Building material flow characterization allowing the realization of multi-scale circular economy studies: from research to practice

Rafaela Tirado, Adélaïde Mailhac, Sylvain Laurenceau and Guillaume Habert

Challenges & opportunities to promote CE in the building sector [1]

Knowledge
Lack of knowledge about materials in building-stock and their characteristics (e.g., the type & quantities of available deposits, CDW flows, secondary resources: mechanical & sanitary properties, LCA) to anticipate needs and plan for optimal resource management.
Stockholders & scales of action (e.g., depending on the amount of material flows to stock, or/and recover).

Technical
Stockholders' training & qualification to apply circular economy (CE) all along building life cycle (e.g., diagnosticians' qualification & training are essential to reconcile the knowledge of materials in the building stock & deposits; and the knowledge of waste and potential sectors to reuse & recycling).
Avoiding deconstruction (if the building can offer suitable characteristics: i.e., structural, sanitary & safety).
Improve deconstructions (e.g., workers qualification, machinery, time & economics investment).
Traceability & digitalization (e.g., to follow-up resources and share information between stockholders).

Market
Include the environmental price for new products and materials.
Create new economic chains around secondary resources, especially local chains

Cultural & regulations challenges
Clients perception & interest in reused material (e.g., materials performances, quality, costs)
Census and synergy of stakeholders
Adapt laws, norms & regulations for secondary resources.

Material flows : the research gap [2-6]

Building stock materiality
Improve knowledge about the nature, condition, and quantity of materials in the building stock (for residential and non-residential uses)

Waste flows
Detailed CDW estimation (e.g., concrete & stones, bricks, wood) to better management of waste & secondary resources; and, an optimal CE strategies formulation (based on model's reliability).

Modeling
Assessment scale depends on data's granulometry, disponibility, & accessibility; however, the model should be preferably flexible, replicable, and have high spatial & temporal resolution.

Results
The reliability, precision, and accuracy of different models' results need to be assessed.
Uncertainty quantification is essential for optimal decision-making.

BTP-Flux : a macro-component based model for building materials flows characterization

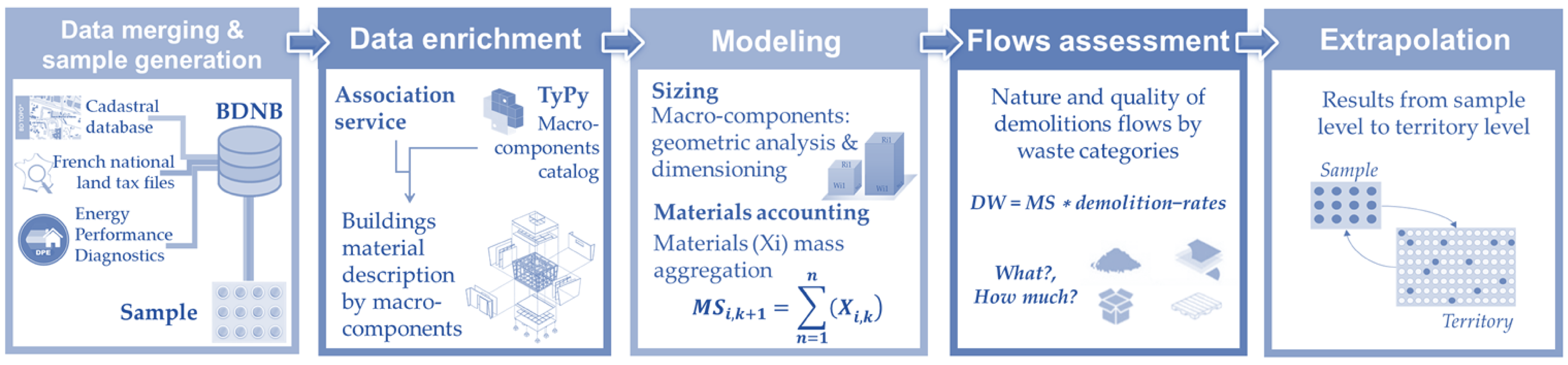


Figure 1. BTP-Flux methodology to perform the material flow analysis (MFA) at territorial scale

BTP-flux main contributions
- **Modular &** systemic structure
- **Multi-scalar** results.
- The methodology integrates **GIS**.
- Possibility to assess all the construction materials present in the building stock (residential and non-residential sector).
- Waste flows: materials granulometry adapted for CE studies (categories of materials (e.g., concrete, stone, wood) instead of waste groups (e.g., inert waste, hazardous waste)).
- **Flexible** & **replicable** model, possibility to expand, for instance, for new buildings, environmental evaluations.

BTP-Flux : the case of Ile-de-France region

The Ile-de-France region represents about 2% of the French territory, nevertheless, it brings about 18% of the total population. Regarding their sub-regions and their urbanization, Paris is about 3 times that of the Petite Couronne and about 8 times that of the Grande Couronne. For the study case, the retained sample comprises 88 749 residential buildings (individual and collective housings) and 12 603 non-residential buildings (offices, industrial and education buildings)

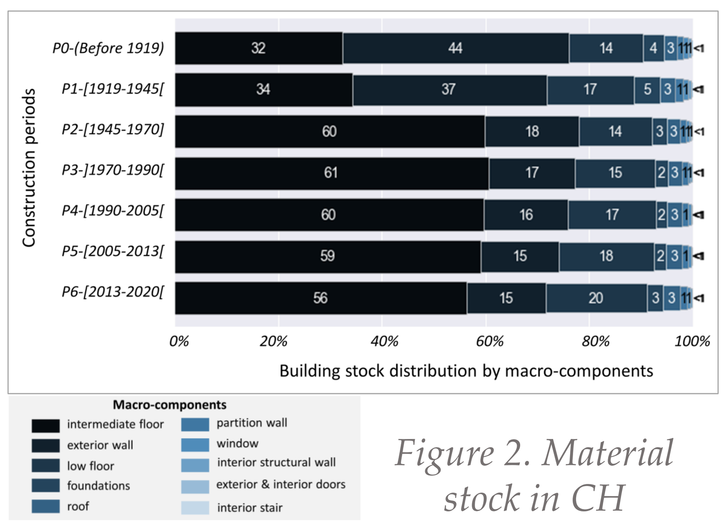
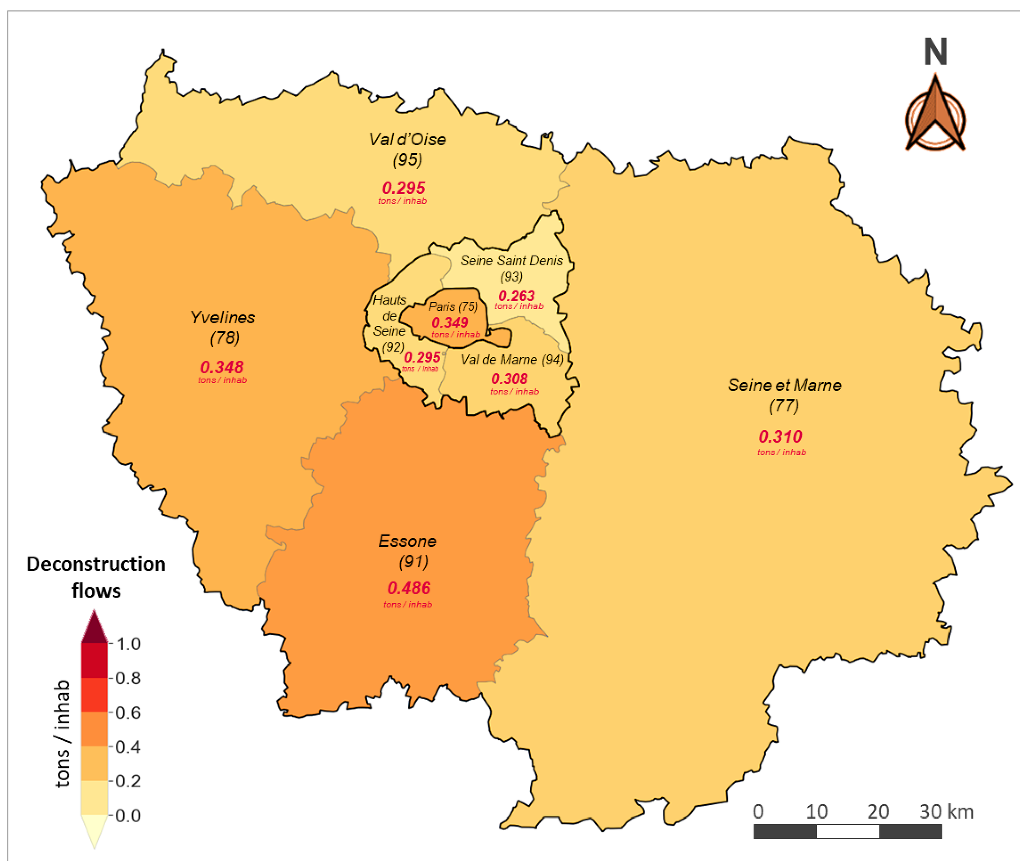


Figure 2. Material stock in CH

BTP-flux allows material accounting in the building stock, whit details by location, building use, construction period (CP), macro-components, and material categories. Figure 2. shows the material stock for collective housing (CH), segmented by CP and building macro-component. A general remark is that around 90% of the building materials are stocked in the load-bearing structure of the building.

Demolition flows per year are estimated at around 4 Mega-tons for the region (Figure 3). The production of flows is homogeneous in the assessed departments and sub-regions. Concrete and stone represent more than 80% of the total wastes; nevertheless, even if the non-concrete waste represents a small part of the total waste, their management could represent one of the major challenges.



Sub-region	Department	Department name	Flows (Kt)		tons/inhab	
Grande Coruonne (GC)	77	Seine et Marne	444	1960	0.310	0.359
	78	Yvelines	506		0.348	
	91	Essonne	639		0.486	
	95	Val d'Oise	371		0.295	
Petite Couronne (PC)	92	Hauts de Seine	482	1358	0.295	0.288
	93	Seine Saint Denis	440		0.263	
	94	Val de Marne	437		0.308	
Paris (P)	75	Paris	747	747	0.349	0.349
	Ile-de-France		4065		0.330	

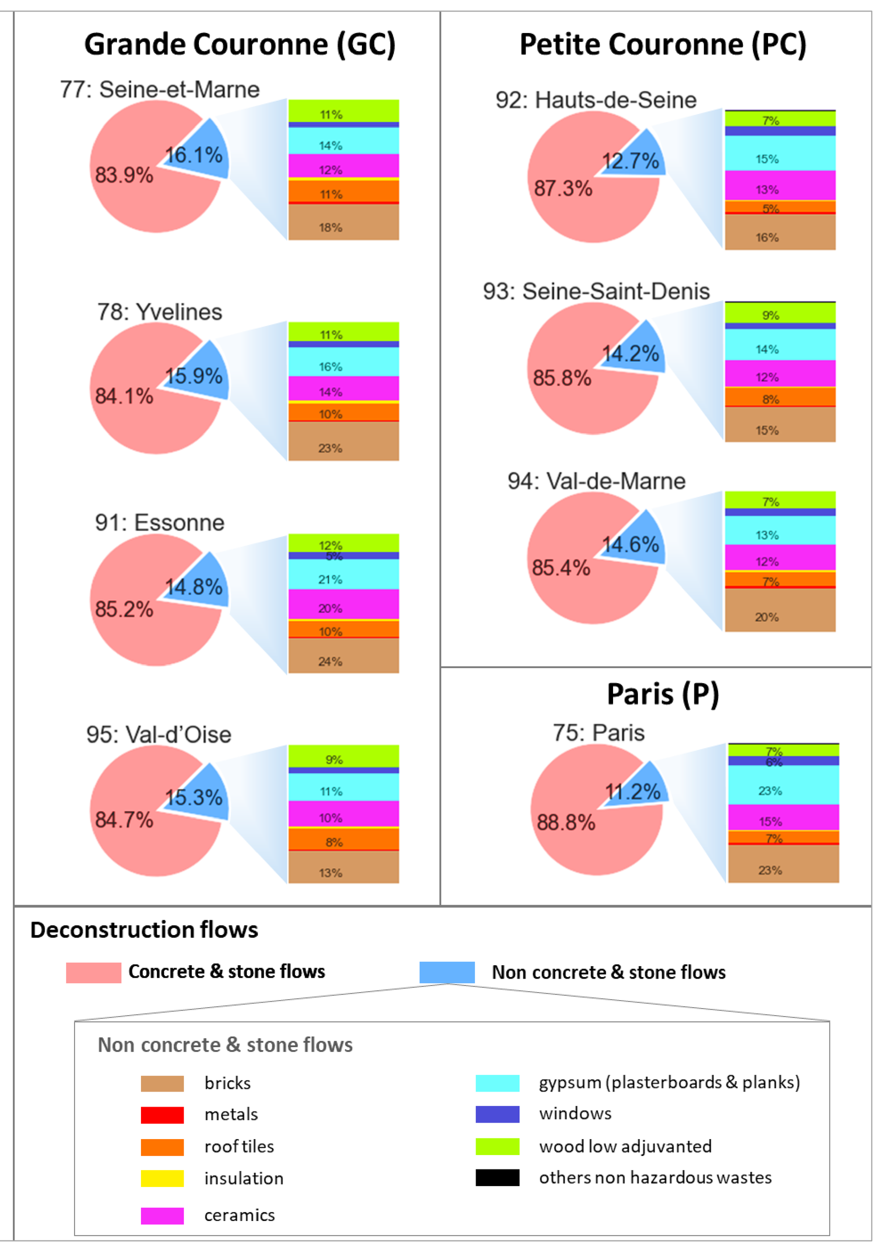


Figure 3. Ile-de-France region demolition flows. Details by department, sub-regions and waste categories

Conclusion

The research presents the principal challenges and opportunities for implement CE in the building sector and proposes a response to the lack of knowledge about materials in building-stock and CDW flows, for which MFA gaps are also identified. Then, BTP-Flux, a macro-component bottom-up-based model, is proposed to estimate, at several scales, the detailed waste material categories. Results obtained can be useful to anticipate needs and plan for optimal waste and resource management. BTP-flux structure allows future improvements like new data incorporation and other transdisciplinary assessments.

Further work

BTP-Flux model uncertainties assessment: results' uncertainties quantification coming from categorical and numeric variables. Adaptation of the confusion-matrix theory for categorical variables uncertainties quantification. Use of the Monte-Carlo method for uncertainties propagation among the model steps.

References

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Contacts
Rafaela TIRADO
rafaela.tirado.f@gmail.com
+33 0610024655
www.linkedin.com/in/rafaela-tirado

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