A fluidized bed separator for biochar – PYSOLO project

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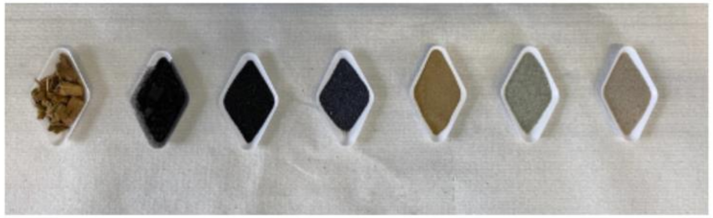
The PYSOLO project

- *Project Overview*

The PYSOLO project

- **PYSOLO** (PYrolysis of biomass by concentrated SOLar pOwer) offers a solution for both decarbonisation and defossilization by **combining concentrated solar power and biomass pyrolysis**.
- Thanks to the **use** of **solar heat in** the **pyrolysis** process, the **production of valuable products bio-oil, biochar and pyrogas can be maximized and the associated CO_2 emission minimized**.



The PYSOLO project

TYPE OF ACTION
Horizon Research & Innovation Action

BUDGET
4,900,000

PARTNERS
9

COUNTRIES
4

TERM
July 2023 – June 2027

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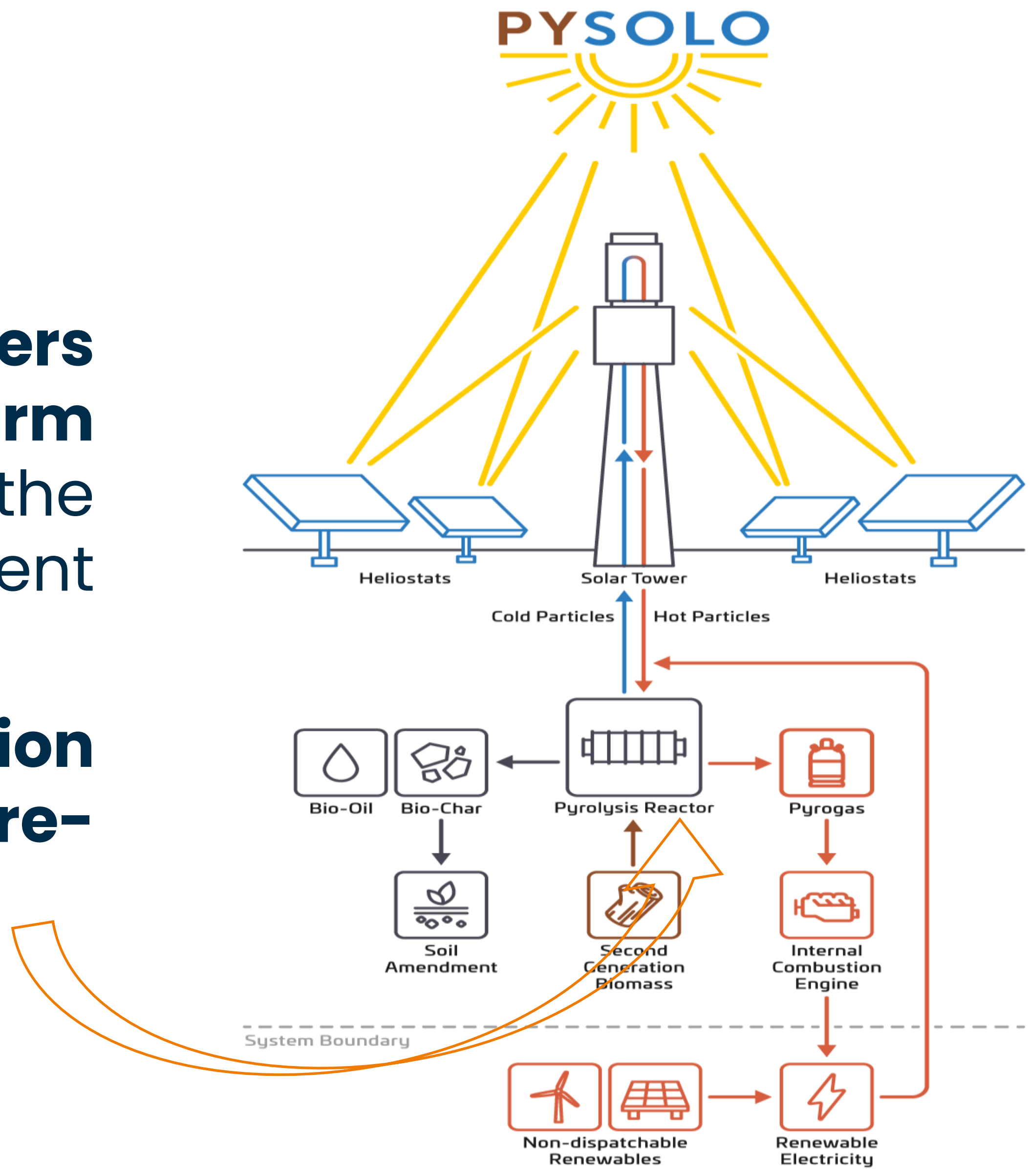
Biochar separator

- *Problem definition*
- *FB technologies*
- *Proposed appraoch*

Problem definition

- **PYSOLO** reactor **uses Particle Heat Carriers** (PHC), such as sand, to **facilitate uniform heating** and **thermal stability** for the process, thereby enabling the efficient conversion of biomass.
- **PYSOLO needs** for an **effective separation device** to **recover** valuable **biochar** and **re-use** the Particle Heat Carrier (PHC).



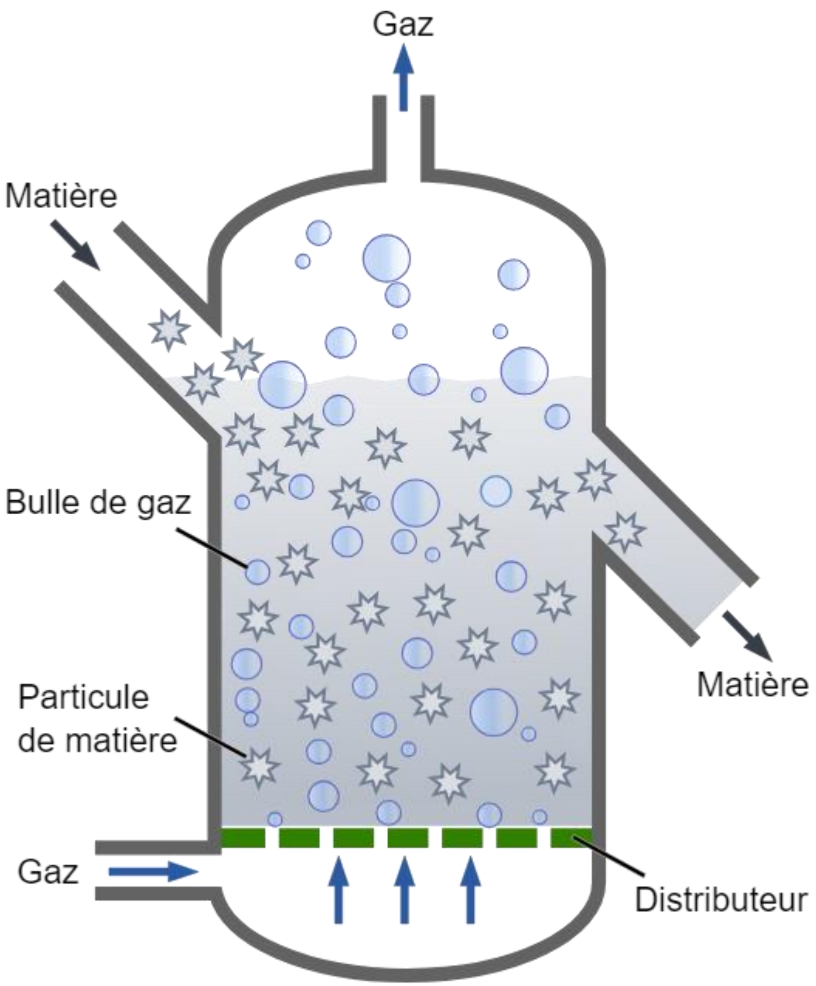
Opportunities of the Fluidised Beds

- **Particle separation technologies**, applied to fast pyrolysis, involve both **mechanical** and **non-mechanical** methods.

  - **Mechanical** methods like **centrifugation** and **vibrating screens**.
  - **Non-mechanical** approaches make use of well-proven technology like **fluidized beds.**

Opportunities of the Fluidised Beds

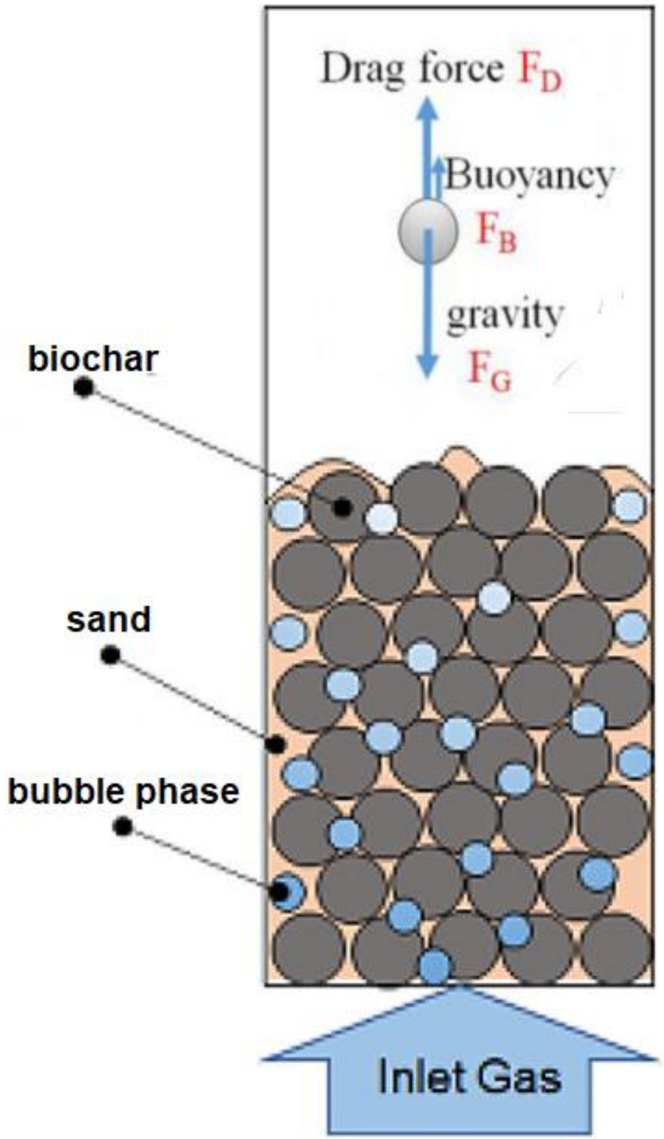
- **Fluidised beds** are a **proven technology**.
- It **can handle hot streams** of fluids and particle with **high reliability**.
- Scientific literature offers a **sound body** of **knowledge** for supporting the development of new concept and designs.



Key Parameters

- **Umf**: determine the condition at which the particles are suspended in the fluid and are free to move. The **behavior** of the **mix** resembles the one of a **fluid**. The "minimum fluidization velocity" (Umf)is a function of the shape, size and density of the particles and the viscosity and density of the fluid.

- **Ut**: The terminal velocity of single particle is a characteristic parameter in fluidized beds, which represents the **velocity** of a **particle whose weight** is **balanced** with the **drag** force from its surrounding viscous fluid.



Experimental formula

$$Umf = \frac{\mu}{Dp.\rho f}\left[\sqrt{22.1^2 + 0.0354\frac{Dp^3.\rho f(\rho p - \rho f)g}{\mu f^2}} - 22.1\right]$$

$$Umf = 1.78\left(\frac{(1-\varepsilon).\rho f.g.Dp^3(\rho p - pf)}{\mu^2}\right)^{0.14}$$

$$Umf = \left(\frac{\rho p - \rho f}{\rho f}\right)^{0.5}.\left(\frac{18\mu}{\rho f.Dp}\right)^{0.5}.Dp^{1.14}$$

$$Umf = \left[\left(27.3^2 + 0.0434\frac{Dp^3.\rho f.(\rho p - \rho f)g}{\mu f^2}\right)^{0.5}\right]\frac{\mu f}{Dp.\rho f}$$

$$Umf = \frac{Dp^2.(\rho p - \rho f)g}{1659\mu f}$$

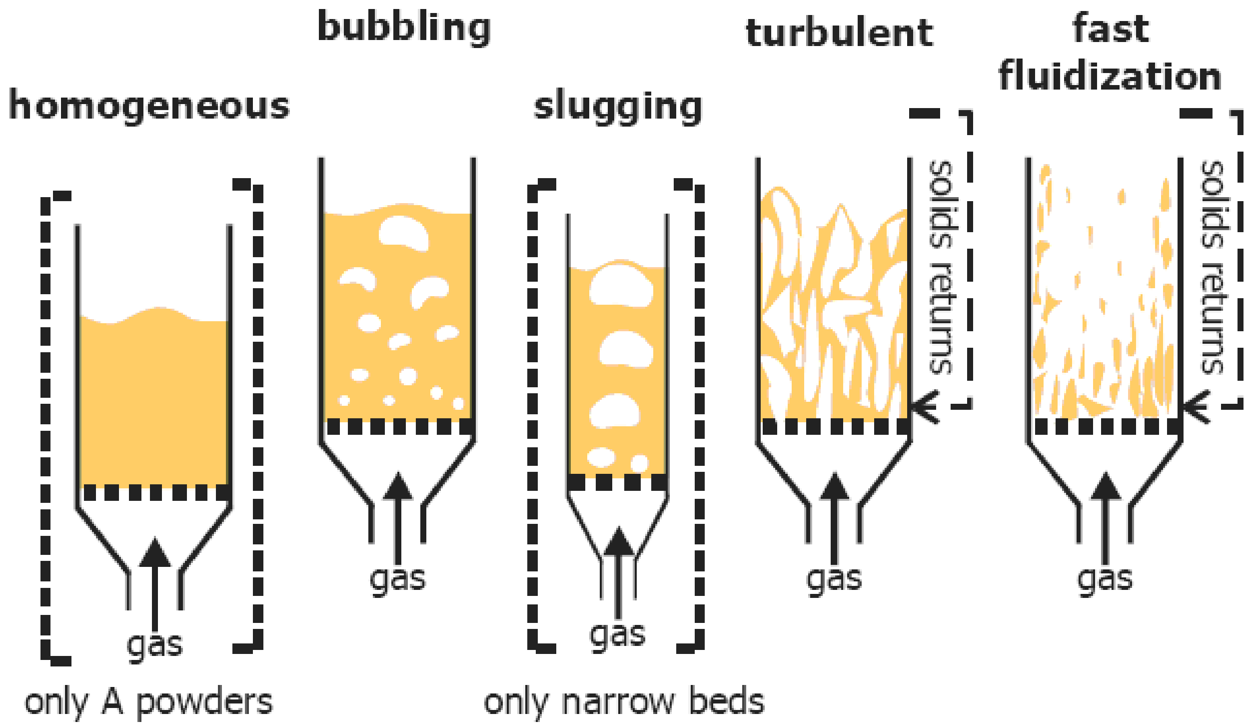
Theoritical formula

$$Umf = \frac{\varepsilon.(\rho p - \rho f).g.Dp^2}{180.(1-\varepsilon).\mu f}$$

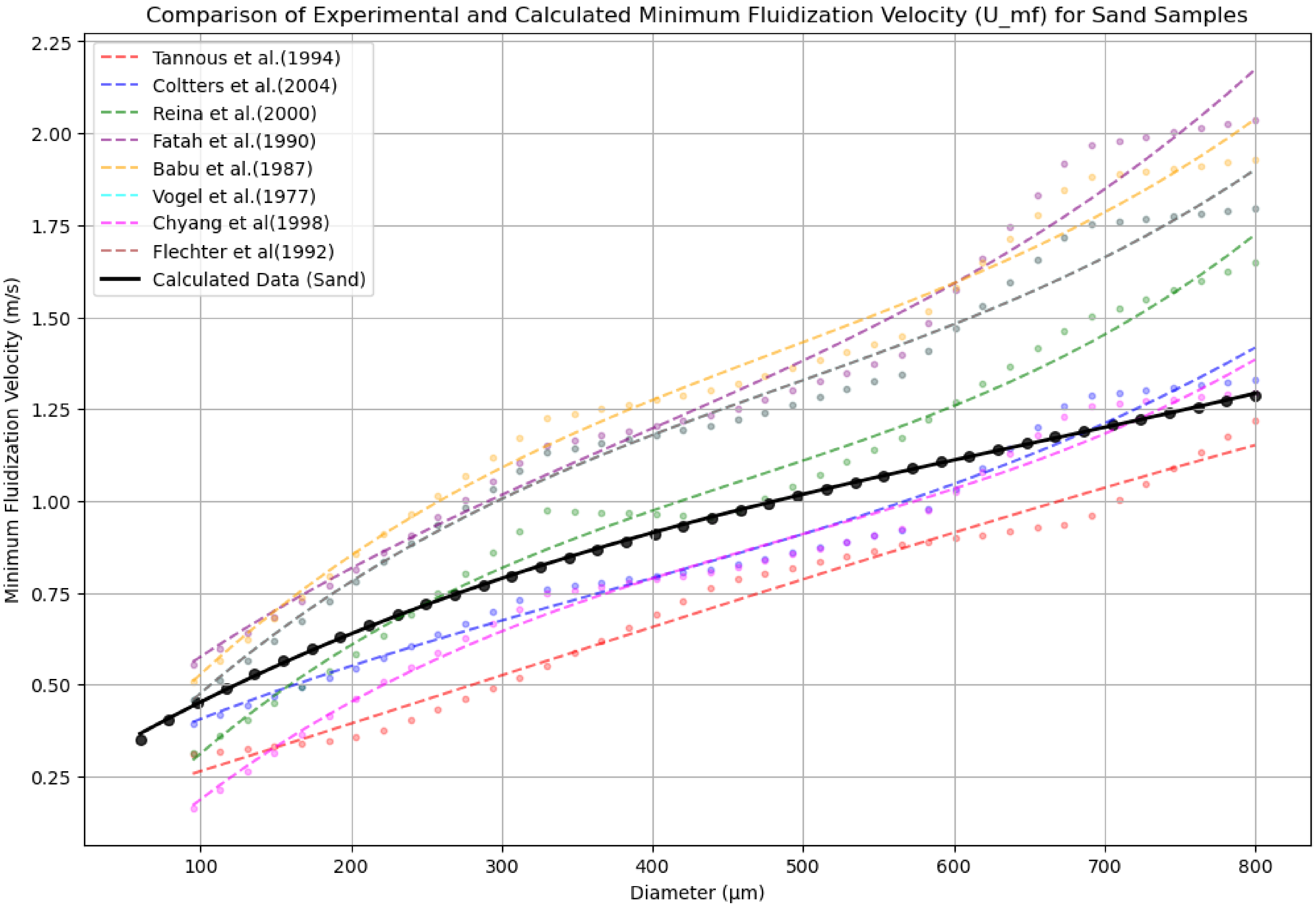
$$Umf = \frac{\varepsilon^3(\rho p - \rho f).g.Dp^2.\emptyset_s{}^2}{150.(1-\varepsilon).\mu f}$$

$$Umf = \sqrt{\frac{\emptyset_s.D_p.(\rho_p - \rho_f).g.\varepsilon^3}{1.75.\rho_p}}$$

Correlative approach



Validation against the literature of **Umf for sand**



Data:

Sand: 95um<d<800 um

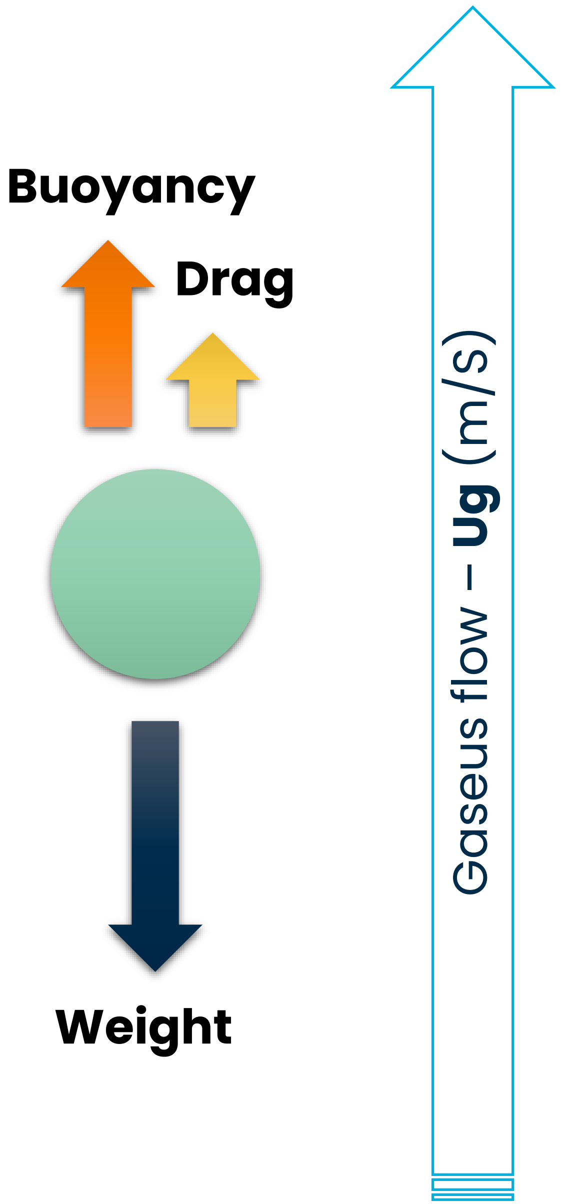
Density: 2000-2650 kg/m3

Proposed approach

- **Ut** it represents the **flow speed** at which the **three main forces balance** and a **steady state** can be considered for a **particle**.
- The core **idea** of this study is to determine the **Ut above which Biochar** is **transported** to the **top** of the separator, **while** the **second phase** (e.g. sand) **not** as its Ut_ph2 is higher.

$$U_{mf} < Ut_{ph1} < U_g < Ut_{ph2}$$

- **Important** to **notice** that **particle side distribution complicate** the **identification** of the **Ut**.



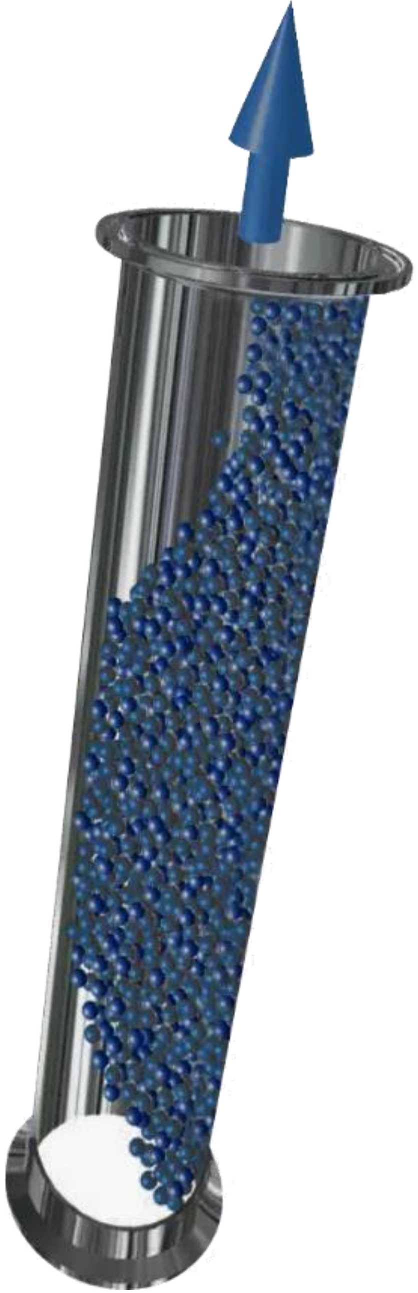
Proposed approach

Definition of the **physico-chemical characteristics** of the **two solid phases**

Determination of the **minimum fluidisation velocity** *Umf*

Determination of the **terminal velocity** *Ut* for the **two** phases.

Selection of an **appropriate** *Ug* *(Ut)* to **maximise separation efficiency**



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Particle Heat Carriers

- *PHC in PYSOLO*
- *Phase characteristics*

PYSOLO Particle Heat Carrier

- **PYSOLO** project partner DLR **just started** the **characterization campaign** to **identify** the best **particle heat carrier** for biomass pyrolysis.
- **Four materials** will be selected among several; for the present study the following materials have been considered:

sand

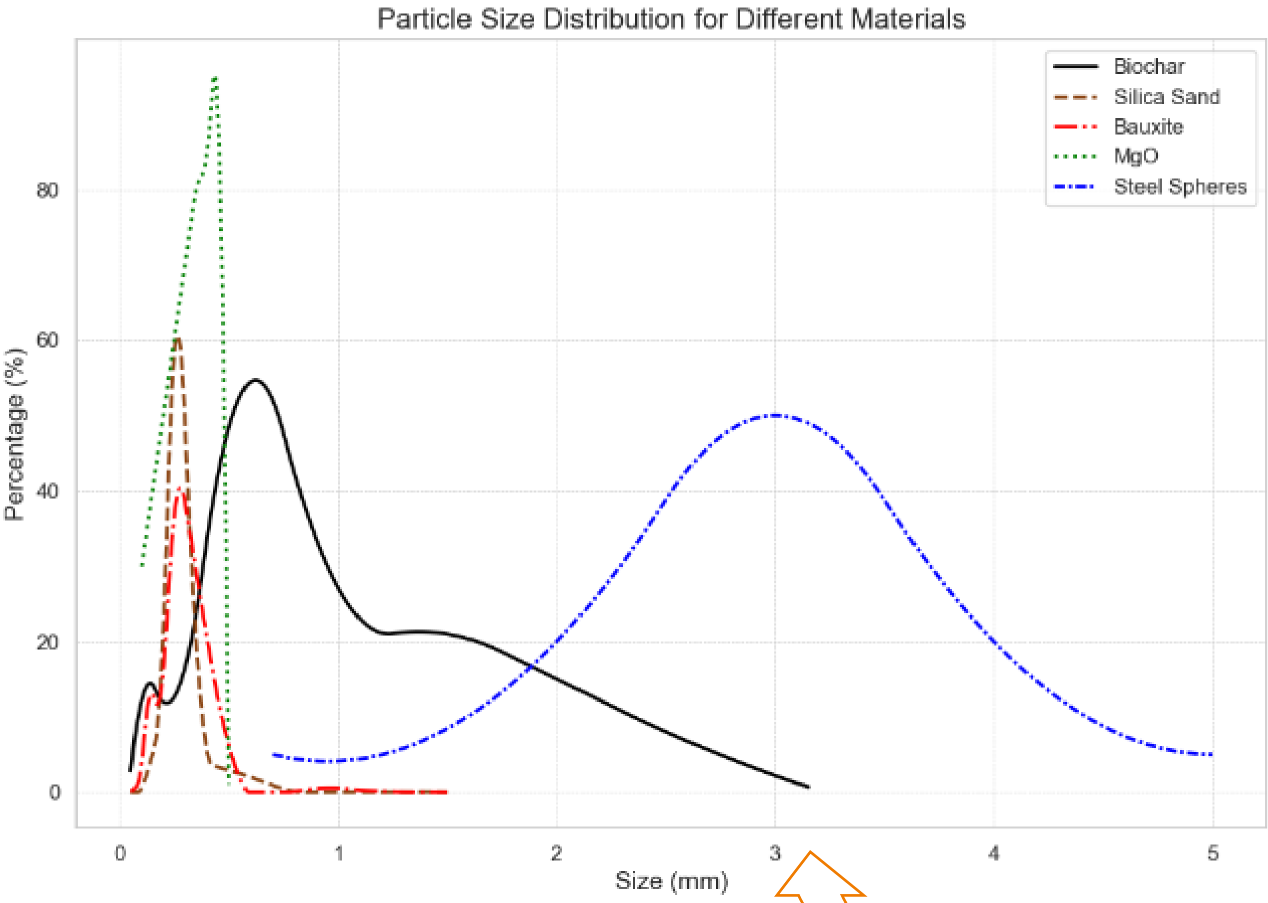
steel

Magnesium oxide

Bauxite

Biochar

Particle distribution in real PHC



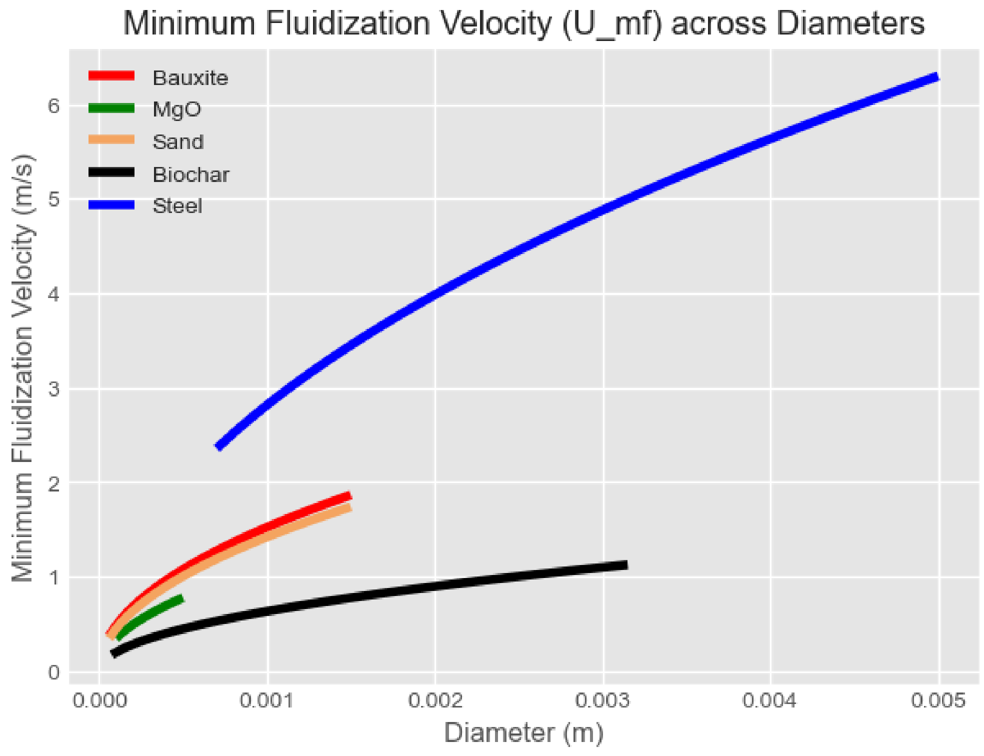
Info recieved from RE-CORD

Material	Diameter (mm)	Particle density (Kg/m³)	Absorptance	Thermal conductivity (W/m·K)	Specific heat capacity (J/Kg·K)
Biochar	0.075-3.15	400	n/a	0.2-0.3	600-1500
Sintered Bauxite	0.06-1.5	2300	0.89-0.93	2	1175-1275
MgO	0.1-0.5	1200	0.90	48.4	955
Sand	0.06-1.5	2000	0.44-0.66	1.4	740-1175
Steel spheres	0.7-5	7860	Depends on polishing and heat treatment	16	540

Fluidization minimum velocity

The **Umf** has been **calculated** for all the **selected materials**.

This is an **important** parameter to **verify** the **preposed** results **against** the exisitng **literature**.



Terminal Velocity

The calculation of the terminal velocity considering the **steady state** equilibrium among the drag force, buoyancy and gravity, as represented.

$$F_d = \frac{C_d U^2 \rho A_p}{2} \quad , \quad F_b = V \rho g, \quad V = \frac{m}{\rho_p} \quad , \quad F_g = mg$$

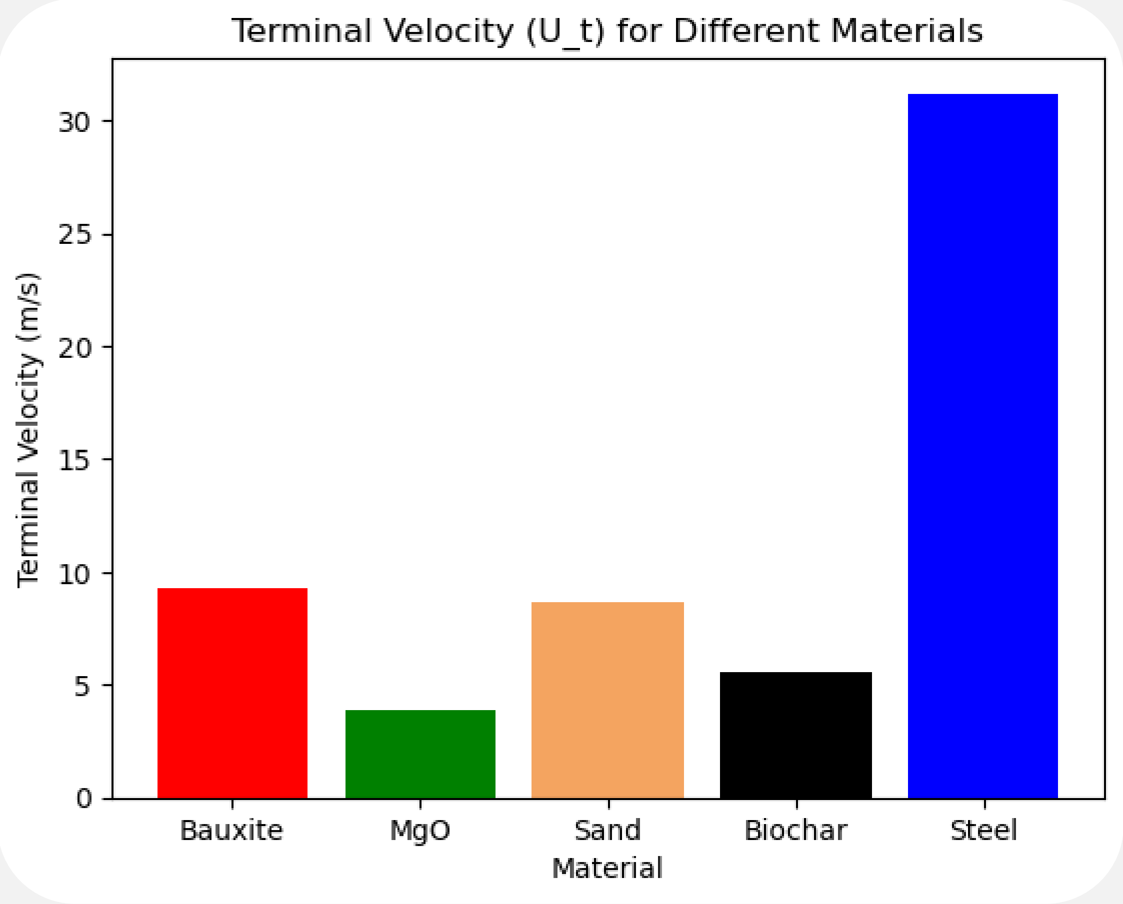
$$\Sigma F = F_g - F_b - F_d \qquad (1)$$

$$m \overset{0}{\cancel{\frac{du}{dt}}} = mg - \frac{m \rho g}{\rho_p} - \frac{C_d U^2 \rho A_p}{2} \qquad (2)$$

$$U = \sqrt{\frac{2mg\left(1 - \frac{\rho}{\rho_p}\right)}{C_d \rho A_p}} \quad (3), \quad A_p = \frac{\pi D_p^2}{4} \quad V = \frac{\pi D_p^3}{6}$$

$$U_t = \sqrt{\frac{4 g D_p (\rho_p - \rho)}{3 C_d \rho}} \qquad (4)$$

Archie-Kenney equation



Results and discussion

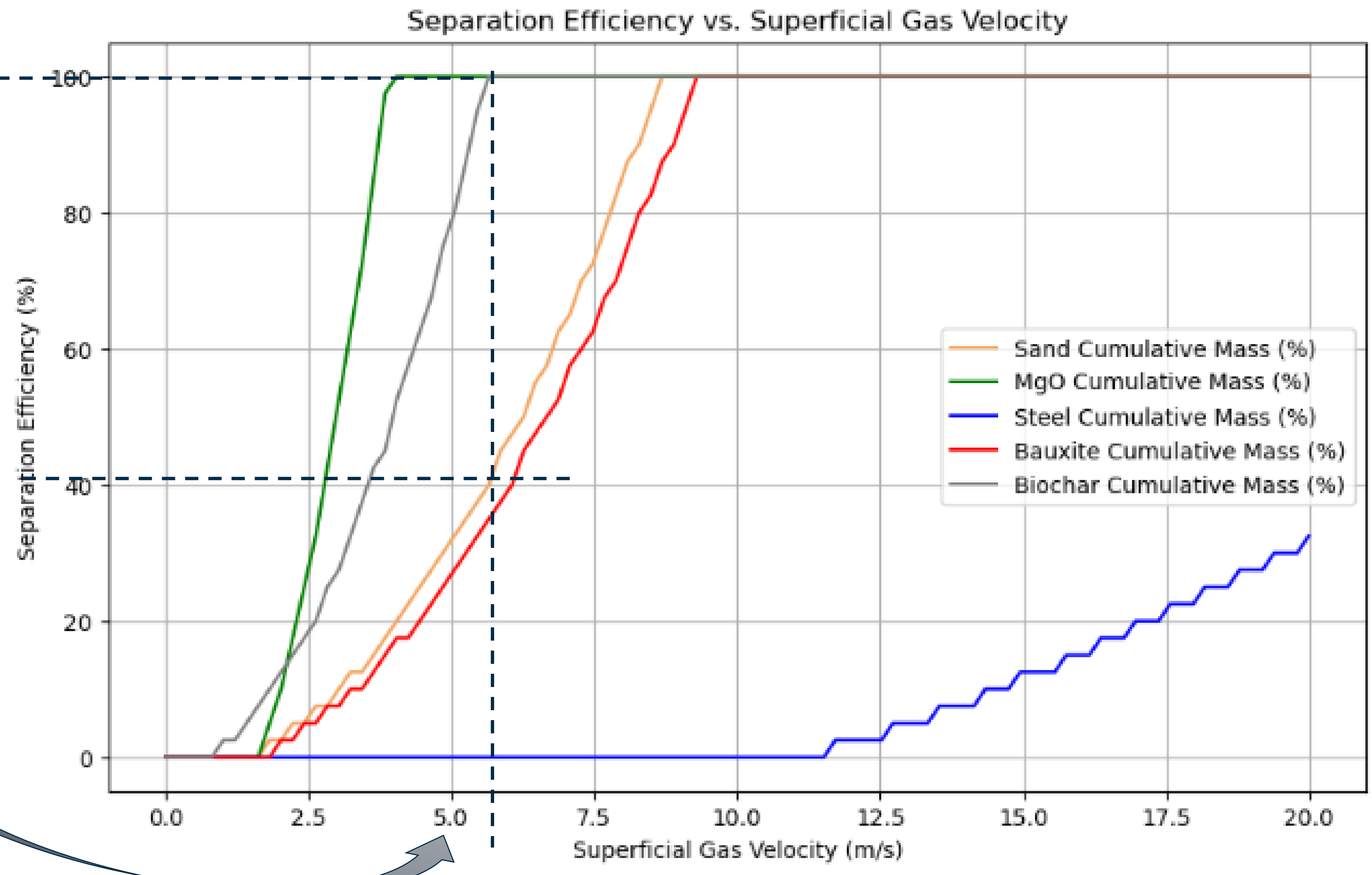
- *Main results*
- *Next steps*

Main results

100% Biochar collected

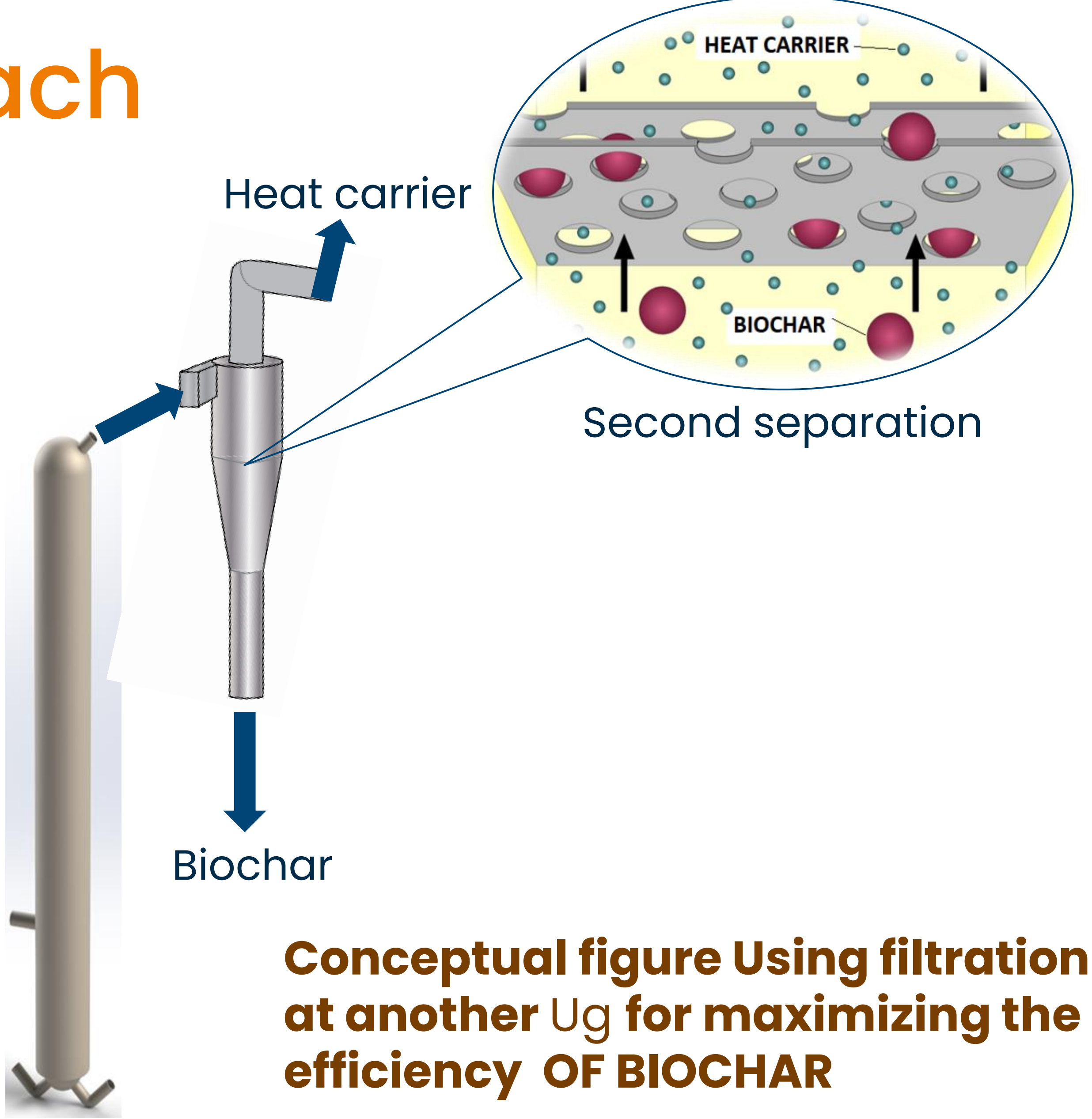
Still 40% sand in the collected phase

Target Ug velocity



Multiple-steps approach

- A **second** separation **step** may be used to **collect** the **residual part** of the **sand,** transported together with the biochar.
- This stage may be operated at different Ug, to increase the biochar separation rate.



Conceptual figure Using filtration at another Ug **for maximizing the efficiency OF BIOCHAR**

Experimental validation and further optimisations

- An **experimental test bench** is under **consideration.**
- **Goal** of experimental testing would be to provide **validation** to the proposed approach.
- **Optimise operative parameters** as function of the **real particle size distribution**.
- Provide **optimization options** for design a full-scale equipment for the **PYSOLO** project.

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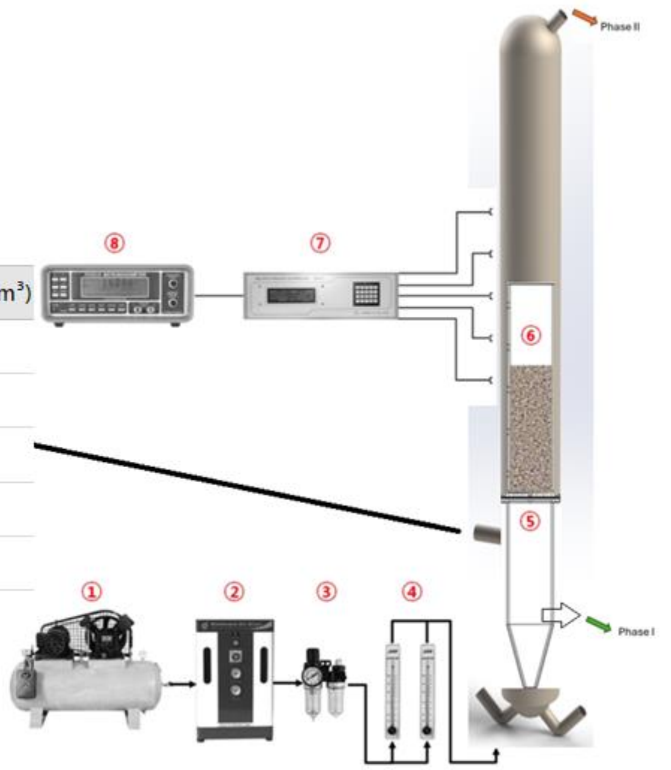

pysolo.eu

PYrolysis of biomass by concentrated SOLar pOwer

Funded by
the European Union

Thanks for your attention!

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