

CATALYST WITH A SPLIT PERSONALITY: THE CURIOUS CASE OF TUNGSTEN IN THERMOCHEMICAL CONVERSION OF BIOMASS

Srigan Moharir*, Dr. Fabian Ejim, Dr. Marta Granollers-Mesa, Dr. Paula Blanco-Sanchez, Dr. Scott Banks*
 Energy and Bioproducts Research Institute, Aston University, Birmingham B4 7ET
 *smoha24@aston.ac.uk | s.banks@aston.ac.uk

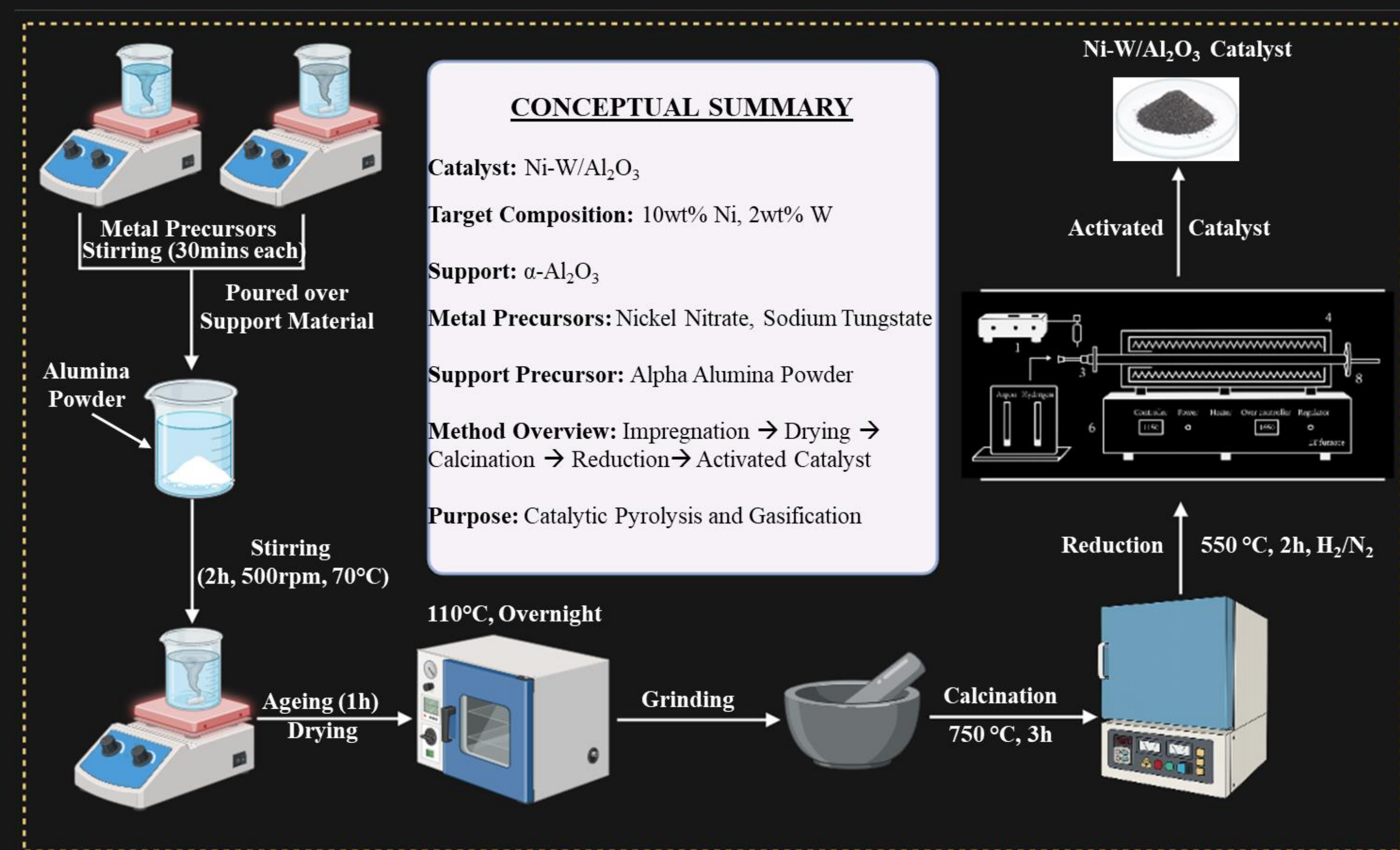
1. INTRODUCTION

- Thermochemical conversion of biomass provides a viable pathway for renewable Hydrogen production.
- Biomass Gasification is an efficient route, but tar formation and low Hydrogen yield remains a major problem.
- Integration of catalysts is integral in cracking heavy tars into lighter hydrocarbons and improving syngas quality and overall system efficiency.
- Ni-based catalysts are widely used for reforming but face challenges such as sintering and carbon-deposition.
- Incorporating tungsten as a promoter could enhance the thermal stability, resistance to coking thus enabling better tar cracking and increasing the Hydrogen yield.
- Since Pyrolysis is a key step of gasification, Py-GC/MS analysis provides critical insight into volatile and tar precursor formation before and after catalytic upgrading.

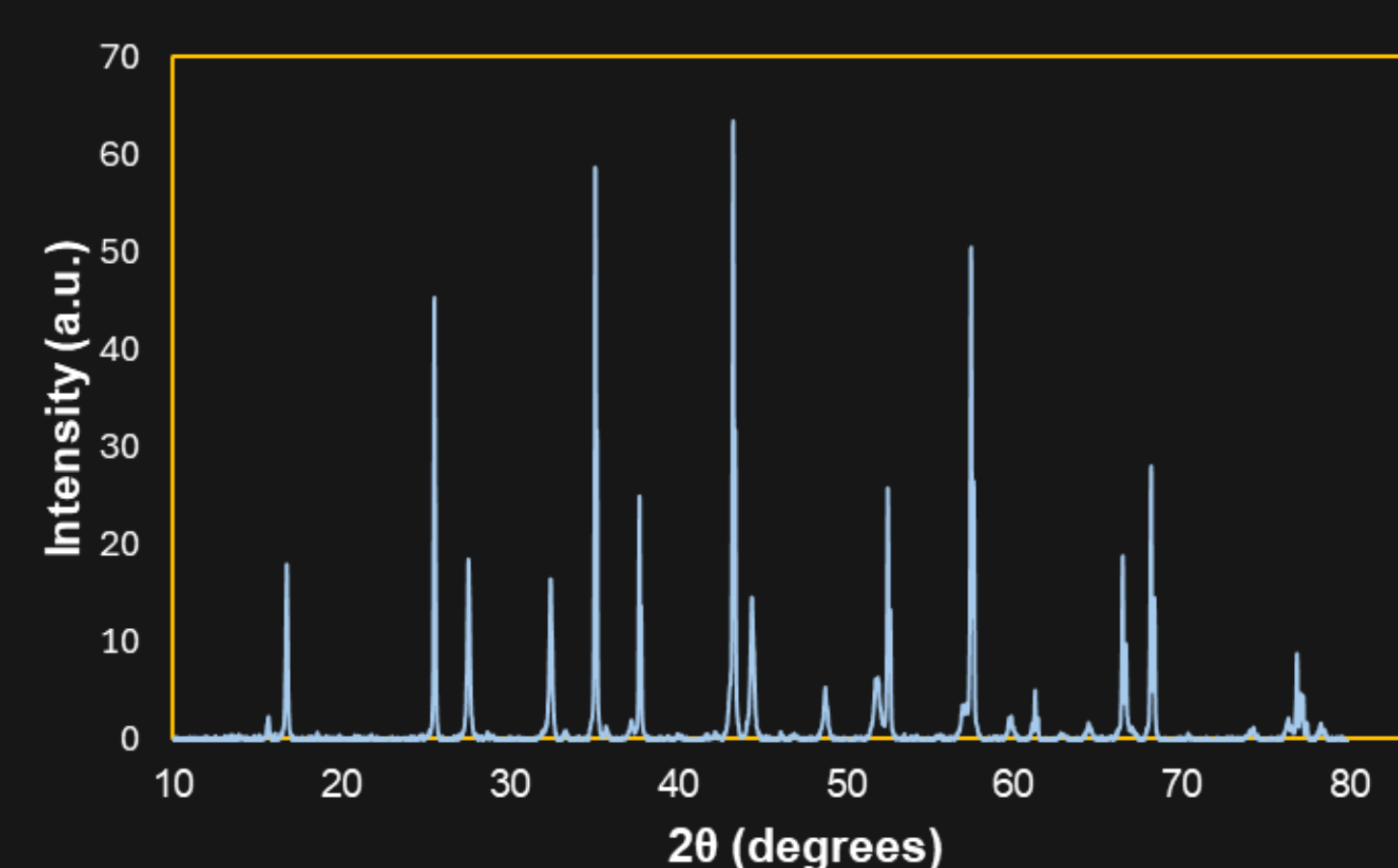
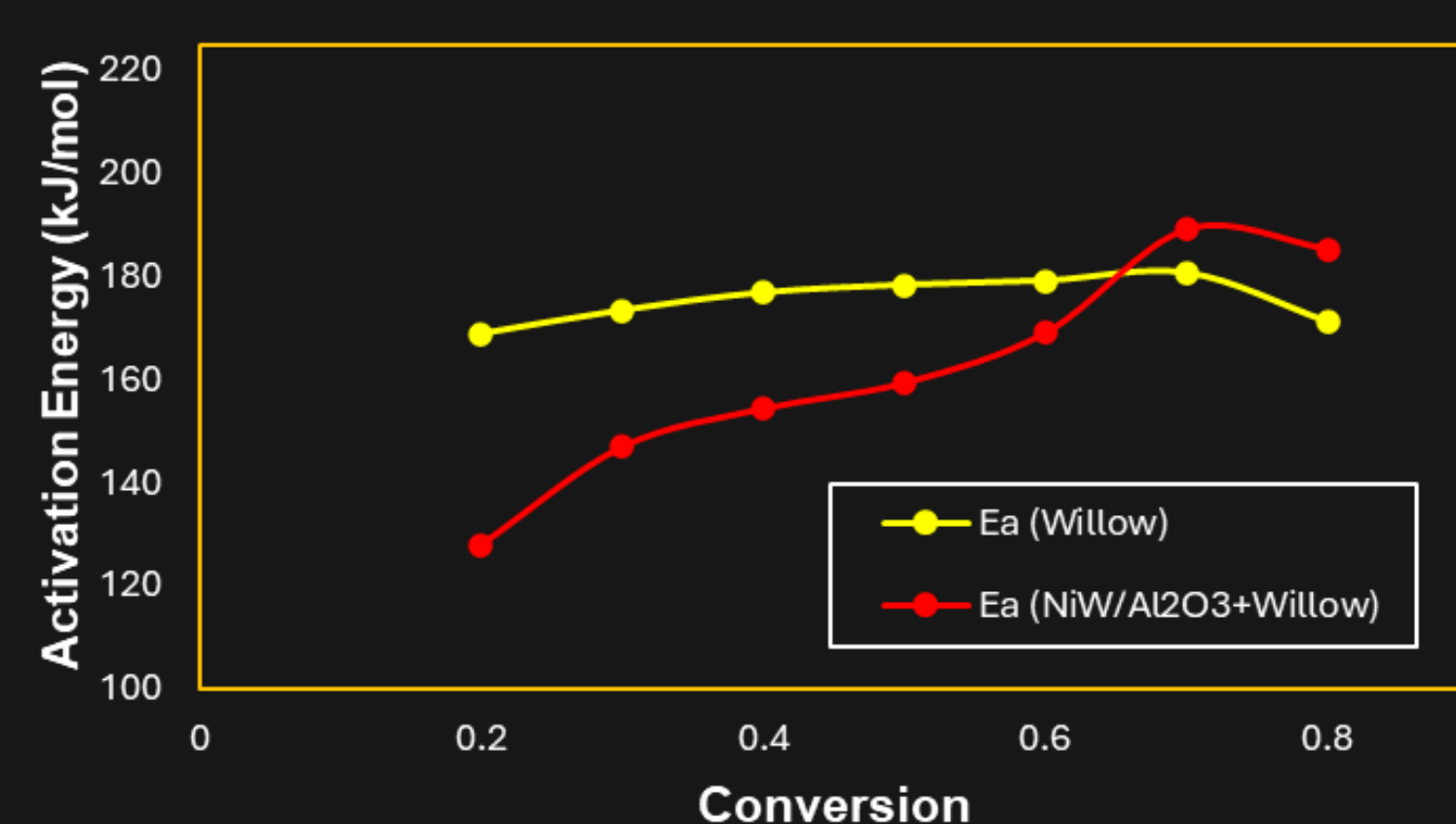
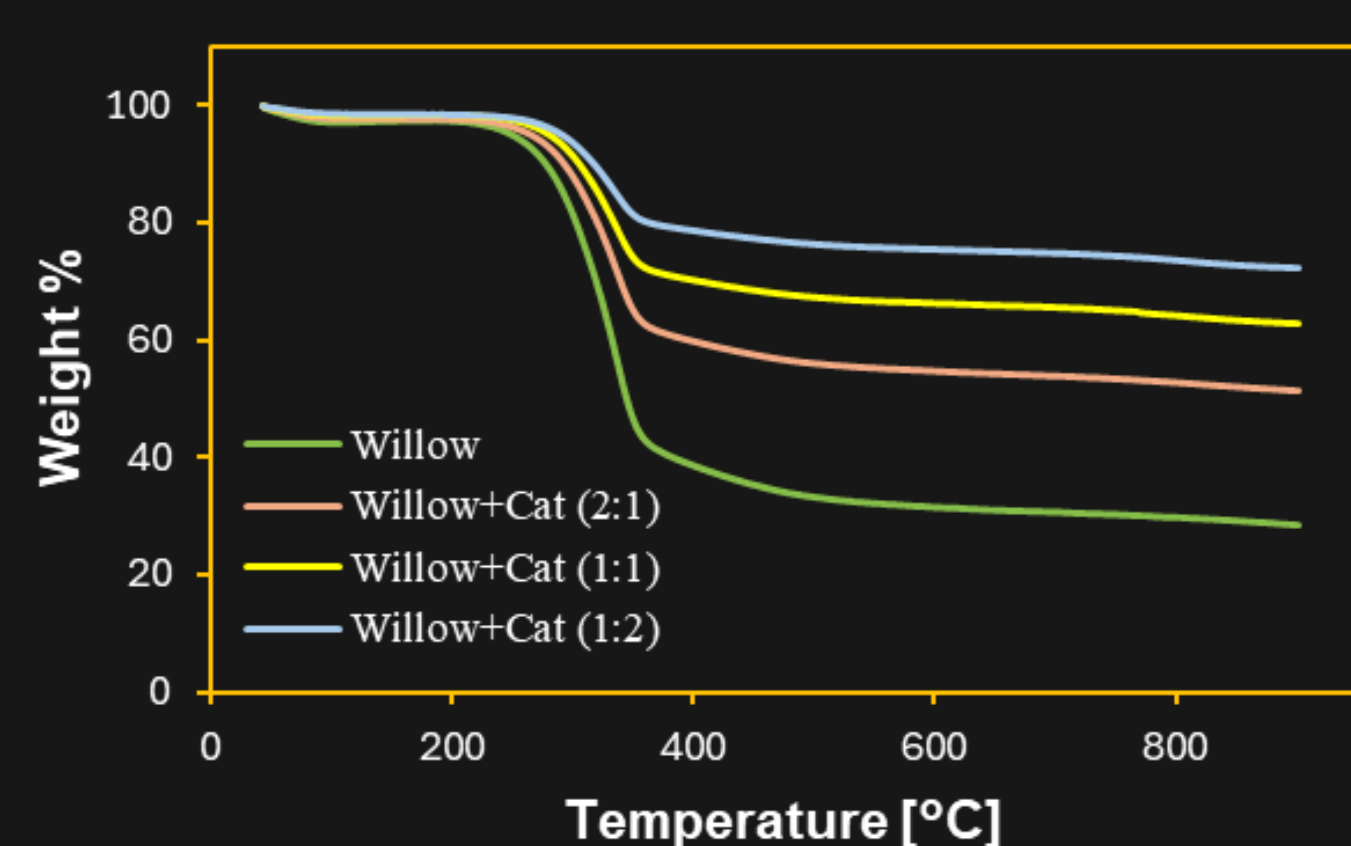
2. PURPOSE OF THIS STUDY

- To synthesise and characterise a **Tungsten-doped catalyst (Ni-W/Al₂O₃)** to understand the physicochemical characteristics of the catalyst for tar reduction and increased Hydrogen yield.
- To conduct Py-GC/MS of **Willow Biomass** with and without catalyst as a precursor study of gasification to understand the catalytic effects on primary volatile composition.
- To assess how the catalyst modifies pyrolysis vapours, reducing oxygenates, phenolic compounds (tar precursors) and promoting aromatics (Hydrocarbons).

3. EXPERIMENTAL PROCEDURE (Catalyst Synthesis)

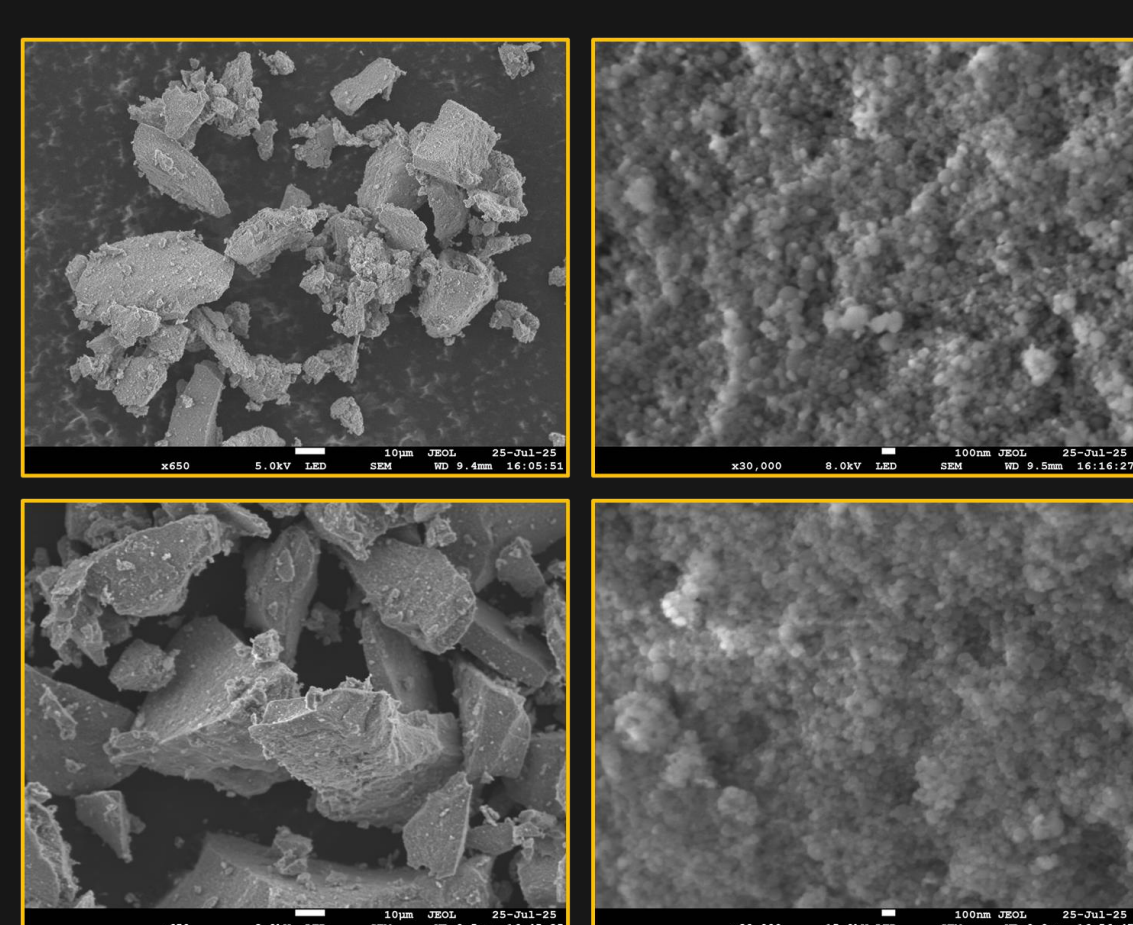


4. RESULTS (Catalyst Characterisation & Py-GC/MS)

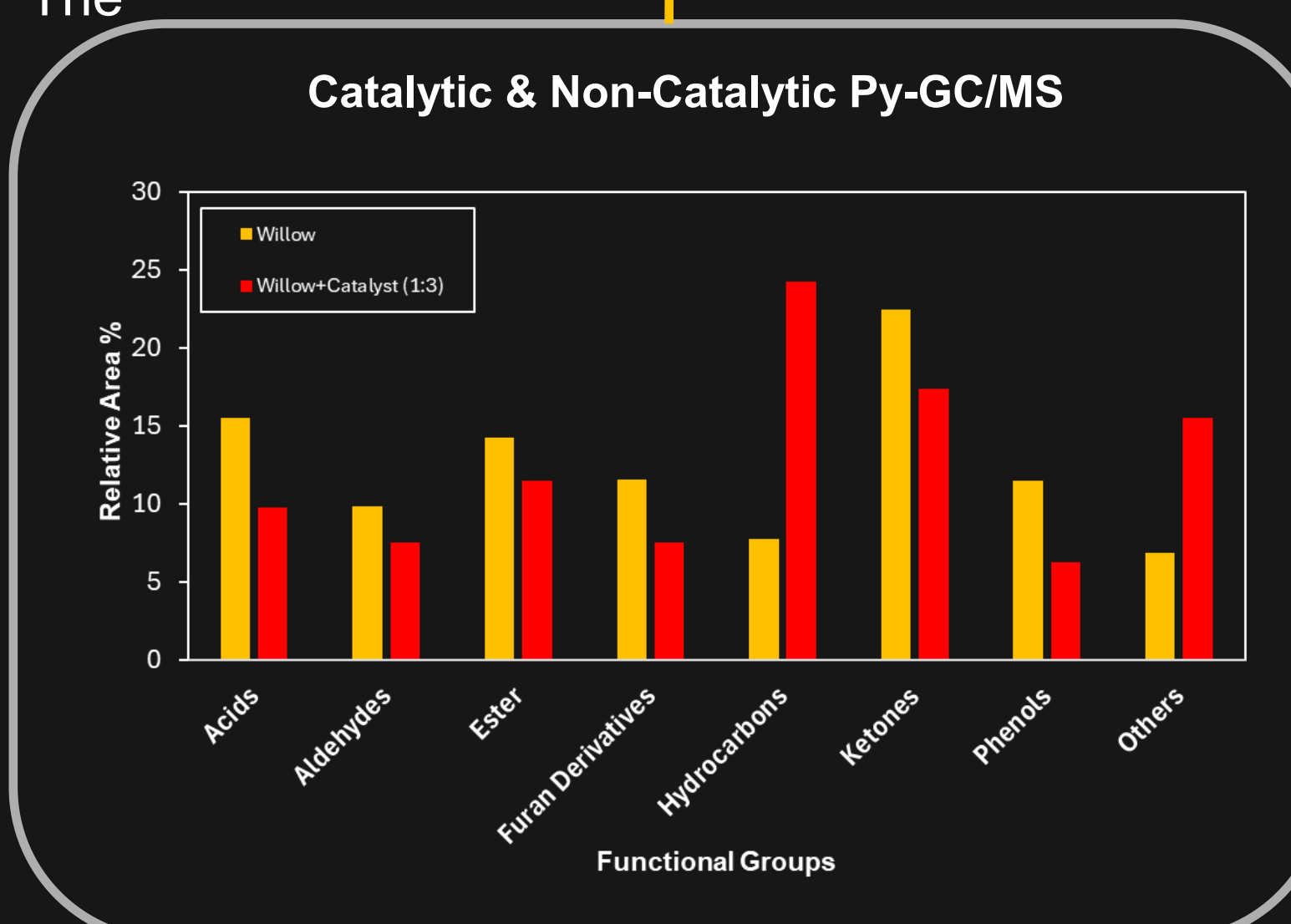


- X-ray diffraction (XRD)** pattern of the calcined and reduced NiW/Al₂O₃ catalyst, showing the dominant peaks of α -Al₂O₃ (25-67°) and metallic Ni⁰ (44.4°, 51.9°, 76.9°), confirming a crystalline support and successful reduction of active Ni sites.
- Minor peaks near 37.8° (NiAl₂O₄) and 27.6° (WO₃) indicate spinel formation and highly dispersed W species contributing to catalyst stability.

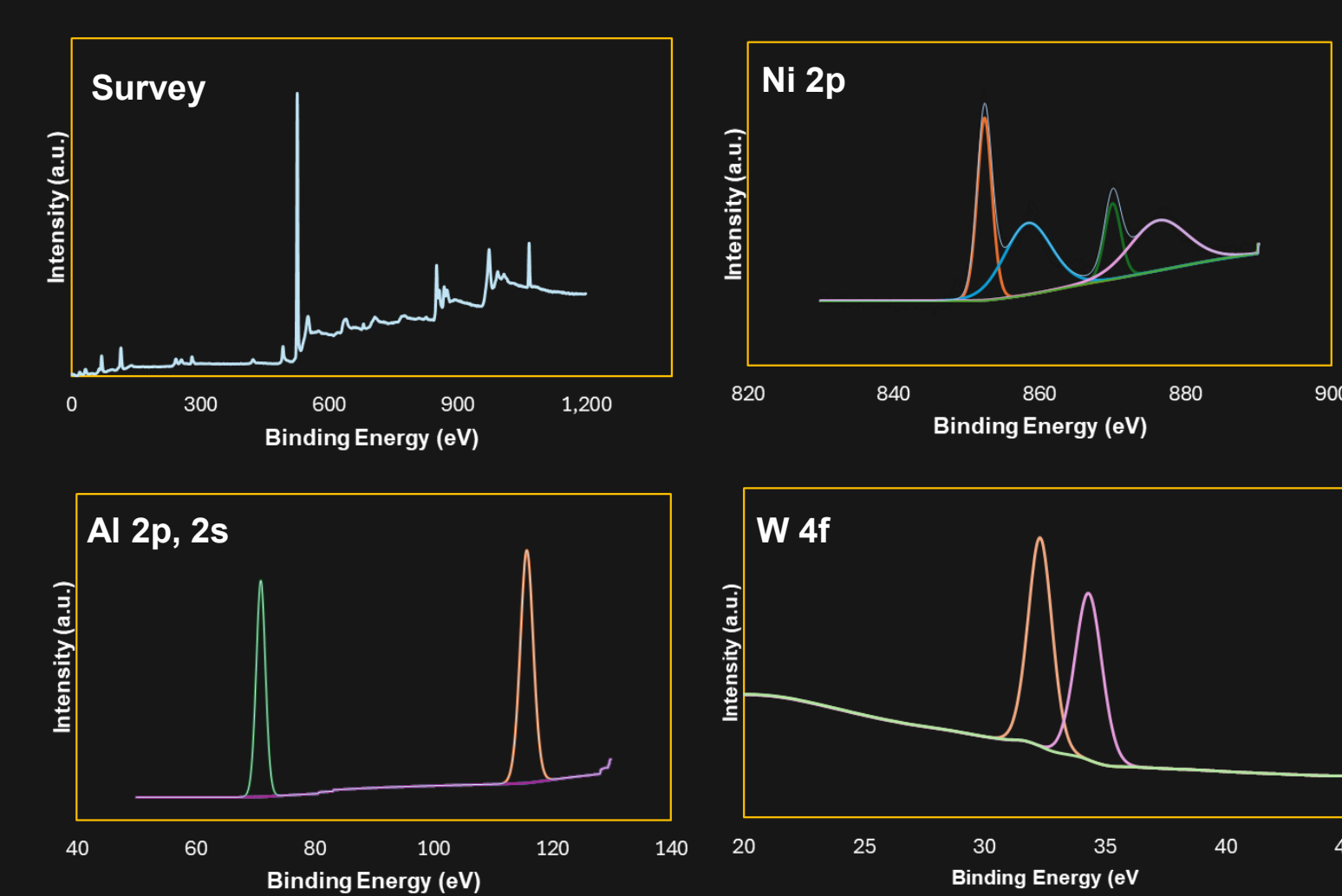
TGA Profiles of raw willow and willow+catalyst mixtures at different ratios. The corresponding activation energy vs conversion profile for the two test cases.



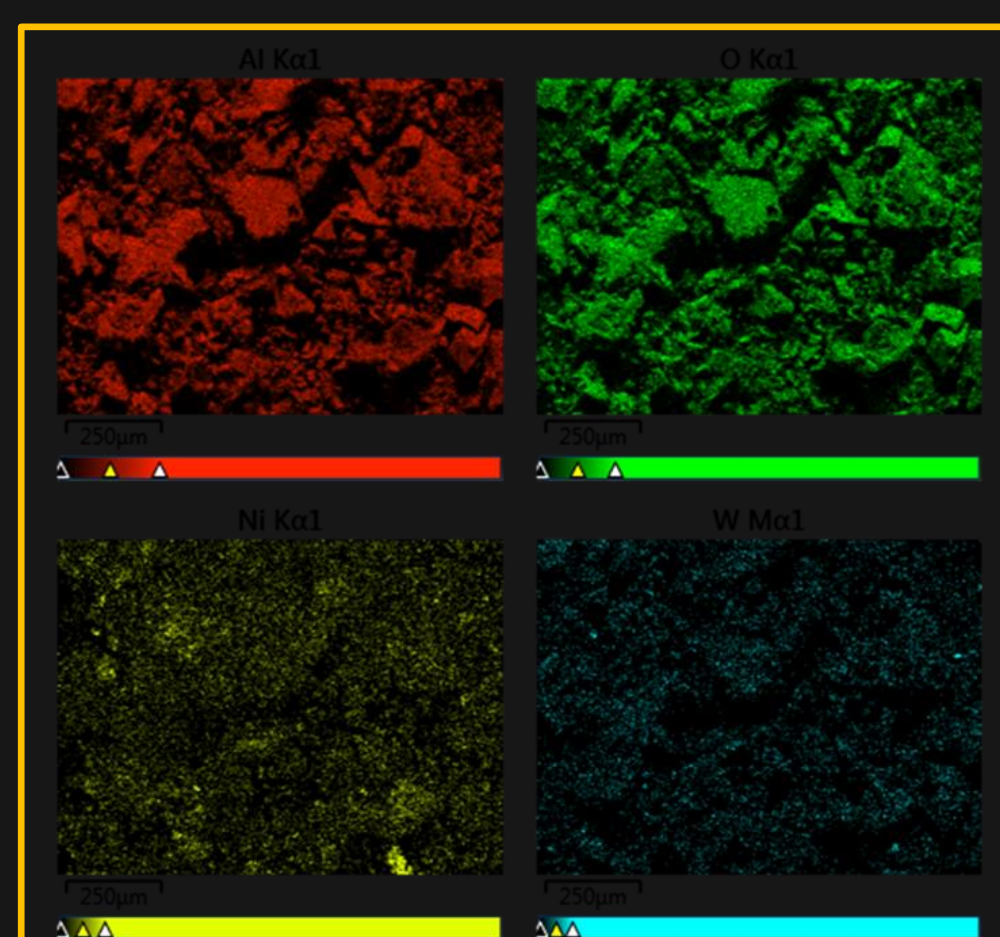
SEM images showing a rough, porous morphology that remained stable before and after the TGA runs confirming high thermal stability and structural robustness from tungsten incorporation essential for sustained catalytic performance.



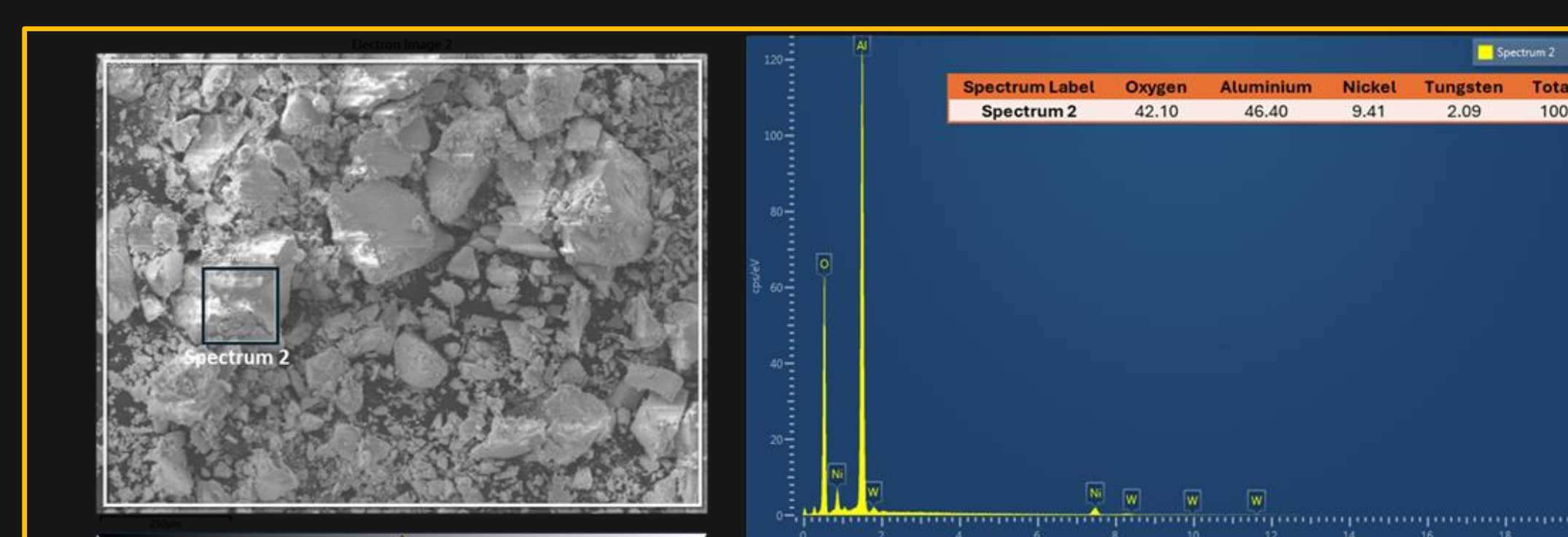
XPS Spectra showing Ni, W, Al signals with strong Al-O bonds. Ni 2p peaks showing Ni⁰/Ni²⁺ and W 4f indicating W⁶⁺ species confirming strong metal-support interaction of active species on the surface.



Elemental mapping showed uniform distribution of Al, O, Ni, and W, confirming well-dispersed active metals within the α -Al₂O₃ matrix and strong metal-support interaction, which enhances catalyst activity and stability during gasification.



Py-GC/MS results show reduced oxygenates (acids, aldehydes, phenols) and increased hydrocarbons, confirming effective deoxygenation and tar cracking by the Ni-W/Al₂O₃ catalyst.

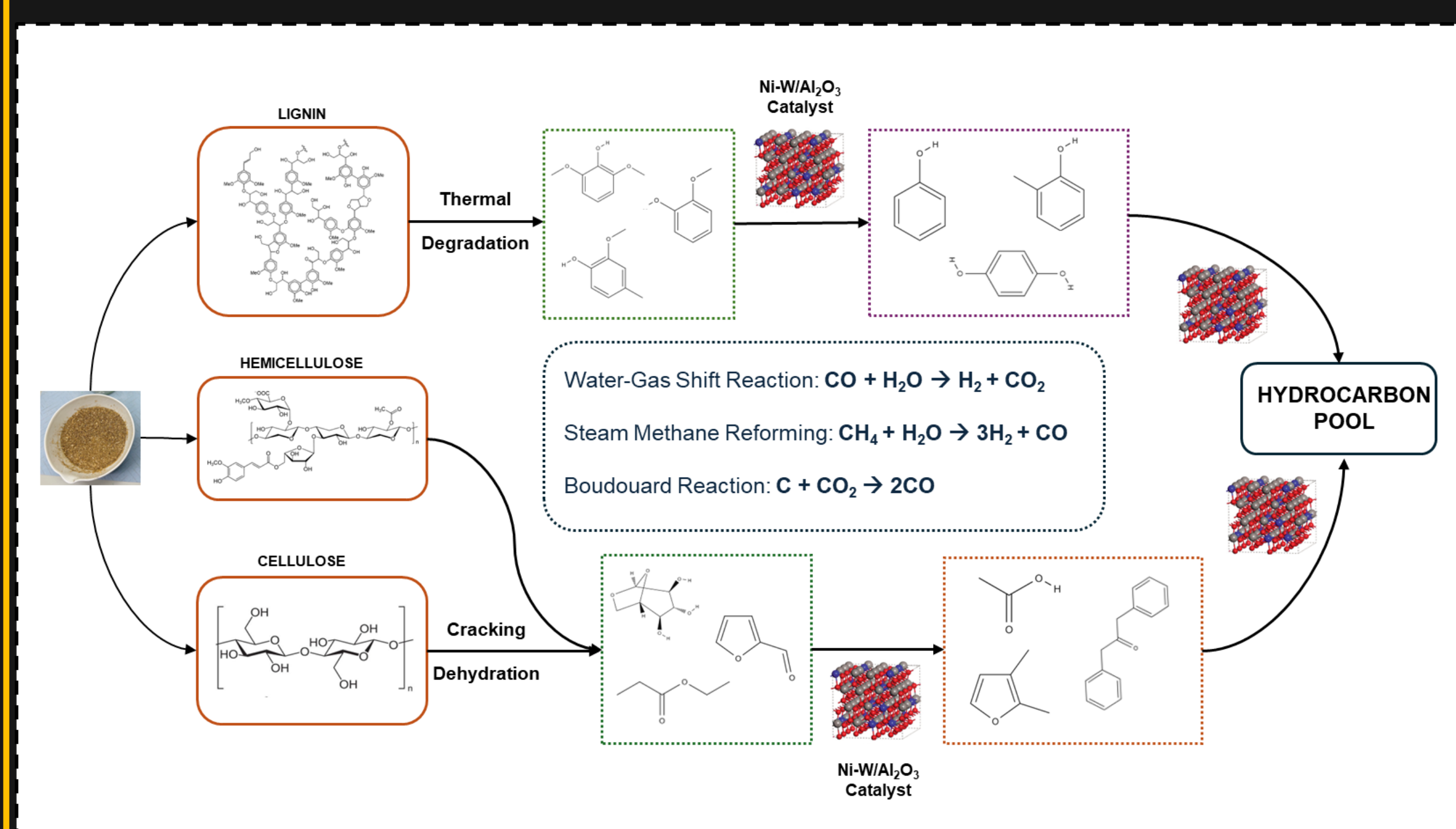


EDX analysis confirming the presence of Al, O, Ni, and W, verifying α -Al₂O₃ as the main support and successful incorporation of Ni and W active species onto the catalyst surface.

5. DISCUSSION

- Characterisation results (XRD, BET, XPS, SEM, EDX, TGA) indicated a well-dispersed Ni and W species, improved surface area, strong metal-support interaction, high thermal stability thus contributing to higher catalytic activity.
- The catalyst lowered the overall activation energy (by 16kJ/mol) for volatile conversion facilitating cracking and reforming.
- Py-GC/MS of raw Willow biomass revealed oxygenated volatiles (acids, furans, phenolics) representing potential tar precursors in gasification.
- The Ni-W/Al₂O₃ catalyst reduced the presence of phenolic compounds (by almost 50%) and oxygenates and enhanced the formation of hydrocarbons.
- Overall, using Tungsten as the promoter increased the catalyst efficiency during thermochemical conversion of biomass.

6. PROPOSED REACTION MECHANISM



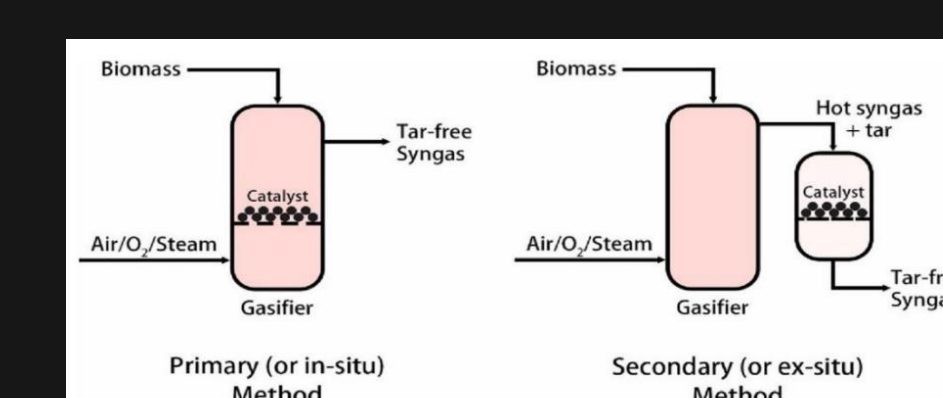
Catalyst Information	BET Surface Area (m ² /g)	BJH Pore Diameter (nm)
Ni-W/Al ₂ O ₃	24.97	27.44

7. CONCLUSION

- The Ni-W/Al₂O₃ catalyst showed strong potential for tar reduction and H₂ enhancement as evidenced by catalytic Py-GC/MS of willow.
- The synergistic role of Ni & W promoted cracking, reforming and deoxygenation thus shifting the products towards increased Hydrocarbons.
- These findings establish pyrolysis behaviour as a predictive tool for gasification performance.

8. FUTURE WORK

- To conduct Catalytic Biomass Gasification experiments to quantify the Hydrogen yield, assess the long-term stability of catalyst and validate reaction pathways under realistic conditions.



9. REFERENCES: 1) C. Zeng, Y. Jiang, R. Xu, L. Han, X. Zhang, *J. Anal. Appl. Pyrolysis*, **2022**, 167, 2) T. F. Panicker, A. K., S. V. Tarkar, R. K. Mishra, X. Wang, K. Mohanty, *Ind. Crops Prod.*, **2025**, 236 3) G. Zeng, S. Li, L. Zhang, et al., *Fuel*, **2022**, 324