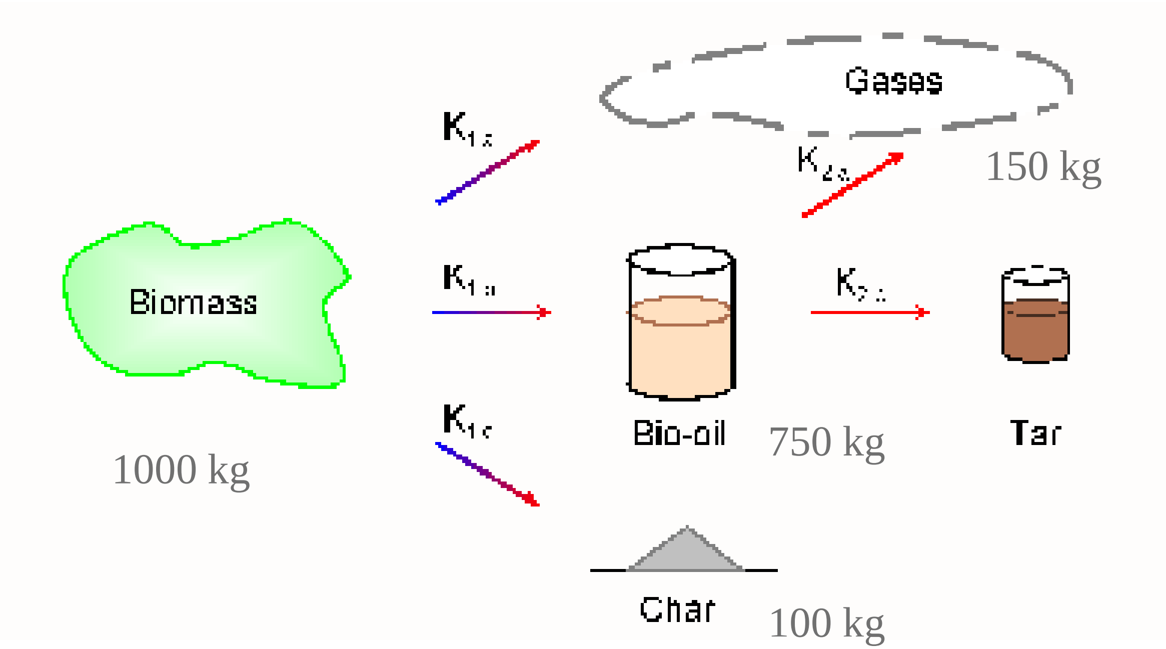
Short contacttime in gasphase (< 1 s)

High liquid yields (70+%)

Atmospheric pressure

400 – 600° C

Fast pyrolysis products



From:http://www.btgworld.com/

Feeds

- Flexible
  - Woody biomass
  - Waste products
    - Straw
    - Cacao shells
  - Algea
  - Gras
- Water content < 10 wt%
- Diameter < 1 cm

Typical product properties

› Oxygen content:	45-50 %
› pH	2-4
› Water Content	15-20 wt%
› Density	1.15 kg/l
› Caloric value	16-18 MJ/kg

› Limited storage stability

Pyrolysis oil versus virgin biomass

Liquid form of biomass

- Higher energy density (20 versus 4 GJ/m^{3})
- Easier to transport and handle
- Less contaminants (e.g. ash)

Pyrolysis oil applications

Stand alone
Boilers

Co-feeding
Oil refineries

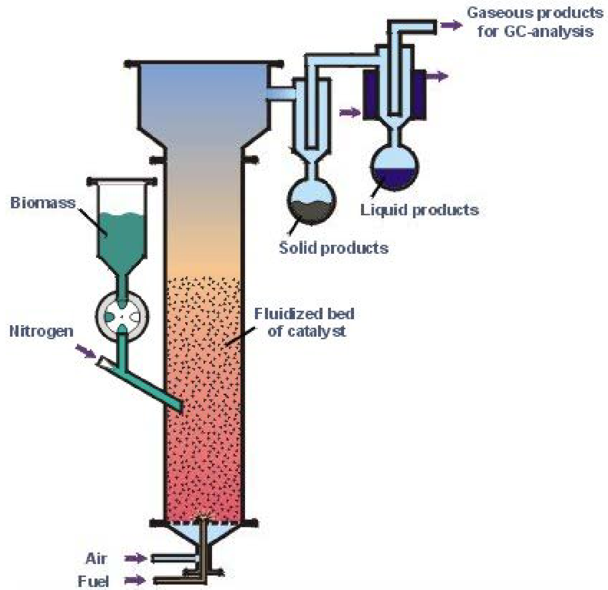
Co-firing
power
stations

Chemicals

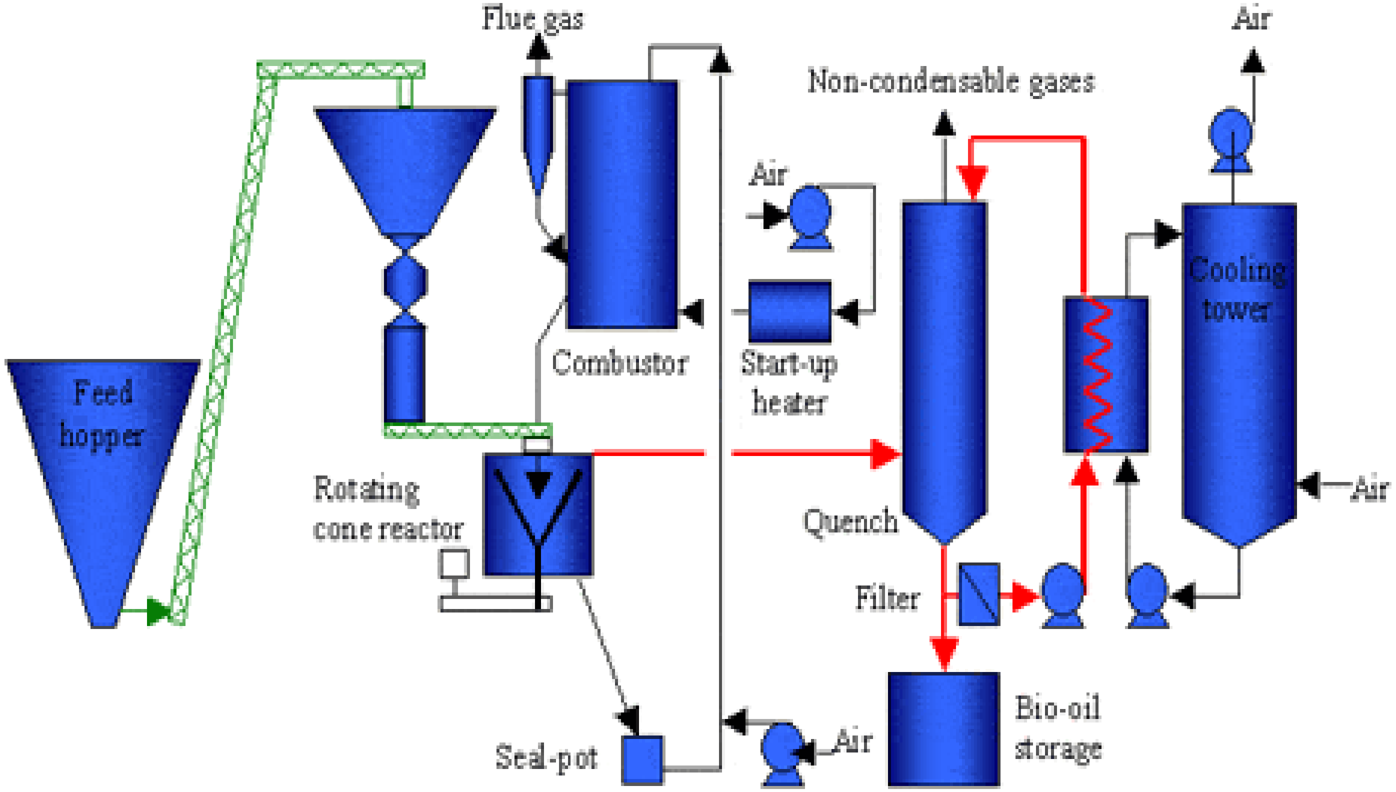
Combustion engines
Turbines

Available technology

- Fluidised bed reactors
- Circulation fluidised bed reactors
- Vacuum pyrolysis reactors
- Screw reactors
- Ablative reactors
- Rotating cone reactors



Rotating cone technology



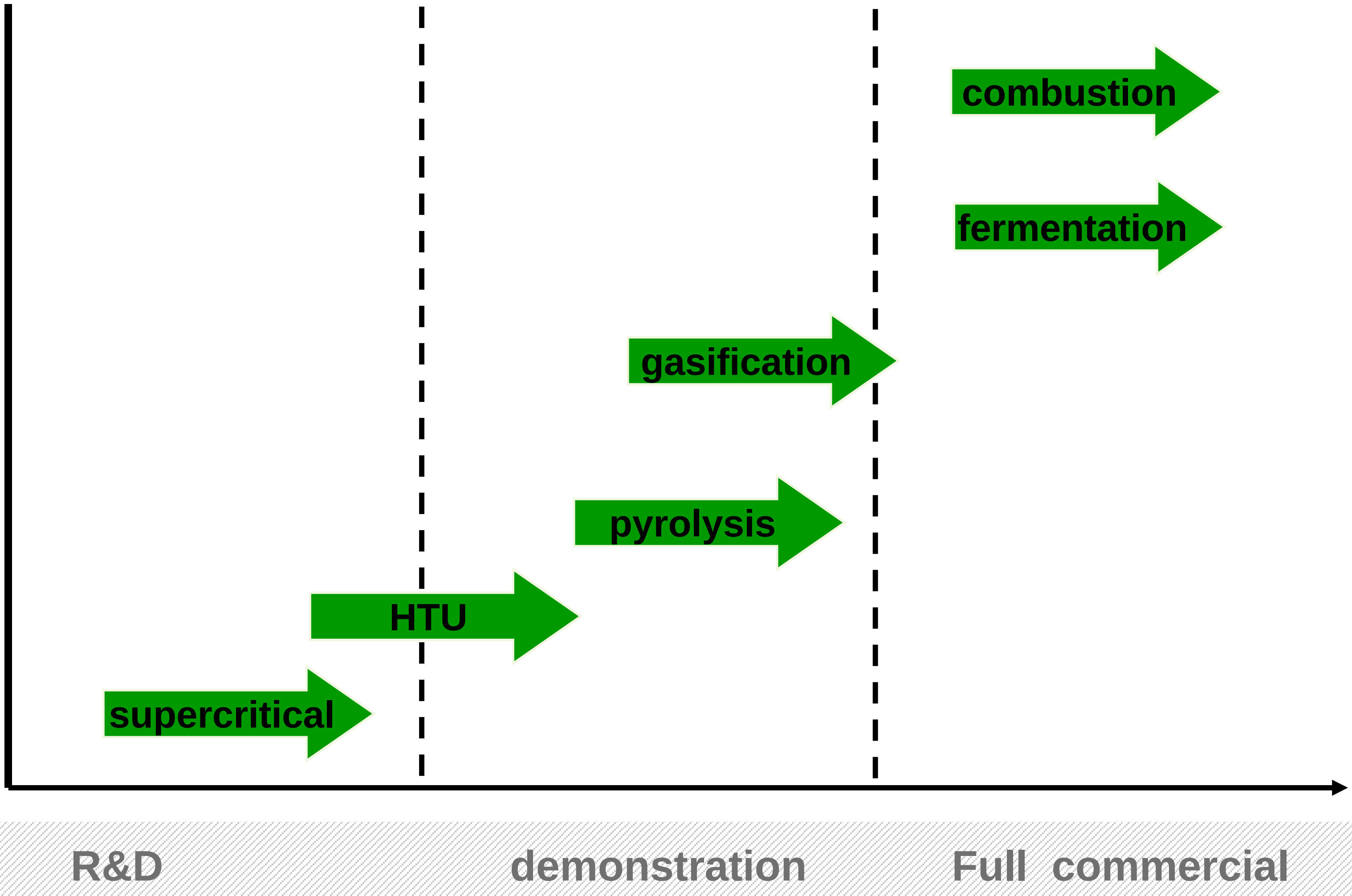
Source: BTG

Rotating cone technology

Technology status

- Dynamotive
  - 5 t/h Ontario (2004), fluidised bed technology
- BTG
  - 2 t/h Malaysia (2005), rotating cone technology
- Ensys (food flavouring)

Technology status



Pyrolysis oil upgrading

- Extend application range

- Strategies
  - Physical upgrading
  - Reactive upgrading

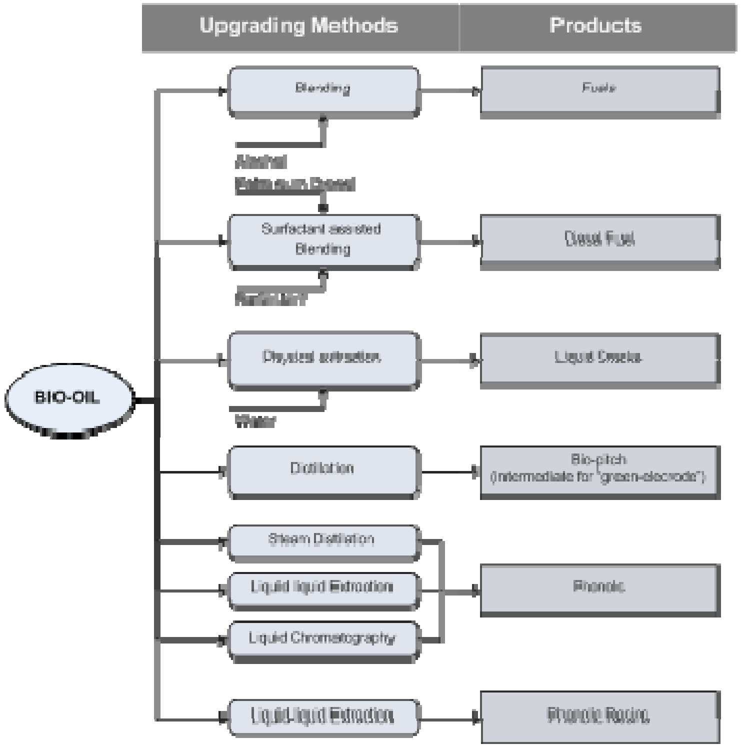
UOP to Develop Second-Generation Biofeedstock Technology Under U.S. Department of Energy Award

October 28, 2008 10:00 AM ET

UOP and partners will develop technology to improve the stability of pyrolysis oil to ensure its viability as a source for power and transportation fuels

DES PLAINES, Ill., Oct. 28 /PRNewswire/ -- UOP LLC, a Honeywell HON company, announced today that it was awarded a $1.5 million grant from the U.S. Department of Energy (DOE) to develop economically viable technology to stabilize pyrolysis oil from second generation biomass feedstocks for use as a renewable fuel source.

Physical upgrading



Chemical upgrading

BO →

Hydrodeoxygentation	Fuel/Chemicals
Steam Reforming	Fuel/Chemicals
Acid recovery using calcium salts	Chemicals
Catalytic upgrading using zeolites	Fuel/Chemicals
Reactive blending with alcohols	Fuel

Research example: hydrodeoxygenation

$$-(CH_2O)- + H_2 \xrightarrow{cat} -(CH_2)- + H_2O$$

- Reduction of acid content
- Stabilization
- Increases energy content (lowering oxygen content)
- Formation of a two phase system after reaction, easy separation of water

Objective RUG upgrading activity

› Determine the technical feasibility of upgrading pyrolysis oil to a liquid biofuel by catalytic HDO

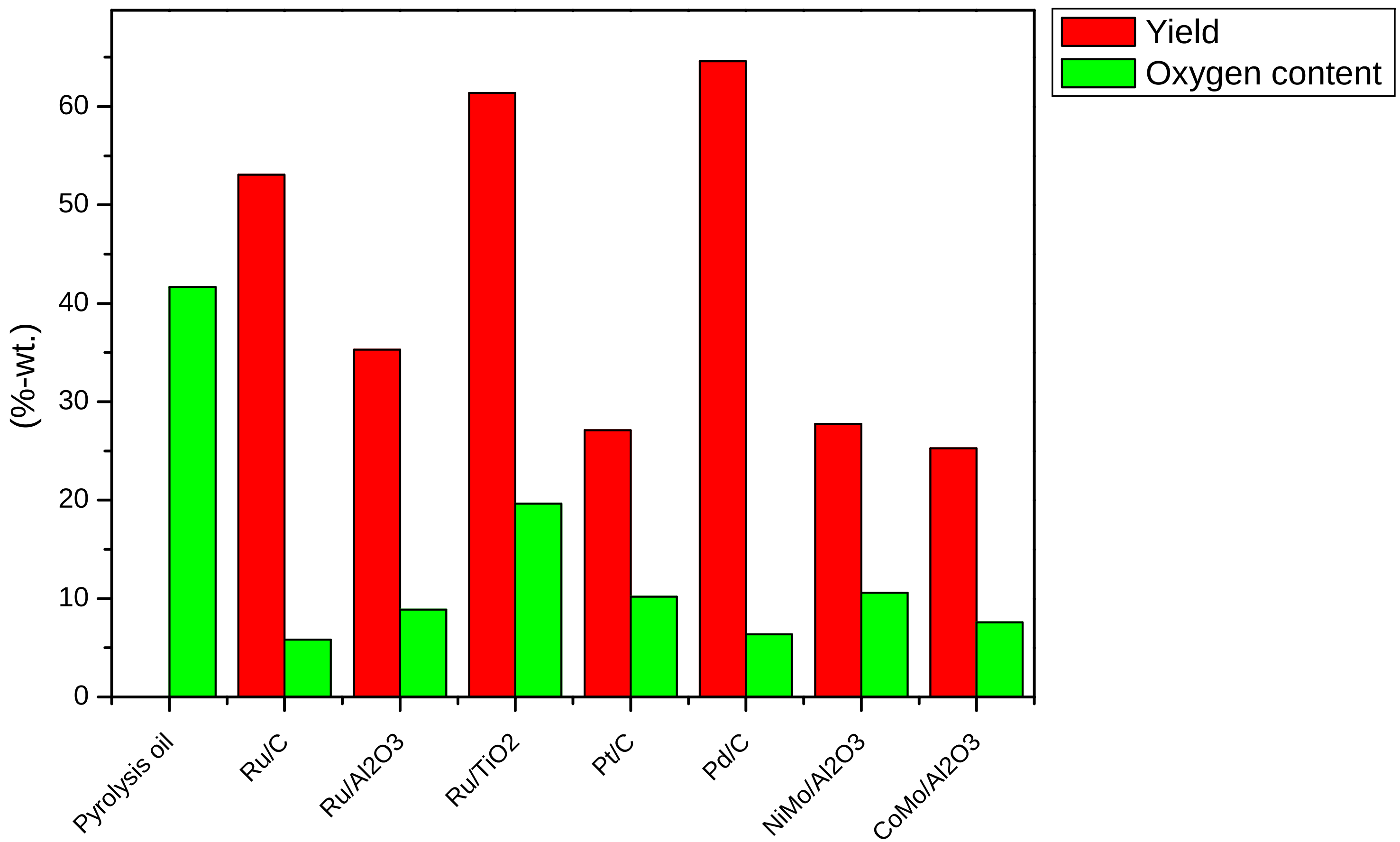
Approach

- Exploratory catalyst screening studies using pyrolysis oil
- Model component studies with selected catalyst
- Catalyst design
- Process research and development.
- Engine tests with HDO oil

Visual appearance

Ru/C 5%, 350 °C
200 bar H_2,.
Reaction time of 4h.

Catalyst studies using Pyrolysis oil



Catalyst screening in semi-Batch system at 350 °C and 200 bar of H_2 for 4h.

Wildschut, J., Heeres, H.J., Catalyst Screening for the Hydrodeoxygenation of Pyrolysis Oil., in preparation.

HDO oil properties

Property	value
Density (kg/l)	0.8 - 0.9
Water content (%-wt)	1-2
Acidity (pH)	5-6
Flash point (°C)	35- 39
Elemental composition (%-wt)	
C	~85
H	~10
O	~5
Heating value (MJ/kg) LHV	40

350 ° C and 200 bar for 4h with a Ru/C catalyst.

Engine tests

- Hatz engine
- 5 Watt
- Minimal modifications

Engine tests

Gas	Diesel	HDO oil
O_2 (%)	12.8	12.4
CO (ppm)	643	1146
NO (ppm)	723	371
NO_2 (ppm)	21	7
NO_x (ppm)	744	378
SO_2 (ppm)	0	0
CO_2 (%)	6	6.3

Red numbers indicate significant differences

Results engine tests

- Higher CO in exhaust compared to diesel
- Lower NO_x in exhaust compared to diesel
- Carbon deposition of the atomizer

Conclusions

› Fast pyrolysis technology is entering the commercialisation stage

› Susbtantial R&D activities ongoing on upgrading to extend application range

› Catalytic hydrotreatment promising option to obtain hydrocarbon like components to be used for
  - Transportation fuels
  - Co-feeding to existing refineries

Acknowledgement

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