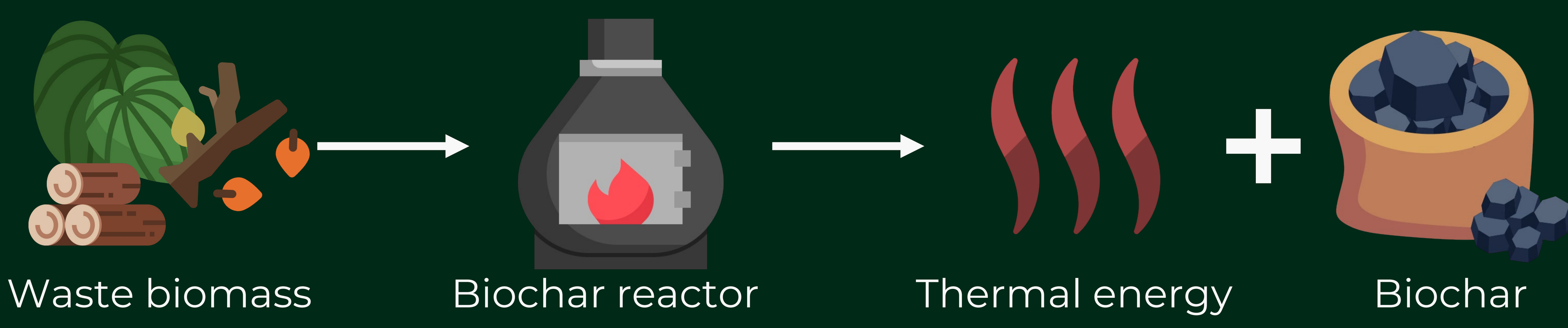
CHAR:ME: biochar and biomass-derived waste products as sustainable and safe domestic fuel

Riccardo Caraccio[1], **Andrea Scialabba**[2,3], **Lotte Capel**[1], **Guido Scaccabarozzi**[4], **Davide Caregnato**[5], **Daniele Della Toffola**[5], **Carlo Ferrato**[5], **Tiziano Faravelli**[1], **Mauro Bracconi**[6], **Andrea Turolla**[3], **Matteo Pelucchi**[1]

[1]Department of Chemistry, Materials and Chemical Engineering, Politecnico di Milano, Italy,
[2]Kukula ONLUS, Italy,
[3]Department of Civil and Environmental Engineering, Politecnico di Milano, Italy
[4]Demetra Onlus
[5]Blucomb SRL, Italy,
[6]Departement of Energy, Politecnico di Milano, Italy,

The CHAR:ME project (**Polisocial Award 2022**) aims to propose a **sustainable alternative to conventional charcoal production** in Sub-Saharan Africa, particularly **Madagascar**. The expanding charcoal industry contributes to deforestation and poses health risks, intensifying climate change impacts in a region with limited resources to address these challenges [1].





The current cookstoves utilize charcoal produced from dirt kilns

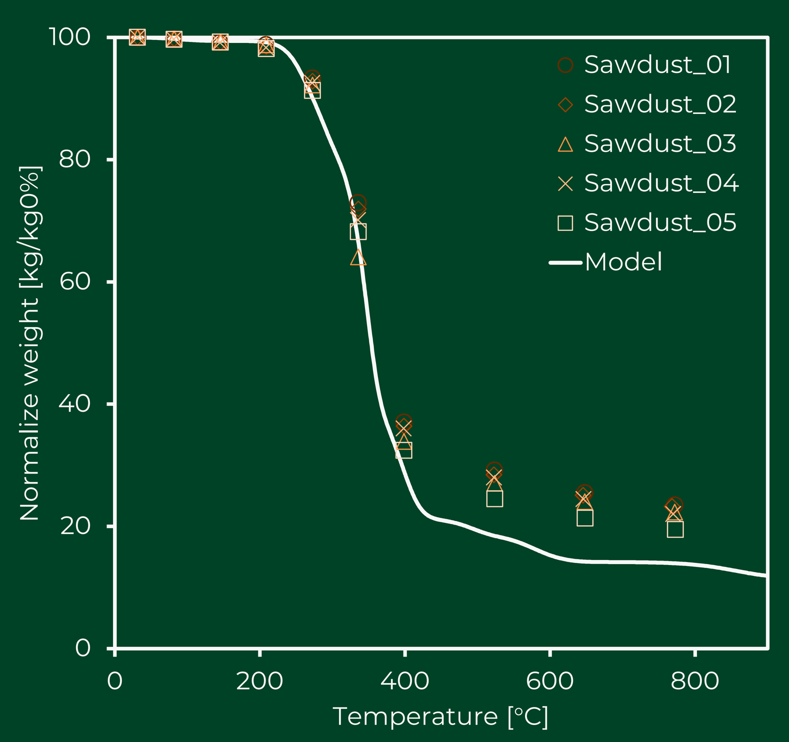
The goal is to design a **Top-Lift-Up-Draft (TLUD) pyrolytic stove** able to efficiently convert **briquettes of waste biomass** into biochar Instead of using virgin biomasses.

Collection and experimental characterization (TGA and C/H/O/N) analysis was carried out for **15 tree and 5 sawdust samples** from the local carpentries to identify the best available source.

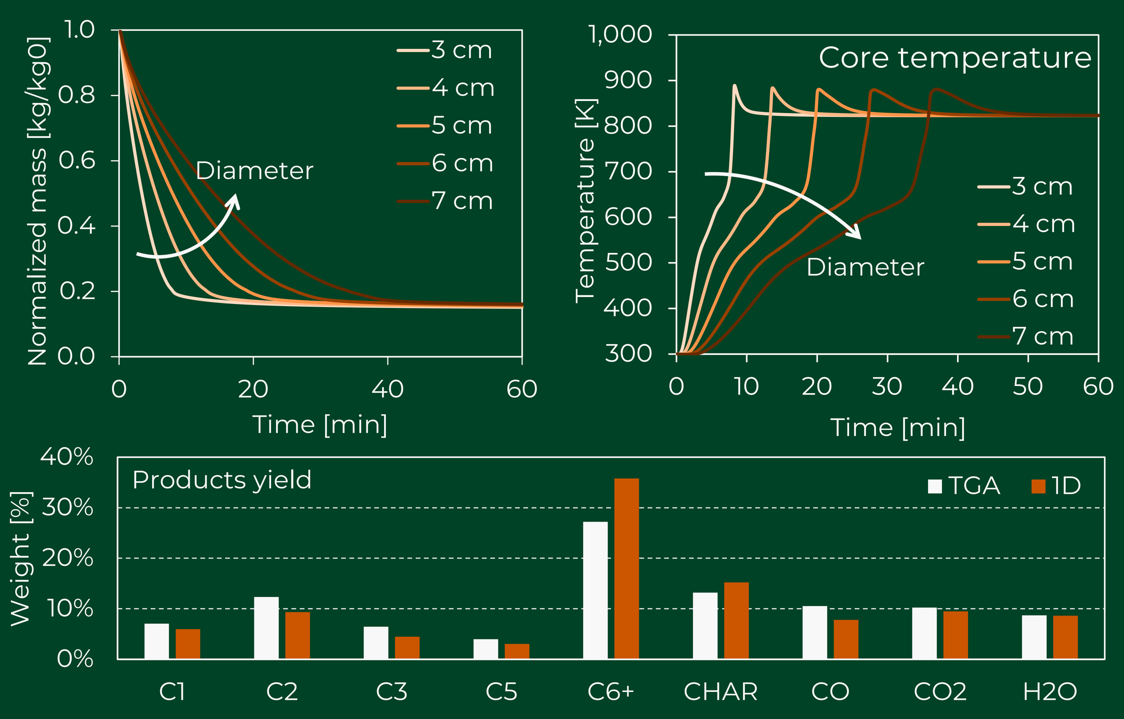
Multiscale modelling

Modelling techniques on different scales were used for an optimal design. Kinetic scheme from [2]

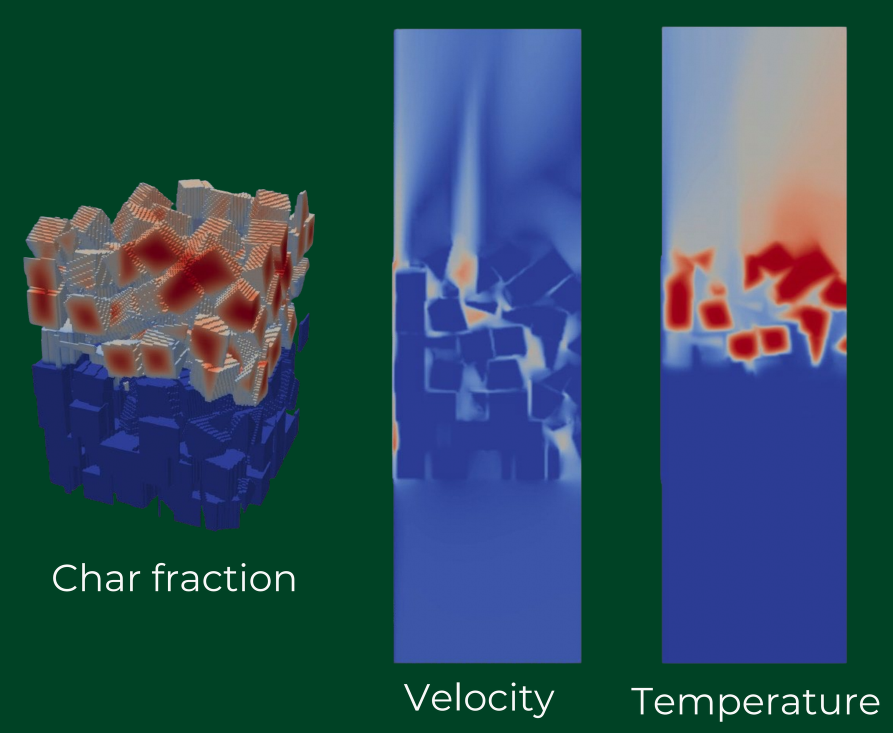
TG experiment simulation



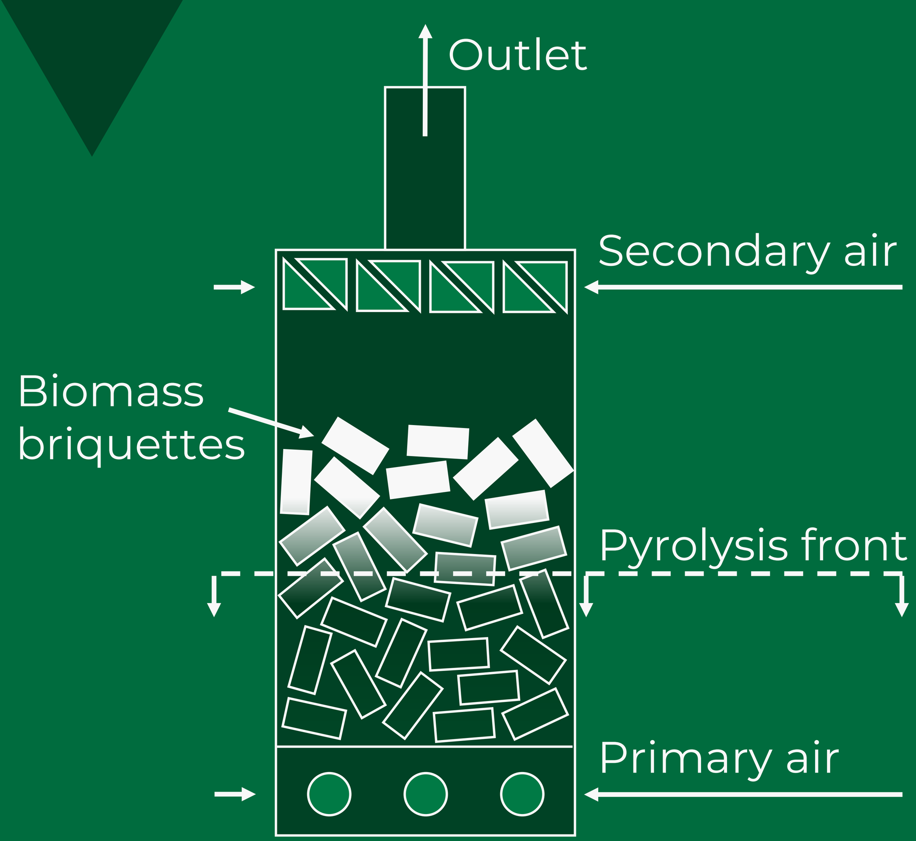
1D particle simulation



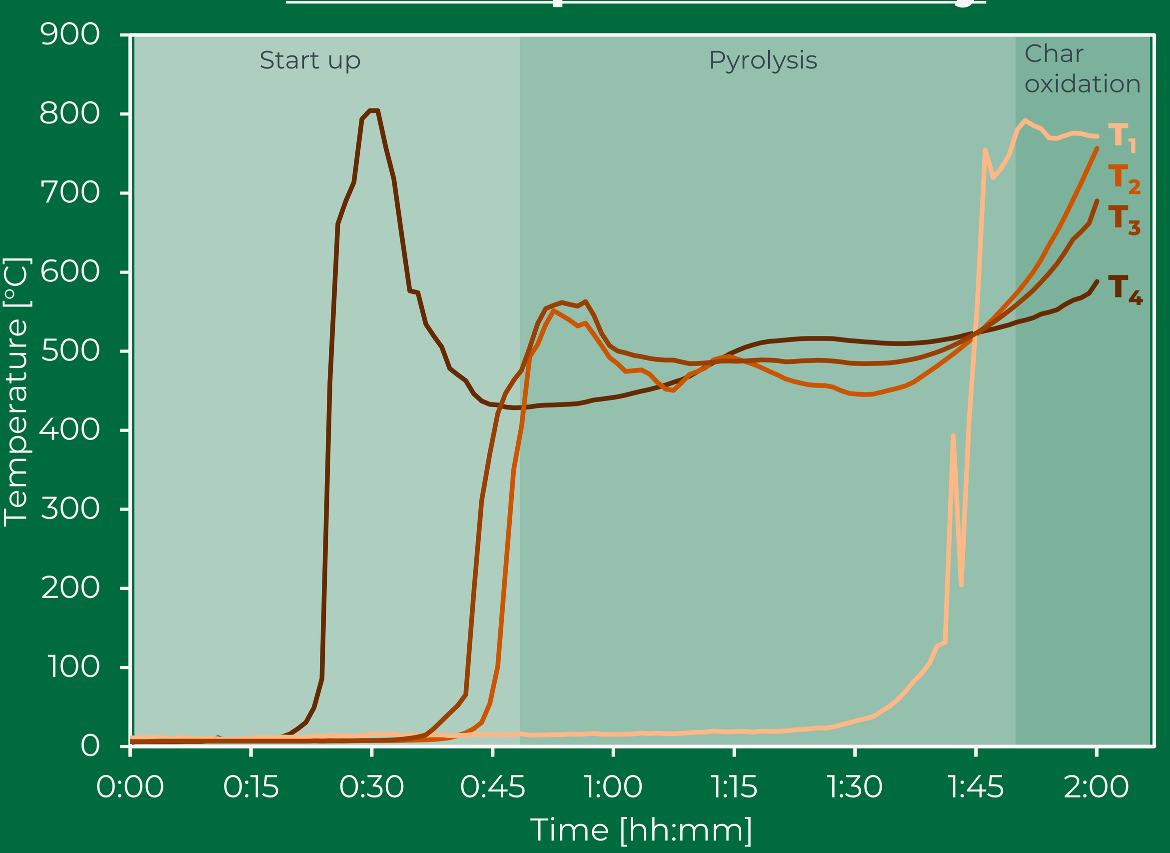
Whole reactor simulation

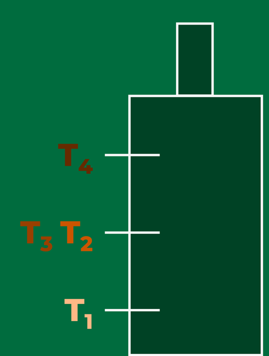


Pyrolysis oven prototype



Oven temperature history

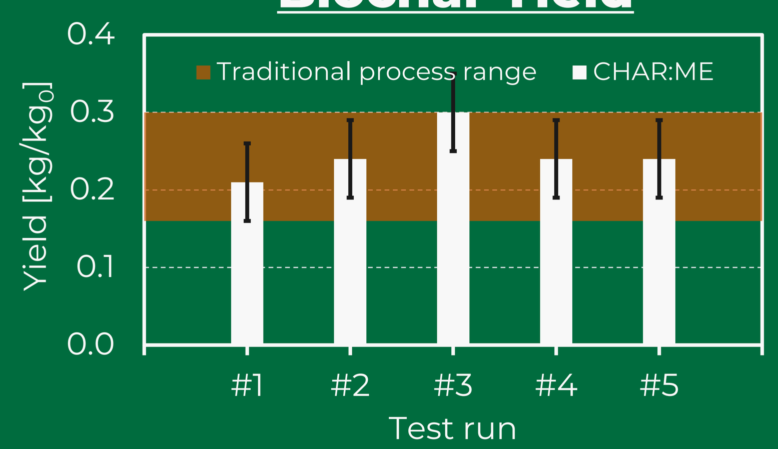




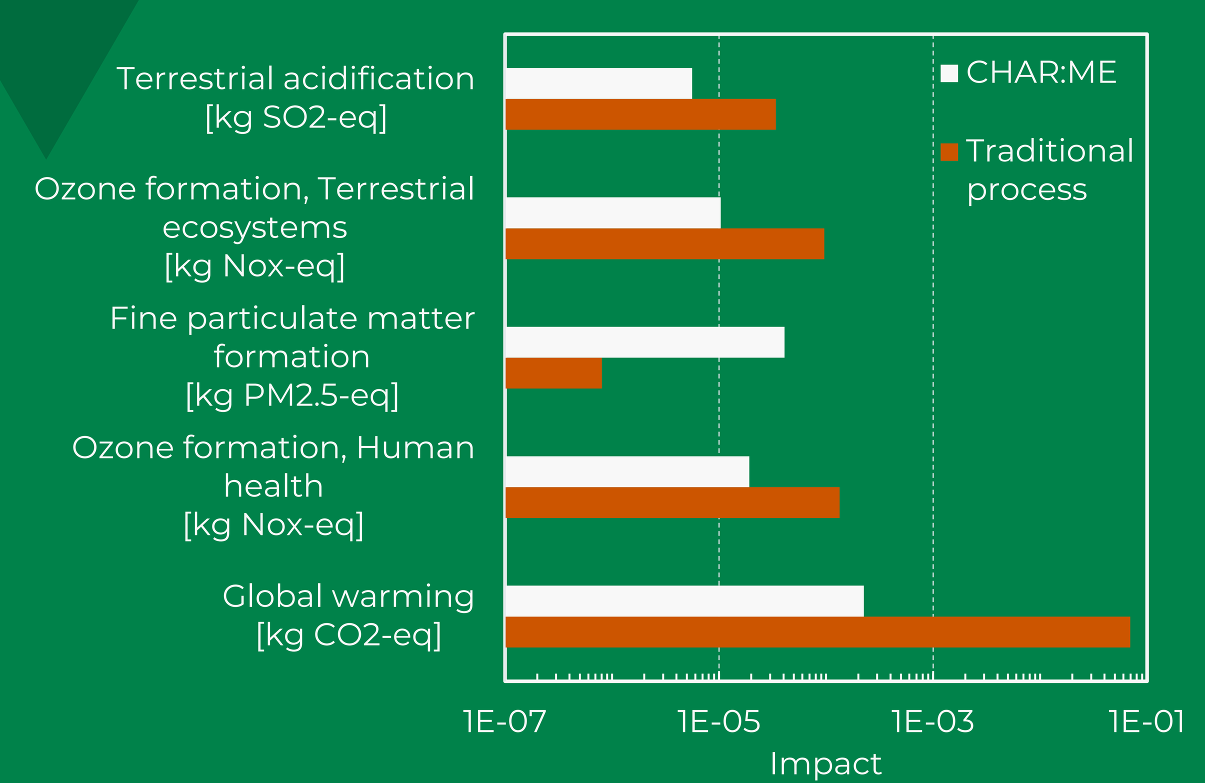
The fire is started at the topmost part: after a short ignition time, the oven moves into pyrolysis conditions, **forming char and burning the tar fraction produced**. Through efficient air management, the **production of pollutants is minimized**. Biochar is retrieved at the end, stopping operations before the char oxidation phase.

The prototype built during our mission in Madagascar

Biochar Yield



LCA and conclusions



Damage	Unit	CHAR:ME	Traditional	Percentage change
Human health	DALY	6.14E-08	4.54E-07	-86.48%
Ecosystems	species.yr	1.21E-05	1.55E-04	-92.16%
Resources	USD2013	1.03E-03	2.07E-04	+396.80%

The CHAR:ME biochar process **significantly reduces impacts on human health and ecosystems**. However, it shows **increased resource use**, primarily due to electricity used for the mixing of wood wastes to form briquettes. This trade-off can be substantially decreased through renewable energy implementation, reducing to just +19.82%

Achievements:

- Characterized local Madagascan **biomass wastes as viable fuel alternatives**
- Created **accurate models predicting pyrolysis behaviour** and product yields
- Designed an innovative **TLUD stove** producing both cooking heat and biochar
- Established a **sustainable waste-to-fuel loop** addressing deforestation concerns
- Created **community-scale solution** using locally available materials

References

[1] A. Walsh, "The ordinary ethics of charcoal in northern Madagascar," Journal of the Royal Anthropological Institute, vol. 25, no. S1, pp. 108–123, Apr. 2019, doi: 10.1111/1467-9655.13017

[2] Debiagi, P., Piazza, V., Papagni, M., Beretta, A., Frassoldati, A., & Faravelli, T. (2023). Cellulose pyrolysis kinetic model: Detailed description of volatile species. Proceedings of the Combustion Institute, 40(1-4), 105651. https://doi.org/10.1016/j.proci.2024.105651