***LABO - Axe et Equipe*: Institut Pascal – GePEB (4Bio)**

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Title of PhD subject
Valorization of Lignin: Development of High-Performance Functional Bio-Based Materials for Sustainable Applications.

Summary:

Lignin is the second most abundant bio-based polymer on Earth after cellulose, accounting for approximately 30% of plant biomass and 40% of its energy content [i,ii]. Despite this abundance, only about 5% of the lignin produced globally (approximately 50–60 million tons per year in the pulp and paper industry) is utilized for high-value applications; the majority is simply burned for energy production[iii]. Its unique chemical structure, composed of an aromatic backbone and various functional groups, makes it a valuable resource for replacing petroleum-derived products. Therefore, its valorization represents a significant opportunity for the development of innovative and sustainable bio-based materials.

This PhD project aims to explore the functionalization and integration of lignin into two main application areas under environmental constraints:
1. Bio-Based Packaging: Development of eco-friendly packaging materials by replacing petroleum-based plastics with composites incorporating lignin. This approach aims to enhance the barrier, mechanical, and thermal properties of packaging while reducing its environmental footprint.
2. Sustainable Construction Materials: Integration of lignin into composites intended for the building sector, such as insulating foams, composite panels, and coatings, to improve the durability, mechanical strength, and thermal insulation of construction materials.

Particular attention will be given to the **eco-design** of materials and processes to meet the United Nations Sustainable Development Goals (SDGs), notably SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Life Cycle Assessment (LCA) will be used as an environmental evaluation tool from the early stages of development, allowing for the identification of critical points and optimization of processes accordingly. The biodegradability of materials will be systematically evaluated according to current standards to ensure their ecological end-of-life.

This thesis proposes an integrated approach to valorize lignin, addressing several contemporary challenges: valorization of industrial waste, development of high-performance bio-based materials, and reduction of the environmental footprint of manufactured products.

[i] R. Shorey et al. Valorization of lignin for advanced material applications: a review, *RSC Sustainability*, 2024, **2**, 804-831 https://doi.org/10.1039/D3SU00401E
[ii] E. Martin et al. Recent advances in laccase activity assays: A crucial challenge for applications on complex substrates, *Enzyme and Microbial Technology*, 2024, **173**, 110373 https://doi.org/10.1016/j.enzmictec.2023.110373
[iii] https://lejournal.cnrs.fr/nos-blogs/focus-sciences/dechets-du-bois-valoriser-la-lignine-en-la-solubilisant