

# **FAST PYROLYSIS OF BIOMASS: Technology and applications**

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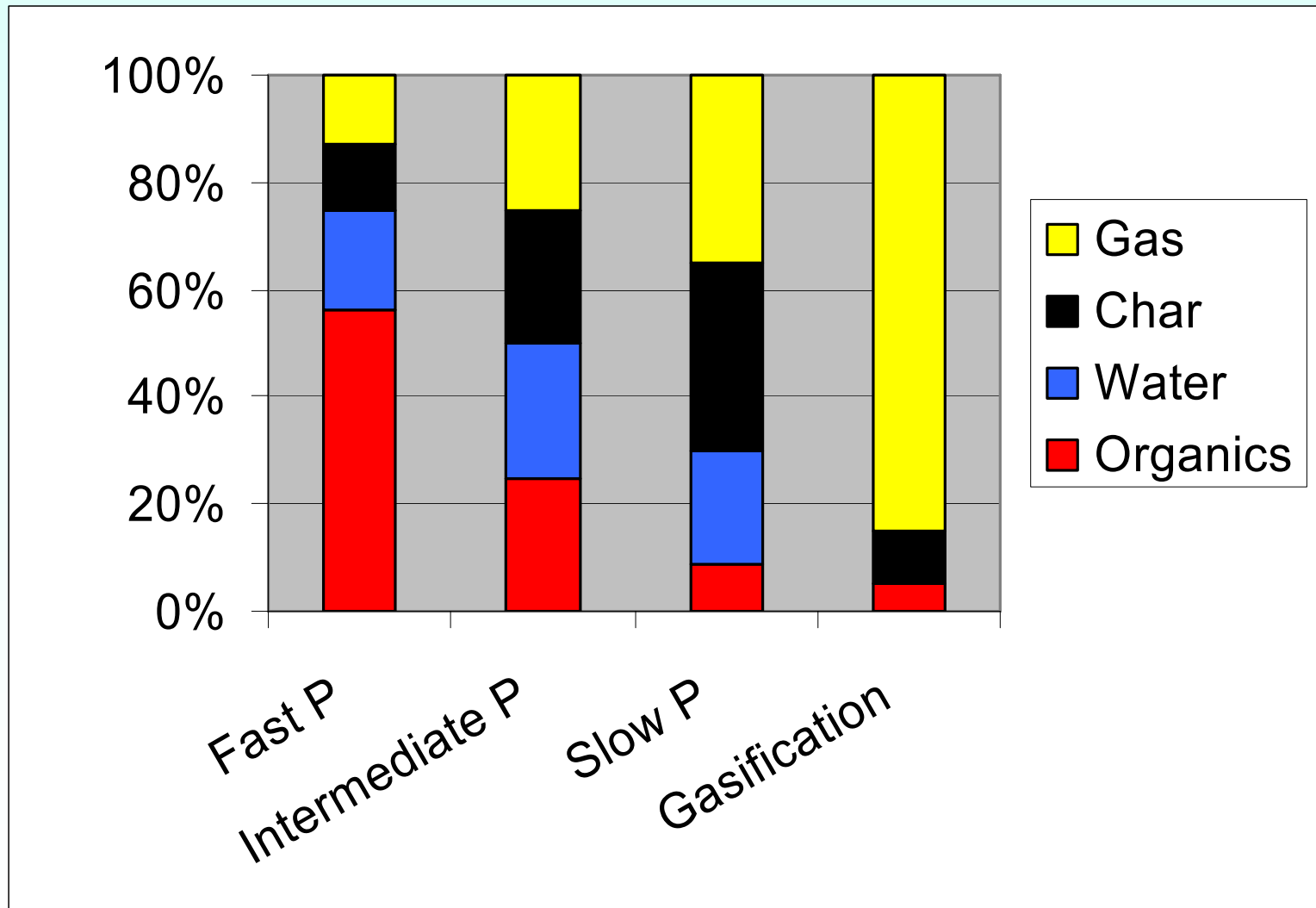


# Pyrolysis

	Liquid	Char	Gas
<b>FAST PYROLYSIS</b> moderate temperature (~500C) short hot vapour residence time (<2 s)	75% 25% water	12%	13%
<b>INTERMEDIATE PYROLYSIS</b> Low-moderate temperature, moderate hot vapour residence times	50% 50% water	25%	25%
<b>SLOW PYROLYSIS</b> Low-moderate temperature, long residence times	30% 70% water	35%	35%
<b>GASIFICATION</b> high temperature (>800C), long vapour residence time	5% tars	10%	85%



# Pyrolysis products



# Process requirements

Drying

- <10%. Feed moisture and reaction water report to bio-oil

Comminution

- -2mm (fluid bed), -6 mm (CFB), +10 mm (ablative)

Fast pyrolysis

- High heating rate, controlled T, short residence time,

Char separation

- Efficient char separation needed

Liquid recovery

- Condensation and coalescence.



# Process modification

**BIOMASS**



**PRETREAT**

Remove ash

Remove HC / C

Add catalysts

**PYROLYSE**

Vary parameters

Thermal cracking

Catalytic cracking

**CONDENSE LIQUID**

Upgrade physically

Differential condensation

Filter liquid

Add solvents

Upgrade catalytically

De-oxygenate

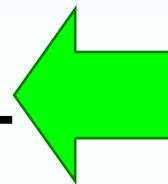
Reform

Upgrade chemically

Gasify to syngas



**BIO-OIL**



# Fluid bed technologies

- DynaMotive Canada: →  
100 t/day unit operating,  
close coupled to 2.5 MWe  
turbine
- UK: 250 kg/h  
awaiting development



- Research at Iowa, IWC,  
Georgia, Aston etc

# Fluid bed reactors

- Good temperature control,
- Char separation is usually by ejection and entrainment; separation by cyclone,
- Easy scaling,
- Well understood technology since first experiments in Univ. Waterloo 1980,
- Small particle sizes needed,
- Heat transfer to bed at large scale has to be proven.



# Transported bed technologies



- Ensyn (Canada): Six plants built. 50 t/day at Red Arrow, USA. Chemicals unit in Canada

- BTG (NL): rotating cone reactor (transported bed) at 5 t/d; 50 t/d plant, 2005 Malaysia.



- Research at VTT (Finland)

# Transported beds and CFB

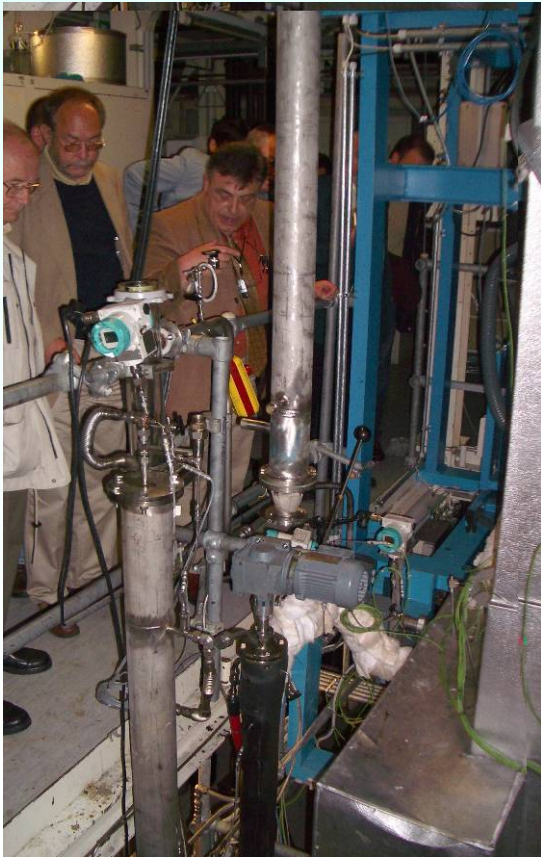
- Good temperature control in reactor,
- Larger particle sizes possible,
- CFBs suitable for very large throughputs,
- Well understood technology,
- Hydrodynamics more complex,
- Char is more attrited due to higher velocities; separation is by cyclone,
- Closely integrated char combustion requires careful control,
- Heat transfer to bed at large scale has to be proven.



# Screw reactors

FZK, Germany

- Pilot plant of 20 kg/h
- Scaling up to 1 t/h



Bio-oil International, Canada & USA

- Small pilot plant in Alabama USA
- Pilot plant in Massachusetts USA

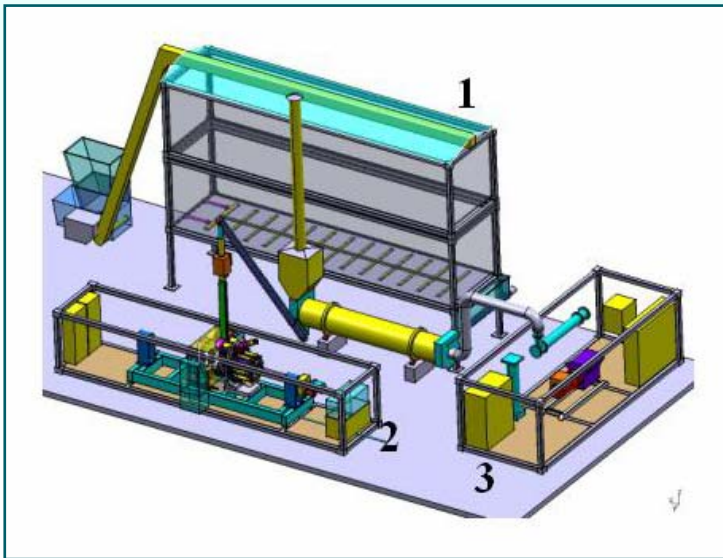
# Screw reactors

- Well established technology,
- Good temperature control in reactor,
- Larger particle sizes possible,
- Wear rates are unknown,
- Hot vapour residence times are higher giving more secondary cracking and phase separated product
- Char is more attrited due to mechanical interactions,
- Sand – char separation may be more difficult
- Heat transfer to bed at large scale has to be proven.



# Ablative pyrolysis

- PyTec 20kg/h research unit in Germany
- PyTec 2 t/h demonstration plant built in Germany



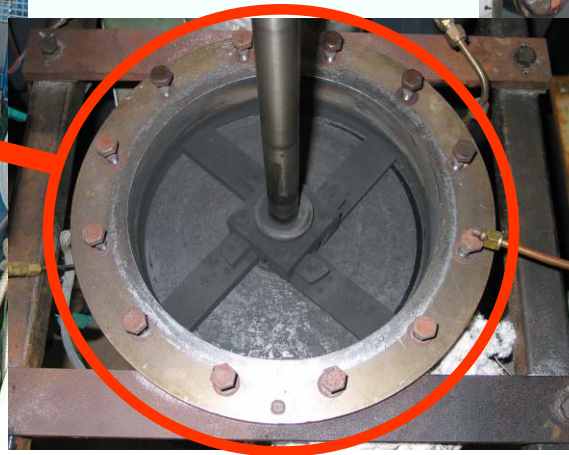
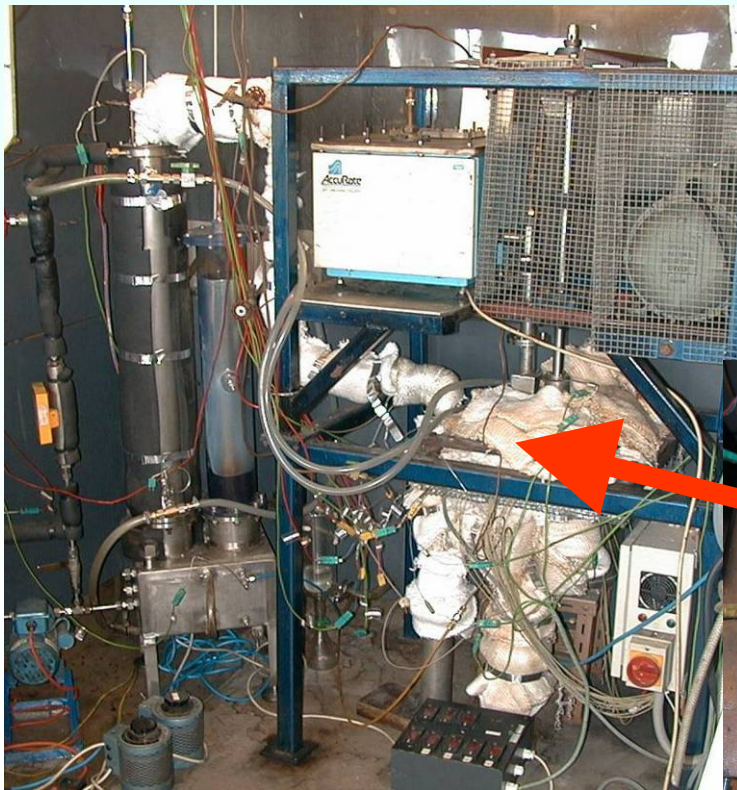
# Research at Aston

- 4 Fluid bed reactors – 100 & 300 g/h; 1 & 5 kg/h
- 2 Ablative reactors – 3 & 20 kg/h
- Microwave reactor
- TGA and Py-GCMS for fundamental research
- Hot vapour filter
- Biomass preparation & pretreatment
- Liquid upgrading & characterisation

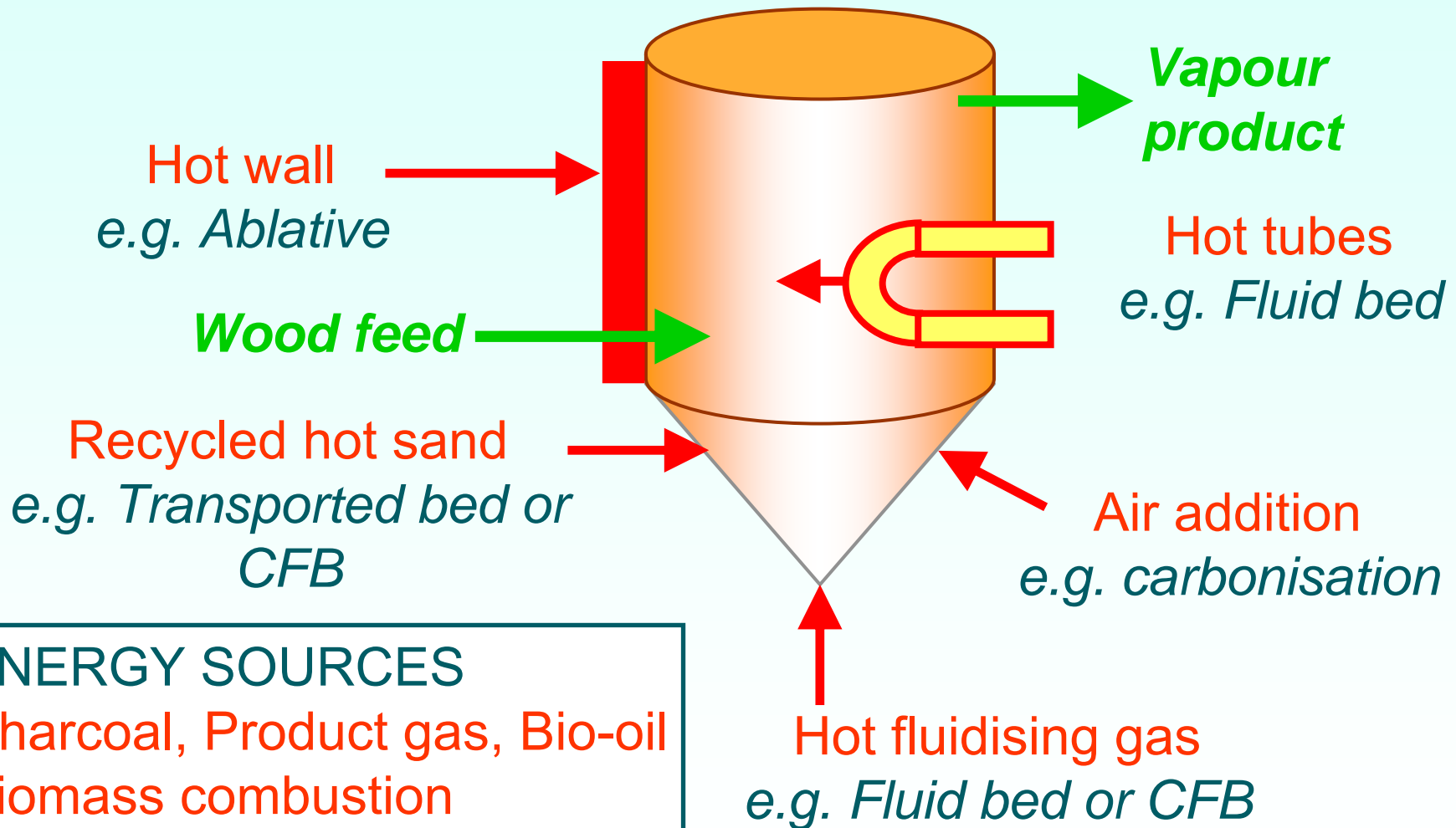


# Research at Aston

- 1 kg/h fluid bed reactors with hot vapour filter
- 3 kg/h ablative reactor



# Challenge: Heat transfer



## ENERGY SOURCES

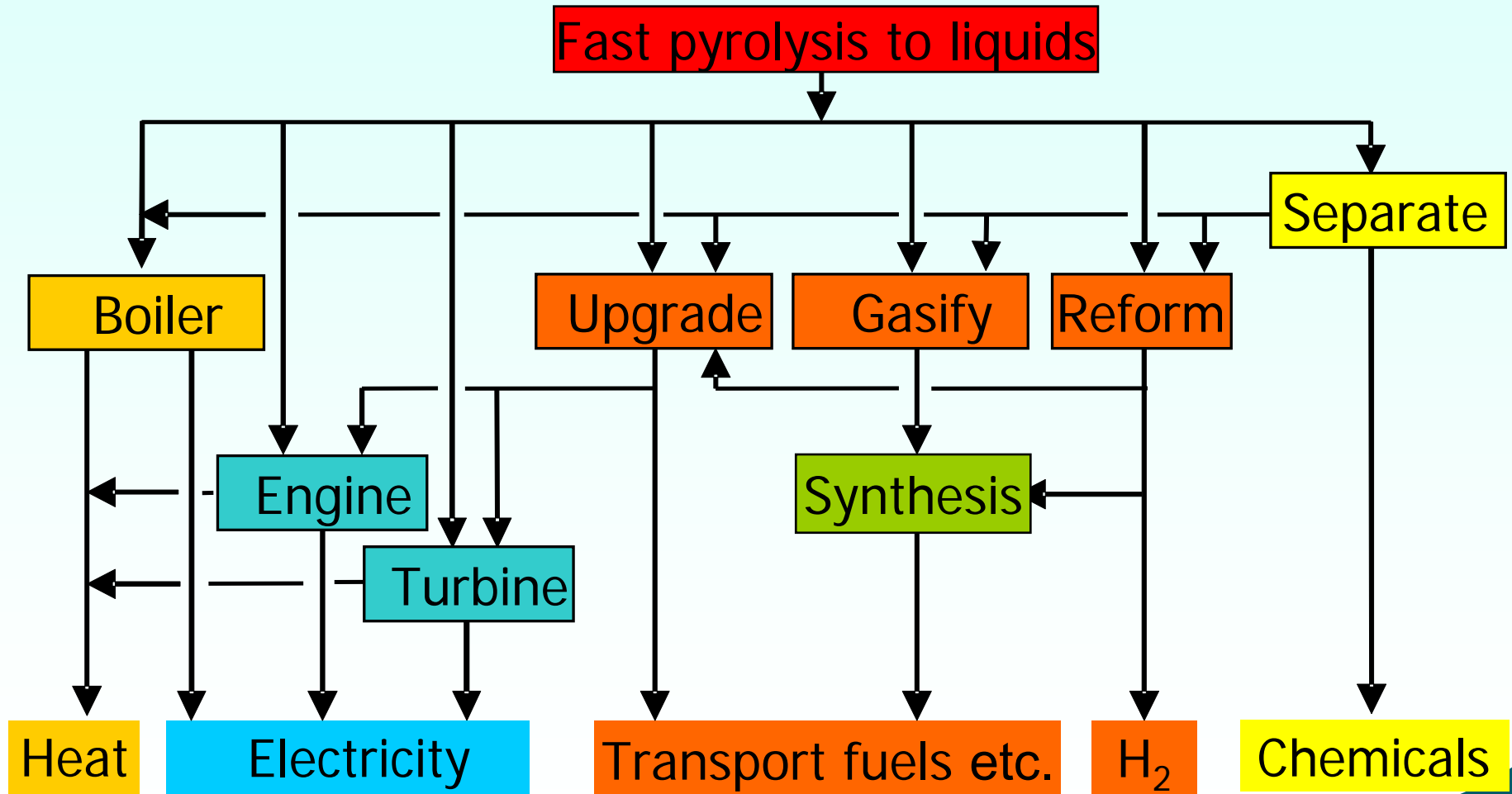
Charcoal, Product gas, Bio-oil  
Biomass combustion  
Gasified biomass or charcoal  
Fossil fuel – gas or oil

# Bio-oil properties

<b>Moisture content</b>	<b>25 %</b>
pH	2.5
Specific gravity	1.20
<b>Elemental analysis</b>	
C	56.4 %
H	6.2 %
<b>O</b>	<b>37.3 %</b>
N	0.1 %
Ash	0.1 %
<b>Miscibility with fossil fuel oils</b>	<b>None</b>
HHV as made (depends on water - 22.5 dry)	17 MJ/kg
Viscosity (at 40°C and 25% water)	40-100 cp
Solids (char)	0.05 %
Vacuum distillation residue	up to 50%



# Applications for bio-oil



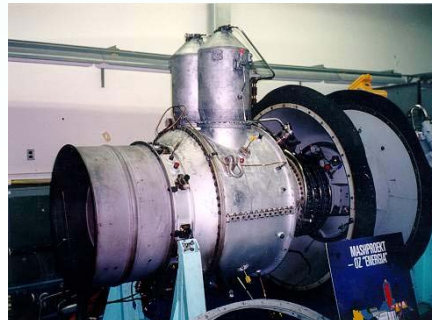
# Heat and power

## HEAT

- Combustible but not flammable. Once ignited, it burns with a stable self-sustaining flame.
- Higher particulates and CO, lower NOx
- Extensive experience

## POWER

- Engines: Mixed experience. 250 kW Dual fuel engine at Ormrod operated for 500 h.
- Gas turbines: Extensive experience at Orenda with 2.5 MWe at Dynamotive



# Applications for chemicals

- **Whole oil**

- Fuel (commercial)
- Transport fuel
- Hydrogen
- Slow release fertiliser
- Emission control
- De-icer
- Preservative
- Resin precursors



- **Fractionated oil**

- Liquid smoke (commercial)
- De-icers
- Resin precursors
- Hydrogen
- Fuel additives

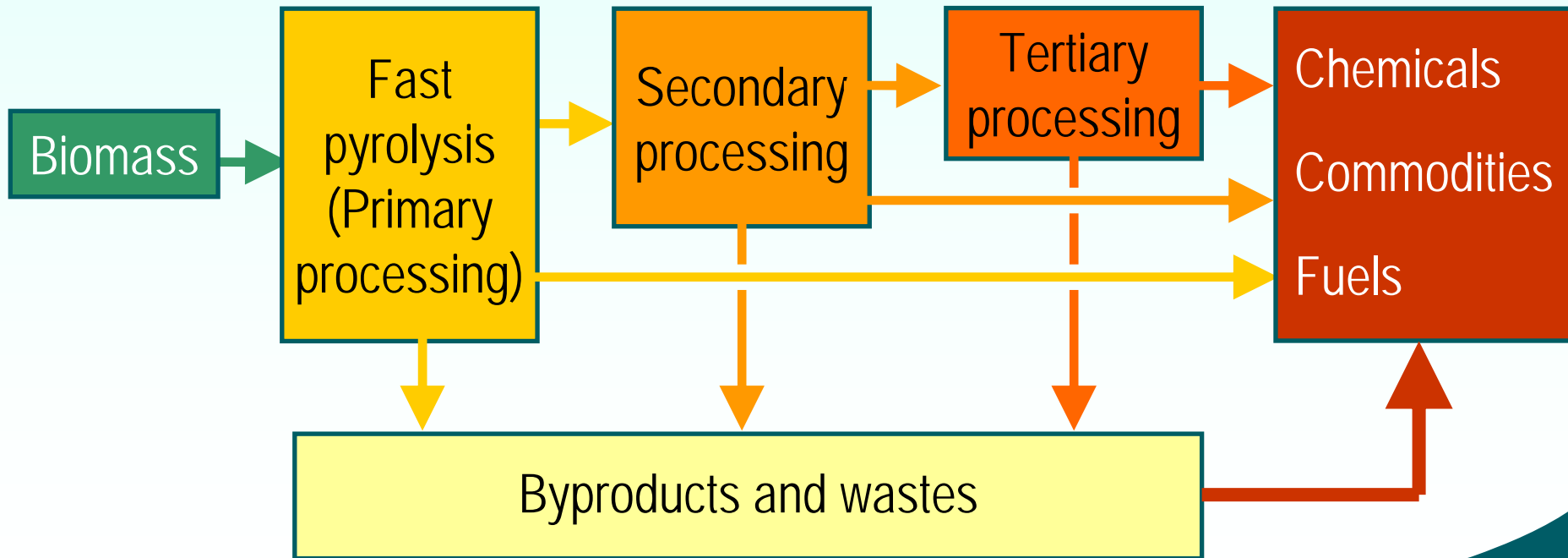
- **Specific chemicals**

- Acetic acid (commercial)
- Hydroxyacetaldehyde
- Levoglucosan
- Levoglucosenone
- Maltol



# Biorefinery concepts

- Integrate production of higher value chemicals and commodities, as well as fuels and energy,
- Optimise use of resources, maximise profitability, maximise benefits, minimise wastes



# Conclusions

- Bio-oil has a major advantage of being storable and transportable with potential as an energy carrier,
- Bio-oil has been successfully used as boiler fuel,
- Bio-oil is commercially used in a gas turbine,
- Bio-oil shows promise in diesel engines,
- Bio-oil shows promise for some chemicals,
- Use of bio-oil as an energy carrier for large scale synthesis of transport fuels etc. is very interesting,
- Hydro-processing has some new directions and offers economic potential,
- Biorefineries offer an opportunity to improve process performance and optimise commercial returns.

