Plastic's Natural Rival: How Lignin is Reinventing Materials

Professor Maurice N Collins

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12.02.2026

Driving Force for Sustainable Materials

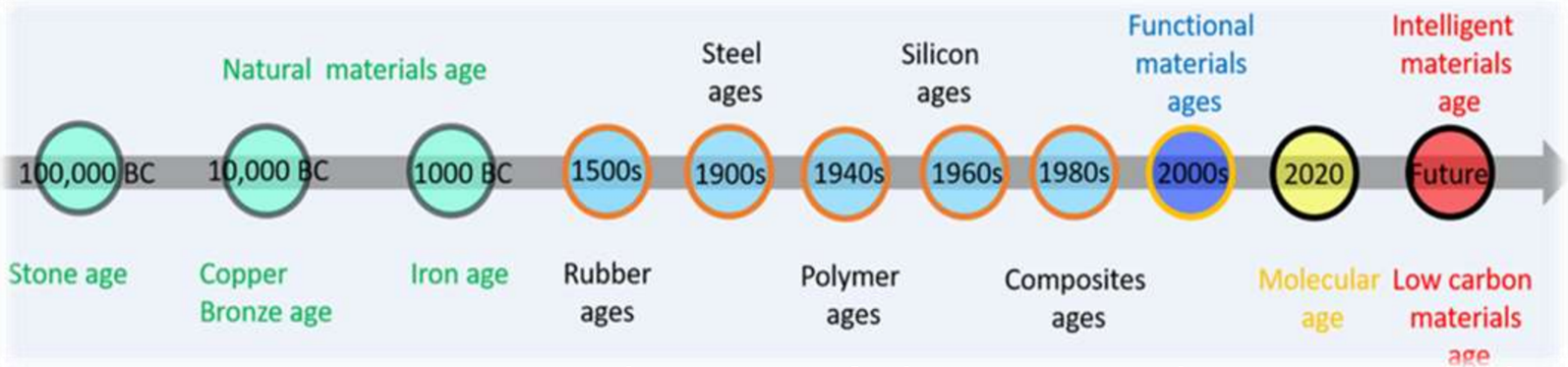
TARGET for Ireland => 51% reduction in overall greenhouse gas emissions from 2018 levels by **2030** (Climate action plan 2021)

Current situation









Sustainable + Circular materials



https://www.vox.com/2014/10/22/18093054/global-warming-explained

- Net zero emissions targets by **2050**, failure to reach targets results in fines > €1 billion (for Ireland)
  => Circular economy cannot be achieved without materials research and innovation

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Driving Force for Sustainable Materials

- Resources of tomorrow (in the EU)













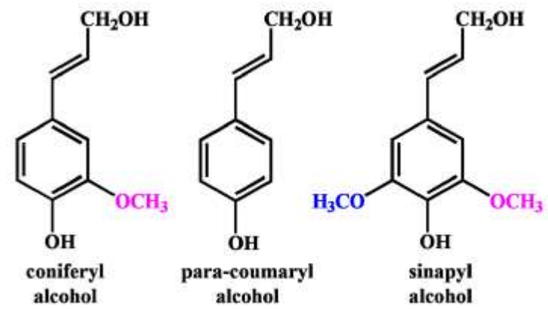




Monomers
Alagninc acid
Phenols
Sugars
Pectin
Proteins
Starch
Lignin
Chitosan
Cellulose
Chitin
Tannin
Waxes
Natural dyes
Lipids



Lignin for advanced materials



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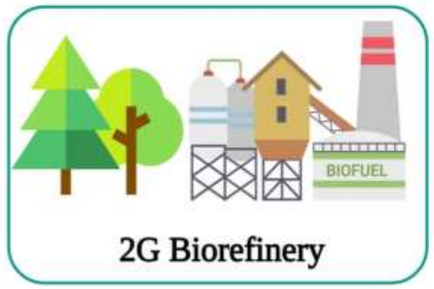
Lignin: A Sustainable Material



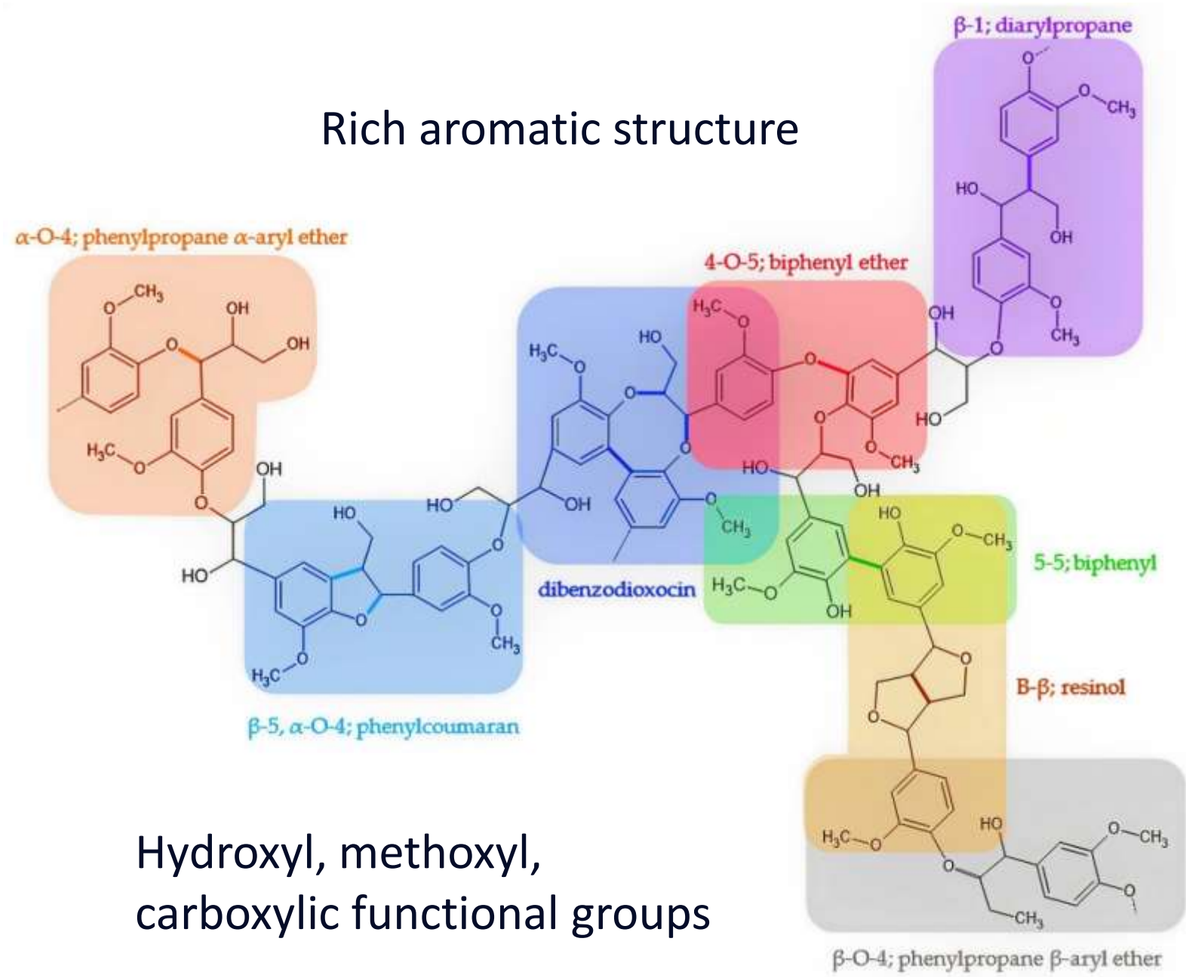
100 million tonnes/year



Lignin



Rich aromatic structure



Hydroxyl, methoxyl, carboxylic functional groups

https://doi.org/10.1016/j.indcrop.2019.111526

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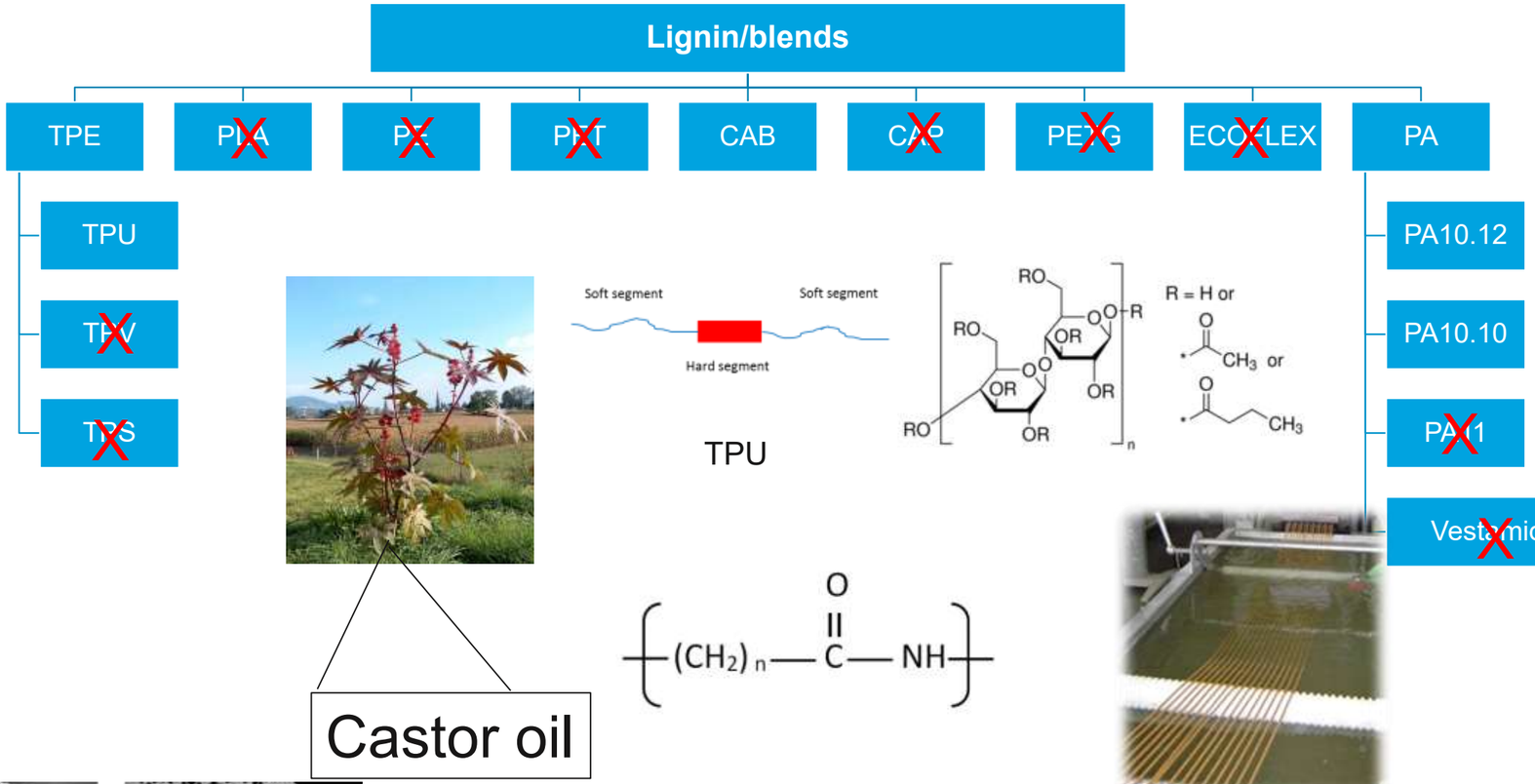
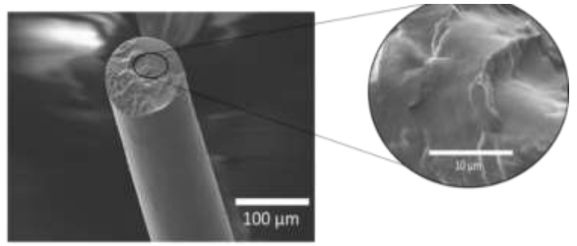
Development of Biobased Blends

Lignin Based Carbon Fibres for Composites

- Successful development of lignin blends for CF precursor

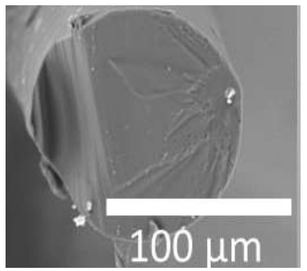


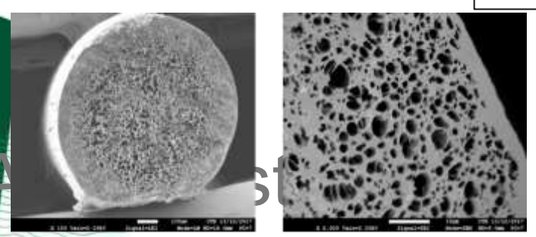
Precursor Fiber



Carbonisation

Carbon fiber





A[illegible] Chemistry & Engineering 6 (7), 8816-8825

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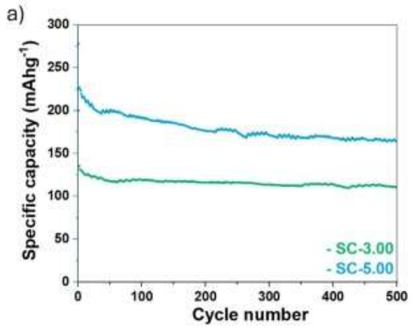
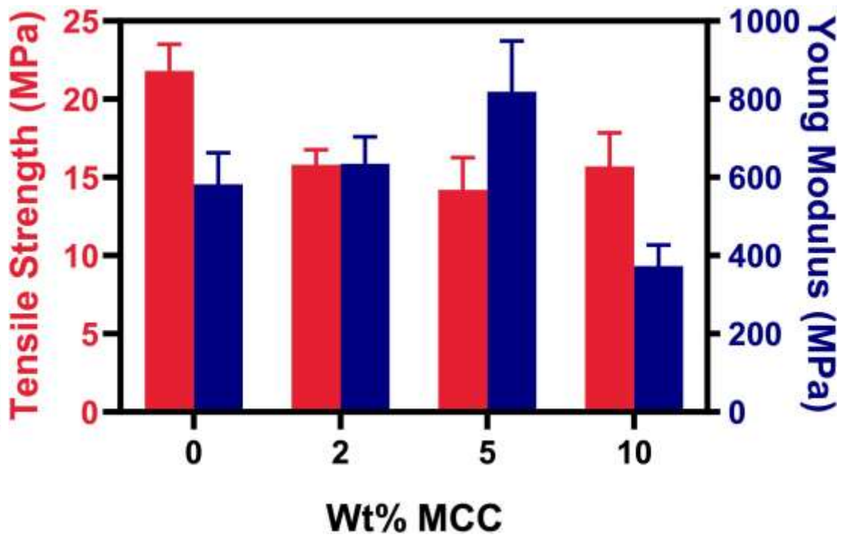
Structure/property/processing/ function relationships in polymers









spe INSPIRING PLASTICS PROFESSIONALS
POLYMER COMPOSITES

RESEARCH ARTICLE | Open Access

Understanding the role of microcrystalline cellulose for the development of high fidelity 3D printing of Kraft lignin filaments via fusion deposition modeling

Anne Beaucamp, Mark Vaughan, Maurice N. Collins



$$L_a = C(\lambda)\left(\frac{I_G}{I_D}\right)$$

Where:

$$C(\lambda) = 4.4\text{nm}$$

$$\left(\frac{I_G}{I_D}\right) = \text{Ratio of D and G bands}$$

$$L_a = \frac{K_a.\lambda}{\beta.\text{Cos}\theta} \;\&\; L_c = \frac{K_c.\lambda}{\beta.\text{Cos}\theta}$$

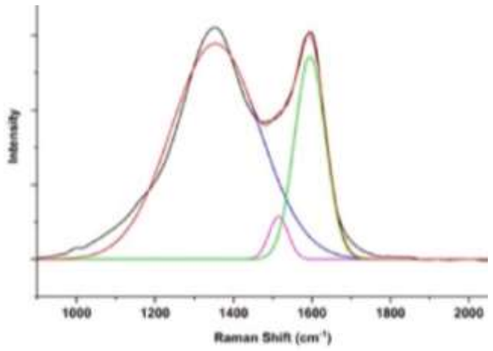
$$d_{002} = \frac{\lambda}{2\ Sin\ \theta_{002}}$$

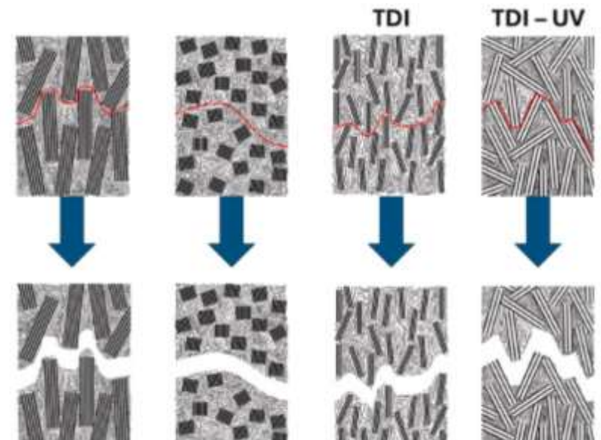
ELSEVIER
Composites Part B: Engineering
Volume 292, 1 March 2025, 112024



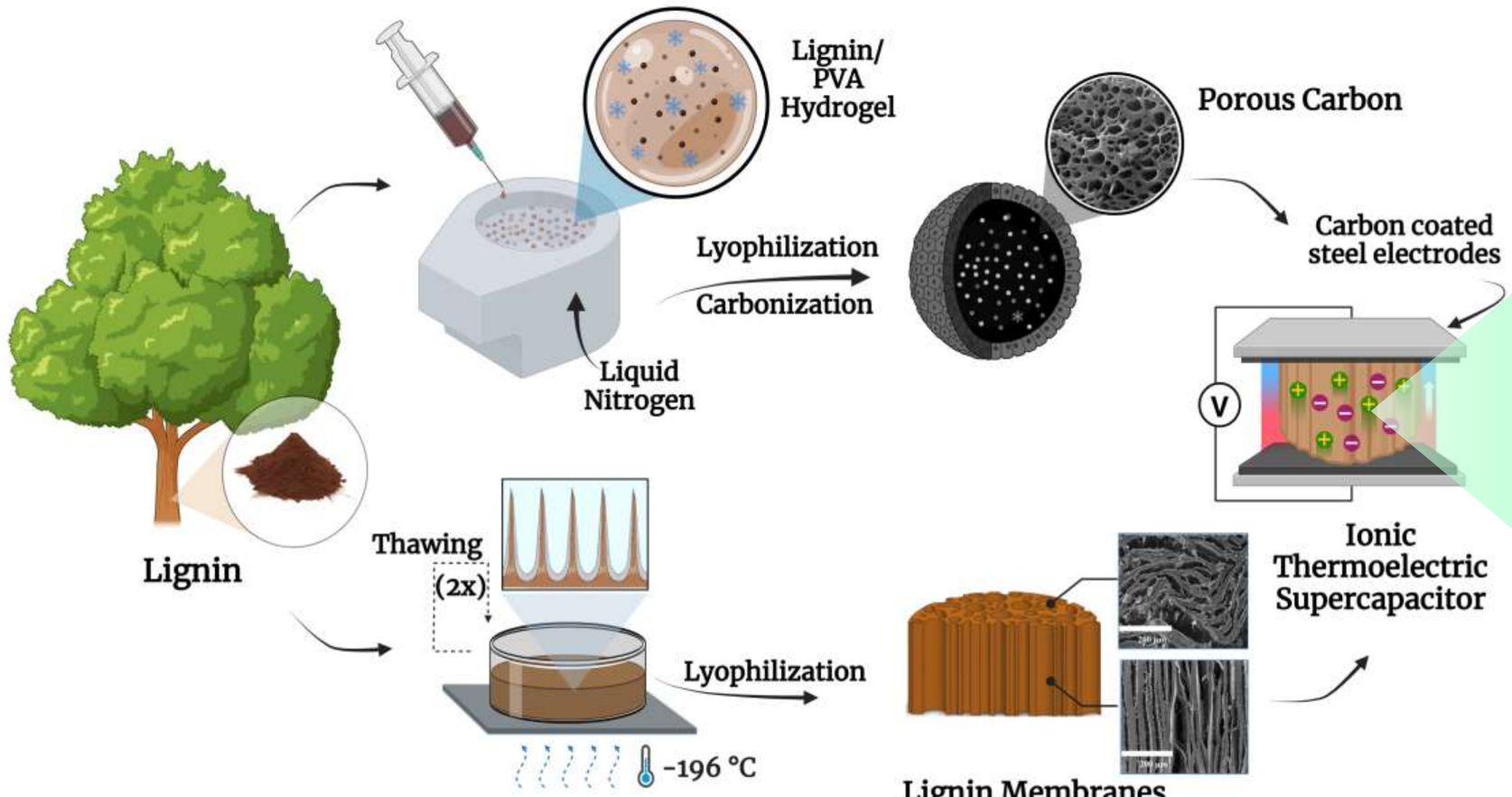
Development of high stiffness carbon fibres from lignin

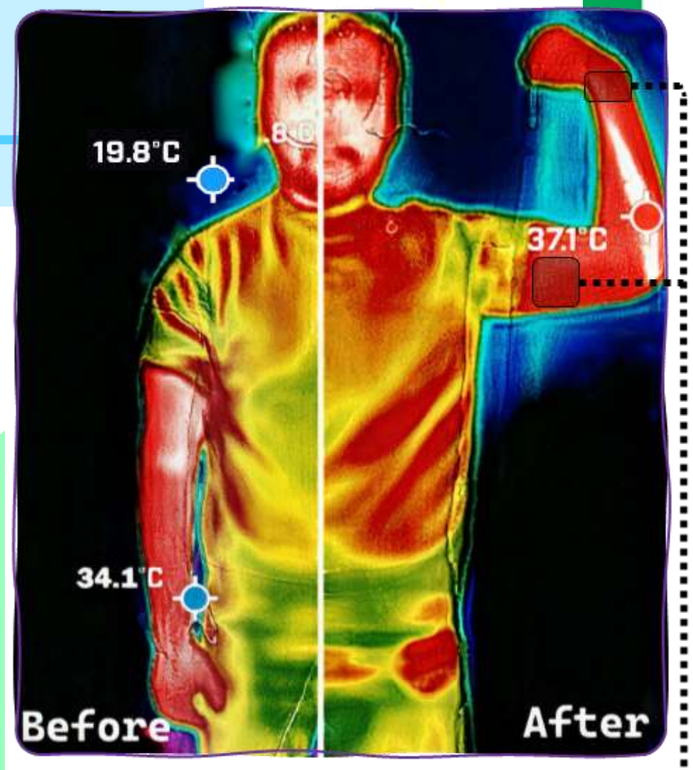
Mark Vaughan [a], Anne Beaucamp [a], Maurice N. Collins [a b]





Some applications- Thermoelectric Supercapacitor







ADVANCED FUNCTIONAL MATERIALS

Lignin-Derived Ionic Conducting Membranes for Low-Grade Thermal Energy Harvesting

Muhammad Muddasar, Mohammad Ali Nasiri, Andres Cantarero, Clara Gómez, Mario Culebras, Maurice N. Collins

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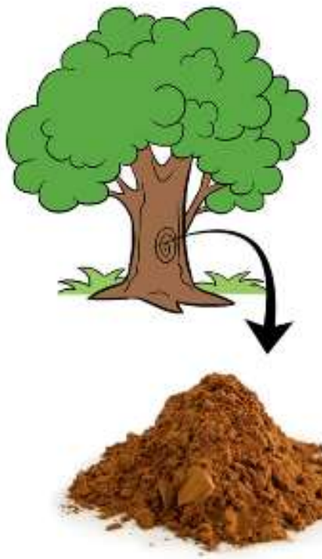
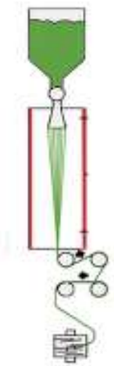
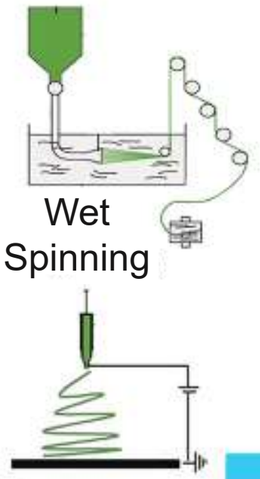
Scaling innovation_Kashif Bangash_Scaling Lignin Valorisation Paper Industry Waste_University of Limerick Ireland-2 1.mp4

Wind Turbine Blade and H_2 Storage Tank Production



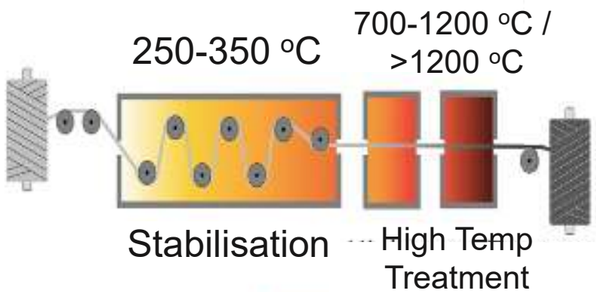




Wet Spinning

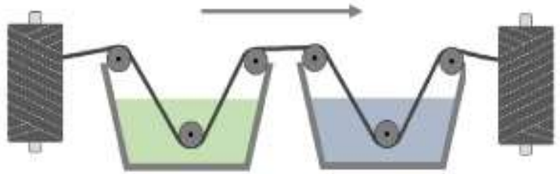
Melt Spinning

Electrospinning



Stabilisation

High Temp Treatment



Fiber Finishing

Lignin Extraction/ Purification

Fiber Spinning

Stabilisation

Carbonisation/ Graphitisation

Surface Treatment/ Sizing



Lignin Derived Carbon Fibers

[redacted]

BLADE2CIRC FORGING THE BLADES OF THE FUTURE WITH COMPOSITE MATERIALS WITH CIRCULAR, SAFE AND SUSTAINABLE DESIGN.

Title: Scaling Lignin Valorisation: Paper Industry Waste to High-Performance Fibres

Dr M Kashif Bangash

University of Limerick, Ireland

Funded by the European Union

The Blade2Circ project is funded by the European Union under the Horizon Europe Programme, grant agreement number 101147451 as part of the HORIZON-CL5-2023-D3-02 call

[redacted]



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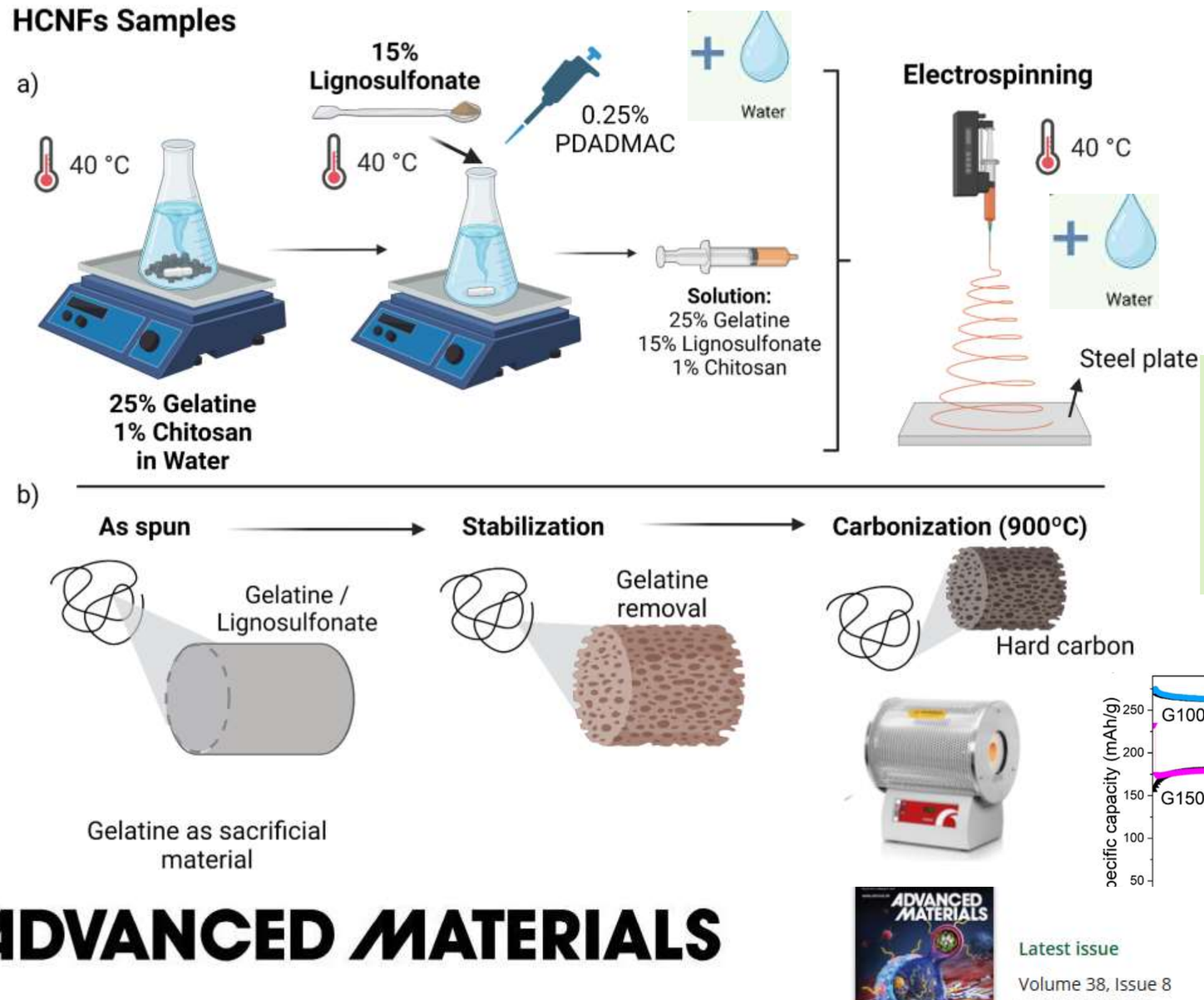
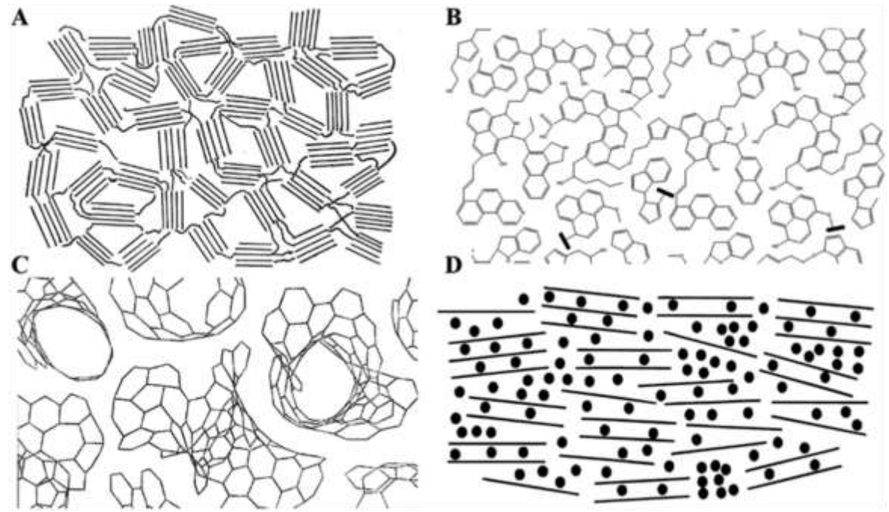
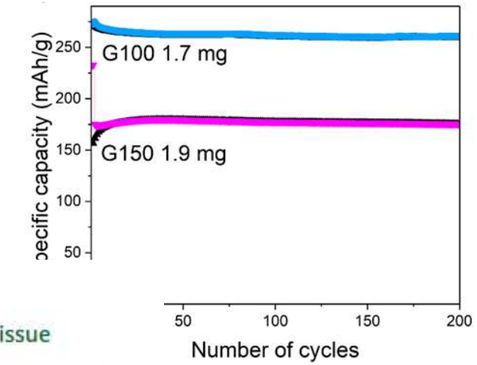
Na^+ Ion Battery Development





sp^2 hybridized carbon:
pseudographitic microdomains → intercalated and ordered Na+ storage.
**Intercalation in graphitic domains*

sp^3 hybridized carbon:
amorphous cavities and defects → micropores for Na+ storage.
** Adsorption and pore filling*



ADVANCED MATERIALS

Latest issue

Volume 38, Issue 8
6 February 2026

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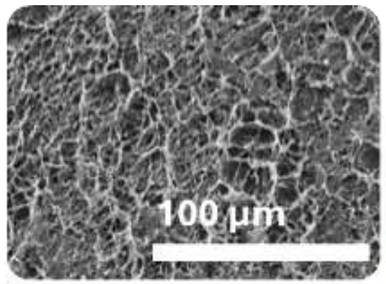
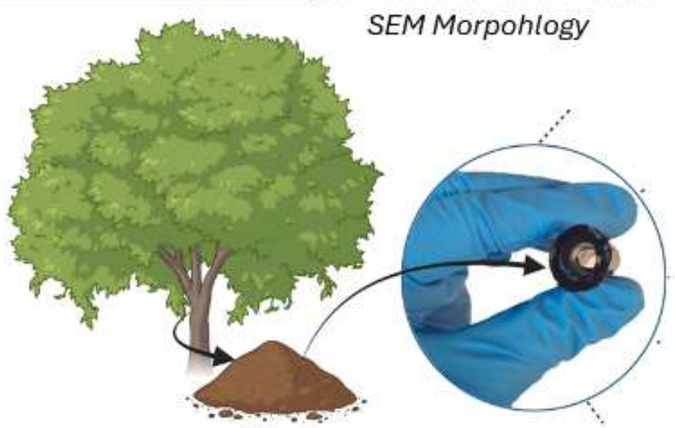
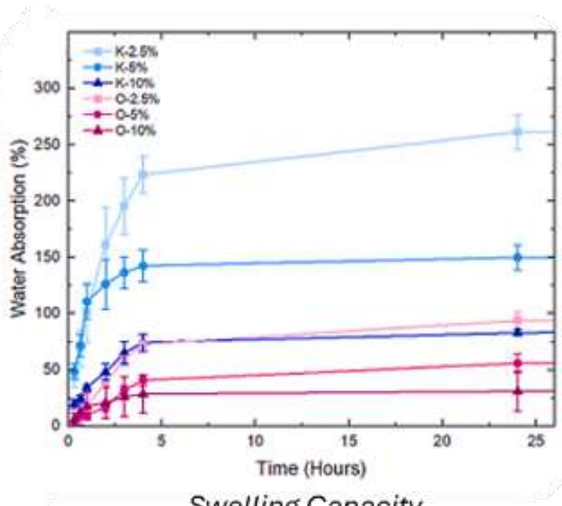
Flexible Lignin for Biomedical Applications - Tendon Recovery



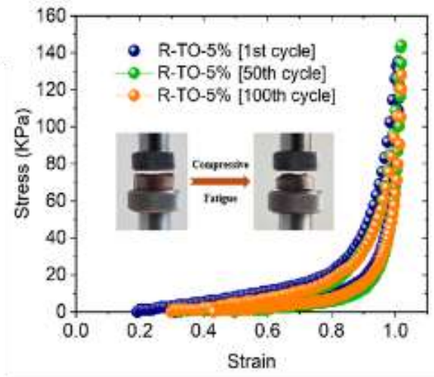
SEM Morpohlogy



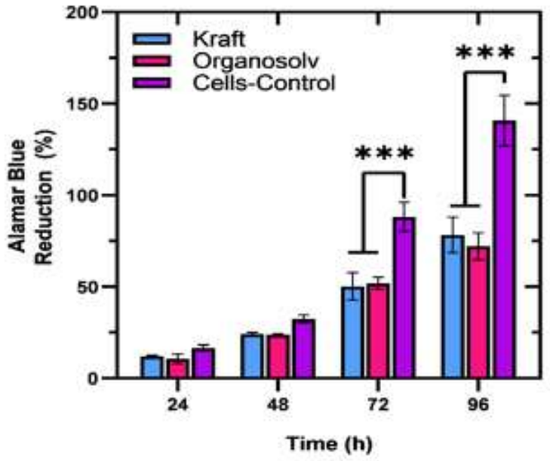
Lignin



Swelling Capacity



Cyclic Fatigue



Almar Blue Reduction

ChemSusChem
Chemistry–Sustainability–Energy–Materials
Chemistry Europe
European Chemical Societies Publishing

Research Article | Open Access

Engineering Lignin-Based Tubular Hydrogel Scaffolds for Load-Bearing Biomedical Applications

Muhammad Muddasar, Grace Joyce, Mathilde Pouzier, Aleksandra Serafin, Maurice N. Collins

First published: 11 September 2025 | https://doi.org/10.1002/cssc.202501520 | VIEW METRICS



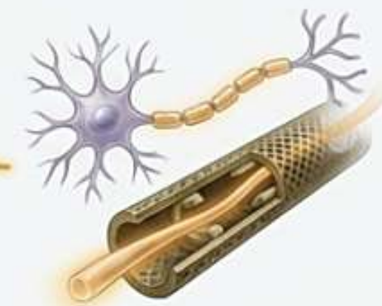
Tendon & Ligament Repair

The tubular, fatigue-resistant structure is ideally suited for guiding regeneration in load-bearing connective tissues.



Vascular Conduits

The porous, biocompatible tube could serve as a scaffold for engineering small-diameter blood vessels.



Nerve Regeneration

The defined geometry can act as a guidance conduit to support and direct axonal regrowth after injury.

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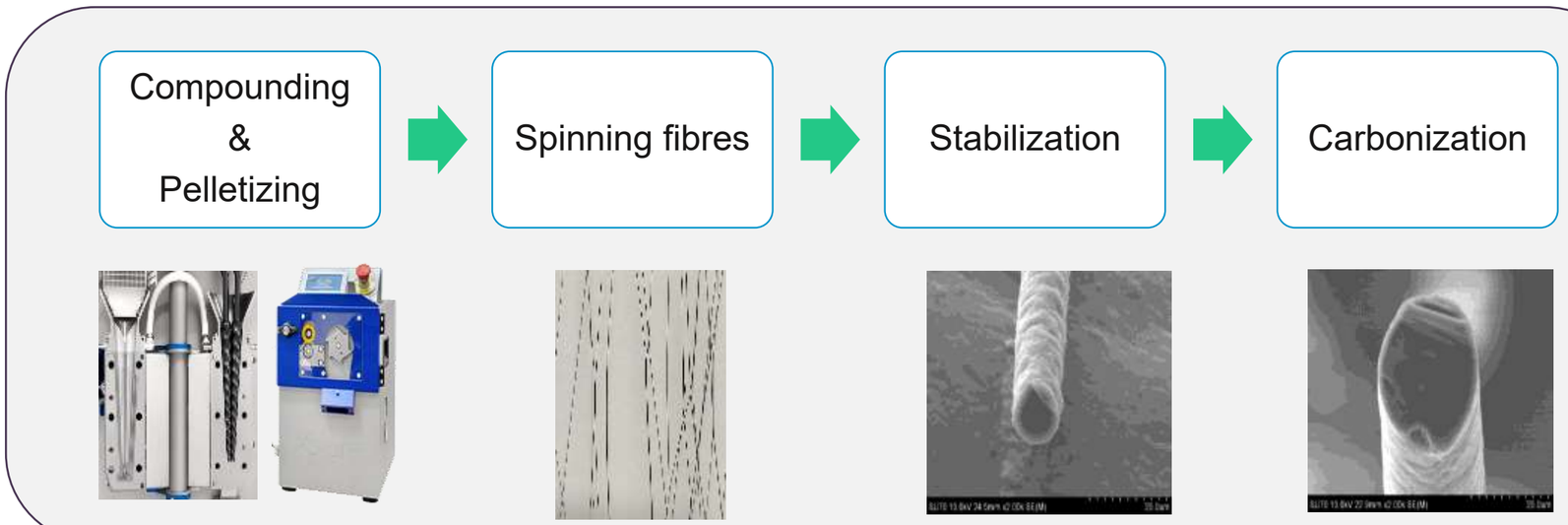
Future Plan multiscale carbon materials production

Lignin to Fiber



Fiber to Fabric

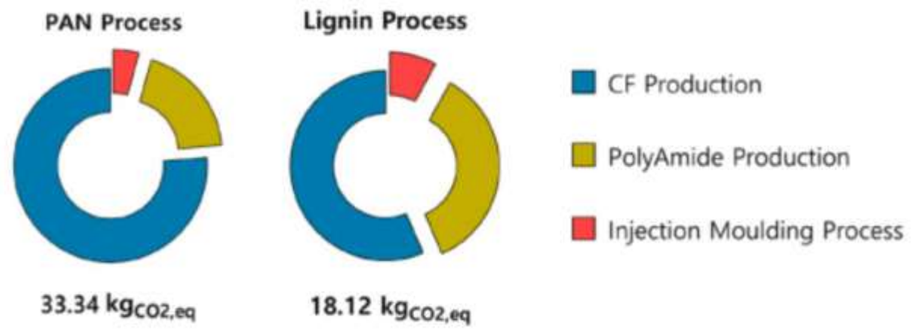


Conclusions

- Lots of progress on sustainable materials for energy related topics
- Opportunities for hybrid materials, life cycle analysis of materials and their processing steps
- Policy discussion around afforestation to mitigate carbon emissions, target to plant 18K hectares per year. Currently we are planting about 2.5 hectares per year. The aim to increase ~11% land coverage to 18 %.







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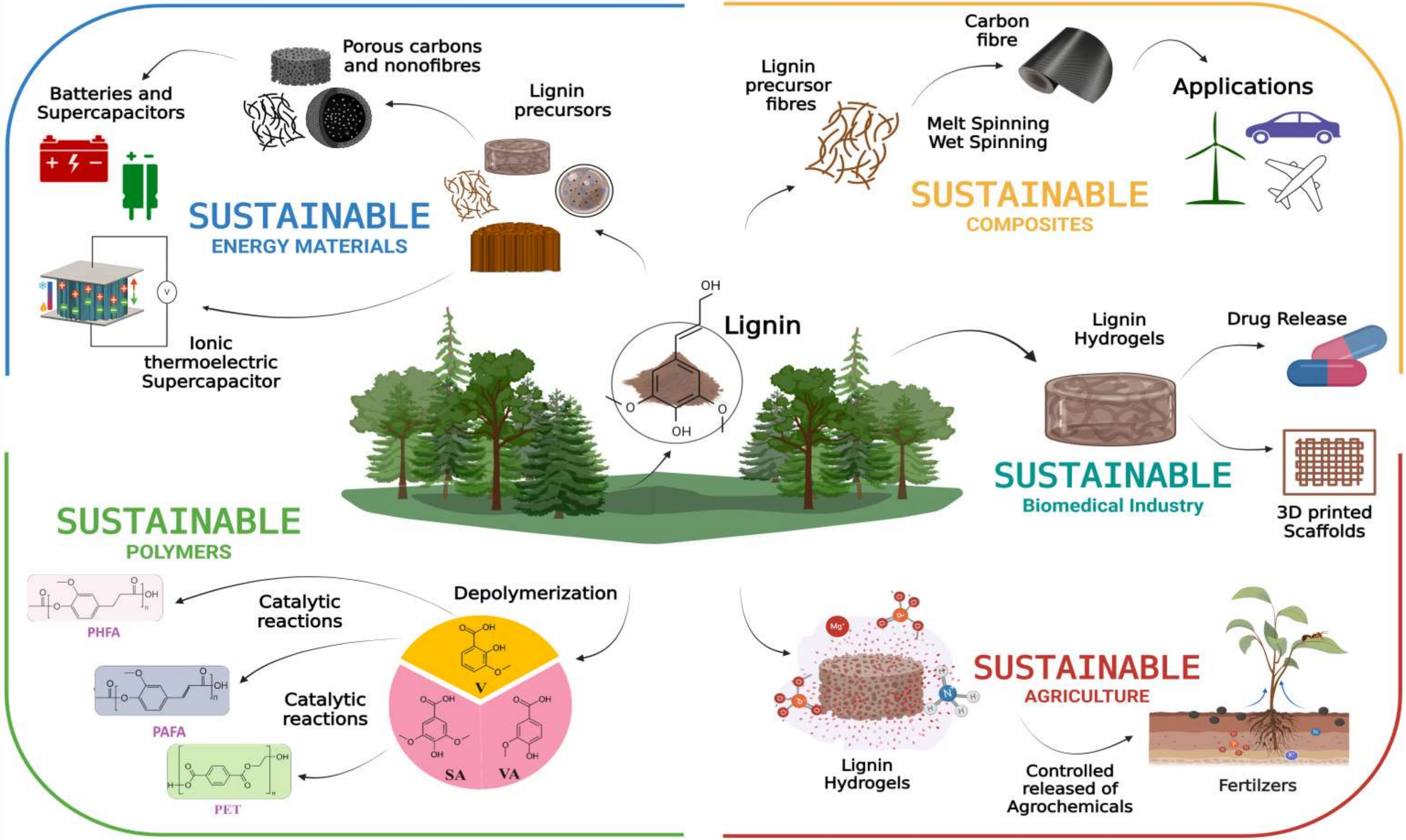
Translating Biomedical Materials knowlege to sustainable materials research



Expensive business bills paid by…..

LIBRE
Lignin Based Carbon Fibres for Composites

BBI JU

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

sfi Science Foundation Ireland

Bio-based Industries Consortium

Horizon 2020
European Union Funding for Research & Innovation

Johnson&Johnson

BIO-UPTAKE

VIBES Green Chemistry Recycling Solution

NXTGENWOOD
next generation wood products

BD

BLADE2CIRC

HORIZON EUROPE

PEPSICO

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

biorbic

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