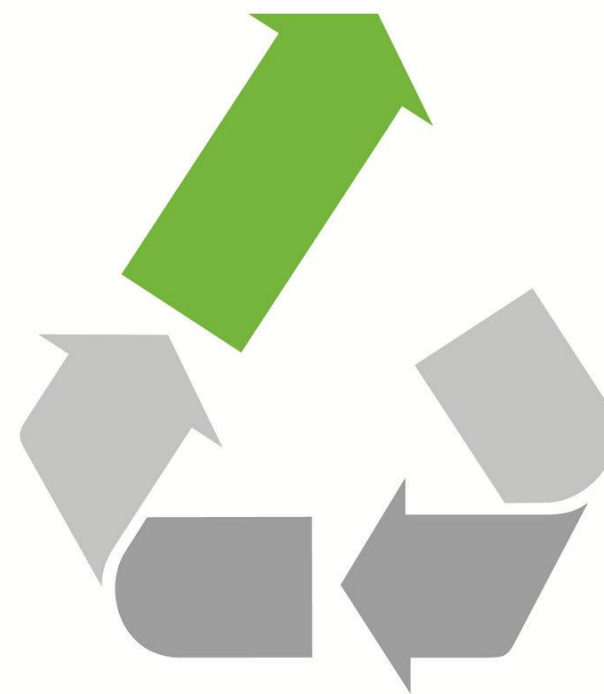


"Upcycling of
bioplastic waste
from eyewear
industry for high
value solid
products"

Lukasz Niedzwiecki, Luca Fambri,
Filippo Marchelli, Anna Pajdak, Luca
Fiori



OCCHIO-AL BIO!®



What is upcycling?

Higher value



UPCYCLING



RECYCLING

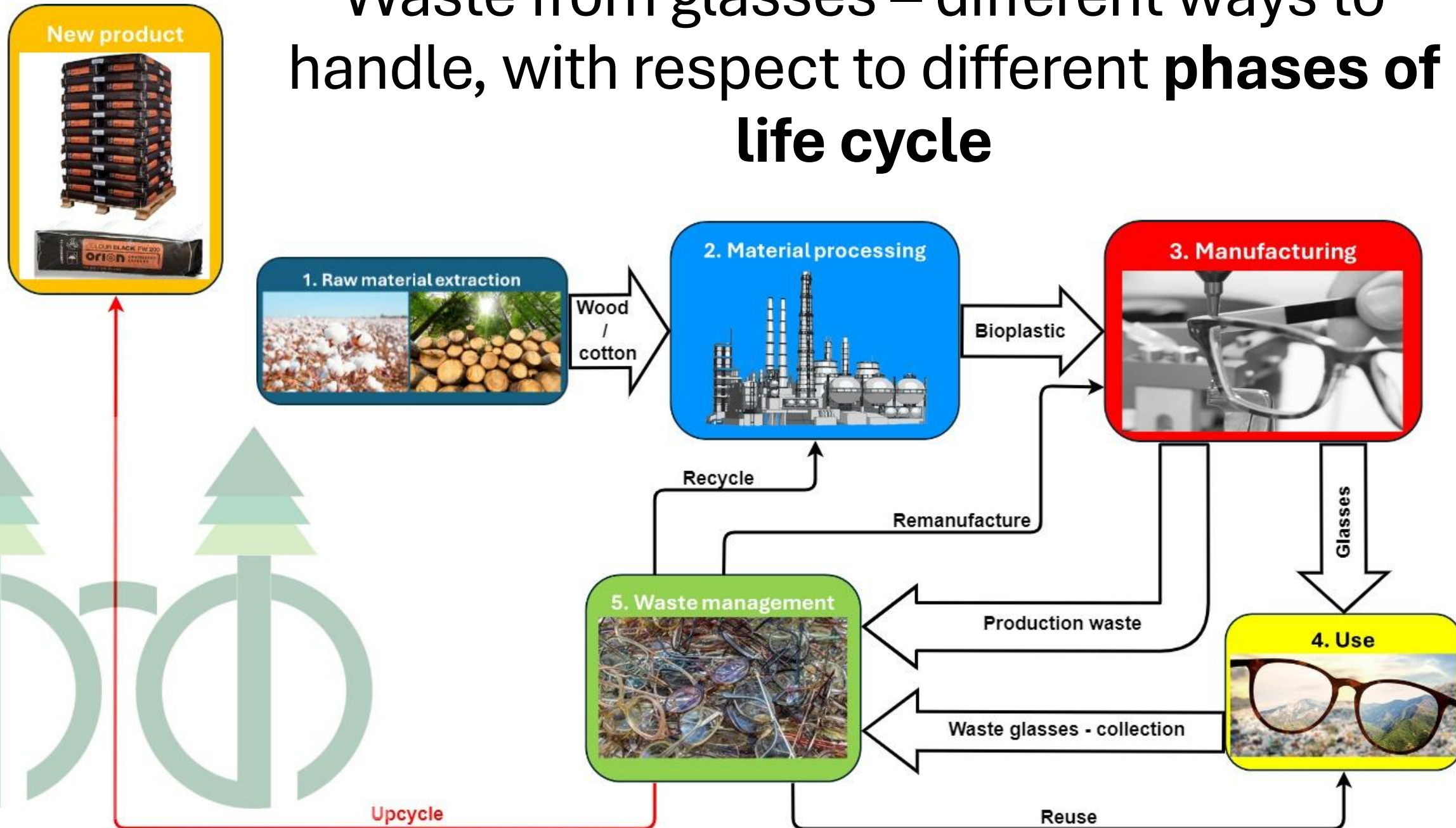


DOWNCYCLING

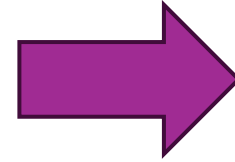
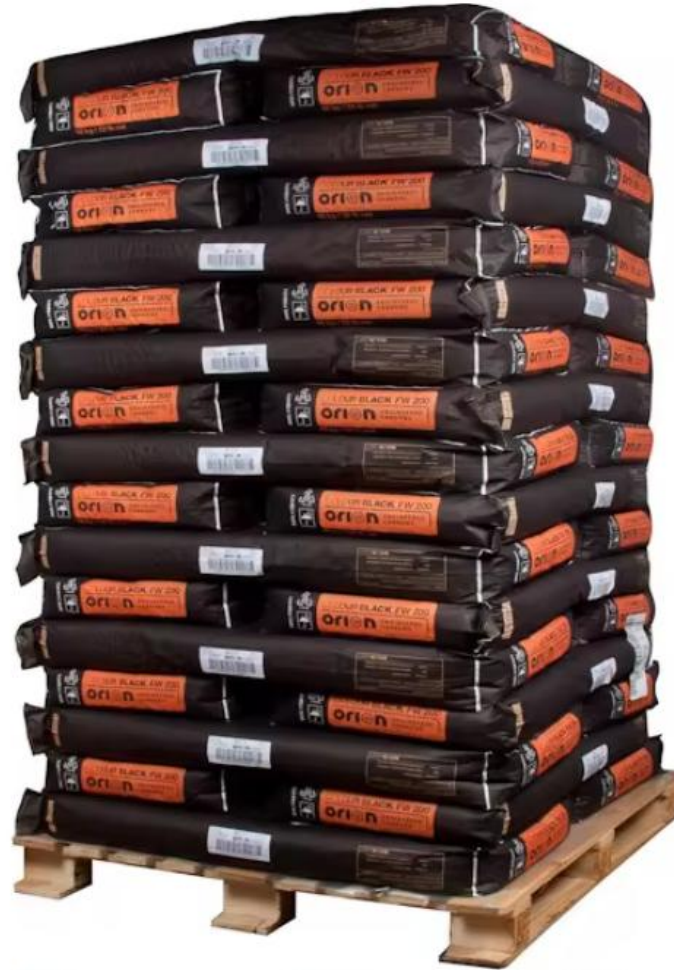


Lower value

Waste from glasses – different ways to handle, with respect to different **phases of life cycle**



What is
carbon
black?

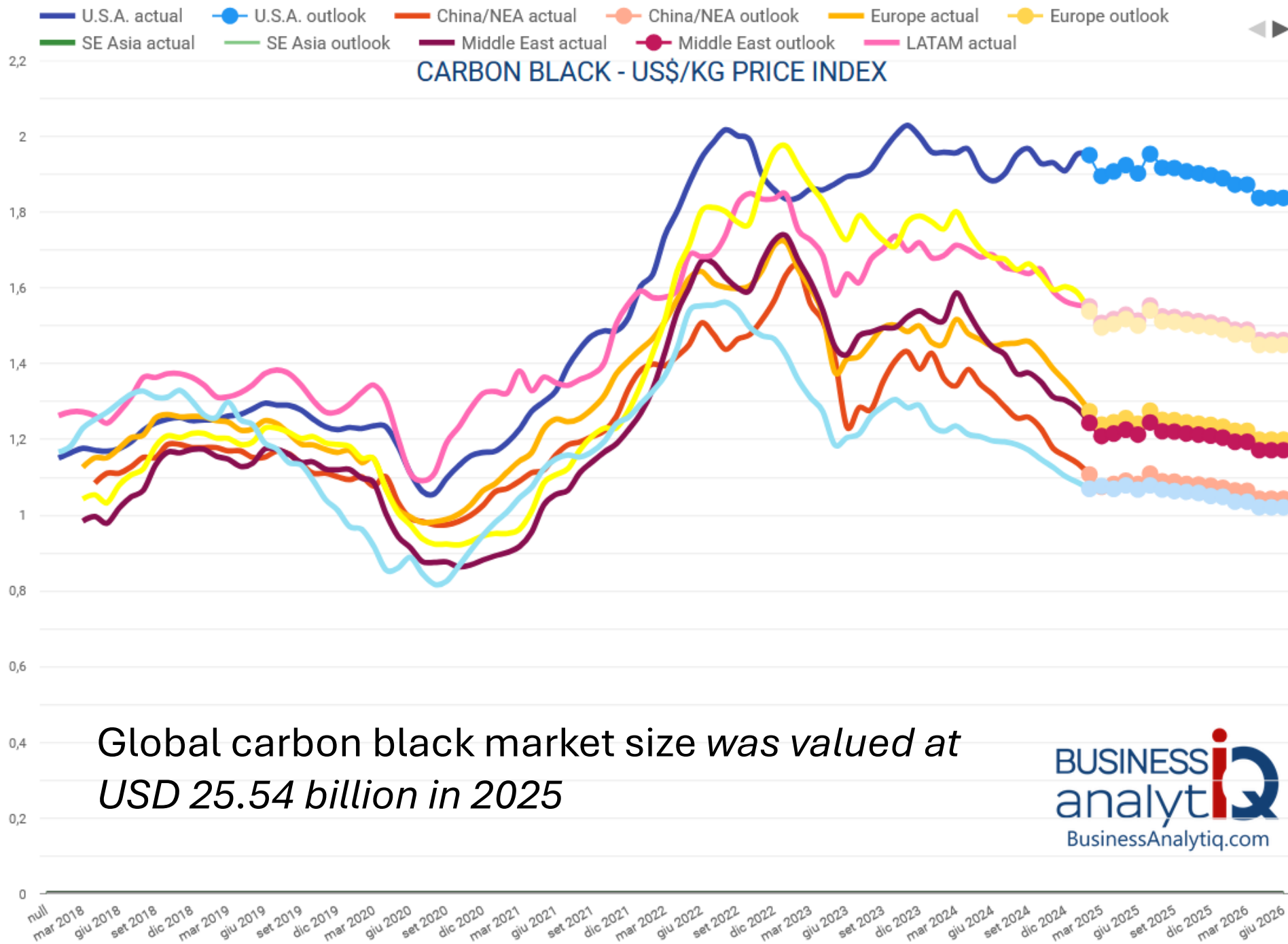


Possible applications:

- ☐ Ink
- ☐ Toner for printers
- ☐ Tyres
- ☐ Plastics (tint)
- ☐ 3D printing filament
- ☐ Electrodes
- ☐ Asphalt



Carbon black - value



Example of carbon black specification

ASTM D1765-23b

ASTM CLASSIFICATION	TARGET VALUES ^A		OIL ABSORPTION NO. COMPRESSED SAMPLE, D 3493, 10 ⁻⁵ m ³ /kg	NSA MULTIPOINT D 6556, 10 ³ m ² /kg (m ² /g)
	IODINE ADSORPTION NO., ^B D 1510 g/kg	OIL ABSORPTION NO. D 2414, 10 ⁻⁵ m ³ /kg		
N110	145	113	97	127
N115	160	113	97	137
N120	122	114	99	126
N121	121	132	111	122
N125	117	104	89	122
N134	142	127	103	143
N135	151	135	117	141
S212	...	85	82	120
N220	121	114	98	119
N231	121	92	86	111
N234	120	125	102	119
N293	145	100	88	122
N299	108	124	104	104
S315	...	79	77	89
N326	82	72	68	78
N330	82	102	88	78
N335	92	110	94	85
N339	90	120	99	91
N343	92	130	104	96

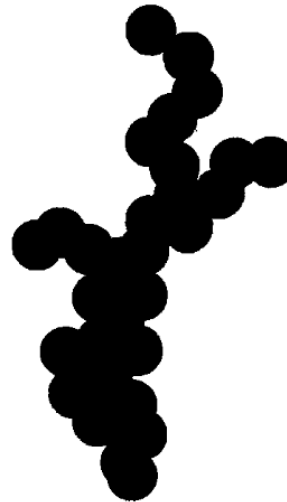
BET



morphology

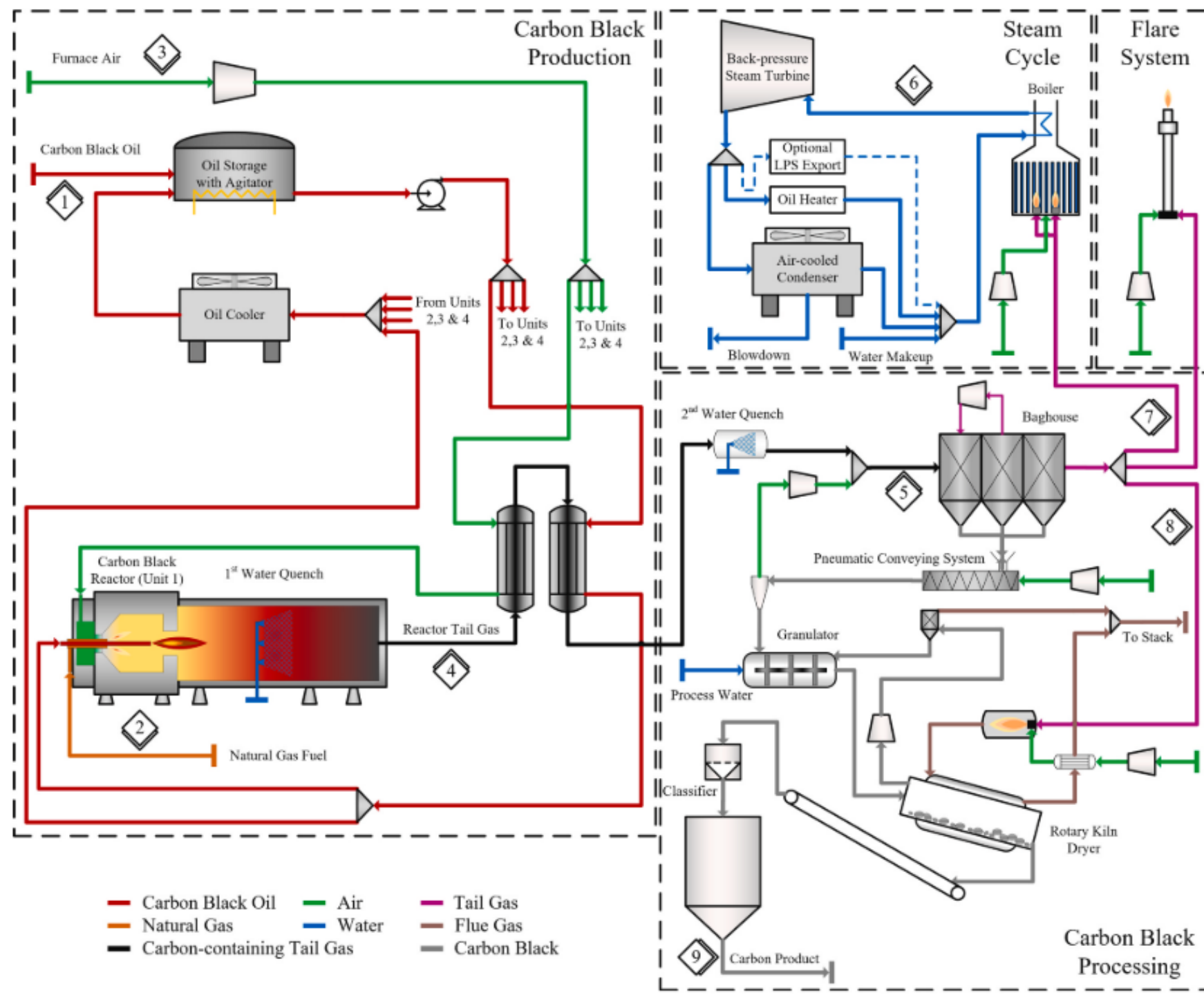


Low Structure



High Structure

State-of-the-art production of carbon black



Traditional method (comparison)

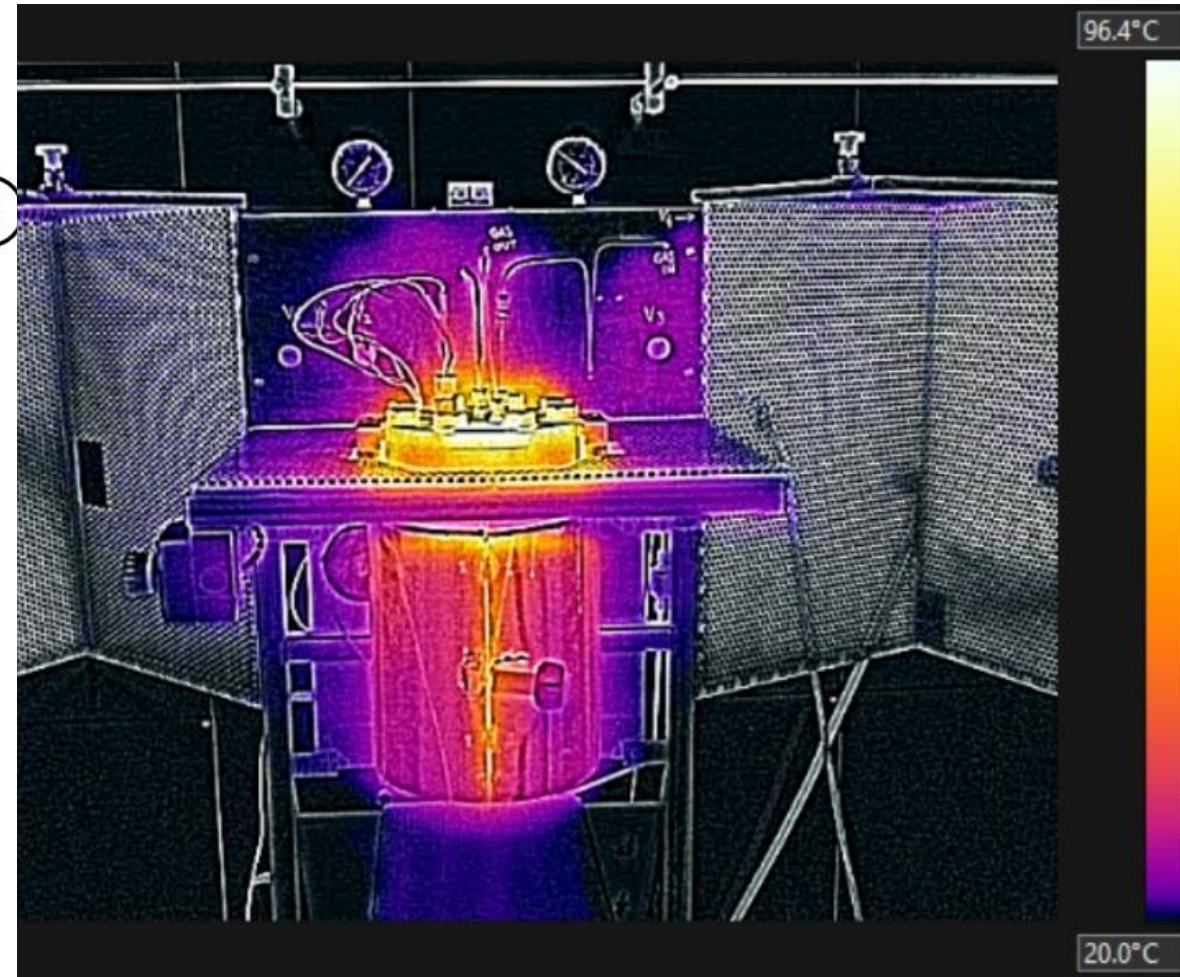
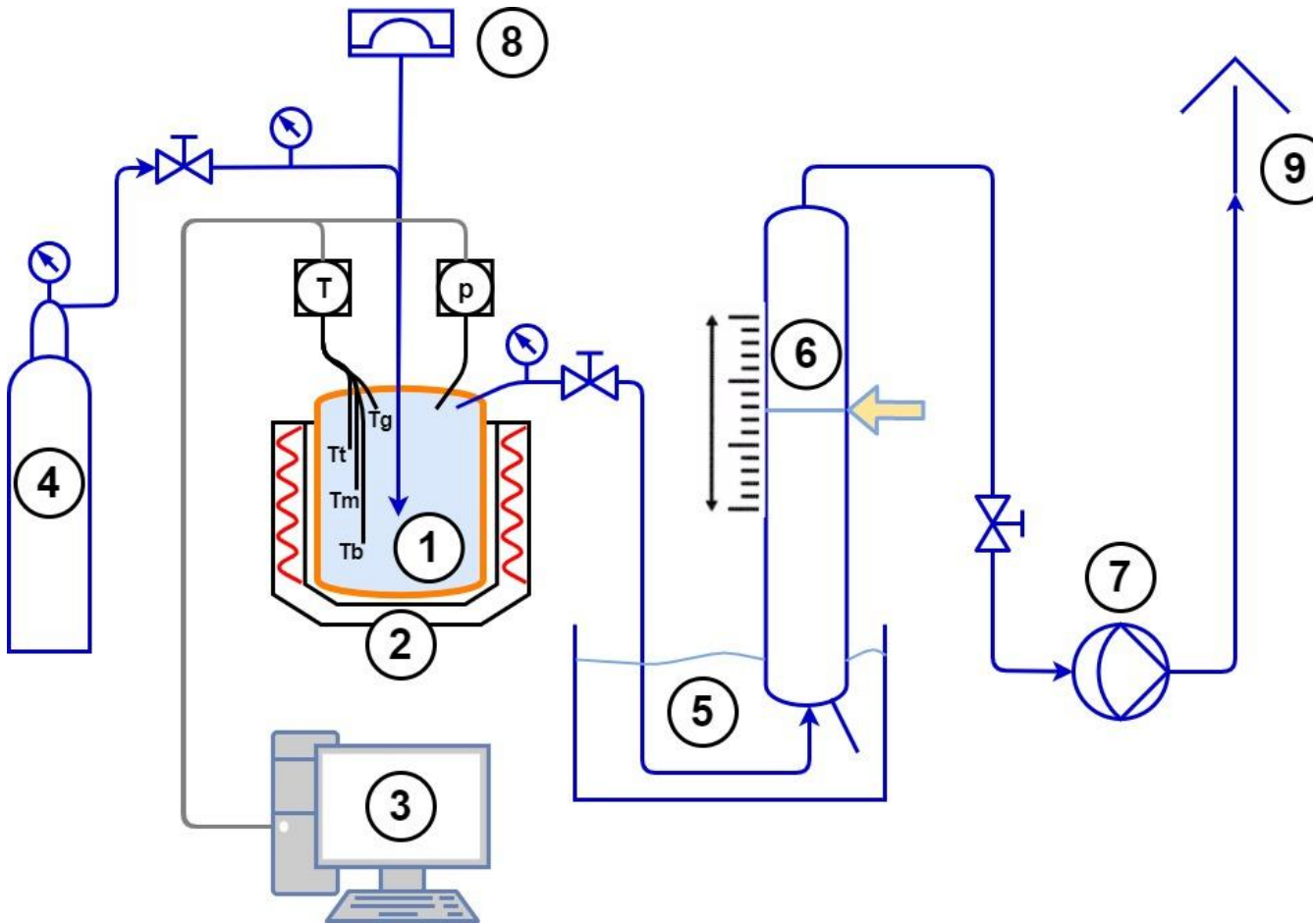


- Dirty
- Fossil fuels used



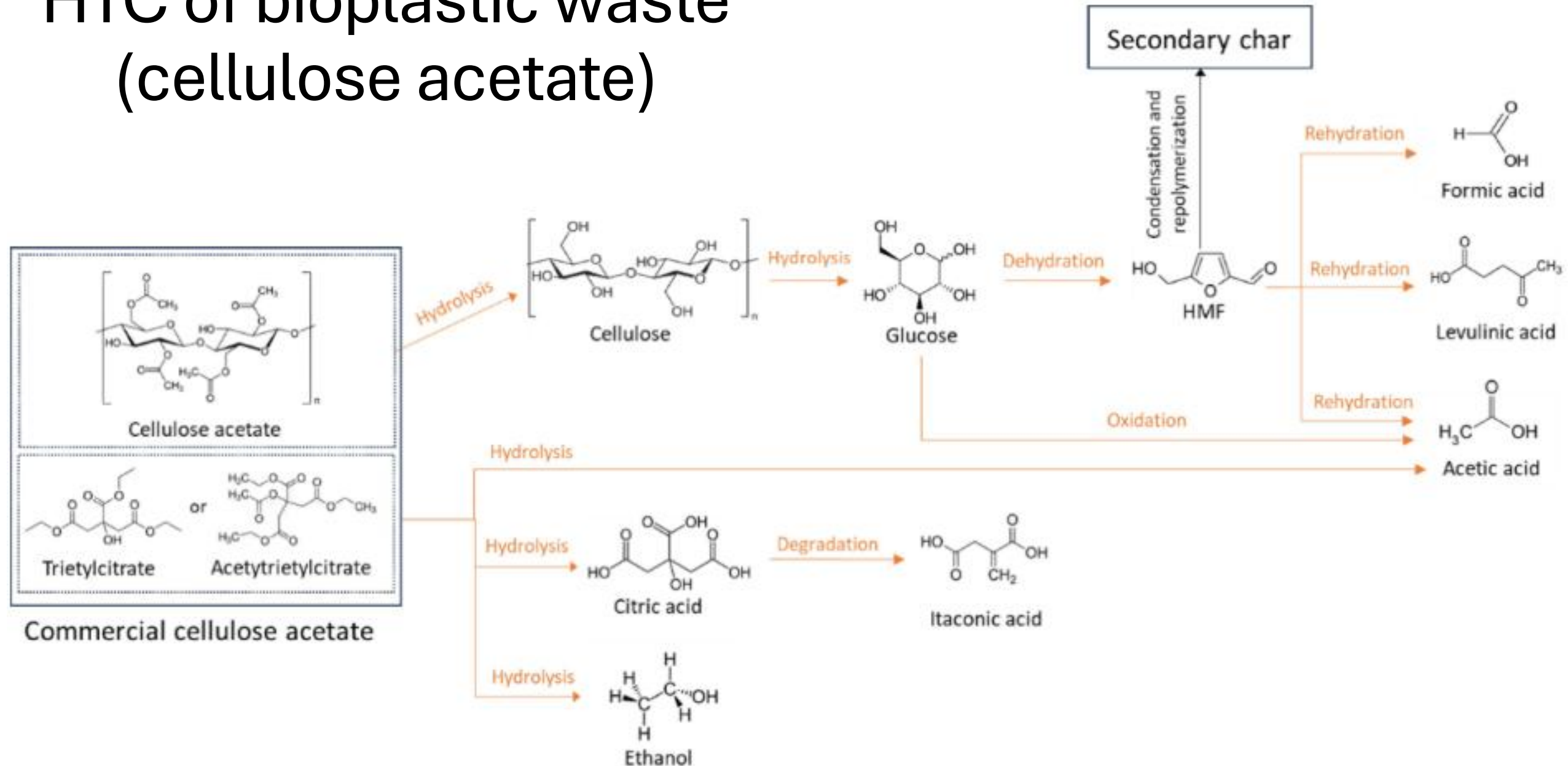
Opportunity

Experimental rig - HTC

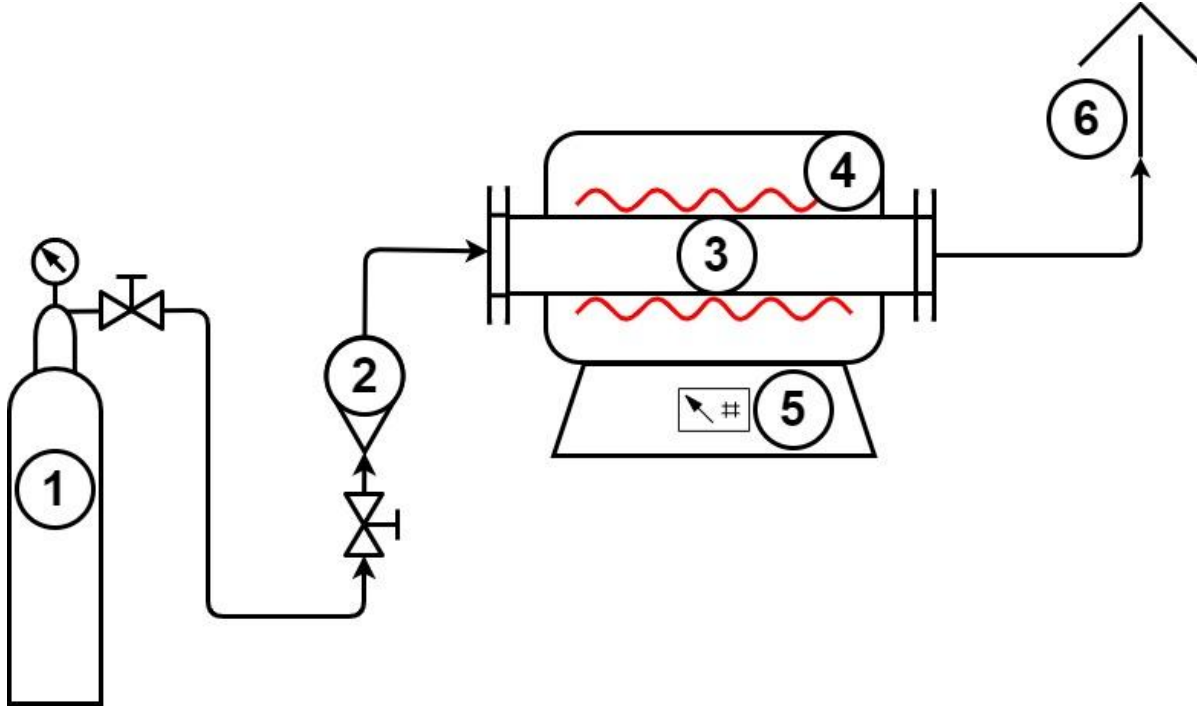


1 – reactor vessel; 2 – heater; 3 – PC with control software and data logging; 4 – N_2 cylinder; 5 – open tank with water; 6 – cylinder for gas volume measurement; 7 – vacuum pump; 8 – rupture disc; 9 – vent of the fume hood cabinet; T – thermocouples; p – pressure sensor; T_g – temperature of the volume always taken by gases and vapours; T_t – temperature of the top layer; T_m – temperature of the middle layer; T_b – temperature of the bottom layer

HTC of bioplastic waste (cellulose acetate)

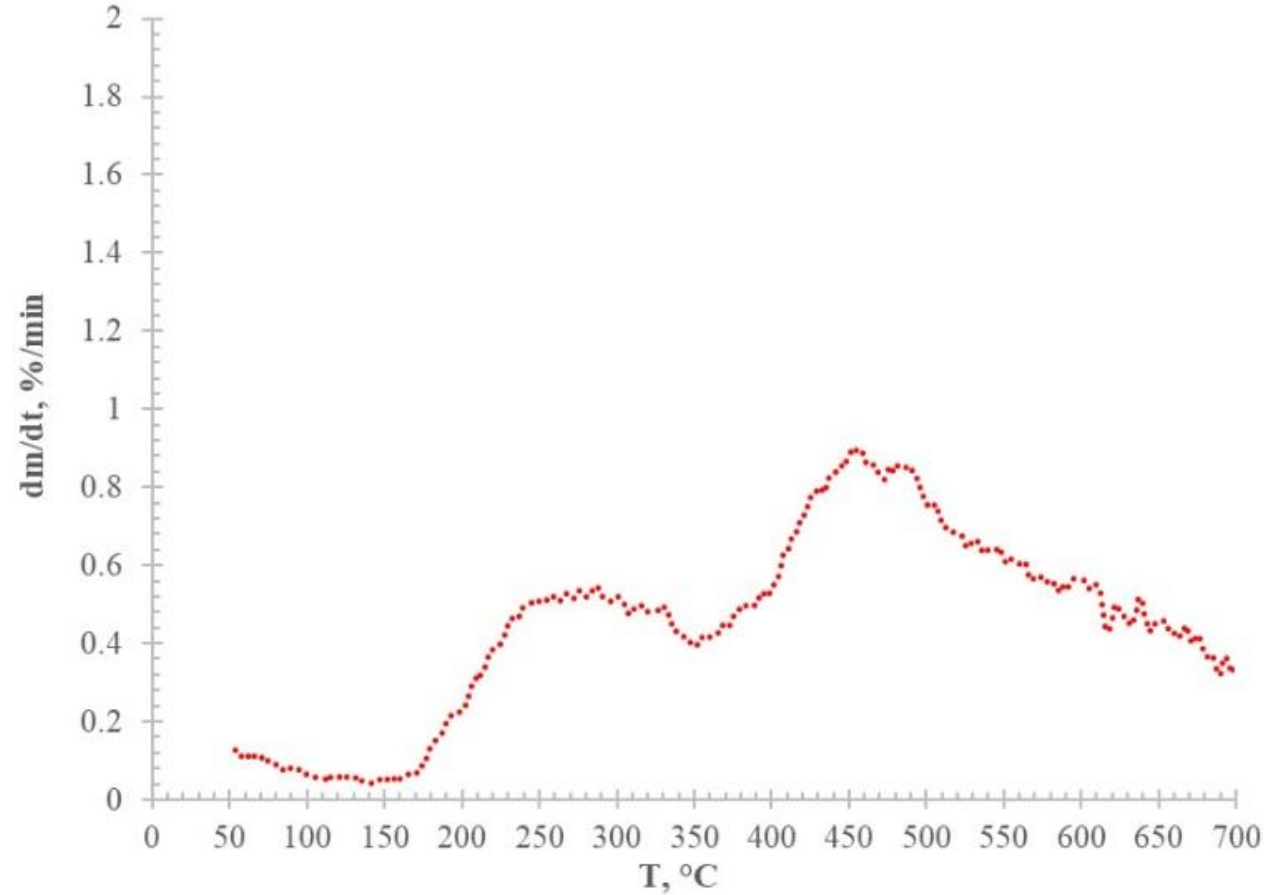
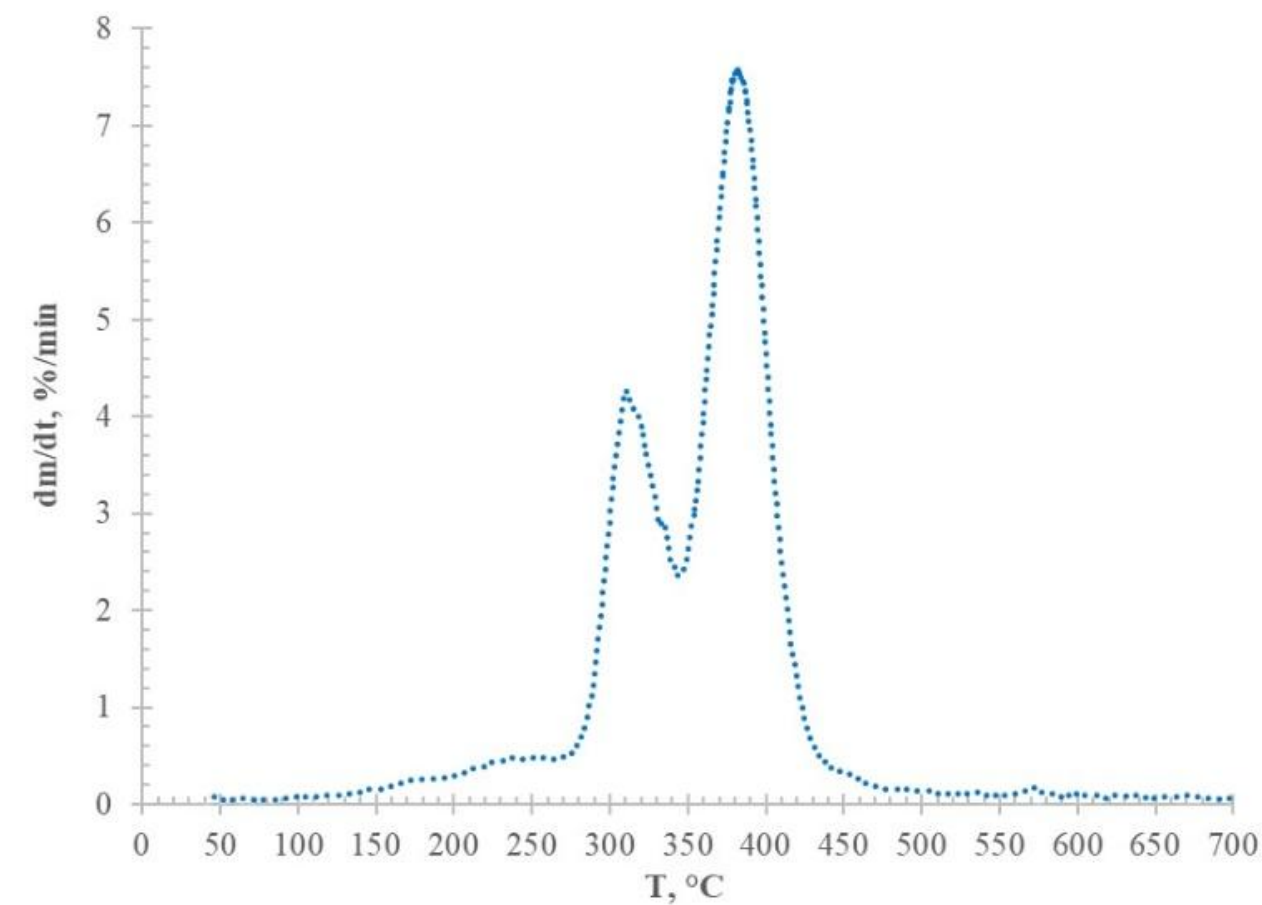


Experimental rig - Pyrolysis



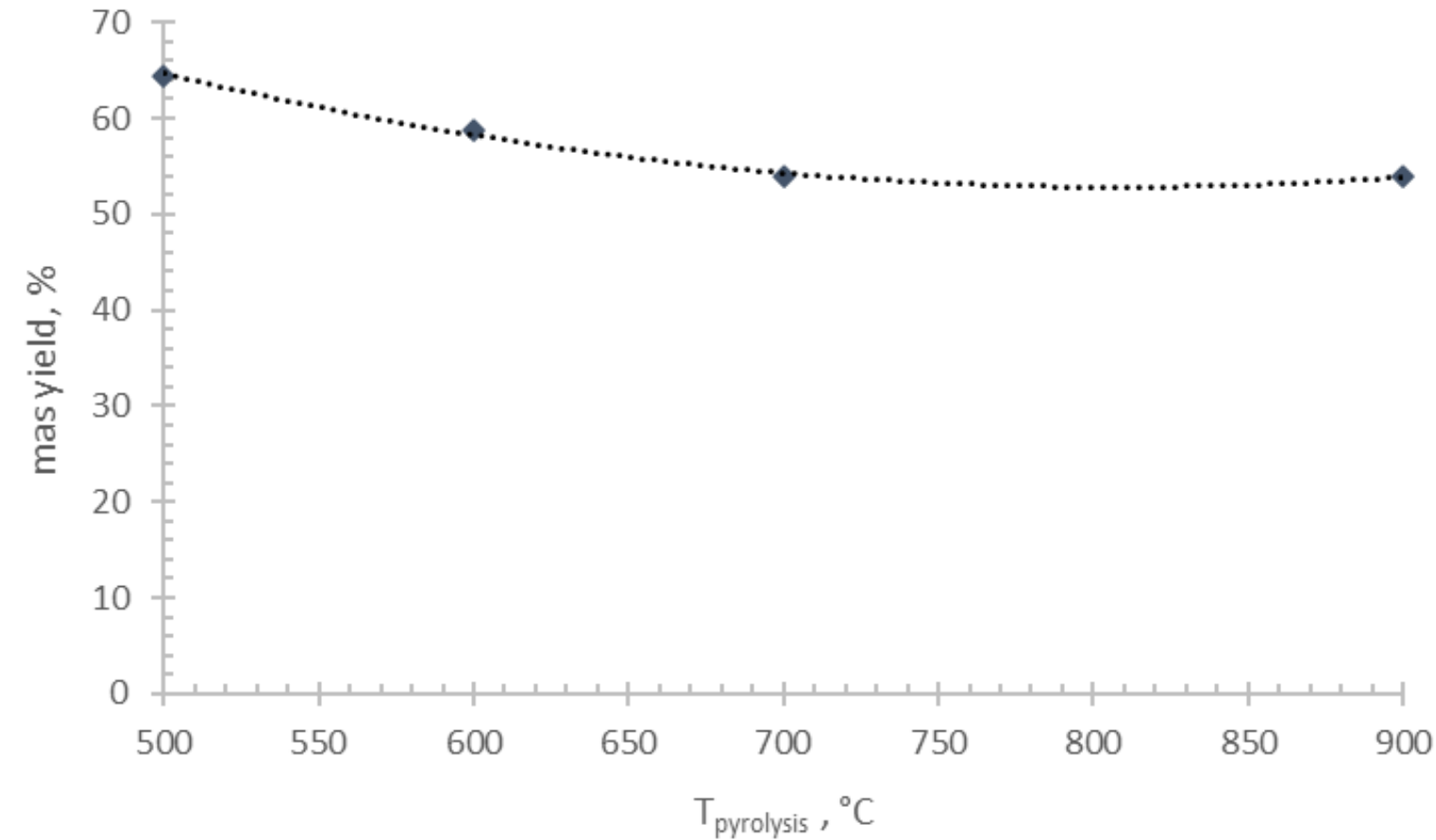
left – diagram (1 – cylinder with nitrogen; 2 – rotameter for measurement of volumetric flow rate; 3 – transparent tube made of quartz; 4 – heating element; 5 – EPC3016 controller; 6 – vent); right – picture of carbolite TF1-1200 furnace

TGA analysis – determination of suitable pyrolysis temperature range for tests

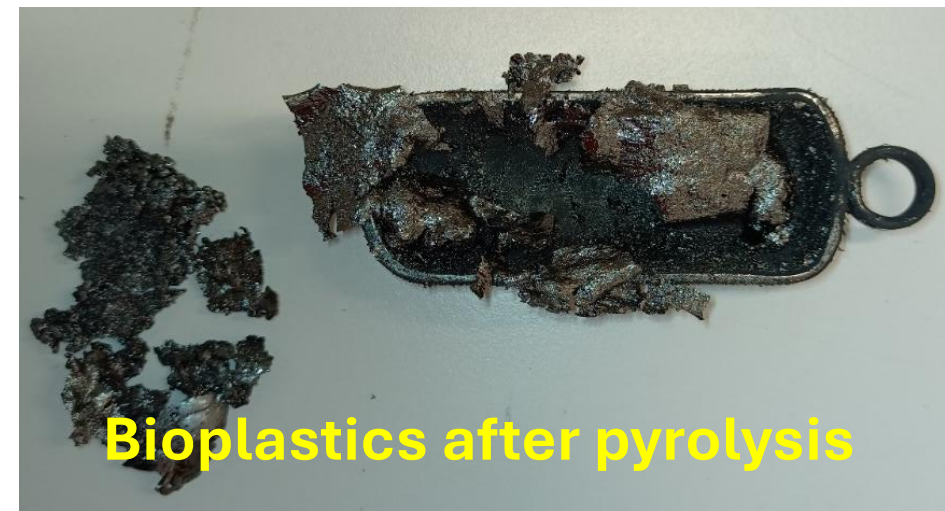


DTG curve obtained in inert atmosphere (N_2) for CDA blocks (left, blue) and hydrochars (right, red) produced by HTC of at 250 °C with residence time of 1 hour

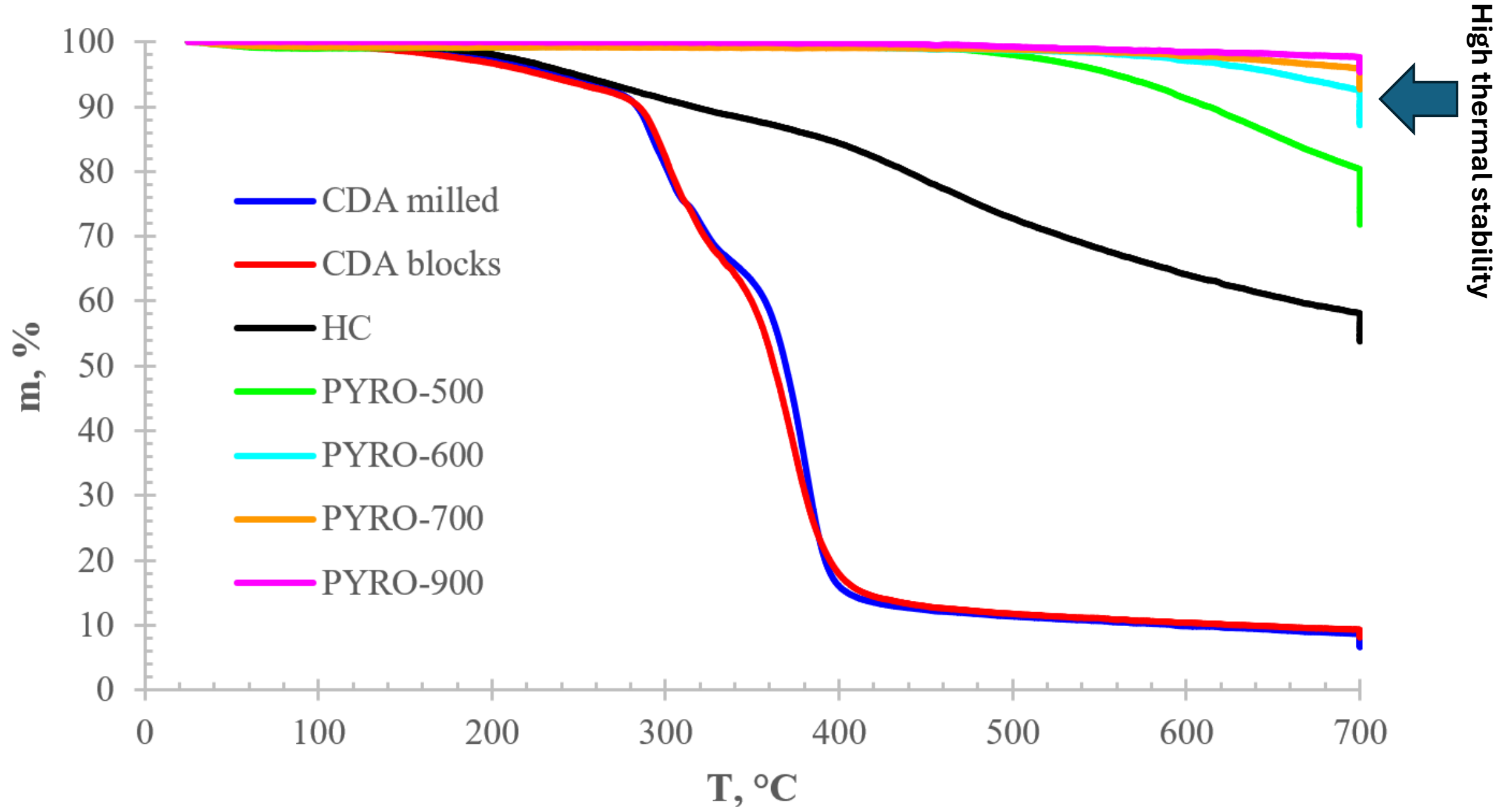
Why not just pyrolysis?



Mass yield depending on the process temperature for pyrolysis of hydrochars produced at 250 °C with residence time of 1 h

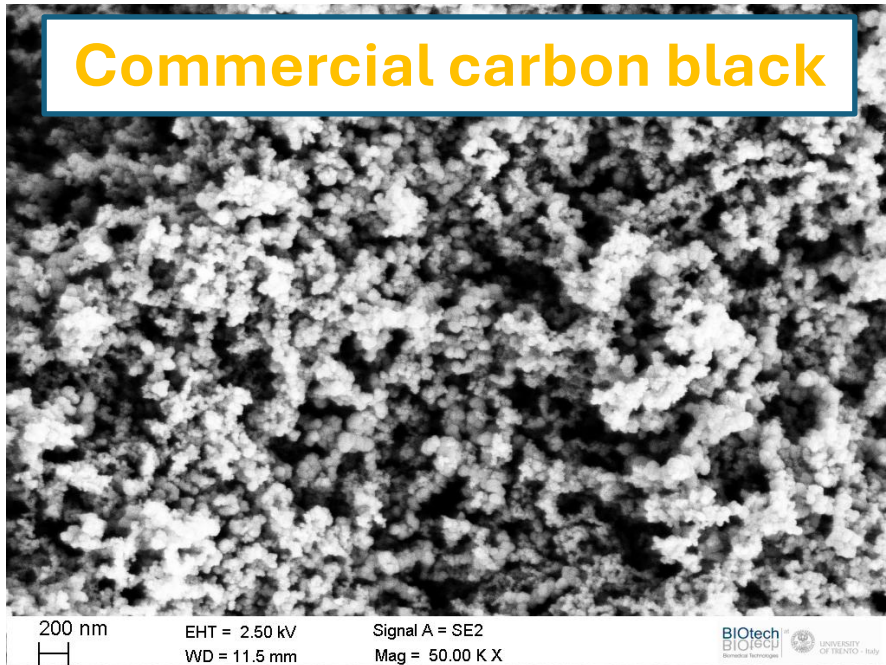


Thermal stability of carbon spheres after pyrolysis

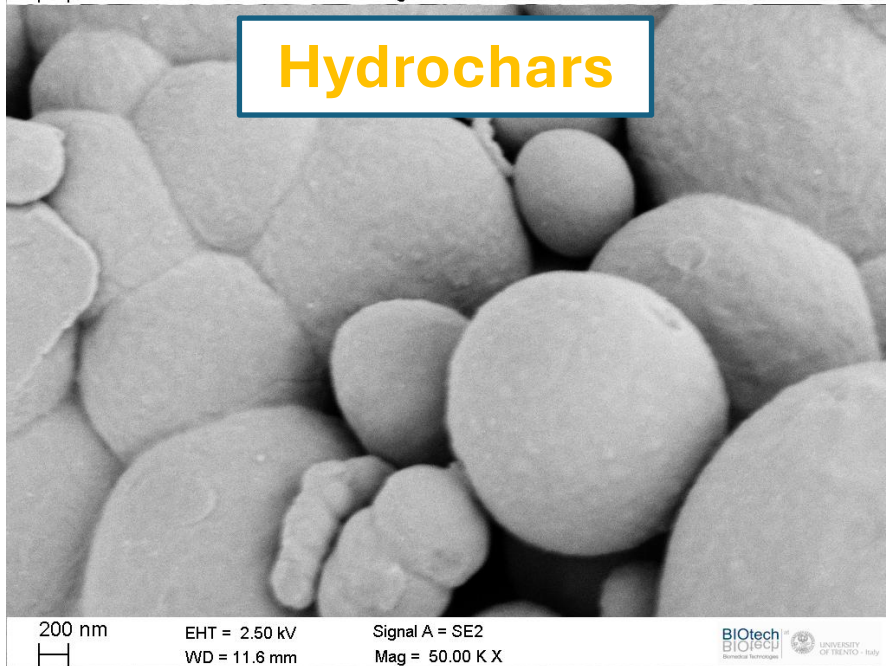


Morphology

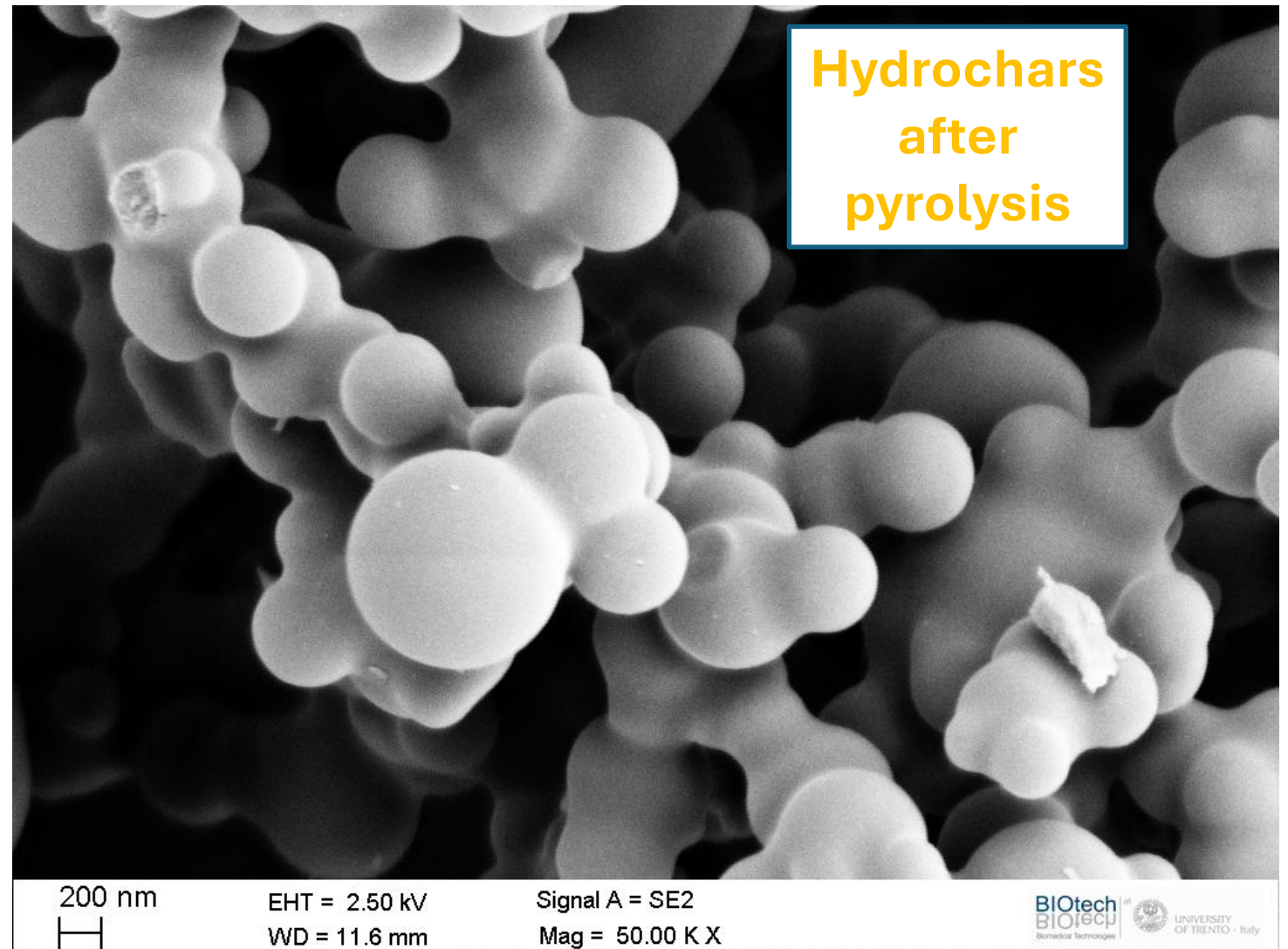
Commercial carbon black



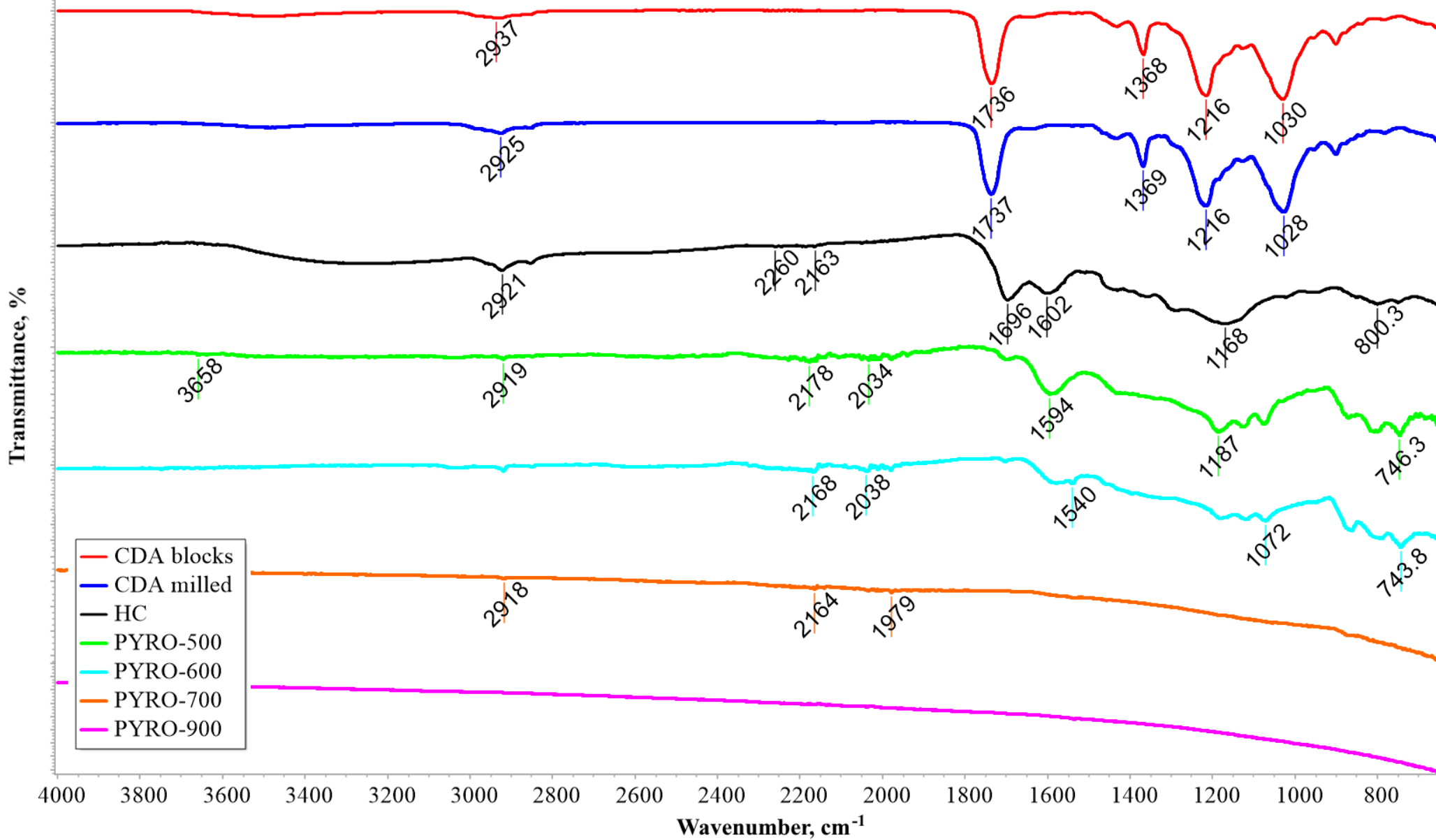
Hydrochars



**Hydrochars
after
pyrolysis**



FTIR ATR

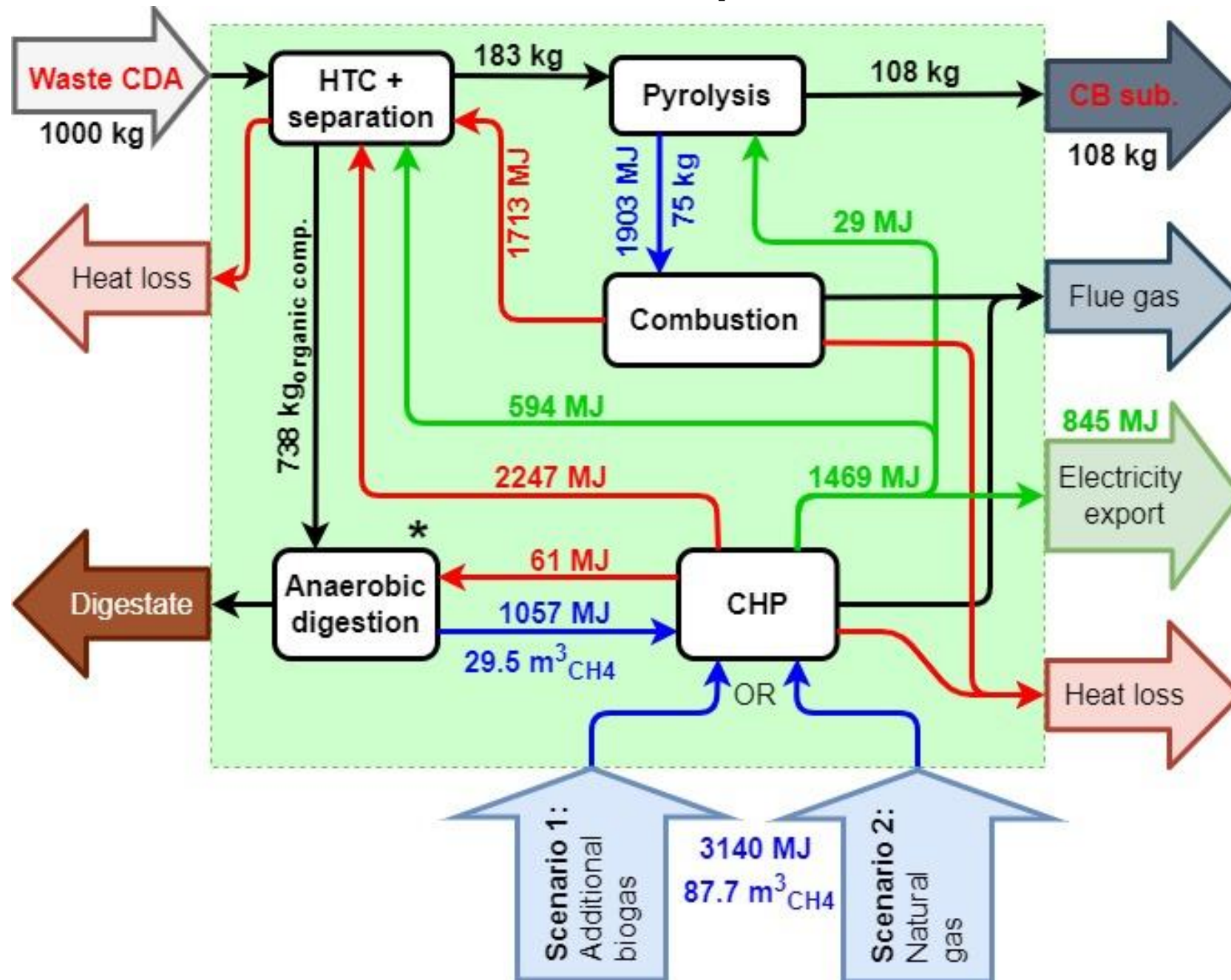


Pyrolysis causes:

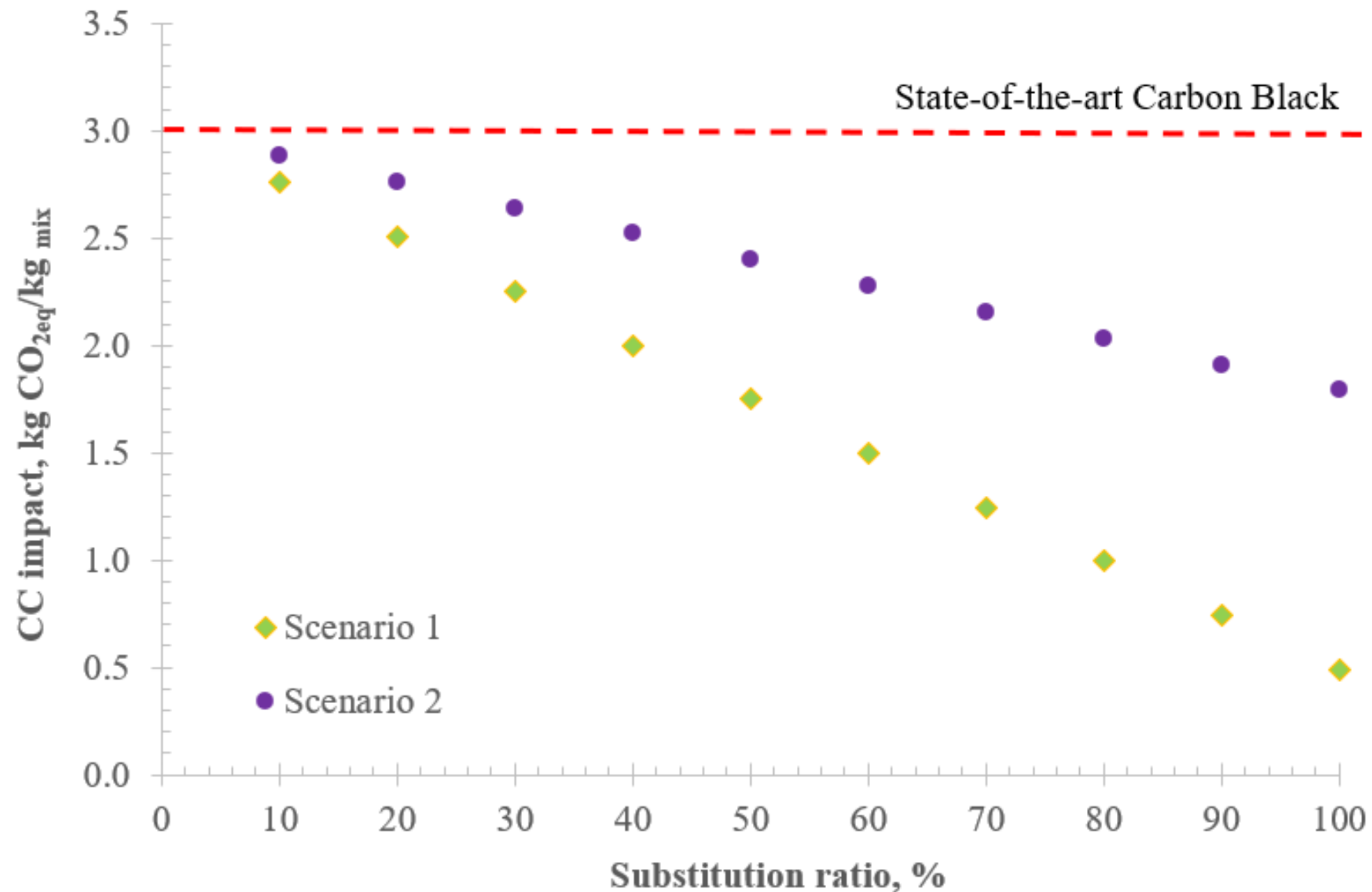
- Loss of functional groups
- Baseline shift similar to **effects observed for carbon black** used as additive in polymers

Sample	Iodine Adsorption Number	BET	Micropore volume
	mg/g	m ² /g	cm ³ /g
HC	327 ±46	5.1 ±0.1	0.003
PYRO-500	318 ±13	18.4 ±0.2	0.017
PYRO-600	464 ±59	175.4 ±3.9	0.083
PYRO-700	488 ±17	4.1 ±0.1	0.002
PYRO-900	457 ±25	3.5 ±0.1	0.002
N110 (ASTM D1765-23b)	145	127	n.d.
Vulcan XC-72 (N472) - commercial	n.d.	245 - 254	0.060
Printex L6 - commercial	n.d.	190	0.040
N660 (ASTM D1765-23b)	36	35	n.d.
Printex XE-2	n.d.	1300	0.030
Black Pearls 2000	n.d.	1635	0.590
N550 (ASTM D1765-23b)	43	40	n.d.
N660 (ASTM D1765-23b)	36	35	n.d.
N750 (ASTM D1765-23b)	27	27	n.d.

Novel carbon black production method



Environmental benefits of new product



Conclusions

- **We can produce a material very similar to carbon black, using waste bioplastics**
- Thermal stability of hydrochars insufficient – pyrolysis after HTC is needed
- **Morphology of hydrochars after pyrolysis closely resembles carbon black**
- Surface area comparable to carbon black with many different designations specified in ASTM D1765-23b, and comparable to some industrial products
- **Climate change impacts ranging between 0.49 and 1.79 kgCO_{2eq} per kg of product**, depending on source of heat, which is substantially lower than **3 kgCO_{2eq} per kg of fossil-based carbon black** produced nowadays
- **Further testing in tyres and plastics needed to confirm industrial applicability**