Production and application of sustainable metallurgical biochar pellets

Lorenzo Riva, Biokarbon i norsk prosessindustri webinar

21 Januar 2021

UiA Universitetet i Agder

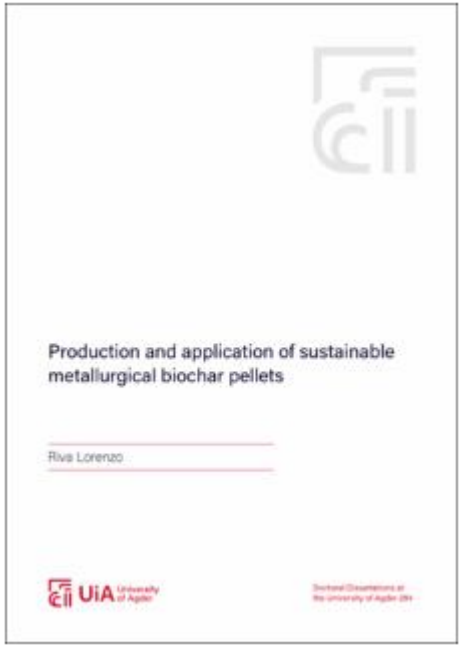
PhD Project title:
Production and Application of Sustainable Metallurgical Biochar pellets

Timeline:
3 years project – from August 2017 to August 2020

Supervisors:
Henrik Kofoed Nielsen (UiA), Therese Videm Buø (Elkem ASA)

Dissertation:
7th September 2020

Publications:
5 journal papers, 2 conference papers



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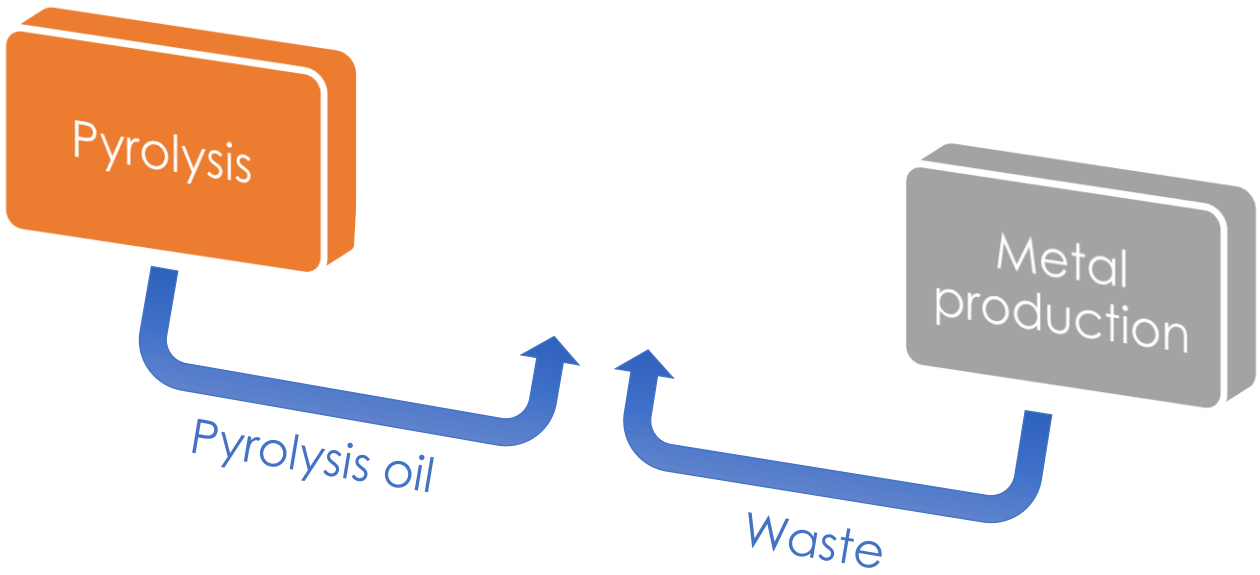
Biochar VS Coal

indiamart.com

chemistryexplained.com

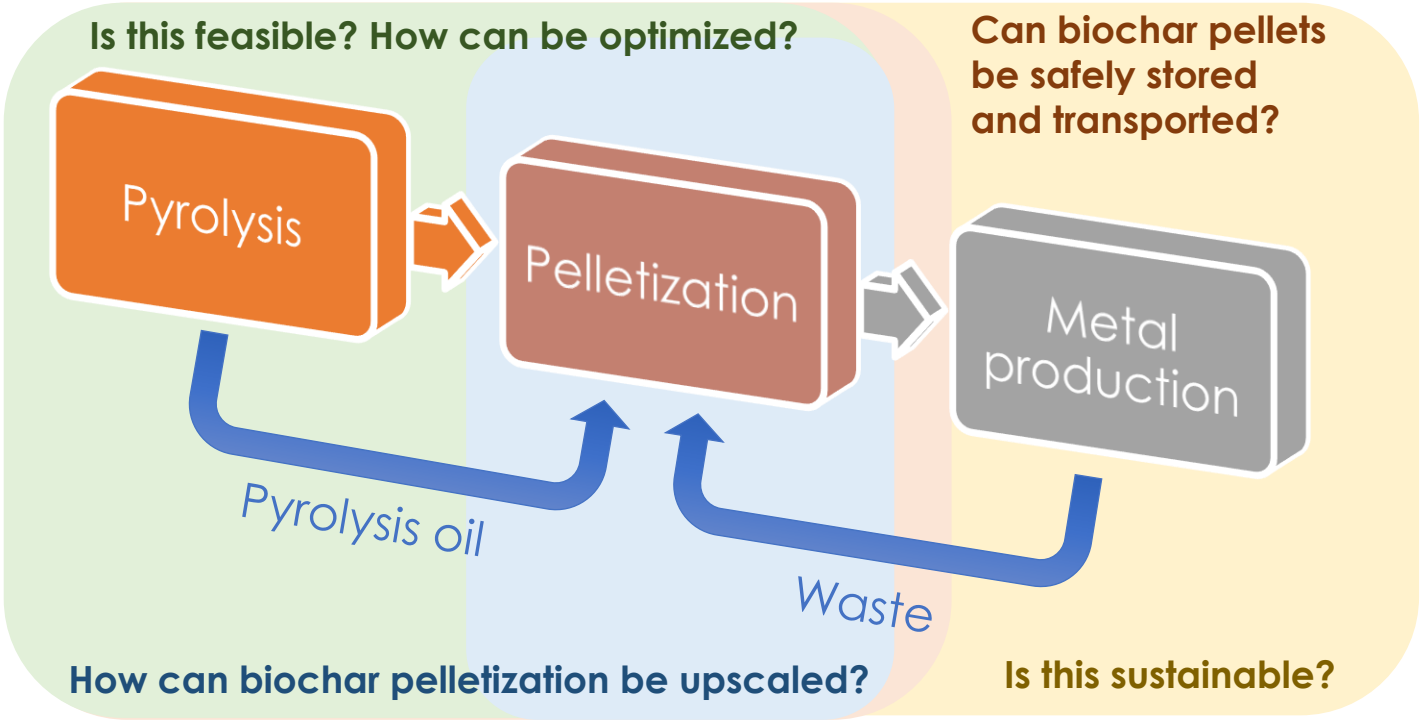
	Biochar	Coal	
Environmental impact	+	−	☺
Costs	−	+	☹
Mechanical properties	−	+	

Issue to address!



Biochar competitiveness

Research questions



Focus on the **Norwegian** potential market!

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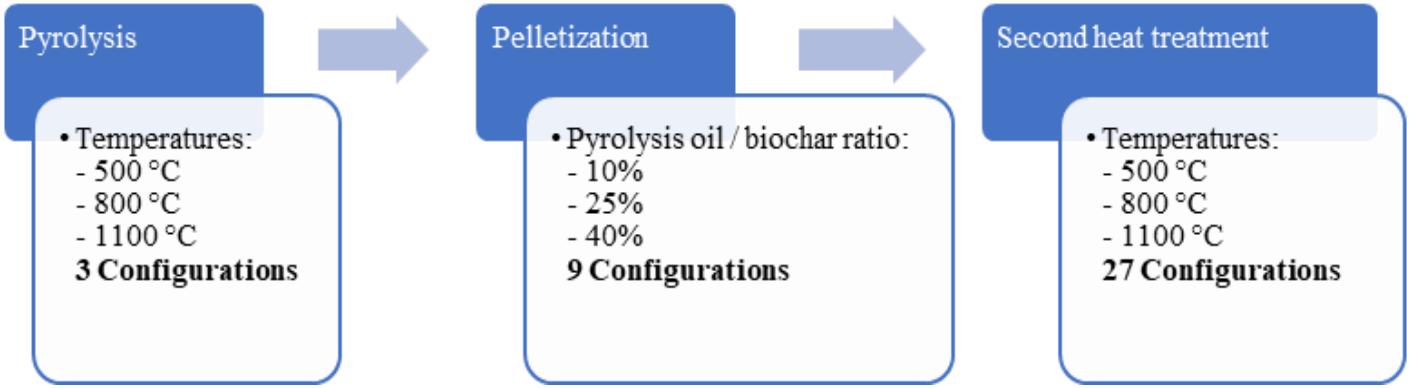
Is biochar pelletization with pyrolysis oil suitable for metallurgical applications?



Original feedstock:
Norway Spruce

Pyrolysis oil:
BTG-BTL oil from Pine

2nd pyrolysis
Purification treatment
Binding enhancer

Several combinations of pyrolysis temperatures, pyrolysis oil content and second heat treatment (SHT) temperatures were tested to evaluate the potential of biochar pellets in metallurgical applications, where reduction is needed

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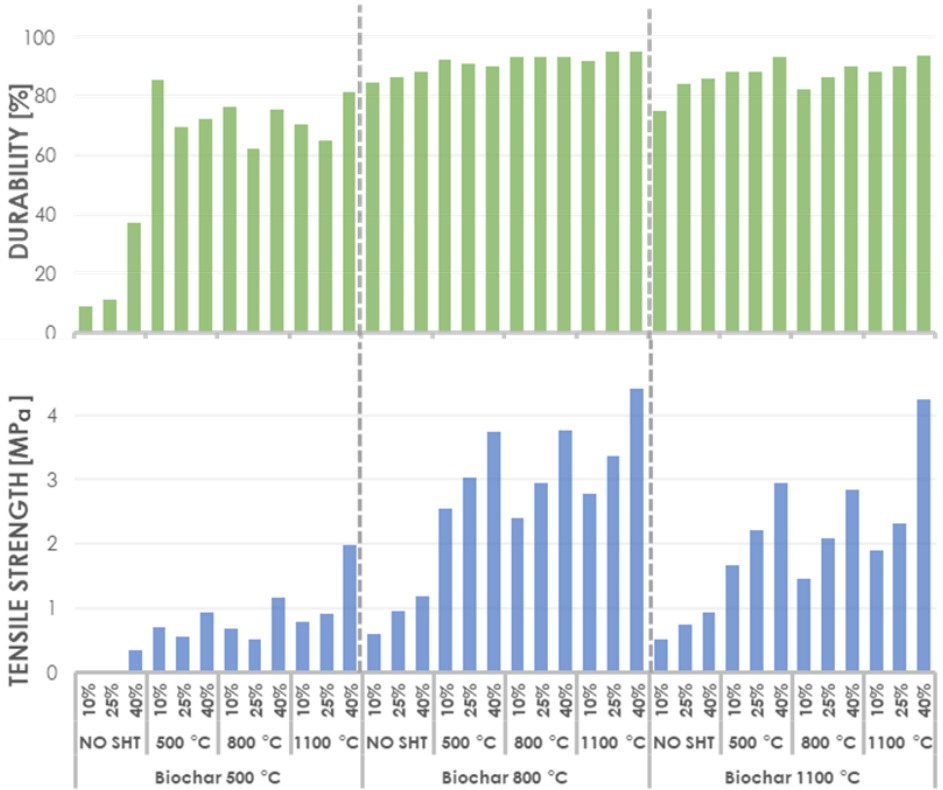
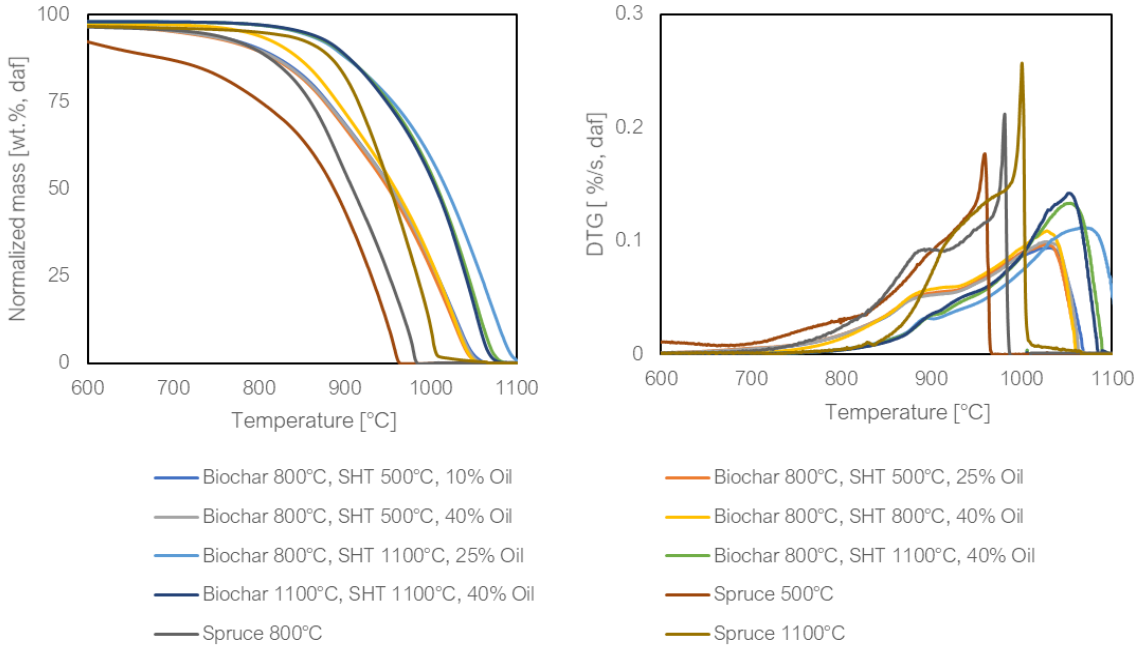
- Low mechanical durability at lowe pyrolysis temperature
- Tensile strength before second heat treatment (SHT) generally weak
- However, oil content is beneficial
- For both durability and strength, high improvements when higher pyrolysis temperatures are applied or SHT is performed





CO2 reactivity gets lower after densification but it is still very high

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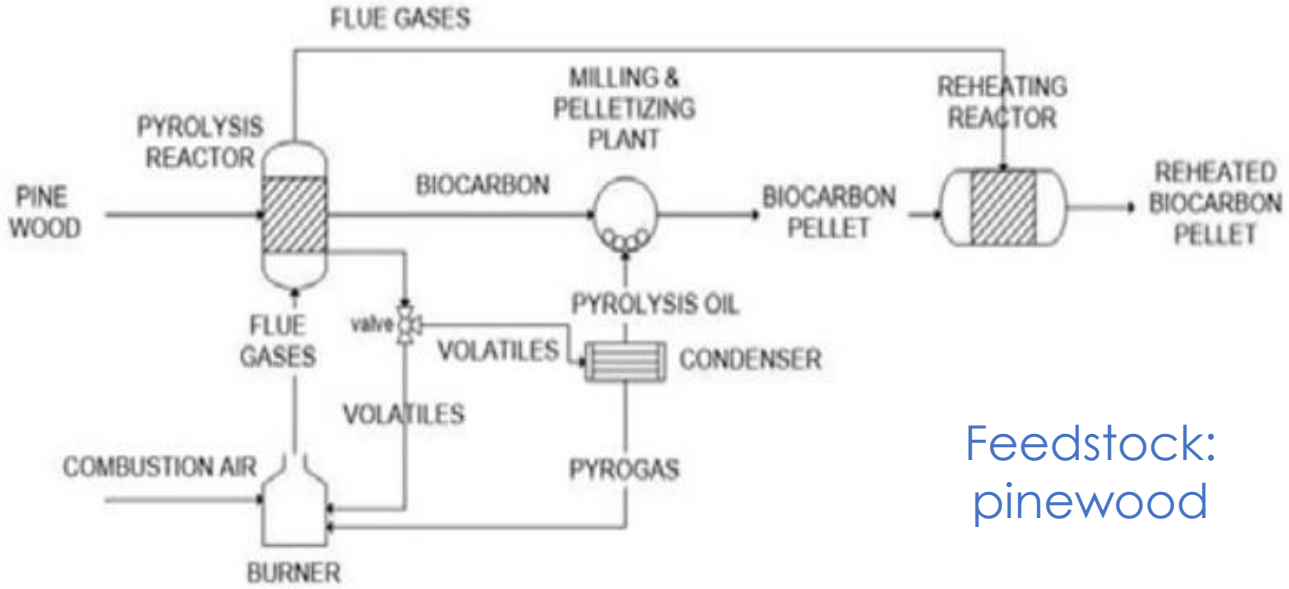
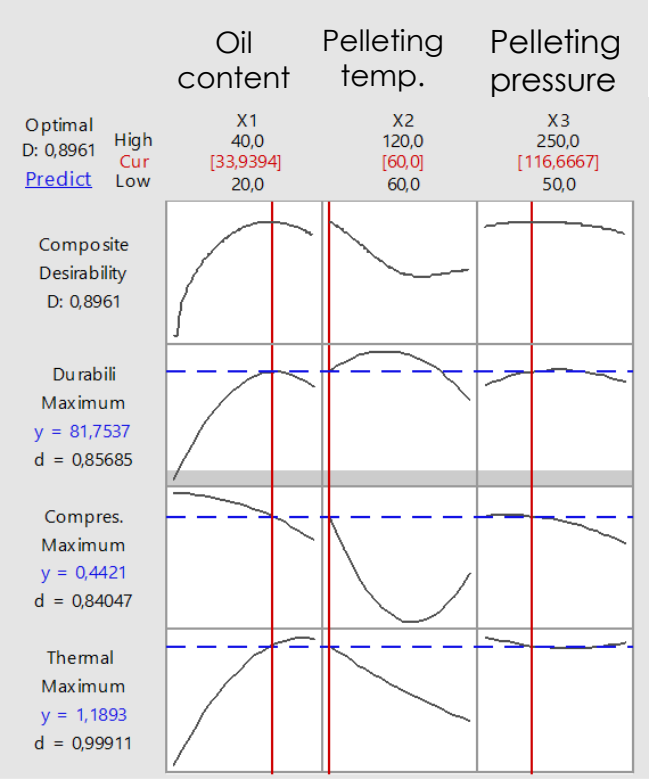
How can the system be optimized?



Feedstock: pinewood

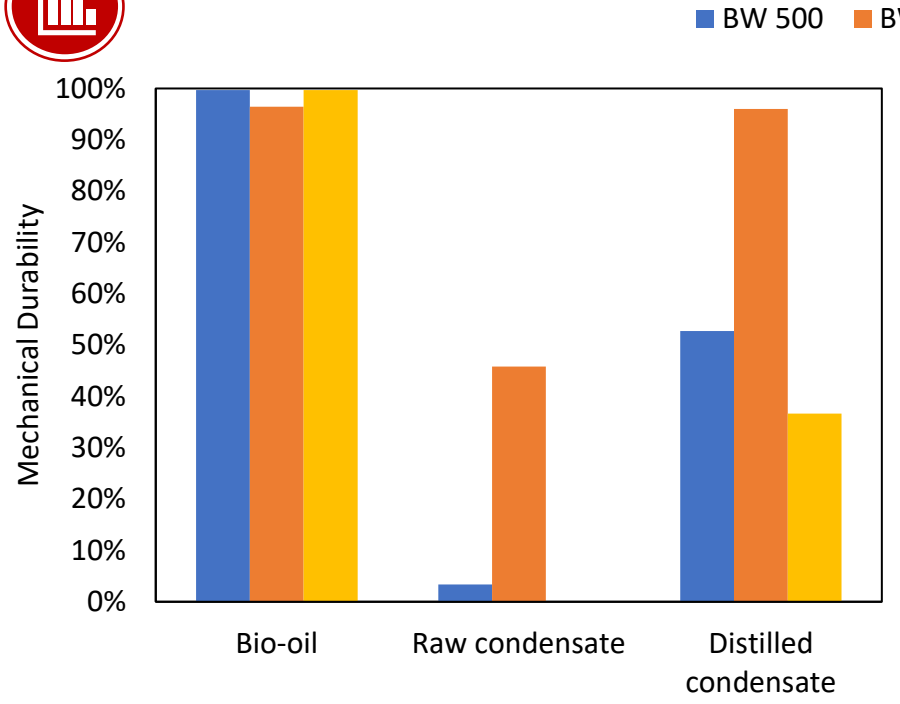
The following layout was analyzed and optimized by varying pelletization temperature, pressure and oil content

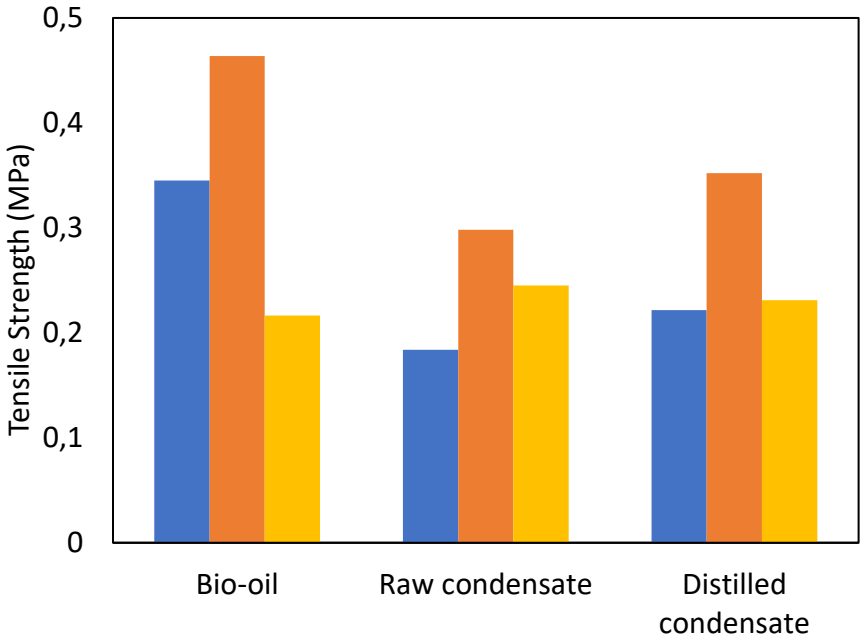


Optimal parameters by desirability function:

- Pelleting pressure: 117 MPa;
- Pelleting temperature: 60 °C;
- Oil content: 34%

Response	Predicted value	Experimental value	Deviation (%)
Compressive strength	0.44	0.42 ± 0.02	-5.26%
Thermal strength	1.19	1.07 ± 0.05	-11.50%
Mechanical durability (%)	81.75	83.20 ± 1.20	1.76%

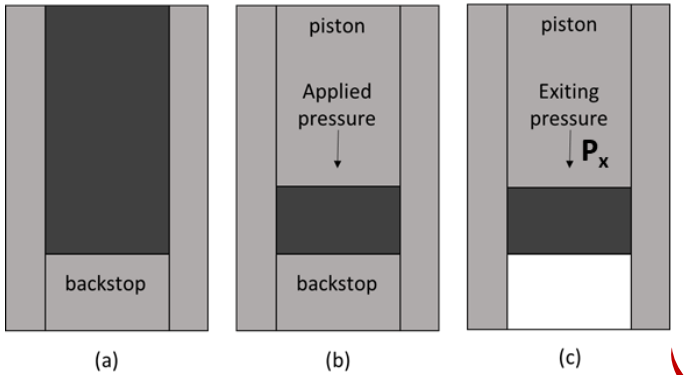




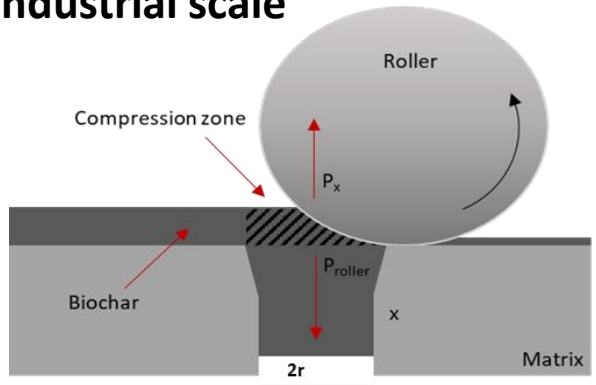
- Comparison softwood (spruce SW) and hardwood (birch BW)
- Comparison industrial oil (Carbofex, produced at 600 °C), with lab-scale pyrolysis oil produced at 500 ° C (raw and distilled at 120 °C)

How can biochar pelletization be upscaled?

From lab-scale…



… to industrial scale

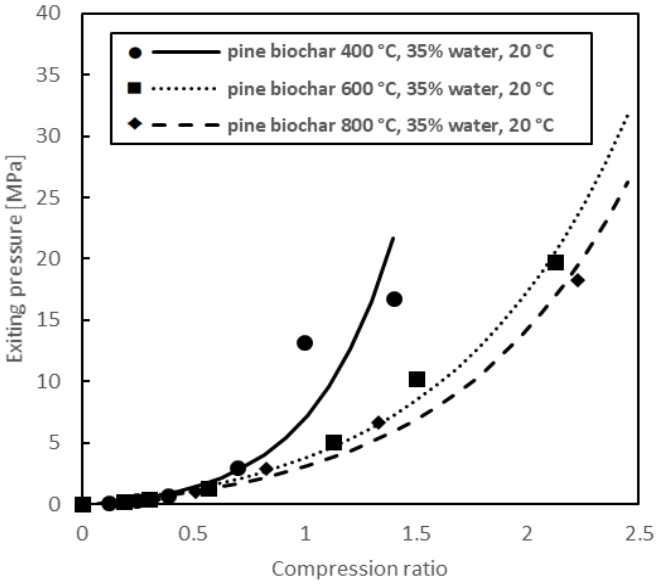


$$P_x(c) = U/J(e^{4Jc} - 1)$$

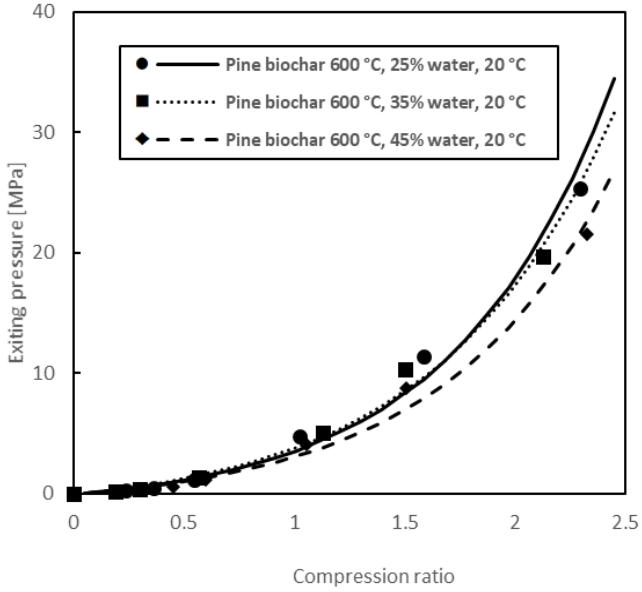
Holm et al., 2011

Relation between the pressure on the die P_x and the compression ratio **c** (x/2r)

Pyrolysis temperature effect



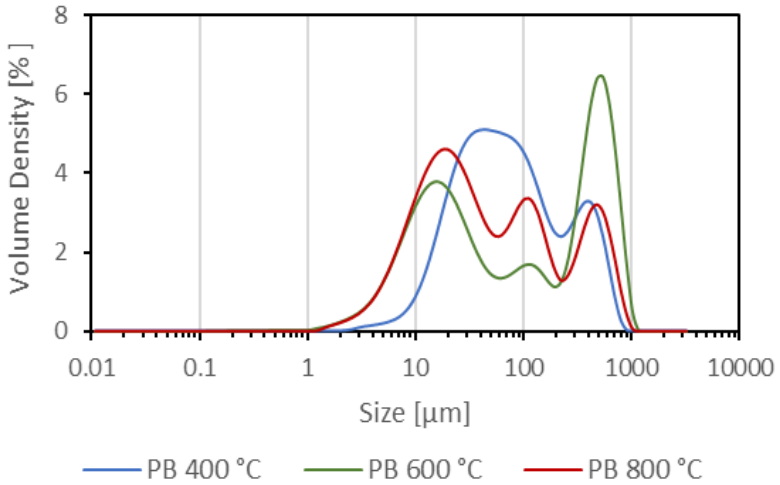
Water content effect



- Strong dependence on pyrolysis temperature
- Mild dependence on water (liquid binder) content

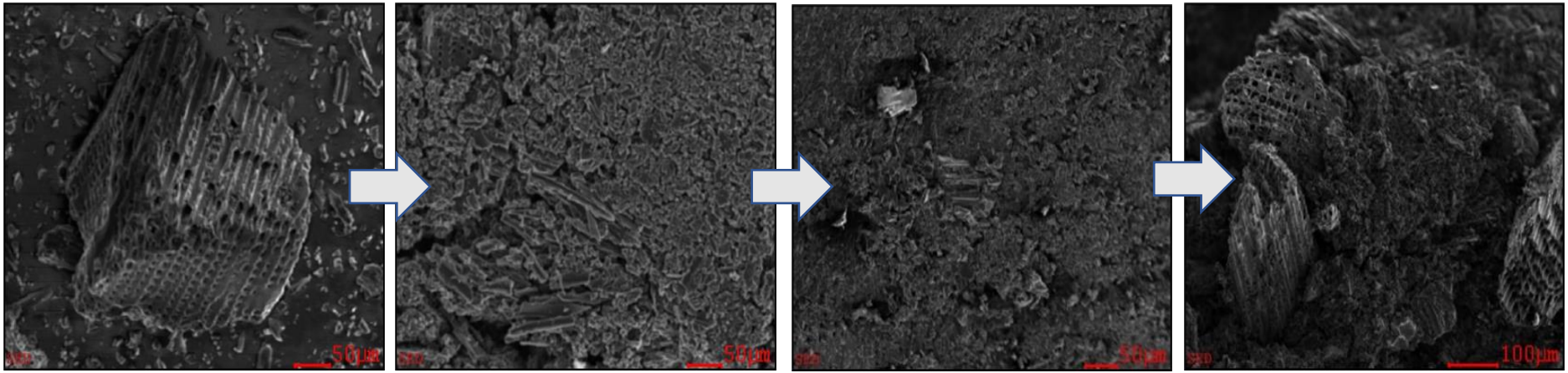
Pyrolysis temperature [°C]	400	600	800
Ultimate analysis			
C [% db]	74.1	85	94.3
H [% db]	4.4	2.6	1.3
N [% db]	-	-	-
O [% db]	21.5	12.4	4.4
Proximate analysis			
Fixed Carbon [% wb]	63.7 (±1.2)	85.2 (±0.5)	93.2 (±0.4)
Volatile matters [% wb]	34.2 (±0.6)	13.0 (±0.1)	4.3 (±0.3)
Ash [% wb]	1.3 (±0.1)	1.5 (±0.1)	1.5 (±0.1)
Moisture content [% wb]	0.8 (±1.0)	0.3 (±0.3)	1.0 (±0.3)
BET [m^2/g]	1.8	169.2	317.1
Porosity [cm^3/g]	0.003	0.115	0.140

Particle size distribution



Higher pyrolysis temperatures lead to:

- Higher fixed carbon
- Higher external surface
- Higher porosity
- Broader particle size distribution



Biochar

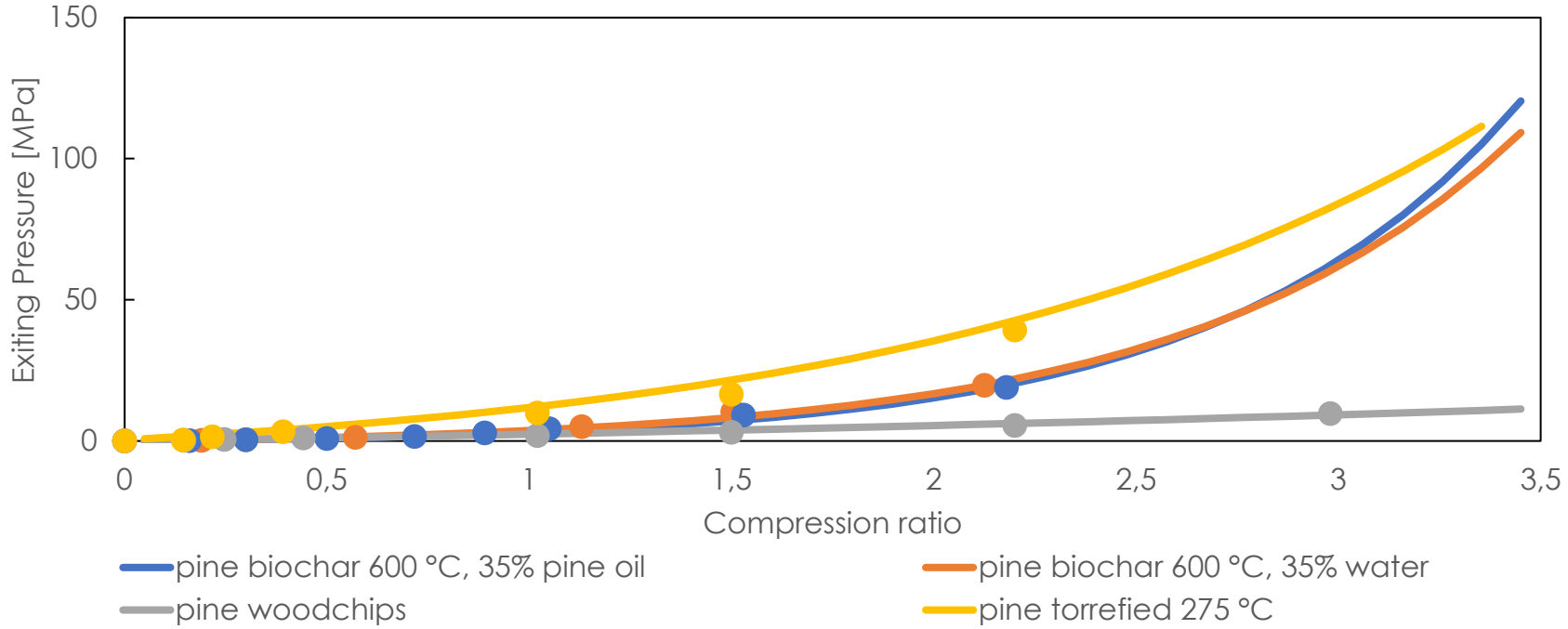
Biochar with pyrolysis oil

Biochar pellet

Biochar pellet after SHT

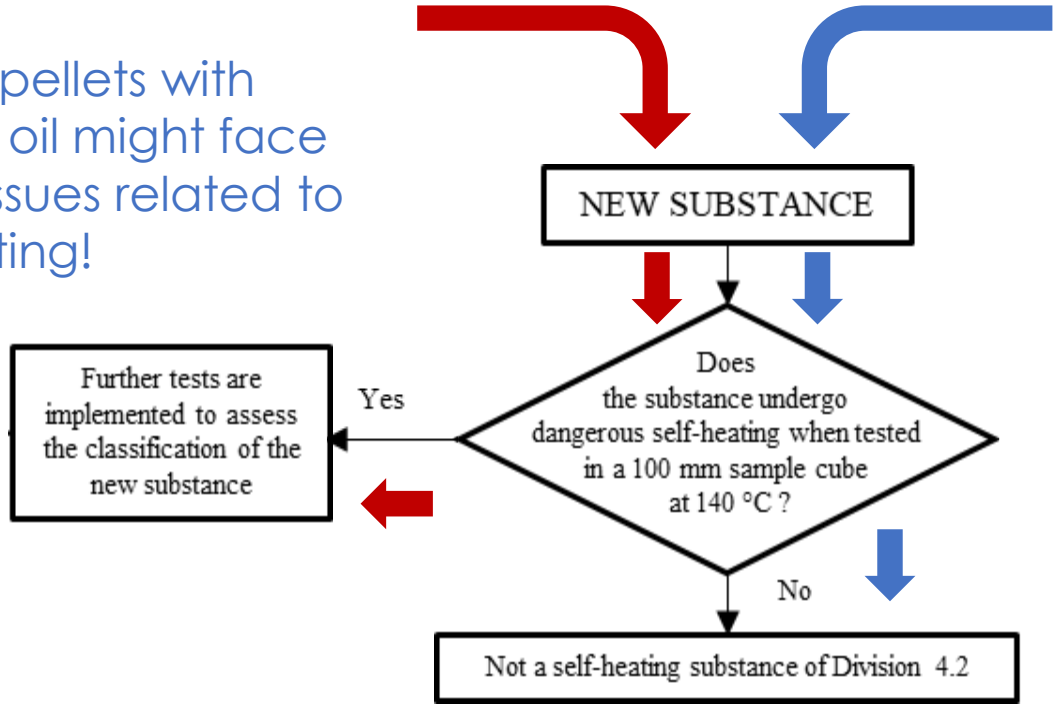
Previous benefits, together with pyrolysis oil as binder and second heat treatments, lead to superior biochar pellets

Comparison to pellets from untreated and torrefied wood as well as from biochar with pyrolysis oil as binder shows that biochar palletization might be industrially feasible



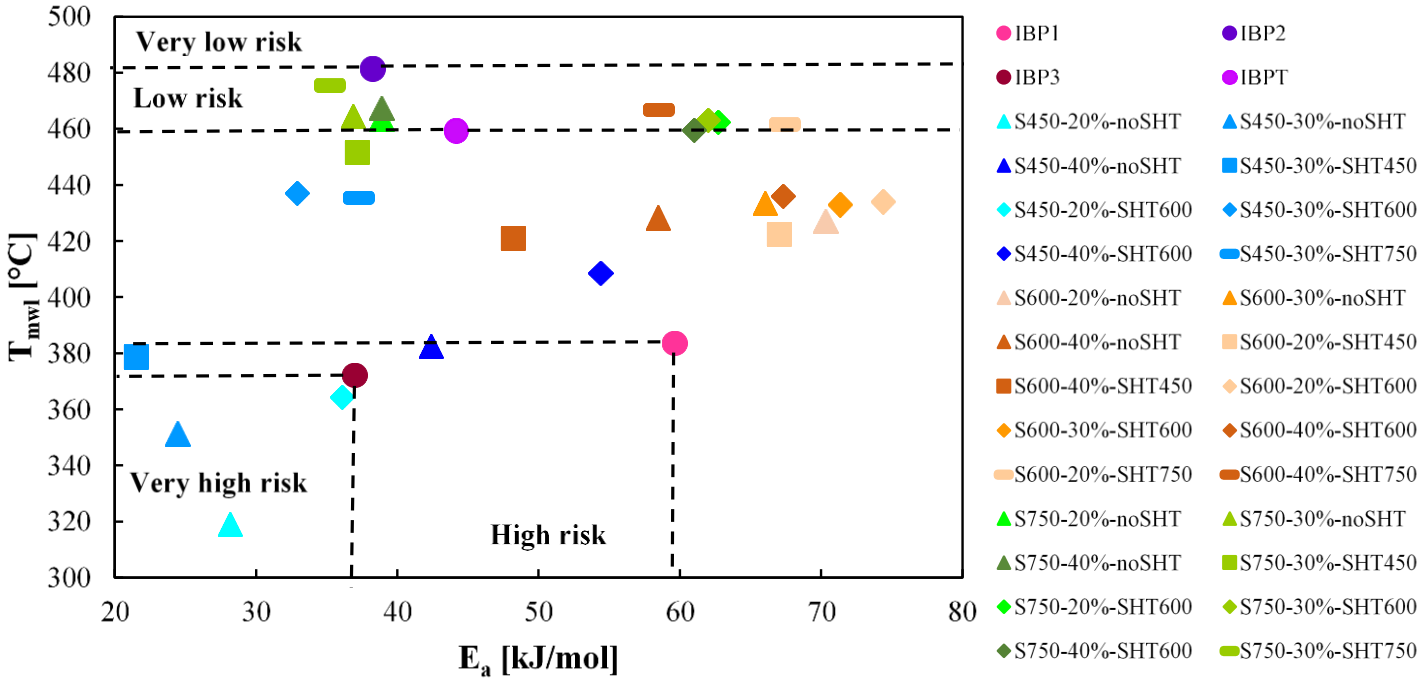
Can biochar pellets be safely stored and transported?

Biochar pellets with pyrolysis oil might face serious issues related to self-heating!



Apparently, not always!

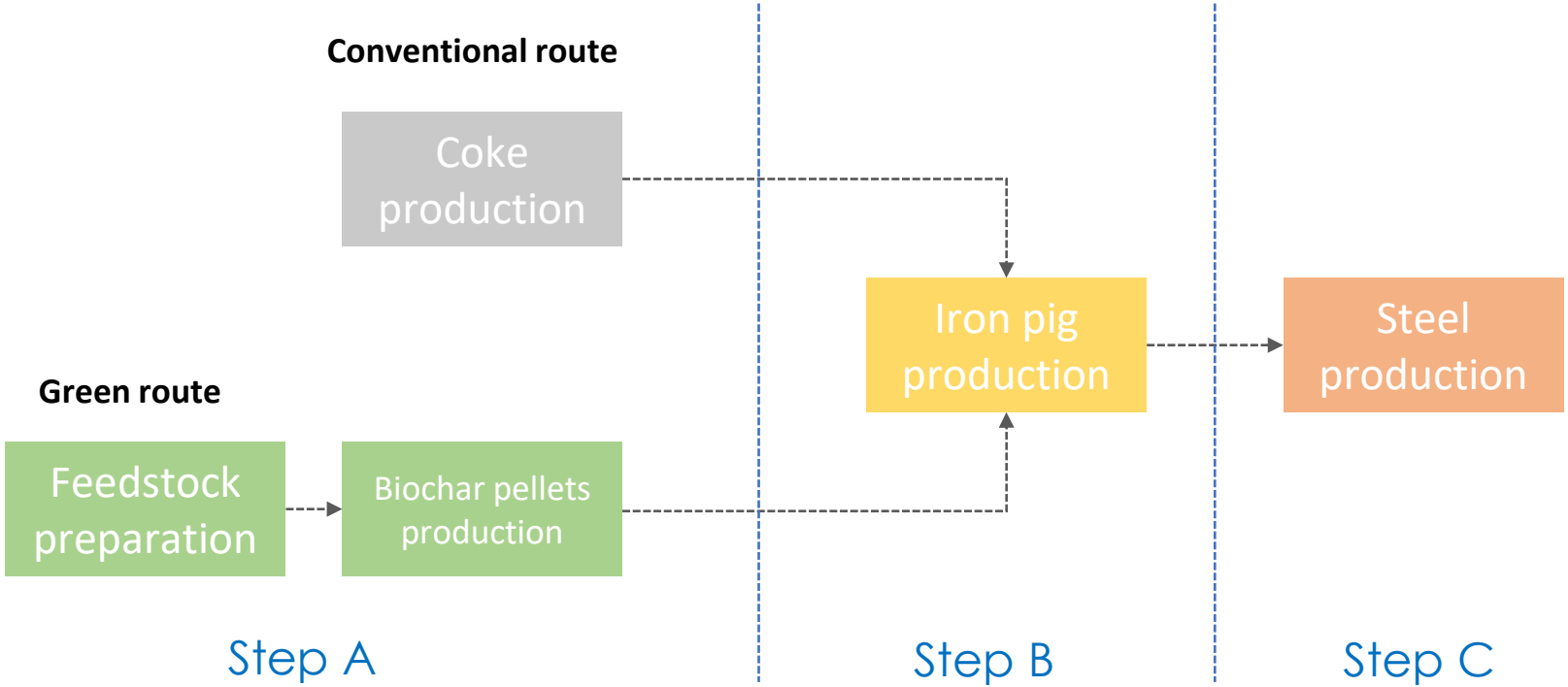
United Nations, 2009



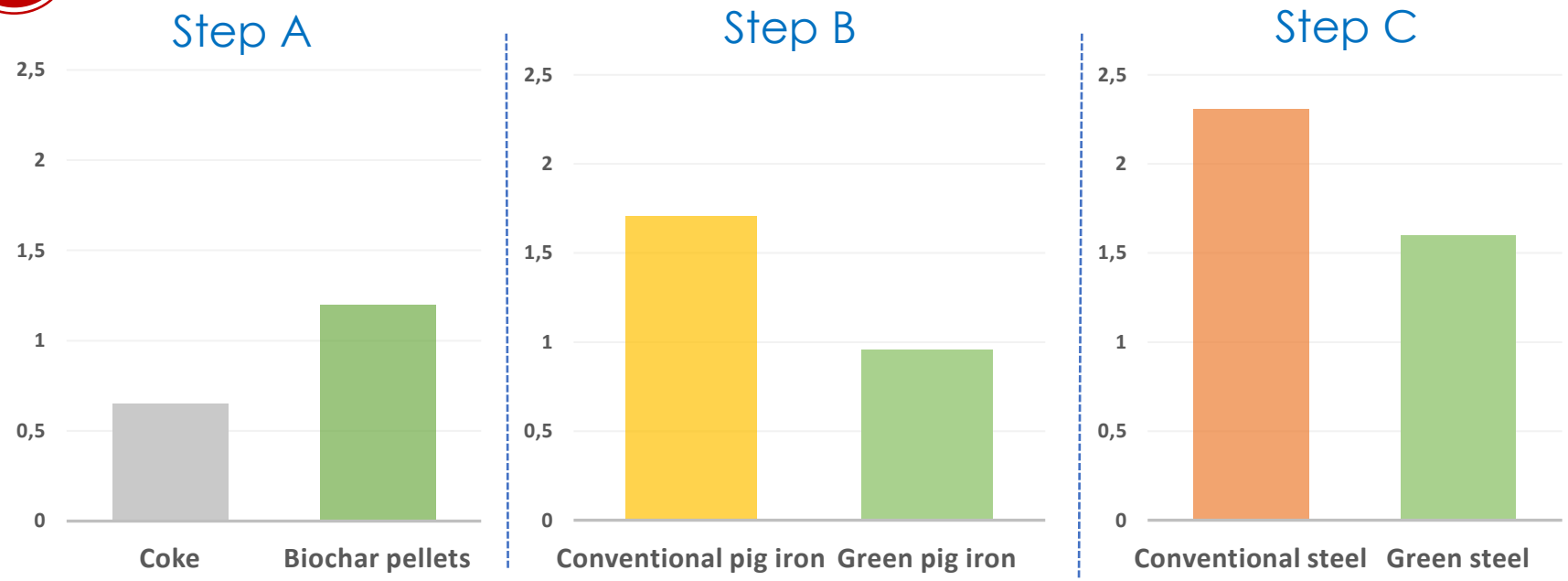
Self-heating issue can be avoided by adopting high temperatures treatments

Is this sustainable?

Life Cycle Assessment Biochar pellets application in steel production in EU



Carbon Footprint (kgCO_2eq/kg of step product)



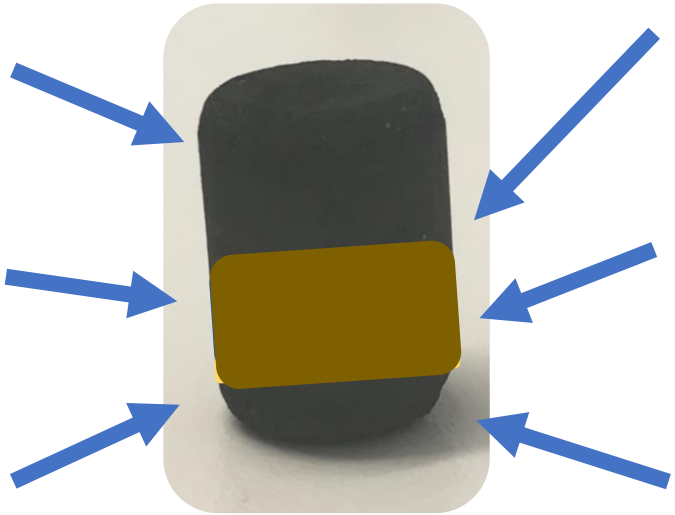
As rough and preliminary production, biochar pellets have higher carbon footprint. However, once applied in the metallurgical sector, the substitution leads to an overall reduction of ca. 30% emissions due to carbon neutrality

Conclusions…

1. Pyrolysis temperature strongly affects the quality, pelletization and post-production issue of the pellets.

2. A considerable amount of liquid binder is needed to guarantee densification. A small amount of hardener (e.g. lignin) is suggested.

3. Pyrolysis oil can successfully substitute other binders and water, with an optimum content of 30-35% wt. However it brings along self-heating problems.



4. A further heat treatment at high temperature increases the quality of the pellets with pyrolysis oil as binder and solve the self-heating issue.

5. The upscaled pelletization of biochar, if optimized, presents similar behavior to already established type of palletization feedstock (e.g. torrefied wood).

6. Biochar pellets with pyrolysis oil have a higher carbon footprint than coal or coke production. However when a potential metallurgical application is considered, the process with biochar pellets is greener

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TAKK!
More questions?
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