Centre Génie Industriel

IMT Mines Albi
École Mines-Télécom

PhD Thesis Proposal
Collaborative Information System for Recycling value chains

lispen

Arts Sciences et Technologies et Métiers

Context

Recycling value chains in France and Europe face significant challenges due to the diversity of actors involved, the fragmentation of management systems, the heterogeneity of material flows, and increasing economic and regulatory constraints. This structural complexity is further amplified by the interdependence of processes, variability in available resources, and the growing need for industrial and technological sovereignty.
While the literature on the circular economy is extensive, much of the existing research remains focused on local process optimization (e.g., energy efficiency, waste reduction, yield improvement) or on individual actors, without fully addressing the systemic dynamics and multi-scale interactions required to build robust and resilient recycling networks.

To address these challenges, recent studies emphasize the need to move beyond siloed approaches and develop systemic models capable of integrating the entire product life cycle, delayed decision feedback, sector-specific constraints, and multi-level governance mechanisms. These approaches must consider not only the physical and economic characteristics of materials but also the collaborative dynamics between heterogeneous actors, the uncertainty of material flows, market unpredictability, and the rapid evolution of technologies and regulations.

Problem Statement

Important note: this is not a PhD in Artificial Intelligence.
The RéGéNexus project proposes an innovative approach to structuring and managing recycling value chains as dynamic, interconnected, and territorially embedded networks. Based on Systems of Systems (SoS) engineering, the project aims to overcome the limitations of local optimization by integrating multi-level interactions, complex feedback loops, and sector-specific constraints. This vision facilitates the coordination of actors with potentially divergent goals, while providing the flexibility needed to respond to the uncertainties of material flows and the rapid changes in market and regulatory conditions.
This PhD will contribute to a task of the RéGéNexus project. It is **centered on the design and architecture of a distributed collaborative information system**, capable of ensuring interoperability between heterogeneous partners, detecting contextual changes, and dynamically reconfiguring itself. Artificial intelligence or data science methods may be used as tools when relevant, but they are not the primary focus of this PhD.

Research Problem Addressed in this Thesis

The PhD is dedicated to the design of a collaborative information system that is distributed, interoperable, and agile. The system should enable data sharing, information synthesis, product traceability, and support for the coordination of decision-making among stakeholders. The research will focus on the definition, modeling, and implementation of software architectures enabling interoperability and adaptability in multi-actor contexts.

State of the Art

The recycling chain is viewed as a collaborative ecosystem of heterogeneous and evolving entities. The definition and development of information systems is a recurring theme at the intersection of computer science and industrial engineering.
Collaborative information systems aim to facilitate data sharing and the orchestration of processes among multiple partners, relying on services provided by various stakeholders involved in the collaboration. To address the need for agile configuration, model-driven and service-oriented architectures have been developed. A persistent challenge in this domain is ensuring the required interoperability among the various information systems.
The supervisory team has experience in the definition and management of collaborative information systems across diverse contexts requiring agile coordination among stakeholders: biomass valorisation (Houngbé et al., 2019), deduction of collaborative processes (Montarnal et al., 2018), Industry 4.0/5.0, and the enhancement of decision-making processes through new technologies (Rosin et al., 2022).

Scientific Challenges

Several gaps have been identified that will be studied during this PhD:

- Integrating agility on several levels: chain reconfiguration, partner changes, decision process changes, late flows adaptation to materials variability,
- Meta-modelling of minimal necessary information needs based on the required levels of collaboration, to ensure both process lifecycle management and situational awareness.
- Assessing data quality and strategies to address data gaps (e.g., data augmentation, synthetic data creation),
- Monitoring a data-driven model of the value chain that can trigger alerts and enable the reconfiguration of the recycling chain as needed,
- Identifying the technologies most suited to support the information system features.
- Defining a set of methods and tools that are generic enough to be applied to various recycling chains and support the required reconfigurations.

Clarification: *While some parts of the RéGéNexus project involve advanced material characterization (e.g., hyperspectral imaging, deep learning), these are not the focus of this PhD. The doctoral work will focus on information system architecture and software integration in a collaborative, volatile environment.*

Action Plan

The main steps of the PhD include:

1. Conducting a literature review on collaborative information systems used in the management of recycling chains.
2. Modelling distributed decision-making processes in the studied context.
3. Assessing opportunities to enhance these processes with emerging information system technologies.
4. Identifying the precise data needs to support decision-making processes.
5. Addressing interoperability requirements at different levels.
6. Designing and orchestrating collaborative processes to ensure their agility through an illustrative case study.

References

1) Houngbé, M., Barthe-Delanoë, A. M., & Négny, S. (2019). Servitization of biomass processing for a virtual biorefinery: application to the lignocellulosic biomass in a French local territory. In 20th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2019, Turin, Italy, September 23–25, 2019, pp. 477-486.
2) Rosin, F., Forget, P., Lamouri, S., Pellerin, R., (2022). "Enhancing the decision-making process through Industry 4.0 technologies", Sustainability, 14(1), 461
3) Montarnal, A., Mu, W., Benaben, F., Lamothe, J., Lauras, M., & Salatge, N. (2018). Automated deduction of cross-organizational collaborative business processes. Information Sciences, 453, 30-49.

Thesis Information

This PhD is part of a joint supervision between CGI (France) and LISPEN (France).

- **Location**: Albi (main location) – Aix-en-Provence
- **Expected start date**: March 2026
- **Funding**: PEPR PRAN RéGéNexus.

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Profile:

Education

- Master's degree in Computer Science or an Engineering degree in Computer Science.

Core competencies

- Information systems architecture and design, particularly distributed systems.
- Software development skills (Java, Python) and knowledge of service-oriented or microservice architectures.
- Enterprise and process modelling (UML, BPMN, meta-modelling).
- Systems interoperability and integration of heterogeneous systems.
- Databases (relational and non-relational) and information flow management.
- Strong proficiency in English (minimum level B2) ***and*** French (minimum level B2)

Transversal skills

- Autonomy and ability to work collaboratively within a research team.
- Motivation to contribute to research on sustainable development through digital sciences and information systems.

Additional desirable skills (not mandatory)

- Knowledge of closed-loop supply chains or circular economy.

Application materials: CV, cover letter, summary of Master's thesis or research work, transcripts, and any other supporting documents.

Application deadline: February 15th, 2026, 12:00 PM.

Notification for interview: no later than February 20th, 2026.

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