

# Impatto dei processi produttivi sulle caratteristiche del biochar

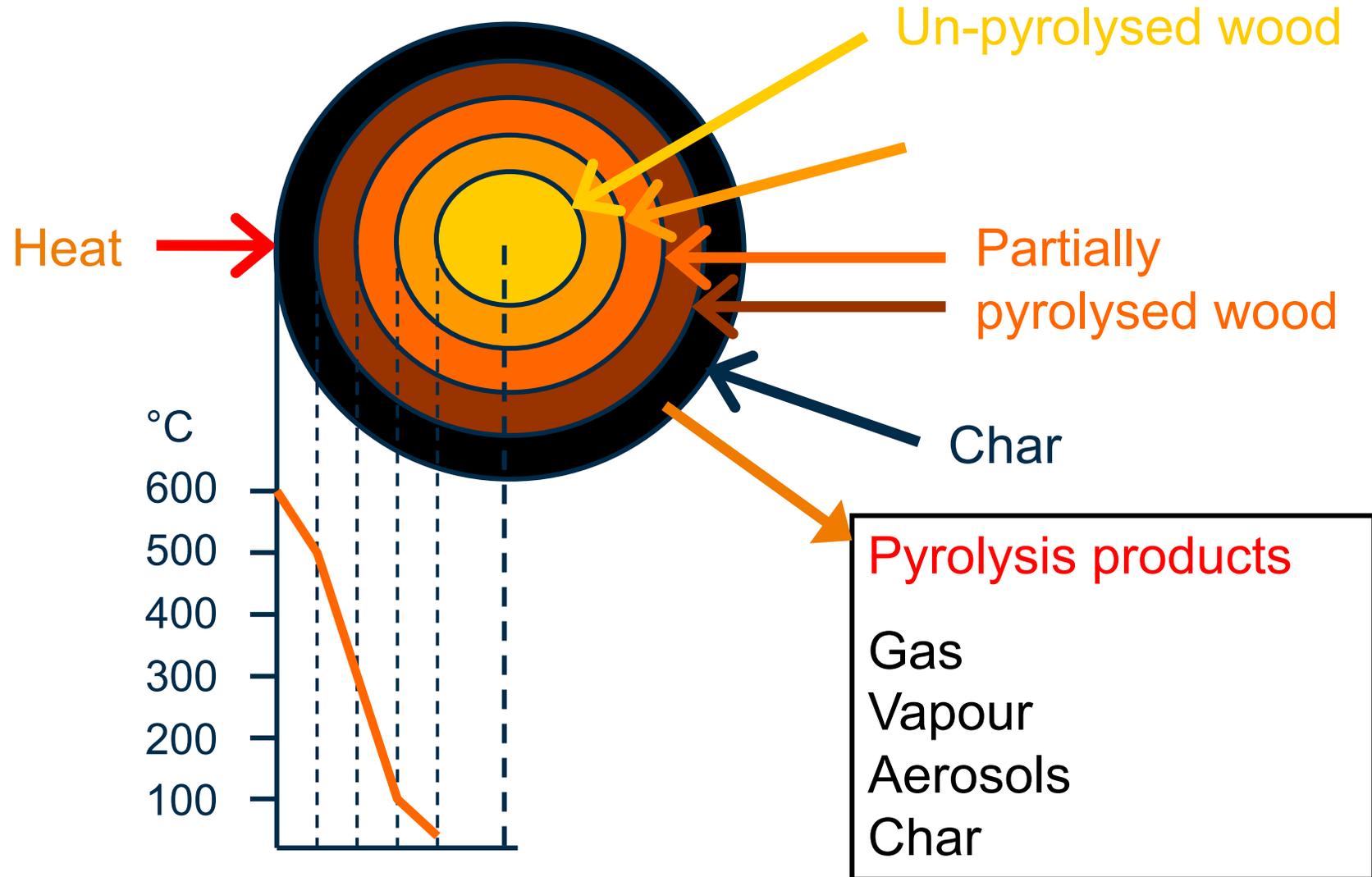
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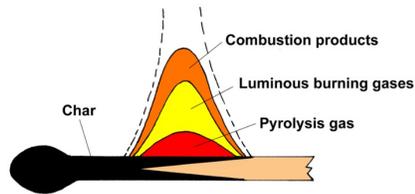


# Particle pyrolysis





# THERMOCHEMICAL DECOMPOSITION (CONVERSION) OF ORGANIC MATERIALS



PRODUCTS OF THERMOCHEMICAL CONVERSION

SOLID



Charcoal

LIQUID



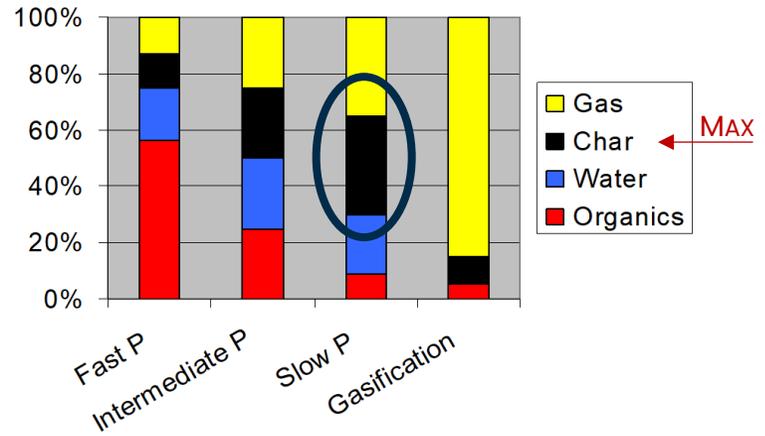
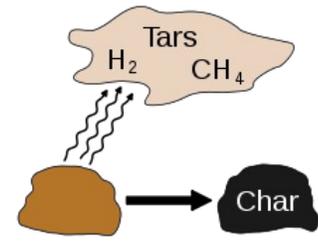
Bio-oil

GAS



Pyrogas

- Pyrolysis (Flow, Fast), Gasification, Hydrothermal Carbonisation
- **SLOW Pyrolysis**: very **robust and mature technology**. Many **reactor** types available at **any size**.
- A **Multi-Feedstock** technology



**SLOW PYROLYSIS**  
 TYPICAL PROCESS TEMPERATURE: 400 ÷ 600 °C  
 LONG RESIDENCE TIME OF SOLIDS AND VAPORS  
 LOW HEATING RATE: 0,1 ÷ 2 °C s<sup>-1</sup>  
 PRODUCTS → CHAR + BIO-OIL + GAS

# UNDERSTANDING THE CHAR STRUCTURE IS KEY FOR APPROPRIATE PRODUCTION AND USE



**130–140 °C: Release of water and steam extraction of VOCs**

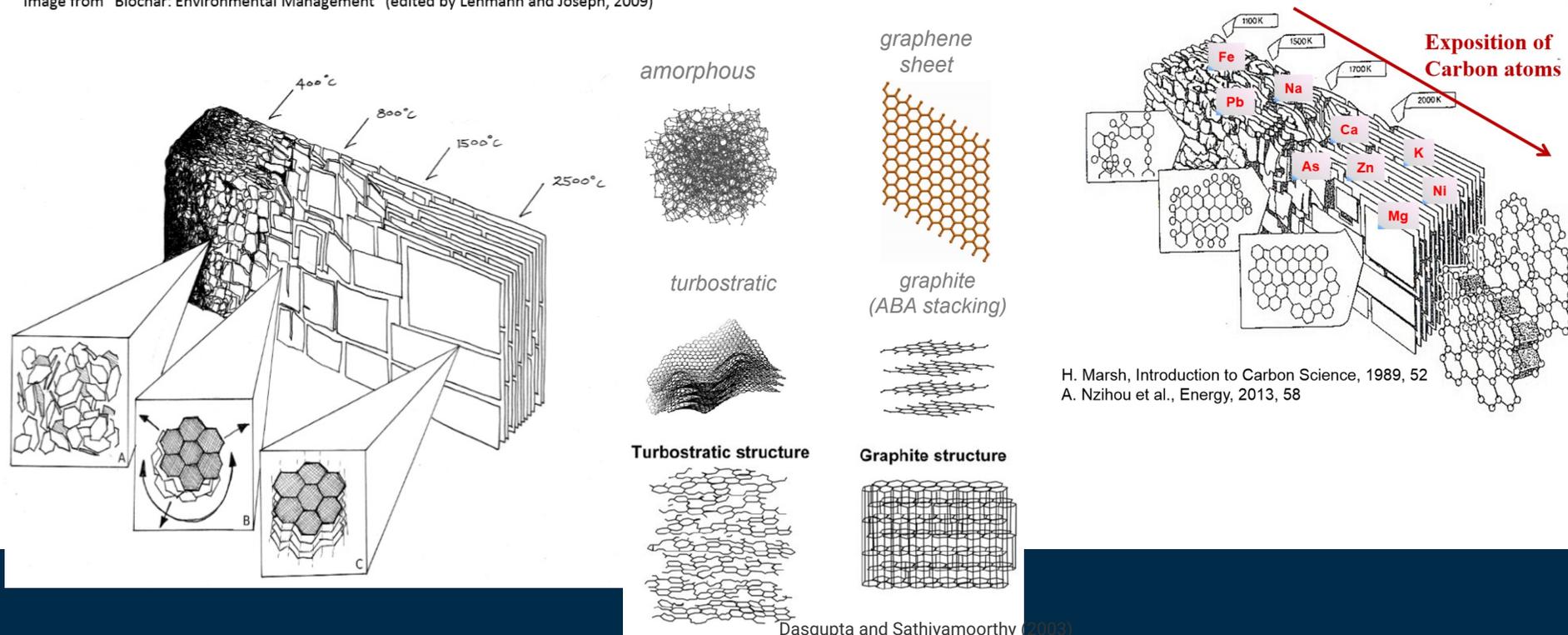
**140–400 °C: Hemicellulose degrades, Cellulose–lignin bonds break down**

**400–600°C: Main Pyrolysis reactions, massive pyrogas release**

**600–800 °C: Aromatic frames development**

**800–2500 °C: Turbostratic rearrangement, towards graphene sheet**

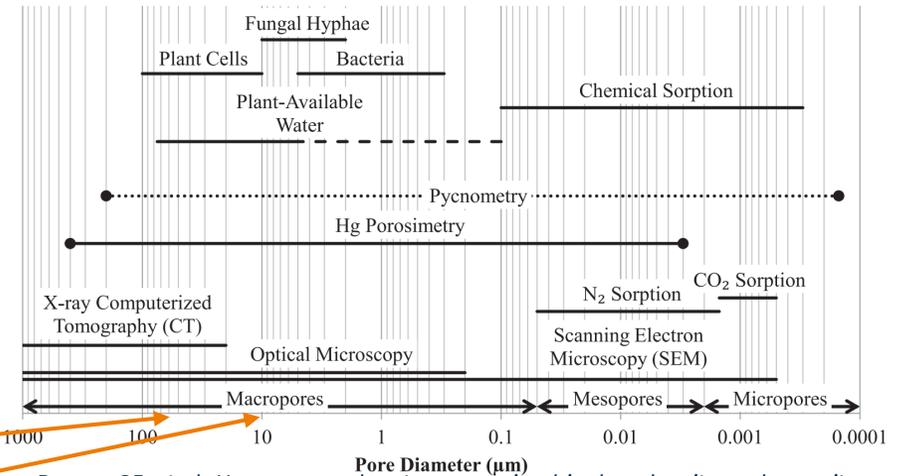
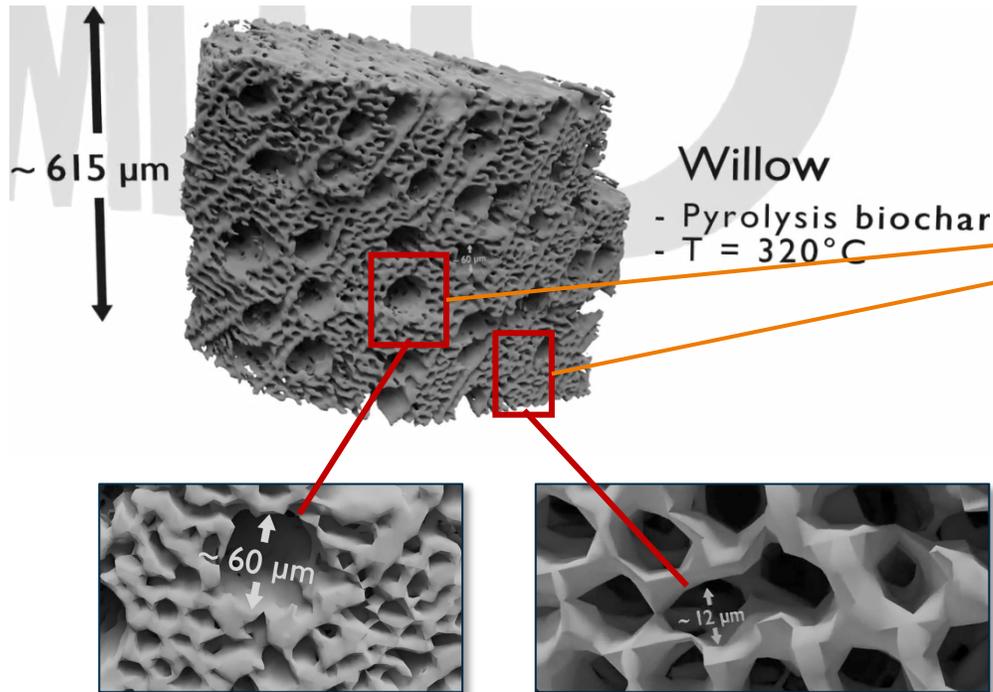
Image from "Biochar: Environmental Management" (edited by Lehmann and Joseph, 2009)



# SPECIFIC SURFACE, WATER RETENTION CAPACITY....

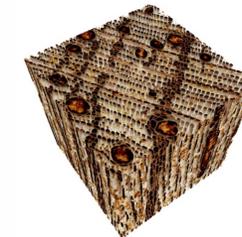
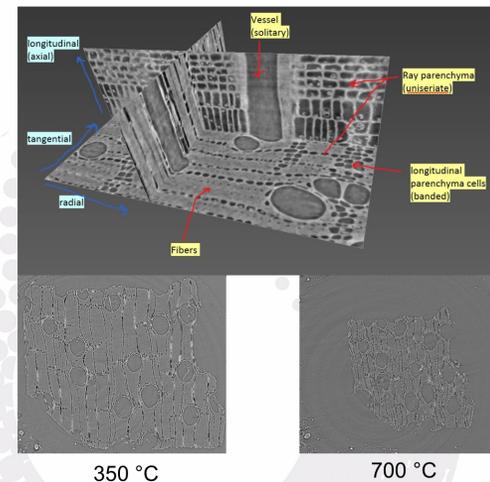


Source: Luke, Finland. X-ray tomographic reconstruction of a willow biochar sample pyrolysed at temperature 320 °C. Image resolution is 1.14 μm. Camera moves through pores relevant for water retention (approx. 10 and 50 μm in diameter).  
<https://www.youtube.com/watch?v=xZeu8mNlxZQ>

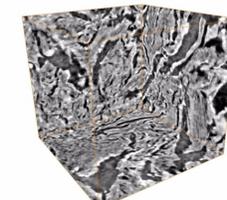


Brewer CE, et al, *New approaches to measuring biochar density and porosity, Biomass and Bioenergy* (2014), <http://dx.doi.org/10.1016/j.biombioe.2014.03.059>

## Biochar structure engineering



Biochar from raw wood



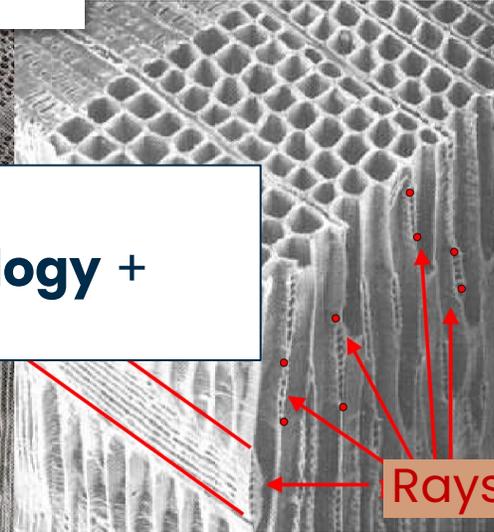
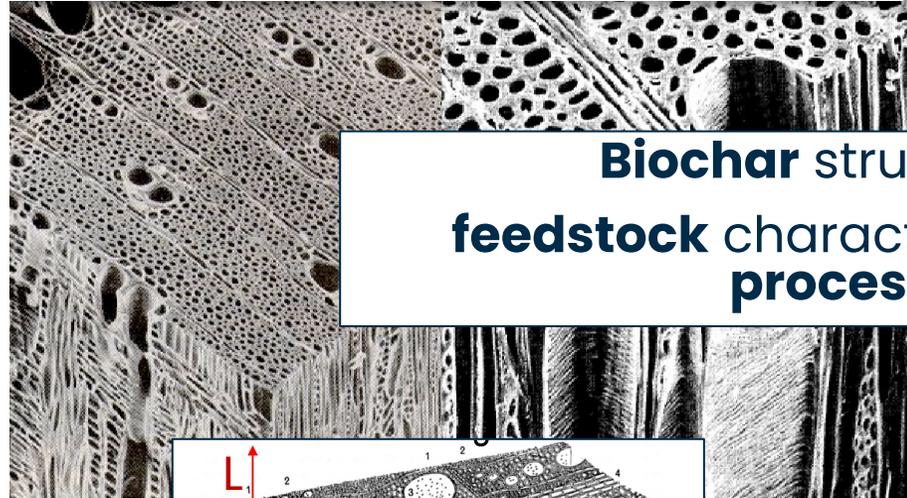
Biochar from pelleted wood

# WOOD STRUCTURE: HARDWOOD/SOFTWOOD

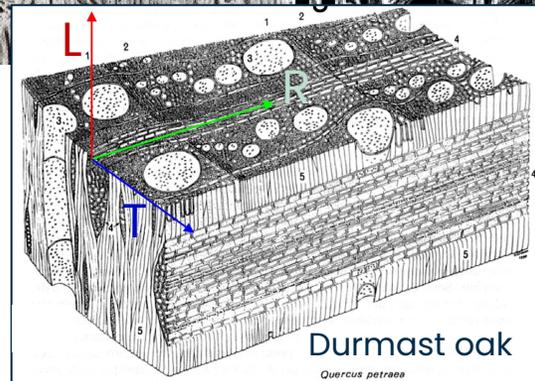


Hardwood *Angiosperms-  
Monocotyledons*

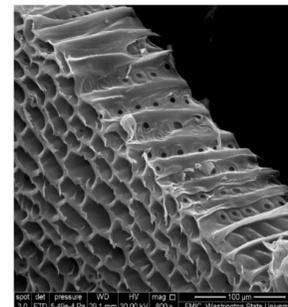
Softwood  
*Coniferous*



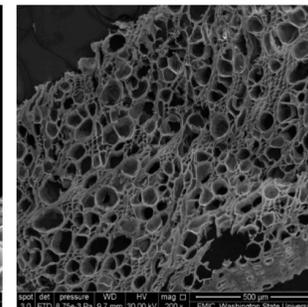
**Biochar** structure depends on  
**feedstock** characteristics + **technology** +  
**process conditions**



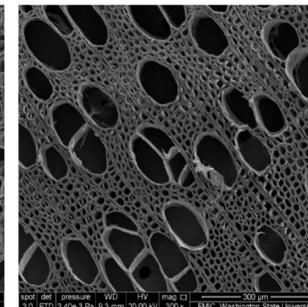
Source: Marco Togni, DEISTAF, University of Florence



Pine wood biochar  
mag. 800X



Pine bark biochar  
mag. 200X



Poplar wood biochar  
mag. 300X

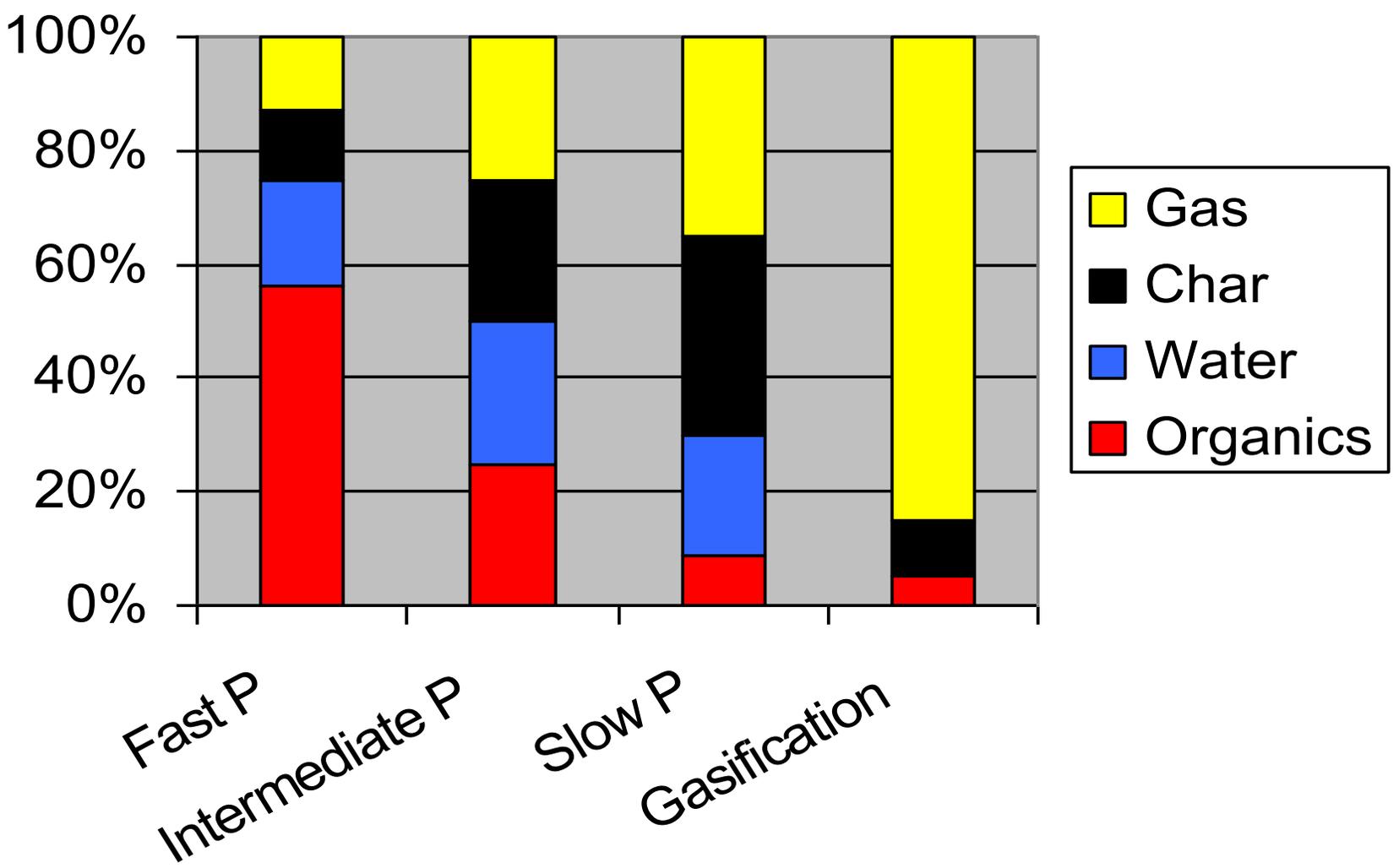
# Pyrolysis modes

- ✓ Based on Hot Vapour Residence Time (HVRT) and Heating Rate (HR), the mode of pyrolysis can be classified as: **slow, intermediate, or fast**
  - **Fast** (final temperature, 500 °C; particle diameter <2 mm; VRT, 1 s),
  - **Intermediate** (final temperature, 500 °C; small particles; VRT, 1 s),
  - **Slow** (final temperature, 500 °C; logs or chips; very long VRT , up to days)

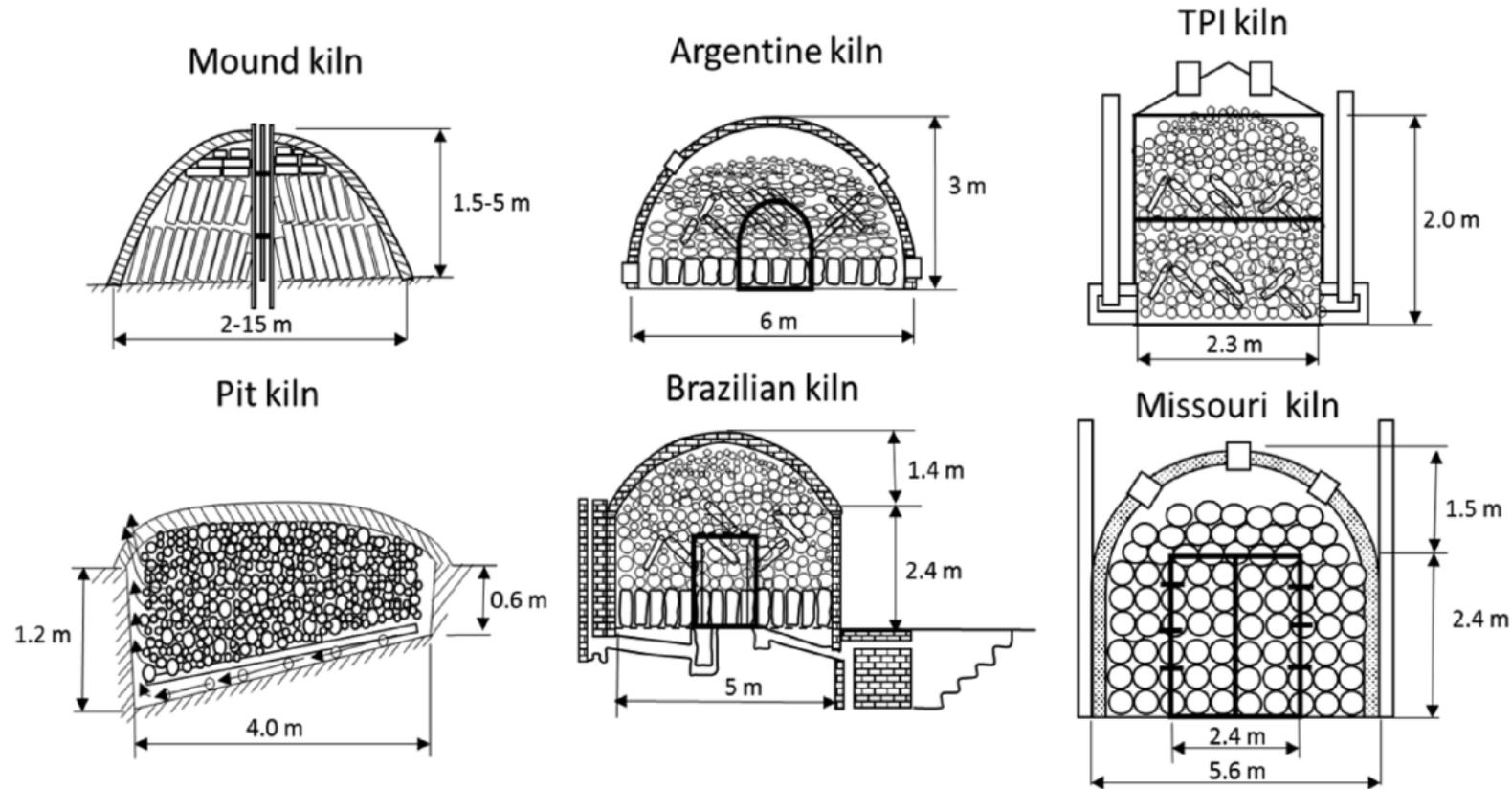
Mode	Conditions wt % products	Liquid	Char	Gas
Flash/Fast	~ 500°C (400-600 °C); very short hot vapour residence time HVRT < 2 s (Fast: ~1 s); short solids RT; HR > 2 s (Fast: ~ 10 <sup>3</sup> -10 <sup>4</sup> K/s)	<u>75%</u>	12%	13%
Intermediate	~ 500°C; short HVRT ~10-30 s; moderate solids RT	50% in 2 phases	25%	25%
Slow	~ 400-500 °C; long HVRT > 5 s; very long (minutes to days) solids RT; HR ~ 0.1 -2 K/s	35%	<u>35%</u>	30%
Torrefaction	~ 300°C; long HVRT; long solids RT	Vapours	<u>85% solid</u>	15% vapours
Gasification	~ 800-900°C; short HVRT; short solids RT	<1-5%	<3-5%	<u>95-99%</u>

**HVRT: Hot Vapour Residence Time; RT: Residence Time; HR: Heating Rate**

# Process and product yields



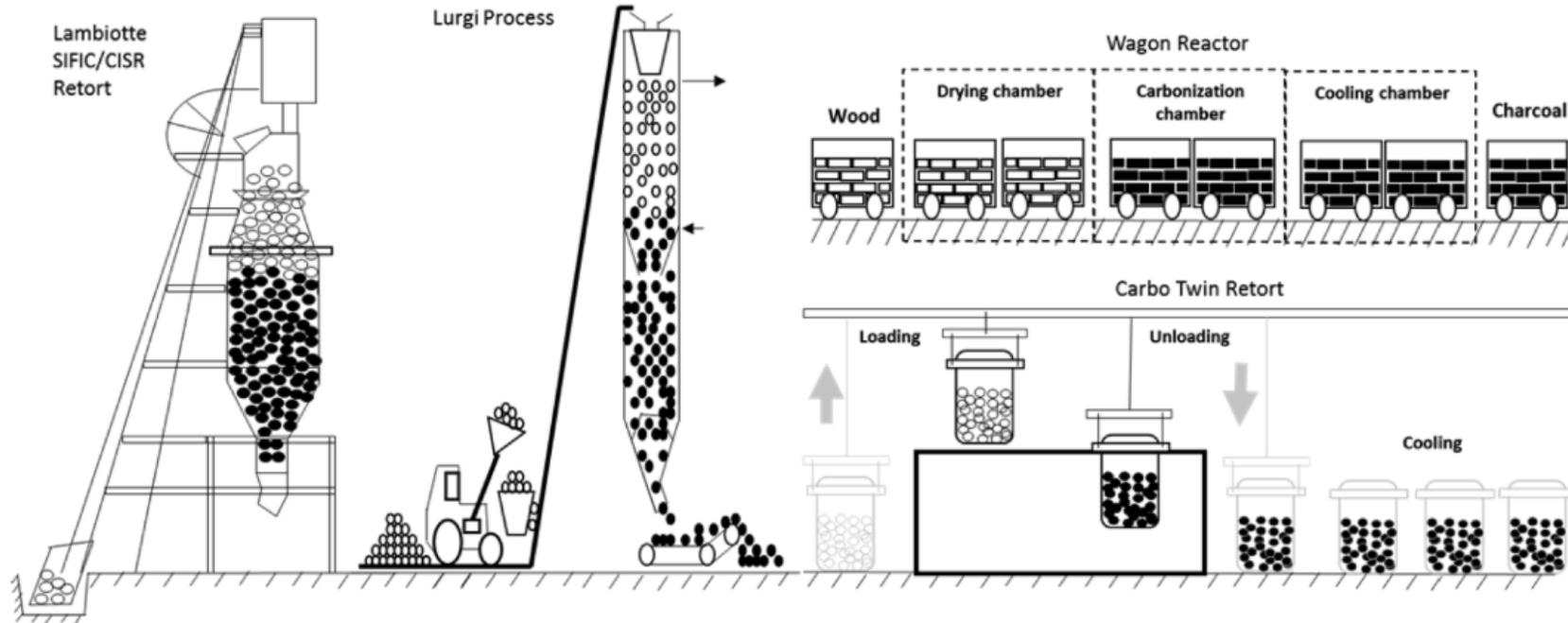
# Slow pyrolysis (carbonization) - Kilns



Sources: Garcia-Nunez et al (in refs.)

Built in place/stationary; 12-30% yield, 1-5 weeks (mound/pit), 10-30 days (brick/metal kilns), logs/roundwood/splitwood

# Slow pyrolysis (carbonization) – Retorts



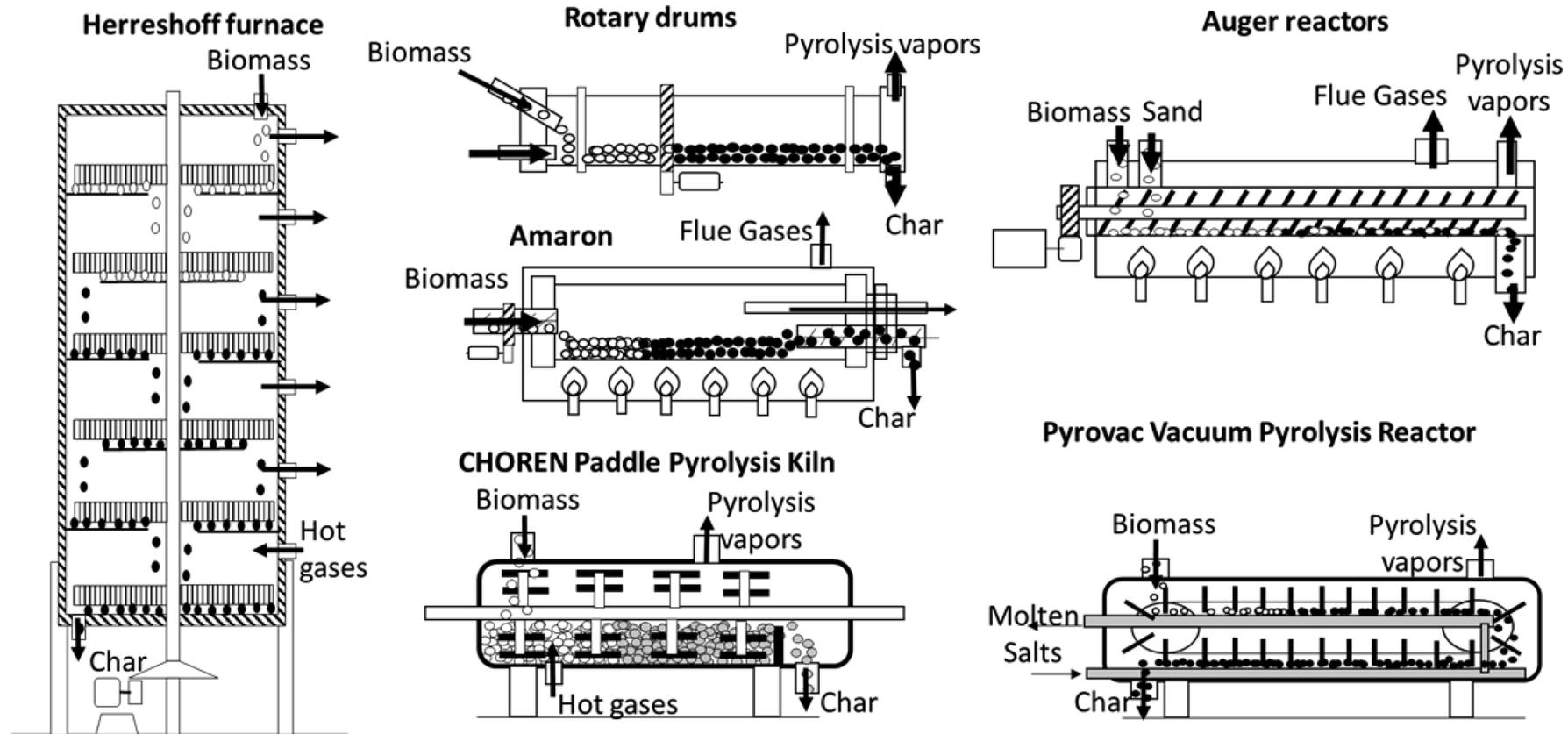
Sources: Garcia-Nunez et al (in refs.)

Stationary; 30–35% yield, 8–25 h carbonization time, large/very large particle size, capacity approx 6000 t/a – 900 t/a (CT), contact with heat gas (Lurgi, Lambiotte) or external heat and volatile combustion (WR, CT)

# Slow pyrolysis – Rotary kilns



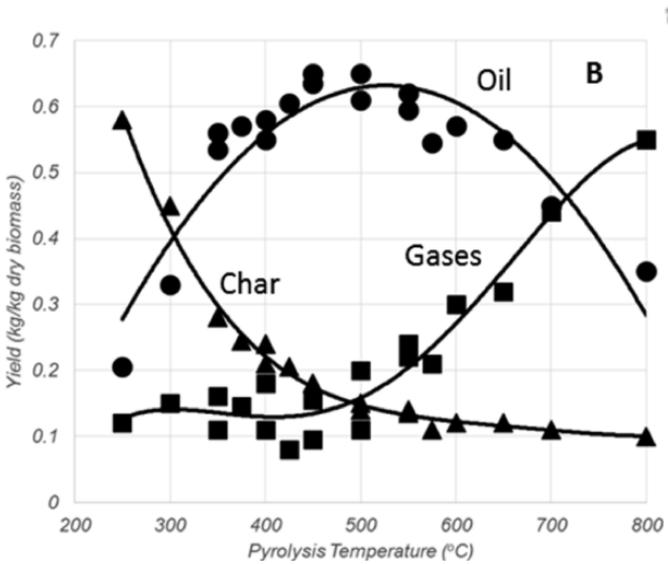
# Intermediate pyrolysis - Converters



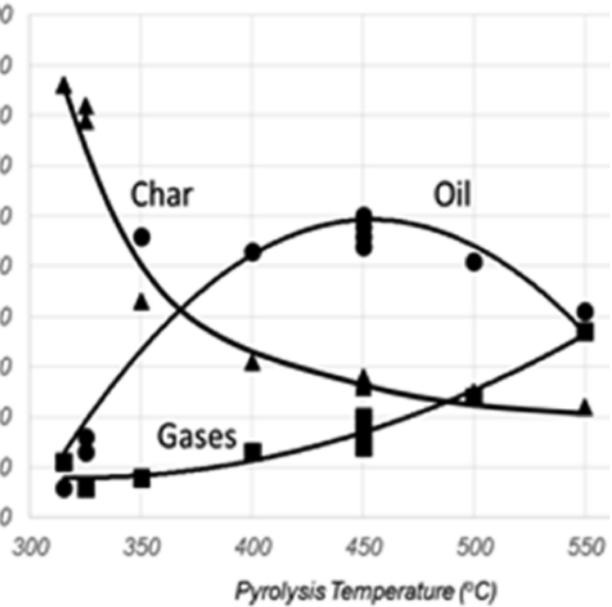
Sources: Garcia-Nunez et al (in refs.)

Yield in the range of 30% wt, direct/indirect contact with heat medium, variable sizes, able to process small/very small particle size

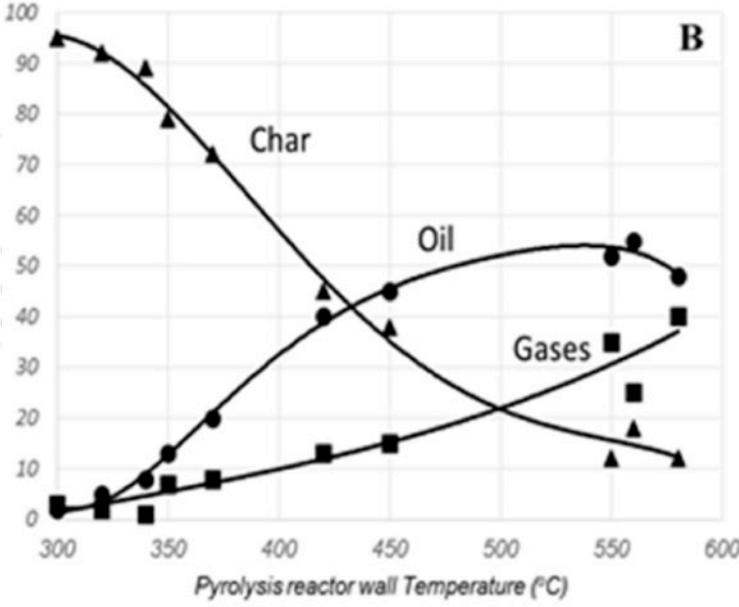
# Pyrolysis: Reactor types vs products



Fluidized bed



Rotary drum



Auger reactor

Sources: Garcia-Nunez et al (in refs.)

# HTC, Slow Pyrolysis, Gasification

- **HydroThermal Carbonization, HTC**

- ✓ Plants operates in pressure and temperature conditions: costs. Complex management of slurry. WWT of water phase needed. Low biochar quality requires downstream processing for many uses.

- **Slow Pyrolysis, SP**

- ✓ It typically works at 450–650 °C T, anaerobic conditions of exploding environment. Complex extraction and handling. Emission control. Multifeedstock increases size and costs and drives reactor type.

- **Gasification**

- ✓ Complex and high CAPEX/OPEX technology, scale needed, skilled operators. Energy focused: energy-incentives needed, unless wastes used as feedstock. Biochar is Carbon not converted to gas (inefficiency). Bioproducts and Biorefining main interest today.

# Comparing HTC, SP and Gasification..

	Slow Pyrolysis	Gasif	HTC
Main product	Solid	Gas	Solid
Main policy area	<b>PRODUCT</b> oriented process. Bioeconomy (including bioenergy) <b>Business model based on product value</b>	<b>ENERGY</b> oriented process. Bioenergy as part of Bioeconomy. <b>Business model based on energy value (incentive dependent)</b>	<b>PRODUCT</b> oriented process. Bioeconomy (including bioenergy). <b>Business model based on product value</b>
Main goal of process (Carbon)	Keep stable <b>C in the solid</b> for multiple uses. <b>C in pyrogas as coproduct</b> <b>C is main component of Business model.</b>	<b>C</b> in the feedstock <b>to gas</b> for energy generation or further processing into fuel & chemicals	Keep stable <b>C in the solid</b> for multiple uses. <b>Organic C (and inorganics) in water.</b> <b>C is main component of Business model.</b>
Relation to Biochar (C in soil)	<b>Very stable recalcitrant C.</b> Bring C back to soil for soil health and BioCCS-BioCCU. <b>Char characteristics can be tailored to soil type</b>	<b>Solid C is a minor amount,</b> waste or co-product. <b>C-in-ash</b> representative of <b>process inefficiency.</b>	<b>Lot of labile-volatile C.</b> Bring C back to soil for soil health and BioCCS-BioCCU.
Relation to Bio-oil/Condensates and water soluble organics	<b>Small amount of biocrude,</b> normally oxidised to provide heat to the process. <b>Large amounts of condensable organic-rich water</b> (various possible uses, regulation pending)	Condensates as <b>tar, to be removed or converted into gas</b>	<b>Very large amounts of condensable organic-rich water:</b> so far subject to <b>WWT</b> (possible other uses, low TRL yet)
Status of Technology	<b>Mature.</b> Available from small/micro to large industrial. Lot of reactor types developed (auger, FB, RK,...)	<b>Mature,</b> at a wide range of scale and different reactor types. Gas cleaning & treatment key element.	<b>Various Demos/first industrial.</b> Various continuous/semi-batch reactor types.
EU and INT most relevant C offsetting regulations	<b>ETS, CORSIA, Soil, CAP</b>	<b>REDII</b>	<b>ETS, CAP</b>
Feedstock sensitivity	<b>Multi-feedstock.</b> Up to 20-25 % m.c. Rather large feed dimension at inlet.	<b>Feedstock-sensitive.</b> High comminution and drying requirement.	<b>Multi-feedstock.</b> Fully wet feed at inlet Rather large dimension.

Thanks for your attention!

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