CFD-Based Design of an Intensified Biomass Pyrolysis Reactor for Hydrogen Production
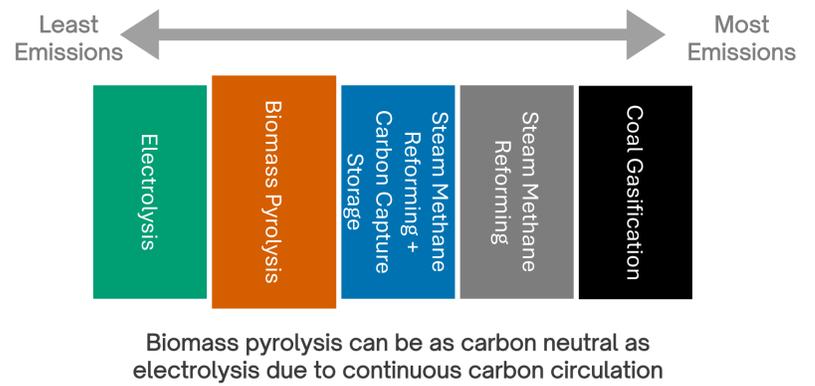
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1 INTRODUCTION

- Africa faces energy access challenges and increasing decarbonisation pressures.[1]

- Hydrogen is a promising clean energy carrier, depending on its production pathway.

- Biomass pyrolysis offers a thermochemical route for cleaner hydrogen production.[2]

- Conventional pyrolysis systems produce relatively low hydrogen yields.[2]

- Computational Fluid Dynamics (CFD) enables digital simulation and optimisation of reactor performance.

Least Emissions ← → Most Emissions

Electrolysis | Biomass Pyrolysis | Steam Methane Reforming + Carbon Capture Storage | Steam Methane Reforming | Coal Gasification

Biomass pyrolysis can be as carbon neutral as electrolysis due to continuous carbon circulation
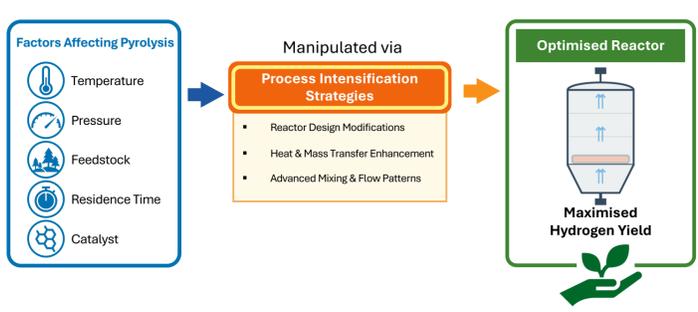
2 RESEARCH PROBLEM

- Conventional pyrolysis systems less studied compared to other thermochemical methods due to low yields even though produces less greenhouse emissions.[3]
- Limited reactor optimization specific to hydrogen production from pyrolysis.
- Need for validated digital models for predictive reactor design

3 RESEARCH OBJECTIVES

- Establish baseline hydrogen yield data from literature.
- Define key physical and chemical processes (physics).
- Develop and validate CFD model based on the physics.
- Design a novel pyrolysis reactor primarily for maximized H2 production.
- Develop a CFD model for the designed novel reactor using the validated physics.

4 METHODOLOGY

Factors Affecting Pyrolysis: Temperature, Pressure, Feedstock, Residence Time, Catalyst

Manipulated via Process Intensification Strategies:
- Reactor Design Modifications
- Heat & Mass Transfer Enhancement
- Advanced Mixing & Flow Patterns

→ Optimised Reactor → Maximised Hydrogen Yield

- Modelling Tool: ANSYS Fluent.
- Key Physics: Multiphase solid-gas interactions, pyrolysis reaction mechanisms, turbulence, heat & mass transfer
- Validation: Comparison with literature experimental data (±10% target accuracy).
- Process Intensification Strategies: Multi-stage reactors, enhanced heating and mass transfer , optimised reactor architecture.
- Parametric Study: Temperature, pressure, carrier gas flow, biomass composition, residence time.
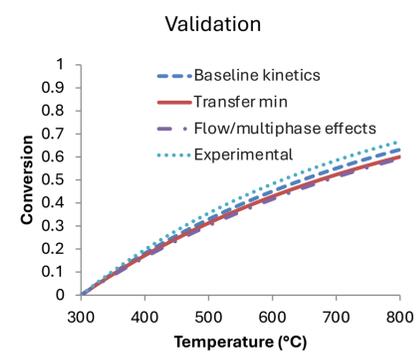
5 EXPECTED OUTCOMES

Validation

Legend: Baseline kinetics, Transfer min, Flow/multiphase effects, Experimental

Fig A: Experimental versus Simulation results comparison[4]

Novel Reactor Geometry
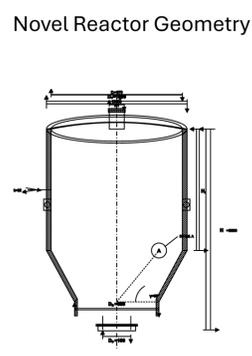
Fig B: Example geometry of the novel reactor.

3D CFD Model
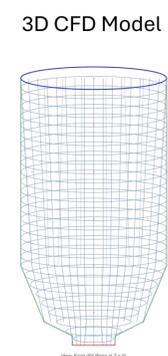
Fig C: Example computational mesh for a 3D model of a reactor
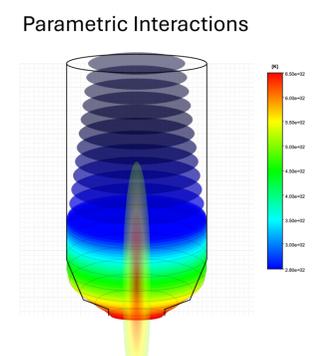

Parametric Interactions

Fig D: Example of how a parameter (temperature) changes along reactor height

6 CONCLUSION & ALIGNMENT TO THEME

- **Just:** Utilises locally abundant African biomass, promotes energy sovereignty, and supports rural economies.
- **Digital:** Advanced CFD modelling enables rapid, low-cost virtual prototyping and optimisation..
- **Energy Transition:** Converts waste biomass into clean hydrogen, accelerating decarbonisation..
- **Africa and Beyond:** Framework applicable to other biomass-rich developing regions.

7 ACKNOWLEDGEMENTS

REFERENCES

[1] IEA, *Africa Energy Outlook 2022*
[2] Zhou et al., *Energy Conversion and Management* 2018
[3] Zayer K., Prussi M., *Applied Sciences* 2025