

Review of Fast Pyrolysis of Biomass

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Outline

- **Pyrolysis of biomass**
- **Fast pyrolysis reactors**
- **Product collection**
- **Liquid properties**
- **Liquid applications**
- **Barriers to development**

Biomass Pyrolysis Products

	Liquid	Char	Gas
FAST PYROLYSIS moderate temperature short residence time	75%	12%	13%
CARBONISATION low temperature long residence time	30%	35%	35%
GASIFICATION high temperature long residence time	5%	10%	85%

Fast Pyrolysis of Biomass

Fast pyrolysis is a thermal process that rapidly heats biomass to a carefully controlled temperature ($\sim 500^{\circ}\text{C}$), then very quickly cools the volatile products (< 2 sec) formed in the reactor

- Offers the unique advantage of giving a liquid that can be stored and transported.
- Has been developed in many configurations
- At present is at relatively early stage of development

Process Requirements

Drying

- <10% moisture. Feed and reaction water end up in bio-oil

Comminution

- -2mm (bubbling bed),
-6 mm (CFB)

Fast pyrolysis

- High heat rate, controlled T, short residence time

Char separation

- Efficient char separation needed

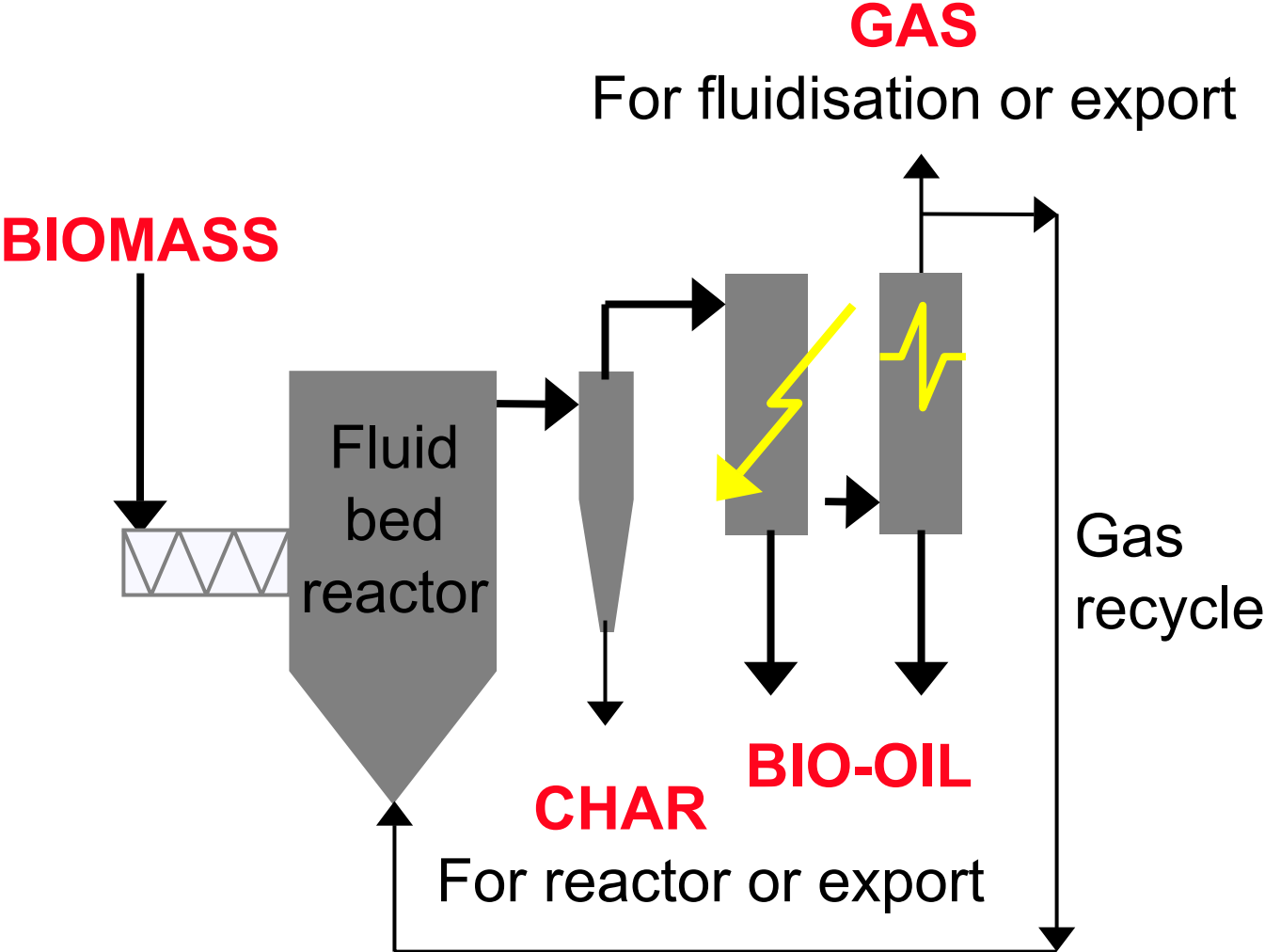
Liquid recovery

- By condensation and coalescence.

Operational Pyrolysis Units

Fluid beds	400 kg/h at Dynamotive 250 kg/h at Wellman (UK) 20 kg/h at RTI Many research units
CFBs	1000 kg/h at Red Arrow (Ensyn) 20 kg/h at VTT (Ensyn)
Rotating cone	120 kg/h at BTG (Netherlands)
Vacuum	3500 kg/h at Pyrovac
Others	350 kg/h (Fortum, Finland)

Bubbling Fluid Bed Pyrolysis



Bubbling Fluid Bed

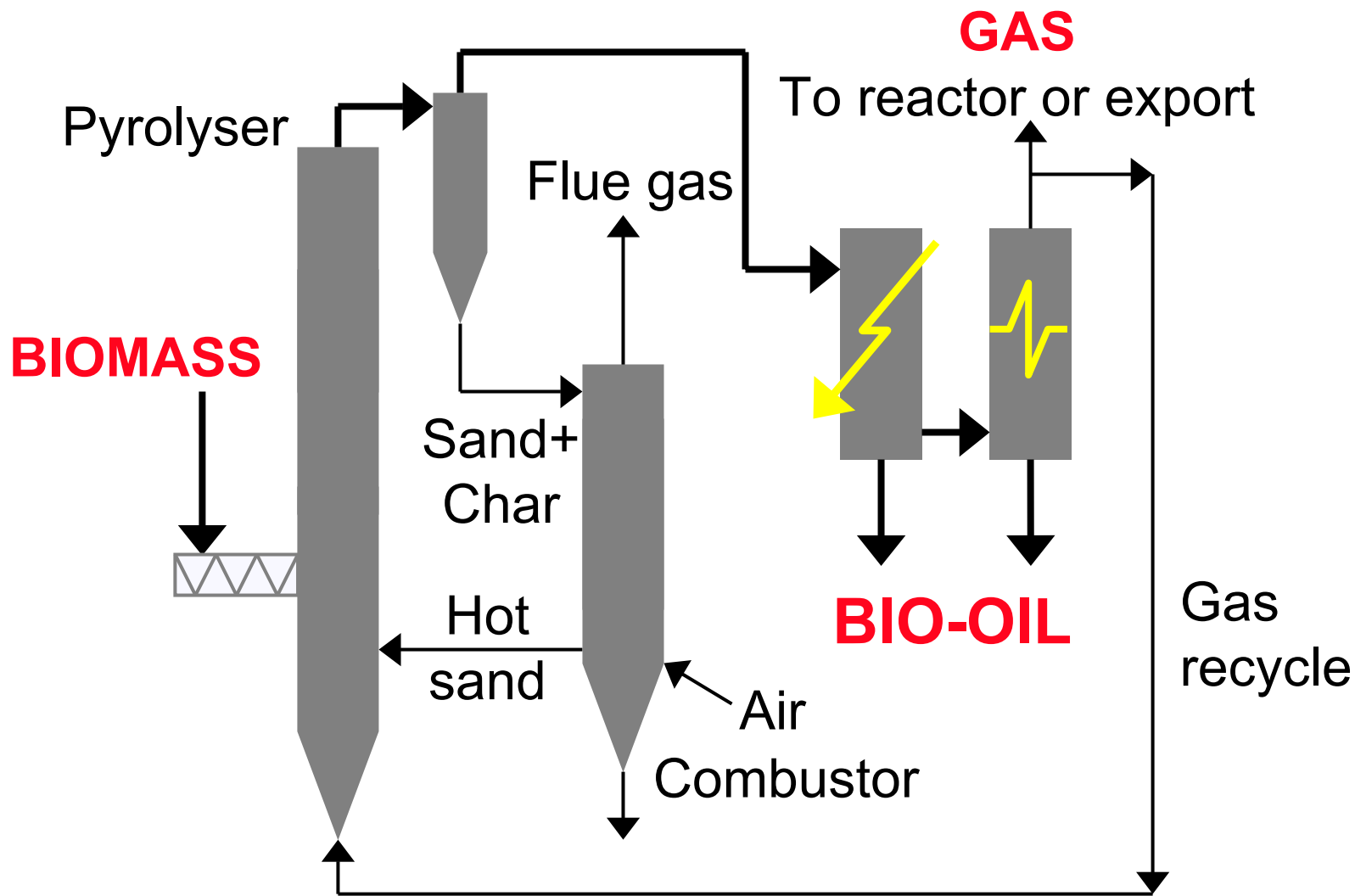


250 kg/h pilot plant at Wellman, UK

Fluid Bed Reactors

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

Circulating Fluid Beds

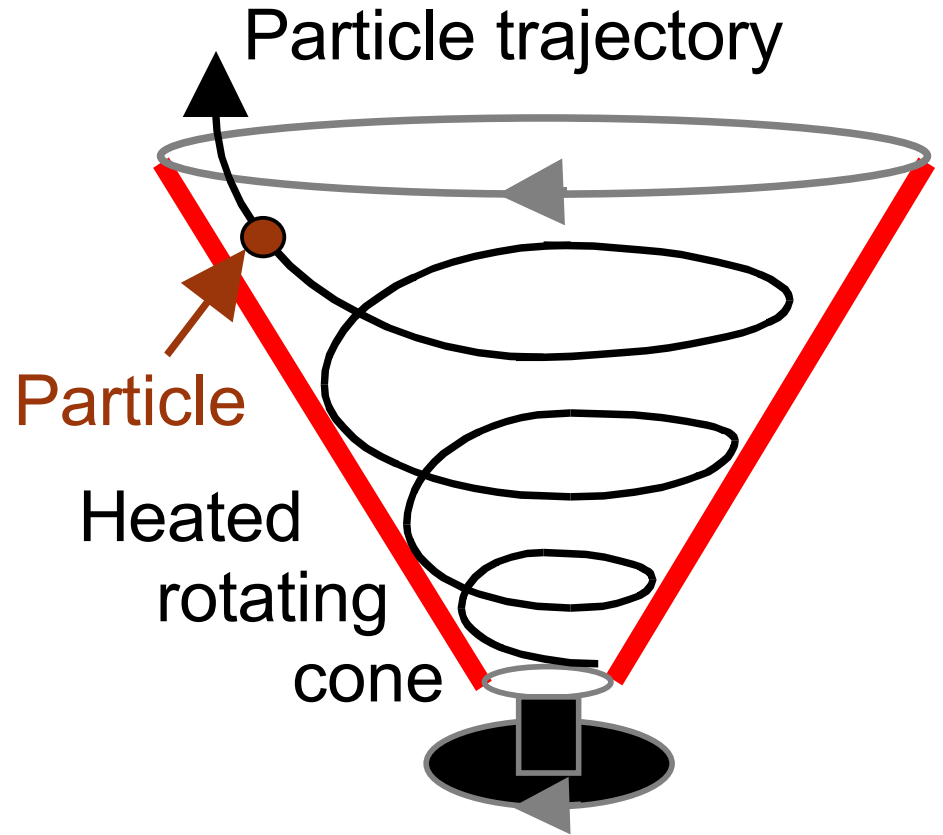


CFB and Transported Beds

- 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.

Rotating Cone (BTG)

- Centrifugation drives hot sand and biomass up rotating heated cone;
- Vapors are condensed;
- Char is burned and hot sand is recirculated.



Vacuum Moving Bed

- Developed at Université Laval, Canada, scaled up by Pyrovac
- Pilot plant operating at 50 kg/h
- **Demonstration unit operating at 3.5 t/h**
- Pyrolysis liquid yield 35-50%
- Analogous to fast pyrolysis as vapor residence time is similar.

Char Removal

- **Char** acts as a vapor cracking catalyst so rapid and effective removal is essential.
- **Cyclones** are usual method of char removal. Fines pass through and collect in liquid product.
- **Hot vapor filtration** gives high quality char free product. Char accumulation cracks vapors and reduces liquid yield (~20%). Limited experience is available.
- **Liquid filtration** is very difficult due to nature of char and pyrolytic lignin.

Liquid Collection

- **Primary pyrolysis products** are vapors and aerosols from decomposition of holocellulose and lignin.
- **Liquid collection** requires cooling and agglomeration or coalescence of aerosols.
- Simple heat exchange can cause preferential deposition of heavier fractions leading to blockage.
- **Quenching in product liquid** or immiscible hydrocarbon followed by electrostatic precipitation is preferred method.

Fast Pyrolysis Liquid

Bio-oil is water miscible and is comprised of many oxygenated organic chemicals.

- Dark brown mobile liquid,
- **Combustible**,
- Not miscible with hydrocarbons,
- Heating value ~ 17 MJ/kg,
- Density ~ 1.2 kg/l,
- Acid, pH ~ 2.5,
- Pungent odour,
- “Ages” - viscosity increases with time



Properties

- The complexity and nature of the liquid results in some unusual properties
- Due to physical-chemical processes such as:
 - ∅ Polymerization/condensation
 - ∅ Esterification and etherification
 - ∅ Agglomeration of oligomeric molecules
- Properties of bio-oil change with time:
 - ∅ **Viscosity increases**
 - ∅ **Volatility decreases**
 - ∅ **Phase separation, deposits, gums**

Upgrading of Pyrolysis Liquid

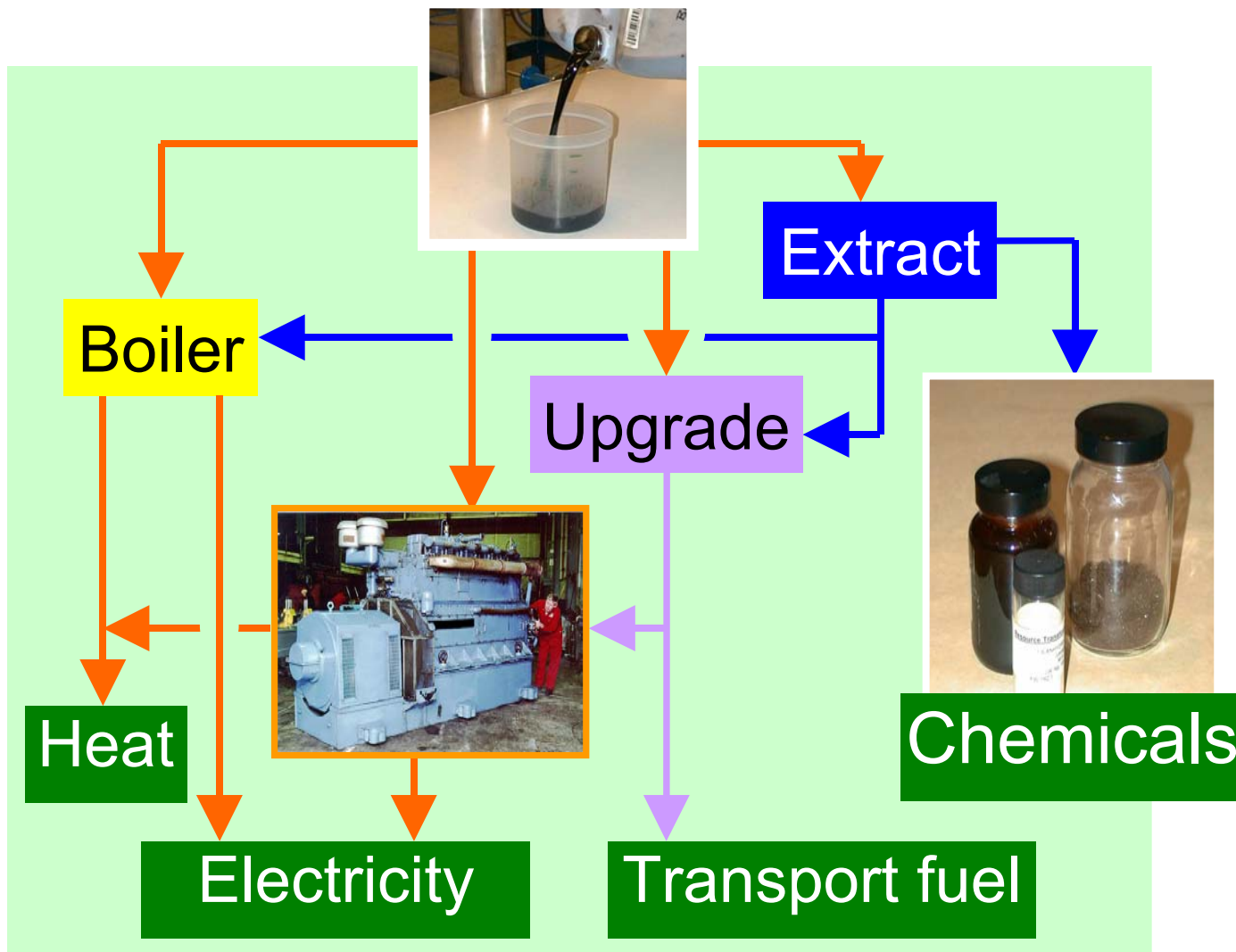
Physical Methods

- Filtration for char removal,
- Emulsification with hydrocarbons,
- Solvent addition,

Chemical Methods

- Reaction with alcohols,
- Catalytic deoxygenation:
 - Hydrotreating,
 - Catalytic (zeolite) vapor cracking.

Applications



Demonstrated Applications

Electricity

diesel, turbine, Stirling;

Heat

CHP and boiler;

Transport fuels

upgrading, emulsions;

Bulk chemicals

e.g. resins, fertilizers;

Fine chemicals

e.g. levoglucosan

Why Is Bio-oil Not Used More?

- **Cost** : 10% – 100% more than fossil fuel,
- **Availability**: limited supplies for testing
- **Standards**; lack of standards and inconsistent quality inhibits wider usage,
- **Incompatibility** with conventional fuels,
- **Unfamiliarity** of users
- **Dedicated fuel handling** needed,
- **Poor image**.

What Is Needed?

- Process development to improve product quality, reduce costs,
- Research into improving product quality including setting norms and standards for producers and users,
- Environment health and safety issues in handling, transport and usage,
- Encouragement for developers to implement processes; and users to implement applications.

Conclusions

Many challenges including:

- Scale-up,
- Cost reduction,
- Better oil quality,
- Norms and standards for bio-oil,
- Information dissemination.

The unique advantage of bio-oil:
liquid that can be stored and transported

Can be used for
fuel and/or chemicals production

Information on Pyrolysis of Biomass

Pyrolysis Network **PyNe**

15 European Countries and USA

<http://www.pyne.co.uk>

Newsletter (two/year) available on-line