

Potential of Biochar for Carbon Capture and Utilisation in Soil Amendment

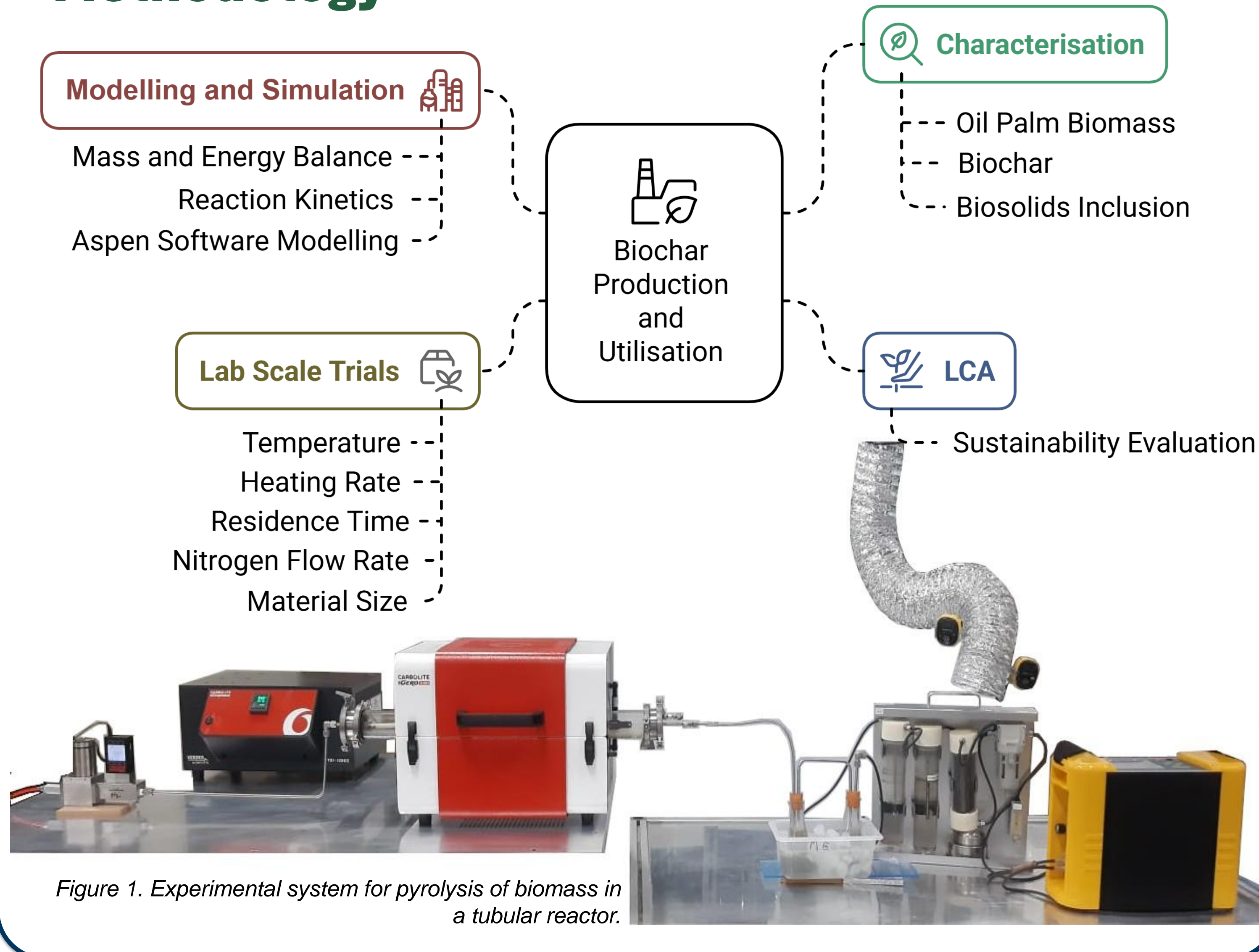
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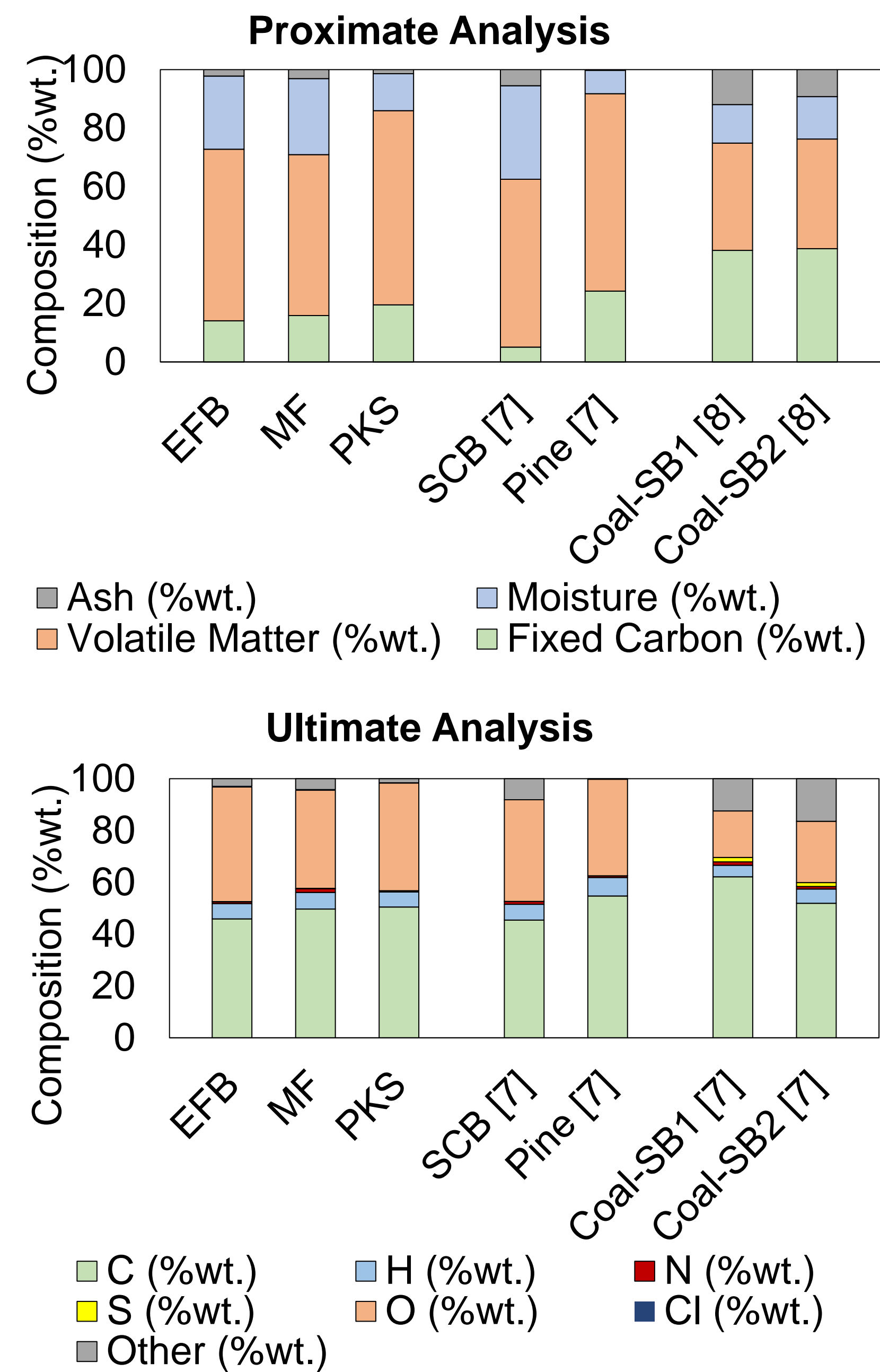
Introduction

Biochar is a carbon-rich solid derived from the thermochemical conversion of organic waste material or biomass under oxygen-limited conditions. This research focuses on addressing existing gaps in the production of biosolids-enhanced biochar (BEB) from oil palm residual biomass (OPRB), by firstly understanding the main characteristics of biochar, providing insights into its physicochemical properties and effectiveness in soil remediation and sustainable agriculture. The simultaneous production of biochar, bio-oil, and bio-syngas during its formation presents opportunities not only for carbon capture, utilisation, and storage (CCUS), but also as a promising avenue for sustainable energy production.

Methodology



Biomass Characterisation



The diversity of biochar properties varies according to both feedstock characteristics and process conditions.

- Higher VM/FC ratio results in higher yields of biochar and lower yields of gaseous by-products [1].
- A high carbon content leads to greater stability, a higher level of reactivity which makes the biochar more effective in capturing and removing impurities and contaminants, and a higher degree of porosity, which increases the surface area available for adsorption [1].

Figure 4. Proximate and ultimate analysis of empty fruit bunch (EFB), mesocarp fiber (MF), palm kernel shell (PKS) compared to sugarcane bagasse (SCB), pine wood and two sources of subbituminous coal (Coal-SB). Source: Daabon Group.

Thermochemical Process

There are different methods to produce biochar: direct combustion, torrefaction, pyrolysis, gasification, hydrothermal carbonization (HTC).

Pyrolysis temperature ranges between 300 to 900° C.

Increase carbon content (up to 90%)

Slow pyrolysis: considered as the main option to produce biochar with yield (~35%).

Heating rate 0.1 – 1° C/s
Residence time: minutes to hours

Fast pyrolysis: preferred for production of bio-oil with yield (~75%).

Heating rate 10 – 200° C/s
Residence time: seconds

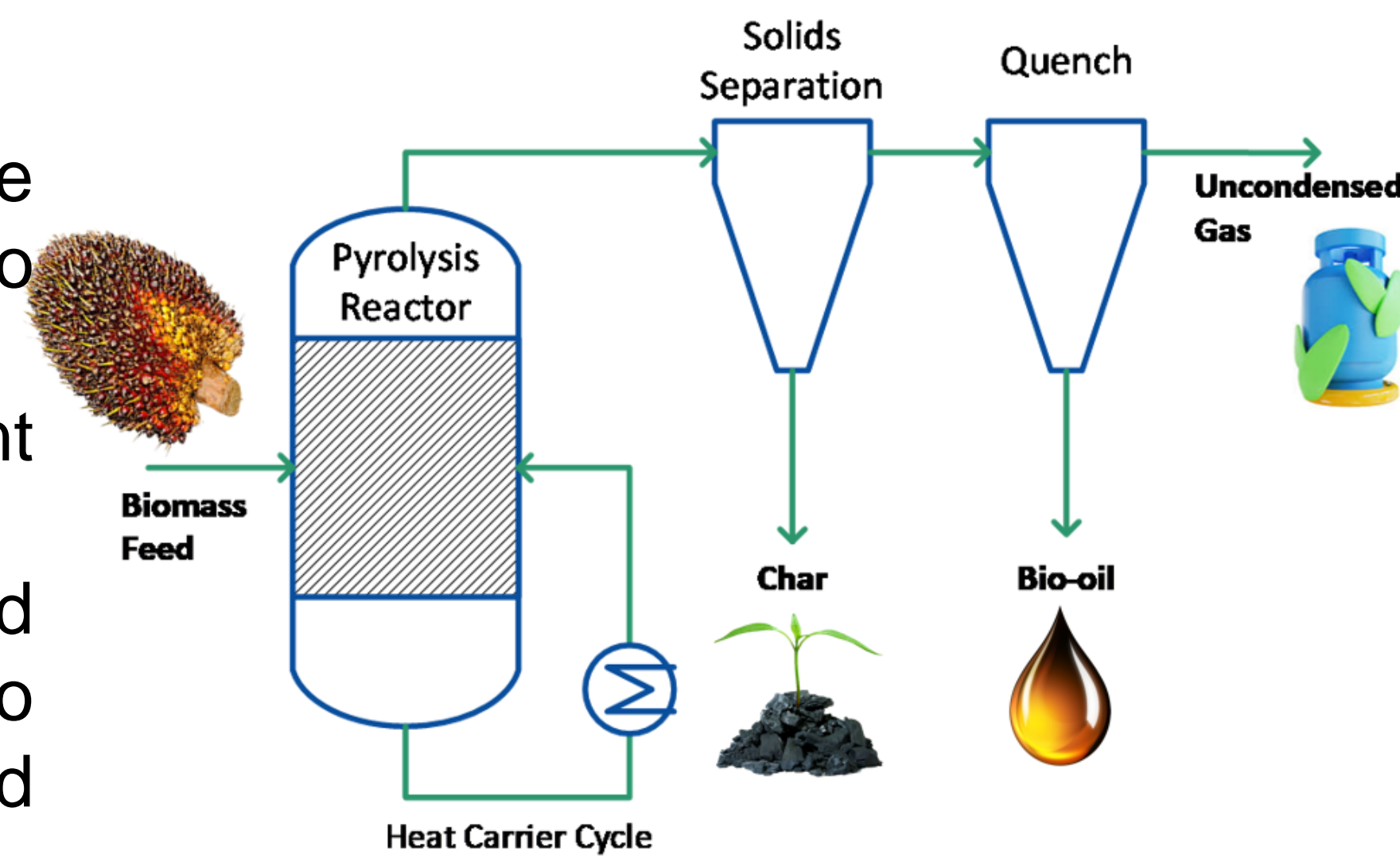


Figure 2. Representation of pyrolysis reactor and products: Biochar, bio-oil and bio-syngas. Source: IEA Bioenergy

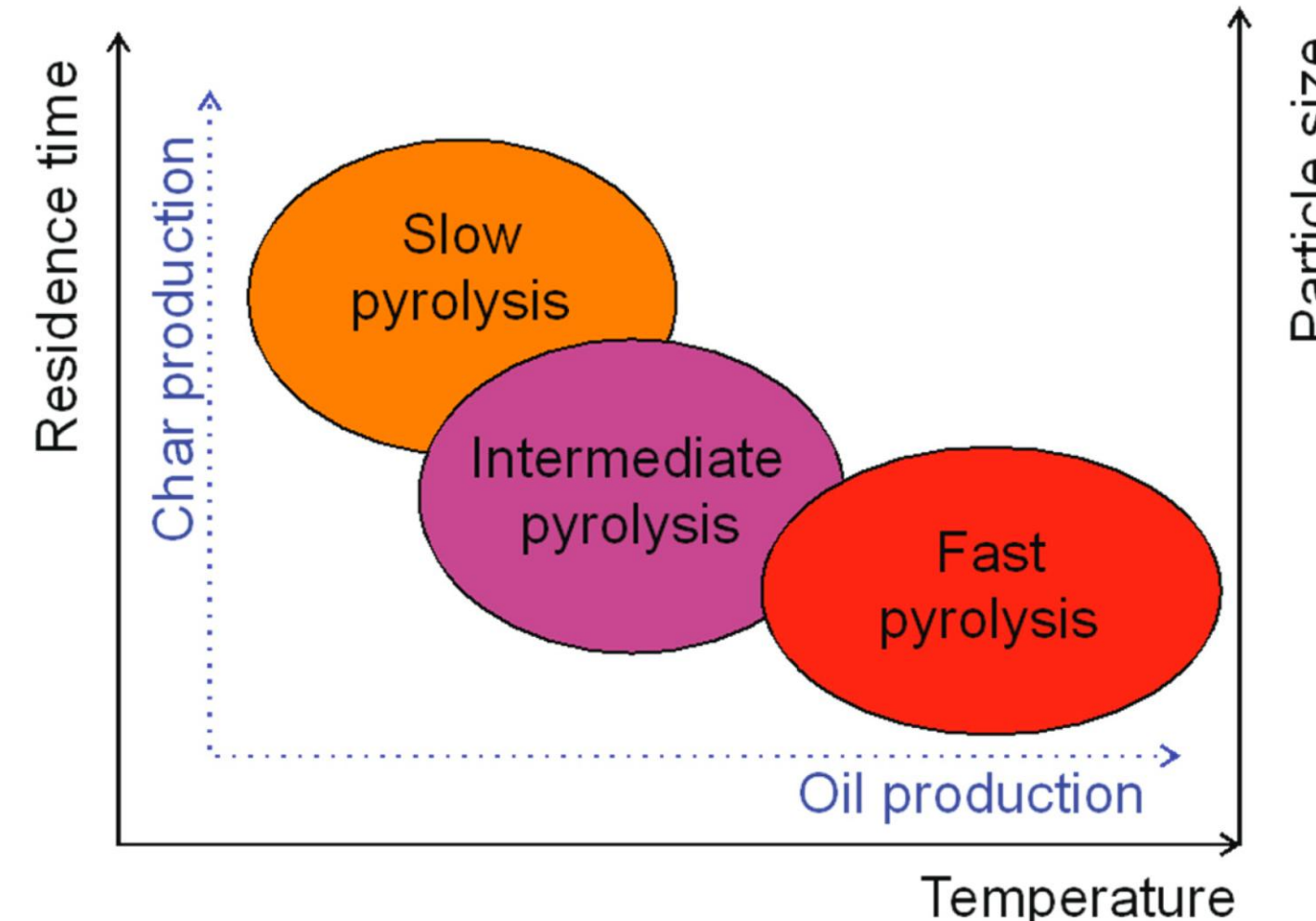


Figure 3. Influence of residence time, temperature and particle size in pyrolysis reaction. Source: Radoslaw Slezak et al. 2023

Biochar Characterisation

The following table summarises some of the main biochar properties to be use for CCUS [2]:

Property	Desirability	Impact
Elemental composition (C, H, N, O)	High C content Low O/C ratio Low H/C ratio	Indicator of carbonization, stability and amorphous carbon structure.
Specific surface area (SSA)	High	Adsorption capacity and water holding capacity
Porosity (ratio of volumes of voids by total volume)	High	Adsorption capacity and water holding capacity
Cation exchange capacity (CEC)	High	Retention of essential nutrients
pH	6 - 8	Acidity/Alkalinity balance
Water retention	High	Water holding capacity
Surface functional group	-	Capacity to adsorb organic and heavy pollutants

Future Work

Comprehensive and integrated modelling of the thermochemical process guiding towards the optimised process that will be validated through experiment.

Acknowledgment

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References

- [1] DOI: 10.1016/j.indcrop.2023.116767
[2] DOI: 10.1016/j.jaap.2021.105405