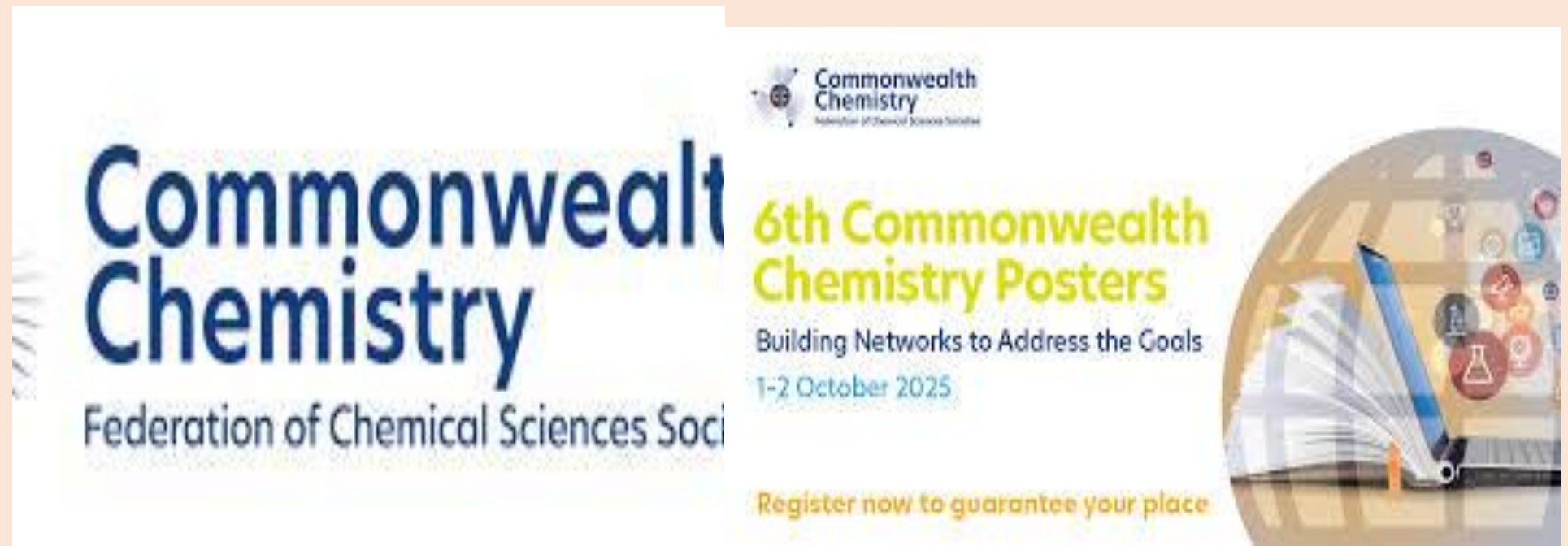




LIGNIN POLYMERS AS SUSTAINABLE MATERIALS: SYNTHESIS, MODIFICATIONS AND EMERGING APPLICATIONS.

VICTORY OLORUNFEMI

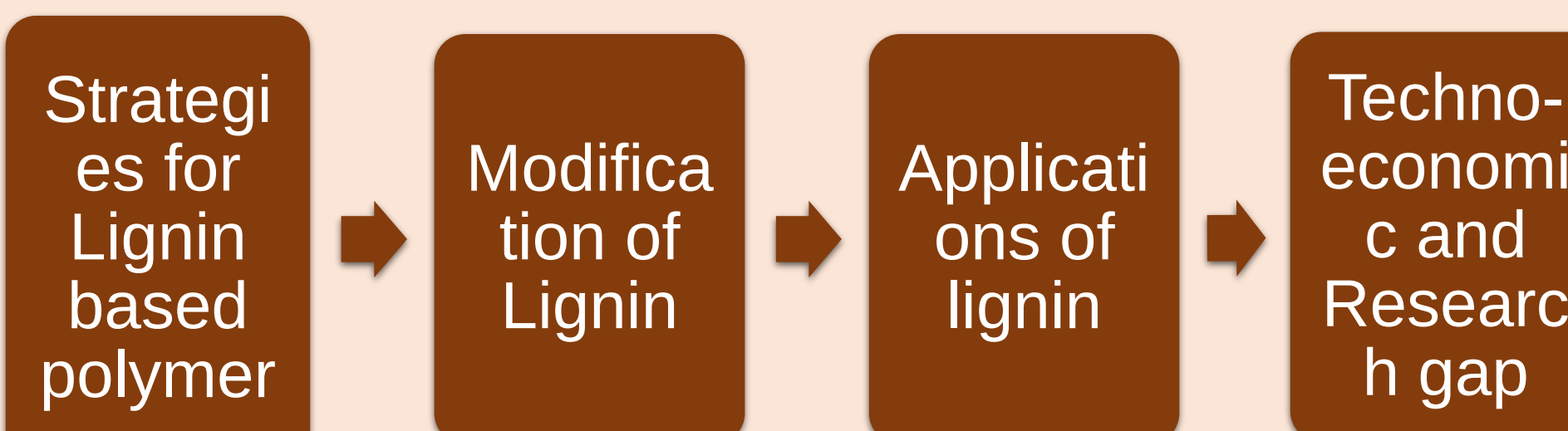
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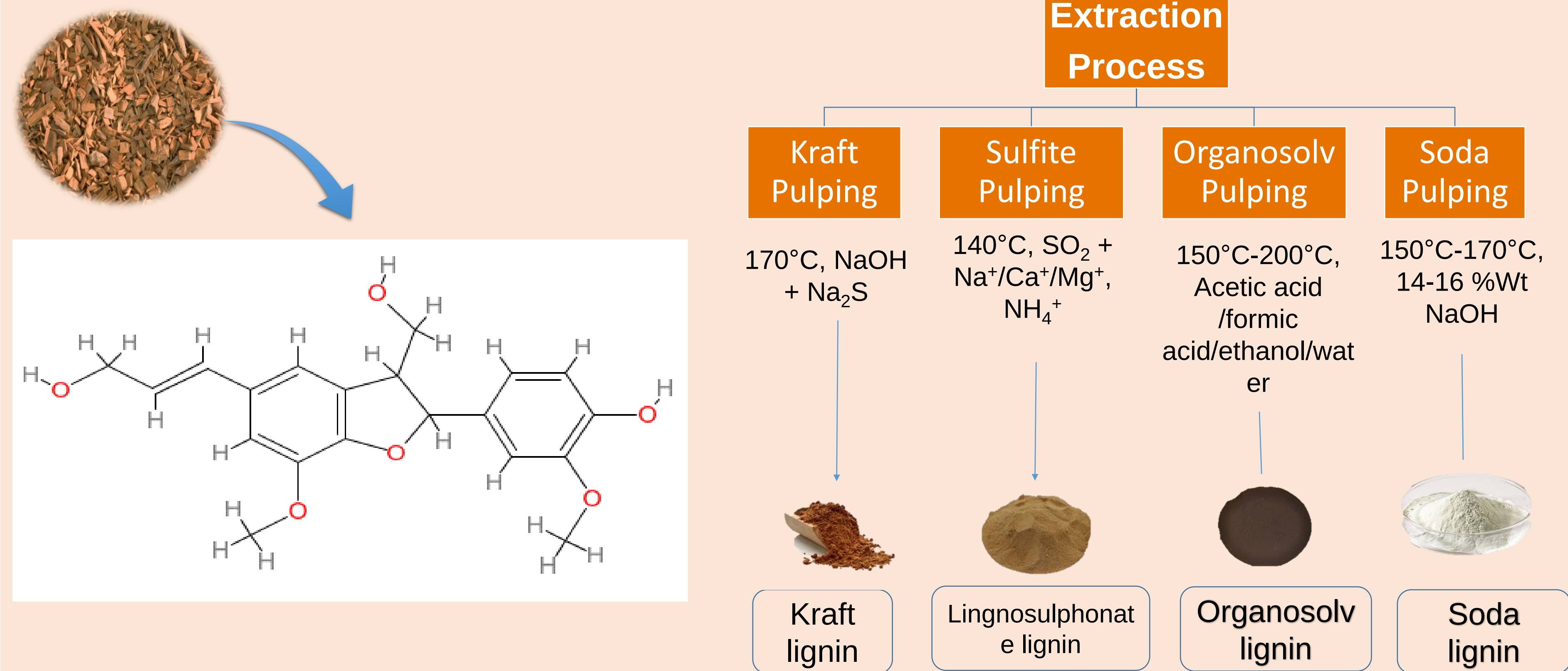
INTRODUCTION

- Lignin is the second most abundant biopolymer on Earth, largely underutilized.
- Current dependence on petrochemicals makes lignin valorization a critical step in the circular bioeconomy.
- Advances in modification techniques have enabled diverse applications.

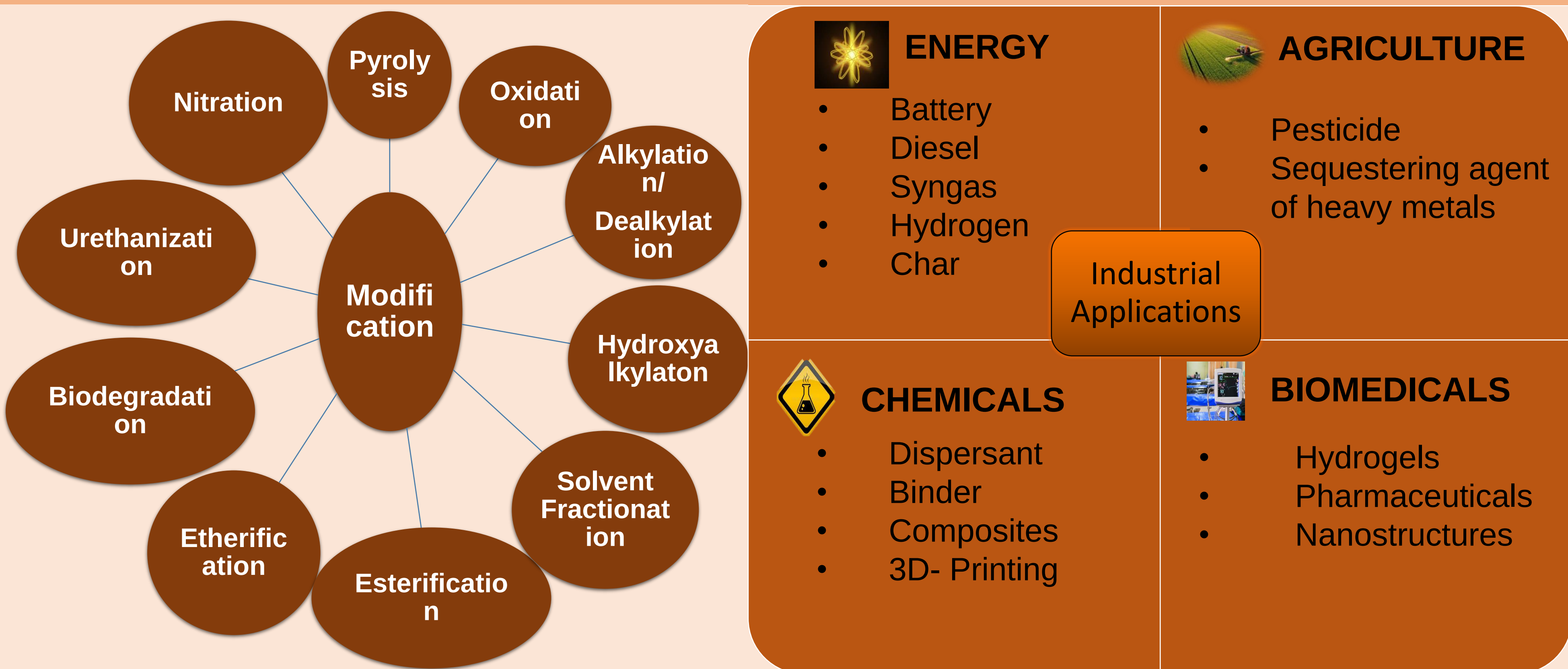
OBJECTIVES



STRUCTURE AND EXTRACTION OF LIGNIN

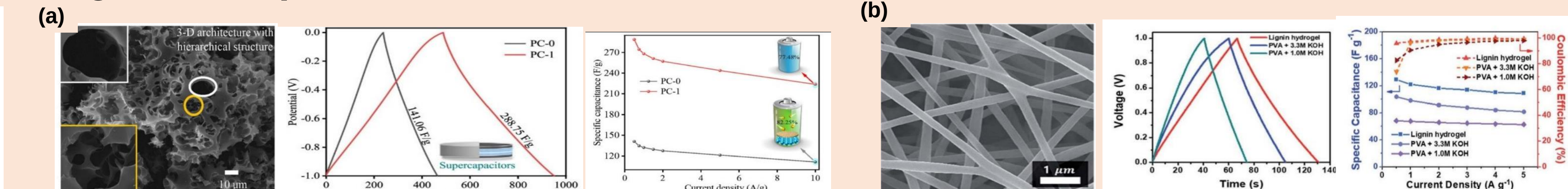


MODIFICATION AND APPLICATION OF LIGNIN



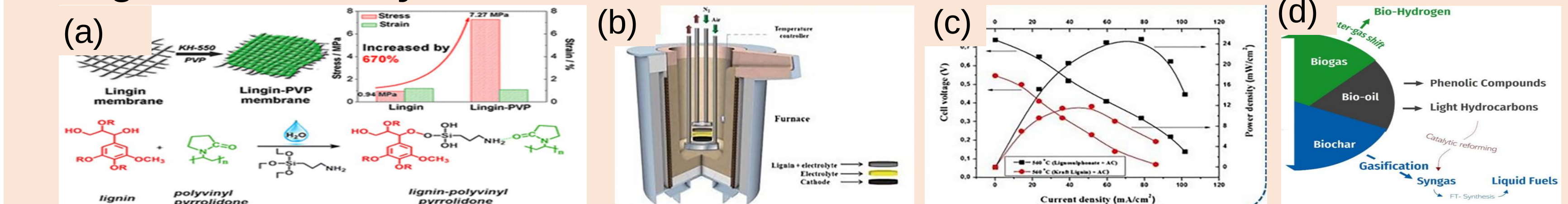
LIGNIN APPLICATION IN SDG 7

1. Lignin in Capacitors



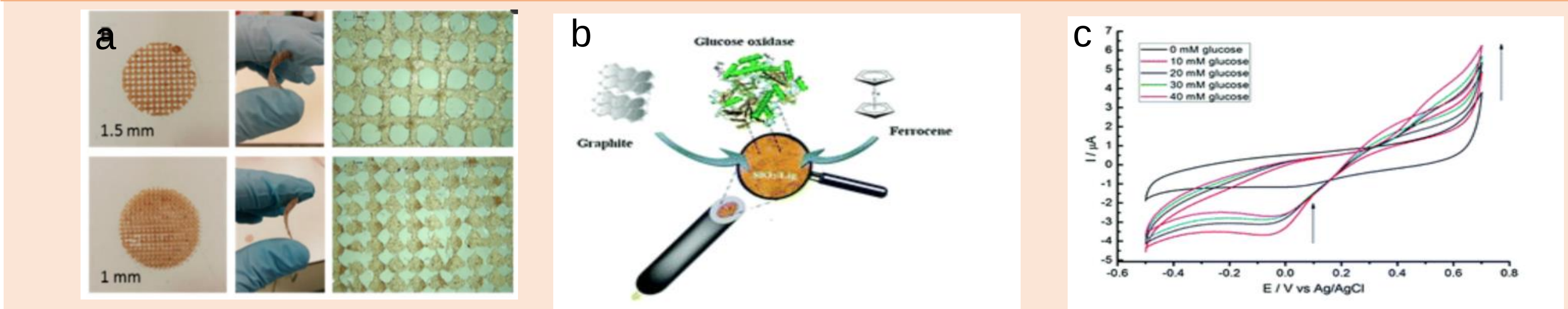
Morphology and electrochemical performance of Lignin-derived carbon materials for supercapacitor applications using (a) activated porous carbon. (b) flexible free-standing conductive carbon electrodes. Adapted from ref (3)

2. Lignin in Electrolyte, Fuel Cell and Bio-Fuel

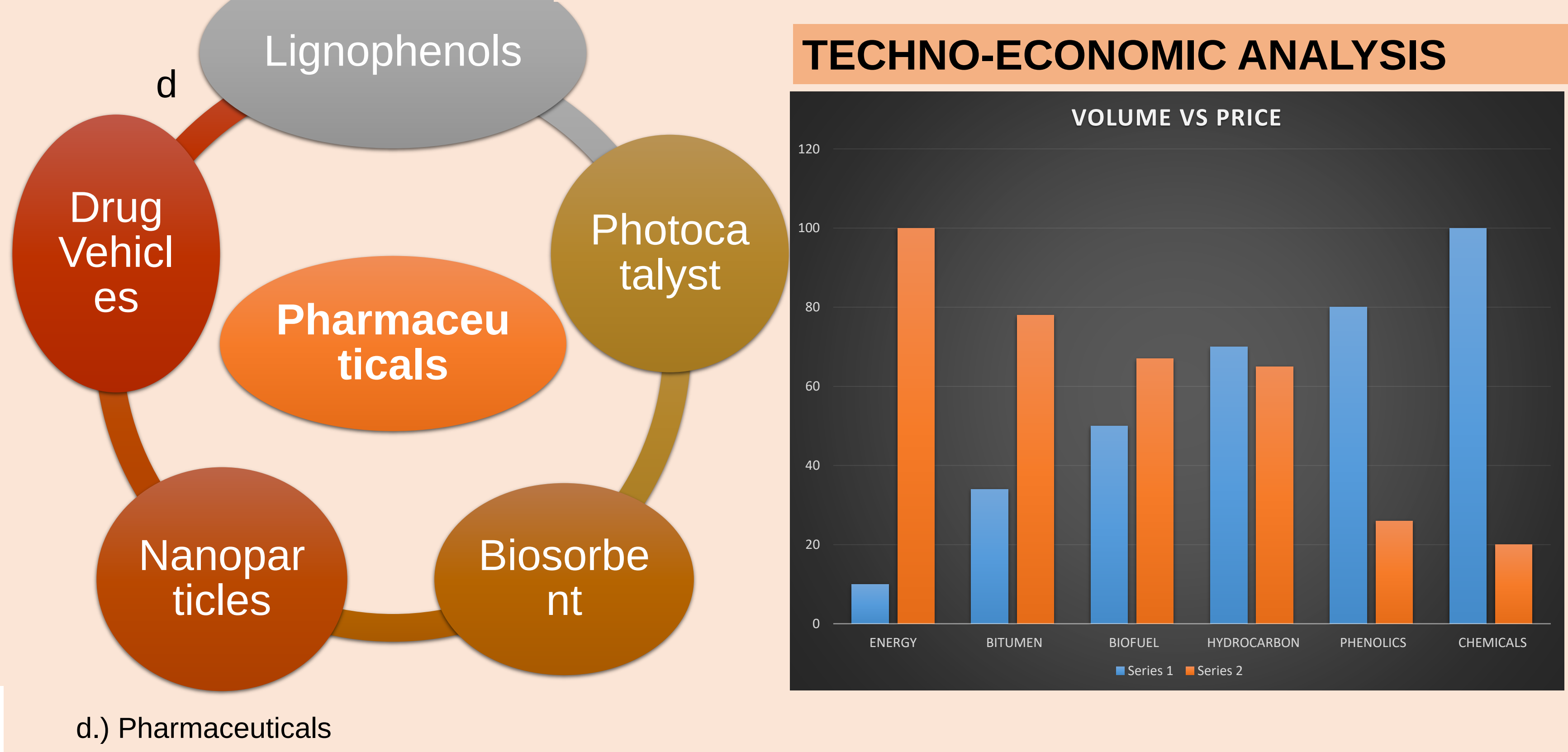


(a) Synthesis of lignin-PolyVinylPyrrolidone as a high-performance and environment-friendly electrolyte. (b) Schematic diagram of a lignin fuel cell; and (c) cell voltage and power density as a function of current density for direct lignin fuel cell with lignosulfonate + AC and Kraft lignin + AC as fuel operated at 560°C. Adapted from ref (6) (d) Schematic representation of the processes involved in bio-fuel production. Adapted from ref (3)

LIGNIN APPLICATION IN SDG 12



a.) Lignin as Hydrogels, Adapted from ref (2) Lignin-based materials as biosensors: (b) schematic representation of preparation of SiO₂-graphite-ferrocene-lignin hybrid electrode; (c) cyclic voltammetry signals of GOx-SiO₂-lignin biosensor (from 10 mM to 40 mM) with an increase in oxidation with increasing glucose concentration. Adapted from ref 7.



TECHNO-ECONOMIC ANALYSIS (TEA) AND LIFE CYCLE ASSESSMENT (LCA)

- Investor perception often discourages lignin commercialization.
- Recent TEA and LCA studies show lignin valorization can improve both economic returns and environmental performance.
- Key outcomes reported include:
 - Lower ethanol production cost to about \$2/gal.
 - Reduction of greenhouse gas emissions by up to 78% compared to gasoline.
 - Production of value-added chemicals (e.g., vanillin) with >20% internal rate of return (IRR) and payback <7 years.
 - Hydrothermal upgrading processes delivering double-digit ROI within 5 years.

Overall: Lignin is a profitable feedstock with strong sustainability potential, though scalability and reproducibility remain challenges.

CONCLUSION

- Lignin-based polymers represent a viable pathway toward sustainable materials, but require process optimization and interdisciplinary research for large-scale adoption.

Future Directions / Applications

- Development of lignin-derived smart materials
- Coupling computational chemistry with experimental studies.
- Exploring lignin for biomedical and electronic applications.
- Scaling green processing technologies to industry

Acknowledgements

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