Co-ingénierie: Bioénergie et fertilité des sols

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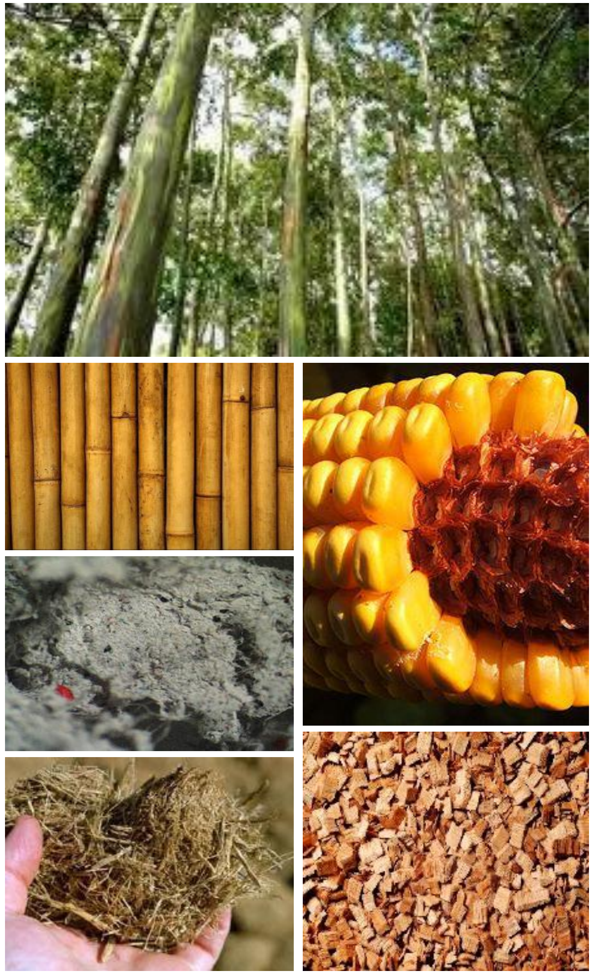
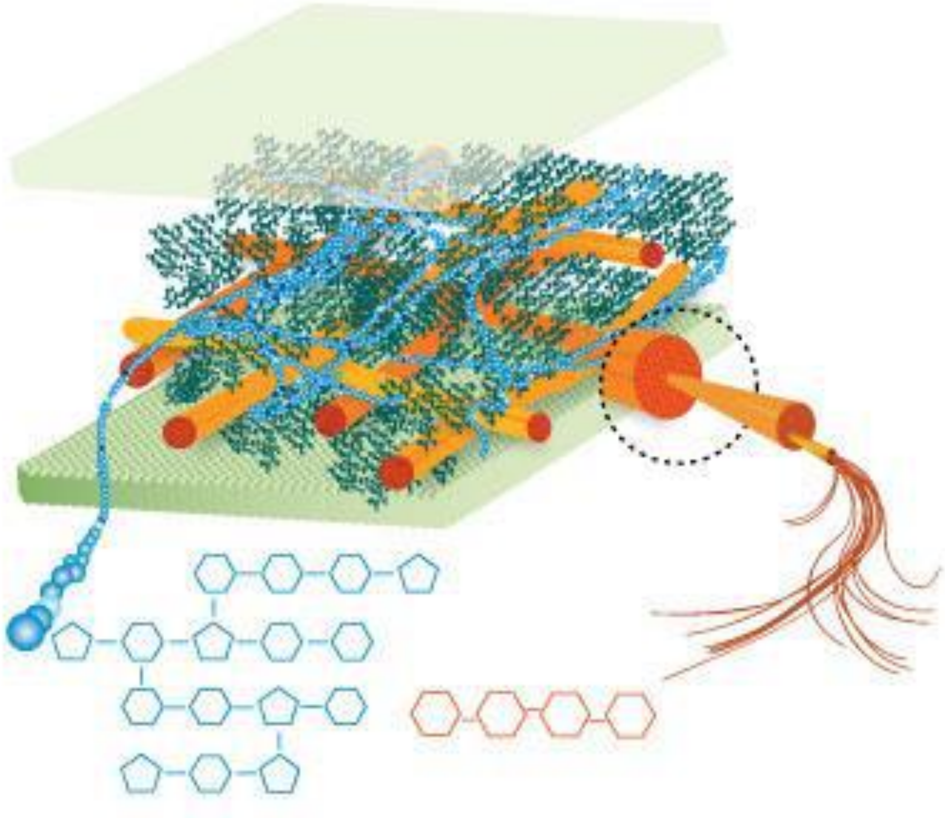
Xylo Dating – Mercredi 15 décembre 2021

Biomasse végétale





Hémicelluloses 20-40 %
Cellulose 43-60 %
Lignine 10-40 %

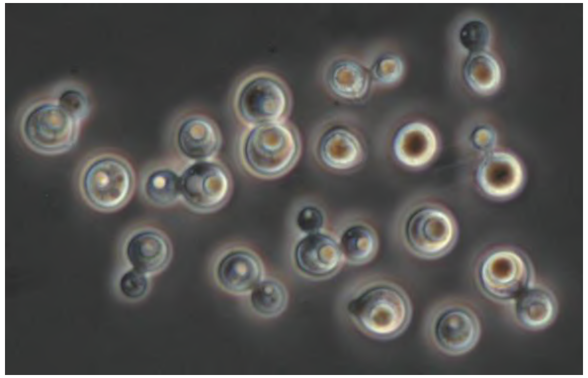
Voies de conversion de la biomasse

Procédés biochimiques

Fermentation

Hydrolyse enzymatique

Digestion anaérobique



Procédés thermochimiques

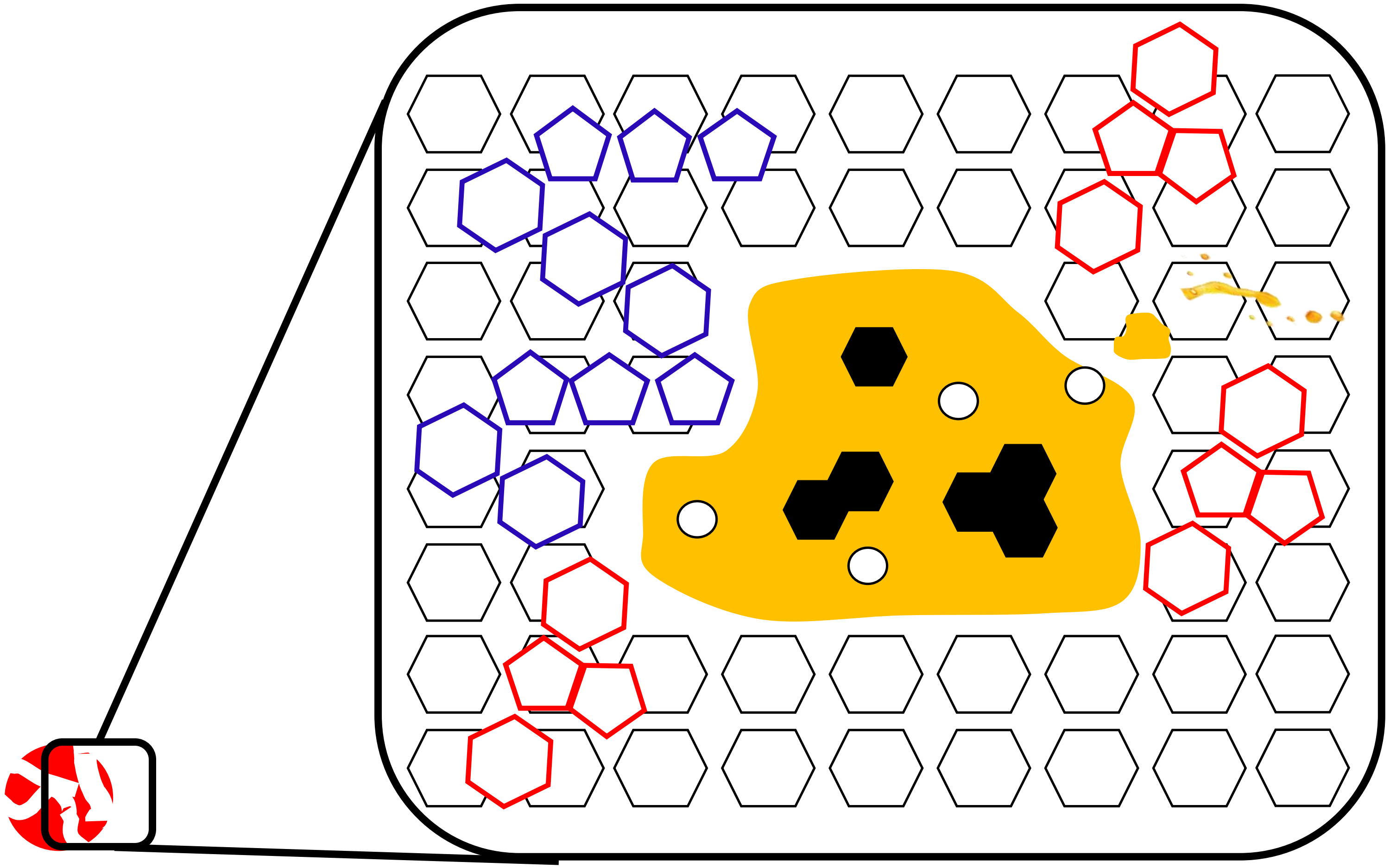
Combustion

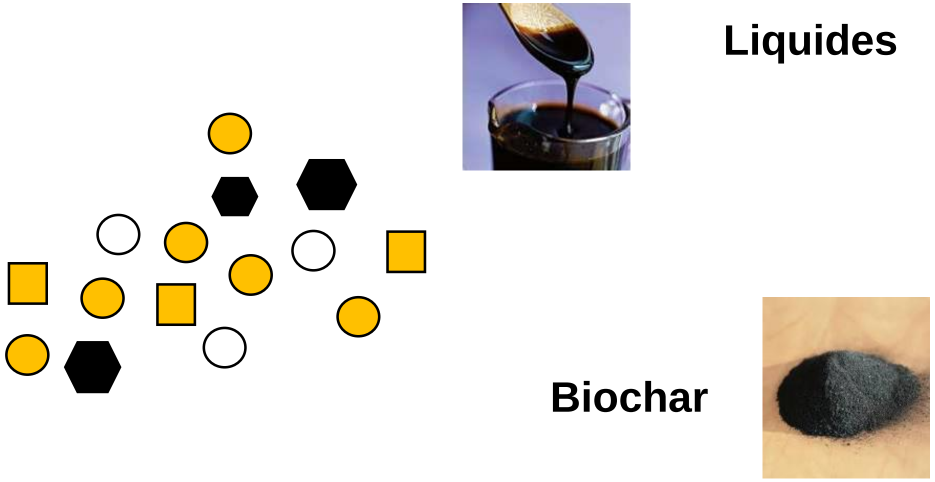
Pyrolyse

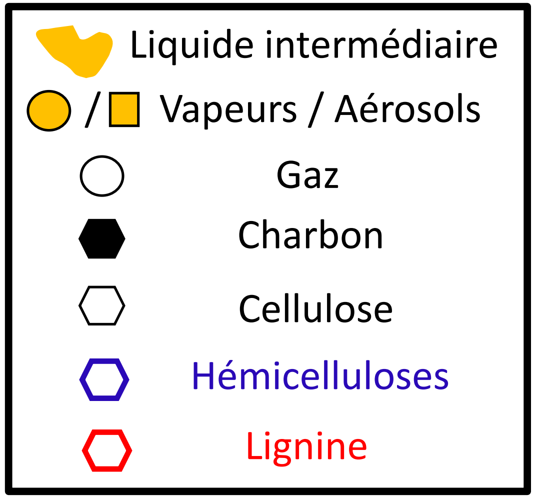
Liquéfaction

Gazéification

Le processus de pyrolyse







$T_{Pyrolyse}$ ~ 250-600 °C / β ~ 1-500 °C/s

$t_{séjour}$ < 1.5 s à X min

Taille de particule < 1 mm

Rendements des produits de pyrolyse

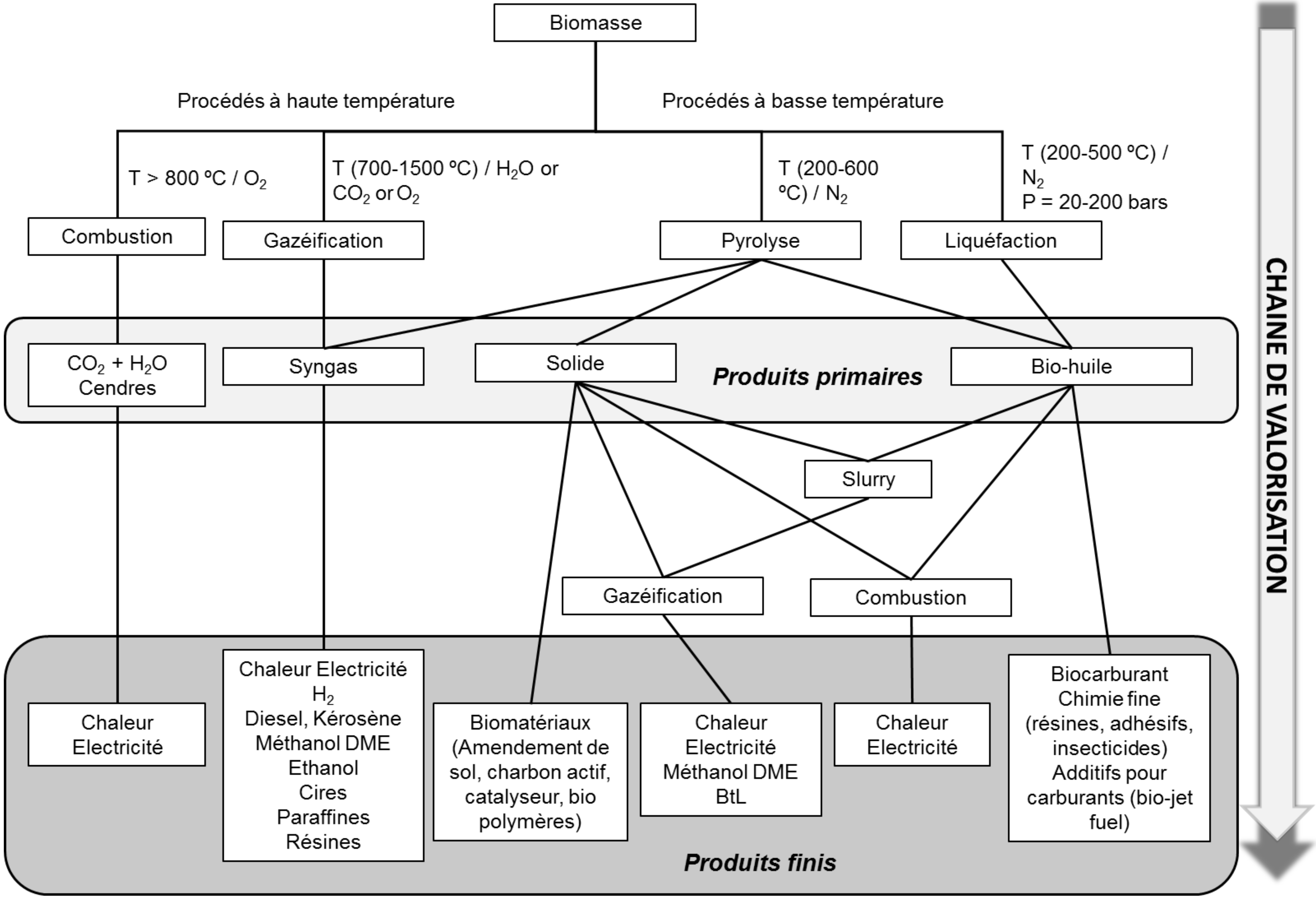
Eucalyptus grandis

Rendement (wt.%)	Liquide	Charbon	Gaz
Rapide	74 440-460 ºC 250-1000 µm	**14** <420 ºC 500-1300 µm	> 34 > 540 ºC 600-1300 µm
Lente	45 > 440 ºC > 14 ºC/min	**95** < 280 ºC > 16 ºC/min	30 > 500 ºC > 14 ºC/min
Sous-vide	65 > 400 ºC > 14 ºC/min	**80** < 300 ºC 4-20 ºC/min	30 200-500 ºC < 8 ºC/min

Caractéristiques des produits de pyrolyse

Gaz	Bio-huile	Biochar
• Gaz de synthèse principalement composé de CO_2, CO, CH_4,H_2 • HHV ≈ 6-40 MJ/kg	• 300-400 de composés organiques et eau (15-30 wt%) • pH = 2-3 • Concentration en Oxygène élevée • Moins de métaux et de Soufre • Stockage = augmentation de la viscosité avec vieillissement • HHV ≈ 17 MJ/kg	• Structure poreuse contenant des minéraux (quartz, calcite, sylvite, nitrates, oxydes, hydroxydes de Ca, Mg, Al, etc.) • Grande surface spécifique • Microporosité élevée • Pouvoir calorifique ≈ 25MJ/kg

Applications des produits de pyrolyse



Contributions potentielles à la réduction des émissions CO_2

Table 1 Comparison of GHG emissions reduction (including fossil fuel offset) for pyrolysis systems with sequestration or use of biochar as fuel and use of other biofuels and products.

Study	Process	Product applications	GHG emissions reduction intensity (g CO_2-eq MJ^{-1})
This study	Biomass pyrolysis poly-generation system Temperature: 600 °C Residence time: >1800 s	Biochar: soil application Pyrolysis gas: substitution of coke oven gas and electricity production Bio-oil: substitution of coal tar in chemical raw materials	136.45
		Biochar: charcoal substitution in industries Pyrolysis gas: substitution of coke oven gas and electricity production Bio-oil: substitution of coal tar in chemical raw materials	46.80
Peters et al.[28] (Spain)	Biomass slow pyrolysis system Temperature: 450 °C Residence time: ~2500 s	Biochar: soil application Pyrolysis gas: heat production for pyrolysis system and substitution of natural gas Bio-oil: heat production for pyrolysis system	122.18
		Biochar: charcoal substitution in coal power plant Pyrolysis gas: heat production for pyrolysis system and substitution of natural gas Bio-oil: heat production for pyrolysis system	63.22[a]
Roberts et al[14]. (the United States)	Biomass slow pyrolysis system Temperature: 450 °C Residence time: long enough	Biochar: soil application Pyrolysis gas: substitution of natural gas for heat product	108.57
		Biochar: charcoal substitution in IGCC plant Pyrolysis gas: substitution of natural gas for heat product	36.64

[a]The reference does not consider the GHG emissions derived from construction process (e.g., equipment and installation) in life-cycle assessment.

+ 292%

+ 12%

+26%

Propriétés du biochar

Bagasse de canne à sucre

Sarments de vigne

Acacia noir

- Propriétés chimiques: pHH_2O, pHKCl, capacité d’échange cationique (CEC), Nutriments extraits par acide citrique, acidité et basicité de surface, calcium carbonate equivalence, teneur en éléments

- Propriétés physiques: Surface spécifique, Conductivité électrique

Propriétés chimiques du biochar

Origine du biochar	Cellulose+ Hemicelluloses	Lignine	Taux de cendres	pH_{H2O}	Acidité de surface	Basicité de surface	CEC
Unité	daf, wt.%	daf, wt.%	wt.%	-	mmol/g	mmol/g	cmolc/kg
Bagasse	75.1	21.4	3.5	6.56	2.3	0.31	122
Acacia	56.4	23.9	1.3	9.74	1.28	1.04	101
Sarment	59.6	27.7	3.1	10.43	0.7	1.67	65

Concentrations des éléments du biochar

Table 5
Citric acid soluble nutrients and toxic elements (mg/kg).

Element	BW	V	SCB [8]	Concentration[a]
P	397 ± 4	**1989 ± 102**	451 ± 32	
Ca	**13,783 ± 120**	**17,177 ± 1367**	**2181 ± 128**	
Mg	**1349 ± 73**	**3908 ± 255**	**1158 ± 71**	
K	**5670 ± 42**	**15,746 ± 982**	**3463 ± 271**	
Fe	24 ± 2	102 ± 7	**3953 ± 192**	
Mn	10 ± 0.3	78 ± 8	162 ± 8	
Zn	**7 ± 0.3**	**179 ± 20**	**42 ± 4**	**7500**
Cu	b/d	1.37 ± 0.3	**9 ± 0.2**	**4300**
Co	0.02 ± 0.004	0.06 ± 0.01	1.9 ± 0.1	
Mo	0.1 ± 0.003	0.02 ± 0.01	0.01	75
Na	2205 ± 15	672 ± 18	289 ± 9	
As	0.06 ± 0.001	0.2 ± 0.01	0.4 ± 0.03	75
Al	82 ± 3.5	83 ± 11	2955 ± 102	
Cd	b/d	0.09 ± 02	0.03	85
Cr	**0.13 ± 0.02**	**0.5 ± 0.1**	**13 ± 1.4**	**3000**
Pb	**b/d**	**0.8 ± 0.2**	**3.6 ± 0.7**	**840**
Ni	**0.46 ± 0.05**	**0.8 ± 0.2**	**4.5 ± 0.7**	**420**
Se	0.07 ± 0.06	0.06 ± 0.01	b/d	100

The text that is shown in bold are sample essential nutrients (i.e. Ca,Mg,K) or heavy metals (i.e. Cr, Pb, Ni).

[a] Concentration limits for all biosolids [42].

Propriétés physiques du biochar

Table 4
EC (dS/m) and water soluble nutrient contents of the biochars (mg/kg).

Biochar	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	PO_4^{-3}	SO_4^{2-}	NO^{3-}
BW	0.67 ± 0.02	60	113 ± 12	1140 ± 40	2300 ± 69	460 ± 35	1033 ± 64	520 ± 87	0
V	0.83 ± 0.05	428 ± 24	421 ± 26	233 ± 21	4380 ± 191	247 ± 23	n/d	813 ± 70	n/d
SCB [8]	0.17 ± 0.01	32 ± 7	25 ± 8	173 ± 5	560 ± 65	84 ± 4	317 ± 20	335 ± 34	0

n/d, not determined.

Origine du biochar	Surface spécifique (m^2/g)	Micropore **(%)**	Mésopore **(%)**	Macropore **(%)**
Bagasse	259	65	11	22
Acacia	241	66	9	22
Sarment	92	49	11	39

RAPSODEE – UMR 5302

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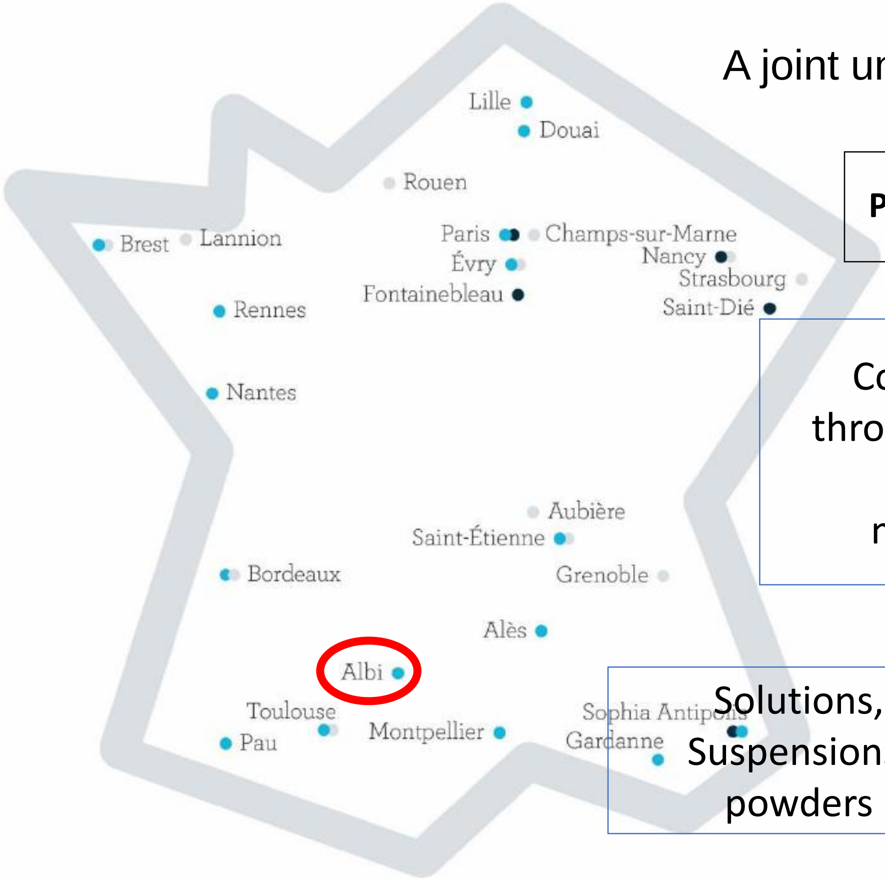

POWDERS AND PROCESSES

Control of solid properties through their production chain suggesting advanced manufacturing methods

Solutions, Suspensions, powders → Size and shape-controlled powders

ENERGY AND ENVIRONMENT

Production of energy carriers and advanced functional materials for energy storage and catalysis applications / Modelization and Optimization

Biomass, Waste → Chemicals, Electricity, Gas and liquid biofuels, Graphenes, Heat

Staff members in 2021

34 Lecturers/Researchers
19 Permanent admin, engineers and technicians
13 Non-permanents: Postdoctoral researchers, engineers and technicians
33 PhD students

99 Staff members in 2021

73 ISI Publications in 2020

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