

Thermochemical conversion of biomass

Pyrolysis

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IPESE

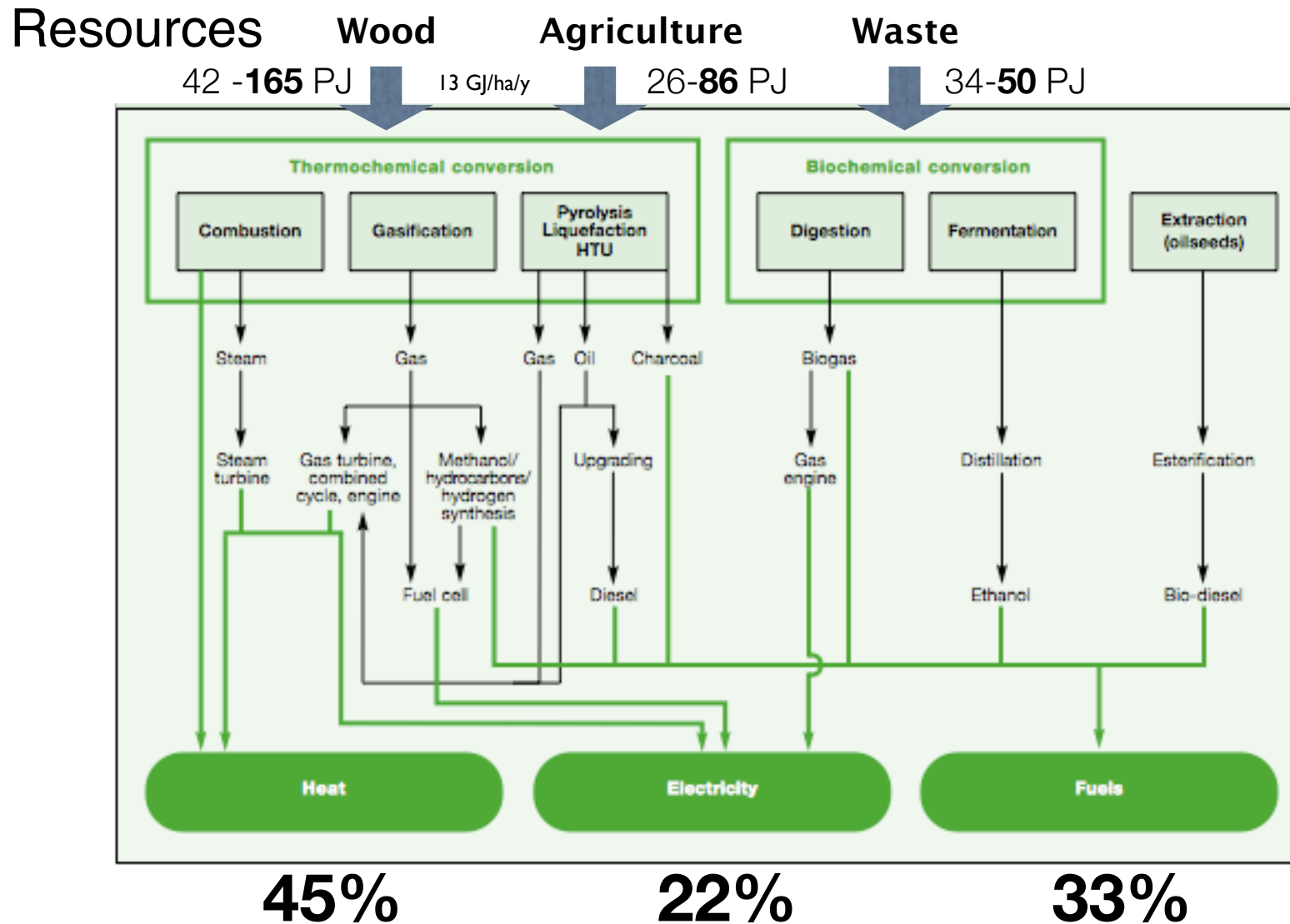
Industrial Process and Energy Systems Engineering

EPFL Valais-Wallis

CH - 1950 Sion

Biomass conversion routes and production potential in Switzerland

sustainable - **Technical** in PJ/year



Figures for Switzerland (sustainable potential : total = 82-301 PJ)

Source : world energy assessment : UNDP 2000

Bioenergy in Switzerland: [assessing the domestic sustainable biomass potential](#)

B Steubing, R Zah, P Waeger, C Ludwig

Renewable and Sustainable Energy Reviews 14 (8), 2256-2265

**Training on
Technologies for Converting Waste Agricultural Biomass into Energy**

**Organized by
United Nations Environment Programme (UNEP DTIE IETC)**

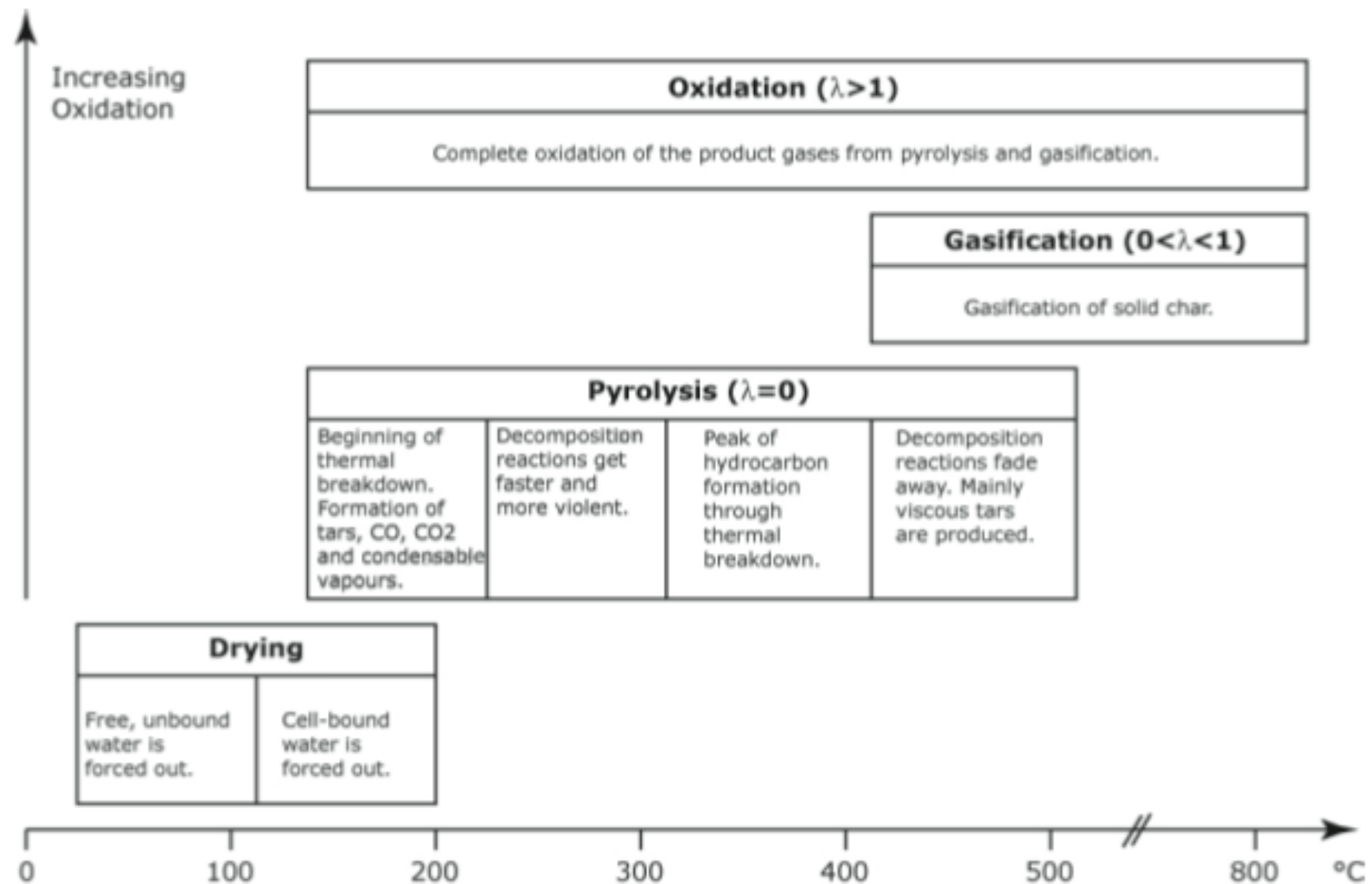
**23-25 September, 2013
San Jose, Costa Rica**

Biomass Pyrolysis

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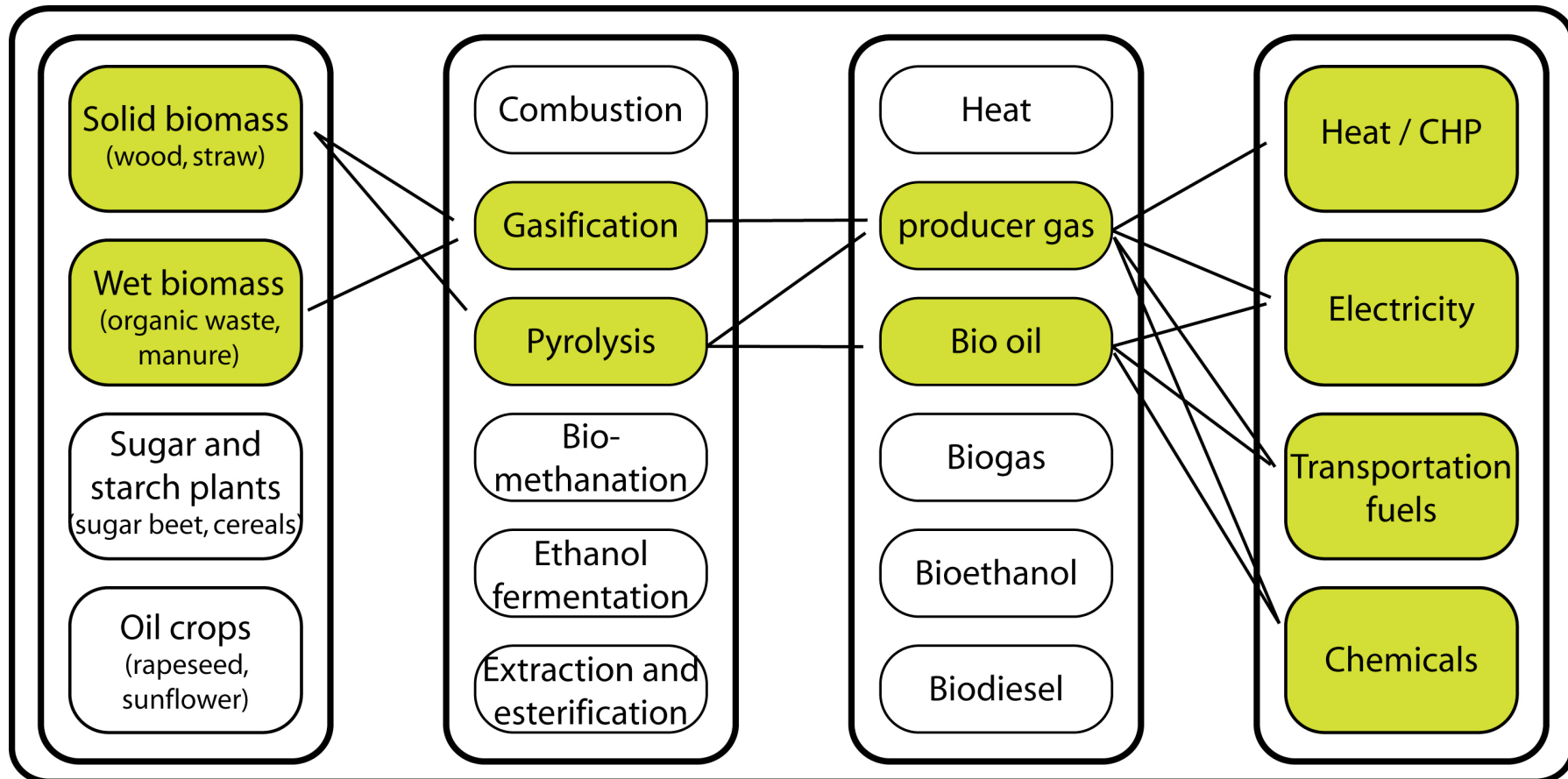
Thermochemical biomass conversion

Process principles: gasification vs. pyrolysis



Biomass conversion

Thermochemical routes



adapted from Chemical Engineering 10 (2006)

INTRODUCTION

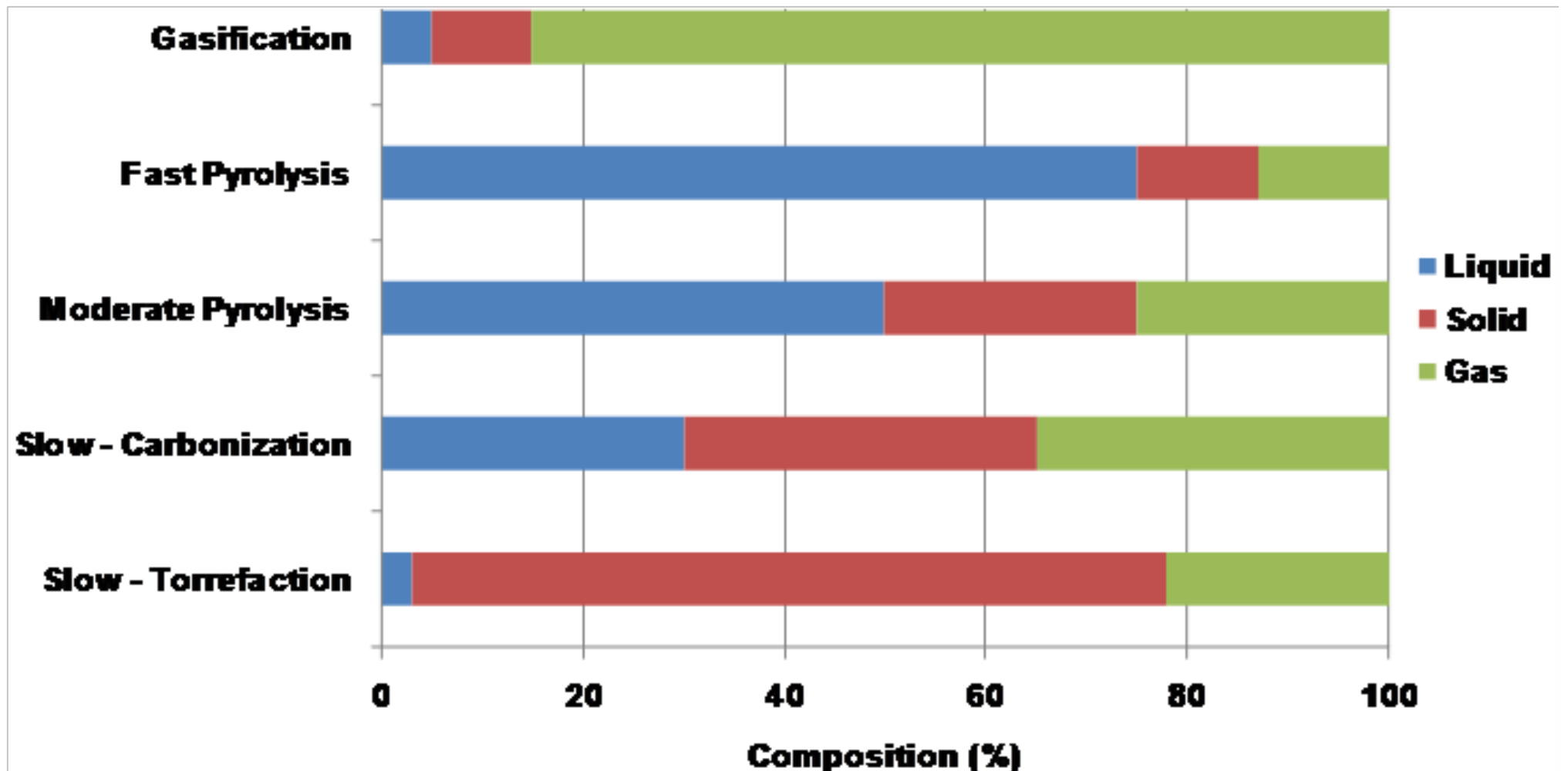
- **Overview**

- **Pyrolysis is defined as irreversible chemical change brought about by heat in the absence of oxygen.**
- **During pyrolysis biomass undergoes a sequence of changes and normally yields a mixture of gases, liquids and solid.**
- **The solid is called charcoal while the condensable liquid is variously referred to as pyroligneous liquid, pyroligneous liquor, pyroligneous acid or pyrolysis oil. The gas is called producer gas or wood gas.**
- **Generally low temperatures and slow heating rates results in high yield of charcoal. This type of pyrolysis is called carbonization**

INTRODUCTION

- **Overview**

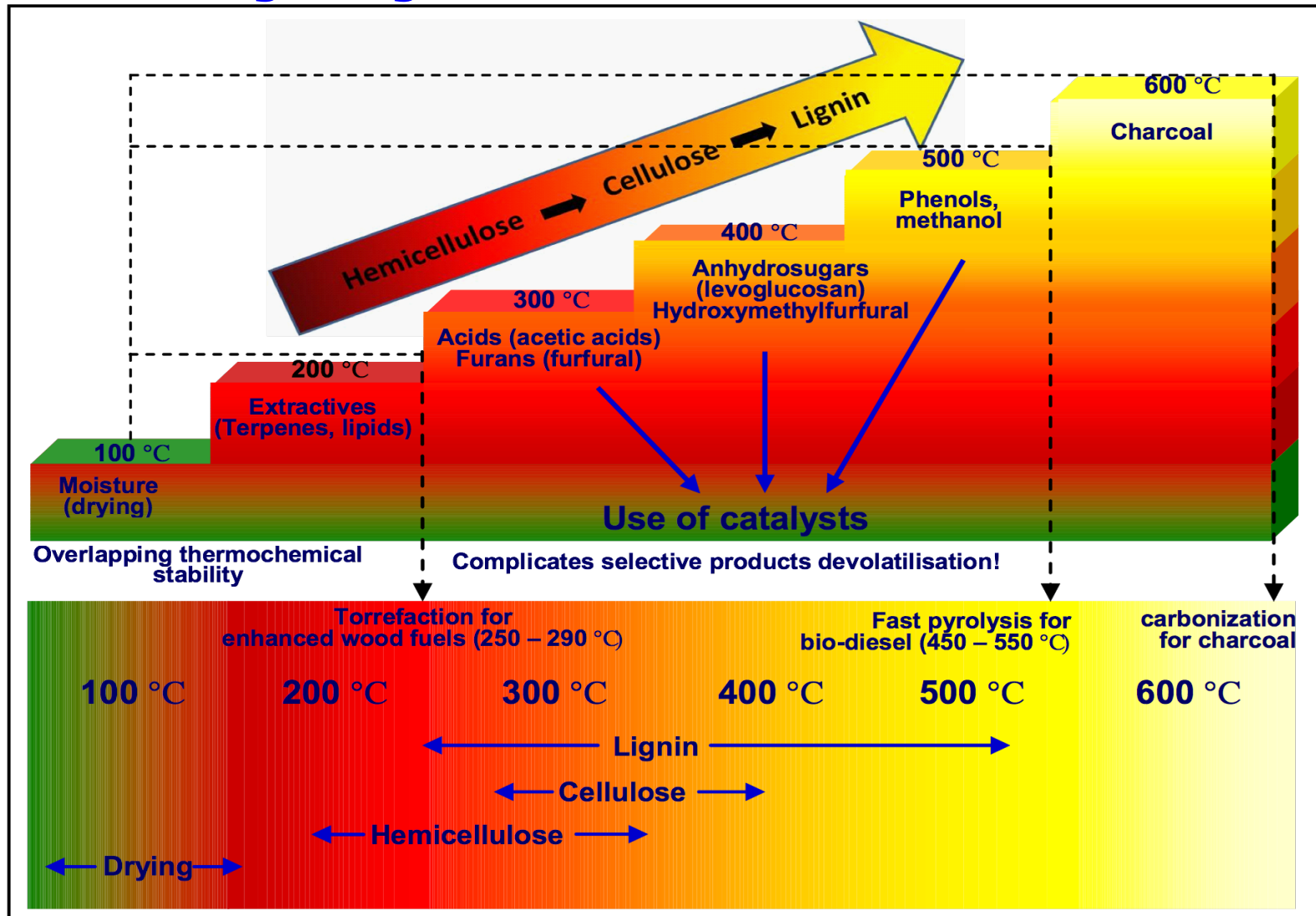
- Percentage composition of liquid, solid and gaseous products of different pyrolysis modes



MECHANISM AND PRODUCTS OF BIOMASS

PYROLYSIS

- Biomass Pyrolysis**

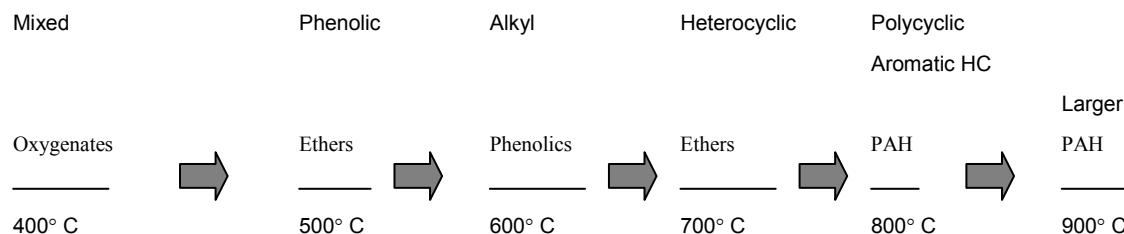


Overview of the thermal fractionation of biomass by a step-wise pyrolysis approach.

Properties of bio-oil

Table 2. Properties of Bio-oil from Various Feedstocks

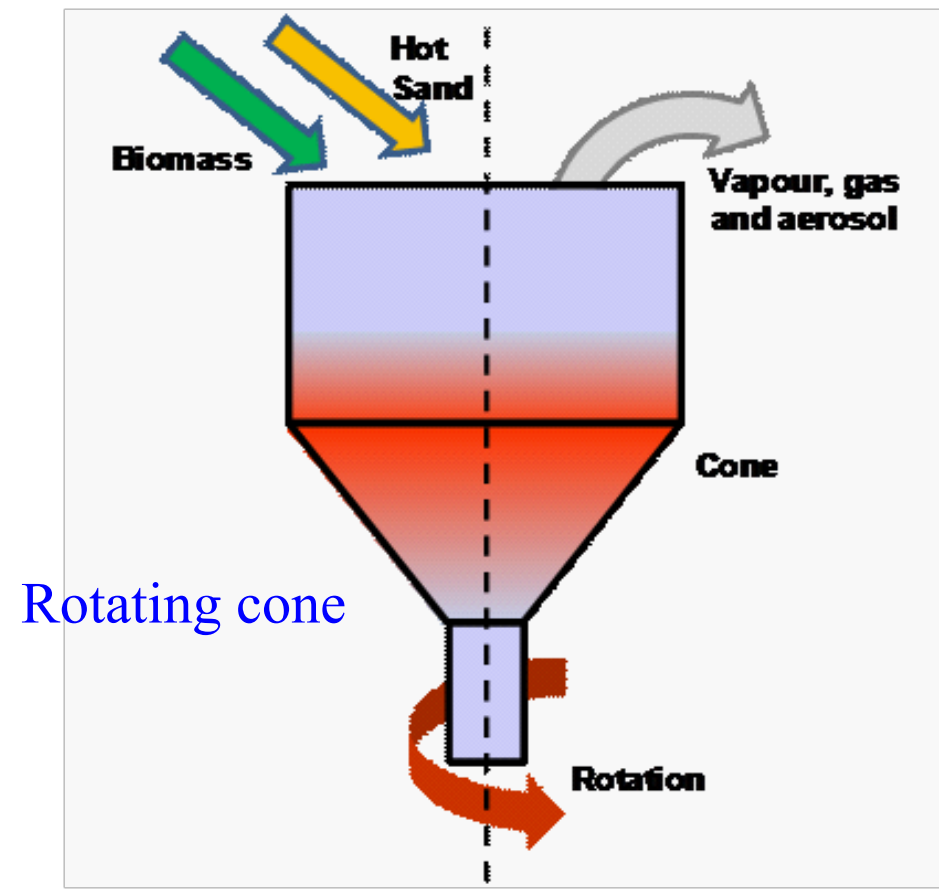
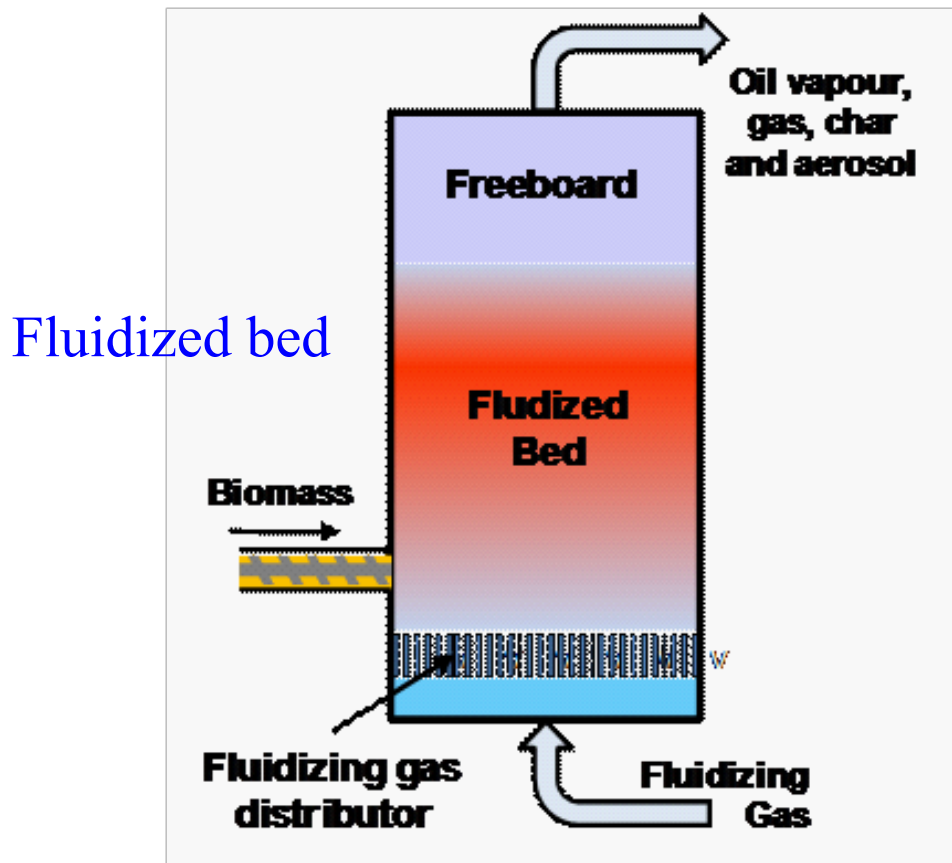
Property	Birch	Pine	Poplar	Various
Solids (wt%)	0.06	0.03	0.045	0.01-1
PH	2.5	2.4	2.8	2.0-3.7
Water (wt%)	18.9	17.0	16.8	15-30
Density (kg/m ³)	1.25	1.24	1.20	1.2-1.3
Viscosity, cSt @ 50°C	28	28	13.5	13-80
LHV (MJ/kg)	16.5	17.2	17.3	13-18
Ash (wt%)	0.004	0.03	0.007	0.004-0.3
CCR (wt%)	20	16	N/M	14-23
C (wt%)	44.0	45.7	48.1	32-49
H (wt%)	6.9	7.0	5.3	6.9-8.6
N (wt%)	<0.1	<0.1	0.14	0.0-0.2
S (wt%)	0.00	0.02	0.04	0.0-0.05
O (wt%)	49.0	47.0	46.1	44-60
Na + K (ppm)	29	22	2	5-500
Ca (ppm)	50	23	1	4-600
Mg (ppm)	12	5	0.7	N/M
Flash Point (°C)	62	95	64	50-100
Pour Point (°C)	-24	-19	N/M	-36 -9



TYPES OF PYROLYTIC REACTORS

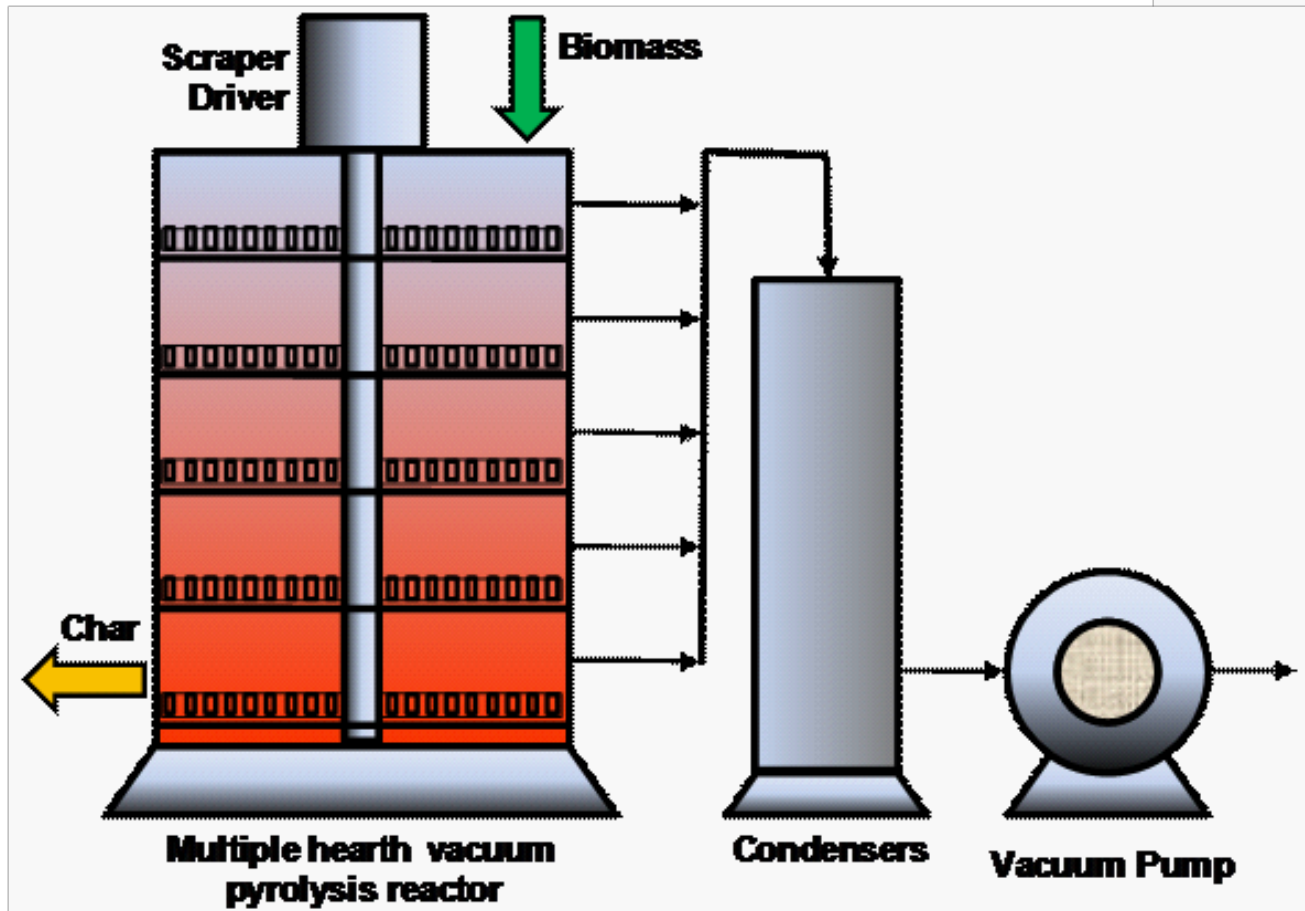
- **Types of Pyrolysis Reactor Designs**

- A number of different pyrolysis reactor designs are available.
- These include Fluidized bed, Re-circulating fluidized bed, Ablative, Rotating cone, Auger (or screw), Vacuum, Transported bed, and Entrained flow.

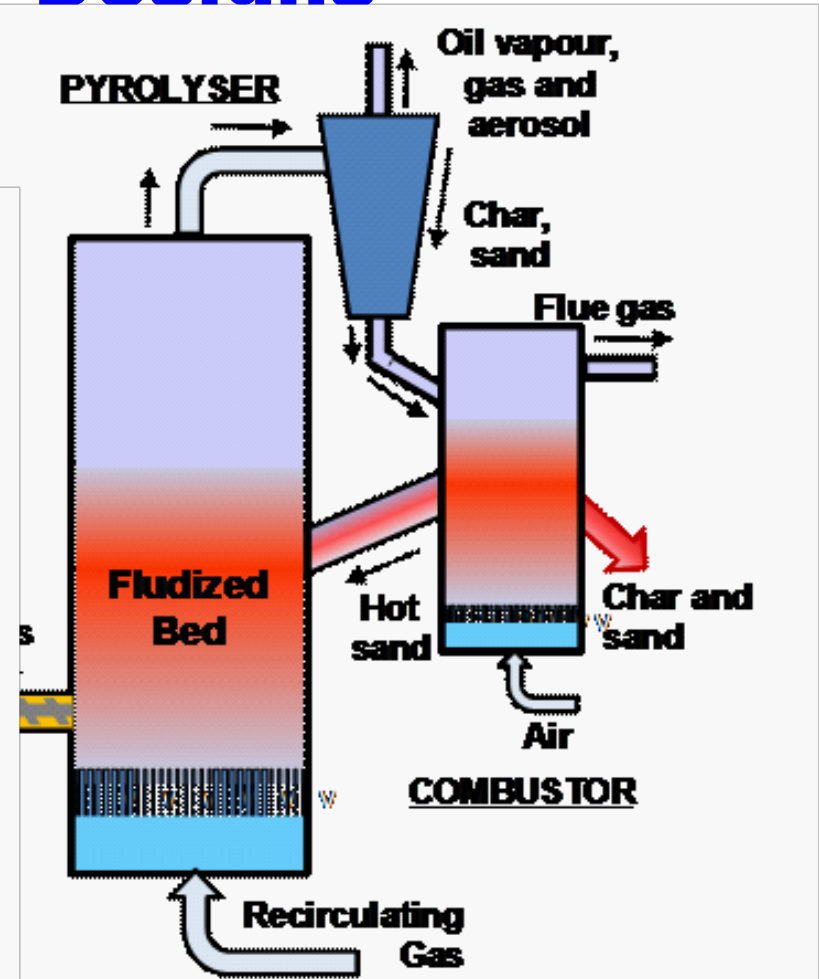


TYPES OF PYROLYTIC REACTORS

- Types of Pyrolysis Reactor Designs

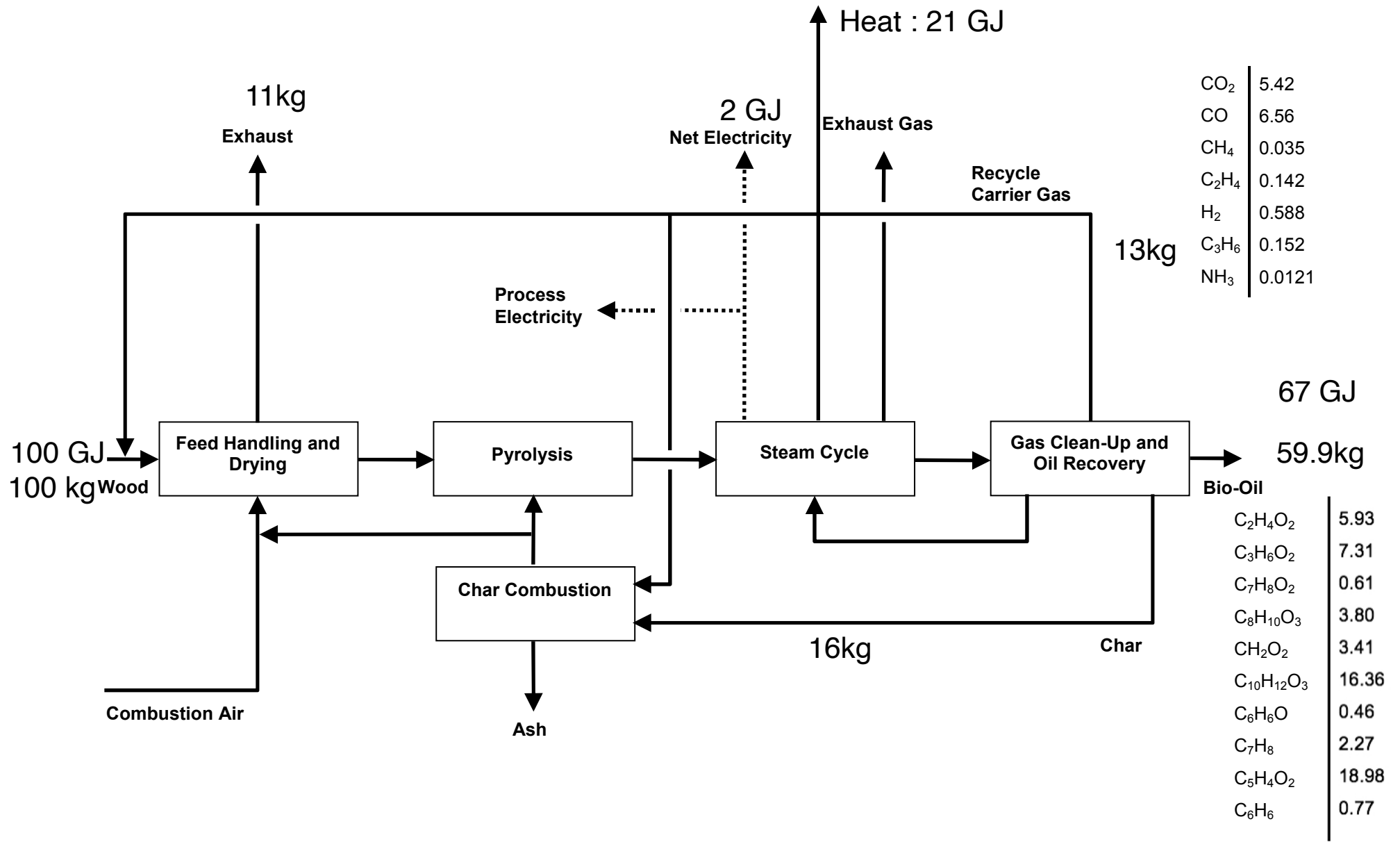


Vacuum



Re-circulating
fluidized bed

Typical pyrolysis process



Pyrolysis processes

- Difficulties
 - Fuel specifications (control of the quality and the distribution of components)
 - Difficult to use in conventional engines
 - Integrate in refineries
 - Minerals
 - Stabilisation of bio-Oil
 - Hydrogenation

Examples of pyrolysis processes

Table 12. Worldwide Current Biomass Pyrolysis Operating Plants

Reactor Design	Capacity (Dry Biomass Feed)	Organization or Company
Fluidized bed	400 kg/hr (11 tons/day)	DynaMotive, Canada
	250 kg/hr (6.6 tons/day)	Wellman, UK
	20 kg/ hr (0.5 tons/day)	RTI, Canada
Circulating Fluidized Bed	1500 kg/hr (40 tons/day)	Red Arrow, WI; Ensyn design
	1700 kg/hr (45 tons/day)	Red Arrow, WI; Ensyn design
	20 kg/hr (0.5 tons/day)	VTT, Finland; Ensyn design
Rotating Cone	200 kg/hr (5.3 tons/day)	BTG, Netherlands
Vacuum	3500 kg/hr (93 tons/day)	Pyrovac, Canada
Other Types	350 kg/hr (9.3 tons/day)	Fortum, Finland