CREATE Embedding advanced urban material stock methods within governance processes to enable circular economy and cities resilience

STAKEHOLDER PRACTICES AND NEEDS

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Abstract	This report analyses the stakeholders' practices and needs related to circular economy in the construction sector. It focuses on the three living labs of the CREATE project : Rennes Métropole (France), Nijmegen (Netherlands) and Gothenburg (Sweden). Analysis is based on three complementary investigation methods: a review of literature, an online questionnaire and interviews with key actors. The study shows that the municipalities are already implementing ambitious and innovative policies for the circular economy in construction. Particularly, environmental assessments of construction projects based on a life cycle approach become "standard", often in response to national legislations. However, the study of material flows and associated environmental impacts at the level of the urban project or the city is still underdeveloped. These observations open interesting perspectives for the CREATE project. They confirm the interest of better producing and sharing data on material stocks and flows at an urban scale (project or territory) as a decision support.
Keywords	circular economy, construction sector, policies, lifecycle assessment, metabolism study, stock and flow analysis

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1 INTRODUCTION

1.1 CREATE

The CREATE project aims at supporting urban transformation processes towards the circular economy by making an inventory of the existing material stocks within urban construction, developing reliable scenarios for future expected material flows, and providing governance arrangements on how to approach the circular economy transition. The project focuses on the largest urban infrastructures and communal assets, namely buildings, municipal roads, water, and wastewater pipes. A truly transdisciplinary consortium works with a mixed research design that integrates quantitative modelling with qualitative study and design of governance aspects.

The project will further improve already existing, validated, and applied tools and arrangements and combine them with new digitalization technologies to inform decision-makers and enable a circular built environment. This will be achieved by engaging with a wide range of stakeholders in a co-creation process with three urban living labs and six fellow cities in five countries, which will result in numerous capacity building moments throughout the entire project.

A thorough analysis of best practices of cities steering the circular economy transition together with new governance interventions will result in concrete proposals of tailored governance arrangements for the participating cities including a concrete proposal for an upscaling strategy for Europe.

The CREATE project follows a set of strategic underpinnings that connect the different work packages in three dimensions:

1. A living lab approach that is used throughout all work packages and allows for an integrated co-production of the project with stakeholders from the quadruple helix;
2. A multi-scalar capacity building approach, where the use of the living labs as the focal point of the work developed, complemented by the dissemination of knowledge to fellow cities and an outreach to urban networks in Europe, will allow for an optimized scalable process;
3. A tailored and adaptable approach that is based on the pre-existing conditions of the urban living labs and fellow cities, i.e., existing data, methods and governance procedures already being utilized by the stakeholders and providing them with new knowledge.

1.2 Objectives of WP2

WP2 aims at :

1. jointly **framing circular economy needs** in terms of data, assessment methods, visualization solutions and interactive platforms related to circular economy policies or projects lead by municipalities;
2. **defining the actions to be carried out** within the CREATE project to meet the needs of the municipalities.

1.3 Task 2.1 : Joint framing of circular economy needs

An integration between relevant stakeholders and decision-makers and the partners in the consortium will be made to formulate the CE needs for the built environment. This will be based on an online survey targeted to a panel of people working on CE in cities. Special attention will be given to available data on stocks and flows their format and current dissemination. An update of the literature review, departing from studies already carried out by the participants of the project, on the use of data about material stocks and flows in urban CE projects and policies and semi-structured interviews and workshops with key players in the 3 urban living labs that will provide information to refine the analysis of the situation and needs.

3 sub-tasks :

- **2.1.1. Literature review** (mapping the barriers and challenges of CE transition and identifying information needs from different stakeholders);
- **2.1.2. Semi-structured interviews and workshops** with key players in the 3 urban living labs;
- **2.1.3. Online questionnaire** (people working on CE in cities, about CE needs for the built environment, including available data on stocks and flows, their format and current dissemination).

Objectives of the interviews and questionnaire are to :

- identify the CE projects and the tools that the living labs already developed and used to support the implementation of the projects/decision process / understand what studies or data were useful in conducting this policy and how this information was disseminated;
- identify the breaks/levers in the decision process of the municipalities for CE in the construction sector in terms of regulations/law, stakeholders, techniques, etc. ;
- identify their needs in terms of tools and studies (information production, data) and visualization platform.

2 METHOD

2.1 General method

The work is based on the combination of three complementary investigation methods:

- a review of the technical and scientific literature, considering previous literature reviews conducted by the members of the consortium;

- an online questionnaire with the main actors of the circular economy in the living labs;

- semi-directed interviews with key players in the three living labs.

The literature review makes it possible to draw on the results of previous research conducted around the world. It allows us to clearly identify the main obstacles and levers for the implementation of circular economy strategies in construction.

A specific survey of the three living labs of the CREATE project allows us to understand precisely what the current practices and needs of these territories are. It illustrates the data, tools and achievements made and highlights the barriers and levers used.

This survey is based on two complementary approaches: questionnaires, which provide synthetic information from a larger number of stakeholders. Finally, a semi-structured interviews process, which provide rich information from an optimized number of stakeholders (time for appointments, interviews, and reports).

2.2 Literature review

The stakeholder needs mapping started with a pre-interview with a stakeholder from an architecture company. This pre-interview provided some information about their needs as a starting point and can be used as supplementary information for the literature review. The search string ("needs" OR "barriers" OR "challenges") AND ("circular economy" OR "circularity" OR "reuse" OR "recycling" OR "reclaimed") AND ("built" OR "building" OR "infrastructure" OR "construction") was used to do a strategic search in Google scholar and Scopus.

The string was used in Google scholar by title search and in Scopus by title and abstract search. Since the search in Scopus is more extensive which includes the search string in title and abstracts, a brief review of titles and abstracts is conducted to exclude articles that were not in the relevant subject area of this study. The literature is sorted by relevance and the first 1500 articles are filtered because there is a large number of irrelevant articles in the search results and after the first 1500 articles, it is difficult to find one article that meets the requirements for every 100 articles. After that, an abstract review is conducted to exclude the articles irrelevant to the objective. Besides the articles from other fields, mostly removed

articles defined as irrelevant to the objective are about: the design of new buildings for reuse in the future; and the construction waste generated during construction processes. The relevant articles from Google scholar and Scopus were selected for further review.

A citation network analysis was performed with the VOSviewer app to select the most representative articles based on the selected literature list. Reports and master thesis were excluded from this process. The articles with greater than or equal to 5 links were identified as representative articles and were reviewed. However, considering that there was a significant amount of literature that didn't appear in the citation network analysis, articles with more than 50 citations were also reviewed. A total of 30 papers were fully read for mapping stakeholder needs.

2.3 Questionnaire

2.3.1 Questionnaire development

The framework of the online questionnaire was informed by the analysis of the literature, for example for the list of difficulties and levers, and includes similar questions to the interviews The questionnaire was limited to a few questions in order to optimize response time and maximize the number of potential respondents.

The questionnaire is presented in Annex A.

2.3.2 Distribution of the questionnaire

A list of professionals from the construction sector working in the Living Labs and/or in the countries where the Living Labs are located was drafted. This process was done in collaboration with the Living Labs representatives. This list aims to collect answers from a large and sufficiently representative panel of professionals in terms of activities: place in the construction value chain and type of activity related to the circular economy carried out.

About 30 professionals for each living lab have been contacted. The questionnaire was distributed on the Jotform platform from March/April 2023. Some very limited answers could be gathered during the first weeks for some livings labs. Therefore, the planning was extended until June 2023. The questionnaire has been distributed in the Netherlands with the support of the Economic Board and the Rijk van Nijmegen, through their regional network of stakeholders involved in the circular construction.

2.3.3 Respondents

47 people answered the questionnaire. As shown below, the number of respondents is almost equal for each living lab.

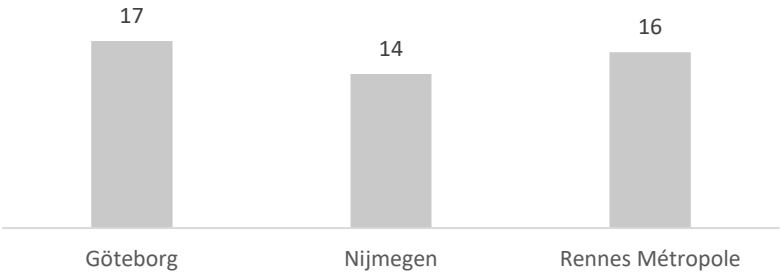

Figure 1. Number of respondents

Most respondents to the questionnaire are designers or engineers (architects or environmental/sustainability engineer/consultant). This is particularly the case for Göteborg and Rennes Métropole. Local authorities are first in Nijmegen (mostly in the environmental department).

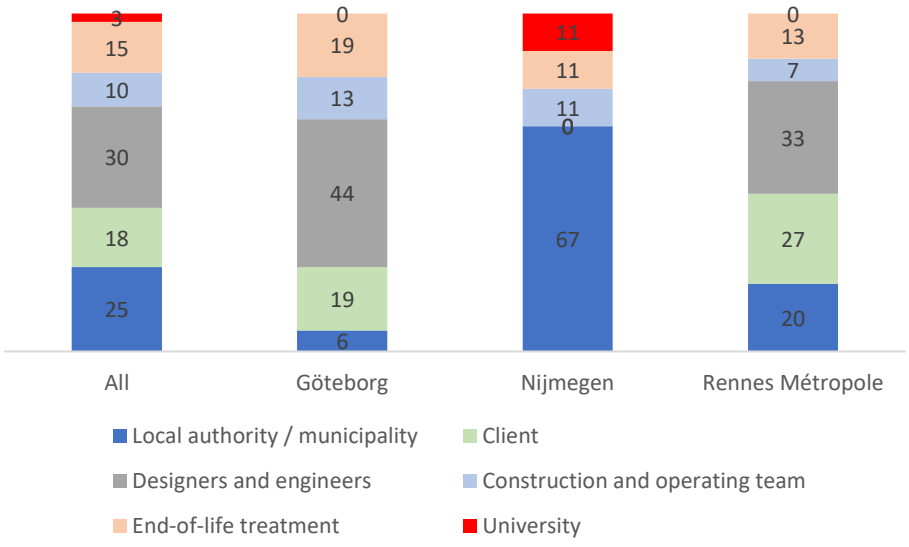

Figure 2. Activities of the respondents, % of answers

Respondents work mostly at the building design phase (for architects and engineers/consultants) and at the urban planning phase (for local authorities mostly). Respectively 19 and 25 % of the respondents in Göteborg and Rennes Métropole intervene in deconstruction/demolition or waste management activities.

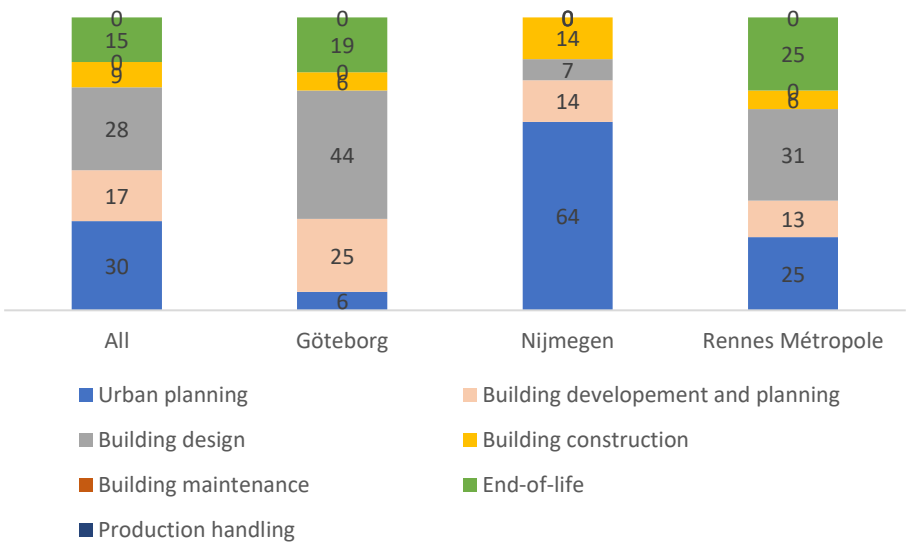

Figure 3. Phase of the construction process where respondents intervene, %

2.4 Semi-structured interviews

2.4.1 Interview framework

The semi-structured interview method was chosen to collect the desired information in a flexible way and in a reasonable amount of time. The interviews were conducted by videoconference and lasted from 1 to 1.5 hours. 2 to 6 members of the consortium were involved in each interview.

An interview framework was initiated by CitéSource and completed by WUR, Chalmers and BRGM. Questions specific to WP4 were added by WUR to optimize the exchange time with the Living Labs.

The interview framework provides reference points for the interviewer, while leaving the freedom to adopt the formulation and the order of the questions according to the answers given by the interviewee. This method allows, for example, to go into more detail on certain points corresponding to the specialty of the interviewee.

The framework is presented in Annex B.

2.4.2 Selection of interviewees

The people to be interviewed were selected in two stages. First of all, the key contacts within each Living Lab were interviewed. Then, to answer the additional questions that emerged during these first interviews, additional contacts were requested from the first three interviewees.

2.4.3 Interviews conducted

Table 1 presents the full list of interviews conducted.

Table 1. Interviews

Living lab	Organization	Role	Date
Rennes Métropole	Rennes Métropole	Responsible of the circular economy mission for the construction sector	2022/10/13
	Rennes Métropole	Responsible of the GIS team	2022/12/06
	Territoires	Urban project manager	2023/01/09
	Territoires and Rennes Métropole	Urban project manager Operations manager Urban planner	2023/01/09
Nijmegen	City of Nijmegen	Advisor in sustainable development	2022/11/24
	W/E Adviseurs	Advisor in sustainability	2023/02/24
Göteborg	City of Göteborg and Framtiden	Responsible for the municipal strategy for circular economy in the construction sector	2023/02/10
		Coordinator for innovation and research Process developer	2023/03/06

2.4.4 Analysis of the results

Reports were written after each interview and submitted to the interviewee for correction and to eventually complement it with additional details.

3 RESULTS

3.1 Challenges and barriers for circular economy

3.1.1 Challenges and barriers according to the literature review

The documents identified in the literature review process identified challenges/barriers and some even contained the enablers for the Circular economy (CE) implementation of materials and components in the built environment. According to the categories' labels from recent studies, the drivers and barriers were always grouped under economic, environmental, social, technical, regulatory and organizational categories. Considering that this study focused on the needs from barriers, it was observed that few barriers were directly linked to environmental factors. For the purpose of this study, we classified challenges/barriers into 5 categories, including 1. Regulatory (Regulation and policy), 2. Social (Lack of awareness and understanding), 3. Organizational (Conflict with stakeholders), 4. Economic (Economic, business and cost), 5. Technical (Lack of knowledge and information). The category labels in parentheses are easier to understand and are consistent with the questions used in the online questionnaire. Within these categories, more subcategories were added for a more detailed classification when needed.

The enablers were organized according to the same categories for challenges / barriers.

After reviewing the literature, a total of 39 barriers and 22 enablers were identified. The list of barriers and enablers are shown in Table 2.

Table 2. Challenges and barriers for circular economy according to the literature review

No.	Category and Subcategory		Challenges/barriers	Enablers
1	Regulatory (Regulation and policy)		1.1 Lack of a consistent regulatory framework 1.2 No circular-specific legislation 1.3 Lack standardization for CE products	1.1 Policy support 1.2 Consistent regulatory framework 1.3 Adequate circular-specific legislation
2	Social (Lack of awareness and understanding)	Customer's perspective	2.1 Limited interest for CE 2.2 Consumers prejudice in using second-hand materials / components	2.1 Awareness campaign 2.2 Education (Consultation, Dialogue, Academic curriculum, Professional workshops)
		Designer's perspective	2.3 Resistance to change/tradition 2.4 The prejudice of poor appearance	
3	Organizational (Conflict with stakeholders and facility	Conflict with stakeholders	3.1 Lack of communication/trust issue 3.2 Unclear distribution of responsibilities and risks 3.3 Program and schedule mess by any change	3.1 Keep close communication and build trust 3.2 Precise and professional project management with a clear chain of responsibility
		Other issues	3.4 Fragmented supply chain 3.5 Lack of infrastructure and facilities	3.3 Tools for conducting project-based supply chain integration frameworks

	etc. issues)		3.6 Ownership issues for the materials/components	3.4 Guideline on ownership of end-of-life materials/components
4	Economic (Economic, business and cost)	Business and market	4.1 Unclear financial case 4.2 Poor and unconvincing business case 4.3 Lack of incentive for CE implementation 4.4 Limited funding 4.5 Lack of formal regional markets for reclaimed components 4.6 Fluctuation of the value of components	4.1 More proven case studies with convincing experience 4.2 New business model 4.3 Policies, financial and market-based incentives 4.4 National/regional level of exchange platforms with standard of specific performance 4.5 Popularization of new voluntary stewardship programs
		Cost	4.7 High upfront investment costs 4.8 Higher design cost 4.9 High insurance fees 4.10 Additional cost for external consultants for expertise 4.11 Additional cost for storage and transportation of reclaimed materials/components 4.12 Expensive to remove the components carefully 4.13 Expensive recovery process and test procedure to certify a reused produce 4.14 More time for deconstruction and dealing with the components/materials	
5	Technical (Lack of knowledge, information and technology)	Technology and tools	5.1 Technical challenges regarding material recovery 5.2 Buildings and building components not designed for deconstruction 5.3 Lack of experience and capability on deconstruction techniques used, and available tools to implement deconstruction 5.4 Insufficient use or development of CE-focused design and collaboration tools, information and metrics 5.5 Construction technique issue (joint technique) 5.6 Lack of guidance of components reuse around design, testing and procurement	5.1 More training in use of available tools and deconstruction techniques 5.2 Development of CE-focused design and collaboration tools, information and metrics 5.3 Flexible design in the choice of components 5.4 Detailed guidance for deconstruction, testing and design procedure 5.5 Comprehensive data management with standard structure and guideline 5.6 Standardized traceability system for materials/waste and pre-demolition audit 5.7 Professional insurance and warranty with test 5.8 Data to show the environmental impacts
		Information and knowledge	5.7 Lack of clear information of stock availability 5.8 Vast variety in quality and size of extracted components from buildings 5.9 Lack of information on buildings components (fire requirements, sound insulation etc.) 5.10 Existence of hazardous substances (fire retardants, coatings, etc.) 5.11 Quality certificates, insurance and warranty issues 5.12 Aesthetic degradation and damage	

3.1.2 Challenges and barriers in the living labs according to the questionnaire

The answers from the 47 respondents to the online questionnaire enables us to prioritize the list of challenges and barriers identified in the literature review.

Indeed, the issues that respondents of the living labs consider facing in their projects relate to economic, business and cost are the obstacles that received the larger number of answers, followed by the lack of knowledge and information. Other issues often mentioned in the literature, such as regulation and policy or insurance and warranty issues, received less answers. However, this is partly due to the fact that, in the questionnaire, more detailed options were possible to choose for economic, business and cost (5 detailed choices possible) and lack of knowledge and information (6). Besides, it can be noticed that in Göteborg, where most respondents are designers or engineers, knowledge and information appear as first choice and is key for these activities.

In the obstacles concerning cost, the lack of formal regional markets for reclaimed components and the limited funding and high investment costs are the first choices. Regarding the issues related to information, a fragmented supply chain and the fact that buildings and building components are not designed for deconstruction are considered as the first obstacles.

Regarding the objectives of the CREATE project, it is interesting to notice that the insufficient use or development of CE-focused design and collaboration tools, information and metrics is considered as a limitation for development of CE for 5 % of the respondents only. Therefore, it could be considered that developing such tools is not enough to boost circular economy. However, it could contribute to the development of formal regional markets for reclaimed components.

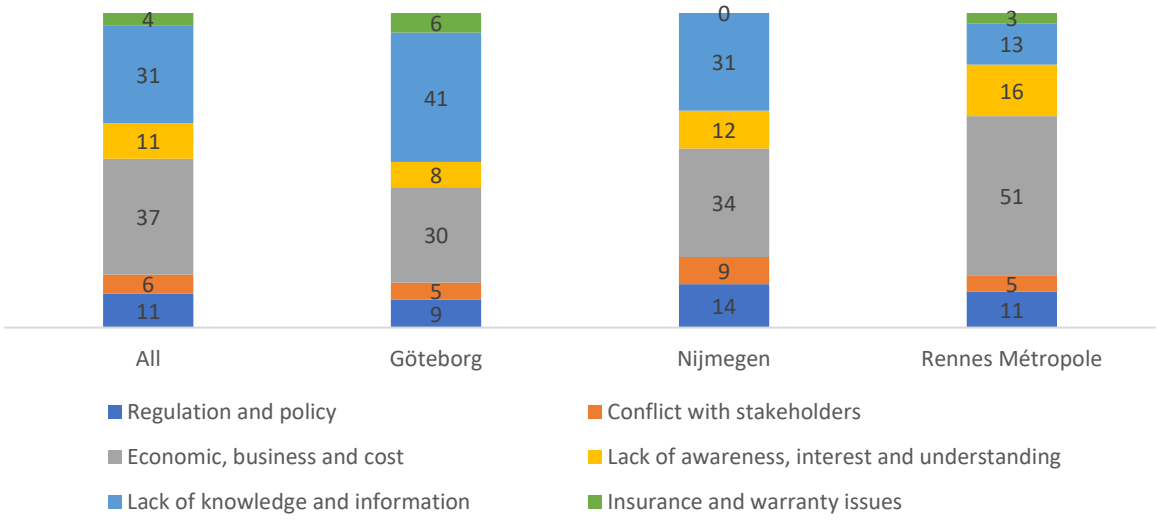

Figure 4. Main obstacles respondents face regarding circular economy in their construction or urban projects, % of answers

Most of the answers about the actions that would enable circular economy concern enforcing knowledge and information. Actions related to economic, business and cost come in second place. As for barriers, more detailed choices were given for those two categories (knowledge and information and economic, business and cost with respectively 6 and 4 choices). Even with this limit, it can be noticed that a consistent regulatory framework and adequate circular specific legislation represents about 1/5 of the answers in Nijmegen and Rennes Métropole. Precise and professional project management and close communication makes about ¼ of the answers in Rennes Métropole when this choice is less frequent in the other cities. This could be related to the high proportion of real estate owners/developers in the respondents for this area, as project management is a big part of their activities.

Regarding information barriers, providing tools for conducting project-based supply chain integration frameworks is the first choice (10 % of total answers). The other choices (development of CE-focused design and collaboration tools, information and metrics, more training in use of available tools and deconstruction techniques, comprehensive data management with standard structure and LCA data to show the environmental impacts) received only 5 to 7 % of the answers. This seems to show that providing information itself is not enough for the respondents but that they consider that it is key to share information to improve project management.

Regarding economic, business and cost barriers, most answers concern market-based incentives and then national / regional exchange platforms with standard for specific performance.

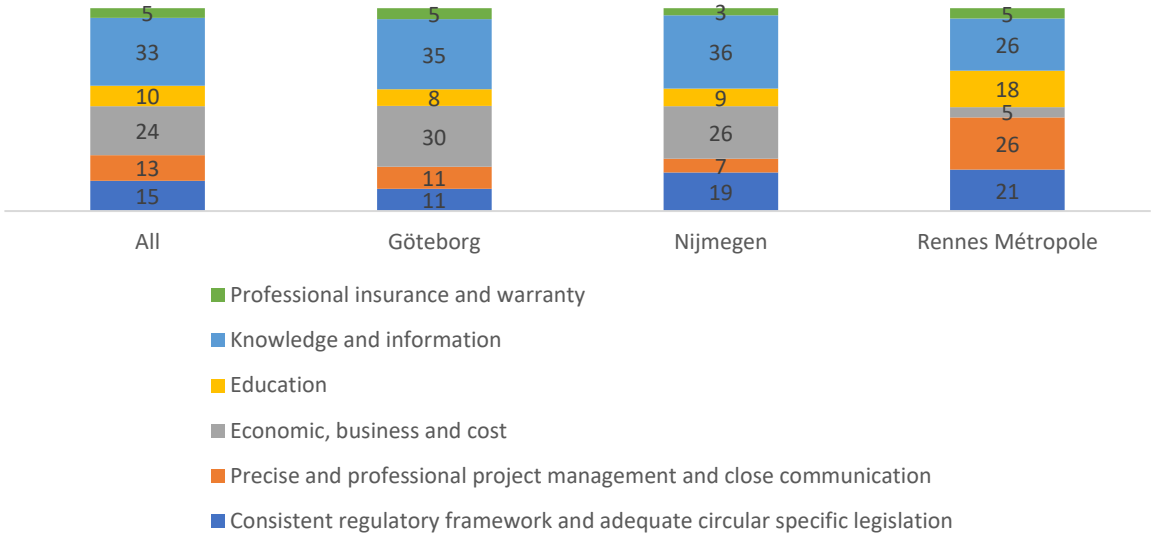

Figure 5. Main levers for the respondents for circular economy in their construction or urban projects, % of answers

3.1.3 Challenges and barriers according to the interviews

The interviews enable a better understanding of the challenges and barriers observed in the questionnaire.

3.1.3.1 Rennes Métropole

CE-related actions that have emerged in the Rennes Métropole are very diverse. This proliferation threatens the coherence in the definition of what is considered as CE by the Métropole. This could imply that in the future there is a need to better prioritize actions to be developed, not only aiming at waste recovery, but also search for efficiency in resource use. The abundance of projects reduces the possibility of properly framing the CE approach and how to think about the city in the long term. Moreover, the impact of projects on import of materials into the Métropole is questionable.

- **Developing recycling and reuse platforms in the urban area**

Regarding the support of business offer development, the main encountered obstacle is the lack of availability and cost of land to install reuse/recycling facilities. Moreover, if such activities are supported by Rennes Métropole policies, it can sometimes be difficult to justify their priority regarding the small number of jobs they generate per square meter of land or building. Moreover, they often generate noise and visual nuisance (e.g., noise from crushers for concrete debris, passing trucks, etc.).

- **The lack of governance of C&D waste strategies by cities**

The second encountered difficulty pertains to the novelty of the issue of construction materials and waste from building sites as an object of policy for an intermunicipality. Indeed, only waste from household (and similar) is currently subject to regulatory responsibilities of the municipalities and public establishments of inter-municipal cooperation (EPCI). Planning of quarries and forestry development, for example, is the responsibility of the regional prefecture (DREAL), while prevention and management of construction waste is the responsibility of the regional council (through the PRPGD – regional waste management plan). It is therefore necessary for Rennes Métropole to establish contact with material producers and managers of construction & demolition waste.

- **Training and skills**

In urban planning, the main encountered obstacle pertains to the human factor and the difficulty for actors to change their practices (e.g., project organization), and the sometimes-lacking high technical skills required on this theme. This change implies awareness-raising, training in the use of new tools, and an organized approach to change management, which requires a long learning process. For Rennes Métropole, it is a matter of putting CE-related issues on the agenda of economic actors.

- **New regulations creating new opportunities for circular economy in building sector**

The Métropole also wants this action linked to urban development to be carried out through urban planning, and especially the Local Housing Plan. This plan, which was revised in 2022 for six years, includes climate and energy objectives. The plan, to be drawn up for 2028, could take better account of the issue of material resources by prioritizing the production of housing within the existing building stock and not through new construction.

This search for efficiency of resource use in the construction industry through better use of existing buildings is encouraged by the objective of Zero Net Artificialization (ZAN) defined in the Climate and Resilience Law of August 22, 2021. This law sets a goal of achieving by 2050 net artificialization of land. It also established an initial intermediate objective of halving the rate of land consumption over the next ten years (2021-2031)[1] .

Two other regulations could encourage a change in production practices, material choices and waste recovery. The first is the creation of an extended producer responsibility channel for construction products and materials in the building sector. According to the Ministry of Ecology: "This new channel will strengthen the network of collection points accessible throughout the territory to workers and construction companies to treat waste closer to sites. It will also support local authorities who take care of construction waste brought in by individuals and develop reuse and recycling of this waste. Finally, it will provide a specific solution to the problem of illegal dumping of construction waste, thanks to the principle of free waste recovery financed by the eco-organizations."[2]

The 2020 Environmental Regulations (*RE 2020*) encourage the choice of materials with lower energy and climate impact. This regulation aims to improve the energy performance and comfort of new buildings while reducing their carbon impact. The aim is to consider all building's emissions over its lifecycle, from the construction phase to the end-of-life (construction materials, equipment) via lifecycle analysis[3]. This regulation will gradually come into force from 2022 and sets maximum authorized thresholds for GHG emissions and energy consumption that will be lowered from year to year.

[1] https://www.ecologie.gouv.fr/artificialisation-des-sols.

[2] https://www.ecologie.gouv.fr/gouvernement-precise-modalites-mise-en-oeuvre-nouvelle-filiere-responsabilite-elargie-des

[3] https://www.ecologie.gouv.fr/reglementation-environnementale-re2020

3.1.3.2 Nijmegen

- **Waste status**

Reused materials are under the regulation of the National waste management Plan (2019). The main objectives of this waste policy are , among others, to reduce the creation of waste and to optimize the use of waste in a circular economy. The government wants to use this policy as an instrument for the circular economy.

According to the Court of Justice, the term 'waste substance' must be interpreted broadly. On the basis of the definition of 'waste substance', in principle every substance and every product can be a waste substance if its owner discards it, intends to discard it or must discard it.`(…) `Article 1.1(6) of the Environmental Management Act refers to the regulation of the so-called 'end-of-waste phase' in Article 6 of the Waste Framework Directive. Article 6 provides that specific waste ceases to be waste if it has undergone a recovery operation and complies with criteria formulated in accordance with the following conditions: a. the material is commonly used for specific purposes; b. there is a market or demand for the material; c. the material fulfils the technical requirements for the specific purposes and the existing legislation and standards for products; and d. the use of the material will not have any overall adverse effects on the environment or human health`. (National Waste management plan, 2019)

The limitation is that in practice, only a few companies can transform a waste to a recycled or reused material. According to our interviewed stakeholders, the term "waste" should be removed because it significantly reduces the efforts or the willingness to have circular ambition for the cities. Also, there isn't any official value for the waste material that could be reused. In this situation, the municipality can't include the use of reused material in their budget to finance housing.

Moreover, in a situation that the municipality could integrate the price of reused materials, a study must also be done to evaluate what could be reused. This study cost also money and it represents a barrier for the municipality.

- **Isolated solutions between cities and lack of coordination between stakeholders**

If different cities and stakeholders are involved in the circularity of the built environment, there is a lack of coordination of the approaches between municipalities, but also between different type of stakeholders. Indeed, there is a lack of communication due sometimes to mistrust between the stakeholders. Despite the technique and solutions being developed, the ambition of circularity appears also as a new way of deciding and collaborating and, according to the person that was interviewed, the change of behavior and approach will take and need time.

For example, the station area of Nijmegen includes 26 different projects driven by different type of stakeholders (public or private) with their own planning. The area could be a good opportunity to develop the collaboration between the construction sites to enable circularity. However, the municipality has no grip on the actions of the private owners and mentioned that even if there is a stock and flow analysis, it will be hard to coordinate in terms of space management, logistic and stakeholders' interests.

To solve this problem, a lot of effort deployed at the regional and municipality level to build bridges between researcher, practitioners and institutions needs to be made. This is the mission of the Economic Board and the Rijk van Nijmegen (RvN). They developed the Lifeport circular - the Living Lab of the station area in Nijmegen, to bring together various stakeholders of the region to make them think about thematics such as `climate adaptation` and `construction and logistics. The RvN work with local companies and specifically developed a circularity network.

- **National and local targets in the construction sector**

The Dutch legislation set some targets for new buildings to be circular. These targets are to be reduced twice every 2 years, to reach the zero level at the end of the transition period. Reusing or recycling materials is promoted as first solutions to apply (concrete for example), followed by using biobased materials (such as timber).

As mentioned above, the Climate Agreement of 2019 also influence the targets for the sector because it mentions an ambition of 49% reduction of the CO_2 emissions with a focus on the housing. Especially, the Circular ambition of the Dutch Economy by 2050 have a goal of reduction of half of the consumption of the raw materials by 2030 and led to a specific Agenda for circularity in the built environment in 2018 with an ambition to reach 100% of circularity by 2030.

A specific law 2018 also has made LCA mandatory for new buildings (the MPG) with a certain level to reach that is reflecting the environmental impact of the building. The leadership of the municipality of Nijmegen is a real lever for circularity. Indeed, if there is some obligation in terms of circularity in the construction sector, the municipality of Nijmegen chose to have higher goal in terms of circularity (or to reach the national ambitions faster than expected).

3.1.3.3 Gothenburg

A national environmental action plan for the building sector has been set in Sweden but it remains voluntary to apply.

The national database Byggsektorns miljöberäkningsverktyg provides a lot of information about materials that are used in a construction project. It is mandatory to gather this information to get a construction permit. However, detailed data are not available for reused

materials. New form or temporary permits could be developed in the future to address this issue.

Moreover, data about potential secondary materials for reuse is missing today as it is only available for some projects. It is also usually shared at a late stage of a project with a short delay to collect materials and without any tool to collect and share data in a structured way.

Besides, guarantees are required to use materials. A guarantee should rather focus on the installation work and not the material itself to enable the use of secondary materials. Finally, another barrier observed is that waste landfill is not very costly in Sweden.

3.1.3.4 Summary of the main barriers and levers observed in the 3 livings labs

Table 3. Main barriers observed with the interviews

Barriers	Rennes Métropole	Nijmegen	Gothenburg
Regulation and policy	Rennes Métropole does not have the C&D waste management and planification competence	Problem with the definition of waste No regulation on the cost of the waste	Guarantees required by the legislation to use materials (limits reuse/recycling)
Cost	Cost and availability of land and buildings to host reuse/recycling activities	Missing information on costs of the potential reused materials	Insufficient cost of landfill that does not incentive recycling of bulk materials
Business	Lack of activities/skills for reuse/recycling	Lack of activities/skills for reuse/recycling	Lack of activities/skills for reuse/recycling
Education	Need for awareness and training	Need for awareness and training	Need for awareness and training
Knowledge and information	Missing information on flows in the predesign of urban projects	Missing information on real recycled and reuse flows at the city level	Missing information on potential reuse resources prior to demolition or refurbishment
	Missing information on building use		
	Missing complete and shared definition of CE		

Table 4. Main enablers observed with the interviews

Enablers	Rennes Métropole	Nijmegen	Gothenburg
Regulation and policy – national level	New national legislation about land use reduction, reuse/recycling development and carbon emissions reduction in construction projects	New national legislation about circular buildings, reuse/recycling development and carbon emissions reduction in construction projects LCA mandatory for new building Wate management plan as an instrument for circular economy	New national legislation about carbon emissions reduction in construction projects
Regulation and policy – local/regional level	Circular economy strategy and toolkit for projects	Local plans with ambitious objectives for carbon emissions reduction Lifeport Circular and RVN Circular to connect stakeholders of the region	Program with ambitious objectives for carbon emissions reduction Platform for carbon neutral construction, agreement with professionals
Knowledge and information	LCA studies in construction projects (mandatory for carbon emissions and energy)	LCA studies in construction projects	LCA studies in construction projects (mandatory for carbon emissions and energy)
	Metabolism study (basis to exchange with all local stakeholders)		

The summary shows that legislation, cost, missing skills/activities and information are barriers for circular economy in the construction sector for the 3 living labs. Municipalities observe that some activities and skills required for reuse and recycling are often missing in their city.

New (or at least recent) legislations are useful to promote actions related to circular economy such as reuse/recycling development. The plans and programs set by cities are key to set and reach objectives with the local stakeholders of the construction sector.

Information/data is also crucial to contribute to decision making. Environmental assessments at the building levels are used to reach some circular objectives. Studies performed at a larger scale such as metabolism studies are useful to better understand the local issues and raise awareness.

Other barriers and enablers could also be observed but are not mentioned here as our focus here within the CREATE project is about tools, studies and data to enable circular economy in construction.

3.2 Objectives, actions, policies and projects for circular economy in construction

3.2.1 Objectives and actions for circular economy observed with the questionnaire

Most of the 47 respondents to the online questionnaire, 87 %, work on construction or urban projects which have objectives related to circular economy. The others don't yet but consider it will be the case soon. Figures are almost the same for the 3 cities.

No real priority can be identified in the main objectives related to circular economy in the projects the respondents take part. Indeed, the six proposed choices received approximately the same numbers of answers. Reduce material consumption comes first in Göteborg and Nijmegen, whereas reuse waste is first for Rennes Métropole. It is interesting to notice that although recycle is often emphasized in some definitions of circular economy, it is the first or second answer which is the least chosen.

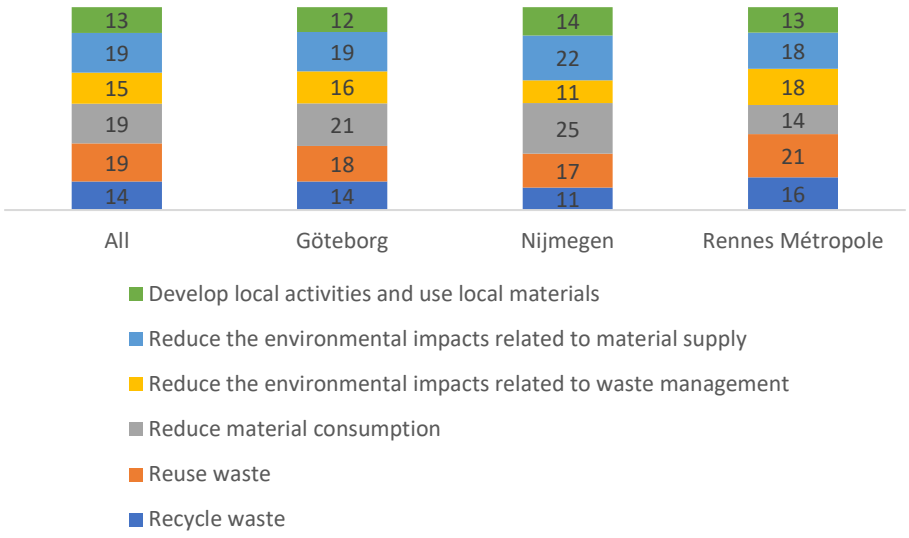

Figure 6. Main objectives related to circular economy in the respondents' projects, % of answers

However, in the examples of actions related to circular economy that respondents implemented in their projects, recycling is mentioned by 42 % of the respondents and reuse by 39 %. Therefore, projects aim generally at reducing the use of primary materials (from natural resources) by using secondary materials (from the anthropogenic stock) rather than reducing the total mass of materials used for construction. Using bio-based materials (such as timber, straw or raw-earth) or local materials is also often mentioned. The table below shows the actions (some of the original text has been summarized by authors).

Table 5. Examples of actions related to circular economy respondents implemented in their projects

Göteborg	**Nijmegen**	**Rennes Métropole**
Recycling of construction materials	Calculation the CO_2 emissions of the planned civil works in the municipality as a method to determine the degree of circularity	Reuse of materials for a project or certification of a construction project with the ECOCYCLE label
Reuse building materials and use materials with a high proportion of recycled materials	Climate adaptation of built environment	Creation of a waste sorting area and search for recycling service providers. Adapting the market to enable re-use.
Building in wood and ensuring that the buildings are demountable for recycling	Integrated strategy of multiple value creation with a focus on 'profit without losts' from a financial, manufactured, intellectual, human, relational and natural perspective	Inventory, diagnosis and preservation deconstruction of buildings. Reuse and recycling.
Match customers with a need for materials and customers with a need to get rid of materials. Find customers whose activities can work in existing buildings. Material recycling.	Sell biobased materials (green circular approach)	Use of local wood. Reuse of products and materials. Green worksite charter and waste reduction. Optimization of structures to reduce material consumption
Design facades with recycled material, design/propose frame with partially recycled material and minimized amount of material. Design based on inventories of existing materials.	Creation of Materials Passport. Objectives regarding MPG standards.	Tri'n'Collect system on 100% of operations. PEMD-resources diagnostics on 100% of deconstruction projects. Integration of reused materials. Other experiments (e.g. gabions made from stones excavated from the site).
Recycling inventory and design of several products in construction documents (demolition & new construction in the same project).	Development of the tool Circulair Impactladder to measure the circularity of building projects. Regional action programme to support and enhance circular industrial building.	Landscaping: integration of recycled materials Fixtures and fittings for rental units
Dismantling drywall and studs instead of demolition. Reuse of doors and partitions.	Giving advice in how to minimize natural sources and reduce waste during the construction	Reuse. Sustainable sourcing (bio-sourced materials).
Choosing climate-friendly products. Trying to find materials/products to reuse. Influencing suppliers to have a recycled range of products.	Concept for building straw houses in a simple and safe way, incorporating all smart technologies	Development of locally sourced earth-based building materials. Reuse of recycled rubble in concrete or asphalt. Creation of *technosols*.
Incoming reuse on e.g. toilet porcelain. Reuse of dismantled doors.	Implement biobased materials true inspiring examples	Reuse of sub-base materials (e.g. road surfaces). Production of fertile soil. Use of reused materials.
Reuse inventory of office buildings to be demolished.	Design, develop and construct new buildings by using secondary materials	Fertilization of inert excavated material to replace topsoil and reduce transport and landfill

Environmental inventory of hospitals to be demolished.		costs. Recycling of demolition concrete into materials for Civil Engineering and Construction.
Creation of a local market for building materials. Recycle more materials and reduce the amount going to landfill.		

3.2.2 Policies and projects in the living labs observed with the interviews

The policies and projects related to the implementation of urban circular economy strategies by the municipalities of the 3 living labs are first presented. A cross analysis is then carried out. Elements from the literature review complete this analysis.

3.2.2.1 Rennes Métropole

Rennes Métropole is currently developing its overarching strategy on CE and a specific one for the construction industry (to be written by April 2023). To initiate its strategy, Rennes Métropole has commissioned a metabolism study in 2021-2022 which was realized by CitéSource and Neo-Eco. From this study, Rennes Métropole is seeking to develop actions along two main lines: business offers and urban planning.

The first matter is to support the development of business offers around the recovery of construction site waste (reuse and recycling, recovery channel) and the production of local materials or materials with lower environmental impact (bio-sourced or geo-sourced). Until today, ongoing projects on the territory have not been initiated by the municipality, but this could change in the future through calls for projects.

Projects of this type include the creation of a physical platform for the reuse of 12 materials by Bâti Récup'[4]. This platform will open in March-April 2023. A feasibility and market study was conducted by this structure in 2020-2021, financed by Rennes Métropole and ADEME. The study included a projection of material flows by CitéSource. In addition, the platform will be in a building located in the Courrouze urban project in Rennes. This location setting was facilitated by Rennes Métropole, and the platform also benefits from an advantageous rent.

Other projects are under development. These include the creation of a production site for compressed raw earth bricks, a physical platform for reuse (material reuse platform) for private individuals, and a plaster recycling site. Rennes Métropole is supporting these projects by co-financing studies and making land and premises available.

Rennes Métropole wants the CE strategy to take shape through both current and future development projects. To this end, it is using an experimental approach to capitalize and learn. Around twelve pilot sites will be launched, for experiments on waste recovery, or use of local materials or with less environmental/carbon impact. The objective is to encourage project owners to change their practices, particularly by considering criteria related to

[4] Architecture agency and collective realizing diagnoses for the reuse of materials prior to the rehabilitation or demolition of buildings: https://batirecup.com/.

efficiency of resource use in the construction industry. This approach will pertain to integrating CE-related criteria into the local toolkit (*référentiel*) for urban and construction projects, which already includes energy and climate issues[5]. A study of flows generated by six development operations was carried out in 2021-2022 to initiate a discussion with the developers involved.

Another ambition is to work on the efficiency of consumption of construction materials in development projects. The future Local Housing Plan (PLH in French) could, for example, include 10 % of housing rehabilitation (thus limiting the consumption of materials). However, the implementation remains unclear, particularly on how to collaborate with the territory's companies on this theme.

3.2.2.2 Nijmegen

The City of Nijmegen has a long track record on sustainability and won the European Green Capital award in 2018. Today, the city has a strong circular ambition written in their political strategy (`Nijmegen 2040`) in terms of sustainability and housing development. Nijmegen wants to reach 25 % of circular construction by 2025 and 50 % by 2030 with the goal to be 100 % circular by 2050 with 0 % loss of raw materials.

This ambition is following the strategy of the Region Arnhem/Nijmegen. The City of Nijmegen is part of the Green Metropolitan Region Arnhem-Nijmegen (GMR)[6] together with 17 other municipalities. The GMR focuses on four domains: sustainable urbanization, raw materials and waste value chains, climate adaptation and the energy transition. The Region wishes to be a pioneer territory in terms of circularity in the urban planning at the national and European level. In that context, the Region design the WoonDeal program, a housing and employment strategy for the territory with a strong ambition of sustainability and circularity (10 to 25 % of circularity in housing; construction of 10 000 housing by 2030, 50 000 by 2040).

These ambitions are also linked to the national directives of the Dutch government: Climate Agreement from 2019 (goal: reduction of 49 % CO_2 emission with a focus on the housing), the Circular ambition of the Dutch Economy by 2050 from 2016 (goal: 100% of circularity by 2050 and reduction of the half of the consumption of the raw materials by 2030), the Raw Agreement in 2017 and the specific Agenda for circularity in the built environment from 2018 (goal: 100 % of circularity).

[5] Low carbon toolkit: https://metropole.rennes.fr/batir-bas-carbone-mode-demploi.

[6] In the Netherlands, the Region is not a local authority (level of governance) but a voluntary gathering of municipalities with the aim of territorial and economic development.

To reach the regional ambition, the project of the redesign and refurbishment of the "Stationsgebied" (train station Nijmegen and surrounding city area) has been chosen as a pilot. Apart from the railway area including its station, 2000 new apartments will be built, and the public green space of the same area should increase from 5 to 22 %. This all must be realized within the coming decade and in line with the principles of the circular economy. The circular economy approach in the region follows the principles of Ellen MacArthur of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

To make this happen, various technical and non-technical innovations are needed. Currently, Nijmegen is involved in a Living Lab setting to accelerate these innovations by synergizing brain power and cash flows of the regional and local public authorities, entrepreneurs, academia and citizens and NGOs (quadruple helix). The RVN@ (Regio Van Nijmegen), an institution who work to develop networks and innovation of stakeholders involved in circularity, is managing the Living Lab[7].

The global project is planned for 15 years. The national Railway company (pro Rail and NS trein) is a main partner of the municipality (joint management team) to manage the whole project. Pro Rail is the owner of a lot of land, and they wish to increase the number of tracks to have more than 2 trains per hour leaving for Amsterdam.

The station project included 28 sub-projects, divided in 4 areas: West Kwartier, PHS, Centrum and Centrum Kwartier. Around 100 people are working on it. The project can be public or public/private, depending on the situation, they also have different plannings. The municipality is trying to apply 10 sustainable principles for each of the 28 projects, including circularity, but they have less influence on the private partners. The Hezelpoort project is one of these 28 sub-project and the one that the municipality chose as a study case for CREATE. It belongs to the West Kwartier, on the North of the station and the land belongs to the municipality.

3.2.2.3 Gothenburg

The city of Gothenburg has developed a general circular economy strategy, including one specific to the construction sector. The latter is integrated in the Environment and climate program for the city of Gothenburg 2021-2030. This program has three areas: nature, people, and climate. It is based on seven strategies, including circular economy. The approach of circular economy as a strategy is innovative and specific to the city of Gothenburg in Sweden.

[7] Kennistafels Stationsgebied Nijmegen: klimaatadaptatie & bouwlogistiek - RvN@ (rvnhub.nl)

The program sets ambitious objectives regarding the climate impact of construction: -50 % of CO_2 emissions by 2025 and -90 % of CO_2 emissions by 2030 (compared to 2020). It focuses on new construction as it is considered that it generates 50 % of the climate impact of the building sector in the city (25 % for heating, 25 % for maintenance and refurbishment). Emissions generated by transport should also be reduced, with objectives to densify used land, including parking lots.

Some objectives also target energy: to reduce energy needs by 20 % in 2030 and to produce renewable energy (including with solar panels). They also concern the ecosystem, green areas, chemicals, and health.

The circular economy strategy for construction sets as a priority to minimize material flows and optimize the building use (longer life for buildings...), then to reuse, to recycle, and finally to use biobased materials and other resources. CO_2 emissions of wooden materials are considered as null.

A platform for carbon neutral construction has been created in November 2022. This network is coordinated by the city. Many actors want to be part of it and reach the goals. This platform could help develop the local market.

The city has set the objective of reducing waste by 40 % by 2030 for the construction projects they manage. The calculation method for this indicator has not been defined yet. But reused materials will not be included in the amount of waste accounted. In general, in Sweden, C&D waste accounting in construction projects is not precisely documented. A national system is being currently developed.

Besides, the city did not set any objective for reuse and recycling of C&D waste. But the impact of reuse and recycling is considered to reach the objectives related to CO_2 emission reduction. Indeed, in the climate declaration for buildings, reused products are considered to generate zero CO_2 emission.

Moreover, the city signed an agreement with about 50 public and private buildings owners in Gothenburg which states that the reuse of secondary materials is to be the first choice by 2025. This document is called “Declaration of sustainable construction”.

To achieve that objective, the city tries to stimulate the professional market for secondary materials. Professional actors to produce the inventory of secondary materials in a building are missing today which is mandatory before construction, refurbishment or demolition in Sweden. Moreover, professionals for separation and sorting of secondary materials are missing. It is also hard to find enough reuse solutions for some materials.

3.2.2.4 Summary of the practices observed in the 3 livings labs

Table 6. Summary of the practices observed in the livings labs

Practices	Rennes Métropole	Nijmegen	Gothenburg
Circular economy strategy defined at the urban level	Strategy defined in April 2023 for all activities and specific strategy for the construction sector	Objectives integrated in two urban plans: Woondeals for 2030 (region Arnhem / Nijmegen), Nijmegen 2040 (city)	Circular economy strategy, including one specific to the construction sector integrated in the Environment and climate program for the city of Gothenburg 2021-2030
Main objectives of the city for circular economy in construction	To support the development of business offers for reuse and recycling and the production of local materials or materials with lower environmental impact (bio-sourced or geo-sourced) Reduce material flows	National objectives : 50 % of the buildings in the country should be "circular" by 2030 Woondeals : 25 % circular in 2025, 50 % in 2030	-50 % of CO_2 emissions by 2025 and -90 % of CO_2 emissions by 2030 To minimize material flows and optimize the building use, then to reuse, to recycle, and finally to use biobased materials and other resources To reduce waste by 40 % by 2030 for the municipal projects
Actions related to circular economy in construction led by the city : urban level	Support to the creation of a physical platform for reuse (funds for the market study and assistance for renting a space) Other similar projects : production site for compressed raw earth bricks, physical platform for reuse for private individuals, plaster recycling site Urban metabolism study	Every new project for Nijmegen must reach the objectives of Nijmegen 2040	Agreement with 50 construction companies to promote reuse
Actions related to circular economy in construction led by the city : urban project level	Local toolkit for urban and construction projects 12 pilot sites for waste reuse/recycle, or use of local materials or with less environmental/carbon impact Experiment of a sourcing study for local and renewable materials and of a LCA assessment for an urban project	Targets in the municipal policies which are applied in urban projects Systematic LCA assessment of buildings Creation of a method of evaluation of circularity in the Hezelpoort project with 5 Key Performance Indicator (LCA score, adaptivity of the building in time, construction methods and use of recycled and biobased materials)	LCA assessments in construction projects Production of a database about materials for all construction projects

The summary shows that objectives for circular economy are set by the 3 municipalities and presented either in a specific document or integrated in a more general plan. These objectives often refer to national legislations, but the cities generally want to go beyond this framework and set more ambitious goals.

Objectives for carbon emissions reduction are often used as a basis for targets concerning circular economy : as it is for example generally considered in the plans that reuse/recycling and local materials have a lower carbon footprint[8], only carbon emissions are considered to reach some circular objectives. However, some criteria are specific to circular economy as for example the reduction of material flows (consumption and waste).

Local strategies are developed in cooperation with the local companies of the construction sector (urban and construction projects developers, material producers, waste managers) to raise awareness, set voluntary objectives and find mutual solutions.

Environmental assessment based on a lifecycle approach are broadly used at the building level for construction projects and contribute to better reaching circular objectives. Few environmental studies are performed at the urban project level today, but this type of study is becoming more common.

[8] We can note that this is not always the case, as shown for example by some results of the Recybéton research project in France : https://www.pnrecybeton.fr/wp-content/uploads/2020/03/RECYBETON_Recommandations_2019-03.pdf

3.3 Tools and studies carried out to implement circular policies and projects

3.3.1 Data and tools used by the respondents to the questionnaire

Respondents use a large variety of types of information when they work on circular projects. Material or component information is the most used, with some almost equal numbers of answers for the 5 detailed choices given : Basic information (Dimensional properties; Material content; Connection details; Structural and functional situation); Design requirements (Accessibility requirements; Acoustic requirements; Fire requirements; Aesthetic information); Availability condition (Quantity / Storage; Time when materials are available); Information of reuse assessment (Components condition; Exposure situation; Remaining lifetime; Types of buildings/infrastructures used), Sustainability information (Energy consumed; Environmental impacts). Data related to economic, business, marketing and cost is the second used, with almost equal numbers of answers for the 4 detailed choices given : Deconstruction price ; Storage price ; Testing price ; Transport cost. In Rennes Métropole, demolition information is the second choice with most answers for information about the demolition method and information about the storage place and capacities.

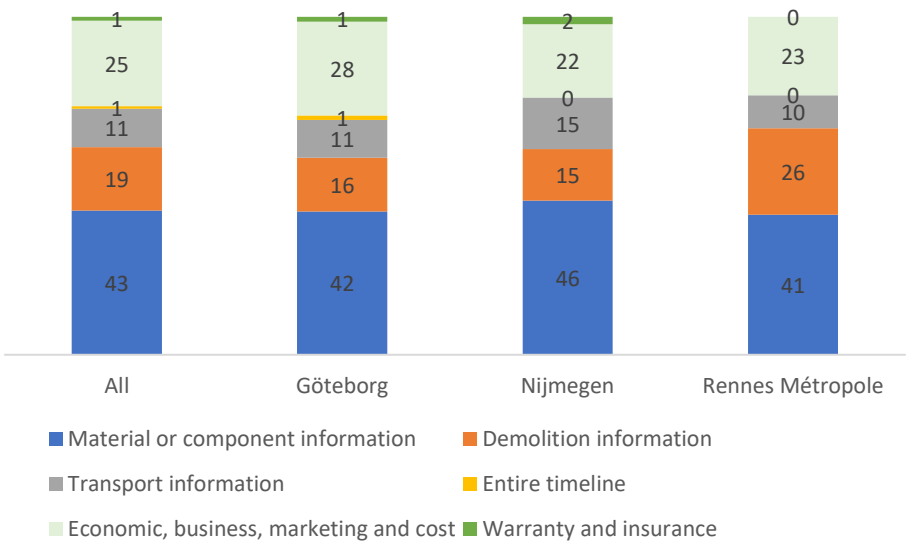

Figure 7. Type of information respondents use when they work on circular projects, % of answers

Information comes from a large variety of sources: for about 1/3 of the answers from specific studies carried on for the project, but also from expert opinion, national databases and local databases (20 to 26 % of answers). No major difference can be observed between cities about the source of information.

The question about the software or tools respondents use today to implement circular economy in their projects received very different answers. Some respondents mention tools which are not specific to circular economy or even construction such as Word, Excel, Internet browsers, Revit, ArchiCad. Some respondents mention online marketplaces for secondary

materials such as CCBuild in Sweden and the website materiauxreemploi.com in France which provides a map of economic actors for reuse. Some tools which are specific to circular economy but concern only a few countries are also mentioned, such as ReCapture in Sweden[9] and MPG and Circulaire Impactladder in the Netherlands (described in the interviews about Nijmegen).

3.3.2 Studies carried out to implement circular policies and projects in the living labs

3.3.2.1 Rennes Métropole

Studies at the territorial level: internal diagnosis and metabolism study

In 2020-2021, Rennes Métropole carried out an internal diagnosis to take stock of actions already carried out and to evaluate the municipality's performance in terms of CE. The ADEME's CE action framework was used for this assessment[10].

To gain a better understanding of the urban metabolism linked to land use planning, the local authority commissioned an external diagnosis, a study known as "urban metabolism on the scale of the Rennes Metropolitan area", to be carried out from September 2021 to September 2022. This study was carried out as part of a study contract (tender procedure) by CitéSource (contractor) and Neo-Eco (subcontractor).

The study called "urban metabolism on the scale of the territory of Rennes Metropole" had three main objectives (specifications):

- Define realistic and ambitious targets for the circular economy in the construction industry;
- Facilitate the identification of high-stake operational sectors on which to launch pilot programs;
- Mobilize actors of the territory to lead them towards CE, by presenting them the data and indicators resulting from the study.

[9] « By integrating reuse into the design process, White ReCapture enables reuse on a larger scale in a time and cost-effective way. Using 3D laser scanning, an inventory of building materials is digitalised. The digital model, in combination with experts, provide information on which materials and parts can be used in new production as well as in rebuilding projects. Thus, the tool is a critical step forward in construction's embrace of the circular economy. » (https://2021.prizes.new-european-bauhaus.eu/index.php/node/269591)

[10] https://www.optigede.ademe.fr/demarche-urbane-economie-circulaire-referentiel

The study included two phases. Phase 1 "Knowledge and modeling of the metabolism of Rennes Metropole" aimed to quantify, characterize, and locate current and future flows of materials and soils related to development and construction. It consisted of:

- Quantification and characterization of the current stocks of materials in buildings and roads at the urban scale (for each of the 43 municipalities of the Métropole);
- Quantification and characterization of flows (consumption of materials and waste including excavated materials) related to building sites (construction, rehabilitation, or demolition) and roads (development, repair) on the scale of the territory (43 municipalities) over 2017-2019 inclusive (annual average).

This diagnosis is completed by a projection of flows from 2020 to 2030 (trend projection of flows according to the objectives of the Local Housing Plan and the Climate Plan for 2020-2022, 2023-2025, 2026-2030 included) to:

- quantify, spatialize, and characterize the flows (consumption of materials and waste including excavated materials) linked to building sites (construction, rehabilitation, or demolition) and roads (development and repair) for the entire territory (43 municipalities);
- quantify, spatialize, and characterize the flows for 6 sectors (development operations, data per building and road section).

The scope of the study includes 29 different types of buildings and 6 different types of roadways, as well as 12 groups of materials and excavated soil and 6 types of construction sites (construction and demolition of buildings, heavy and energy rehabilitation of housing, development, and renewal of the road network).

The diagnosis and projection of flows were used by Neo-Eco during the phase 2 "Techno-economic study waste recovery channels in the construction industry" to:

- evaluate territory dynamics via the actors and locally established channels of valorization, as well as their capacities of valorization;
- propose scenarios of valorization under distinct temporalities, with variable objectives per sector/chain
- Identify the need for creation and structuring of value-added loops to complement existing ones;
- Identify areas for action to build a strategy to consolidate and CE in the territory.

The work carried out helps defining an action strategy in favor of the CE in the field of construction and public works.

Online data share from the urban metabolism study via CirculApp

The data on flows, stocks and actors produced in the framework of the metabolism study are disseminated online via CirculApp[11], an interactive visualization tool for geolocalized data on resources and actors developed by CitéSource. It was developed within the framework of the RUDI (Rennes Urban Data Interface) pilot project call, a project led by Rennes Métropole.

CirculApp is a digital solution for interactive mapping of local actors for the circular economy in the construction industry and of waste deposits and material needs (by type of construction site or operation, material, year). The solution allows you to explore data interactively, find local actors, create custom maps, download graphics (Sankey and pie charts). It also offers the possibility to enter or complete data on actors, with moderation by the client municipality or CitéSource. The solution respects the confidentiality of certain data, by restricting its distribution to certain users[12] . It provides transparent information indicating the sources and methods used.

Impacts of the metabolism study

The metabolism study allowed to define objectives in terms of material production or waste recovery channels to be structured or developed. According to the conclusions of the study, certain sectors (earth, plastics, woodwork, insulation) will require establishment of new players to improve the network in the territory, as flows of materials towards these outlets increases. Wood, gypsum, and earth waste materials would benefit from support, particularly through investments in R&D projects, to develop recovery processes and outlets.

The study also identified high-stake operational sectors on which to launch pilot programs. Of the 6 projects studied, 3 will launch a circular economy approach. The results of the flow accounting on these projects have been shared to the project owners. In addition, the data were integrated into circular economy calls for tender launched for some projects.

Although the results did not contribute to programming or design of development operations (which was not an objective stated in the study's specifications), they did allow Rennes Métropole to encourage the developers of the six projects studied to adopt a circular economy approach in their projects. Results of the study of stocks and flows have been useful

[11] https://www.circulapp.fr

[12] The data on local actors are open to any CirculApp user, except for some data with restricted access for CirculApp Collectivity accounts. Data can be modified or completed by users having a CirculApp Local actor account (moderation by CitéSource). They are organized according to the type of structure, the type of valuation and the scope of activity. For Rennes Metropole departments in charge of development and circular economy, restricted access information allows sharing contacts, feedback and offers of materials available on building sites. The data on stocks and flows on an urban scale are open to any CirculApp user. They are available by municipality and for the whole Métropole. The data on the flows related to the 6 urban projectsstudied are restricted to users with a CirculApp account.

for the time being in raising awareness and informing development, construction and public works sector, and producers of materials and waste management actors. They have contributed to "putting the circular economy on the agenda" in the building and public works sector but have not yet been used for decision support.

The importance of current and projected flows of material consumption in relation to waste points to the need to aim for efficiency in resource use and not just waste recovery. The strong difference observed between current stocks per inhabitant between peripheral municipalities and those located in the center of the Métropole shows the role of development forms in material consumption. The high share of excavated materials in total construction waste shows the importance of acting to reduce and better recover these materials.

The study also provided an overview of the circular economy actors on the territory. Results of the study are also disseminated to project leaders of reuse or recycling solutions. These data can be useful to conduct a market study for new actors who want to position themselves (knowledge of existing offers, orders of magnitude on potential future flows).

The digital solution for online data dissemination simplifies the sharing of the study results since the municipality only needs to communicate the link. The interactive data visualization format (maps and diagrams) is a priori less of a deterrent than a written report. The actual use of data and digital solution by actors to whom Rennes Métropole has communicated this information has not yet been studied.

Studies at the urban project level

La Courrouze is a development project with strong environmental ambitions. To achieve ambitious carbon emission targets, a partnership was established with the certification body Cerqual. Targets are contractually agreed with the promoters who have an obligation to produce results. These objectives are based on a territorialization of the NF Habitat HQE label with E+C- and ENR: level E2C1 (1 = entry level) and E2C2, Cerqual's Low Carbon profile and level 3 Biosourced label. At a minimum, the performance thresholds for 2025 of the environmental regulation (RE2025) is targeted today.

In the Courrouze area, the Grande Prairie operation has recently been the subject of an innovative approach to sourcing materials to limit their environmental impact (including climate and energy) and to give priority to local and renewable resources (bio-sourced). The public urban developer Territoires also wanted to choose sustainable sources and control costs because the project includes subsidized housing. It was thus a question of being able to massify and only choose materials already benefiting from professional rules.

For this, Territoires was accompanied by a consulting company (ZEFCO) and organized a workshop with 6 teams of design engineers (including architect and engineering) The workshops focused on the following themes: 1. expectations; 2. volumetry, construction

methods; 3. frames, channels, LCA, costs with the involvement of the consulting firms; 4. façades, materials and landscapes; 5. stabilization of projects.

This approach led to the choice of conventional concrete structures with a wood-frame façade and straw insulation. According to Territoires, the work in workshops was a success because it allowed to mobilize the targeted sectors, to remove the main technical and insurance barriers and to capitalize on the results. The main difficulties encountered are the additional costs generated by the approach and in particular the investment in time to organize the workshops.

LCA assessment at development project level

The Urban Print[13] application, which makes it possible to carry out an evaluation according to a life cycle approach to a development project, was tested for the Grande Prairie operation. This test was carried out rather downstream of the project's design choices, particularly the materials. Nevertheless, it made it possible to validate these choices. In particular, the study showed that the reduction in environmental impacts that could be achieved with 100% biobased materials was marginal compared to the concrete structure solution with biobased materials chosen. The test required an adaptation of the software that did not include sufficient data on the chosen construction method. A "manual" adaptation of the data about public spaces was also necessary. Finally, the main point of satisfaction with the tool is that it offers a diagram showing the impacts of a scenario and the potential impact reductions by improvement path. This makes it easier to identify courses of action to optimize a project.

Tool about all ongoing projects : Urb@map

Urb@map is an online application developed since 2019 by Rennes Métropole. It lists all the operations, sectors and programs in the Metropole as they happen. The development was carried out on the GIS data portal GéOrchestra (https://www.georchestra.org/fr/). The application is INSPIRE compatible, everything is standardized. The code is open source. The application is reserved for the staff of Rennes Métropole and the municipalities of the territory.

The application centralizes all data on operations and allows for more frequent updating of planning data. The information includes: operation manager, municipality, procedure, location, description, vocations, total surface area, current use, framework, operational set-

[13] https://efficacity.com/quartiers-bas-carbone/no-logiciels/urbanprint/. Software developed since 2018 by the CSTB and Efficacity and sold for €2,500 excl. tax (classic annual subscription per floating license).

up, existing land tool. A dashboard allowing to follow all the stages of the project is available for consultation.

The environmental objectives of the project could, in the context of a future development not yet decided by the community - be entered in a dedicated field but without details. For the time being, it is also possible to indicate for each operation whether it is carried out as an urban renewal, urban extension or mixed-use project (interesting data for monitoring the objectives of Zero Net Artificialization - ZAN). Demolished built-up areas are not currently monitored in Urb@map.

3.3.2.2 Nijmegen

Studies led by the city

First, a study of material flows for the region has been done by Metabolic, a group of organizations based in Amsterdam[14]. Metabolic made an economic evaluation of the region and give advice to the municipality to develop its circularity strategy in 2017. They map the flows of materials for Nijmegen. It was useful for the municipality, but it can't be used for their project around the station because the data does not concern the same scale. Indeed, the information is quite aggregate and there is no spatial information about the materials.

The region developed an assessment tool for housing projects and circular economy: Circulair Impactladder Groene Metropol Regio. It became available in the summer of 2022. The objective is to evaluate Woondeal 24 projects in 2024. The person in the municipality responsible for the tool is Ultsje van Gorcum. This tool is concerning housing projects only, no specific tool has been developed yet for urban projects.

The first experience with the GMR will be integrated in a wider project: the Het Nieuw Normaal (*the new norm* in English)[15]. This project has been adopted at the national level and created by the Ministry of the Interior and by CircleCity. The main goal is to see how the main aspects of the circular construction can be calculated and evaluated in a standard manner. A pilot tool will be test in the beginning of 2023 and the final version should be delivered at the end of the year. The result of the pilot of the HNN will be used to developed new regulation. It has 6 regional woondeal as pilot. The HNN has 4 themes: waste management, environmental impact, capacity of adaptation, healthy material.

[14] https://www.metabolic.nl/

[15] Het Nieuwe Normaal (HNN) - Cirkelstad

The region does not have any information about the stocks of materials in every building and infrastructure (resource cadaster). However, data about some newly constructed or refurbished buildings are integrated in a database by Madaster[16].

Besides, some information on reuse or recycle sites is available in the Netherlands. For the region, one company is responsible for public waste and manages construction and demolition (and refurbishment) waste. The region is also leading some actions aiming at better knowing the materials exchanged between cities. That data could be available in the next 4/5 years.

Lifecycle assessment at the building level

W/E Adviseurs developed 25 years ago a calculation/rating instrument called GPR[17] which assesses the sustainability of a construction project (building level). It is based on a life cycle approach (LCA) and is comparable with BREEAM[18]. GPR is broadly used in the Netherlands. It is organized according to 3 main themes: Planet - People – Profit, and sets criteria regarding energy, health issues, user quality, materials and others.

Material analysis is mostly based on MPG (standing for MilieuPrestatie Gebouwen in Dutch or environmental performance of buildings in English) which is a material footprint assessment method for the Netherlands. This assessment is required since 2018 by the Dutch legislation to obtain a construction permit. It is based on the national database, Milieu Database[19], about the environmental impacts of construction products made by material producers[20]. MPG considers the total assumed cost of all the materials used in a building (material that will be replaced during its lifetime), the lifetime of materials, the potential reuse. Results are expressed in €/m²/year. Calculations refers to the norm EN 15804 and therefore enables the full cradle-to-cradle life cycle assessment of buildings, including construction wastes and environmental impacts and benefits outside the system boundary of

[16] According to the website (https://madaster.com/platform/): « Madaster is the online library of information on materials and products. For registered buildings and infrastructure objects, our platform provides insight into the materials and products used and their location, as well as their impact on circularity and the environment. By thus providing these materials with an identity, we create awareness and understanding and make reuse easier, reduce waste and minimise the impact on our environment. »

[17] Software: www.gprsoftware.nl. GPR material: environmental impact of a project. GPR gebouw: integral sustainability (like BREAM). Material flow: project and portfolio level https://www.ivvd.nl/bossche-corporaties-brengen-materiaalstromen-in-kaart/.

[18] It is also similar to HQE certificates in France such as the ones by Qualitel which are used by Rennes Métropole.

[19] https://milieudatabase.nl/en/. The database is managed by SBK (Stichting Bouwkwaliteit).

[20] This is equivalent to the INIES database in France.

construction works. The MPG of the evaluated building is compared to the MPG of a standard building. The assumed price must be less than 60 % of the standard value.

The approach in MPG is performance driven and not material driven. There is no minimum share of biobased or secondary materials to be used in the project. Spatial origin is not included as well, apart from the assessment of the impact of transport. Reuse potential is also not rewarded. However, in a second level, the tool developed by W/E Adviseurs enables to show the impacts related to material choice.

Their tool also includes other criteria for circularity such as flexibility: reuse of layers, possibility to change floor division, change roof structure for green roof. Shares of biobased and secondary materials are also considered, with a focus on structural materials (roof, façade).

Those tools and databases on materials are used at the procurement level. For example, objectives such as to reuse, leave materials in place, or use biobased materials are set. However, the project manager does not ask the contractor at this stage to make the design of the project. Information on materials and their impacts are only available at the end of the design stage. Therefore, the level of information on circularity is the highest when the project is already finished. It is then hard for the municipality to know how much percentage of circularity is going to be reached in a project.

Besides, BIM (building information modeling) is currently used for the design of building projects in the Netherlands. It can be used to assess the quantity of materials used[21].

The circular ambition and methods of the Hezelport project

The circular ambition of the project was set during the tender process by the real estate developer Van Wonen with objectives such as reducing energy consumption and construction waste. The city of Nijmegen was assisted by the consulting company W/E adviseur[22] who is responsible for the sustainability measurement of the project.

The strategy for the Hezelport project is based on 4 Key Performance Indicators (KPI):

-**KPI 1: MPG Score[23]** (Milieu Prestatie Gebouw or Environmental Performance of the Building) The goal of the degree of circularity of the building might be known by this evaluation. The evaluation gives an overview of the environmental impact of the conception by having a

[21] And data from BIM can be integrated in larger databases like the ones developed by Madaster.

[22] W/E advisor. Adviesbureau voor duurzame gebouwen | W/E Adviseurs (w-e.nl)

[23] Calculation of the MPG: take into account the Total of fictive cost of all the materials used in a building+material that will be replace, the lifetime of the material, its potential reuse, the surface of the building. Result in MPG $/m2/year. Based on a norm: EN 15978 . Then the result is compared to an MPG of a normal building. The fictive price must be less than 60% of the standards value. MilieuPrestatie Gebouwen - MPG (rvo.nl)

minimal impact or by protecting the environment (efficient construction with a minimum of material or choice of product and materials with a good environmental performance evaluated by an AVC, etc.) The score must be as low as possible[24]. Van Wonen want to reach an MPG of 0,45m2/year (good one) by using bio sourced and recycled materials and using a small amount of glass. Their BENG score ambition is also high (energy performance of the building).

To reach that ambition, Van Wonen wants to work with the demolition company New Horizon Urban Mining[25] (provider) which is specialist in reuse of materials and evaluation of reuse and recycling of materials. They can provide freemen (circular cement) and reuse of material from bitumen (citumen). They want to use bio sourced material for the support structure. The last levels of the tower will be built with cross laminated timber (CLT). The outside envelope of the tower will be in wood and use cellulose for the isolation.

-**KPI2: Adaptivity**: the main objective is to build a building that can adapt its use in the future depending on the needs. In that way, in the long term the investment is preserved (for example the first level will have high ceiling height, so it can be a supermarket or a restaurant, etc.). The KPI will give an overview of the degree of adaptability of the concept. For example, the main elements of the structure and the façade will be removable. The beam, column and floor will be in concrete elements which can be dismantled for example.

-**KPI 3: Construction method:** the objective is to design the Duet tower as a bank of materials so the raw materials that will be used can be reused in the future and therefore increase the lifetime of the materials. The building will be built with a structure that is easily removable. The materials and products that are used in the building will be registered in Madaster[26] (an online platform of registry for material and product that are incorporated in a real state or infrastructure object, used in the Netherlands, Belgium, Germany, Austria, Switzerland, Norway). Van Wonen will develop the material passport to register each element of the building, their degree of dismantling, the toxicity of the material, etc. to see which product and material could be reusable after disassembly. The KPI will evaluate the degree of removability of the elements and products of the buildings .

-KPI 4 Use of circular materials: the objective is to reuse product and materials as much as possible with a high quality, from their partner New Horizon (freement etc, see above). The

[24] Legal measurement: max 0.8. above 0.55: poor; o,55 to 0,5: sufficient; 0,5-0,45: good; under 0.45: excellent).

[25] New Horizon - New Horizon

[26] Madaster: het kadaster voor materialen en producten

KPI will show the use of recycled materials and the goal is also to explain in the conception/design how the product and materials will be used. At this stage, it is not clear to see if there will be enough recycled product. The KPI explains the ambition and the degree of certainty to reach that ambition.

-**KPI 5 Use Biobased material:** a goal of having 10% of bio-based material in the construction is established for wood and cellulose for isolation. 100% of the wood used will be with label FSC (Forest Stewardship Council) or PEPC (Programme for the Endorsement of Forest certification).

To measure these KPI of circularity a transparent method will be used. The first KPI about the MGP has its own official measurement tool and method of calculation from the government. But for the evaluation of the 4 other KPI (adaptivity, construction method, use of reused material, use of bio sourced material), the GPR Gebouw[27], developed by W/E advisor will be used.

3.3.2.3 Gothenburg

National databases

An important source of data used in Sweden is the Byggsektorns miljöberäkningsverktyg - IVL Svenska Miljöinstitutet[28]. This database documents the chemical content of materials, as it is mandatory in Sweden to evaluate the toxicity of the materials for every new building (and some renovated buildings). Data on climate is also available but not for any product, as well as some information regarding social responsibility (e.g., labor), but not for all stages of the value chain. Few information on the spatial origin of materials can be found.

Another data source about secondary materials is available in Sweden: the national system called CCBuild[29]. However, it does not include any information about the quantity of secondary materials that could be used in a construction project.

Framtiden's data on their building

A third source is specific to Framtiden and documents their own buildings. It includes some information about the type of construction, structure, insulation, energy used. For some buildings, it indicates the materials in windows (for constructions after 2010). The renovation plan is also included (work to be done within 5 years). However, prior to any renovation work, buildings are visited to produce a complete information about materials. A similar database

[27] GPR software - maakt duurzaamheid van gebouwen meetbaar

[28] https://www.ivl.se/projektwebbar/byggsektorns-miljoberakningsverktyg.html

[29] https://www.ccbuild.se/

has been developed by the city about public buildings such as schools. Similar information about private buildings highly depends on the owners.

Stock study on Gothenburg

A material stock database, based on the bottom-up approach, for residential buildings in Gothenburg is available. In this database, the residential buildings constructed between the years 1890-2010 are investigated. The elements included are window, bottom slab, roof and external wall and the material calculated are concrete, wood, brick and metal. Combined with GIS modelling, the distribution of elements and materials in each region is visible. Currently, a more comprehensive material stock database with more types of elements is under development. At the same time an attempt to combine demolition permits with existing databases and to calculate when and where the elements and materials with reuse and recycling potential is being made.

3.3.2.4 Summary of the tools and studies used in the 3 livings labs

Table 7. Tools and studies used in the livings labs

Tools and studies	Rennes Métropole	Nijmegen	Gothenburg
City level	Urban metabolism study : mapping of stocks, flows and local actors, online data share Shared database on all ongoing urban projects	Urban metabolism study : mapping of stocks, flows	Stock assessment (research project) and database of Framtiden about its buildings
Urban project level	Material flow assessment Sourcing for local and renewable materials LCA assessment at the urban project level	MPG tool for neighborhoods	
Building level	NF Habitat HQE label LCA assessment (energy and carbon)	LCA assessment (GPR, MPG) Assessment tool for housing projects and circular economy (Circulair Impactladder)	LCA assessment with details about materials from Byggsektorns miljöberäkningsverktyg

The summary shows that few studies are performed at the city level, although some urban metabolism studies are observed. Those studies provide some information on the existing stocks of materials and sometimes on the current and future flows (consumption and waste), as well as on the local stakeholders of the construction sector. Data produced through a metabolism study can be shared online to all local stakeholders.

Some studies are performed at the urban project level and are sometimes based on a lifecycle approach. They aim at better anticipating future flows generated by the urban project (at a predesign or design stage) or at identifying the local renewable materials which are available (sourcing). Most studies today are realized at the building level and based on a lifecycle approach. They sometimes refer to a complete circular economy framework (with multiple criteria such as building flexibility).

3.4 Needs in terms of tools and data

3.4.1 Needs according to the questionnaire

The answers about the needs in terms of production of new data or access to existing data to improve circular economy in respondents' projects are shown below (some of the original text has been summarized by the authors). Some answers relate to data about potential secondary materials (to better know them, to better share and use this information in projects). Some answers relate to business offers of secondary materials (marketplace - business directory/map, places for storage). Respondents also wish to better know the costs related to reuse or recycling.

Table 8. Needs in terms of production of new data or access to existing data (answers are not classified by categories)

Göteborg	**Nijmegen**	**Rennes Métropole**
Building a digital marketplace and logistics warehouse	Data about neighborhoods (physical data about water, soil, green and building environment, as well as social and economic data)	Product sheets for reusing materials, and indicators to provide visibility for project owners
Storage of available recycled materials	Standardization - availability - transparency (for instance, a fire label for insulation, is sometimes reported with a fire resisting barrier in front of it, sometimes without)	Tests to ensure the insurability of materials. Dedicated storage platforms for reused materials. Economic benefits of reuse.
Smoother way to inventory, smoother transfer of information from products to 3D objects	More general accepted/national database (for example Madaster) of circular products/systems and their circular components (toxicity/CO_2 storage/biobased)	Demonstrate the economic and social relevance at local and environmental level (for reuse/recycling)
Access to older data	Sufficient availability of used materials	Access to resource diagnostics and PEMD in the areas where we operate
More EPDs. Better reuse databases. Recycling database.	Cost of materials used	Additional cost of materials from the reuse sector today - forecast for 2024 and beyond
Functional and user-friendly inventory tools for reuse and climate calculation	Online tools with consistent information	Identification of locally recognized structures / consultants to support project owners in integrating reuse into their projects
Collaboration between value chain actors to share data	Central database containing everything about circular materials and their properties. A database that simply contains all possibilities of financing and subsidies for new development projects, both national and European. Extended BIM model with integration of our 14R circularity model and track & trace information on our 'legolized' datamodels of demolition projects.	Transmission of information to companies on site
		Mapping deposits and characterizing materials
		Measuring real development potential: what volumes are involved?
		To enable a better storage
		A complete network of resources

When asked about other needs/ideas that would help the decision process for circular economy in their projects, respondents point the role of governments – municipalities with

actions such as changing regulations and financial support or facilitated access to land (some of the original text has been summarized by authors).

Other needs/ideas that would help the decision process for circular economy in the respondents' projects (answers are not classified by categories)

Table 9. Other needs or ideas to help the decision process for circular economy

Göteborg	**Nijmegen**	**Rennes Métropole**
Increased demands from municipalities and real estate companies	More knowledge and support from the government/city council	Access to land and financial aid to support the creation of local economic activities
Mostly stuck on labeling, requirements and accessibility measures so far.	Increased expertise and availability of circular materials (used, reusable) for large-scale housing projects	Promote the availability of materials
Suppliers taking back and upgrading their products to a reusable range. Climate data at system level.	Legislation. Level playing field.	Mobilize companies rather than designers to a greater extent
Standards for reused products and suppliers who reclaim their products and recondition for reuse with classifications and guarantees	Regulations that make it possible to finance small projects without always having to work together with other companies or knowledge institutions	Organize information/awareness-raising/training sessions for local elected officials (mayors and their deputies responsible for urban planning, the environment, energy, etc.).
Mandate government and municipalities to prioritize circular solutions in public procurement	Supporting small projects much more financially	Informing companies about reuse = deconstruction and construction so that they can make proposals and do it
Will and policy, i.e. owners and client competence. Major challenges in obtaining the right materials for renovation and new construction. No market for buying recycled materials.	Direct linking of development projects with donor (demolition) projects	Diagnosis for reuse mandatory before any demolition

3.4.2 Needs according to the interviews

3.4.2.1 Rennes Métropole

A need for new data is identified by the municipality to better define objectives and carry out actions. The metabolism study has allowed to initiate the development of the strategy by providing data to better understand the issues of the territory related to its material consumption and waste generation and management. It also allowed a better understanding about existing and developing sectors and to prioritize those that could benefit most from support from the municipality. Finally, it supports the initiation of a dialogue between municipality and urban developers on the one hand, and companies working on material production and waste management on the other hand.

- **To evaluate the environmental impact of scenarios**

To act on the scale of development operations, data on environmental impacts would be useful to be able to better compare different project design scenarios and to help choose the most favorable scenario in terms of circular economy criteria. For example, there is the question of impacts related to the choice between rehabilitating or demolishing a building[30]. This question arises in the context of the project to transform the Hôpital Sud in Rennes. However, other criteria are considered in the decision, such as the adaptation of current building to desired future uses.

Carbon and material assessment data for rehabilitation or demolishing/construction scenarios, as well as their cost, would support decision making.

Data would then be used to help design an operation, especially for the choice of management methods for the waste generated and the choice of materials to be used. This would imply being able to consider the local availability of resources for construction. Indeed, the most widely used indicator of resource depletion in LCA, the contribution to the depletion of abiotic resources, only considers the global availability of resources[31] . Moreover, the interpretation of results of an LCA study is often complex and making this information more accessible remains a real challenge. Finally, additional indicators could be used, such as avoided resources.

- **To trace the origin of construction materials and materials/waste flows**

To complete the knowledge already produced on the territory and to meet the objectives presented above, data on the origin of materials consumed in the territory, destination of materials produced on the territory, and construction waste generated could be useful[32].

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[30] This type of question has been the common practice in France for the last five years or so in the form of contracts for assistance to the project owner (AMO) in the circular economy linked to a specific project or carried out within framework agreements between a developer and a study group for several projects. The study of flows is generally based on a model carried out via GIS data processing on the building and which is then completed by targeted diagnostics of a sample of buildings. Online tools such as Evalmetab (https://www.evalmetab.fr/) can also provide an indicative estimate based on modeling only, data on surfaces entered directly by the user and according to predefined building types.

[31] For example, on the indicators used for construction products in the INIES database: https://www.inies.fr/inies-pour-le-batiment/lacv-produit/. For an analysis of the limitations of LCA in taking into account the availability of local resources, see Augiseau and Monfort (2020) : https://www.researchgate.net/profile/Vincent-Augiseau/publication/346528792_Prise_en_compte_du_contexte_local_ressources_materielles_pour_les_proj ets_de_construction_et_amenagement/links/605cb6cf92851cd8ce69206e/Prise-en-compte-du-contexte-local- ressources-materielles-pour-les-projets-de-construction-et-amenagement.pdf

[32] Note that this information could be produced from data on road freight transport that are produced and disseminated by the Ministry of Ecology (CGDD) on a municipal scale. However, access to these data requires a request to the Comité du Secret Statistique. Customs data on international imports and exports, on the other

However, some data sources which could be used to provide such information have a restricted access. In addition, a better understanding of the proportion of consumed materials that are reused and recycled would allow a better understanding of issues at stake and monitoring implementation of actions[33]. Access to data from waste diagnostics prior to rehabilitation or demolition of buildings would make it possible to better monitor the evolution of part of the waste flows generated[34].

- **Tools for the technical implementation of circular economy**

Very precise technical data are also required to identify sectors or land to be supported and to help them in their development. Indeed, very practical questions are asked by actors, such as technical barriers posed by the presence of pollutants in the materials which one wishes to dismantle for material reuse or recycling. These questions are rather related to technical studies that must be carried out by the actors involved and not directly by the municipality.

- **Data on building use**

Additional data on buildings and their use (past, present, and future) could contribute to the definition and implementation of actions for the circular economy in the building and public works sector. Indeed, it would be necessary to better identify the needs for built space for housing or business premises that could be covered by a better use of existing buildings. In the absence of data, these needs are often considered today to be covered only by new construction. Moreover, demolishing and then rebuilding a building is often less expensive than rehabilitating it.

These data would contribute to the development of the future housing plan by defining housing production objectives for existing buildings. They could also be useful in the framework of the economic development plan. The Rennes Urban Planning Agency (AUDIAR) is carrying out this type of reflection by studying opportunities for building densification.

hand, are only available at the departmental level. Moreover, these two data sources have strong limitations in terms of completeness and accuracy, as analyzed for example in CitéSource (2022 - Metabolism study of the Greater Paris Métropole).

[33] Data on waste could be provided by the National Register of Waste, Excavated Soil and Sediments managed by BRGM (https://www.brgm.fr/fr/site-web/registre-national-dechets-terres-excavees-sediments). However, anonymization of these data is required and these data are largely confidential. The dissemination of these data on a spatial scale such as the Métropole and guaranteeing their anonymization would be very useful for the communities.

[34] Data from product, equipment, material and waste diagnostics (PEMD), the centralization and dissemination of which are the subject of a project currently being carried out by the CSTB (https://www.cstb.fr/fr/actualites/detail/cstb-developpe-future-plateforme-associee-au-nouveau-diagnostic- produits-equipements-materiaux-dechets-pemd-2021-09/). Strong anonymization constraints could restrict thedissemination of this data at the scale of the construction site, or even the municipality or intercommunal area.Moreover, the PEMD diagnosis is only mandatory for a part of the building rehabilitation or demolition sites.

Digital tools based on artificial intelligence could help anticipate changes in use or obsolescence and demolition. A better understanding of the potential of existing building stock would allow the definition of adapted objectives. These objectives could then be evaluated with respect to the study of environmental impacts.

However, this type of approach seems to be more of a medium to long-term project in France, as it may take time for specific circular economy criteria to be considered in urban planning. In the case of Rennes Métropole, the next housing plan will only be implemented in 6 years. The same is true for the definition of criteria in urban planning regulations (inter-communal local urban plan[35]). This type of approach is still unprecedented in France and is largely the result of national or European regulatory changes.

Thus, developing a short-term strategy for urban development projects seems to be a relevant avenue to which the CREATE project could contribute. This would involve providing data on material and waste flows from construction sites and their environmental impact, with respect to existing local material production and waste management activities and physical availability of resources (e.g., availability of wood for construction). For this, collection of data on projects from Building Information Modeling (BIM) or a digital model could facilitate provision of information. It would also be necessary to facilitate use of this data by making it accessible to development professionals (e.g., most relevant indicators, presentation format and data visualization).

3.4.2.2 Nijmegen

No tool is currently used at the level of urban projects to help decision making at a predesign stage. This could be a relevant option for CREATE. The tool would help to have an understanding on how much certain urban development project can contribute to circular economy objectives. It would assess how much a project could be circular relating to objectives (30 % or 40 % of the objectives for example). They could then know what the rhythm of progression towards their circular goals is.

At this stage of the urban project, information would have a high level of abstraction. Indeed, the earlier the stage in a project, the less information is available. But also, the more decisions can have impacts[36]. Therefore, a good balance should be found between the quality and reliability of the information available at this stage and its use in the decision-making process.

[35] https://metropole.rennes.fr/mieux-comprendre-le-plui-questions-et-reponses

[36] This is called « paradox of the design process » (*paradoxe du processus de conception* in French) by Luc Adolphe: Adolphe, L. (1995). L'intégration des connaissances techniques dans le processus de conception architecturale et urbaine. *Habilitation à diriger des recherches (HDR), UPS-Toulouse, France* :

W/E Adviseurs' experience shows that while environmental assessments based on a life-cycle approach are massively delivered today in the Netherlands for buildings, they still face limits. One limit concerns the data on construction products which is required to perform those assessments. The Dutch Milieu database is not complete : some materials by small local producers are not included. This is also the case for most reused materials. Discussions about data quality also appear as the latter often varies from one material producer to another. There is therefore still an ongoing process to improve the database.

Another limit relates to the use of such assessments at a building level. Contradictions are observed for some criteria such as embodied energy and CO_2 emissions and other impacts such as resource depletion. Choices based on a multicriteria approach are difficult. The Dutch Ministry of housing also announced that they would create an extra rule to promote timber : CO_2 emissions would not be based on a full cradle to cradle approach.

A third limit relates to the spatial scope. While W/E Adviseurs commercializes a tool for the environmental assessment of an urban project, this tool is not very used (less than 10 licenses sold per year). This could be explained by the fact that urban planning is rather focused on the prevention of environmental and health impacts, instead of an improvement approach. Also, environmental assessment of an urban project based on life-cycle approach is not mandatory in the Netherlands, while it is the case at the building level. But this could change in the next years.

Besides, another limit related to circular economy strategies in urban project is the lack of data on available secondary materials. No database provides such information today for the city of Nijmegen (or for the region Arnhem/Nijmegen). However, the services delivered by the company Madaster can be useful. Moreover, reusing secondary materials raises difficulties in terms of time, cost and expertise required. Demolition/demounting contracting partners are key stakeholders for such projects in Netherlands today.

3.4.2.3 Gothenburg

Within the CREATE project, the city aims at developing and better using the inventory of material stocks created by Chalmers. That inventory could be enriched with information on secondary materials which might be reused such as windows, doors, kitchen products... Information on stocks could be crossed with GIS data on the urban development areas in the city and construction permits to estimate future flows. This data on flows could be shared

http://lra.toulouse.archi.fr:8080/lra/productions/theses-et-hdr-soutenues/hdr-soutenues/Luc_Adolphe/synthesehdrlucadolphe.pdf

with project developers. The level of detail of data on urban development areas in the city is to be defined (today, they do not know how many buildings will be demolished in the city).

Besides, the city is currently working on another research project for Sweden about the use of existing buildings to produce dwellings (how to better use existing buildings to reduce construction needs and therefore material flows).

3.4.2.4 Summary of the needs in terms of tools and studies for the 3 livings labs

Table 10. Needs in terms of tools and studies in the living labs

Studies / data	**Rennes Métropole**	**Nijmegen**	**Gothenburg**
Inflows and outflows	Data on origin of materials consumed in the territory, destination of materials produced and construction waste	Data on origin of materials consumed in the territory, destination of materials produced and construction waste	
	Frequent data on waste flows for monitoring (waste production, waste management)	Frequent data on waste flows for monitoring (waste production, waste management)	
Local and renewable materials	Data on the availability of local and renewal materials and of their environmental impacts	Data on the availability of local and renewal materials and of their environmental impacts	
Secondary materials	Data on the availability of secondary materials and of their environmental impacts	Data on the availability of secondary materials and of their environmental impacts	Data on the availability of secondary materials and of their environmental impacts
Cost	Cost of reuse/recycling	Cost of reuse/recycling	
Building use	Data on building use		Data on building use
Environmental evaluation	Scenario comparison in terms of waste management, CO_2 emissions, resource uses	More LCA at urban level	

The summary shows that needs are expressed in terms of data about all inflows (materials used) and outflows (waste produced) of materials at the city level. Better knowing the origin and destination of these flows is a question raised.

A second set of data needed is about the availability of local primary and secondary materials and the environmental impacts of these materials. The cost of using secondary materials is

also a question which is raised. Better knowing how buildings are used is also key to better optimize the existing building stock and reduce flows.

More detailed questions are also formulated in terms of technical or logistical solutions to reuse or recycle secondary materials. Only the key findings related to tools, studies and data about material stock and flow which is the focus of the CREATE project are presented here.

4 CONCLUSION

4.1 Challenges and barriers according to the literature review

The literature review shows that a total of 39 barriers and 22 enablers can be identified. The list of barriers and enablers is presented in table 2. The drivers and barriers were grouped under economic, environmental, social, technical, regulatory and organizational categories. Considering that this study focused on the needs from barriers, that few barriers were directly linked to environmental factors, for the purpose of this study, we classified challenges/barriers into 5 categories :

- Regulatory (Regulation and policy)
- Social (Lack of awareness and understanding)
- Organizational (Conflict with stakeholders)
- Economic (Economic, business and cost)
- Technical (Lack of knowledge and information)

The enablers were organized according to the categories of challenges / barriers.

4.2 Main results of the questionnaire

The questionnaire shows that circular economy projects are developed in each living lab and that they imply a variety of actors along the value chain and the project stages. Designers and engineers, local authorities and clients, who mostly intervene at the urban planning or building design stages, are the most represented. Through their actions for circular economy, respondents often aim at reusing secondary materials or recycling waste, to reduce the use of primary materials. They also aim at reducing the impact of material supply through the choice of bio-based materials (such as timber, straw or raw-earth) and also promote local materials.

Many barriers the respondents consider facing in their projects relate to economic, business and cost and particularly the lack of formal regional markets for reclaimed components and the limited funding and high upfront investment costs. The lack of knowledge and information comes next, with barriers such as a fragmented supply chain and the fact that buildings and building components are not designed for deconstruction.

Actions that would enable circular economy which relate to knowledge and information received most answers. Such information could be first provided with tools for conducting project-based supply chain integration framework according to the number of answers for this choice. Actions related to economic, business and cost are second and most answers in this category concern market-based incentives and then national / regional level of exchange platforms with standard of specific performance. A consistent regulatory framework and

adequate circular specific legislation, as well as precise and professional project management and close communication are also considered as key for the respondents.

Information about materials or components are the most used, followed by data related to economic, business, marketing and cost and demolition information. This information comes from a large variety of sources. Online marketplaces for secondary materials or online map/directory of economic actors for reuse are used to gather some information. A very few tools which are specific to circular economy but concern only a few countries are also mentioned.

Respondents express some needs related to data about potential secondary materials (to better know them, to better share and use this information in projects) and to business offers of secondary materials (marketplace - business directory/map, places for storage). Respondents also wish to better know the costs related to reuse or recycling. Although many different needs are expressed, its seems that respondents would like to access to more data about secondary resources (or materials in general) but also to better be able to share that kind of information between the different actors of a project.

Those findings show that the objectives of the CREATE project match with some important needs of the actors in the three cities, particularly about better knowing available secondary resources and the environmental impact of their use and about improving governance. However, it is important to notice that all needs could not be addressed through the project, particularly for issues regarding cost.

4.3 Main results of the interviews

Interviews show that objectives for circular economy are set by the three municipalities and presented either in a specific document or integrated in a more general plan. Objectives for carbon emissions reduction are often used as a basis for targets concerning circular economy. However, some criteria are specific to circular economy.

Environmental assessment based on a lifecycle approach are broadly used at the building level for construction projects. Few environmental studies are performed at the urban project level today, but this kind of study is getting more common.

The framework of LCA is very well regulated in the three living labs by national construction guidelines/rules. However, LCA of buildings are mostly driven by building use during the whole life span and energy performance, consequently circular economy efforts can be sometimes unnoticed by LCA assessment.

Information/data is crucial to contribute to decision making. Environmental assessments at the building levels are used to reach some circular objectives. Studies performed at a larger

scale such as metabolism studies are useful to better understand the local issues and raise awareness about the size of the urban mine.

Metabolism studies provide some information on the existing stocks of materials and sometimes on the current and future flows, as well as on the local stakeholders of the construction sector. Data can be shared online to all local stakeholders.

Some studies are performed at the urban project level and are sometimes based on lifecycle approach. They aim at better anticipating future flows generated by the urban project (at a predesign or design stage) or at identifying the local renewable materials which are available (sourcing).

Most studies today are realized at the building level and based on a lifecycle approach. They sometime refer to a complete circular economy framework (with multiple criteria such as building flexibility).

Needs are expressed by the cities in terms of data about all inflows and outflows of materials at the city level. Better knowing the origin and destination of these flows is a question raised.

A second set of data needed is about the availability of local primary and secondary materials and the environmental impacts of these materials. Better anticipating the impacts related to renewable or secondary materials at the predesign stage of urban projects is needed.

The cost of using secondary materials is also a question which is raised. Better knowing how buildings are used is also key to better optimize the existing building stock and reduce flows. More detailed questions are also formulated in terms of technical or logistical solutions to reuse or recycle secondary materials.

4.4 Discussions and perspectives

WP2.1 has enabled a better understanding of the general policies and actions which are being carried out for circular economy in the construction sector in the three living labs. It has allowed to identify some key barriers and enablers, concerning the issues related to information, data and digital tools that can help the implementation of circular economy strategies, which is the focus of the CREATE project.

It is important to note that an in-depth analysis of policies, barriers and enablers would require a detailed study of the cultural, political, social, economic and environmental context of the countries and territories in which the three living labs are located, which is outside the scope of the work targeted here. Moreover, the understanding of the policies from the point of view of the governance arrangements they involve, and the barriers and enablers encountered is analyzed in more detail in task WP4.

Similarly, the study made it possible to better identify the studies and data that are generally mobilized during urban or construction projects and to identify some needs. This inventory is

not exhaustive. Very detailed and specific studies can be carried out for certain projects and were not identified during the interviews. In addition, many data sources are used, which may come from national, regional or local producers and which are difficult to identify in an exhaustive manner.

Despite these limitations, the study has shown that the three municipalities are implementing ambitious and innovative policies for the circular economy in construction. These policies call for new studies and information to better anticipate the material flows generated by the metabolism of the city in general, and by urban or construction projects in particular.

Environmental assessments of construction projects (buildings) based on a life cycle approach become “standard”, often in response to regulatory obligations. On the other hand, the study of material flows and associated environmental impacts at the scale of the urban project is still underdeveloped.

These observations open interesting perspectives for the CREATE project. They confirm the interest of better producing and sharing data on material stocks and flows at an urban scale (project or territory) as a decision support for urban development projects or urban planning. However, in some cases it is still unclear how cities or urban planners can use this kind of data to take concrete decisions. The criteria material and all associated items (availability of resource, waste management, transport impact, etc.) is only a part of the decision-making process which includes many other topics.

The work carried out allows us to identify avenues for data production which are presented in the second report of WP2.

ANNEXES

A. Questionnaire (English version)

1. Your activity

You are currently working for :

- Local authority / municipality
  - Urban planning department
  - Transport and infrastructure department
  - Building control department
  - Environment department
- Client
  - Real estate owners/developers
  - Investors
  - Insurance company
  - Estimator
  - Project manager
- Designers and engineers
  - Architects
  - Structural engineer
  - Building service engineer
  - Civil engineer
  - Environmental/sustainability engineer or consultant
- Construction and operating team
  - Construction company
  - Facilities manager
- End-of-life treatment
  - Waste manager
  - Demolition company
- Manufacturers and producers of building components
- Other : please indicate your activity

In which phase of the construction process do you intervene?

- Urban planning and design phase
- Building development and planning phase
- Building design phase (pre-design phase, design phase)
- Building construction phase (pre-construction phase, procurement phase, construction phase)
- Building maintenance and refurbishment phase
- End-of-life phase (deconstruction/demolition)
- Production handling (products processing and manufacture, transportation and distribution)

2. Circular economy in your projects

Does your organization have a circular economy policy or strategy ?

- Yes
- Not yet but it will be implemented soon

- Not yet and there is no plan to implement it

If so, what are its main objectives?
- Recycle waste
- Reuse waste
- Reduce material consumption
- Reduce the environmental impacts related to waste management
- Reduce the environmental impacts related to material supply
- Develop local activities and use local materials
- Other : please indicate

If so, could you present briefly 1 or 2 examples of actions that have already been implemented?
…

Which sort of barriers did you face/are you facing ?
- Regulation and policy
- Conflict with stakeholders
- Economic, business and cost
  - Unclear financial case and poor and unconvincing business case
  - Lack of incentive for CE implementation
  - Lack of formal regional markets for reclaimed components
  - Limited funding and high upfront investment costs
  - Additional cost for external consultants for expertise
- Lack of awareness, interest and understanding
- Lack of knowledge and information
  - Fragmented supply chain
  - Buildings and building components not designed for deconstruction
  - Insufficient use or development of CE-focused design and collaboration tools, information and metrics
  - Vast variety in quality and size of extracted components from buildings
  - Lack of information on buildings components (fire requirements, sound insulation etc.)
  - Existence of hazardous substances (fire retardants, coatings, etc.)
- Insurance and warranty issues

In the opposite, what enables circularity ?
- Consistent regulatory framework and adequate circular specific legislation
- Precise and professional project management and close communication
- Economic, business and cost
  - More proven case studies with convincing experience
  - Market-based incentives
  - National / regional level of exchange platforms with standard of specific performance
  - Financial support
- Education
- Knowledge and information
  - Tools for conducting project-based supply chain integration frameworks
  - More training in use of available tools and deconstruction techniques
  - Development of CE-focused design and collaboration tools, information and metrics
  - Comprehensive data management with standard structure

- Professional insurance and warranty
- LCA data to show the environmental impacts

3. Data and tools you use for circular economy

What type of information do you use when you work on circular projects ?

- Building design, construction, maintenance and dismantlement and demolition
  - Material or component information
    - Basic information (Dimensional properties: size, length etc.; Material content; Connection details; Structural and functional situation)
    - Design requirements (Accessibility requirements; Acoustic requirements; Fire requirements; Aesthetic information)
    - Availability condition (Quantity / Storage; Time when materials are available)
    - Information of reuse assessment (Components condition; Exposure situation; Remaining lifetime; Types of buildings/infrastructures used)
    - Sustainability information (Energy consumed; Environmental impacts)
  - Demolition information
    - Demolition method
    - Likelihood of damage or contamination
    - Storage place and capacities
- Supply chain
  - Transport information
    - Shipping method
    - Storage place
    - Transit time
    - Transport distance
  - Other
    - Entire timeline
- Economic, business, marketing and cost
  - Cost
    - Deconstruction price
    - Storage price
    - Testing price
    - Transport cost
- Warranty and insurance

Where does this information come from ?

- Specific studies carried on for the project
- Expert opinion
- National databases
- Local databases
- Other : please indicate

Which softwares/tools do you identify today to implement circular economy in your projects?

What needs in terms of production of new data or access to existing data do you identify today to improve circular economy in your projects?

Do you have other needs/ideas that we didn't mention that could help you in the decision process for circular economy in your projects ?

B. Framework for the semi-structured interviews

Introduction of the interviews

As a prelude to the questionnaire, present in about 10 minutes:

- Permission to record/data protection
- Introduce ourselves
- Main objectives and framework of the CREATE project
- Main objectives of the interview

Questions

1. Your function and your department

Could you please introduce yourself, stating your position and the department in which you work?

Describe some tasks that you perform in your regular activities?

2. The circular economy policy for construction in your municipality

Does your municipality have a circular economy policy (or vision) for the construction sector (buildings and infrastructure)? If so, what are its objectives?

What actions have already been implemented?

What actions will be carried out in the next few years?

Has any action been dropped/reshaped? If so, why?/Which sort of barriers did you face/are you facing ? (rules, regulation, conflict with stakeholders, lack of resources (human, economical, knowledge...)).

In the opposite, what enables circularity ?

3. Tools and studies carried out to implement this policy

What type of information do you need and use when you work on circular projects ?

Where does this information come from (diagnosis, survey...) ?

Who carried out these studies and under what conditions (study contract carried out by service providers and if so which ones, internal study and if so which department, research work and if so by whom)? What was the cost of these studies?

How did you integrate and evaluate this information in your process of decision making (public tender, decision for investment, budget) and how did it influence the process?

What information from these studies was most useful in defining and then conducting your policy? What information was missing or of insufficient quality or accuracy?

Are you using other form of support to help to carry out your policy such as circularity scale, building network, workshop, change inside the municipality, etc. ? How does that help you?

How were the results of these studies disseminated (paper report, online report, online mapping...)?

Was this information sharing successful? If not, why?

4. Stakeholders

Which stakeholders is involved in your CE ambition in the building sector?

What does the ambition of CE in your project change in the way to collaborate with other stakeholders (relationship between public and private stakeholders, conflict, different goal coordination, etc.)?

Does this new relationship with the stakeholders change your process of decision making? How? (who is involved in the process at first)

5. What your municipality needs to improve its policy

In your opinion, what should be changed in the government context to accelerate and upscale circular projects? (regulation, rules, resources, coordination with other level of governance, ...)

Do you have special needs regarding the organization with the stakeholders that could participate to improve your policy?

What needs in terms of studies (production of new data) or access to existing data do you identify today to improve your policy?

Do you have a budget for that? If yes, what budget is the municipality prepared to allocate to these future studies?

What visualization tool needs do you identify today to improve your policy?

What budget is the municipality willing to allocate to visualization platforms?

How could a visualization tool enable you to work on the circular economy within your municipality. In your opinion ?

What do you think a visualization tool could not provide?

What budget would you be willing to allocate to the acquisition of this visualization tool (annual cost excluding development)?

Do you have other needs/ideas that we didn’t mention that could help you in the decision process for your policy?