Valorisation énergétique et chimique du bois : mécanismes, procédés et filières

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LRGP LABORATOIRE RÉACTIONS ET GÉNIE DES PROCÉDÉS

cnrs

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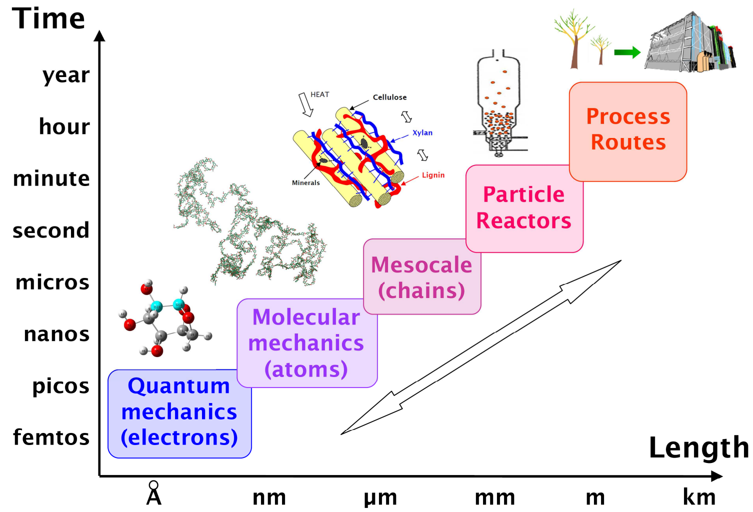
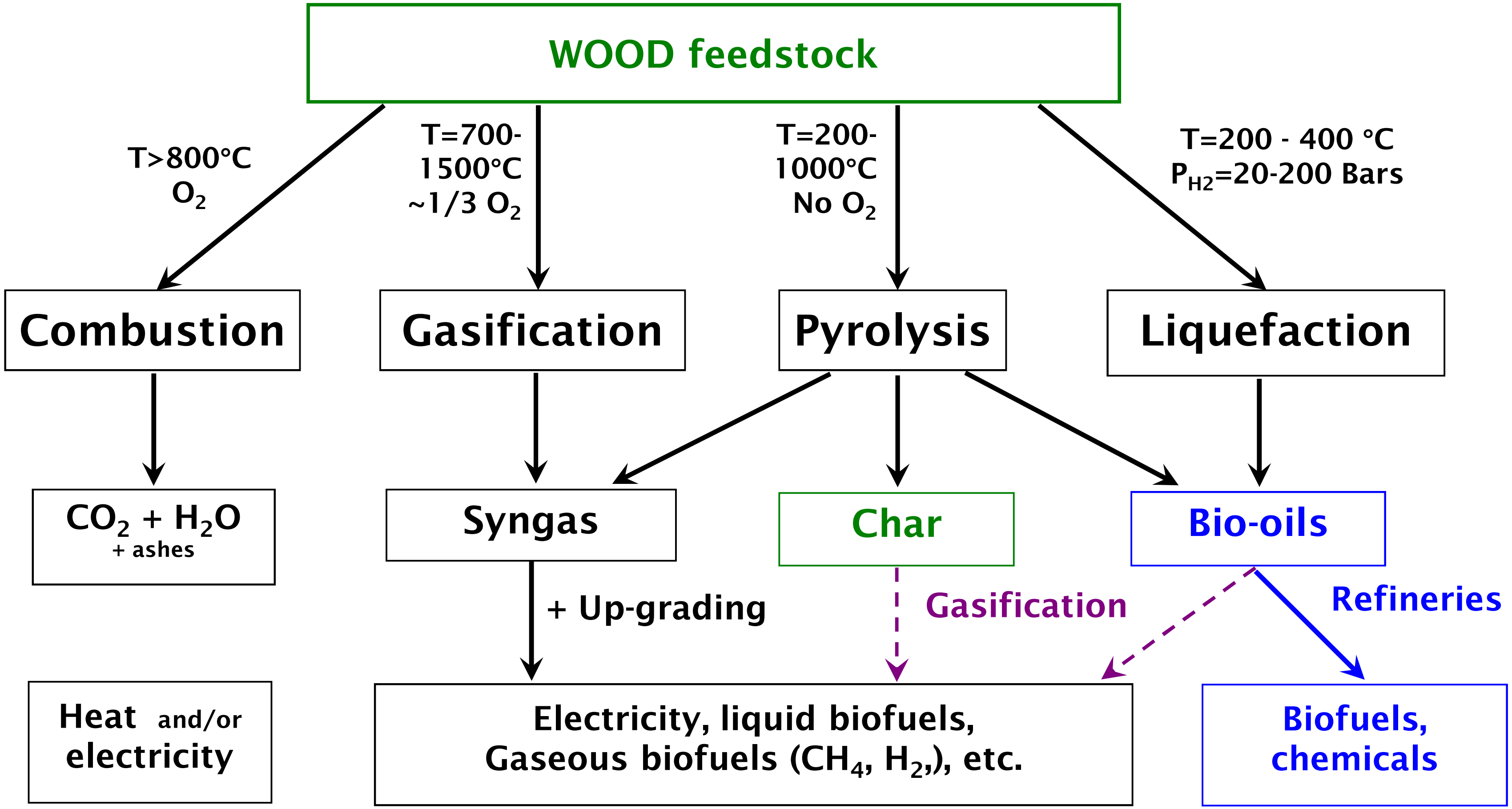


Valorisation « prioritaire » de la biomasse…

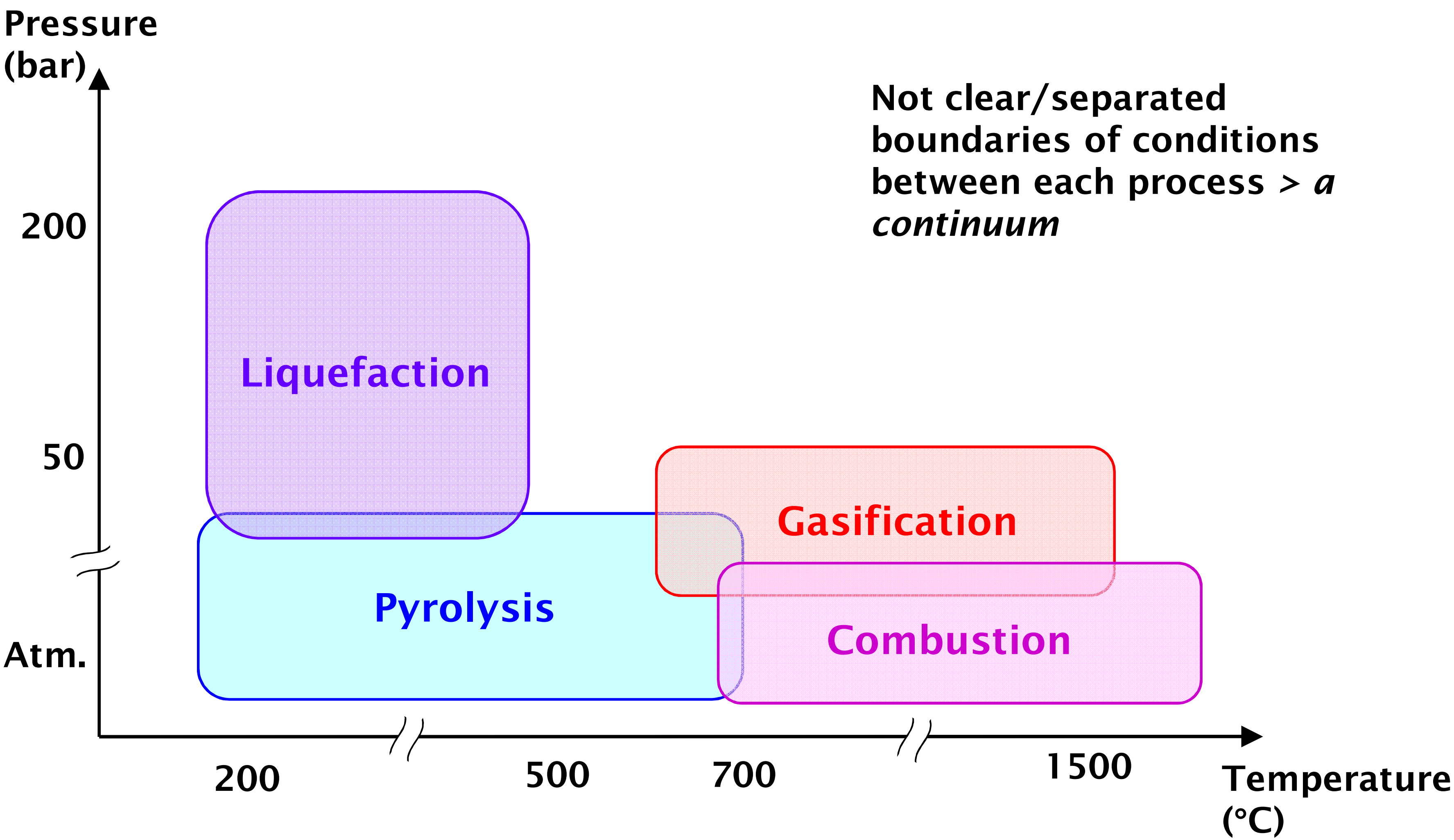
Valorisation prioritaire ↑

- Maintien de la biodiversité
- Patrimoine culturel
- Valorisation chimique des molécules (santé)
- Valorisation alimentaire
- Valorisation matière (construction, fibres)
- Valorisation énergétique

Heat, electricity, biofuels and chemicals can be produced by wood thermochemical conversion



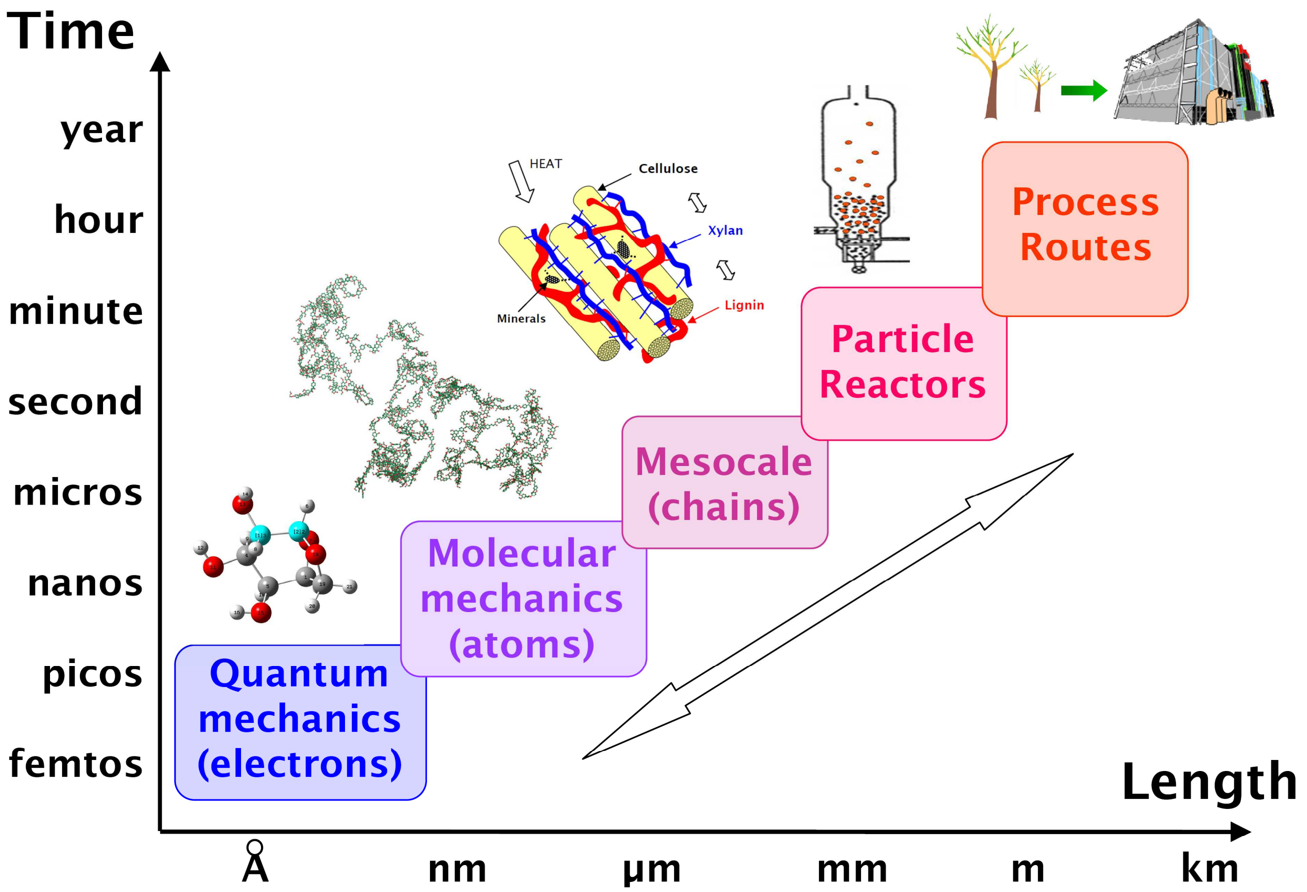
Thermochemical routes presented as functions of temperature and pressure of the reactors



Not clear/separated boundaries of conditions between each process > *a continuum*

Different scales of investigation of wood thermochemical conversion

Talk: from « small » (molecules) to « big » scales (process)



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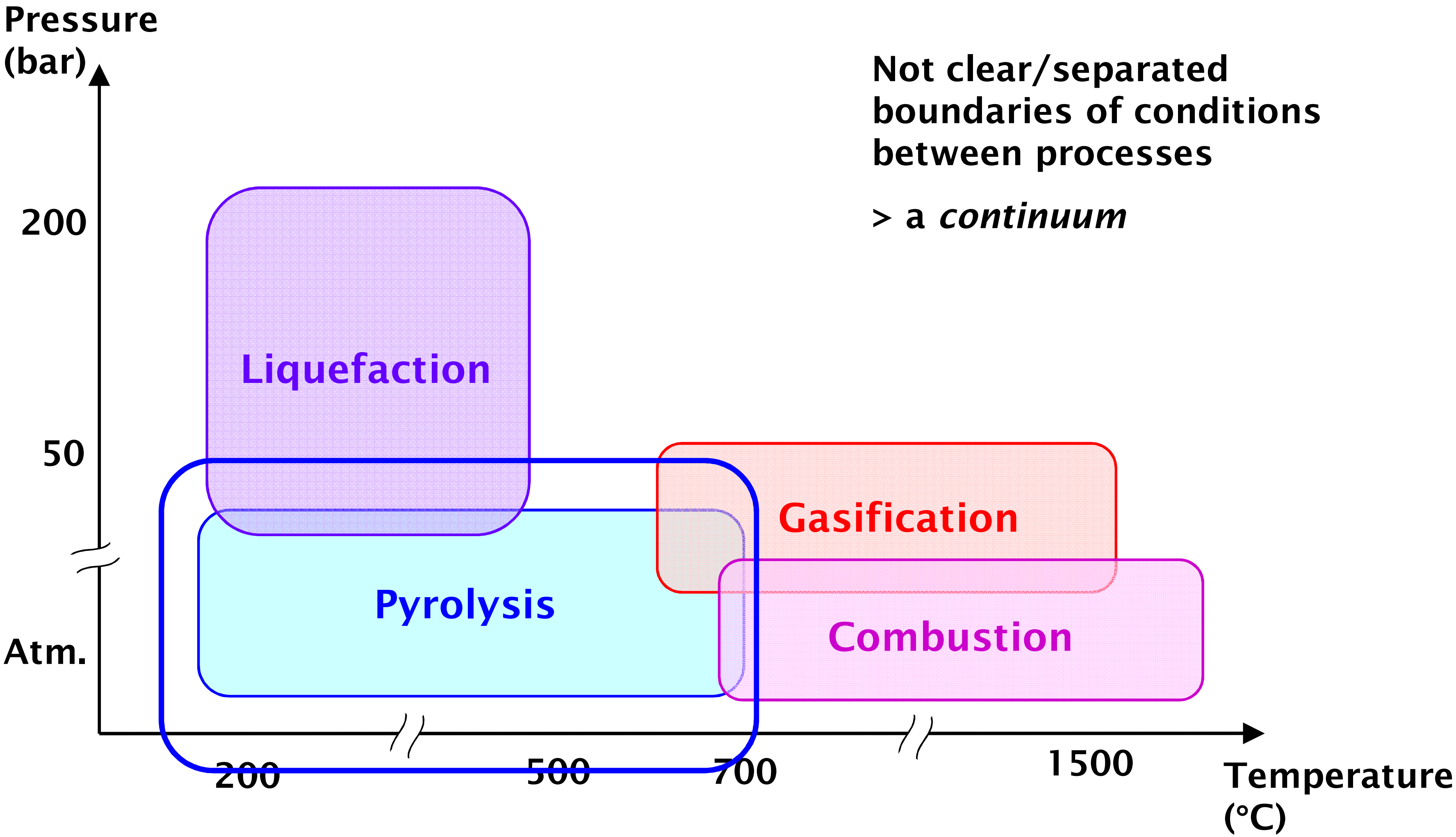
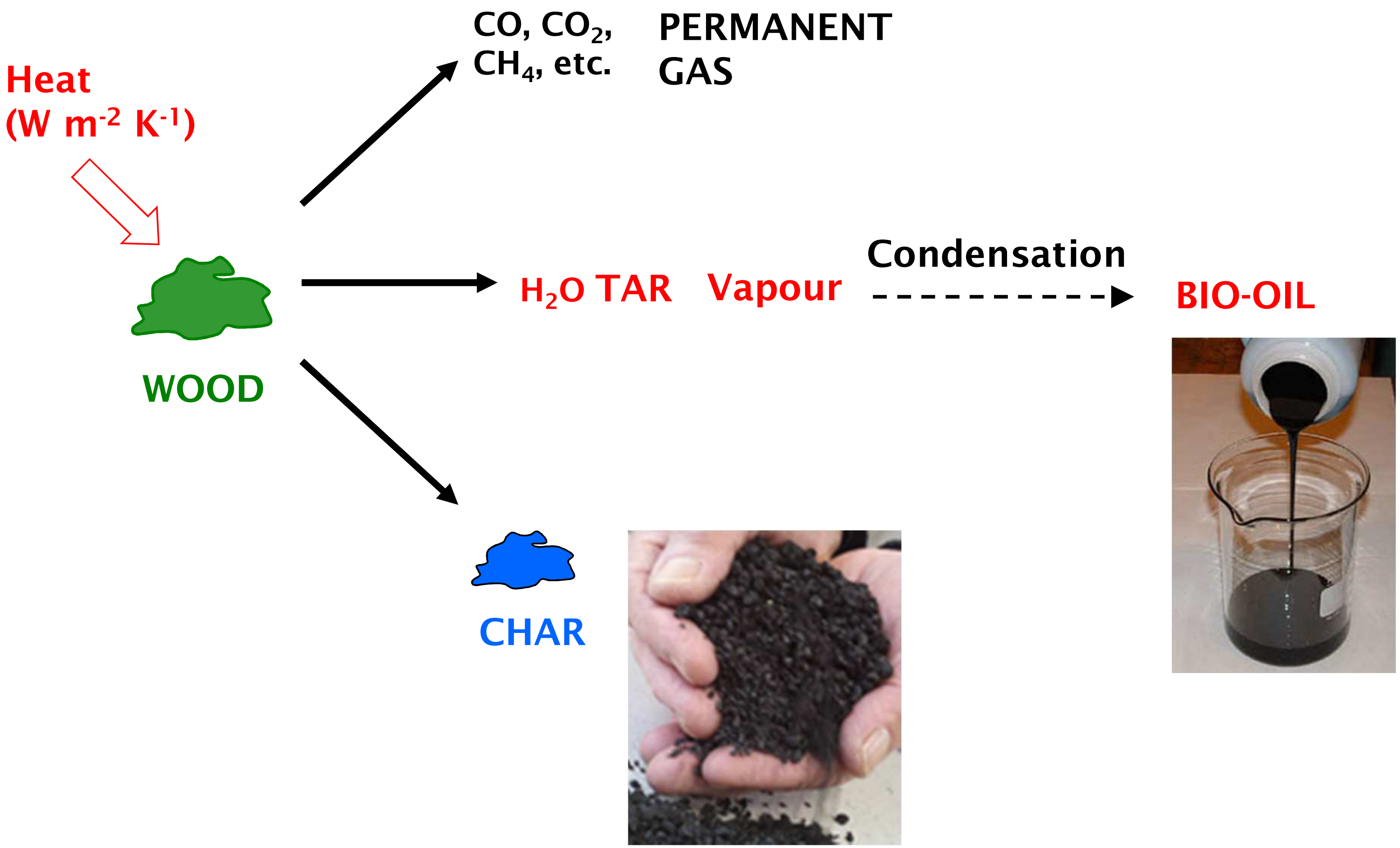


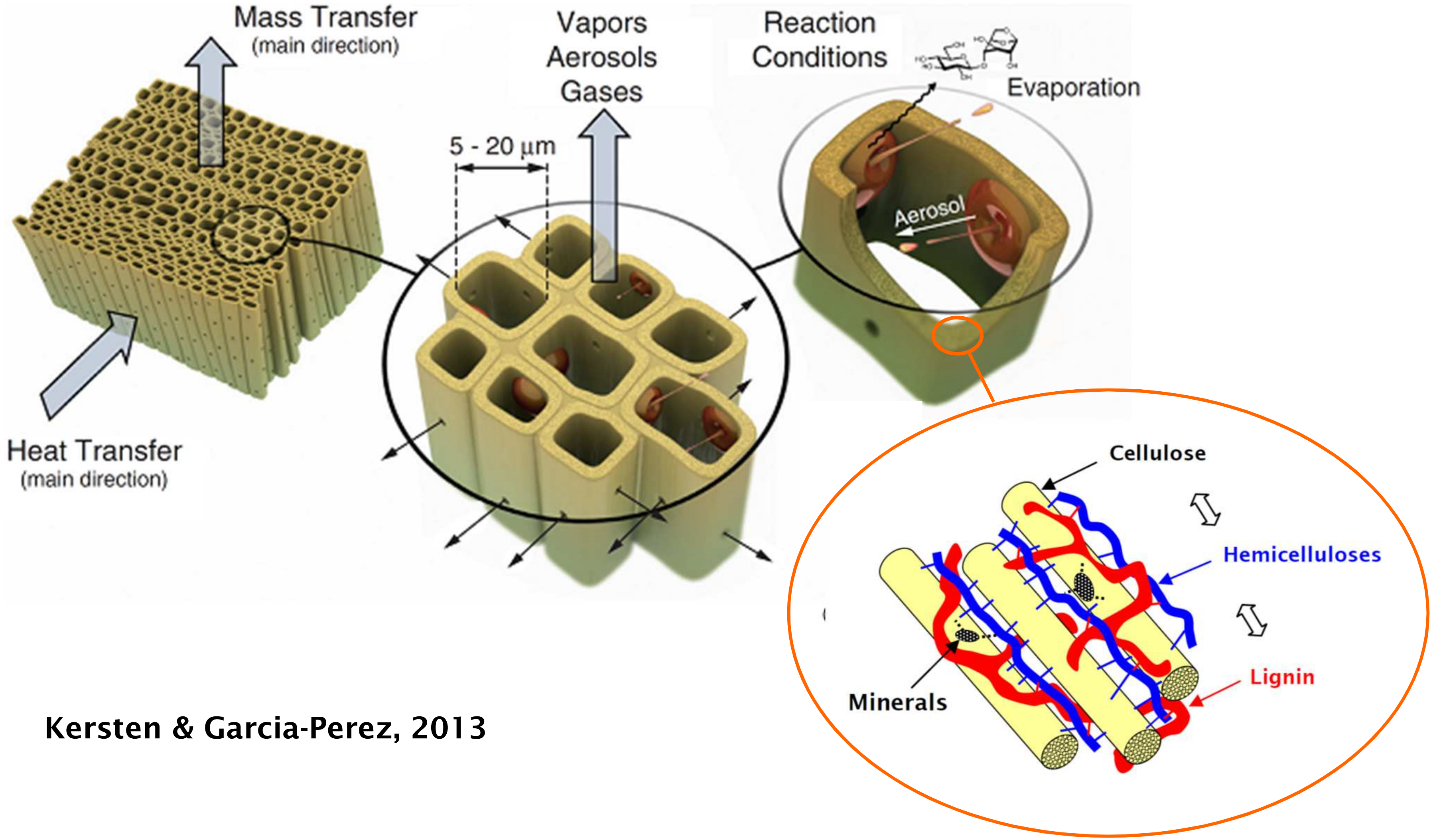
Not clear/separated boundaries of conditions between processes

> a *continuum*

Pyrolysis forms char, gas and liquid (bio-oil or tar).

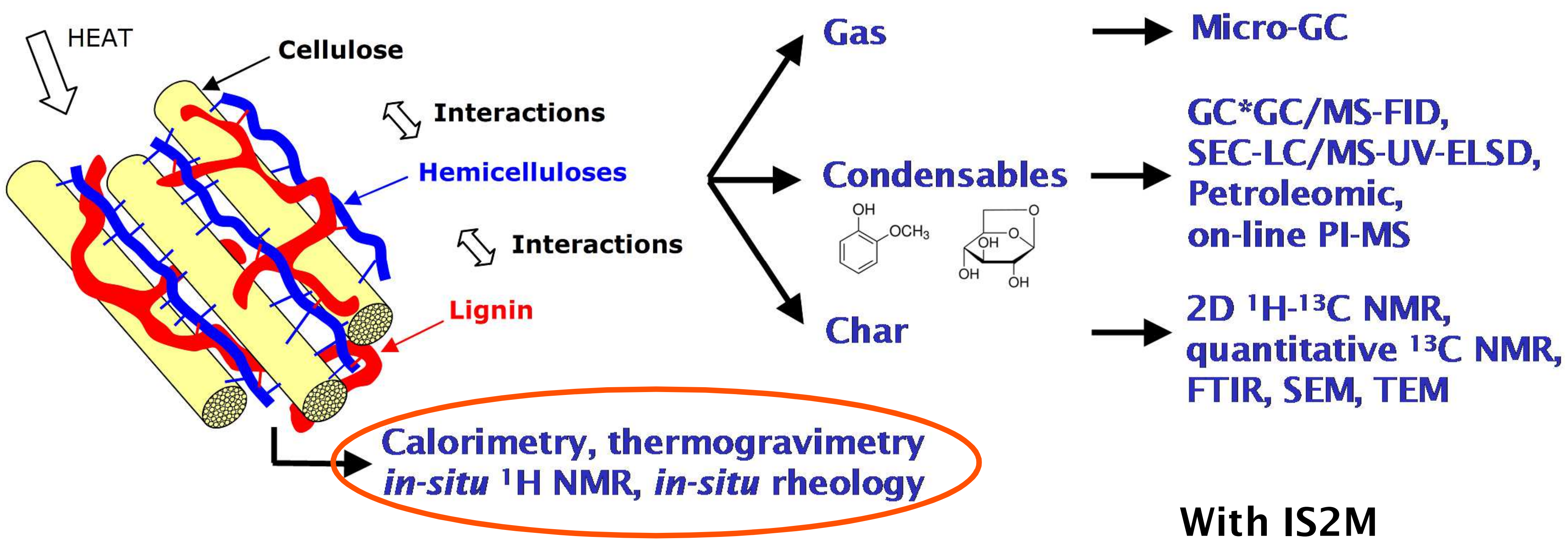


On veut comprendre la pyrolyse du bois à l'échelle des parois…



Kersten & Garcia-Perez, 2013

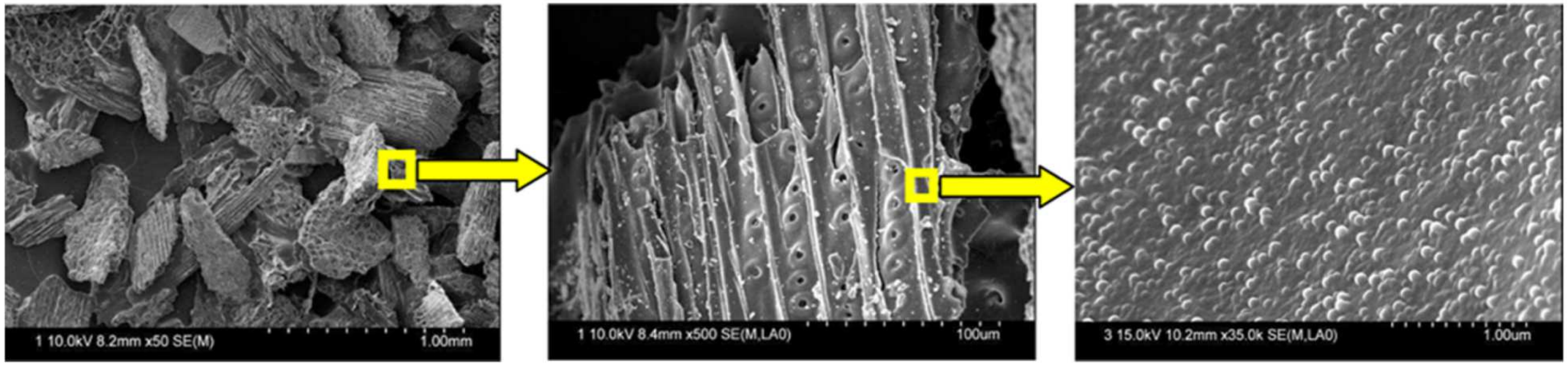
Wood pyrolysis is studied by various analytical methods in “Grand Est”!



Focus on in-situ analysis

With IS2M Mulhouse,
ICStrasbourg,
LEMTA Nancy,
LCPA2MC Metz

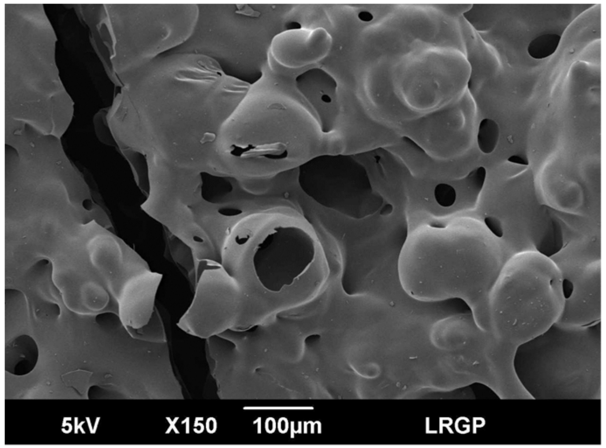
Why char remains a solid while many components from wood soften?



Wood char particles, slow pyrolysis, from mm to µm: bubbles formation at µm length scale (Dufour, Chem. Eng. Res. Des., 2011)

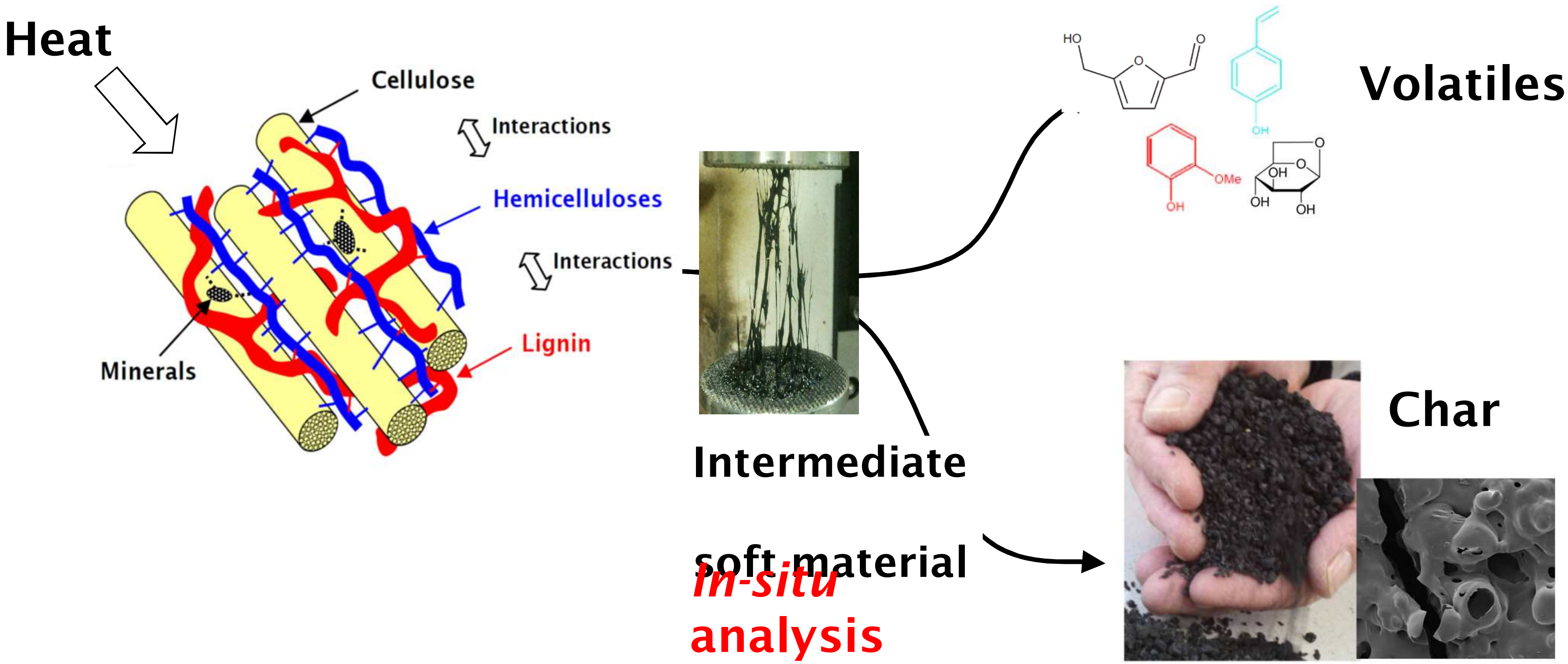
Lignin and hemicelluloses soften.

Klason, 1901; Göring, 1963; Sharma, 2014



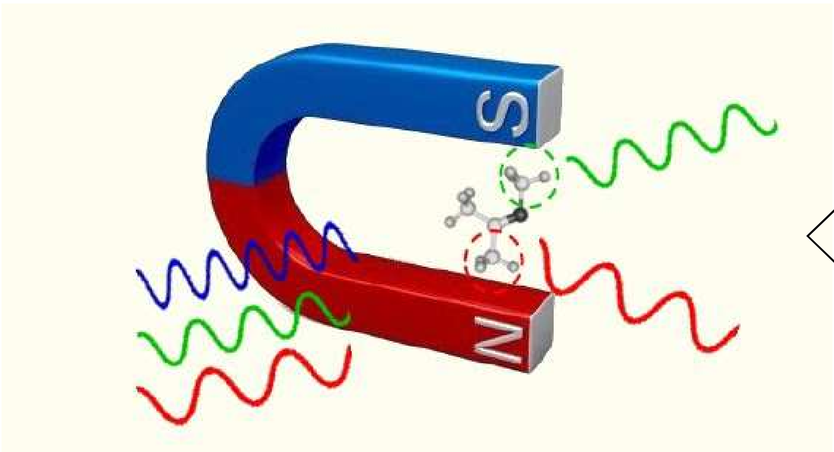
The intermediate soft material is very labile and short life time.

In-situ analysis is required…



In-situ analysis of biomass pyrolysis

⇨ **In-situ ¹H NMR and rheology have been extensively used for understanding "metaplast" during coal pyrolysis** (Sato, 1979, Lynch, 1988, Castro-Diaz, 2005) **but <u>not yet for biomass</u>.**



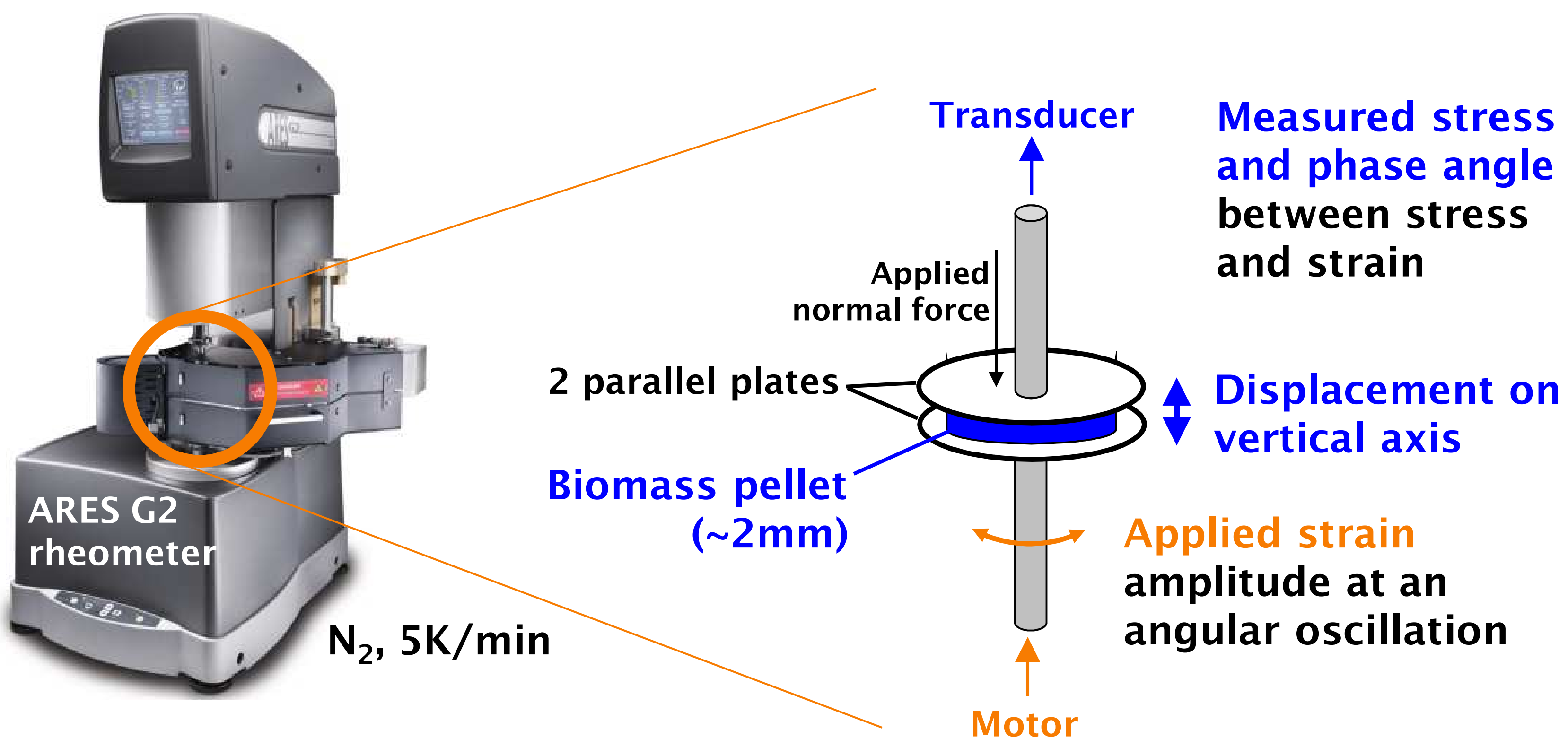
NMR

⇔

Rheology

Basics of in-situ rheology

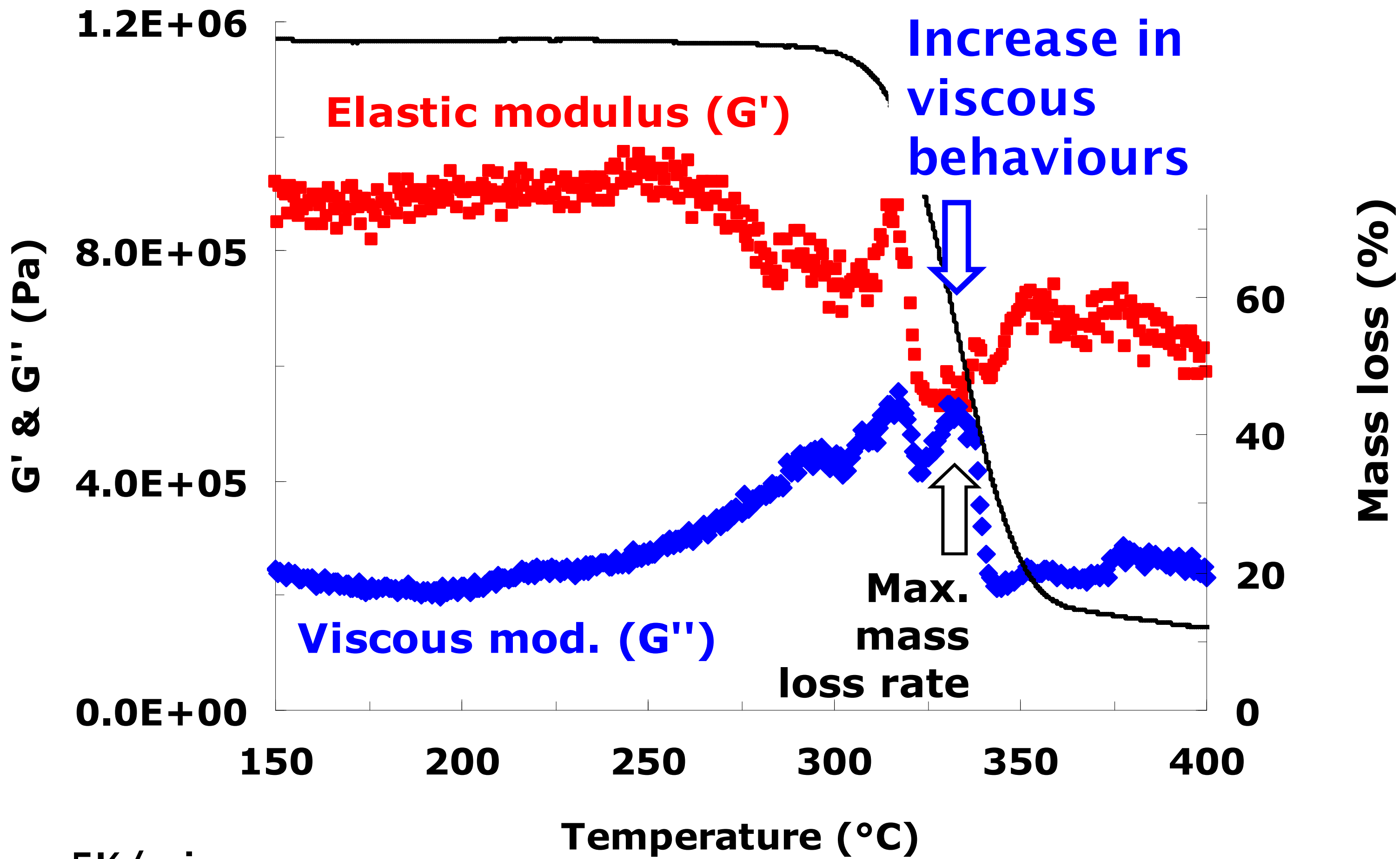
Pyrolysis is conducted inside the rheometer.



Determination of viscous and elastic moduli based on phase angle

Swelling and shrinking of particles based on the displacement between plates (results not shown)

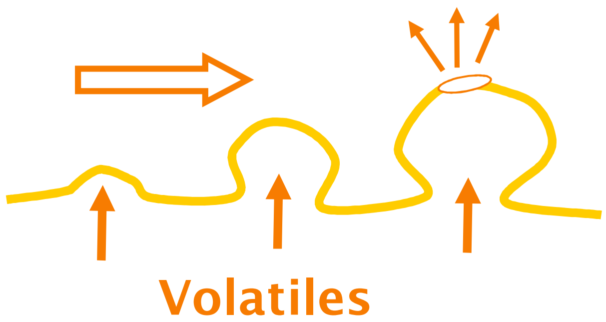
In-situ rheology during cellulose pyrolysis: it stays mainly hard & elastic (under slow cond.)



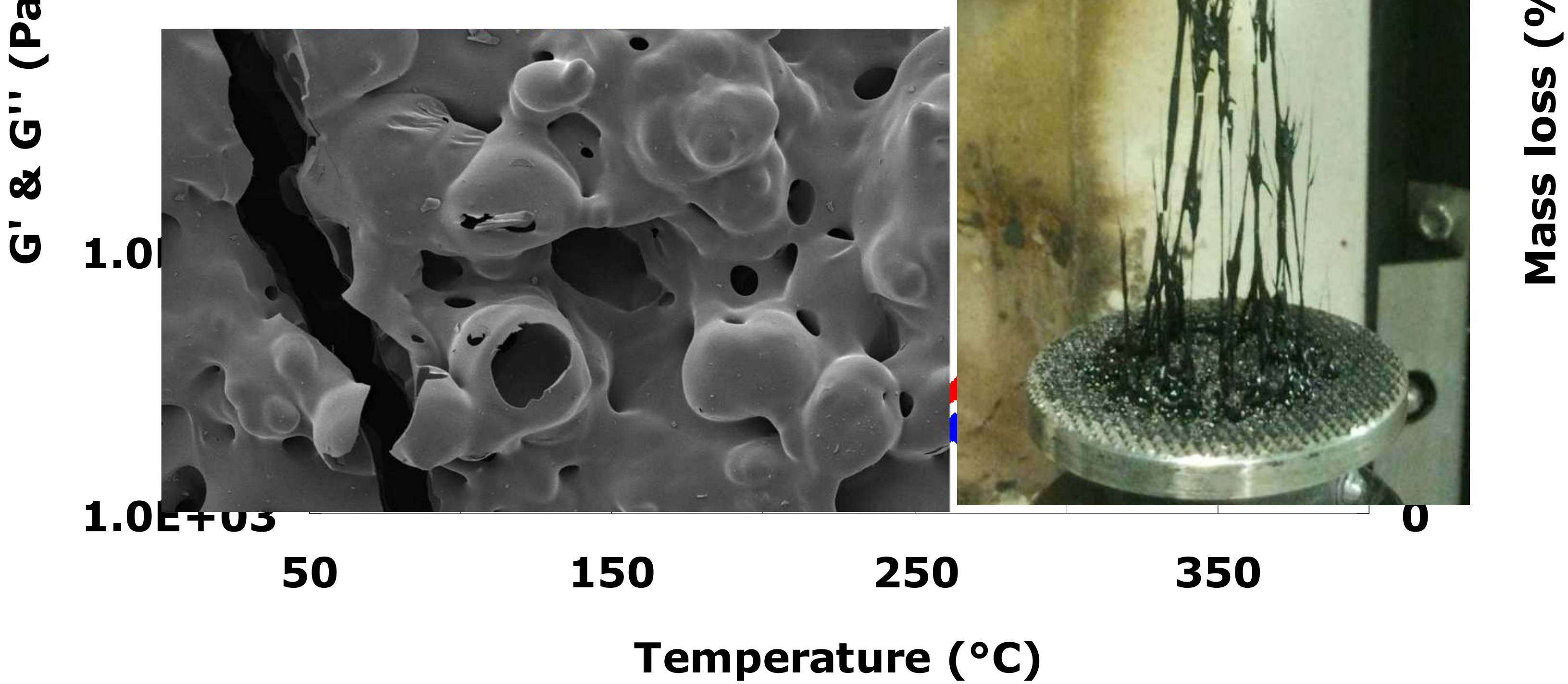
5K/min

Energy & Fuels, 26 (10), 6432, 2012.

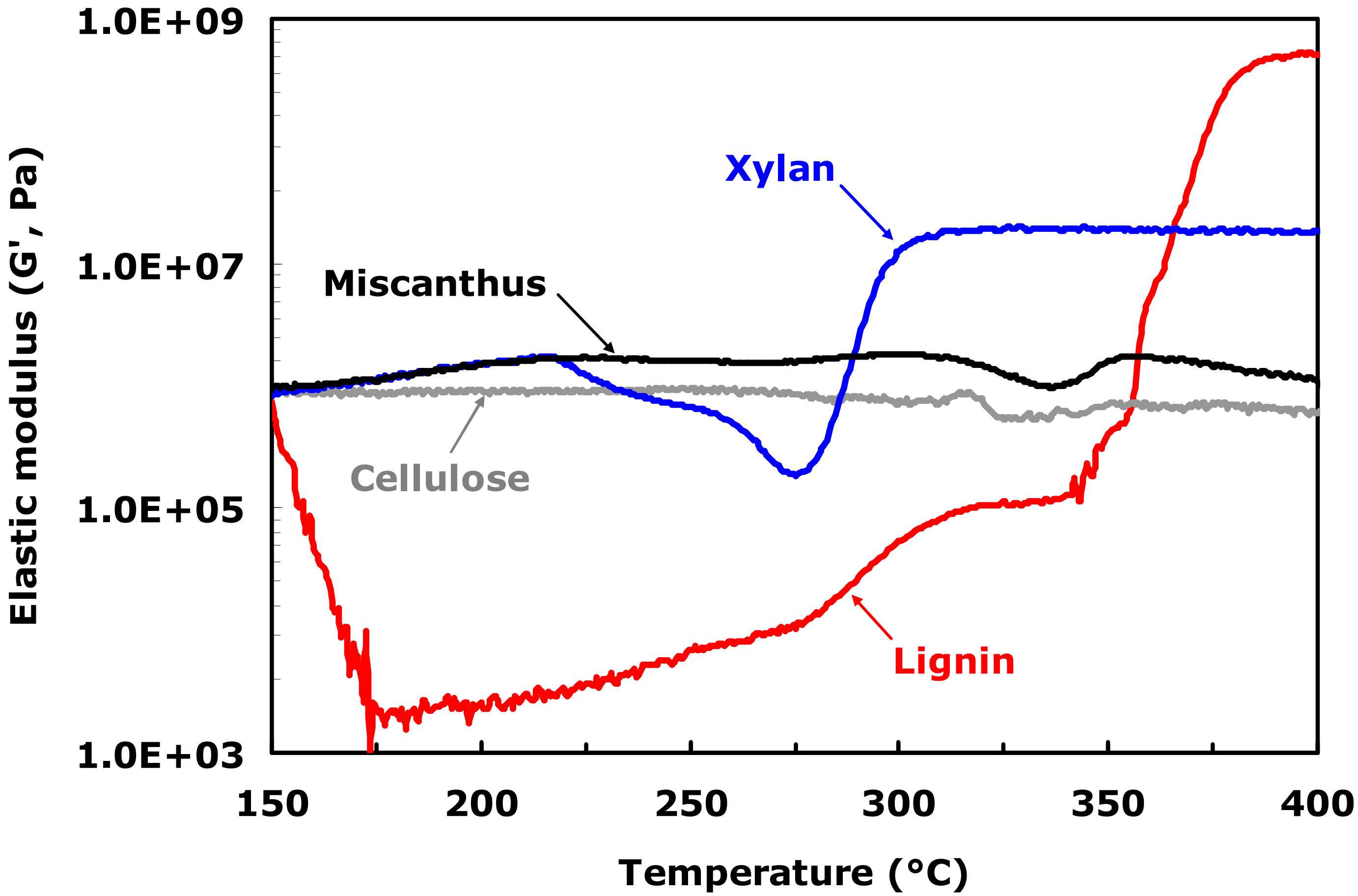
Lignin presents very different behaviours than cellulose.



Formation of a "carbon foam" by volatiles pushing the visco-elastic material.

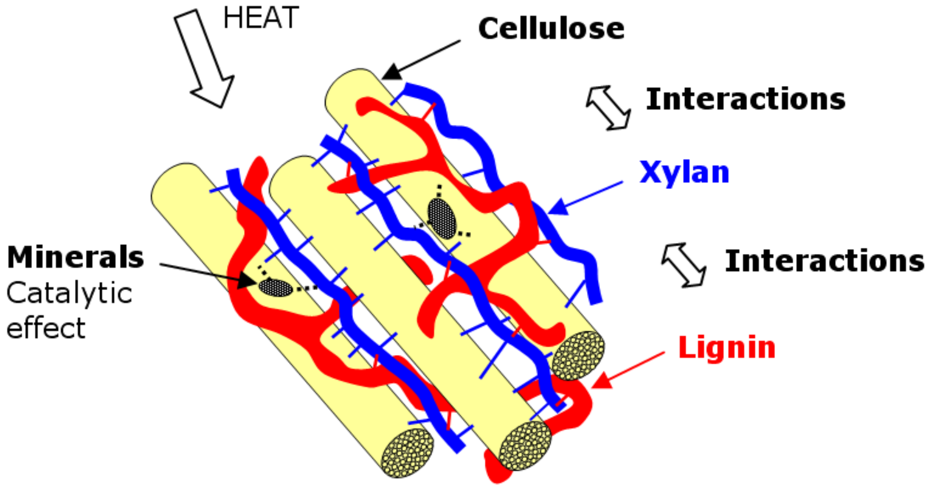


Comparison between cellulose, xylan, lignin and miscanthus for elastic modulus evolution

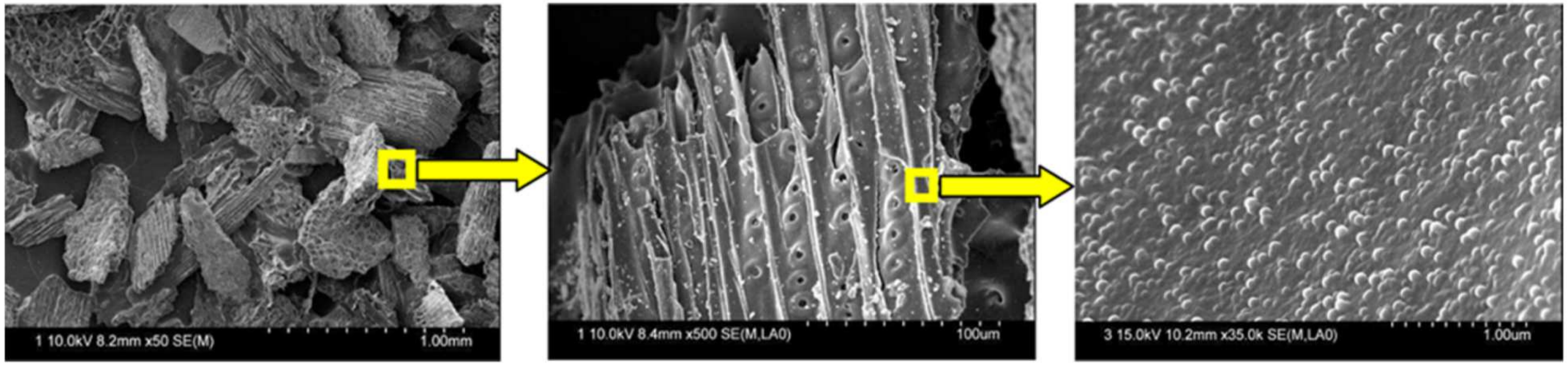


Lignin softening is not seen in the native network of biomass while G′ is 3 orders of magnitude lower & then higher than cellulose.

Cellulose imposes its rigidity to the network and maintains the overall solid structure of wood/char under slow heating conditions.



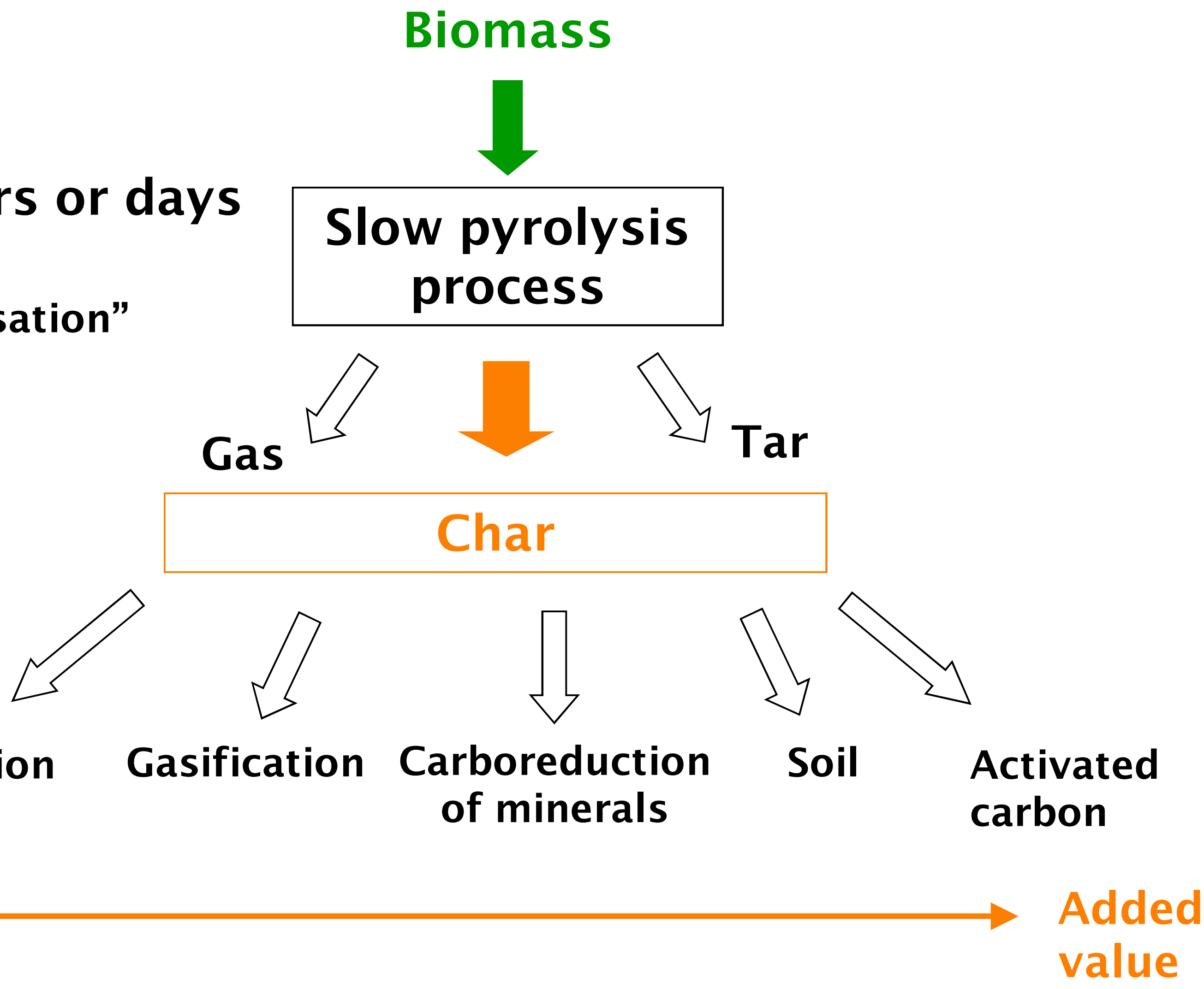
This finding explains why char globally keeps the same macro-structure of biomass cells (at slow heating) although forming an intermediate soft material.



Use of charcoal (or « biochar »)

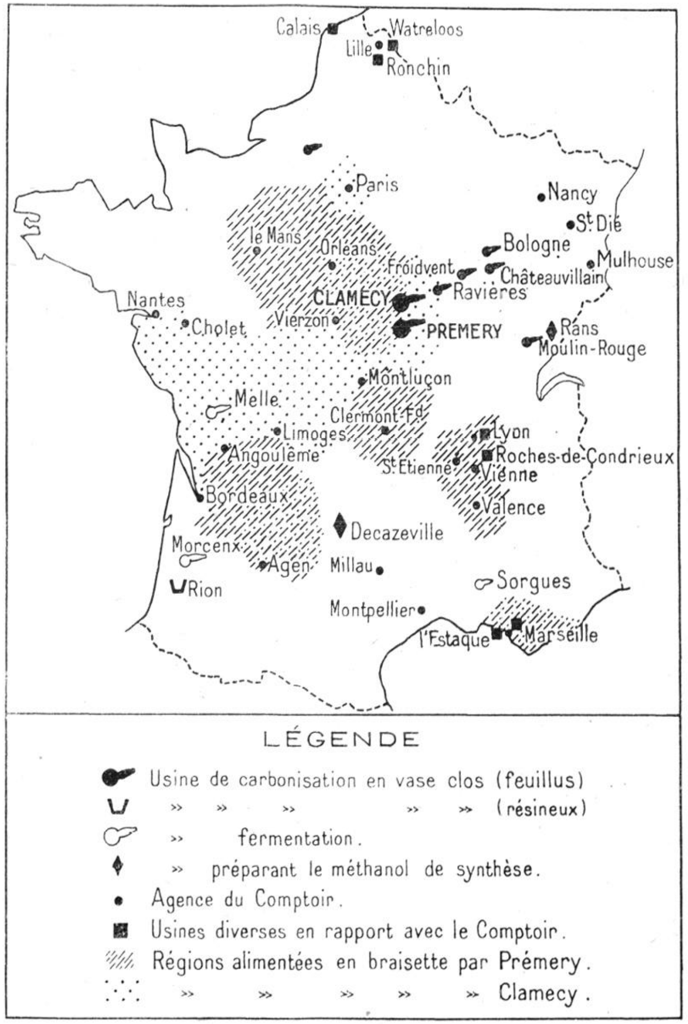
Several hours or days

Antal, 2003
"Flash Carbonisation"
in < 30 min



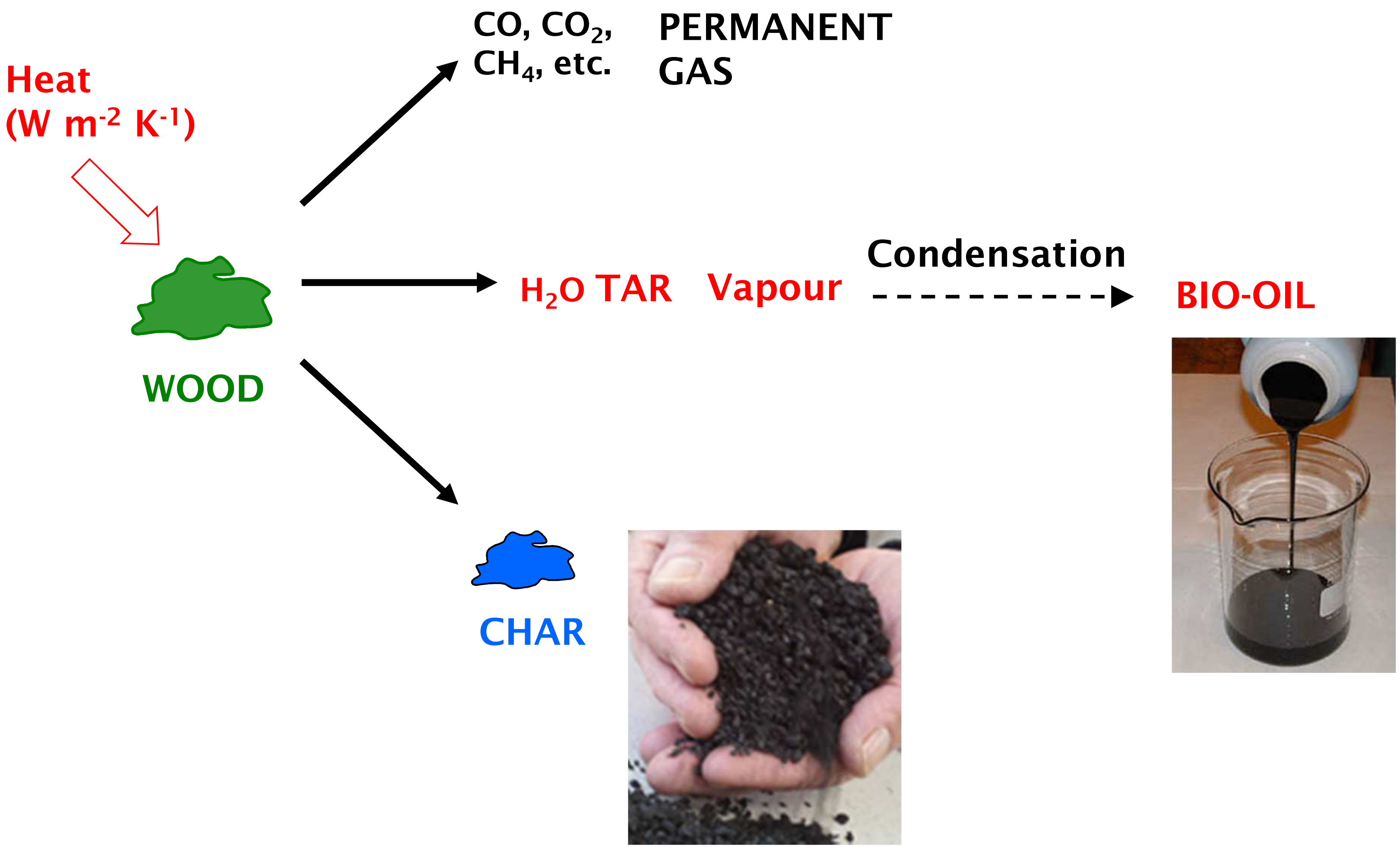
Pyrolysis « reactors » have been developped for a long time!...

Traditional hot tail kilns

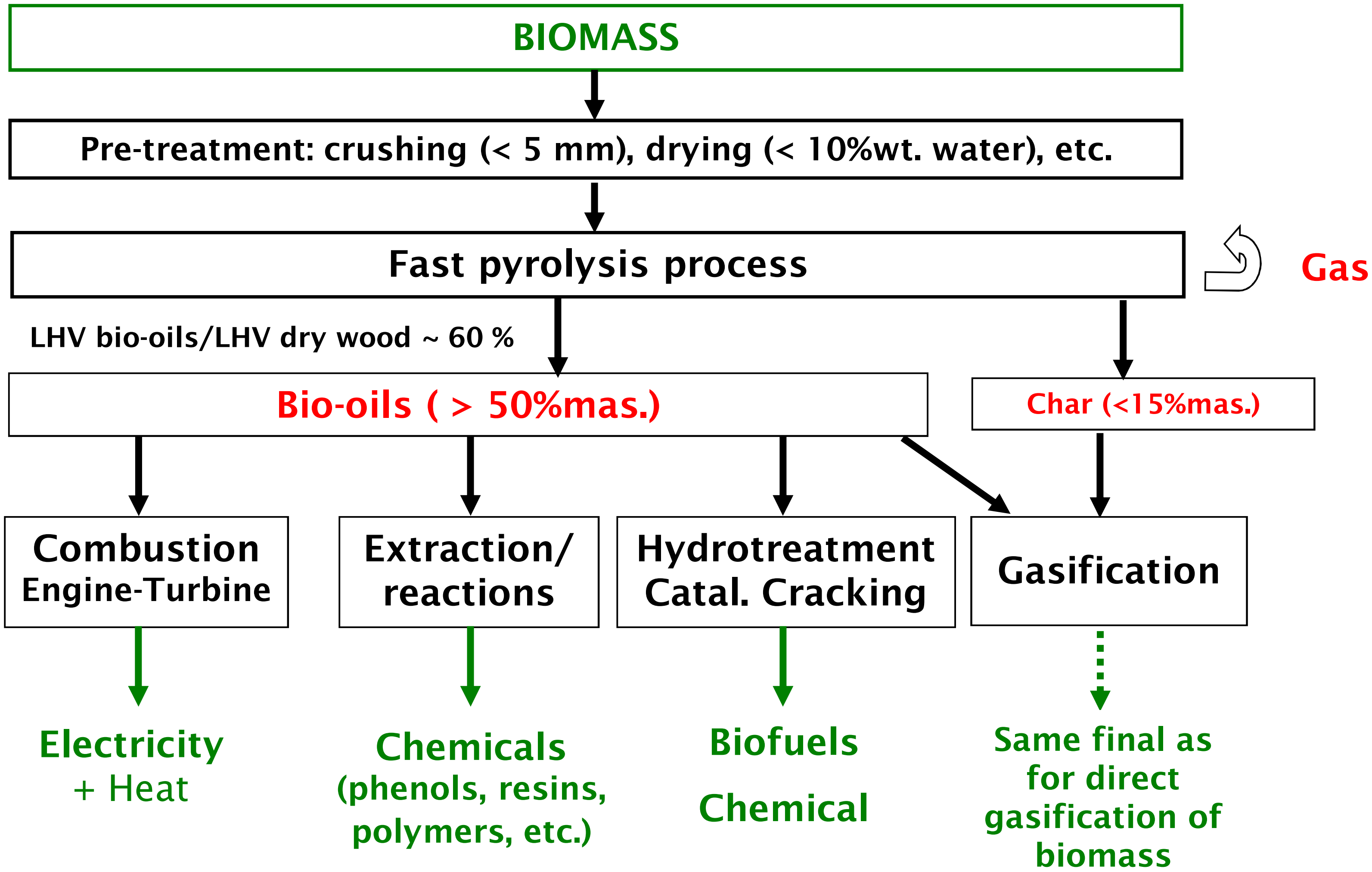


Locations of plants for carbonisation of wood (« distillation ») in France **(Braque, 1949)**

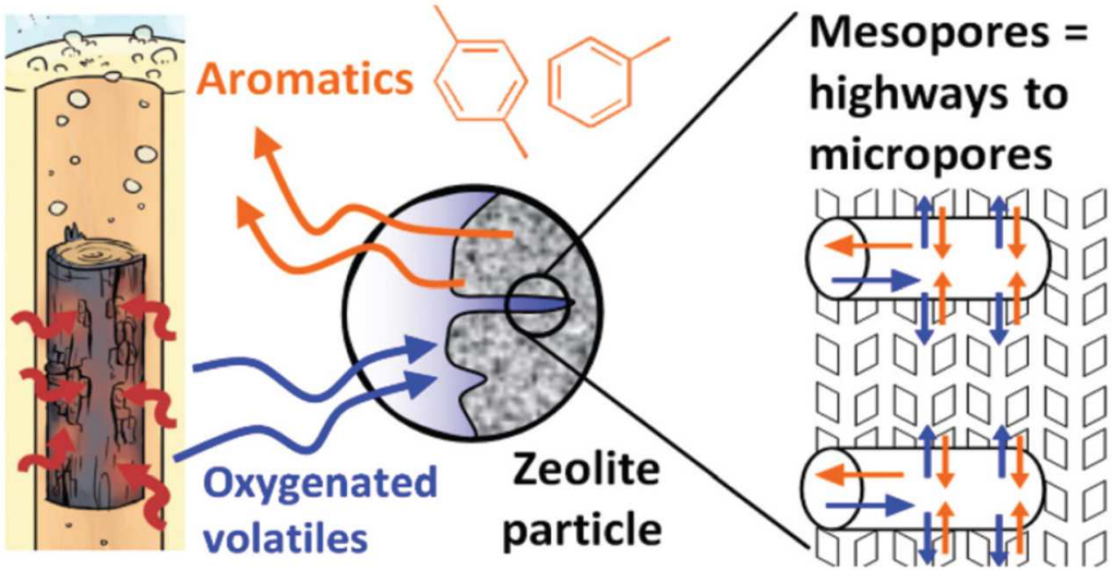
Pyrolysis forms char, gas and liquid (bio-oil or tar).



Main applications for bio-oils (high oxygen content)



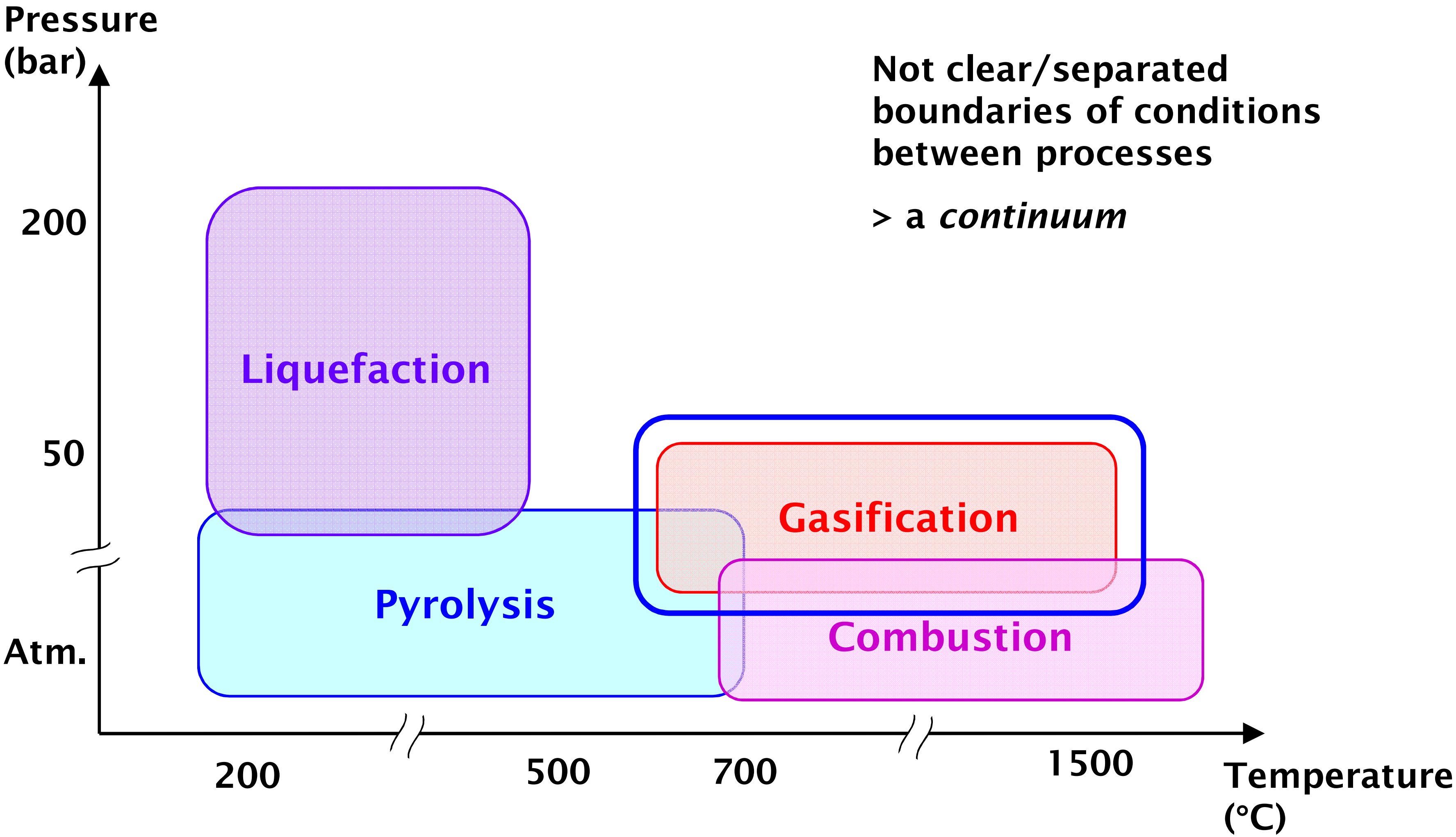
Catalytic pyrolysis of wood by zeolites to remove oxygen from bio-oil



Hierarchical zeolites (= micro+mesopores) improve the stability and the selectivity to aromatic hydrocarbons.

Jia, Green Chem. 2017 - **with L. Pinard, IC2MP, Poitiers**

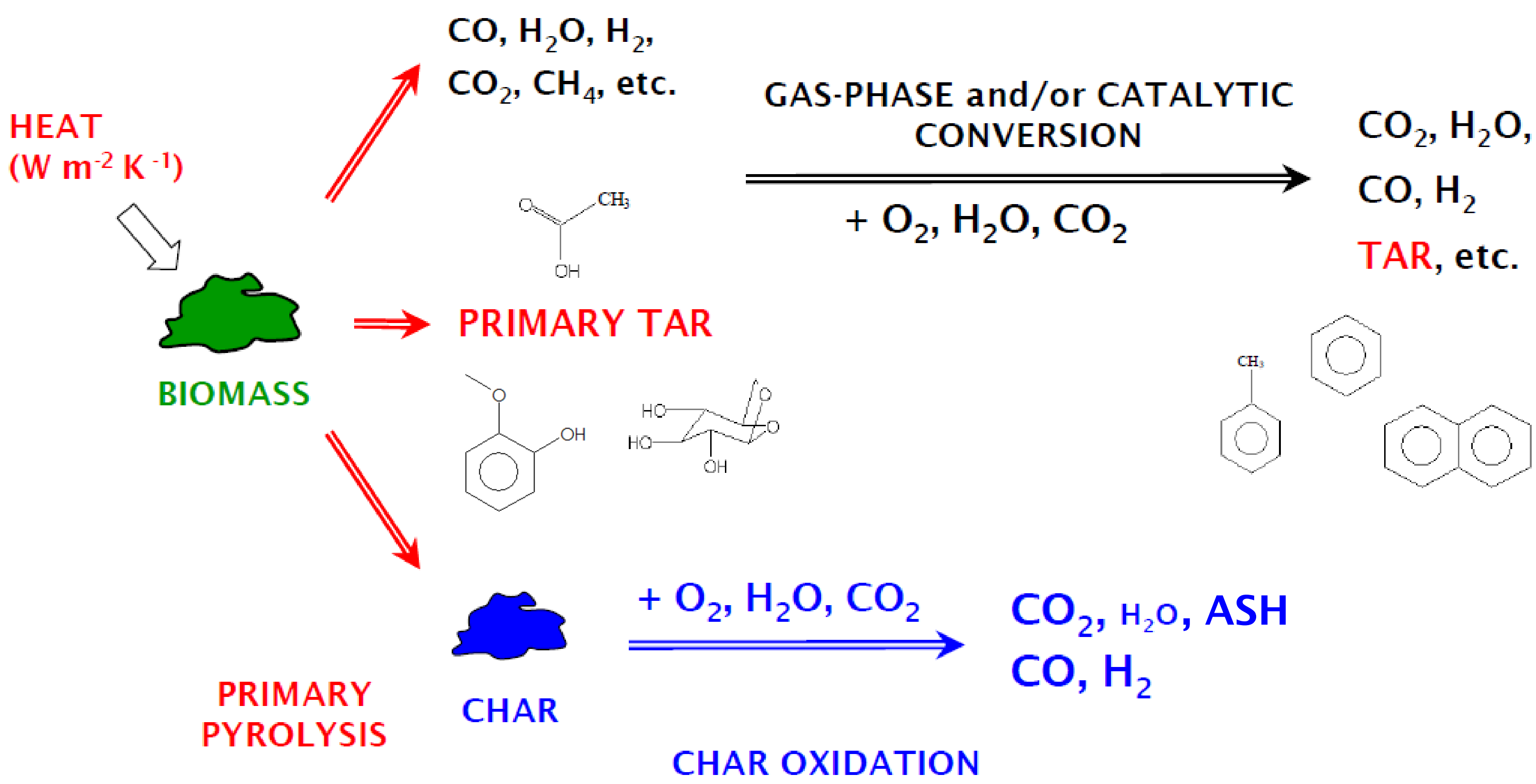
Thermochemical routes presented as functions of temperature and pressure of the reactors



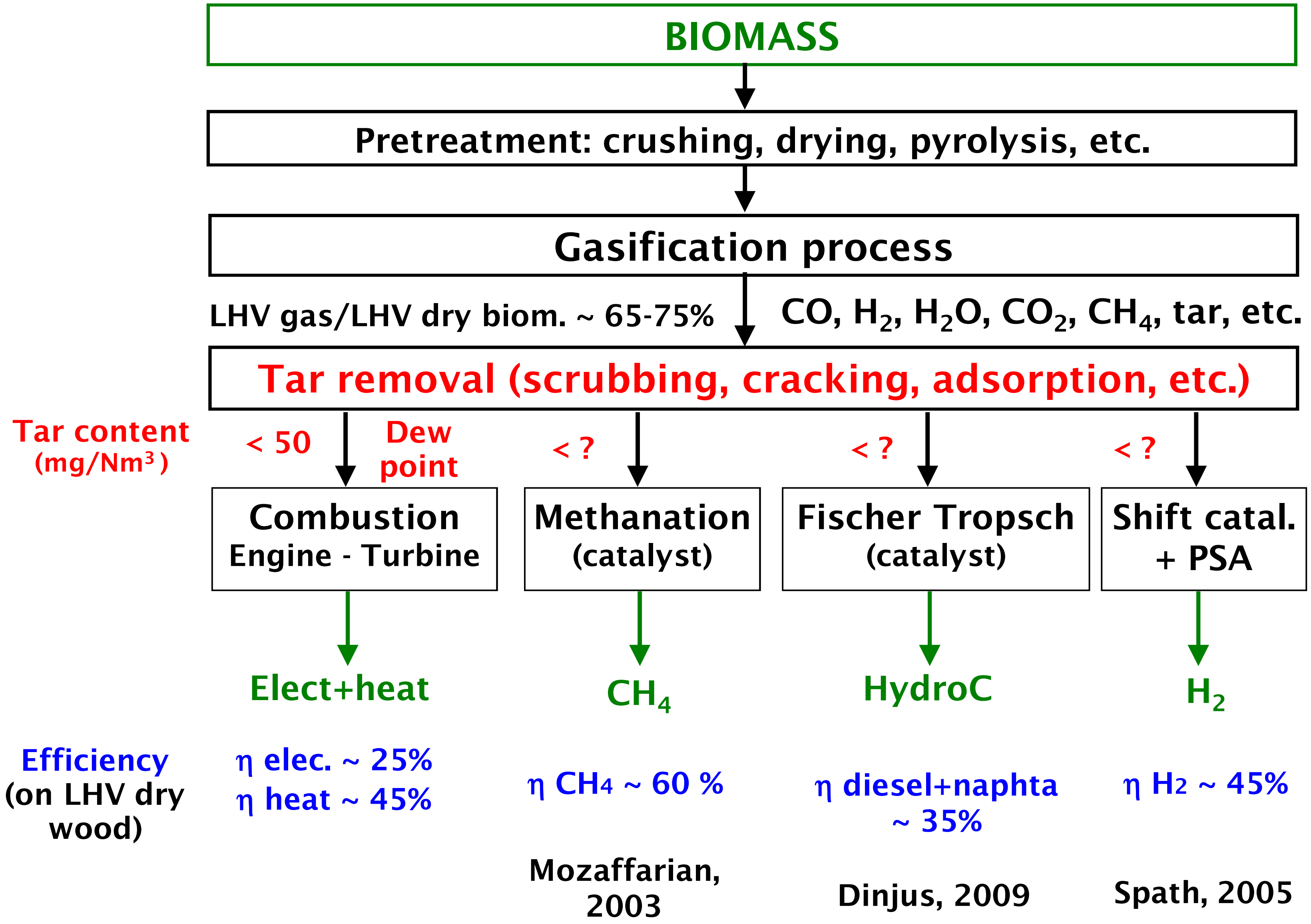
Not clear/separated boundaries of conditions between processes

> a *continuum*

Mechanisms of wood gasification and combustion

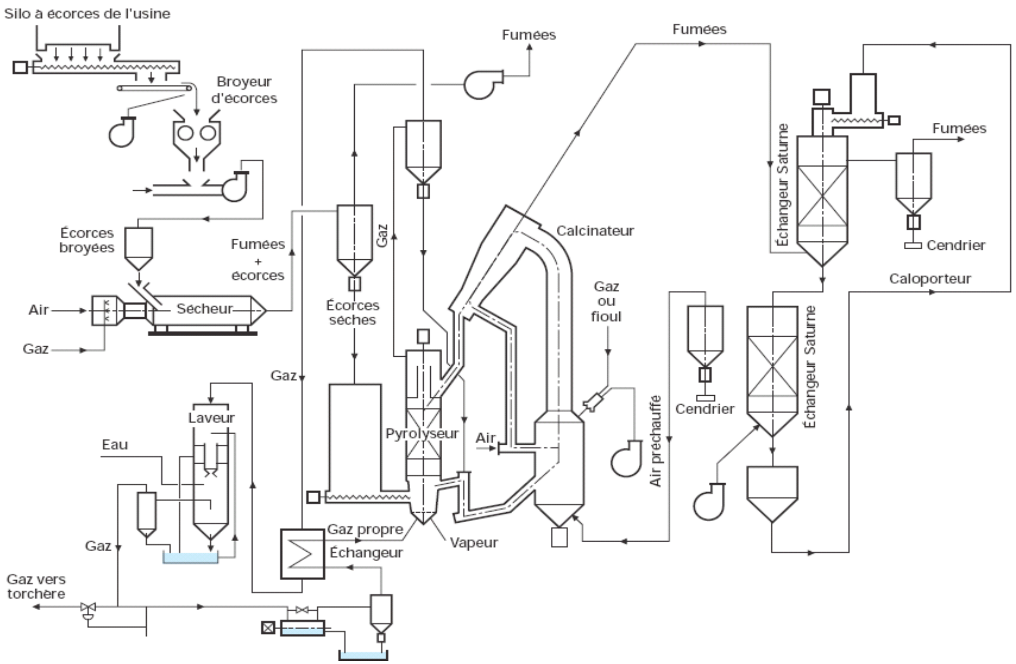


Main applications for syngas

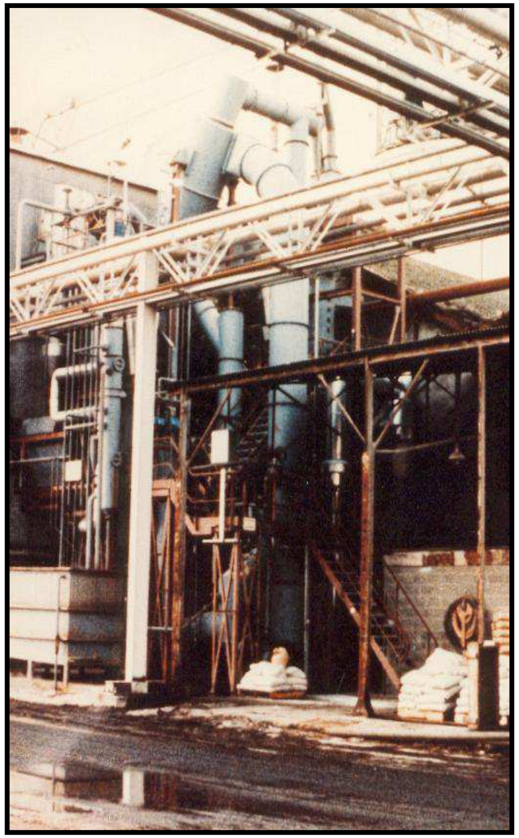


An excellent gasification process has been developped in France in the 80's (TNEE/Cellulose du Pin).

Then in the 90's a similar process developed in Vienna (Güssing), currently GAYA project in France (ENGIE at St Fons)



500 kg/h of bark operated in 1984-1985
(at Facture, France)
LHV of gas ~16 MJ/m^3

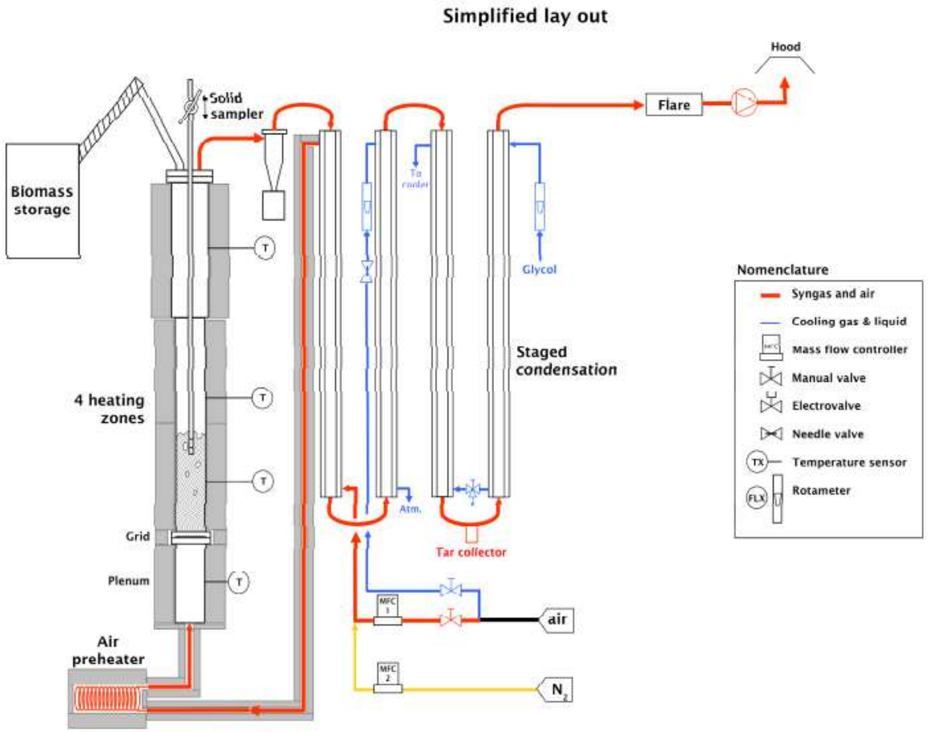


Deglise, 1985

High heat transfer and good control of temperature in fluidized bed

Char in sand <u>during</u> wood pyrolysis

Dense fluidised bed gasification reactor (5-10kg/h) studied at LRGP (with EDF, LERMAB & Leroux&Lotz)

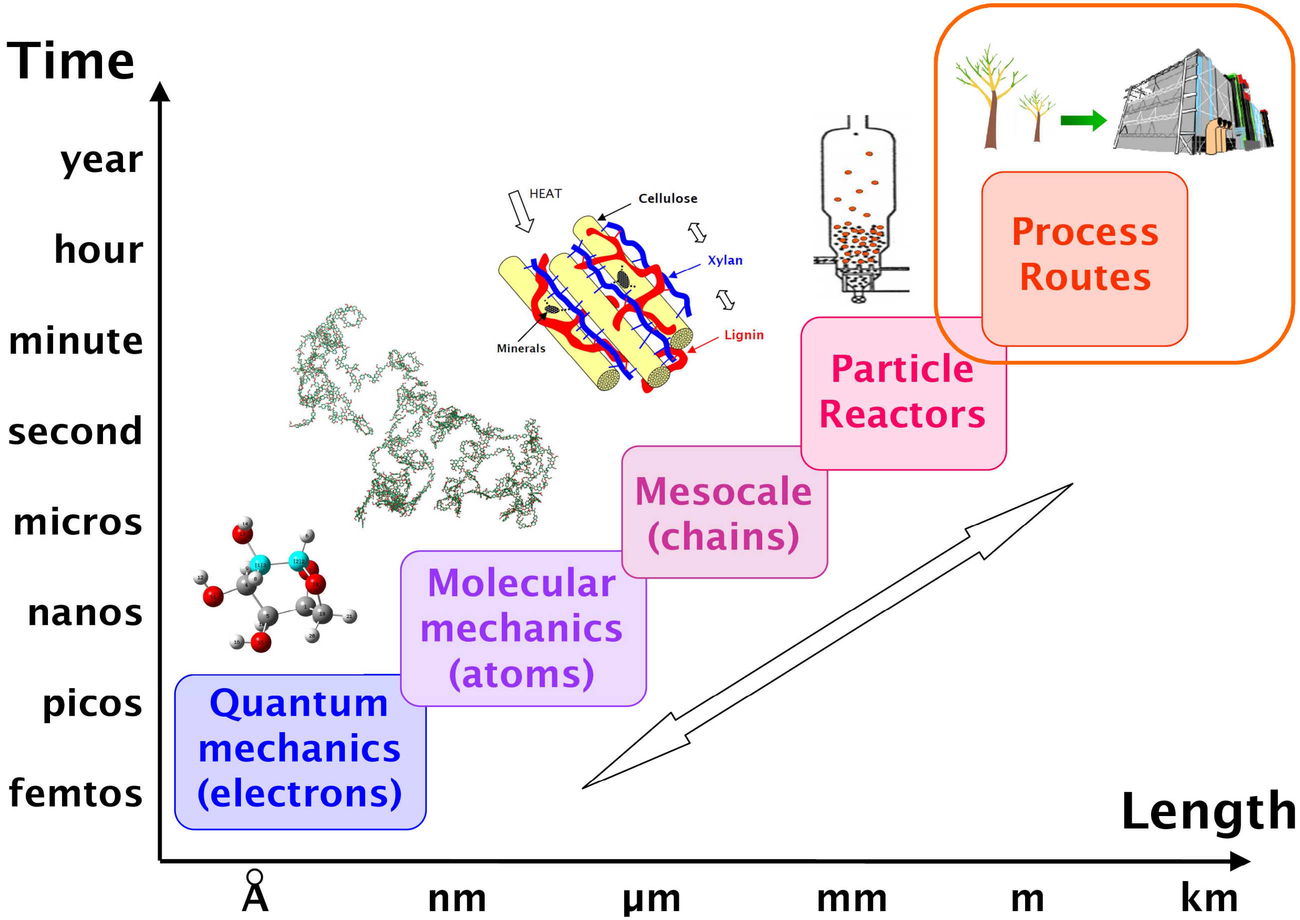


More than 40 temperature and pressure sensors
Sampling of the bed during operation, under hot conditions
Home-made pilot by our machine and electronic workshops

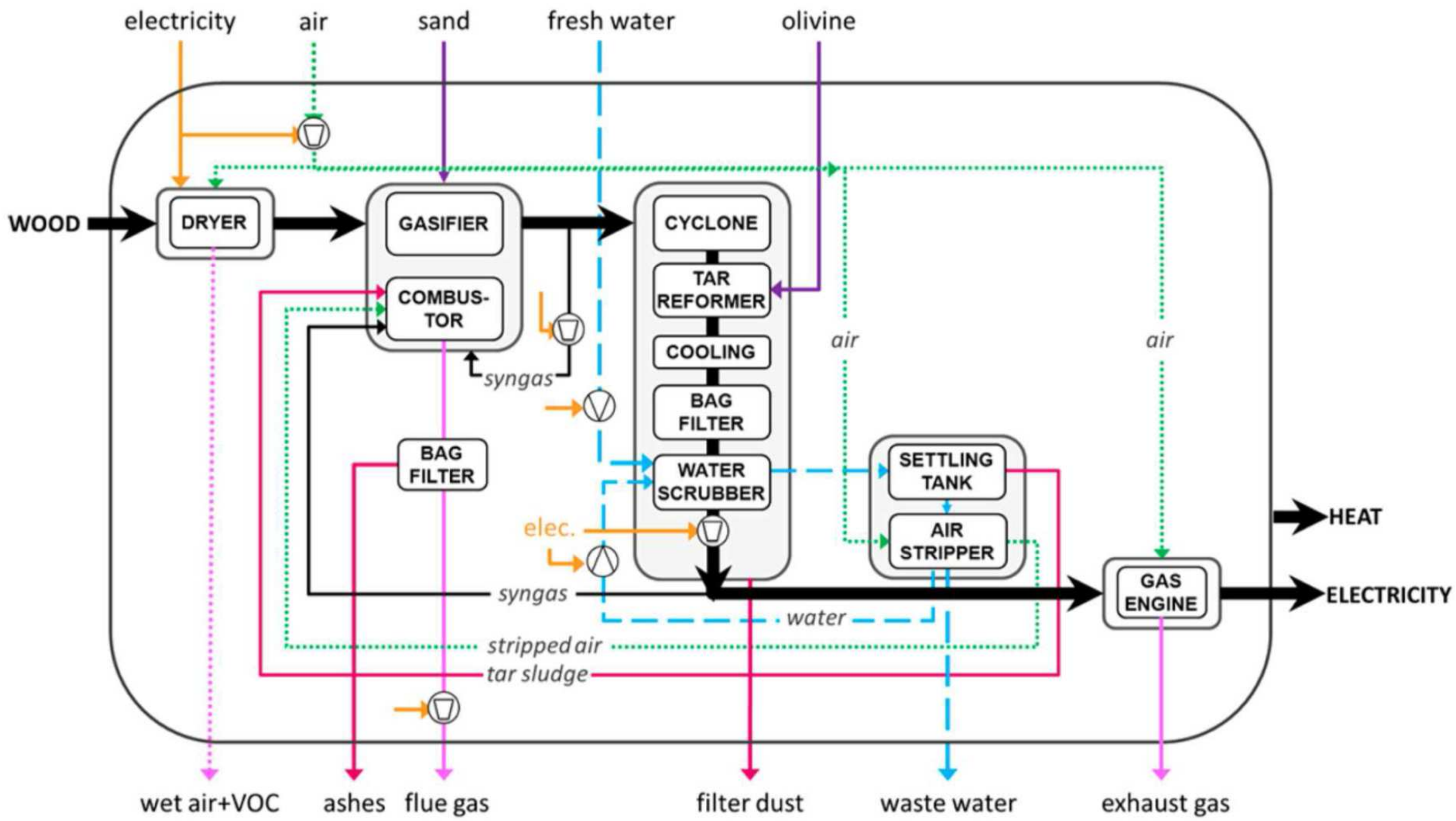
G. Mauviel, G. Lardier et al. En&Fuels, 2016

Different scales of investigation of wood thermochemical conversion

Talk: from « small » (molecules) to « big » scales (process)

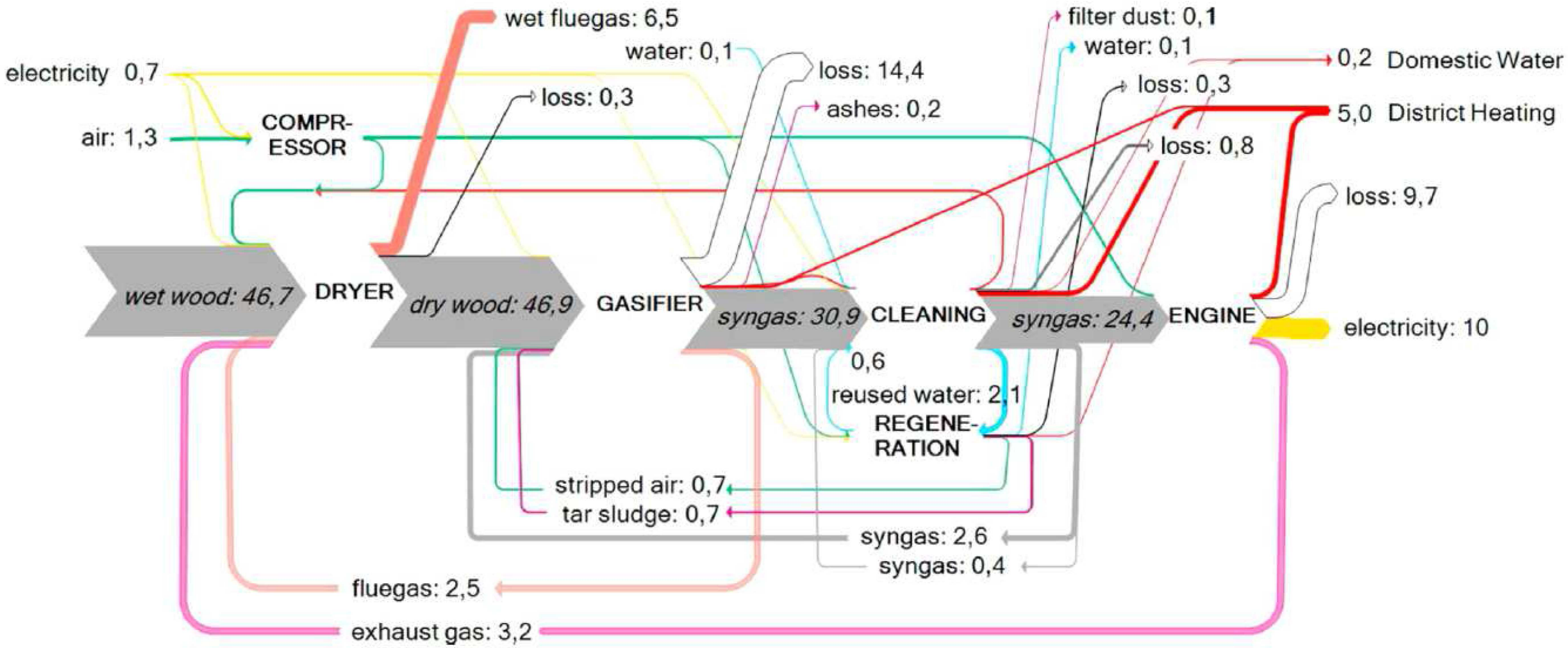


Advanced process models are developed under Aspen Plus® software in Nancy.



J. Francois et al., Biom.Bioenergy, 2013.

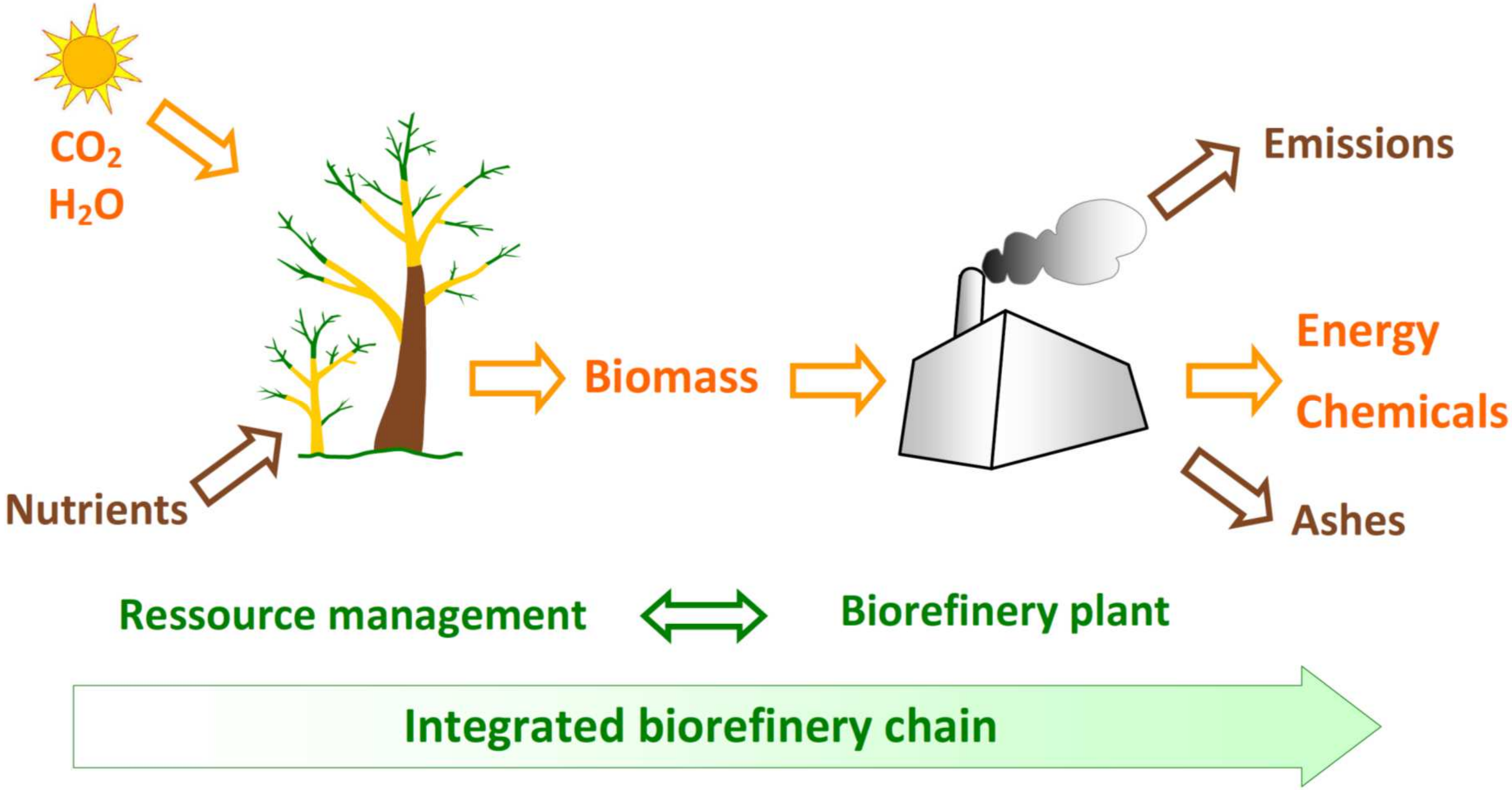
Exergy balance of the integrated gasification plant



Exergetic efficiency ~32% (elec.+heat [10+5]/wood [46.7])
Main exergy degradation occurs in the reactor of gasification
Technical problems caused by tar formed in the gasifier

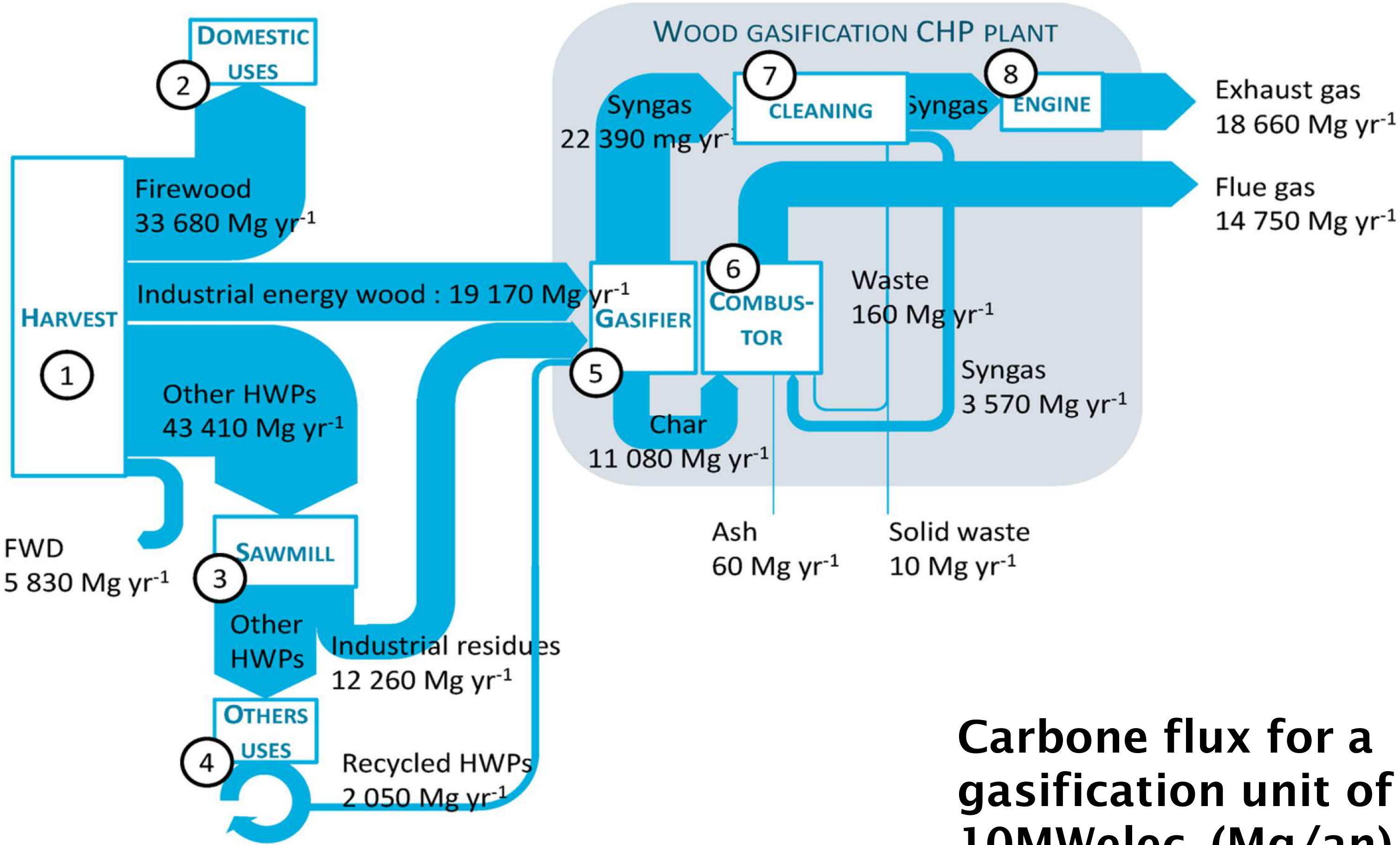
J. Francois et al., Energy & Fuels 2013.

Mass and energy balance of the whole chain: from the soil to the final use



François, Env. Sci. Technol. with M. Fortin SILVA

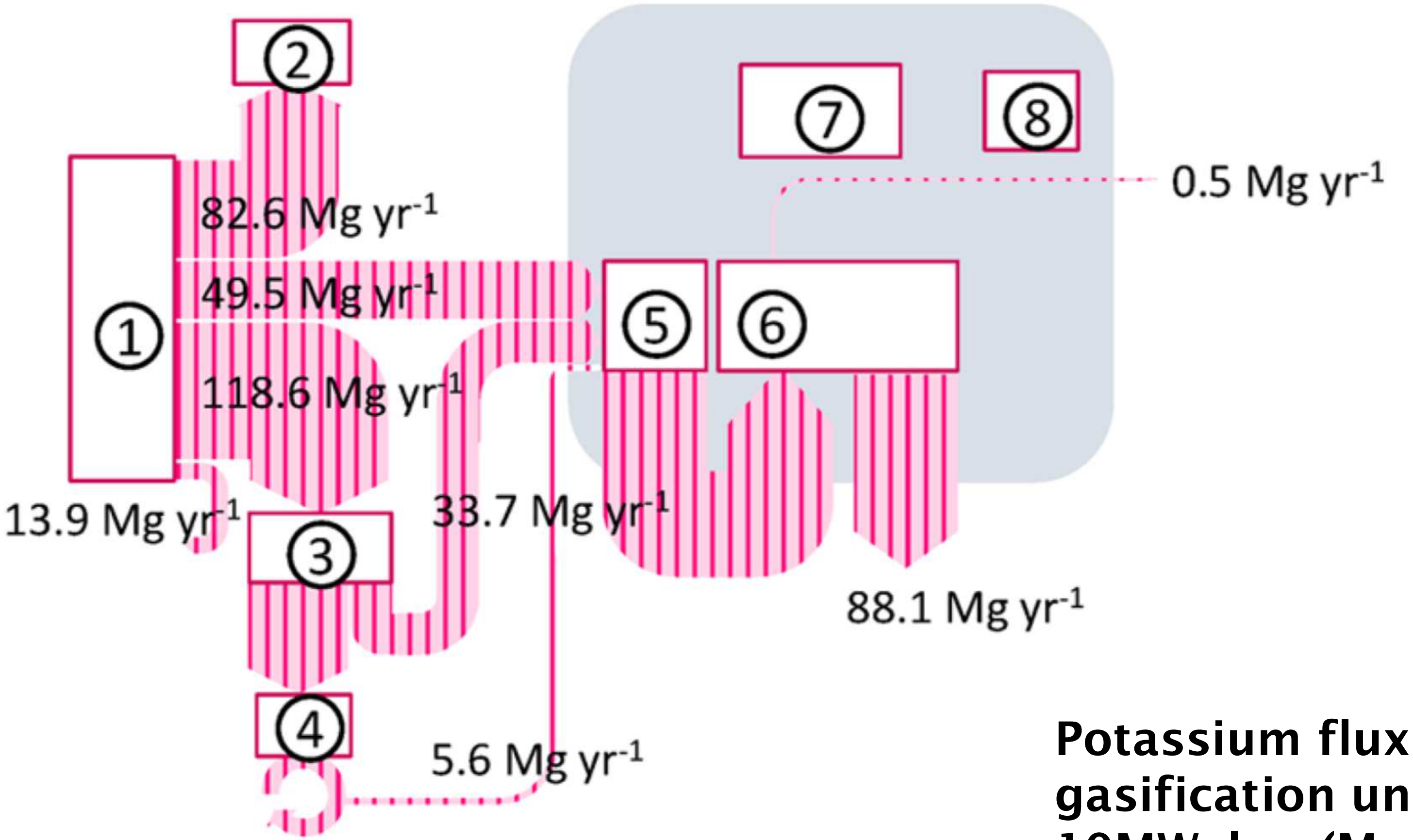
Carbon balance of forest to energy chain



Carbone flux for a gasification unit of 10MWelec. (Mg/an)

J. Francois, M. Fortin et al., Env. Sc. Technol. 2014.

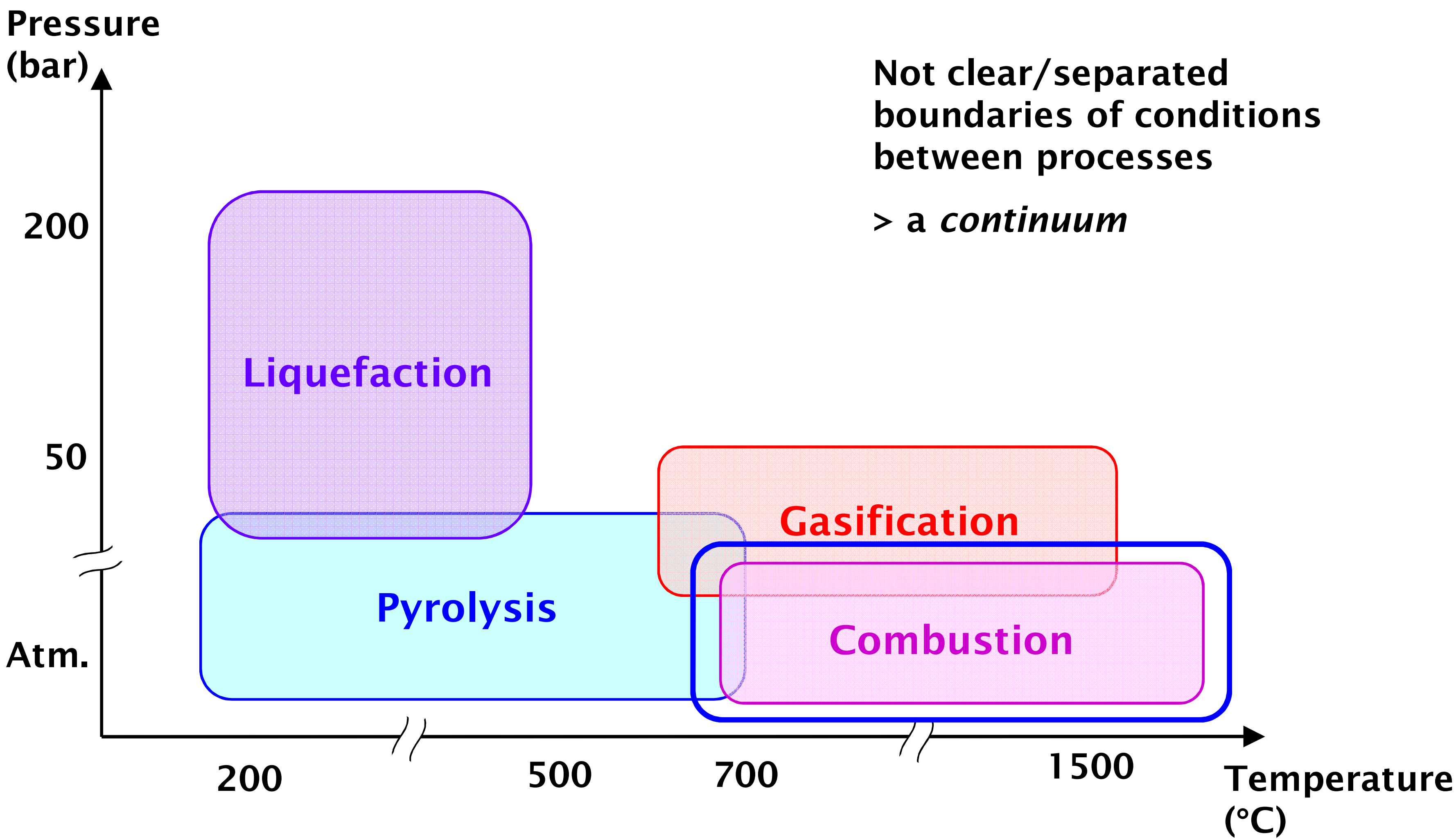
Soil nutriments in soil: balance and fate…



Potassium flux for a gasification unit of 10MWelec. (Mg/an)

J. Francois, M. Fortin et al., Env. Sc. Technol. 2014.

Thermochemical routes presented as functions of temperature and pressure of the reactors



Not clear/separated boundaries of conditions between processes

> a *continuum*

Combustion is the most important process for renewable energy : half of world population!

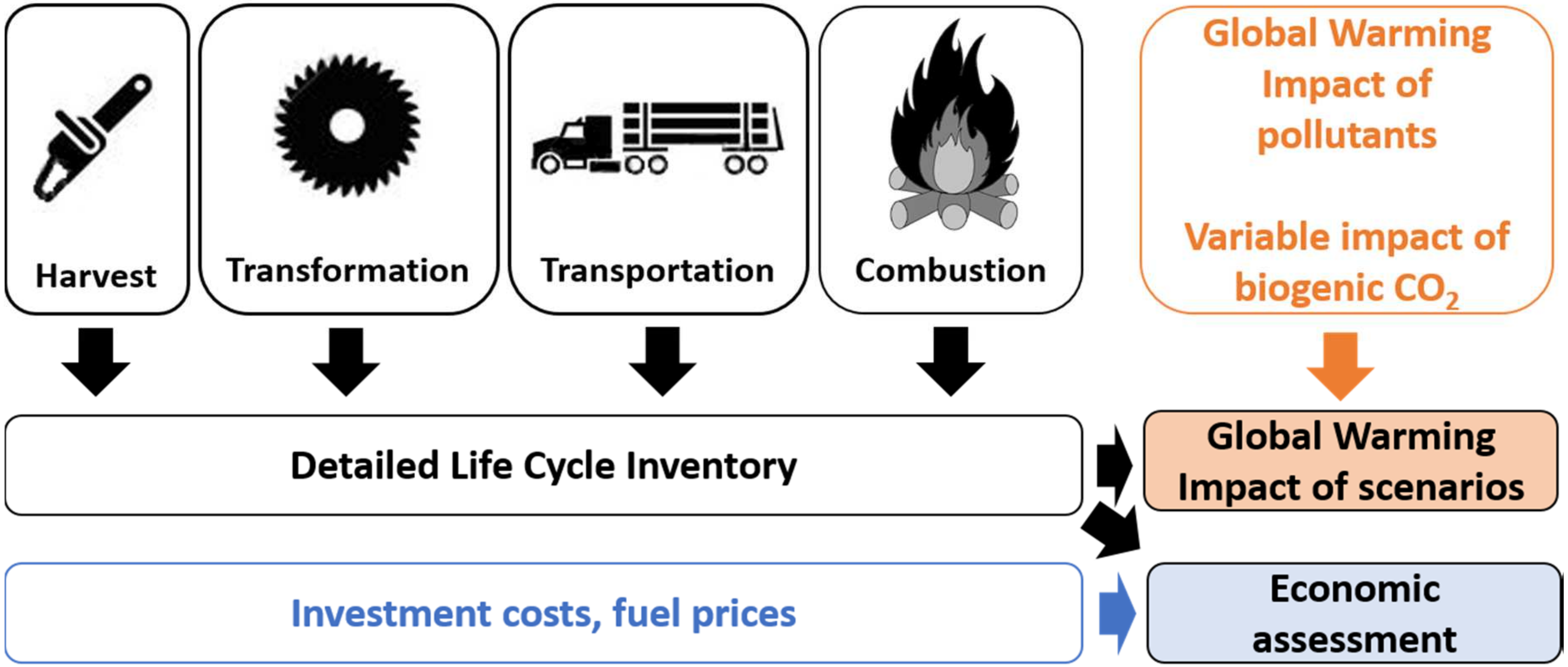
Anenberg, 2013

More than 3 billion people rely on the use of biomass for cooking in inefficient open fire stoves...

Huge impact for health and social development of women and children.

Environmental and economical assessment of combustion routes

C. Pelletier Ph-D at LRGP in collaboration with CIRED, SILVA, EIFER, LERMAB



C. Pelletier, App. Energy in press

Different combustion routes have been studied.

Pretreatment

Log

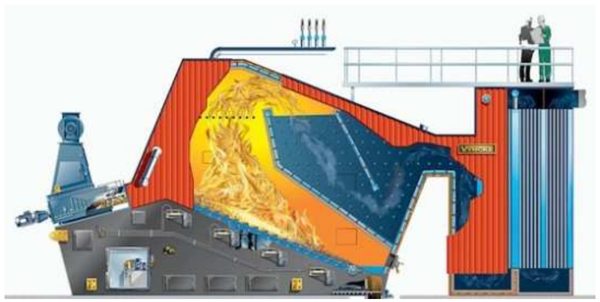
Chips

Pellets

Transport distance

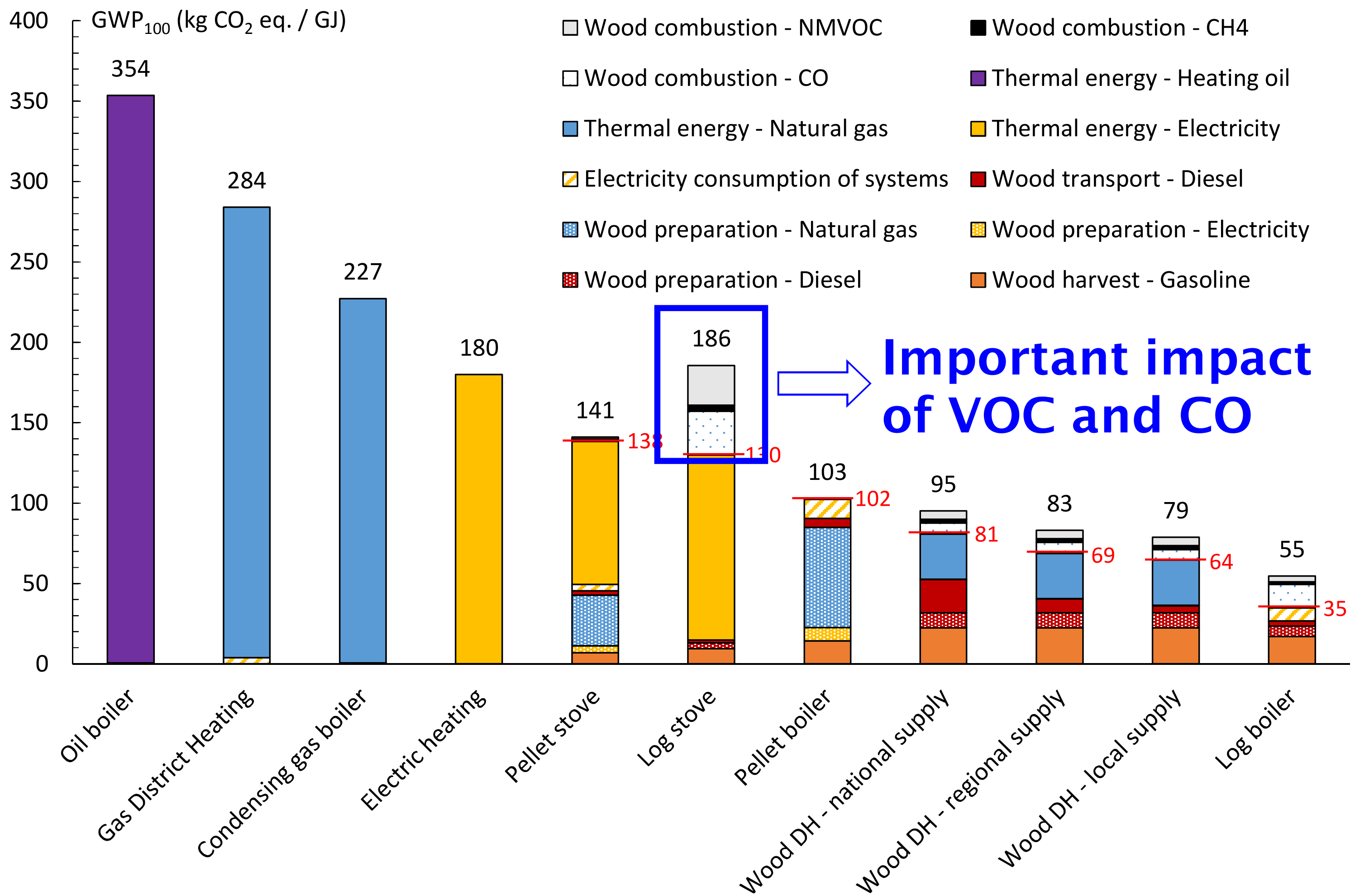
Combustion technologies

Emissions



C. Pelletier, App. Energy in press

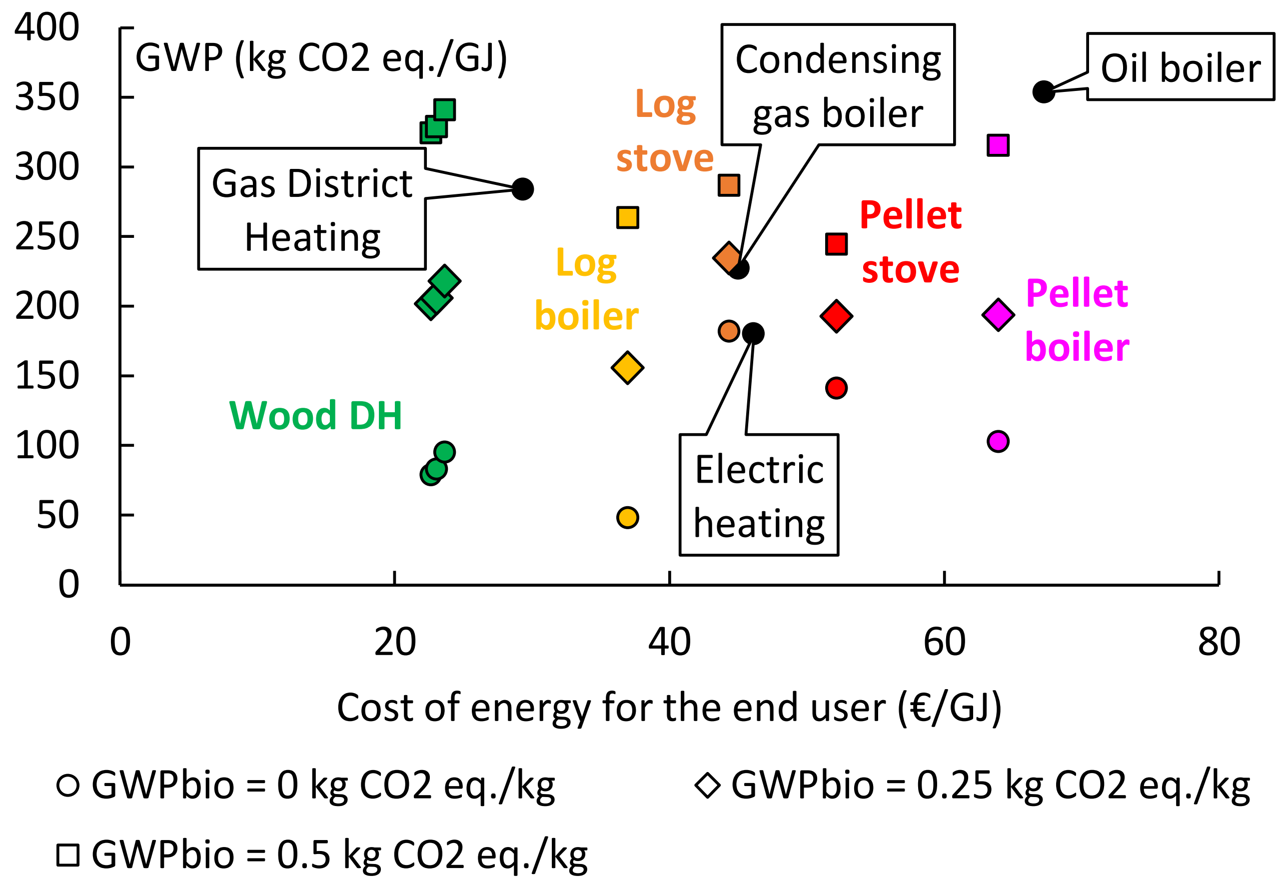
Global warming impact of wood combustion vs. technologies and other heat sources (gas, oil, elec.)



C. Pelletier, App. Energy in press

Global warming potential and cost of various technologies

Huge effect of the biogenic CO_2 impact factor



Cost: collaboration with EIFER

C. Pelletier, App. Energy in press

Les nouvelles technologies doivent être adaptées aux besoins et à la perception de la société…

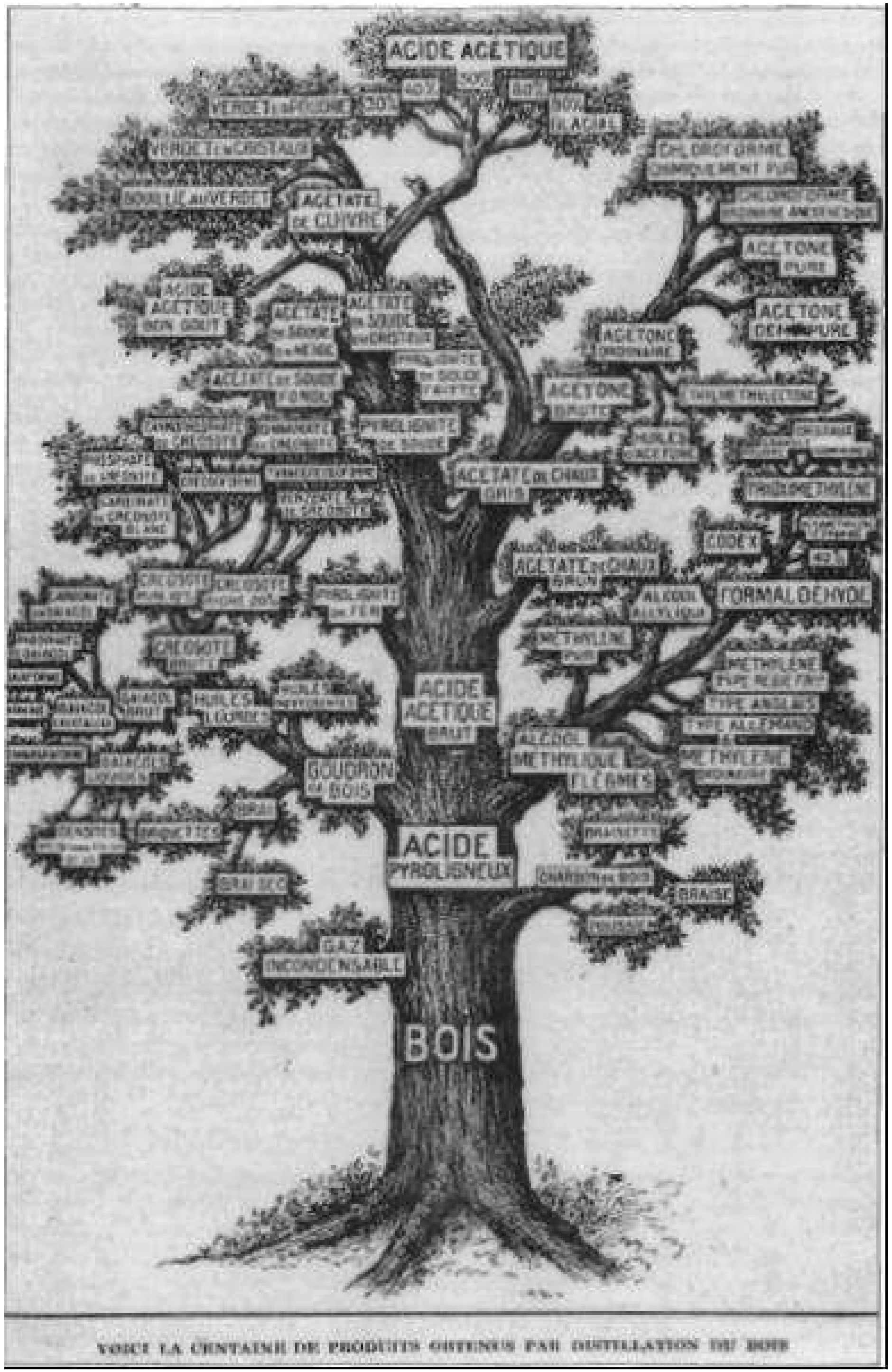
Anenberg, 2013

Faut-il implanter des bioraffineries industrielles de grosse taille ?…

Des bioraffineries industrielles ont fonctionné en France durant plus de 100 ans !

~ 100 000 tonnes bois/an/usine

Produits obtenus par la pyrolyse du bois au milieu du 20ème siècle



Intéractions possibles entre notre équipe et d'autres équipes de ce GDR sur :

1) l'imagerie et l'analyse physico-chimique du bois avant et après pyrolyse (= charbon)

2) la caractérisation « thermo-mécanique » du bois durant son chauffage, in-situ

3) l'évaluation économique et environnementale des filières bois (matière/énergie)

4) la psychologie sociale de la valorisation du bois

Merci et à bientôt à Nancy !

Supplementary slides