Reflow | Co-Creating Circular Resource FDlows in Cities

Constructive metabolic processes for material flows in urban and peri-urban environments across Europe

Deliverable 3.2

URBAN METABOLISM ANALYSIS: INITIAL ASSESSMENTS

Due date of deliverable: 29/05/2020
Actual submission date: 29/05/2020
Start date of project: 01/06/2019 Duration (36 Months)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

DELIVERABLE

Work Package	WP 3 Circular Engineering
Deliverable	D3.2 Urban Metabolism Analysis: Initial Assessments
Tasks	Task 3.3 Environmental Systems Design [M03-M24]
Document Name	Urban Metabolism Analysis: Initial Assessments
Due Date	M24: 31 May 2021
Submission Date	M24: 31 May 2021
Dissemination Level	P-Public
Deliverable Lead	Metabolic Institute (MET)
Author(s)	Liz Corbin (MET), Tobias Bichler (MET), Pilar Bolumburu (MAT), Savanna Browne (MET), Elodie Chatel (MET), Antoine Coudard (MET), Alysia Garmulewicz (MAT), Martijn Kamps (MET), Zoe Powell (MAT), Frenzi Ritter (MET), Apurva Singh (MET), Charlene Smith (MAT), Tamara Streefland (MET), Fanny Thibault (MET)
Point of Contact	Liz Corbin, elizabeth@metabolic.nl
Reviewers	Rossana Torri (Comune di Milano); Thomas van de Sandt (Pakhuis de Zwijger)
Status	[X] Final
Abstract (for public dissemination only)	This report presents the methodology and results of WP 3, Task 3.3 Environmental Systems Design within the REFLOW project. Its aims to communicate the outcomes of each pilot city's urban metabolism analysis -including the material flow analyses, initial impact assessments, and resulting recommended actions.
Keywords	Urban metabolism; Material flow analysis (MFA); Environmental impact assessment, Impact hotspots, Circular action roadmap; Circular strategies
Statement of Originality	This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

REVISION HISTORY

Revision	Date	Author(s)	Organization	Description
D3.2 v0.1	03/05/21	Liz Corbin (MET), Tobias Bichler (MET), Pilar Bolumburu (MAT), Savanna Browne (MET), Elodie Chatel (MET), Antoine Coudard (MET), Alysia Garmulewicz (MAT), Martijn Kamps (MET), Zoe Powell (MAT), Frenzi Ritter (MET), Apurva Singh (MET), Charlene Smith (MAT), Tamara Streefland (MET), Fanny Thibault (MET)	MET & MAT	First draft
D3.2 v0.2	28/05/21	Liz Corbin (MET), Tobias Bichler (MET), Savanna Browne (MET), Elodie Chatel (MET), Antoine Coudard (MET), Martijn Kamps (MET), Frenzi Ritter (MET), Apurva Singh (MET)	MET & MAT	Change by partners
D3.2 v1.0	31/05/21	Liz Corbin (MET), Tobias Bichler (MET), Savanna Browne (MET), Elodie Chatel (MET), Antoine Coudard (MET), Martijn Kamps (MET), Frenzi Ritter (MET), Apurva Singh (MET)	MET & MAT	Final version by the consortium to be submitted to the EC.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

INDEX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

EXECUTIVE SUMMARY

Cities account for 2% of the planet's land surface, yet use 75% of the resources extracted by our global economy. This trend is projected to increase, as by 2050, urban dwellers are expected to represent 66% of the 9.5 billion human population. **Maximizing the circular and regenerative nature of urban resources, while minimizing urban waste and impacts has become both a pan-European priority and a key leverage to transition the European economy to a fundamentally sustainable state.**

A core concept upon which the REFLOW project is built is the concept of **Urban Metabolism**, which seeks to understand the flows of materials and energy within a city and provide a framework for assessing the interactions between and impacts associated with natural and human systems. At the core of the Urban Metabolism concept is the **Material Flow Analysis (MFA)** methodology; an analytical method to quantify the stocks and flows of materials, water, energy in a system in order to study biophysical aspects of human activity on different spatial and temporal scales.

REFLOW activities associated with Urban Metabolism and MFAs are led by **Metabolic Institute** and **Materiom** as part of **Work Package 3: Circular Engineering**. The purpose of WP 3 is to map and assess each pilot city's urban metabolism and its associated social and environmental impacts. The process is done in close collaboration with each pilot team and the results are used to support the continual development and assessment of the circular resource strategies and interventions piloted within each REFLOW city. The process undertaken by WP 3 to complete each pilot city's assessment is documented within this report - **D3.2: Urban Metabolism Analysis:** Initial Assessment - as are the results derived.

Key insights from this work include:

- The MFA and impact analyses conducted thus far highlight **the importance of EU cities becoming (once again) productive places with the tools and knowledge needed to continuously cycle urban products and materials at high value.** Recycling materials and products within city boundaries should be seen as an economic, social, and environmental priority -as this leads not only to new employment opportunities, but the ability to reduce a city's dependency on virgin materials.
- Close collaboration with REFLOW pilot teams enabled the development of novel 'bottom-up' MFAs that identify and engage local stakeholders and provide practical insights on the (in)efficiencies and impacts within and between supply chains that may otherwise go undetected. Importantly, the process to date has highlighted how **local industry leaders (e.g. SoGeMi in Milan and FIAC in Paris) can play a pivotal role spearheading the transition of their industry towards a circular economy.**
- By taking a whole-life-cycle approach to each REFLOW city's environmental impact analysis, it becomes clear that the impacts associated with urban resource flows are often not directly felt within the city itself. When assessing the circularity of an urban system, **it is critical to apply a holistic and systemic lense -not only through the identification of environmental, social, and economic impact factors, but also in the identification of upstream and downstream impacts.**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

LIST OF ABBREVIATIONS

Abbreviations:

B2B: Business-to-Business
B2C: Business-to-Consumer
CE: Circular economy
CLT: Cross-Laminated Timber
DEHP: Bis(2-ethylhexyl) phthalate
EEA: European Economic Area
EFA: Energy flow analysis
EOL: End-of-life
EPR: Extended Producer Responsibility
EPS: Expanded polystyrene
EU: European Union
EVA: Ethylene-vinyl acetate
FIAC: Foire Internationale d'Art Contemporain
GHG: Greenhouse gas
HDPE: High-density polyethylene
JRC: Joint Research Center
LCA: Life-cycle assessment
LDPE: Low-density polyethylene
LED: Light-emitting diode
MDF: Medium Density Fibreboard
MFA: Material flow analysis
MUFPP: Milan Urban Food Policy Pact
OSB: Oriented Strand Board
PET: Polyethylene terephthalate
PP: Polypropylene
PS: Polystyrene
PVC: Polyvinyl chloride
SME: Small and medium-sized enterprises

Units:

Mass:

kg: kilogram
ton: 1 metric ton
kton: Thousand metric tons
Mton: Million metric ton

Environmental emissions:

ton CO_2-eq: 1 ton of carbon dioxide-equivalent of greenhouse gases
Mton CO_2-eq: 1 million tons of carbon dioxide-equivalent of greenhouse gases
ton-14 DCB-eq: 1 ton of dichlorobenzene-equivalent

Energy:

MWh: Megawatt hour
GWh: Gigawatt hour

Volume

Mm^3 : Million cubic meter

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

LIST OF FIGURES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

DEFINITIONS AND KEYWORDS

Biodiversity Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

Biomaterial A material intentionally made from substances derived from living (or once-living) organisms.

Circular economy A circular economy is an alternative to the present-day dominant linear industrial model of design, produce, purchase, consume and dispose. A circular model aims to redefine growth and generate positive societal and environmental impact. It entails a transition from using finite resources, to using renewable ones (designing the concept of waste out of the system), while building economic, natural, and social capital. Although starting from material resources as a point of departure in REFLOW, the focus of the circular economy gradually extends beyond these issues related to material management and covers broader aspects such as social impact and the evolution of urban governance structures. The social components of a circular economy are fundamental to consider within the transition.

Ecosystem Biological community of interacting organisms and their physical environment.

Endangered species Any species that has a high risk of extinction in the near future.

Environmental impact assessment Environmental impact assessment is a process of evaluating the environmental impacts of a material, product, or any type of proposed project or development, taking into account its entire life-cycle. It also considers the inter-related socio-economic, cultural, and human-health impacts, both beneficial and adverse.

Eutrophication Process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life which usually results in the depletion of dissolved oxygen, and negatively impacting freshwater and marine ecosystems.

Feedstock Raw material or resources needed in order to supply or fuel an industrial process. Within REFLOW, feedstock refers to recycled resources that re-enter the production chain as "new" supplies for the manufacturing processes.

Food Desert Refers to an urban or rural location where there is little fresh or healthy food available.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Food surplus	Edible food produced in a quantity exceeding the needs of the commercial food sector.
Food Waste	Food intended for human consumption that is discarded at any point of the value chain. It can be due to spoilage, oversupply, or individual consumer/eating habits.
Material flow analysis (MFA)	A material flow analysis is defined as 'a systematic assessment of the flows and stocks of materials within a system defined in space and time' (Brunner and Rechberger, 2003). It is a method that quantifies flows and stocks of resources in a defined system.
Urban metabolism	Urban metabolism is a concept focusing on the quantitative assessment of urban resource flows. It is a process of identifying the collection of complex sociotechnical and socio-ecological processes by which flows of materials, energy, people, and information shape the urban space.
REFLOWOS	An online exchange platform acting as a Value-Based Network platform for recycled resources. REFLOWOS has the ambition to create a marketplace to facilitate exchanges of materials, help locate and track materials and resources, and facilitate exchange through smart contracts.
Regenerative Agriculture	Conservation and rehabilitation approach to food and farming systems. It focuses on topsoil regeneration, increasing biodiversity, improving the water cycle, enhancing ecosystem services, supporting biosequestration, increasing resilience to climate change, and strengthening the health and vitality of farm soil.
Resource flows	A physical volume of material, energy, or water moving from one place to another in a specific timeframe.
Sankey diagrams	Sankey diagrams visualize material, energy, and other resource flows as arrow-like shapes with their width shown proportionally to the flow quantity they represent. They are often used to visualize results from a material flow analysis.
Soil degradation	Decline in soil condition (low organic content, low water retention, low fertility) caused by improper management or use. Usually, it results from agricultural, industrial, or urban activities.
Water stress	Situation in which the water resources in a region or country do not satisfy its needs. Water stress often affects crops and plants growth as their moisture requirements cannot be fulfilled.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

1. INTRODUCTION

1.1 Introduction to the REFLOW project

REFLOW is an EU Horizon 2020 research project running from 2019-2022, which aims to enable the transition of European cities towards circular and regenerative practices. More specifically, REFLOW uses Fab Labs and makerspaces as catalysers of a systemic change in urban and peri-urban environments, which enable, visualize, and regulate "four freedoms:" free movement of materials, people, (technological) knowledge, and commons, in order to reduce materials consumption, maximize multifunctional use of (public) spaces, and envisage regenerative practices. The project will provide best practices aligning market and government needs in order to create favourable conditions for the public and private sector to adopt circular economy (CE) practices. REFLOW is creating new CE business models within six pilot cities: Amsterdam, Berlin, Cluj-Napoca, Milan, Paris and Vejle and assessing their social, environmental, and economic impact, by enabling active citizen involvement and systemic change to re-think the current approach to material flows in cities.

The primary elements of the REFLOW project are listed below, as well as their associated Work Package:

- **Co-Creation Design & Frameworks (Work Package 1):** Design, delivery and evaluation of CE practices that respond to urgent citizen and business needs. A core component of this work within the REFLOW project is facilitating the alignment between REFLOWOS (WP2), circular resource management practices (WP3), and urban governance and planning practices (WP4) -bringing these three dimensions into an overarching strategy for business model activation and citizen-drive action.
- **Technical Infrastructure & Software (Work Package 2):** Integration of new technological solutions that facilitate the (re)circulation of data and resources.
- **Creating & Managing Circular Resource Flows (Work Package 3):** Mapping and monitoring of each pilot city's urban metabolism through a core set of methodologies including Material Flow Analysis (MFA) and environmental impact analyses. Results are co-iteratively translated into interventions and strategies tested by pilots.
- **Collaborative Governance & Urban Strategies (Work Package 4):** Redesign of urban governance models towards more collaborative and distributed public-private-people alliances.
- **Pilots Framework (Work Package 5):** Coordination of REFLOW pilot cities from the perspective of their unique contexts, while recording progress and lessons-learned to discover and share best practice.
- **Capacity Building (Work Package 6):** Facilitation of capacity building activities that align the needs and vision of city stakeholders with required skills and know-how.
- **Communication (Work Package 7):** Ongoing strategic communication to inform and engage stakeholders and create a successful narrative for the circular economy transition.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

1.2 Introduction to Urban Metabolisms and Material Flow Analysis (WP 3: Circular Engineering)

A core concept of the REFLOW project is **Urban Metabolism**, which seeks to (i) understand the flows of materials, energy, and water within a city, and (ii) provide a framework for studying the interactions between natural and human systems in specific peri-urban regions. At the core of the Urban Metabolism concept is the **Material Flow Analysis (MFA)** methodology: an analytical method for quantifying stocks and flows of materials, water and energy in a pre-defined system in order to study biophysical aspects of human activity at different spatial and temporal scales.

REFLOW activities associated with Urban Metabolism and MFAs are led by **Metabolic Institute** and **Materiom** as part of **Work Package 3: Circular Engineering.** The purpose of WP 3 is to map and measure each pilot city's urban metabolism and its associated social and environmental impacts. The process is done in close collaboration with each pilot team and the results are used to support the continual development and assessment of the circular resource strategies and interventions piloted within each REFLOW city.

Within WP 3, **MFAs have been used to assess and model the key material and energy flows selected by five REFLOW pilot cities - Vejle: plastics, Paris: timber, Cluj: energy, Amsterdam: textiles, and Milan: food) - specifically how these resources are moving into, out of, and within each city.** From a mathematical perspective, the guiding principles of an MFA is that all the inputs and outputs of a system must be accounted for and the overall mass balance of the system must be correct. The correct mass balance is represented by the following relation: Input = Output + Stock.

Setting the **system boundaries** is an important first step in any MFA process as it defines where the inputs and outputs inventories start and end. An MFA also has a **temporal scope** - in REFLOW, the usual time frame is one year. The MFAs conducted by WP 3 and shared in this report are static: they provide **a snapshot of the studied metabolic flows for a given year.** The results of each MFA is visualized in a Sankey diagram. A **Sankey diagram** is often read from left to right and visualizes the sources of a flow (on the left), how they are used, transformed or stored within the city (center), and how they are managed at the end of their life (e.g. re-processed or treated as waste within the city or exported)(on the right). For reference, a visual representation of a sankey diagram is included below. (Figure 01).

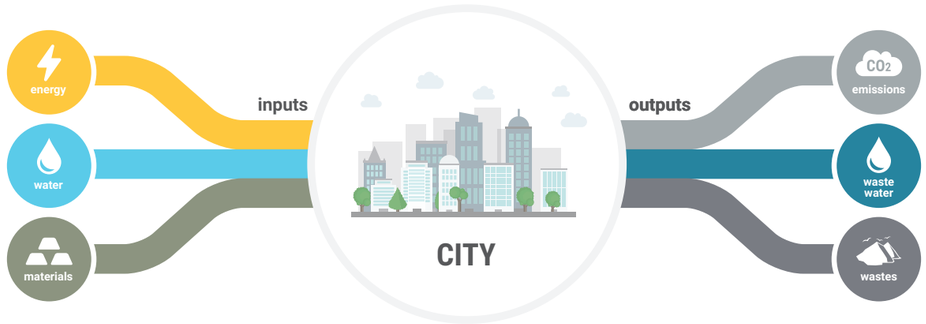


Figure 01: Visual representation of a sankey diagram

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Within REFLOW, MFAs provide several key insights into each pilot city's metabolism. MFAs provide a view of the different **economic sectors that use particular resources** within the city. Additionally, the MFAs give an indication of the **relative size of the different resource and waste flows** going through a city. Gaining a sense of the order of magnitude of such flows can help decision-makers within policy and industry to **set priorities when developing circular interventions and strategies.** Within REFLOW, the MFAs have the additional benefit of **illustrating the interconnections between different economic sectors and stakeholders** shaping the city's metabolism. Consequently, it highlights **which stakeholders must come together** around a specific intervention to activate positive change.

Within WP 3, an **environmental impact analysis** has been performed for each REFLOW pilot city to complement its MFA(s) and derive a holistic view of the current state and associated impacts of each city's metabolism. In this additional analytical layer, we've taken a **whole-life-cycle approach** (from production to end-of-life) to identify and quantify the environmental impacts associated with the flows studied in each MFA. This step is necessary to **understand the direct and indirect impacts associated with urban resource flows -an important step as impacts associated with urban resource flows are often hidden upstream.**[1] Within REFLOW, this analysis has been used to support pilot cities in **prioritizing interventions towards the most problematic flows,** from an environmental perspective.

1.3 Introduction to Deliverable 3.2 Urban Metabolism Analysis: Initial Assessments

A primary objective of WP 3 is to map and assess the urban metabolism of each pilot city -translating the results in ways that support the pilot teams to iteratively devise and pilot circular strategies and interventions. To date, results of this process include: a series of sankey diagrams (a city-level MFA and a site-level MFA), an environmental impact assessment of each pilot's urban metabolism (including volume, temporal, and spatial factors), and a circular intervention roadmap for each pilot city.

The process undertaken by WP 3 to complete each pilot city's assessment is documented within this report, as are the results derived. D3.2: **Urban Metabolism Analysis: Initial Assessment** is organized into five main sections -one section per REFLOW pilot city that participated in the analysis. Included within each pilot chapter are the following sections:

- **Introduction and Results:** A brief introduction to the scope and method applied by Metabolic Institute in collaboration with the pilot team to perform the urban metabolism analysis. An in-depth summary of the results of the analysis.

[1] e.g. flows and impacts associated with raw material extraction, production processes, distribution and transport throughout the value chain.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- **Vision:** A brief visionary statement for what a circular sector in the pilot city could look like that not only mitigates its current linear impacts, but contributes towards a positive, regenerative city for people and planet.
- **Focus Areas:** A series of recommended focal areas and actions which, based on the results of the analysis, Metabolic Institute recommends the pilot team to take on within the REFLOW project to further enhance the circularity of their pilot action plan and focal sector(s).
- **Relevance for Pilot Activities:** A visual depiction of how Metabolic Institute's analysis and resulting recommendations directly map onto and support the pilot team's existing pilot action plan and Theory of Change.

Due to the explorative and interactive nature of the pilots, it is important to note the content contained within this report provides an overview of the activities and results of WP 3's analysis up to Month 24 of the project. As WP 3 seeks to mirror the iterative and co-creative nature of the REFLOW project and pilots, the outcomes included herein will be revisited and adjusted where necessary throughout the next 12 months of the project to ensure they remain aligned with the evolving vision and objectives of the pilots.

Milan

Pilot Ambition: Circular Urban Food System

Urban Metabolism Assessment:
- 4 MFAs
- 3 Environmental Impact Analyses
- 21 Use Cases
- 81 Recommended Actions

3 Recommended Areas of Focus:
- Optimally redistribute food surplus within known food deserts across Milan
- Ensure sustainable sourcing for all three of SoGeMi's food markets with a fully traceable supply chain
- Build shorter climate-resilient supply chains to ensure the security of healthy and nutritious food and contribute to Milan's social economy

Vejle

Pilot Ambition: Circular Plastics Sector

Urban Metabolism Assessment:
- 1 MFA
- 2 Environmental Impact Analyses
- 23 Use Cases
- 68 Recommended Actions

5 Recommended Areas of Focus:
- Tackle plastics in Vejle's food value chain
- Ensure the responsible and sustainable use of PVC in construction and healthcare
- Increase the effectiveness of municipal waste management systems
- Build momentum for plastic-free businesses in Vejle
- Build a culture of responsible plastics consumption

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Paris

Pilot Ambition: Circular Events & Temporary Construction

Urban Metabolism Assessment:
- 2 MFAs
- 2 Environmental Impact Analyses
- 31 Use Cases
- 80 Recommended Actions

3 Recommended Areas of Focus:
- Increasing carbon storage in the built and natural environment
- Sustainable waste management of wood
- Build a culture of responsible production and consumption of wood

Amsterdam

Pilot Ambition: Circular Textiles Sector

Urban Metabolism Assessment:
- 1 MFA
- 1 Spatial Neighborhood Analysis
- 3 Environmental Impact Analyses
- 45 Use Cases
- 46 Recommended Actions

2 Recommended Areas of Focus:
- Rapidly increase the rate of separated textile collection and extend the life cycle
- Build, enhance, and incentivize local reuse and remanufacturing value chains

Cluj-Napoca

Pilot Ambition: Efficiency and Renewable Energy System

Urban Metabolism Assessment:
- 1 EFA
- 1 Environmental Impact Analysis
- 3 Consumption Trend & Projection Assessments
- 18 Use Cases
- 45 Recommended Actions

2 Recommended Areas of Focus:
- Increase the energy efficiency of public buildings and assets
- Prepare Cluj-Napoca for a future decentralized, renewable energy system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2. MILAN

2.1 Introduction to Milan's food markets

2.1.1 Background and scope of the analysis

Milan is a city located in the north-western part of Italy. It is the capital of the Lombardia Region and the unofficial economic capital of Northern Italy. The City has more than 1.35 million inhabitants, while the broader metropolitan area of Milan accounts for 3.25 million people, thus making Milan one of the largest cities in Europe.

Since the universal exhibition "Expo 2015" focused on 'Feeding the Planet - Energy for Life", Milan has been at the center of a coordinated policy effort, with initiatives targeting innovative activities in rural and urban agriculture, food processing and distribution, food education and culture. Additionally, as a C40 City Group member, Milan Municipality provides a dynamic setting upon which the exploration and implementation of interventions in transitioning the city towards becoming circular and regenerative take place.

An important step in Milan's leadership in sustainable peri-urban food systems is the Milan Food Policy which was enacted following the Expo. In 2014 Milan started an action-research process that produced an analysis of its food system, articulated in 10 main issues. After that, the City launched a public consultation engaging its different departments, universities, civil society organizations, start-ups, private sector and ended the process with a vote in the City Council of 5 priorities, 16 guidelines and 48 actions of Milan Food Policy:

1. Ensure healthy food and water for all citizens
2. Promote the sustainability of the food system
3. Promote food education
4. Fight against food waste
5. Support scientific research in the agri-food sector

During the same period, Milan engaged in an international city-to-city diplomacy action that led to the launch of the Milan Urban Food Policy Pact (MUFPP) in 2015, now signed by 161 cities worldwide. These cities are connected by a shared goal of developing "sustainable food systems that are inclusive, resilient, safe, and diverse, that provide healthy and affordable food to all people in a human rights-based framework, that minimize waste and conserve biodiversity while adapting to and mitigating impacts of climate change".[2] On a practical level, the pact encourages cities to reconsider the food system by which their citizens are fed and consider how this system could be transformed to become increasingly sustainable and climate-resilient.

[2] Milan Urban Food Policy Pact. (2015). The Milan Pact - Milan Urban Food Policy Pact.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

The city's approach crosses ordinary and special policies, and is characterized by action strongly supporting open and social innovation projects developed by Fab Labs, makerspaces, and other citizen/community labs which evolve in the metropolitan area. Within this context, the REFLOW Milan pilot team focuses on "Circular Markets." **The pilot objective is to increase the role of the circular economy in the local food system and support the development of long-term sustainable technological solutions on the logistics, transportation, transformation, distribution, and conservation of food that will enable the connection of local peri-urban agricultural areas with municipal covered markets.** Milan's municipal markets have historically served as connecting places between the rural and the urban, but in recent years, they have suffered from degrading facilities and low demand. The Milan pilot seeks to tackle this macro-level issue by implementing circular economy solutions at the neighbourhood scale. The opportunity to work on the public covered markets has led to indirect actions that address critical problems, such as tracking food flows at city level, the prevention of food waste, and upcycling the waste that is produced into new products. Additionally, during the implementation of the Milan Pilot City Action Plan, important changes to policy have taken place that led the Municipality to pass a municipal act in which it formally instructs SoGeMI, Milan's main food wholesaling market[3], to manage the Rombon covered municipal market (one of the 23 public covered markets). The act put a strong emphasis on product traceability and on circular economy solutions.

The Milan pilot team thus focuses on tracking food flows across the city, specifically looking at the flows going through Milan's main food wholesaler SoGeMi and Milan's 23 covered markets. The pilot set out to focus on specific food flows to test new food prototypes, support existing projects that transform food waste into new food products, and enable initiatives that focus on reducing food waste at the wholesale and market stage. Through these circular food innovations, the pilot aims to drive forward a local sustainable food system for the city.

Scope and Method of the Material Flow Analyses (MFAs)

In order to support the Milan pilot team in (i) assessing the city-wide and wholesaling food flows, and (ii) identifying high-potential interventions the City and SoGeMi can take on to improve waste reduction practices, food traceability, and food logistics, Metabolic Institute conducted multiple Material Flow Analyses (MFAs).

A city-wide agrifood MFA was developed by Metabolic Institute to map the flows of food products coming into the city through various value chains and provide the pilot team a clearer picture of the current urban food system. This MFA provided the pilot team key insights into Milan's food system throughout the development of their action plan and intervention areas. This first MFA focuses on food consumption within the municipal boundaries of Milan in the year 2017, following a top-down approach. The main data sources used to produced this MFA include:

- Milan municipal waste datasets from ISPRA (Italian environmental protection institute)[4]
- An Italian national dietary survey from Leclercq et al. (2009)[5]

[3] SogeMi. (2021). I Mercati all'ingrosso di Milano - Sogemi Spa.
[4] ISPRA. (2019). Ricerca produzione e raccolta differenziata del singolo comune - Produzione del comune di Milano.
[5] Leclercq, C., et al. (2009). The Italian National Food Consumption Survey INRAN-SCAI 2005-06: main results in terms

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- A European study on food waste generation across the food supply chain - with specific data for Italy - from Bräutigam et al. (2014)[6]
- A report on Milan food waste anaerobic treatment by the Consortium of Italian Composters
- Report of waste incineration from AMSA[7]
- A European Input-Output database for import and export statistics[8]

Once the Milan pilot developed a strong partnership with SoGeMi, a second iteration of MFAs - comprising of three distinct MFAs - was carried out by Metabolic Institute to provide a granular and bottom-up analysis of food flows going through SoGeMi wholesale markets into Milan's retail sectors. The scope and focus of these MFAs was developed through an iterative and highly interactive process with the Milan pilot team and SoGeMi stakeholders to ensure strong alignment with the pilot's and its partners' core objectives. The temporal scope of the MFAs was set to the fiscal year 2019. As part of this process, and to improve the granularity and accuracy of Metabolic Institute's results, SoGeMi provided bottom-up data, including:

- A dataset covering all transactions (except direct sales to restaurants) of fish and seafood products in 2019 inclusive of product type and origin for the majority of transactions[9]
- Datasets covering 2019 and 2014 vegetable and fruits sales estimate[10]
- Monthly waste reporting datasets for each vendor of the fish market[11]
- A fruit and vegetable waste survey[12]
- An internal report of meat sales, accompanied with surveys from meat vendors to identify further product sourcing countries[13]
- A city-wide food report that included food surplus recovery data for SoGeMi in 2019[14]

The MFAs creation also benefited from several interview rounds with the SoGeMi team to refine the understanding of the wholesale market food flows.

Additionally, Metabolic Institute conducted a preliminary environmental impact assessment of SoGeMi food products. This work specifically assessed production-based impacts associated with suppliers from Italian

[6] Bräutigam, K.-R., et al. (2014). The extent of food waste generation across EU-27: different calculation methods and the reliability of their results.
[7] Amsa. (2008). Il termovalorizzatore Silla 2.
[8] PBL Netherlands Environmental Assessment Agency. (2018). CONSTRUCTION OF REGIONAL TRADE-LINKED SUPPLY AND USE TABLES FOR THE EU28.
[9] SoGeMI (2021). Personal communications (January & February 2021).
[10] Ibid.
[11] Ibid.
[12] Ibid.
[13] Ibid.
[14] Comune di Milano. (2020). Economia circolare del cibo a Milano.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

regions and foreign countries, and potential environmental risks to both the ecosystems SoGeMi's vendors sourced from and to the long-term availability of supply for the markets. For the impact assessment, several data sources were used, mainly:

- MapSPAM to locate specific crop land areas across the world
- A spatial land degradation dataset from Trends.Earth developed by Conservation International to understand how crop areas are affected by soil health degradation
- A spatial water stress dataset from Aqueduct developed by the World Resource Institute to understand how crop areas are affected by water stress across the world
- A spatial biodiversity threat dataset, Global Safety Net to detect crop land areas in need of biodiversity protection
- IUCN Red List for endangered species - compiled for seafood product by Roberson et al., (2020)[15]

Metabolic Institute undertook several methodological steps to develop the three SoGeMi MFAs. The whole workflow is modelled in Python to increase transparency and reusability. The point of departure for the MFA is the overarching dataset that SoGeMI provided which includes daily transactions for the fish market and yearly sales for the fruits & vegetables and meat markets. Once processed, the datasets are collated together (e.g., fish sales with fish waste datasets) to create the different flows of the markets, using a mass balance approach. The sourcing countries of the products sold in the markets are then extracted across the different datasets, while the different crop and impact maps are overlaid and connected to each other to identify environmental risks and impacts connected to the products sold in Milan wholesaling markets.

2.1.2 Current system and its Impacts

Material flow analysis for the city of Milan

The city-level MFA has highlighted that **around 1 Mton of food is consumed principally through households (~70%),** and the remainder through food services. The main food products are vegetables and fruits, representing almost 40% of the total food consumed, followed by dairy products, meat, and bread. Cereal products (bread, pasta, wheat products, and rice) represent an important food group, with around 190 ktons consumed annually, or a little less than 20%.

In terms of household food waste, it is key to highlight that **more than half of the food waste (~58%) is actually considered to be avoidable food waste,** that is food that could have been consumed by humans, while the rest is unavoidable food waste, such as peels, bones, and shells.

At the end-of-life stage, **Milan residents and food businesses separate food waste efficiently,** with an 86% separation rate for food waste diversion to organic waste streams with little impurities. **The vast majority of food waste gets digested in an anaerobic digestion plant** in the vicinity of Milan (~40km) producing an estimated amount of 18 Mm^3 of biogas. The digestion process also produces around 24 ktons of compost as a by-product. The non-diverted food waste is usually incinerated with the rest of the residual waste.

[15] Roberson, L. A., et al. (2020). Over 90 endangered fish and invertebrates are caught in industrial fisheries.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

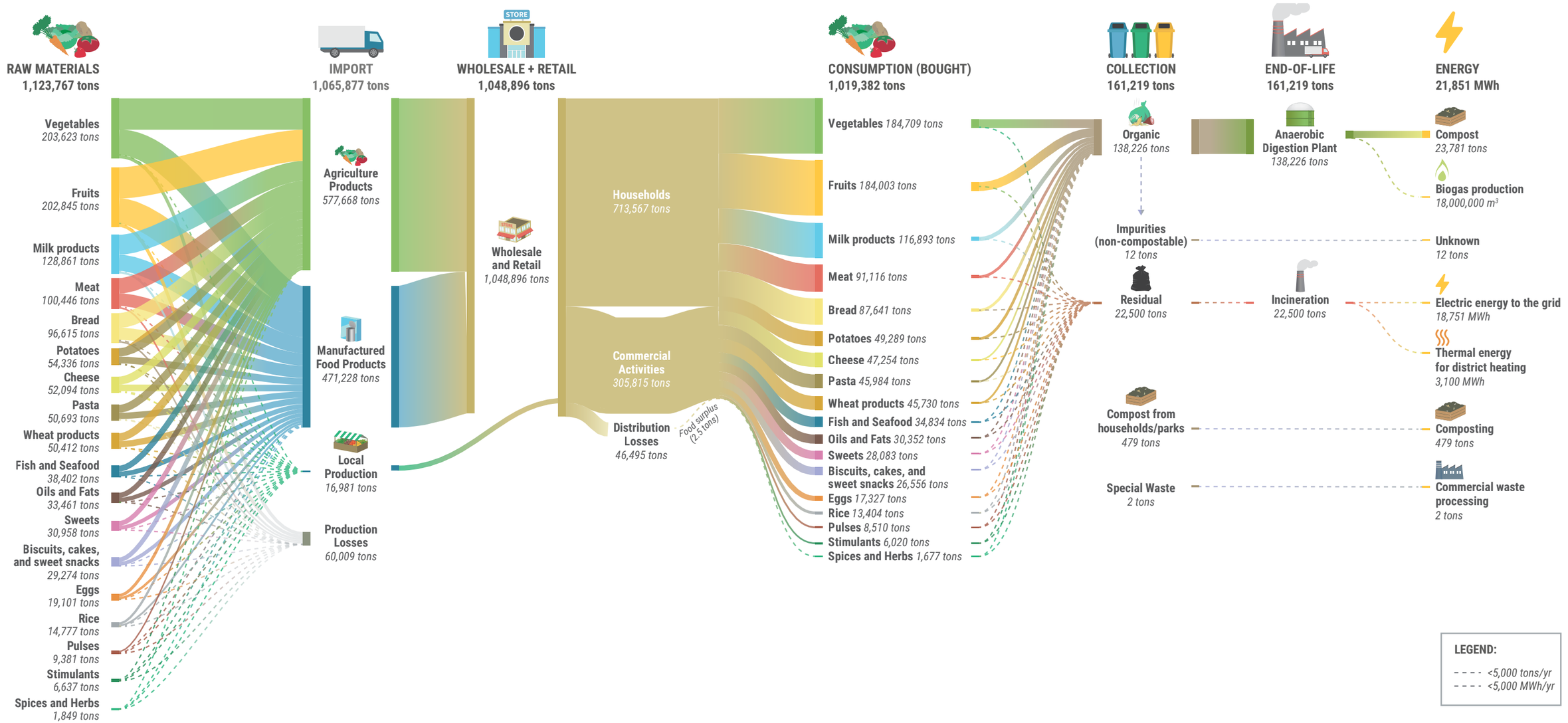


Figure 02: City-Level Food Material Flow Analysis for Milan

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Material flow analyses of SoGeMi - Milan's main wholesaler

The three MFAs conducted with the wholesaling center SogeMi have highlighted a very wide diversity of products sold across all three food markets - fish, fruits and vegetables, and meat - sourcing from a total of 92 different countries from across the globe. The sales data used for this analysis represents the annual sales for the year 2019. An environmental risk analysis was conducted for the products supplied across the three markets.

Section Highlights

SoGeMi is Italy's largest agrifood wholesaler, and one of the largest in Europe - connecting thousands of suppliers and consumers across the world.

The fruits and vegetables market is by far the largest market with 1 Mtons of products sold every year - a majority supplied by Italian regions. We analyzed the environmental risks (water, biodiversity, and land) across the 51 supplying countries. We found that products from Italy and Spain appear as the main source of concern for supply disruption due to extreme high water risks.

The fish market is the second largest market with 10,000 tons of seafood annually sold. We reviewed a total of 600 species supplied and found that 21 species are considered endangered or vulnerable. High traceability for products from the Mediterranenan sea, vulnerable to overfishing, and from aquaculture products is recommended.

The meat market is relatively small -with 3,000 tons of products sold annually, mostly supplied by Italian farmers. We found that Lombardia is affected by eutrophication issues; and as the main supplier of meat, SoGeMi vendors should ensure that their regional suppliers have adequate manure management practices.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

SoGeMi Fruits and vegetable market

The MFA of SoGeMi's fruits and vegetables market was developed using SoGeMi annual sales data and through interviews with key stakeholders within SoGeMi.

The fruits and vegetables market of SoGeMi is by far the largest market in total volume of products sold, with almost **1 Mtons of recorded sales in 2019,** almost equally split between fruits (589 ktons) and vegetables (542 ktons), and minimal amounts of pulses, nuts, and herbs.

The MFA identified the sourcing countries and regions of the 373 distinct products sold in this market. **Italy is by far the largest supplier of SoGeMi fruits and vegetables,** with 71% of sold products. **The regions of Sicily and Puglia are the two main contributing regions,** with respectively **27% and 15% of the total supply from Italy.** Oranges, cherry tomatoes, and zucchini represent almost half of Sicilian-based products.

Around **29% of SoGeMi products come from foreign countries. Spain represents** the main foreign supplying country with 146 ktons, or around **44% of the total volume of foreign imports.** This is followed by Costa Rica (43 ktons), the Netherlands (37 ktons), and France (22 kton). African countries, such as South Africa, Morocco, and Cameroon, and South American countries like Argentina and Brazil are notable contributors to SoGeMi's supply chains. The top products by mass that are imported by SoGeMi vendors from abroad include:

- Bananas (9.5%) - mainly from Cameroon, Turkey, Costa Rica, and Uruguay
- Potatoes (8%) - mainly from France, The Netherlands, and Germany
- Tomatoes (6%) - mainly from Spain, The Netherlands, and Morocco
- Pineapples (5%) - largely from Costa Rica

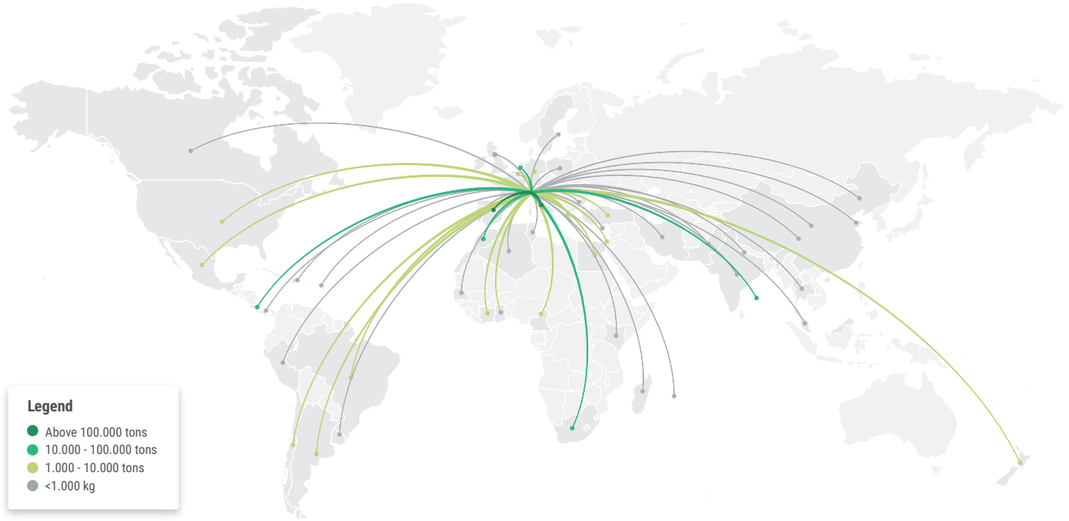


Figure 03: Spatial flows of fruits and vegetables products from SoGeMi's supplying countries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

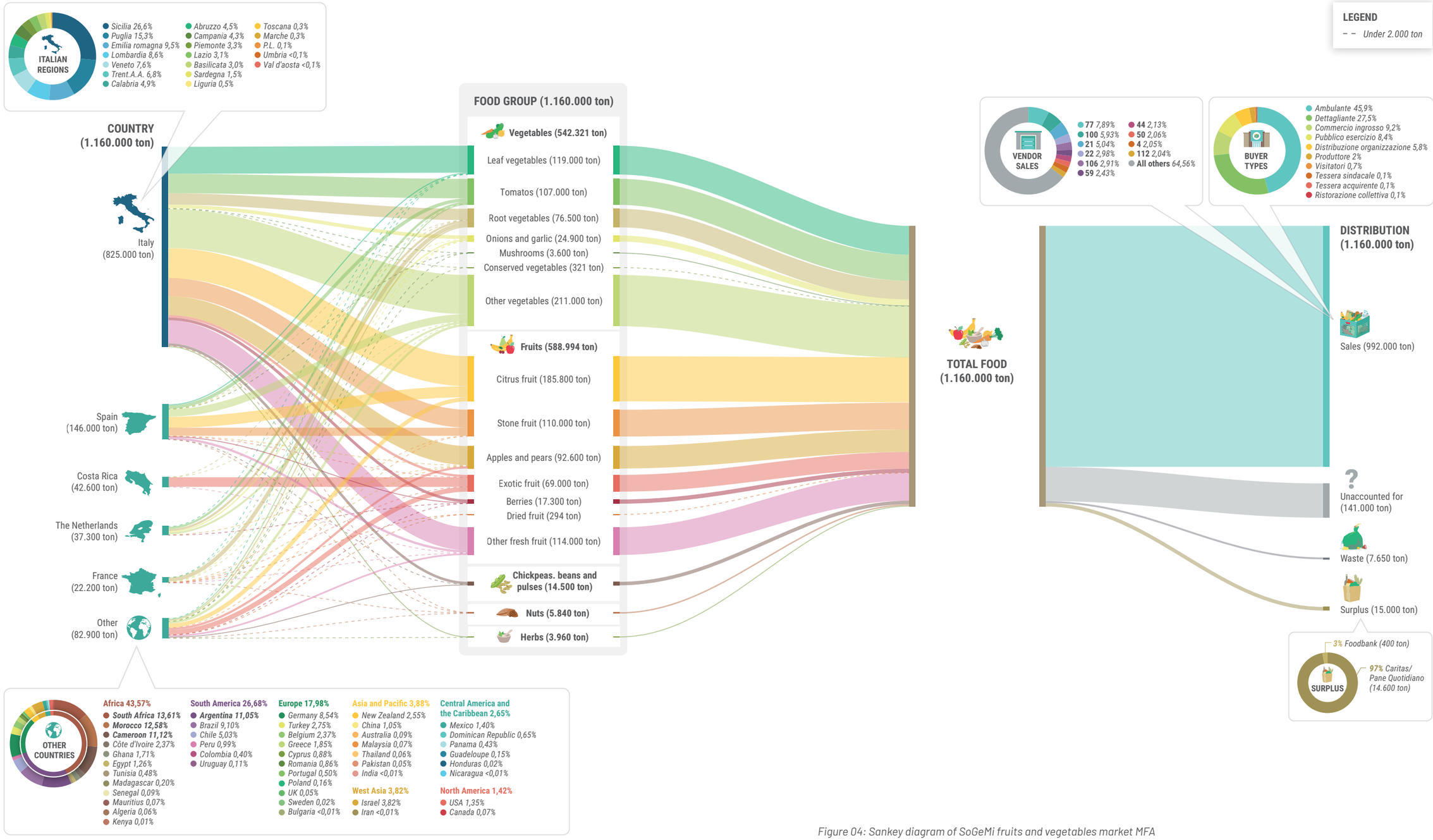


Figure 04: Sankey diagram of SoGeMi fruits and vegetables market MFA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Around 10-15% of products going through SoGeMi's fruits and vegetables market are not properly accounted for in market sales. There are around 22 ktons of unsold products. About two-thirds, or 15 ktons of food, were successfully re-distributed to food organizations and delivered to communities in need in Milan. The rest - 7.65 ktons - was collected in the organic waste bin, collected by municipal waste collectors, and sent to Milan's anaerobic digestion plant to produce biogas and compost. The largest purchasers of SoGeMi fruits and vegetables are 'ambulante,' which are vendors from Milan's metropolitan area operating in open-air markets.

SoGeMi Sourcing Analysis

Highlights

More than 70% of SoGeMi fruits and vegetable supply come from Italy. Lombardy is only the fourth largest supplying region in SoGeMi's Italian supply chain - while Sicily and Puglia are the two largest regions. From the Italian supply analysis, it was determined that a maximum of half of the supply can potentially be produced in Lombardy, depending on the different crops' production capacity in the region.

Spain, the Netherlands, and France are some of the largest supplying countries in SoGeMi's supply chains - but on the contrary of Costa Rica that supplies exotic products, these three countries supply food products readily found in Italy.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Fruits and vegetables from within Italy

From the 373 distinct products sold in SoGeMi's total portfolio for fruits and vegetables, 170 are uniquely sourced from within Italy. Lombardia supplies 88 of these Italian food products currently sold in the market, these distinct products are aggregated into 50 fruits and vegetables types (Figure 05). Among SoGeMi's Italian-based supply, Lombardia is an important provider of melon, watermelon, lettuce, beetroot, chard, squash, corn salad, herbs, and basil (Figure 06). Since SoGeMi's portfolio of products coming from Lombardia is already expansive, but not in high volumes for most fruits and vegetables products, it opens the opportunity to increase sourcing from Lombardia in order to shorten SoGeMi's Milanese supply chain. **About half of the volumes sourced from Italy have the potential to be sourced directly from within Lombardia.**

Figure 05: Spatial flows of fruits and vegetables products from SoGeMi's Italian supplying regions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

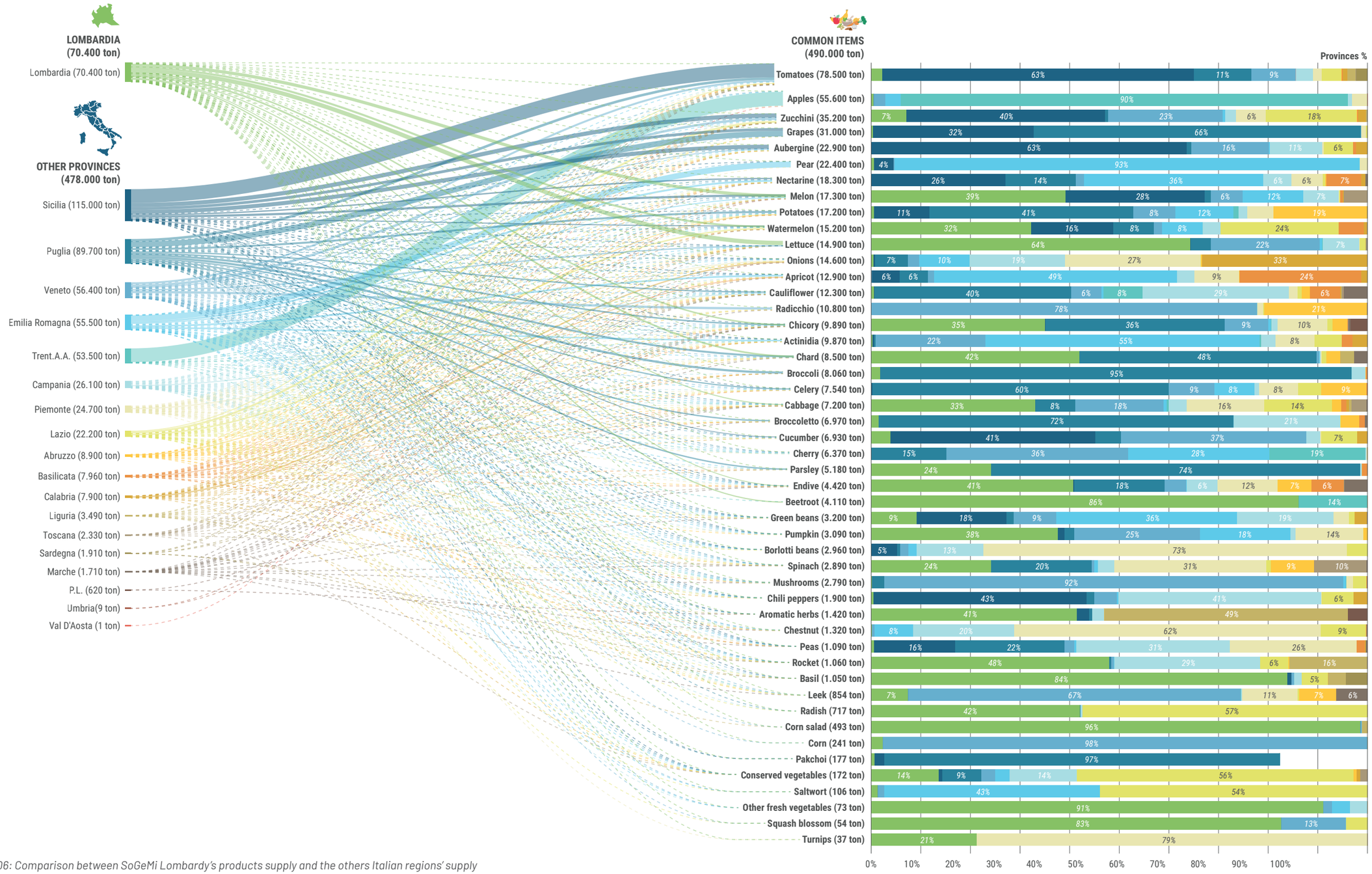


Figure 06: Comparison between SoGeMi Lombardy's products supply and the others Italian regions' supply

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

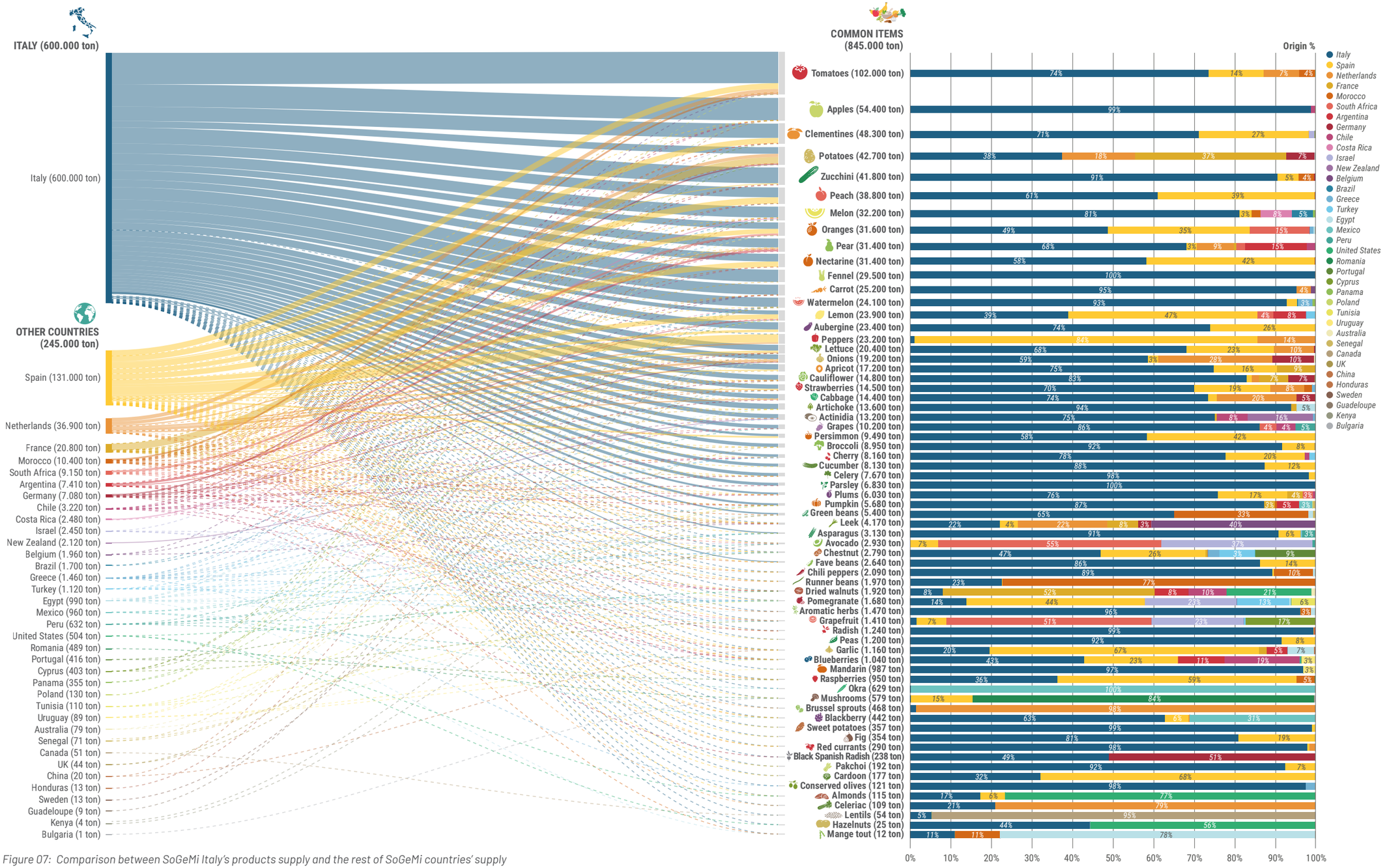


Figure 07: Comparison between SoGeMi Italy's products supply and the rest of SoGeMi countries' supply

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

67 vegetable and fruit types are both sourced in Italy and from abroad (Figure 07). Spain, The Netherlands, and France provide notable quantities of vegetables and fruits that are also sourced in Italy.

Mangetout, hazelnuts, and lentils are sourced in very low volumes from countries outside the EEA whilst also being sourced from within Italy. Those countries outside the EEA include: Tunisia (110 tons), Uruguay (89 tons), Australia (79 tons), Senegal (71 tons), Canada (51 tons), China (20 tons), Honduras (13 tons), Guadeloupe (9 tons), and Kenya (4 tons) (Figure 07). Such low quantities offer the opportunity to further regionalize these specific supply chains.

SoGeMi Climate and Environmental Risk Assessment

An impact assessment was conducted for all the sourcing countries and Italian regions presented in the MFA. This analysis highlights sourcing areas that are most impacted by climate and environmental vulnerabilities and key agricultural lands which may be negatively impacted by the cultivation of fruit and vegetables. The assessment includes three environmental indicators: soil degradation,[16] water stress,[17] and biodiversity loss.[18] Each of the three indicators were measured in terms of production impact intensity.

- **Land degradation:** Measures the share (in percentage) of agricultural land producing vegetables and fruits that is degrading in quality over the entire total land area producing vegetables and fruits.
- **Water Risk:** Measures the share (in percentage) of agricultural land producing vegetables and fruits that is on water basins classified as high water risk (composite index of the quantity and quality of water as well as regulatory and reputation risk) over the entire total land area producing vegetables and fruits.
- **Biodiversity Loss:** Measures the share (in percentage) of agricultural land producing vegetables and fruits that needs biodiversity protection to prevent further biodiversity loss over the entire total land area producing vegetables and fruits.

[16] Trends.Earth. (2018). Trends.Earth — Trends.Earth 1.0.2 documentation.
[17] World Resource Institute. (2021). Aqueduct | World Resources Institute
[18] Global Safety Net 1.0. (2021). Global Safety Net.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

International Supply: Environmental Risks

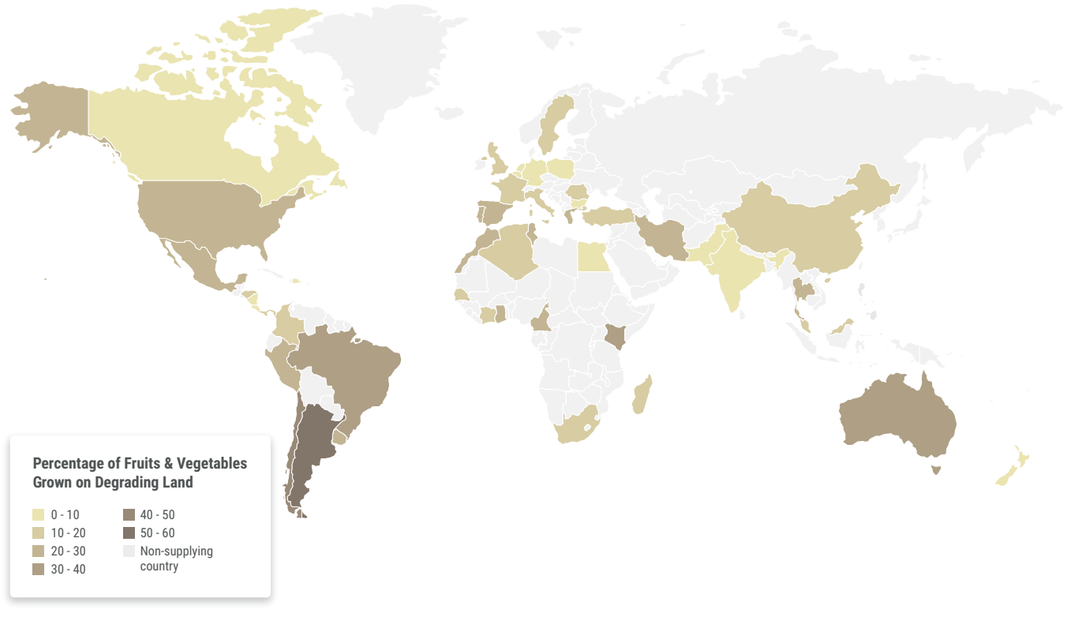


Figure 08: SoGeMi's supplying countries and their land degradation risk profile

Land Degradation Risks

SoGeMi products may be vulnerable to supply risks due to the degrading conditions of soil health in land producing vegetables and fruits. Among SoGeMi supplying countries, **Argentina** and **Spain** appear as two key suppliers increasingly exposed to degrading soil health in their vegetable and fruit producing lands. In the medium term, these lands may not be as productive as they are now.

Argentina (~9,000 tons) appears most vulnerable to soil health degradation, among SoGeMi supplying countries. More than half of Argentinian arable land producing vegetables and fruits have degrading soil health, thus fruits and vegetables sourced by SoGeMi vendors may participate in worsening the environmental impact from the agricultural sector. The top products being sourced from Argentina are pears (6,500 tons) and lemons (1,900 tons), two crops that can be readily sourced from within Europe. Spain, the second largest provider of produce for SoGeMi, has a quarter of its fruits and vegetables producing lands that have declining quality. Spain supplies a wide variety of products, such as tomatoes, oranges, clementines, nectarines, and lemons, though most of them are also present in Italy and other European suppliers, with more healthy soils,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Additionally, in South America, Chile (~4,000 tons) and Brazil (~7,500 tons) are also notable suppliers, which have fruit-producing arable land with high levels of soil degradation with, respectively, 43% and 32% of fruit-producing lands degraded. More than half of Chile's supply includes products readily available in Italy and Europe, such as apples, kiwis, grapes, and pears. In Africa, the three largest suppliers, namely South Africa, Morocco, and Cameroon all present between 20 and 30% of fruit and vegetable land with declining soil quality.

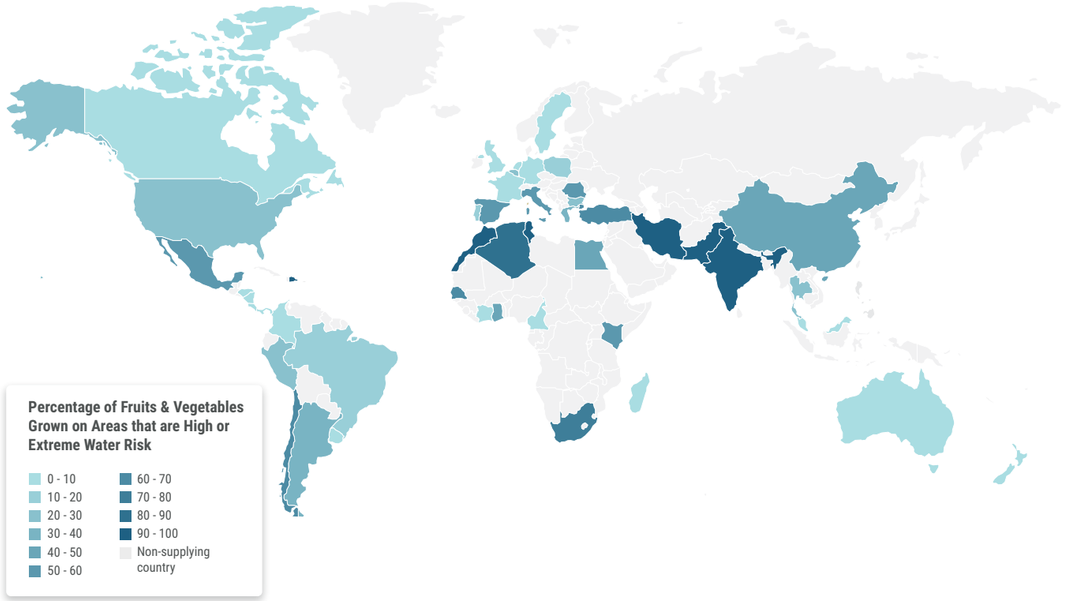


Figure 09: SoGeMi's supplying countries and their water risk profile

Water risks Highlights

SoGeMi products are highly vulnerable to water risks - water shortage and competition, as well as droughts, and regulatory barriers may lead to higher prices or less reliable supply. From its international supply, **South Africa, Spain, Morocco,** and **Chile** are the most exposed with very high shares of their **vegetables and fruits producing lands exposed to very high water risks.**

South Africa, the largest supplier from Africa, with 11,300 tons **has 73% of its total vegetables and fruits producing lands that are subject to high water risks.** Thus, there are high chances that fruits from South Africa are contributing to damage water basins in the southern African state. Oranges are the largest produce from this country, accounting for 41% of South African imports, followed by avocados (1,600 tons), lemons (900

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

tons), grapefruits (700 tons), and pears (650 tons). Morocco, the second largest African supplier (10,400 tons) is also experiencing extreme high water stress in its fruits and vegetables arable lands, with almost all land in a situation of high water risks (96%). Tomatoes (4,000 tons), green beans (1,800 tons), and zucchini (1,600 tons) constitute roughly 70% of the Moroccan supply. In South America, Chile can be noted as a country with very high water risk (70%) -as mentioned Chile mostly produces apples, kiwis, grapes, and pears. In Europe, Spain, which is the main supplier of SoGeMi outside of Italy, also experiences high water stress, with over half (55%) of its vegetable and fruit cultures located in high water risk areas.

Although their supplied volumes are very low (<750 tons), the Dominican Republic (100%), Cyprus (100%), Israel (100%), India (98%), and Pakistan (96%) should be cited as countries where fruit and vegetable production is being undertaken in areas with high or extremely high water risk.

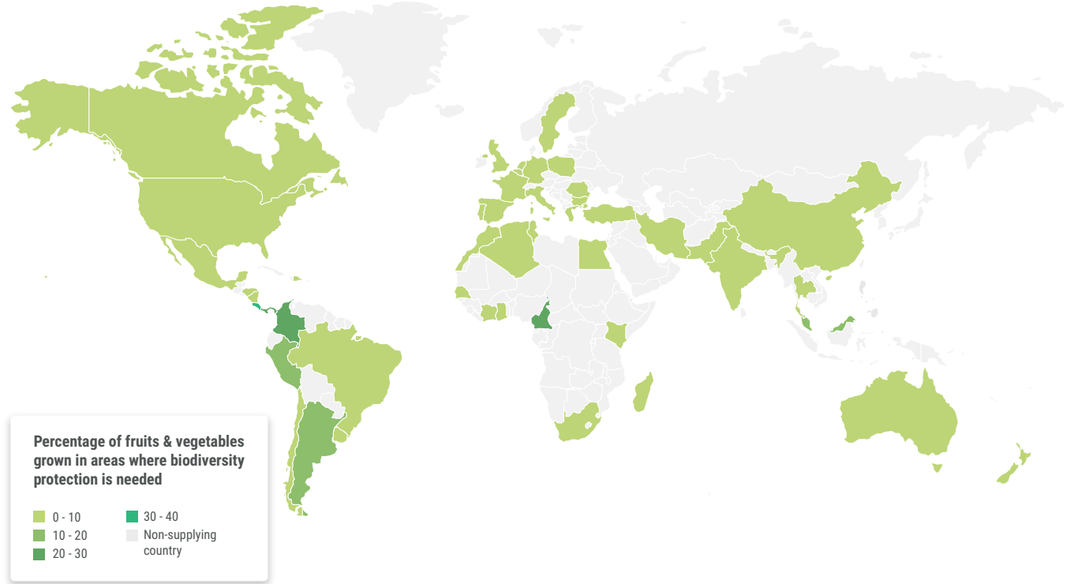


Figure 10: SoGeMi's supplying countries and their biodiversity risk profile

Biodiversity risk Highlights

SoGeMi products are grown near or within valuable natural ecosystems. Conventional agricultural practices may have adverse impacts on local biodiversity due to the use of pesticide, synthetic fertilizer, or fungicide. On the other hand, low biodiversity can lead to lower production due to the absence of pollinators for example. In SoGeMi's supply chain, **Costa Rica and Cameroon** appear as the highest risk profiles in terms of potential biodiversity hotspots.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Costa Rica and Cameroon are countries that **appear as potential biodiversity hotspots in SoGeMi's supply chain.** Costa Rica is SoGeMi's third largest supplier, and appears as a priority in terms of traceability, with **31% of fruit and vegetable arable land in need of higher biodiversity protection** to prevent further biodiversity loss. For example, Costa Rican pineapples are often grown in monoculture, with high levels of pesticide used to maintain high yields.[19] Cameroon, in Africa, has also relatively high biodiversity risks, since a quarter of its vegetable and fruit crops are located in areas where biodiversity is threatened.

The vast majority of countries supplying SoGeMi's vendors have between 0% and 15% of the land dedicated to fruits and vegetables in need of further biodiversity protection. It should also be noted that, although they supply very low volumes to Milan's market, the islands of Barbados, Grenada, St-Vincent and Grenadines, French Polynesia, and Solomon Islands are in need of urgent biodiversity protection with between 80% and 100% of vegetables and fruits land located in areas in need of immediate protection. Overall most island-states are biodiversity hotspots in SoGeMi supply chains.

Italian Supply: Environmental Risks

Fig 11, 12, 13 show the Italian regions based on their vulnerability to water, land degradation, and biodiversity loss risks.

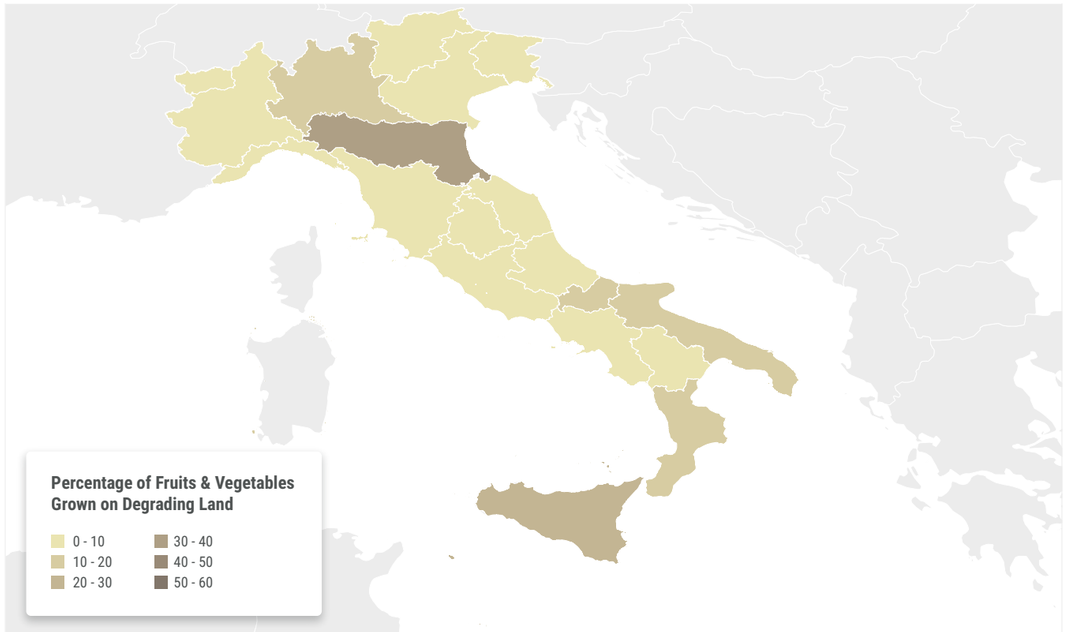


Figure 11: SoGeMi's Italian supplying regions and their land degradation risk profile

[19] Echeverría-Sáenz, S., et al. (2012). Environmental hazards of pesticides from pineapple crop production in the Río Jiménez watershed (Caribbean Coast, Costa Rica).

Land degradation risk highlight in SoGeMi Italian supply

SoGeMi relies heavily on its domestic supply for its vegetables and fruits. Land degradation leading to poor soil health may reduce the reliability of SoGeMi's breadbasket regions. The regions of **Emilia-Romagna** and **Sicily** are the most concerned about this environmental challenge.

In Italy, **Emilia-Romagna is the main region of concern** regarding Italian-based supply of fruits and vegetables that may participate in agricultural soil degradation, **with 34% of vegetable and fruit-producing land from this region with declining soil health.** The region is the third largest supplying region (9% of Italian volumes) for SoGeMi. **Sicily**, the largest supplying region in Italy also has a relatively high risk, **with 27% of its vegetable and fruit lands affected by land degradation.** Puglia and Lombardia, two large regional suppliers, as well as Calabria and Sardegna, all show soil health decline for between 15% and 20% of their vegetable and fruit arable lands.

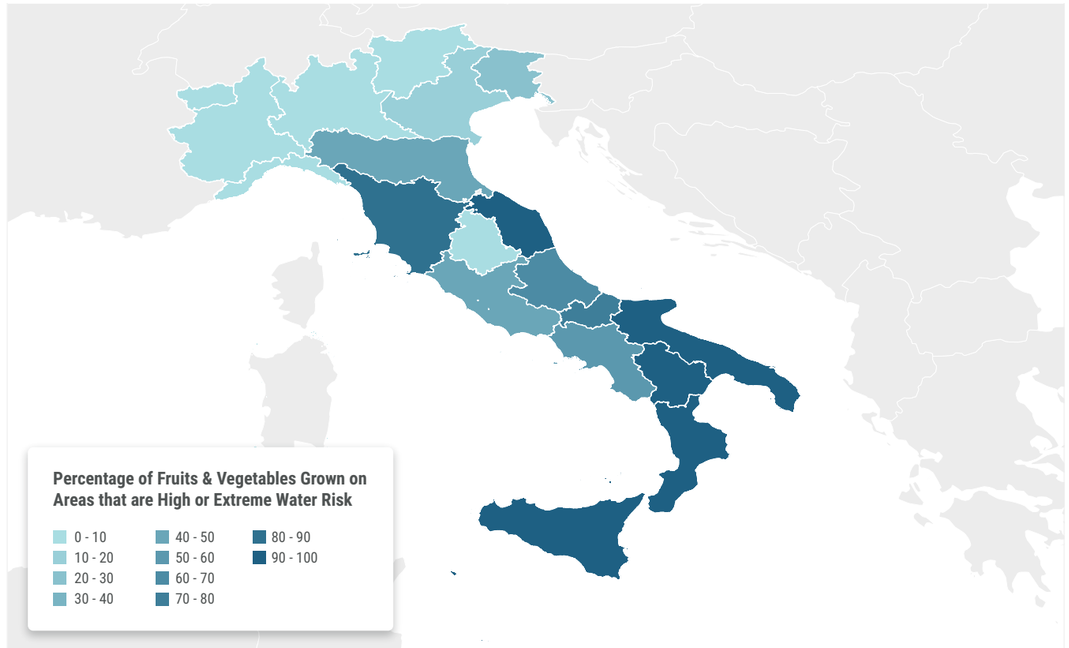


Figure 12: SoGeMi's Italian supplying regions and their water risk profile

Water risk highlights in SoGeMi Italian supply

Water risks leading to water shortages and droughts are the greatest environmental risks across SoGeMi's supply chains. The core southern breadbasket regions of SoGeMi,namely **Sicily**, **Puglia**, and **Calabria** are all impacted by increasing water stress, which can negatively affect in the short and medium term the reliability and stability (both in terms of prices and volumes) of their vegetables and fruits supplies.

By and large, Italian vegetable and fruit arable lands are experiencing high to extremely high water risks. **Sicily, Puglia, Calabria, Basilicata, and Marche are experiencing extreme high water risks,** with 100% of their lands producing vegetables and fruits under high stress.

These five regions represent **50% of SoGeMi's Italian supply,** and 36% of the entire supply of vegetables and fruits of SoGeMi. Water scarcity in southern Italy is exacerbated by higher annual temperatures and low soil moisture. Extreme heat waves that compound water shortages in the Southern regions are expected to increase in severity and frequency with rising global temperatures. Emilia-Romagna, further north, and the third largest supplying region also experiences relatively high water stress for half of its vegetable and fruits production areas. This constitutes the greatest single threat to SoGeMi supply chains since water stress may reduce supply, increase prices, and cause loss of healthy water basins and groundwater aquifers.[20]

[20] Hofste, R., et al. (2019). Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

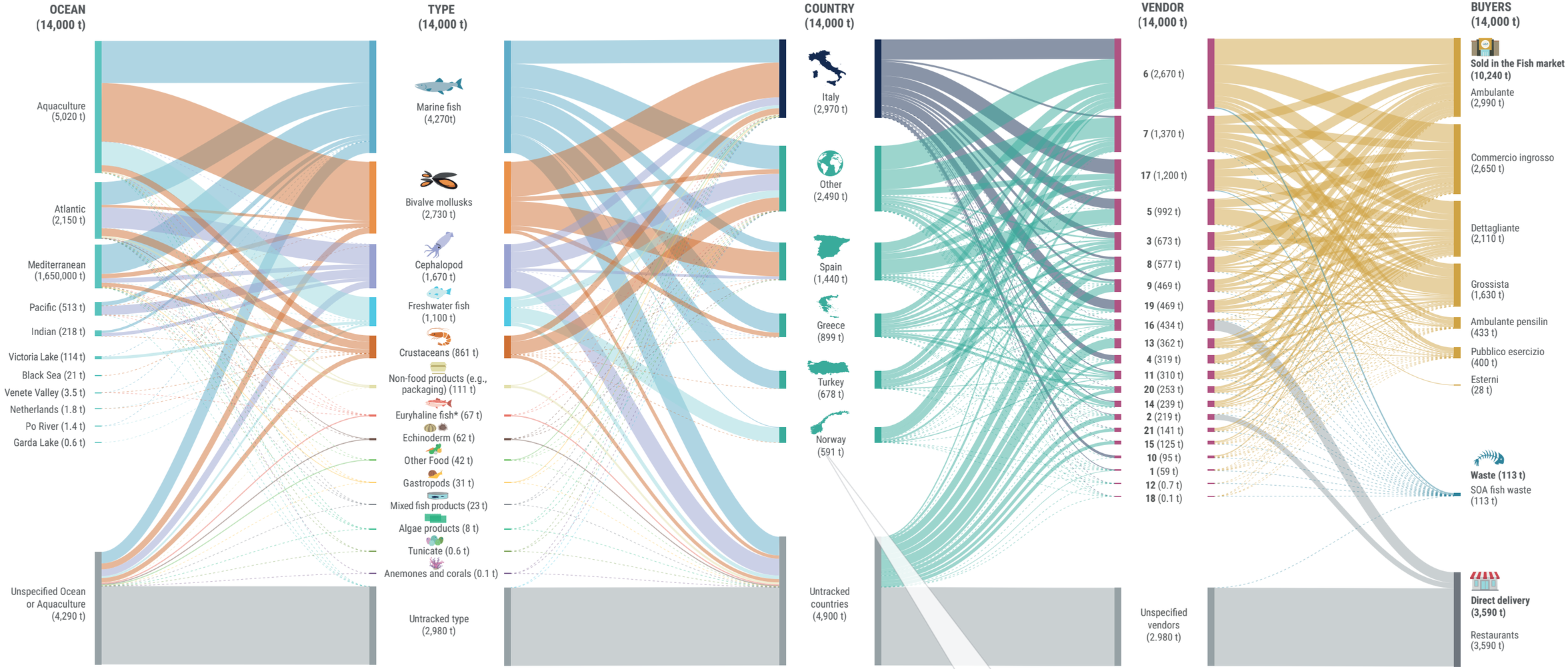
Figure 13: SoGeMi's Italian supplying regions and their biodiversity risk profile

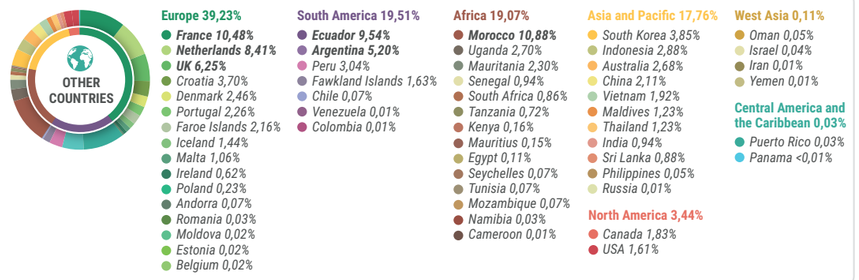
In terms of biodiversity risks, there are relatively low risks in SoGeMi's Italian-based supply chains. The majority of Italian regions do not require major or urgent biodiversity protections. Only the region of Liguria (0.5% of SoGeMi supply) requires almost a fifth (18%) of its vegetables and fruits to engage in urgent biodiversity protection.

Environmental risk analysis conclusion

A handful of supplying countries have been identified as suffering from several environmental degradations. First, **Italy**, SoGeMi's primary supplier is a cause of increasing concern, experiencing **severe water stress** in its breadbasket regions (i.e. Sicilia, Puglia) that supply half of SoGeMi Italian vegetables and fruits. **Spain**, SoGeMi's second supplying country, also appears as a country of concern, since half of its lands producing vegetables and fruits is **suffering from high-water stress** and a quarter of them have **declining soil health**. To ensure that **biodiversity loss** is avoided, SoGeMi must pay particular attention to products from **Costa Rica**, SoGeMi's third supplying country, but also products originating from **Cameroon**. Finally, products from **Argentina** (soil degradation) and **South Africa** (extreme water stress) should also be further investigated, as well as **Chile** (soil degradation and water stress) and **Morocco** (extreme water stress).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.





LEGEND

**Fish living both in freshwater and marine environments*

---- *Under 30 t*

Figure 14: Sankey diagram of SoGeMi fish market MFA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

SoGeMi Fish market

The fish market is the second largest market in SoGeMi with around **14,000 tons of fish and seafood products sold in 2019.** The portfolio of fish and seafood products cover **600 species** coming from **78 countries.**

Around **10,000 tons of products** are tracked through SoGeMi's transaction system while around 3,500 tons are sold directly to restaurants, which does not enable an accurate assessment of the products sold. Among the tracked products, the largest category of seafood products are **marine fish** (e.g., tuna), with a little less than **40% of the total tracked volume** (4,270 tons). Bivalves, such as mussels and clams, represent the second largest category with **~25% of products sold** in the fish market. This is followed by cephalopods (e.g., octopus), freshwater fish, and crustaceans with, respectively, 15%, 10%, and 8% of the volumes sold.

Overall, **about half of the products tracked** in the market were **produced in aquaculture systems. Wild catches** mostly came from the **Atlantic ocean and the Mediterranean sea,** with respectively 20% and 17% of the total volume tracked. A large portion of fish caught in the Mediteranean came from Italy (almost 1,000 tons out of the ~ 1,600 tons). Around 1,300 tons of the fish tracked did not properly register the body of water in which the product was caught nor specify if the product came from the aquaculture sector.

Seafood supply Highlights

SoGeMi fish supply chains heavily rely on European countries, with **69% of total tracked volumes coming from the European continent** (inclusive of Turkey). This European supply is mostly supported by Italy, with almost a third of total volume tracked (~3,000 tons), followed by **Spain** (14%), **Greece** (9%), and **Turkey** (~7%). These four countries represent almost 80% of the volumes coming from Europe.

From the Italian supply, 40% comes from the aquaculture sector (1,200 tons), with almost 1,000 tons being bivalves, mainly Mediterranean mussels (mytilus galloprovincialis), and clams (ruditapes philippinarum). Two-thirds of the entire supply of seafood products from Spain stem from aquaculture, mainly producing Mediterranean mussels. Spain and Italy are some of the largest producers of Mediterranean mussels in Europe.[21] Almost the entire supply of Greece comes from the aquaculture sector, with the European sea bass (dicentrarchus labrax), the Gilt-head bream (sparus aurata), and the Mediterranean mussels representing the vast majority of Greek products. Turkey's supply exclusively revolves around two species, namely the European seabass and the Gilt-head bream, both produced in aquaculture systems. The Norwegian supply is almost exclusively constituted of aquaculture-based Atlantic salmon (salmo salar).

[21] Tamburini, E., et al. (2020). Sustainability of Mussel (Mytilus galloprovincialis) farming in the Po River delta, northern Italy, based on a life cycle assessment approach.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

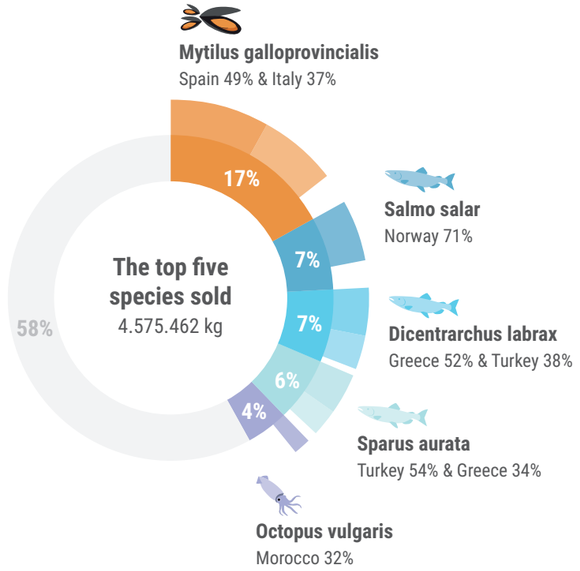


Figure 15: Top 5 species sold in SoGeMi fish market in 2019

The top five species represent more than 40% of the total tracked volumes of seafood products sold in 2019 (Figure 15). A sankey diagram representing the entire range of species sold in the market can be found in Appendix A. Venus clams (ruditapes philippinarum), anchovies (engraulis encrasicolus), swordfish (xiphias gladius), yellowfin tuna (thunnus albacares), and whiteleg shrimps (litopenaeus vannamei) complete the top 10 of most sold species.

In terms of buyers of SoGeMi's seafood products, **seafood market operators from open-air markets** ("ambulante") constitute almost **a third of volumes purchased** for the tracked products or around 25% of the total products sold by SoGeMi vendors. Restaurants, which receive direct deliveries and represent the main buyers of untracked products, make up about a quarter of total sales. Seafood retailers from **Milan's covered markets** ("Dettagliante") account for about **20%** of SoGeMi tracked sales.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Figure 16: Spatial material flow analysis shows the full diversity of SoGeMi fish market's sourcing locations

Endangered species Highlights

SoGeMi's seafood supply was found to have a very small volume of products that are either considered endangered or vulnerable - these products can mostly be found in the **tuna** and **shark** product families.

Fish Market: Environmental Risks

The entire species range of SoGeMi seafood products were reviewed to identify potential risks in terms of threatened or vulnerable species, based on the IUCN Red List.[22] Overall, **1.2% of the entire tracked volumes** (~130 tons) of SoGeMi fish and seafood products are present on the IUCN Red List. A total of 21 species were identified to be part of IUCN "Critically Endangered,"[23] 'Endangered,"[24] and "Vulnerable"[25] lists (Figure 17).

Three species are present on the **'Criticality Endangered'** list, four species are present in the '**Endangered**' list, and 14 species are listed as "**Vulnerable**" (Figure 17). Overall products in the **tuna family** (Atlantic Bluefin and Bigeye tunas) and the **shark family** (porbeagle, shortfin mako, spiny dogfish, common smooth-hound, and school sharks) are the most represented in SoGeMi species listed in IUCN Red Lists, with 58 tons (45%), and 41 tons (32%).

[22] Roberson, L. A., et al. (2020). Over 90 endangered fish and invertebrates are caught in industrial fisheries.
[23] Any species that has an extremely high risk of extinction in the immediate future - IUCN
[24] Any species that is highly likely to become extinct in the near future - IUCN
[25] Any species that is likely to become endangered within the foreseeable future - IUCN

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

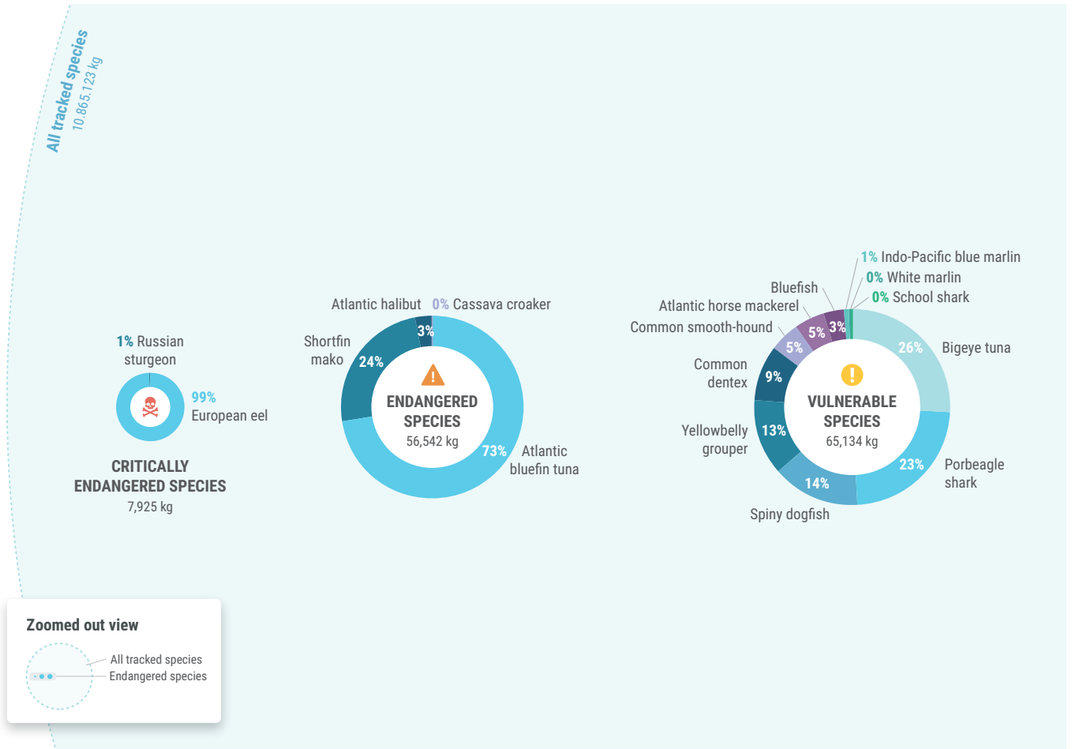


Figure 17: Critically Endangered, Endangered, and Vulnerable Species sold in SoGeMi fish market in 2019

Seafood supply risks Highlights

SoGeMi seafood supply relies heavily on the aquaculture sector and on the Mediterranean sea. The Mediterranean sea has been overfished in the last decades by European fleets, overexploited and vulnerable fish stocks should be further protected, which will have implications, both in terms of prices and volumes, on SoGeMi supply of products from the Mediterranean basin.

The aquaculture sector, which supplies almost half of SoGeMi supply, has been scrutinized in recent years, mainly due to its environmental impacts, caused by its feed and nutrients released into marine and freshwater ecosystems, as well as the introduction of pests and diseases in these natural systems.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

While it is not the scope of this analysis to quantify in detail the impacts of the vast portfolio of SoGeMi fish market, a few environmental hotspots linked to SoGeMi supply chains should be noted. The Mediterranean sea is a key body of water for SoGeMi supply chains with around 17% of the total supply of fish and seafood. Latest research on the Mediterranean reveals that **96% of stocks** fished exclusively by EU countries are **overexploited** above what is considered sustainable (i.e Maximum Sustainable Yield, MSY3).[26] Contrary to Atlantic fisheries that account for 20% of SoGeMi supply, the Mediterranean sea is still being over exploited. In the last 12 years, **Mediterranean fish stocks have decreased by 20%** – with some close to collapse, while Atlantic stocks have increased by 35%.[27] Half of the Mediterranean's sharks and rays are threatened with extinction and the number of top predators have declined by over 40%.[28] This is mainly due to the Total Allowable Catch (TAC) fishing limits in the Atlantic moving closer to scientific advice, while the situation in the Mediterranean is mainly managed through effort control (days at sea, gear restrictions etc.).[29]

As half of SoGeMi supply comes from the aquaculture industry, and since it is one of the fastest-growing food production sectors[30] it is a key sector to highlight environmental hotspots for Milan's wholesaling market. Mediterranean mussels are the largest products coming from aquaculture in SoGeMi seafood supply. LCA studies have shown that the growing and harvesting phases are the main hotspots in mussel aquaculture due to the equipment needed (boats and high-density polyethylene socks),[31] accounting for example for 80% of the global warming impact. There is an ongoing discussion about the impact mussel farming has on eutrophication, since mussels are filter feeders and sequester excess nutrients, which can be seen as a buffer against eutrophication mechanisms. Additionally, regarding Venus or Manilla clams, another staple of SoGeMi's Italian supply, the farming of manila clams (ruditapes philippinarum) can potentially have some positive effects on the environment. Manila clams perform a similar filter feeder function as mussels and are capable of removing carbon, nitrogen, and phosphorus from the marine environment.[32] Italy is the largest producer in Europe of Manilla clams and second largest worldwide after China.[33] The rapid growth in aquaculture has brought about an increase in bacterial, viral, fungal, and parasitic diseases with environmental interactions.[34] This situation has increased the use of antibiotics, pesticides, and other chemicals to prevent and control diseases.[35]

[26] OCEANA. (2016). Mediterranean Sea - A Key EU Fishing Region in a Bleak State of Overfishing.
[27] Hubbard, R. (2017). Why are Mediterranean Fisheries Failing, while Atlantic Fishing Improves? – Our Fish.
[28] IUCN. (2016). The Conservation Status of Sharks, Rays and Chimaeras in the Mediterranean Sea.
[29] Hubbard, R. (2017). Why are Mediterranean Fisheries Failing, while Atlantic Fishing Improves? – Our Fish.
[30] Anderson, J. L., et al. (2017). Aquaculture: Its role in the future of food.
[31] Tamburini, E., et al. (2020). Sustainability of Mussel (Mytilus galloprovincialis) farming in the Po River delta, northern Italy, based on a life cycle assessment approach.
[32] Turolla, E., et al. (2020). Life cycle assessment (LCA) proves that Manila clam farming (Ruditapes philippinarum) is a fully sustainable aquaculture practice and a carbon sink.
[33] Ibid.
[34] Bondad-Reantaso, M. G., et al. (2005). Disease and health management in Asian aquaculture.
[35] Lulijwa, R., et al. (2020). Antibiotic use in aquaculture, policies and regulation, health and environmental risks: a review of the top 15 major producers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Concerning salmon (salmo salar), more than 70% of which comes from Norway in SoGeMi market, research has shown that **feed production is the most dominant contributor to most impact categories,** farm-level nutrient emissions are the highest contributor to eutrophication impacts. Similar to salmon production, the production of seabass and gilt-head bream is mainly influenced by fish feed choices as well as the metabolism of fishes (N and P emissions).[36, 37] 93% of sea bream produced on Spanish Mediterranean and Atlantic coasts comes from offshore cage production, which can release nutrients in high quantities.[38] SoGeMi sources 34% of its sea bream from Spain.

Relatively little research has been done on the common octopus, the fifth largest species sold in the SoGeMi market, and on the environmental impacts[39] which stem from octopus fishing. Discard rates are around 19.5% for studied systems, slightly lower than other trawling fishing fleets worldwide (22.8%).[40] Fishery specific indicators also show high seafloor impacts and fuel consumption per ton of landed octopus.[41]

Environmental risk analysis conclusion

A very limited number of products sold in SoGeMI's fish market were identified as endangered or vulnerable -SoGeMi must eliminate these **endangered species** from its portfolio, specifically focusing on **tuna** and **shark species,** the two families of fish most represented. Additionally, since the **Mediterranean sea** is experiencing **declining fish stocks** and is affected by **diverse environmental degradations**, it is key to ensure sustainable sourcing of all products stemming from the Mediterranean basin, and consider healthier and sustainably managed fish stocks present in other oceans and seas.

SoGeMi Meat market

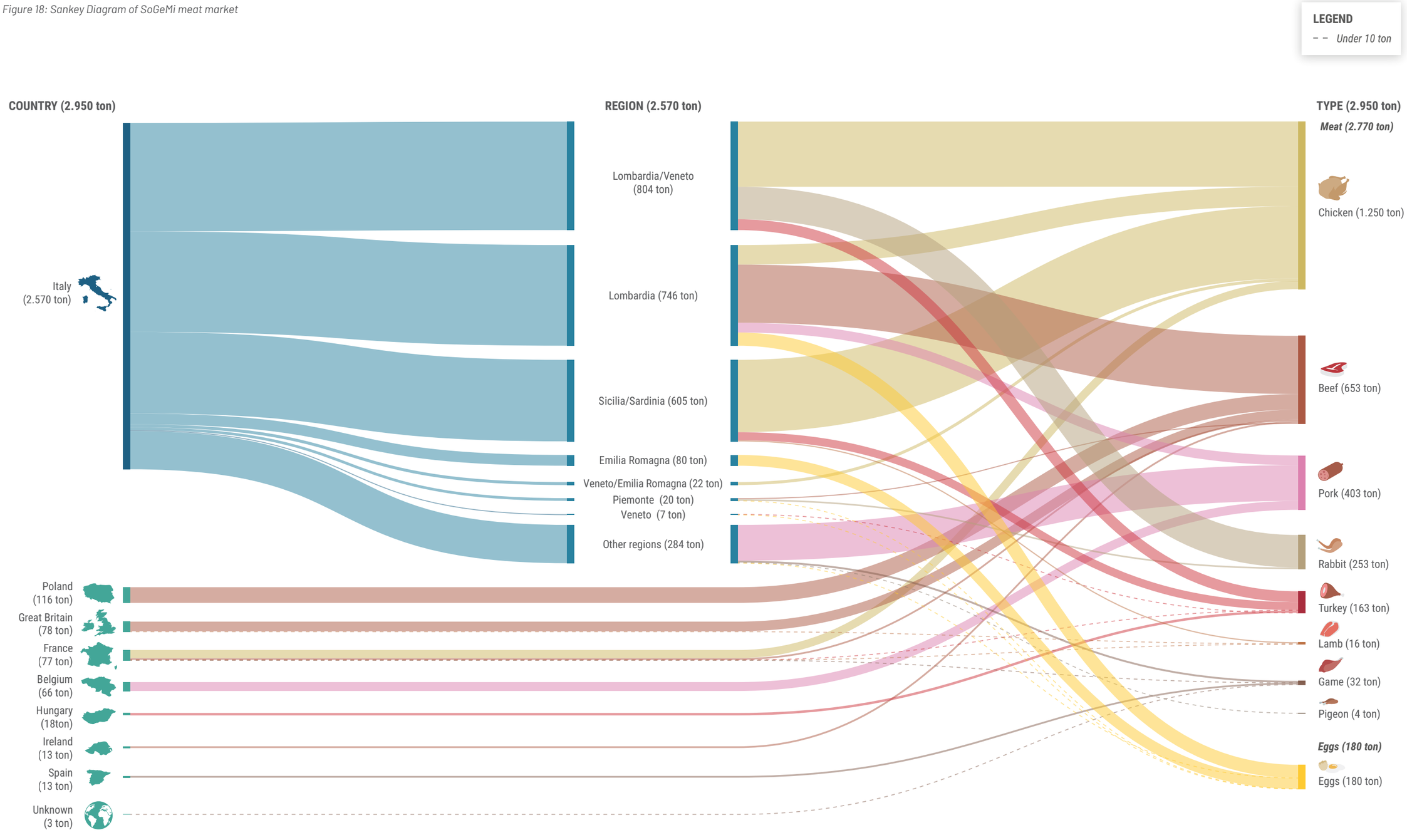
The third food market of SoGeMi is a very small meat wholesale market, with less than **3,000 tons of meat products sold in 2019.** The vast majority of meat products (86%) procured by SoGeMi's vendors are sourced from within Italy. **Lombardia is the main supplying region,** covering **60%** of the Italian supply, providing around half of all sold chickens, about two-thirds of the beef, and 98% of the rabbit products. Almost a quarter of meat products come from the southern regions of Sicily and Puglia, providing around half of the chicken sold in the market.

From the international supply of meat, all supplying countries are within the EEA. The largest countries are Poland and the United Kingdom, providing about a third of all beef products combined. France supplies a small amount of chicken meat, while Belgium supplies mostly pork. Overall, chicken is the largest meat type sold in the market, with 43% of the total meat volume, followed by beef (22%), pork (14%), and rabbit (8.5%).

[37] Abdou, K., et al. (2017). Environmental assessment of seabass (Dicentrarchus labrax) and seabream (Sparus aurata) farming from a life cycle perspective: A case study of a Tunisian aquaculture farm.
[38] Calle Lobo, S. (2016). A Life Cycle Assessment of Gilt-head Seabream (Sparus aurata L.) aquaculture using different fish feeds.
[39] García, B. G., et al. (2016). Life cycle assessment of gilthead seabream (Sparus aurata) production in offshore fish farms.
[40] Tsagarakis, K., et al. (2014). Mediterranean fishery discards: Review of the existing knowledge.
[41] Vázquez-Rowe, I., et al. (2012). Environmental assessment of frozen common octopus (Octopus vulgaris) captured by Spanish fishing vessels in the Mauritanian EEZ.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Figure 18: Sankey Diagram of SoGeMi meat market



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Meat Market: Environmental Risk

In the region of Lombardy around 1.5 Mton of live weight is slaughtered on an annual basis, pork represents the largest amount (0.85 Mton - 40% of national production), followed by beef products (0.44 Mton - 37% of national supply), chicken (0.19 Mton), and rabbit (0.004 Mton).[42] Previous research has calculated the global warming impact of meat production in Lombardy (CO_2 eq./kg Live Weight) of around 8.37 Mtons CO_2 eq. The meat products sold at SoGeMi amount to around 0.002 Mt and have a **global warming impact of 0.029 Mtons CO_2 eq.,** and thus are equivalent to about 0.35% of the total impact of the region. Although the rabbit meat market is small, the rabbit meat sold at SoGeMi market represents around 11% (concerning live weight) of the total rabbit meat market in the region of Lombardy. As a result, although rabbits only contribute to 8.5% of the total meat portfolio, they contribute 11.42% of the total freshwater and marine eutrophication impact from the small Lombardian rabbit industry.

Nutrient runoffs and eutrophication are causes of major concern in Lombardy. Eutrophication of freshwater occurs in Lombardy and nitrate levels occasionally exceed the drinking water threshold. Marine water is also indirectly affected by nutrient losses in the region, with 43% of the nitrogen load carried by the Po River to the Adriatic Sea originating in Lombardy.[43] Nitrate contamination of groundwater also occurs frequently in the upper plains, impacting drinking water and posing risks to human health.

Environmental risk analysis conclusion

As Lombardy is the primary supplier of meat products in SoGeMi's meat market, and the region is experiencing eutrophication issues due to excessive nutrient runoffs, a key focus is to investigate sustainable meat sourcing from the region.

[42] Zucali, M., et al. (2017). Global warming and mitigation potential of milk and meat production in Lombardy (Italy).
[43] Provolo, G.; Sarteel, M. (2015). Good practices to reduce nutrient loss in the Lombardy region (Italy).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2.2 Vision for sustainable food markets in Milan

A circular and regenerative city-region food system can be defined as an industrial system that mimics natural systems of regeneration: where waste is eliminated and biomass is kept in circulation indefinitely. Ultimately a sustainable city-region food system ensures the long-term health and biodiversity of its ecosystems, while supplying healthy and fresh food to its inhabitants.

All biological resources (such as soil, plant, and animal biomass) must be extracted at rates lower than or equal to regeneration rates. At the end of their life cycle, they must be free from contaminants and safely returned to the soil in the form of organic fertiliser. Non-biological resources used within supply chains (e.g. plastic packaging) must be effectively collected and reused within the systems to avoid use of virgin material. As large amounts of resources such as water and energy go into producing complex food products, the value of food products should be maintained for as long as possible by extending the lifespan of agrifood products and ensuring waste is cascaded at maximum value before being returned back to the soil or downgraded. These cycles regenerate living systems, such as soil and structurally support biodiversity.

Figure 19: A circular and regenerative city-region food system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

The Milan Urban Food Policy Pact (MUFPP) and Food Policy, both launched by the Milan Municipality, have set the path forward for sustainable food innovation in the city of Milan whereby the city has committed to "developing sustainable food systems that are inclusive, resilient, safe and diverse, that provide healthy and affordable food to all people in a human rights-based framework, that minimize waste and conserve biodiversity while adapting to and mitigating impacts of climate change".[44]

The objectives within the MUFPP are strongly aligned with a circular and regenerative city-region food system:

- To ensure healthy food and sufficient drinking water as primary nourishment for everybody: Ensure access to healthy drinking water and sufficient food to all citizens as primary nourishment in order to protect human dignity and improve the quality of life.
- To promote the sustainability of the food system: Facilitate the consolidation of all the components and activities necessary for managing a sustainable food system and promote local production and consumption of fresh and seasonal quality food.

Based on Metabolic Institute's research on the current state of Milan's food system food wholesaling sector, three strategic focal areas have been developed as recommendations for the Milan pilot and partners, including SoGeMi, to adopt within their work towards building a sustainable and circular food sector in Milan.

- **Optimally redistribute food surplus within known food deserts across Milan** to reduce and eventually eliminate food waste and increase access to healthy food.
- **Ensuring sustainable sourcing for all three of SoGeMi's food markets** with a fully traceable supply chain.
- **Building shorter, climate-resilient supply chains** to ensure the security of healthy and nutritious food through a more regionalized supply chain built upon regenerative agricultural practices.

2.3 Focus Area 1: Optimally redistribute food surplus within known food deserts across Milan

2.3.1 Introduction

The MFA highlights that in 2019 **15,000 tons of surplus fruits and vegetables** were redistributed within the City of Milan through informal contracts between specific vendors within SoGeMi and different organisations including local food banks, Pane Quotidiano, Caritas, and RECUP. Beyond ensuring that as much avoidable food waste is redistributed as possible, SoGeMi can work with their vendors to ensure that surplus food is being directed towards areas of Milan that have been identified as "food deserts." These deserts are neighbourhoods concentrated within the south of Milan, where healthy and affordable food options are not easily accessible to residents.

[44] MUFPP Sectreteriat. (2021). Milan Urban Food Policy Pact.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

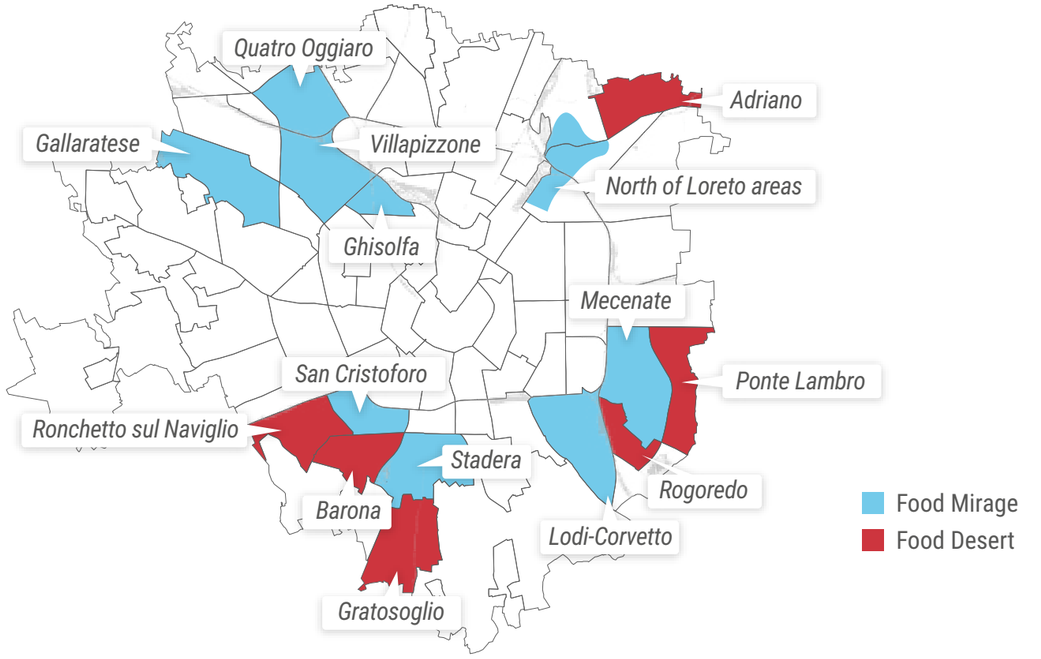


Figure 20:Milan's districts considered to be food deserts or food mirages - Adapted from Comune di Milano.

The areas of **Adriano** (Municipio 2), **Ponte Lambro**, **Rogoredo** (Municipio 4), **Gratosoglio** (Municipio 5), **Barona**, and **Ronchetto sul Naviglio** (Municipio 6) constitute **known food deserts** in areas of low socio-economic status.[45] A key barrier in food deserts is that processed and ultra-processed foods that are energy-dense, but nutrient poor are dominating the food supply; these foods are often cheaper than healthy, fresh foods. SoGeMi and the Milan pilot therefore have a role to play to provide the high-quality fresh food that remains sometimes unsold to these priority areas.

Advance logistics and monitoring systems that facilitate the redistribution of avoidable food waste across SoGeMi wholesale markets and Milanese open-air and covered markets are key to ensuring optimal distribution. Through the MFA process the SoGeMi fish market transaction system and a granular daily waste database were combined together, offering initial insight on how waste data can be integrated into the monitoring of complex supply chains and the potential for food waste prevention and redistribution. With plans in place to extend their transaction system to the fruits and vegetables market over the coming year, this represents a great opportunity for SoGeMi to expand their data infrastructure to include precise waste monitoring measures. Three emerging strategic directions for optimal food surplus redistribution and advanced waste monitoring with key action items are presented below.

[45] Comune di Milano. (2018). The Food System in Milan - Five priorities for a sustainable development.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2.3.2 Strategic direction 1.1: Improving data management systems to monitor waste management

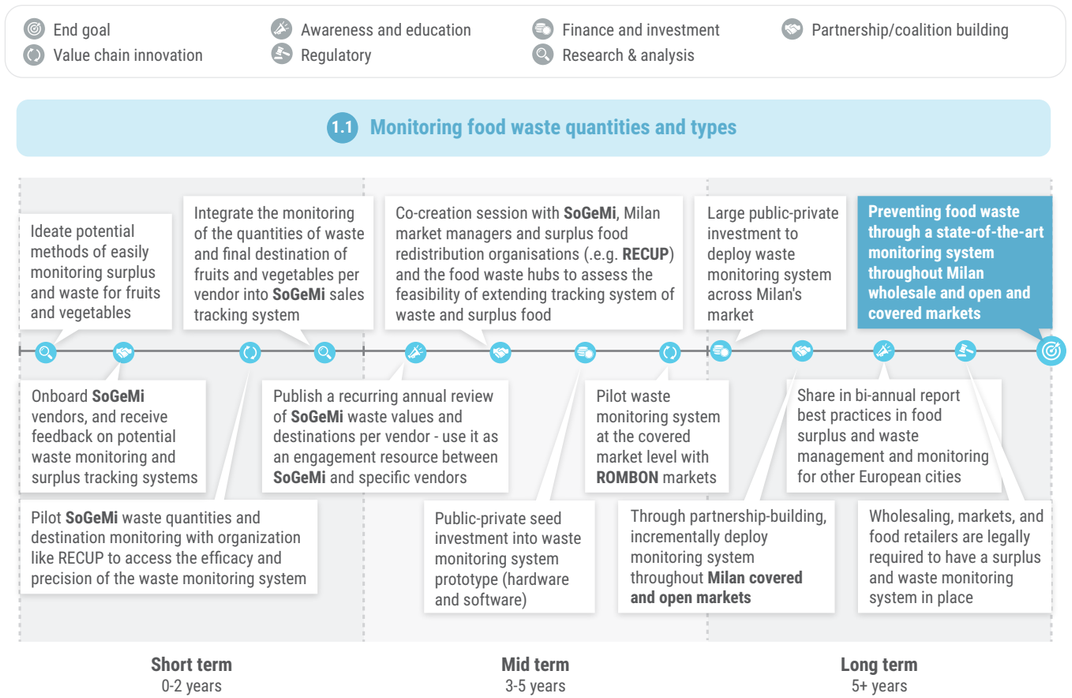
While SoGeMi does not produce significant quantities of food waste in its fruits and vegetables, fish, and meat markets relative to its total sales, it is still key to capture at a granular level food surplus and food waste produced across its different markets. To ensure a full understanding of food-specific waste and surplus flows, and recover as much food as possible for redistribution in Milan's neighbourhoods, a digital monitoring system must be trialed and deployed in the wholesaling center. Several software companies showcase how Artificial Intelligence can be used in large-scale kitchens (for example in IKEA restaurants) to track food surplus in a convenient way.[46] A similar digital system can be tested with Milan pilot partners, such as RECUP that operate within the market to recover food surplus. SoGeMi is the main supplier of fruits and vegetables to Milan's covered markets, it is therefore a key node in the local supply of food and represents the ideal launchpad to develop and deploy a digital infrastructure for food surplus and redistribution across the city. Real time reporting of achieved impacts can be an additional incentive for SoGeMi. Additionally, as the future manager of the Rombon covered market and a close partner of the Milan pilot, SoGeMi has the opportunity to test and deploy a waste monitoring system at the market-level. A potential pilot can open the possibility of incrementally deploying such a system to Milan's network of covered and open-air markets, to build **a uniquely robust and accurate food surplus and waste monitoring system** for wholesale and retail activities in Milan, and structurally support food redistribution and waste management at the city-scale.

Use-cases

- Winnow: Winnow is an AI-based software that quantifies and tracks food waste in the food industry.
- Leanpath: Leanpatch is another AI-based software that quantifies and tracks food waste in the foodservice sector.
- Goodr: Goodr is a food surplus logistics management company.

[46] Winnow. (2021). Winnow | Cutting Food Waste Within Hospitality. and Leanpath. (2021). Leanpath Food Waste Prevention Technology and Solutions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



2.3.3 Strategic direction 1.2: Aiding logistics (with cold storage) in the distribution of avoidable food waste by other organisations

As SoGeMi vendors engage more and more with food redistribution organizations like RECUP and as the city of Milan increasingly develops its concept and network of food hubs[47] for food redistribution, an important next step is to optimize the logistic system, especially for highly perishable food such as fruits and vegetables. **A key bottleneck to solve is the need for cold storage,** especially during warm periods, to extend the shelf life of collected food products while they await redistribution. Research already shows how programmed logistic models are used to find the most sustainable route for goods on long-range routes.[48] As SoGeMi and the Milan pilot team work with RECUP, there is an opportunity to test and deploy cold storage capabilities within the wholesale market. A novel approach is represented for example by Fiware/Foodko, who try to provide cooled supply chains through the principle of sharing the logistic network and including small retailers who would be left without cooling capacity otherwise.[49] As the market manager of Rombon market, SoGeMi can test cold storage logistics for surplus food as a test pilot for other covered markets. The testing of cold storage

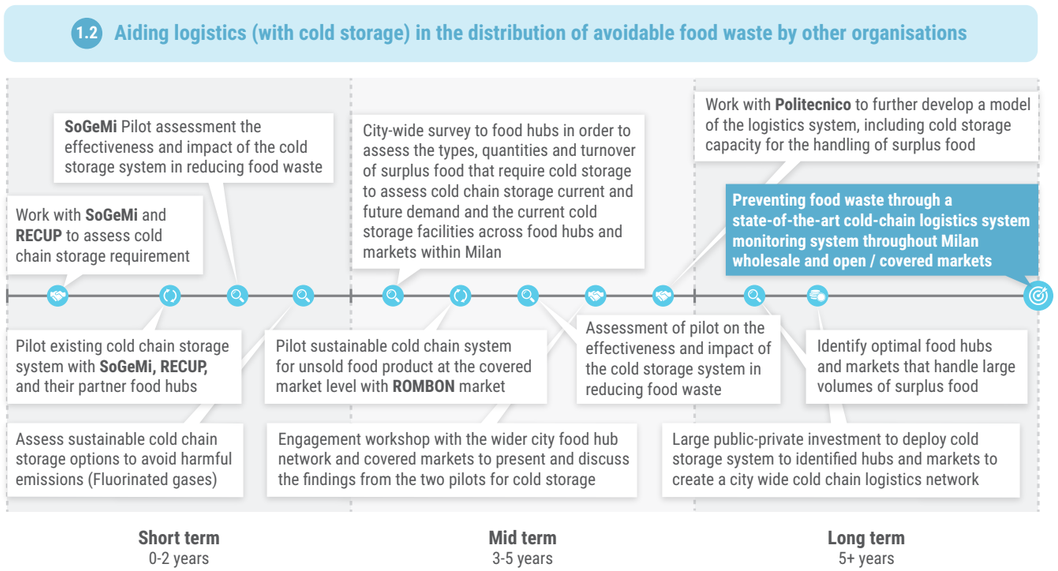
[47] Milan Urban Food Policy Pact. (2019). Local Food Waste Hub.
[48] Gallo, A., et al. (2017). Designing Sustainable Cold Chains for Long-Range Food Distribution: Energy-Effective Corridors on the Silk Road Belt.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

technologies offers the opportunity to explore **sustainable cold storage**, for example natural insulation materials like sheep wool[50] options in the city's wholesale and retail sectors since cold storage represents potentially high GHG emitters.[51] In the long-run, the entire food surplus redistribution network across SoGeMi, Milan's covered and open-air markets, and the food hubs may require important cold chain capacities, therefore it is key to test and trial the most sustainable options, and create an uninterrupted sustainable cold chain to reduce as much food waste as possible.

Use-cases

- Foodko: Foodko by Fiware enables perishable food producers and distributors to share temperature-controlled supply chain assets (i.e. transportation and storage).
- Woolcool: Woolcool replaces polystyrene insulation with 100% pure sheep's wool. The Wool is sustainable, compostable, and due to Wool's superior insulative properties, more effective than other solutions at keeping contents consistently colder for longer.



[49] FIWARE. (2021). Foodko: Empowering Food Producers & Allowing Smart Logistics - FIWARE.
[50] https://www.woolcool.com/
[51] Project Drawdown. (2021). Refrigerant Management | Project Drawdown.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2.3.4 Strategic direction 1.3: Incentivising all vendors to partner with food distribution organisations working in known food deserts within the city

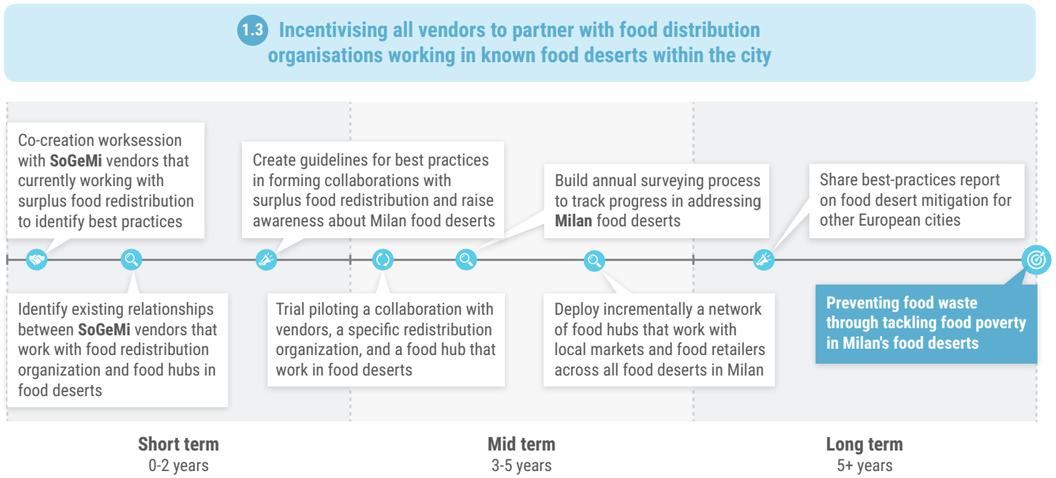
Milan has a dense network of covered, open-air markets, food retailers, and supermarkets. Nonetheless, several of its districts are still considered to be "food deserts," where residents do not have access to fresh and healthy food due to their low economic purchasing power. SoGeMi vendors have the opportunity to work with organizations, such as RECUP, to recover their food surplus and target specific districts with low fresh food access. This has been done for example by New York City through the Greencart initiative, where vendors can sell raw produce in specific boroughs in order to provide fresh, healthy food to citizens.[52] The City of Milan can tackle food deserts in a similar fashion or by encouraging the creation of food hubs within these food deserts. Engaging communities, educating them about Urban Agriculture, and showing them how to live an active, healthy life is also the goal of the SWAG project[53] in order to fight food deserts. To track progress, the City must create a **monitoring system to assess the accessibility of fresh food in the city's food deserts** over time, and assess the effectiveness of food surplus redistribution programs in these neighbourhoods. Developing special food environment maps that are designated for policy makers and show the operating food system, as done for example by the city of Baltimore[54] is an option to put the right focus on city areas that need more attention in development.

Use-cases

- New York City Green Cart: The Green Carts are mobile food vendors providing fresh fruits and vegetables in neighborhoods having limited access to fresh produce.
- Food Environment Map: The Baltimore food environment is analysed through mapping and research to indicate the effectiveness of Baltimore Food Policy Initiatives (BFPI) and provide insight to policy makers.
- SWAG Project: The SWAG Project is an urban community farm in the Weequahic district of Newark that educates hundreds of local students and sells fresh produce at its market.

[52] NYC Health. (2021). Green Carts - NYC Health.
[53] SWAG Project. (2021). SWAG Project – Growing Food. Building Community.
[54] City of Baltimore. (2021). Food Environment Maps | Department of Planning.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



2.4 Focus Area 2: Ensure sustainable sourcing for all three of SoGeMi's food markets with a fully traceable supply chain

2.4.1 Introduction

The MFA conducted for all three SoGeMi food markets has revealed the diverse range of products supplied by more than 75 countries from across the globe. The impact assessment revealed many of these countries, such as Spain, Costa Rica, Argentina, South Africa, and Morocco, are vulnerable to environmental pressures such as **water stress, land degradation, and biodiversity loss,** including those that could be potential candidates for introducing shorter supply chains, such as Spain and even Italy itself. For example, Spain contributes around 15% of SoGeMi's fruit and vegetable portfolio, but is affected by water stress and land degradation, and therefore should be a focus for building awareness of regenerative farming practices amongst the supplier network.

The impact assessment further revealed specific product groups whose cultivation may exacerbate the climate and environmental pressures already faced within the sourcing country. Although the sourcing locations for specific fish, meat, fruit, and vegetable products are rather well documented, further collaboration upstream in the supply chain should be prioritised in order to **understand the conditions of vegetables and fruits production,** as well as **achieve greater insights into the management of fisheries and aquaculture systems.** Additionally, the analysis has also shown that, although in low volumes, some fish products sold are currently endangered and that there is still not a full coverage of the seafood products in terms of species, production system, and country of origin, especially for seafood products sold directly to restaurants.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

SoGeMi therefore finds itself in an influential position, as a major logistics node for markets in Milan, to be able to promote change and transparency amongst its network of vendors to ensure responsible and sustainable sourcing practices. To leverage their position within the food market sector, the following three strategic directions have emerged.

2.4.2 Strategic direction 2.1: Ensuring that all marine and freshwater products are sourced responsibly

Working with SoGeMi's vendors will form a core part of this strategic direction, as collaboration will be required upstream in the fish market supply chain. **Eliminating the import of threatened species from the marine and freshwater product portfolio** will be a critical starting point before further exploring the fishing practices of other fish species. Through working with vendors to introduce reputable certifications into their tendering process, such as the MSC Fisheries Standard,[55] SoGeMi can ensure that all vendors are consciously choosing suppliers that are working towards regenerative fishing practices. The international NGO World Wildlife Fund (WWF) frequently reviews and compares fishery certification schemes and tracks the progress they make, which can be helpful for finding certification schemes.[56]

Consumer responsibility should also be addressed in this matter, since demand is largely influenced by consumer choices. Several guides for choosing sustainable fish and seafood exist, which can help SoGeMi buyers to choose responsibly and will ultimately also help to rid the supply chain of marine and freshwater products from unsustainable or even endangered species.[57]

In the Mediterranean basin, 85% of assessed fish stocks in this region are fished at biologically unsustainable levels. The Mediterranean is home to many small-scale fisheries, some of which catch multiple species with a variety of different gears on the same trip. These fisheries often lack accurate data and the organization to ensure efficient management. Since SoGeMi already has a more established data management system for tracking fish, efforts should be made to build out and trial the integration of a monitoring framework for fishing practices, integrating labels and additional information on local management of fish into their data infrastructure. Comprehensive reviews of Spanish and French mediterranean fisheries is being carried out as a part of the Medfish project, a joint commitment between WWF and MSC in order to establish a benchmark for sustainable fisheries.[58]

A focus on responsible aquaculture for the largest volume products, especially in Turkey, Spain, and Greece as they operate in the Mediterranean basin should be sought. A special focus should be given to the type of gear (e.g. sustainable alternatives to HDPE nets, such as hemp net) and fish feed as well as information on

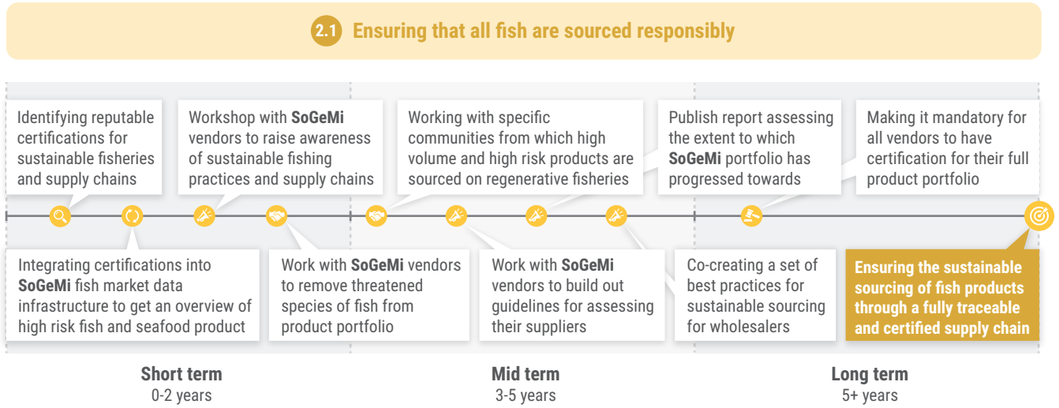
[55] Marine Stewardship Council. (2021). Sustainable Fishing | MSC | Marine Stewardship Council.
[56] WWF. (2012). Smart Fishing Initiative: Comparison of Wild-Capture Fisheries Certification Schemes.
[57] E.g. WWF. (2021). Sustainable seafood guides | WWF. and Good Fish. (2021). Compact VISwijzer - VISwijzer.
[58] Medfish. (2021). Medfish: Fisheries moving towards sustainability – Rigorous and comprehensive analysis of French and Spanish Mediterranean fisheries using the MSC Fisheries Standard as a benchmark for sustainability.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

the intensity of fish farming practices (e.g. stock density) to ensure that the aquaculture farms are helping to reduce pressure on Mediterranean fish stock, while not causing adverse effects on local ecosystems.

Use-cases

- Medfish Project: The Project aimed to carry out a rigorous and comprehensive analysis of French and Spanish Mediterranean fisheries using the MSC Fisheries Standard as a benchmark for sustainability.
- Good Fish: Good FIsh is a label for Dutch supermarkets and restaurants with a robust traceability system for fish products.



2.4.3 Strategic direction 2.2: Ensuring that all fruit and vegetable products are sourced responsibly

As presented in the Milan Food Policy, the Municipality, which is the largest shareholder of SoGeMi, aims to "have an active direct or indirect role" in providing healthy food produced in a sustainable way for Milan residents.

As with the fish market, this strategic direction will require collaboration amongst multiple actors upstream of the fruit and vegetable market. In the short term, the key objective should be to evaluate the feasibility of shifting the sourcing of high volume products from very high risk countries to low risk regions, working with vendors to ensure the implementation of viable alternatives. For example, Spain is SoGeMi's second largest supplier of fruits and vegetables after Italy, but also faces extreme stressors from agricultural practices. This strategic direction will be focused not only on making steps to **phase out sourcing from vulnerable countries,** but increasing the quality of data with regards to sourcing, by including key information on farm management practices. For example, the association Alvelal[59] regroups a community of farmers committed to producing crops with high ecological standards and a robust water management system.

[59] Alvelal. (2021). Asociación AlVelAl | Agroecología.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

An initial step is to undertake a feasibility assessment of shifting the sourcing of large quantity products from high risk countries including decreasing the import of crops with high water demand from Spain or working with Spanish farms that have rigorous water and soil health management practices. Such assessment must also include a financial assessment to ensure the economic feasibility of the shift in SoGeMi's supply chains. Products from sustainable suppliers may have higher costs, thus it is key . Additionally, several countries, such as Bulgaria, Kenya, Guadalupa, Honduras, USA, China, UK, Senegal, and Australia supply very low volumes (<100 tons) of products that can also be sustainably sourced from within Italy. These volumes can therefore be replaced by local alternatives, **with higher traceability.**

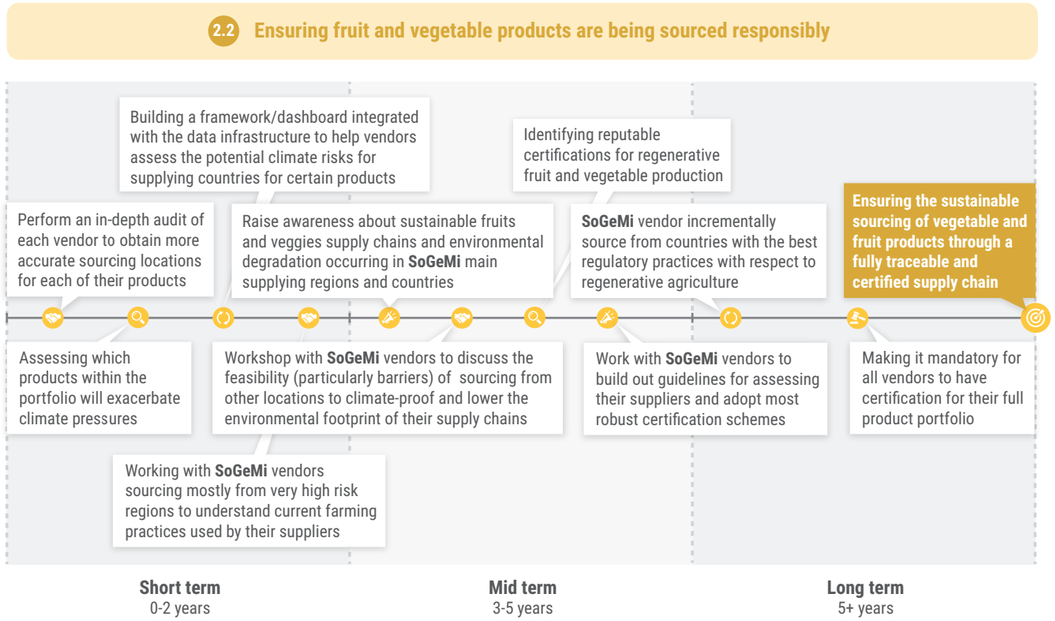
Within Italy, it will be key to work with SoGeMi vendors and their suppliers to implement practices to **reduce water stress** in the regions of **Sicily, Basilicata, Marche, Puglia, and Calabria,** especially focusing on the most spruced regions of Sicily and Puglia (SoGeMi's largest supplying regions). SoGeMi and its vendors can also work with farmers in the region of Emilia-Romagna to implement practices to improve soil organic carbon sequestration, soil fertility and biodiversity, and protect against soil erosion, since the region's arable land is one of the most affected by loss of high-quality soil. Moreover, specific LCA databases, like Eaternity, can be used to assess environmental pressures.[60] SoGeMi can leverage its influential position through the introduction of certifications for regenerative and sustainable farming practices. Many of the practices require local knowledge of plants, climate, topography, soil, food webs, pest pressure, and cropping patterns. This often means that partnering with local supporting organizations, such as those listed by Regeneration International.[61] In Italy, such organizations can be the FAO,[62] and the World Permaculture Association.[63]

Use-cases

- Regeneration International: The organisation is dedicated to building a global grassroots movement around regenerative agriculture while engaging stakeholders and providing guidance.
- Asociación AlVelAl: Their main goal is to mobilize the local farming communities to adopt more sustainable agricultural practices.

[60] Eaternity. (2021). Eaternity Datenbank.
[61] Regeneration International. (2021). Our Network - Regeneration International.
[62] Food Agriculture Organization. (2021). Home | Food and Agriculture Organization of the United Nations.
[63] World Permaculture Association. (2021). World Permaculture Association - We Believe In Abundance!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



2.4.4 Strategic direction 2.3: Deploying integrated tracking systems to ensure full traceability of products across the food markets

The existing fish transaction system, and the upcoming deployment of the new data management system for fruits and vegetables sales offer a unique opportunity to increase the granularity and transparency of SoGeMi supply chains.

The tracking system should be co-developed with SoGeMi vendors and deployed as a unified system across the three markets. The system must rely on a standardized framework to include a full coverage of the country of origin, body of water of origin, or aquaculture system. Information on the type of production system for the fruits and vegetables, following the example of the fish fleet information already present in SoGeMi, should be put in place and expanded to include further information on production practices and certification schemes. The new system should leverage international standards, such as ISO 3 code for countries[64] or FAO code for oceanic regions[65] already used partly by SoGeMi seafood vendors. The overarching goal is to achieve **a clear and accurate tracking system of all food flows entering and leaving the markets.** Another approach, established by an Austrian brand is a web based approach, which allows the consumer to view the origins of products.[66]

[64] UN Trade Statistics. (2016). Country Code (ISO 3166-1 alpha-3).
[65] New Sea Aps. (2021). FAO Fishing Areas.
[66] Zurück zum Ursprung. (2021). Zurück zum Ursprung: Bio, das weiter geht. | Zurück zum Ursprung.

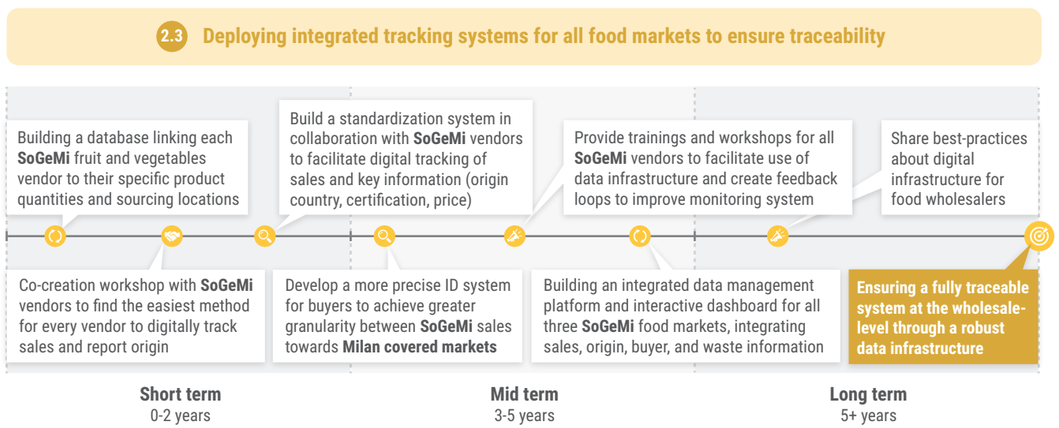
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Additionally, while it was possible to roughly estimate the destination of SoGeMi sales during the MFA process, a more granular ID system of SoGeMi buyers can be deployed to understand at a more granular level the flows of food into Milan's covered markets -this is a key step in ensuring a fully traceable food system in Milan markets and of great interest to the Milan pilot. This ID system can be piloted with the Rombom market, the Milan covered market managed by SoGeMi.

In the longer term, this system due to its increased granularity can be coupled with an **environmental risk framework** to identify in a timely manner the risks of supplying certain products from key regions and countries and provide a robust basis to help vendors integrate responsible sourcing in their procurement processes.

Use-cases

- QR Codes and Blockchain use in Italy: In Italy, the supply chain of carrots have been traced with the use of a QR code system.
- Zurück zum Ursprung: Zurück zum Ursprung ("back to the origin") is an Austrian organic food label that lets consumers trace their products back to the farm via a mobile app.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2.5 Focus Area 3: Build shorter climate-resilient supply chains to ensure the security of healthy and nutritious food and contribute to Milan's social economy

2.5.1 Introduction

This focus area looks to tackle challenges associated with long supply chains within the food sector, by limiting the number of food chain operators and increasing the geographic proximity of products to consumers.[67] The MFA has shown that Milan wholesaling markets heavily rely on other regions of Italy, like Sicily and Puglia, and countries, such as Spain and Costa Rica for its vegetables and fruits supply. Our analysis has also shown a significant amount of produce could be sourced from within Lombardia. Shorter supply chains will allow for greater transparency and greater influence in the farming practices used by suppliers as well as decrease the emissions associated with food imports.

While shifting to local supply is key to increasing SoGeMi's resilience to environmental pressures, such as water stress or crises such as the Covid-19 pandemic, it is even more important to **source locally from farmers that protect Lombardia's agricultural lands and biodiversity.** Thus, while shortening the supply chain a special focus should be given to local sustainable and regenerative suppliers. Additionally, while it was shown that SoGeMi's meat market is small in comparison to its fruits and vegetables market, it was highlighted that the Lombardia meat industry is a key contributor to nutrient runoff leading to eutrophication and significant environmental damage. Thus, a special focus should be given to farmers with strict manure and nutrient management practices in the region. By implementing shorter supply chains, SoGeMi should not only be operating within the critical thresholds of local ecosystems, but building their resilience in light of climate pressures. These shorter supply chains will also provide greater resilience to the City of Milan, with the security of fresh produce that delivers the nutritional requirements to inhabitants of the city.

Shorter supply chains and increased sourcing from Milan peri-urban regions means new employment opportunities for the city. In Milan, almost 30% of its under 25s are unemployed and 18% of under 30s are not in education, employment or training.[68] Thus, shorter supply chains can open employment opportunities in the local agrifood sector.

2.5.2 Strategic Direction 3.1: Finding a balance of shorter and responsibly sourced supply chains within Italy

To increase its local sourcing, SoGeMi can perform a review of its entire portfolio of products and identify the products with the greatest environmental risks. Building on its current network of local suppliers, SoGeMi can identify local farmers capable of supplying products currently identified as high-risk. For products with

[67] Vittersø, G., et al. (2019). Short food supply chains and their contributions to sustainability: Participants' views and perceptions from 12 European cases.
[68] Urban Innovative Actions. (2021). OpenAgri - New Skills for new Jobs in Peri-urban Agriculture | UIA - Urban Innovative Actions.

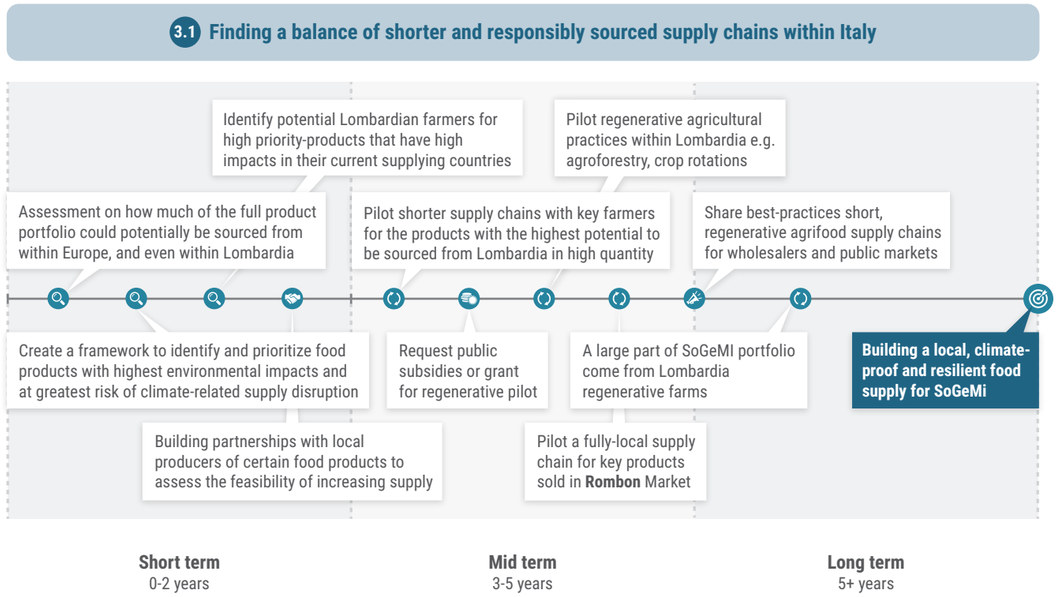
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

little sustainable supply available, but great potential in terms of sourcing in Lombardia, SoGeMi can work with the City of Milan and regional authorities to support pilots of regenerative farms that can supply key products for Milan fruits and vegetables and meat markets. Several research projects focus on novel farming techniques, for example the Metabolic Urban Aquaponics Farms.[69] Pilots like this can be used to draw out knowledge on sustainable food production techniques. The pilots can help initiate a network of regenerative farmers in the region.

Building on top of the regenerative farming pilots, and as SoGeMi assumes its function as Rombon market manager, the wholesaling center can trial sustainable short supply chains in the covered market to make Rombon market the first covered market in Milan offering only produce from local regenerative farms. Over time, SoGeMi can shift to a more local and sustainable network of actors, balancing its supply with **sustainable procurement from other Italian regions** and other countries.

Use-cases

- Metabolic Greenhouse: Metabolic has built a greenhouse where urban farming techniques, such as aquaponics, are tested to analyse the potential of further implementation on a larger scale.
- Metro: The Metro company, a French wholesaler for the restaurant market and other French organisations, has committed themselves to deliver fresh products produced within a certain distance from their warehouse.



[69] Metabolic. (2018). Advancing aquaponics at the Metabolic greenhouse.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

2.5.3 Strategic Direction 3.2: Shorter supply chains as a driver of local employment in the urban, peri-urban, and rural farms around Milan

Building on top of existing EU-funded projects that combine urban agriculture and youth employment such as Open Agri,[70] SoGeMi and the growing activated network of Lombardian and Milanese farmers supplying the market can expand employment opportunities in the urban and peri-urban agricultural sector of the city. For instance, the city of Locmariaquer in Bretagne, bought abandoned agricultural land for agricultural cultivation, which then in turn is rented out at a low price to producers who commit to selling through local food networks.[71] A research effort to inventorize all the peri-urban and urban farmers active in Milan, **and assess their current and potential production capacity** would constitute a first step to comprehend further the potential supply of hyper-local fruits and vegetables.

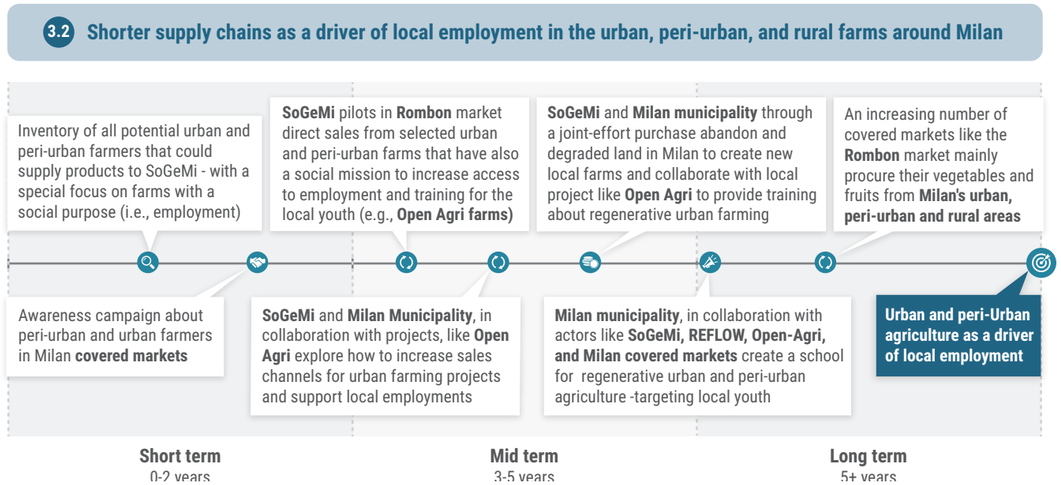
SoGeMi, the Milan REFLOW pilot, and their partners can become active participants in the local economy by providing new sales channels for the urban agriculture initiatives identified and supporting the implementation of new pilots over time. Rombon market can become a key market to display and raise awareness about local urban and peri-urban farms and their associated social and economic value. One such promotable project could be the start-up Urban Farm Milano, which focuses on repurposing old buildings for urban farming and knowledge gathering. To support initiatives, such as Urban Farm Milano,[72] the Municipality, with local actors, could make available unused lands and buildings at a low rate. Finally, in the long-term, providing training and upskilling to local youth through regenerative urban agriculture projects and official curriculum could provide a significant opportunity to **reduce youth unemployment.**

Use-cases

- Locmariaquer, Bretagne: The Municipality of Locmariaquer has acquired the majority of abandoned agricultural land where organic agriculture was implemented on a communal farm. The municipality is one of the only ones of the region to increase its permanent population.
- Saveurs du Coin: Saveur du Coin is a Swiss farm selling directly its authentic and artisanal meat products to the consumer. The farm aims to offer good quality products while maintaining strong city-to-country relations.
- Urban Farm Milano: The company studies systems for the renovation of abandoned buildings and their redevelopment in vertical farms and bio-technological factories. They develop regenerative business models involving all actors at the urban, social, production, and distribution levels.

[70] Openagri. (2021). Openagri – Openagri.
[71] European Network for Rural Development. (2012). Local Food and Short Supply Chains.
[72] Urban Farm Milano. (2021). Urban Farm Milano – Benvenuti in Urban Farm Milano.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



2.5.4 Strategic Direction 3.3: Responsible nutrient management for all suppliers within the Lombardy region

Since the main environmental impact of the Lombardia agricultural sector is nutrient runoffs leading to eutrophication, a key endeavour for Milan's meat market will be to source from meat suppliers with **robust manure management systems,** and for its vegetables and fruits vendors to source from farmers with **low synthetic fertilizer inputs**. Several new businesses already focus on using machine learning in order to analyze soil samples and give the farmer valuable insights into the amount and type of fertilizer they need to apply, like for example TRACE-Genomics.[73]

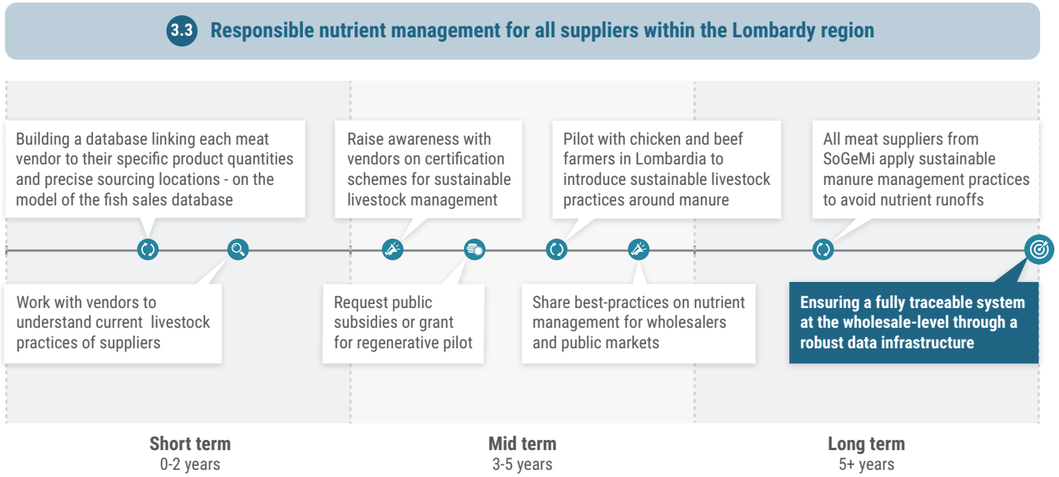
SoGeMi and its vendors can conduct a review of its main regional suppliers and **assess the farm management practices** of its meat suppliers. In collaboration with organizations like FAO, they can support the piloting of new manure management systems, and provide a greater sales channel for sustainable meat producers. Lombardia has the capacity to supply the entire portfolio of meat products sold in the SoGeMi meat market, thus overtime SoGeMi and its vendors can develop supply chains solely based in Lombardia, with a network of sustainable meat producers. Due to SoGeMi procurement of both fruits and meat products, SoGeMi is in the position to support innovative silvopasture pilots in Lombardia that can greatly participate in reducing nutrient runoff.

[73] TRACE Genomics. (2021). Corporate Partners.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Use-cases

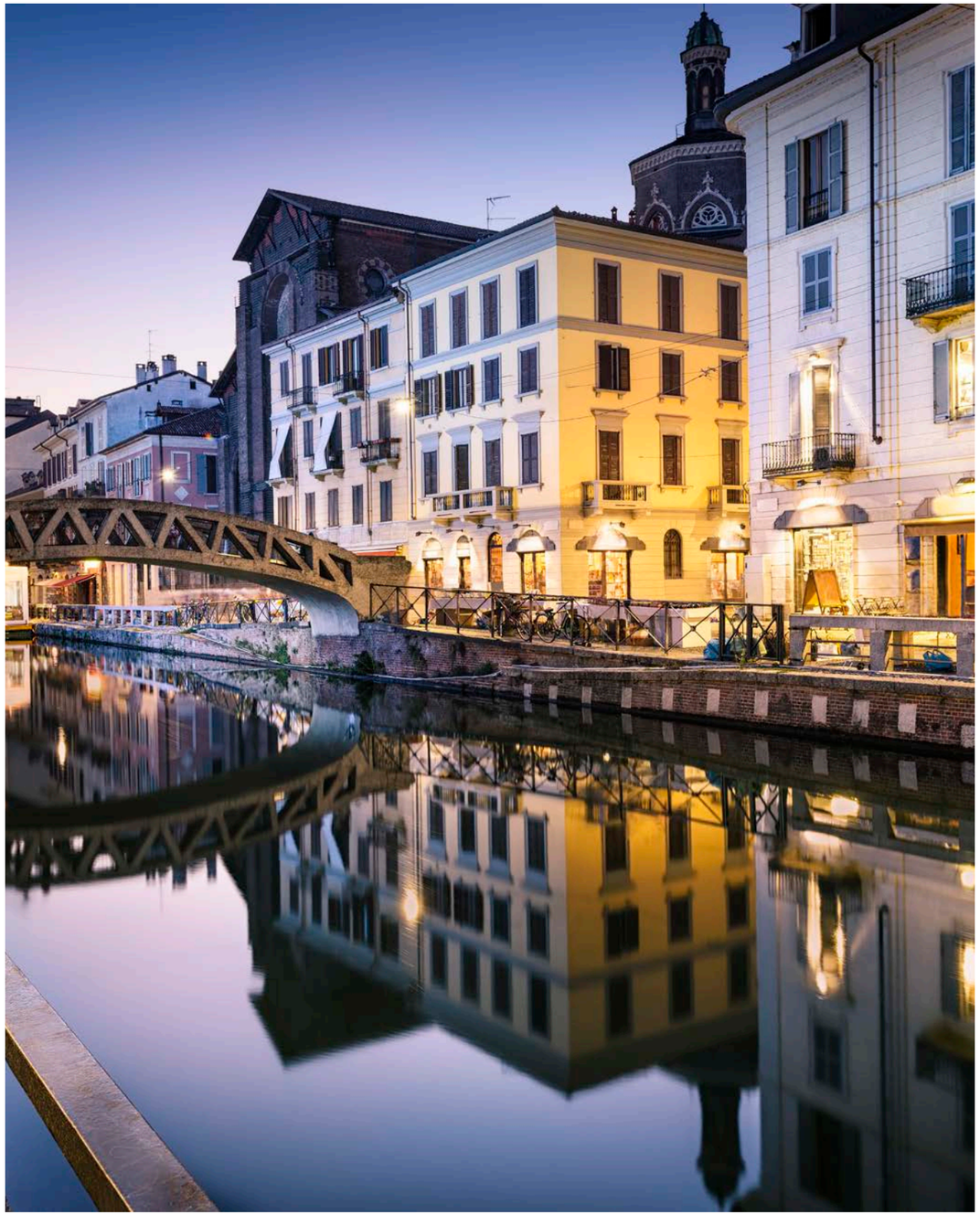
- TRACE-Genomics: TRACE-Genomics turns soil samples into meaningful insights to facilitate action. Data-driven and evidence-based recommendations are provided after the soil analysis.
- Silvopasture Sardinia: Silvopasture, an ancient agricultural method is used by young farmers in Sardinia. This technique is a climate solution as it does not alter natural landscapes and allows a large amount of carbon to be sequestered.



2.6 Relevance for pilot activities

The Milan Pilot's action plan and Theory of Change outline the key activities that will be done during the period of the REFLOW project to promote and achieve a **circular food system rooted in Milanese municipal markets.** To communicate how and where Metabolic Institute's urban metabolism analyses and resulting recommendations directly support the Milan pilot's planned activities, desired outcomes, and impacts, we mapped out all touchpoints between the Theory of Change and our proposed three focus areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

SCENARIOS

ACTIVITIES

MID-TERM OUTCOMES

LONG-TERM OUTCOMES

IMPACT

S1 Scenario 1 1
Upcycle and food waste systems

S2 Scenario 2 1 2 3
Processes & tools for empowering markets & product traceability

S3 Scenario 3 1
Reinvent the physical space pushing the mixed use of the Markets as places for culture, socializing, & commerce

S4 Scenario 4 1 3
Logistic and retail chain systems for inclusive food system

S5 Scenario 5 1 2 3
Business and organizational models for circular food systems

3.1 Markets' managers engagement

3.2 Selection of 5 municipal markets

3.3 Map material flows & characteristics of flows (macro, micro)

3.4 Mapping through hands-on field research

3.5 Identifying 5 areas of intervention & its stakeholders

3.6 Catalogue of circular solutions

3.7 Municipal Markets' traders & external stakeholders workshop

3.8 Definition/refinement of scenarios for experiments

3.9 **Co-Production** Series of 3 co-design labs

3.10 Series of 3 co-production prototyping workshops

CO-CREATION

CO-DESIGN

Change **buyers**/ mindset towards food waste 1 2

Change **traders'** / mindset towards food waste as opportunity for the seller 2 3

Changing **citizens'** perception of municipal markets as spaces for the local community 1 2

Change mindset of **for-profit stakeholders** towards food waste - as a business opportunity 2 3

A new culture of food, health and environment 1 2

A city that enables wide, systems-level circular behaviours and model 'Milan Model' 1 2 3

Circular food system rooted in municipal markets
1 2 3

THEMES

1 Optimally redistributing food surplus within known food deserts across Milan to reduce and eventually eliminate food waste and increase access to healthy food.

2 Ensuring sustainable sourcing for all three of SoGeMi's food markets with a fully traceable supply chain.

3 Building shorter, climate-resilient supply chains to ensure the security of healthy and nutritious food.

Figure 21: Touchpoints between the Milan Pilot's Theory of Change and the proposed focus areas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3. VEJLE

3.1 Introduction to Vejle's plastic sector

3.1.1 Background and scope of the analysis

Vejle is a mid-sized Danish city located in southeast Jutland, 241 kilometres east of Copenhagen, at the conjunction of Vejle Fjord, Vejle River, and Grejs River. The city of Vejle is inhabited by a population of 57,051 while the broader Vejle Municipality (Kommune) has a population of 111,743, making it the 6th largest in Denmark.

Over the years, Vejle has developed a strong focus on resilience and sustainability, and was selected in 2013 to be one of the 100 Resilient Cities[74] of The Rockefeller Foundation's initiative to foster future planning for cities to provide 'safer, healthier, and increased livelihood options' for their citizens. In this capacity, Vejle Municipality published its Resilience Strategy highlighting the city's dedication towards developing a cohesive, robust and sustainable city.[75] **Waste management and recycling have been among the strategic goals of Vejle's Resilience Strategy,** paving the way for Vejle's focus on plastic waste. Like many other European cities, accumulation of non-recyclable plastic, plastic-based waste, and its poor management is a problem faced by Vejle. Going beyond the aim to recycle more plastics, Vejle seeks to integrate circular economy business models, where the overall amount of plastic will be reduced through the use and reuse of plastic, through practices that contribute to a positive combination of social, environmental, and economic impacts.[76]

The REFLOW Vejle pilot has set out to gain insights into urban plastic consumption and to increase the circularity of the city's plastic value chains. Through targeted stakeholders interviews and waste analyses at seven test sites across the city, the Vejle pilot investigated current barriers and outstanding opportunities for increasing local plastic recycling. These seven test sites covered key nodes and locations within the local plastic value chain include: (1) public housing projects, (2) local food retailers, (3) two healthcare institutions, (4) public schools, (5) the construction industry, and (6) an innovation center for local entrepreneurs.

Out of these seven initial sites, three were chosen for deeper investigation of the potential for circular plastic loops. At these sites - a branch of the REMA 1000[77] supermarket chain, the public housing block Dem Gamle Gård, and the public elderly home Sofiegården - the Vejle pilot will run targeted experimentations, workshops, and engagement sessions to identify and showcase solutions for increased plastics reuse, recovery and reduction. This mission responds to the European directive on disposable plastics[78] and the recent Danish government action plan on the reduction of plastics from production and household consumption.[79]

[74] The Rockefeller Foundation. (2021). 100 Resilient Cities - The Rockefeller Foundation.
[75] Vejle Kommune. (2015). Vejle's Resilience Strategy.
[76] Parisi, C., et al. (2020). H2020 REFLOW Deliverable 1.2: Cities' Circular Action Plan.
[77] REMA1000. (2021). REMA 1000.
[78] EC. (2019). EUR-Lex - 32019L0904 - EN - EUR-Lex.
[79] Miljø- og Fødevareministeriet. (2018). Plastik uden splid.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Scope and Method of the Material Flow Analysis (MFA)

While the bottom-up test sites provide valuable snapshots of local plastic value chains (Annex B), they do not uncover the cross-sectoral plastic consumption patterns and resulting impacts at the city-level. Within WP3 Task 3.3 Environmental Systems Design, Metabolic Institute collaborated with the Vejle pilot to supplement the pilot's bottom-up studies with a city-level analysis on urban-scale plastic imports, consumption, and end-of-life pathways. Vejle's current plastic system and its related environmental impacts was analysed for the year of 2018 and defined by the geographic scope of the administrative boundaries of the Municipality of Vejle. The resulting **Material Flow Analysis** (MFA) for the Municipality of Vejle (see Figure 21) covers the following nodes:

- **Production of resins** used for plastic raw materials and goods imported into Vejle
- **Final and intermediate consumption** of plastic raw materials and goods by key sectors within the municipal boundaries of Vejle
- **Collection of plastic waste** managed through municipal and private waste handlers
- **End-of-life treatment of plastic waste** from the Municipality of Vejle

Additionally, Metabolic Institute conducted a **set of environmental impact assessments** on (1) the cradle-to-gate production[80] impacts of polymers imported into the city for intermediate and final use (Figure 23), and (2) the end-of-life impacts associated with the current waste management of plastic polymers coming from Vejle households, businesses, and industry (Figure 27). Therefore, the flows were analyzed from both - an urban metabolism point-of-view and a value chain point-of-view.

To align the scope and focus of Metabolic Institute's analyses with the needs and objectives of the Vejle pilot, Metabolic Institute and the Vejle pilot team followed a close interactive and co-creative process. This iterative process also ensured that the current state analysis depicted the realities of the city, and validated the coherence of the data sources used in the analysis.

As part of this process, and to improve the granularity and accuracy of our results, the Municipality of Vejle provided bottom-up data, including:

- Collection data from the four Municipal recycling stations in the city, with amounts of plastic waste collected, sorted and sent to specific end-of-life treatments in 2018.
- Bottom up data on hospital waste generated in Vejle in 2019.

In addition to municipal data sets, the Metabolic Institute team leveraged a series of external datasets to

[80] Under "cradle-to-gate" we understand the first steps of a product's life cycle, including the extraction and production phases. Ending at the gate of the factory, a cradle-to-gate impact assessment omits the impacts associated with the use phase and end-of-life treatment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

develop the MFA, including:

- Danish national level data[81] on quantities of imports, exports, consumption and domestic production of plastic materials and commodities in the form of finished and semi-finished plastic goods.
- Danish waste statistics[82] to estimate the amounts of consumer packaging used in Vejle by combining bottom up waste data from the municipality as well as other Danish studies that analysed plastic waste in residual household waste.
- Employment data in the local plastics industry[83] in Vejle and Denmark to understand the share of the plastics production market held by the city.
- Employment data in other industrial sectors in Vejle and Denmark to downscale industrial plastic consumption as part of intermediate or semi-finished goods, and commercial packaging.[84]
- An independent bottom up study on the composition of municipal solid waste in Denmark.[85]
- Waste production reported by the construction industry in Denmark[86] and the mapping of PVC[87] applications and supply for the Danish construction sector.
- Statistics on new construction that occured in Vejle in 2018 to downscale municipal plastic consumption as building materials.[88]
- Studies conducted by WRAP on the polymer composition of plastic packaging. These composition numbers are used to calculate the raw materials that are estimated to be used in the production of consumer and non-consumer packaging distributed to households in Vejle.
- Polymer compositions of consumer goods across European markets.[89, 90]
- National statistics on direct plastic waste generated by Danish industries.[91]
- A study conducted by the Aarhus University hospital on plastics in the healthcare sector.[92]
- A study on the composition and characterisation of the plastic fraction of small combustible waste collected at 8 Danish recycling centers.[93]

[81] Ministry of Environment; Food of Denmark. (2019). Preliminary assessment of plastic material flows in Denmark - Technical Report.
[82] Ministry of Environment; Food of Denmark. (2020). Affaldsstatistik.
[83] Virk. (2021). Virk | Data.
[84] Ibid.
[85] Edjabou, M. E. (2016). Composition of municipal solid waste in Denmark.
[86] Ministry of Environment; Food of Denmark - Environmental Protection Agency. (2017). Affaldsforebyggelse i byggeriet - Forprojekt.
[87] Ministry of Environment; Food of Denmark - Environmental Protection Agency. (2018). Kortlægning af PVC i Danmark 2018.
[88] Statistics Denmark. (2018). Statistics Denmark: Total Construction 2018 (net floor area, by region).
[89] Eriksen, M. K. (2018). Quality and Recyclability of Plastic from Household Waste.
[90] Plastics Europe. (2018). Plastics - the Facts 2018.
[91] Statistics Denmark. (2021). Statistics Denmark - Geography, Environment and Energy.
[92] Aarhus Universitetshospital. (2019). Gentænk Plast - på vores hospitaler.
[93] Faraca, G., et al. (2019). Combustible waste collected at Danish recycling centres: Characterisation, recycling potentials and contribution to environmental savings.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.1.2 Current System and its Impacts

Based upon the current system analysis, we can derive key insights and hotspots related to (i) the production of plastic goods and raw materials which are imported into the city, (ii) the key consuming sectors of plastic products and materials, and (iii) the end-of-life treatment of plastic waste collected by municipal and private schemes.

Starting with insights and hotspots related to the import of plastic goods and raw materials, our analysis shows that the **majority of plastics enter the city as either finished plastic products** or as intermediate plastic goods used in further processing. From a total volume of 23,300 tons of plastics imported into the city, a small part of only 400 tons is used as raw materials by the local primary plastic industry. Considering that only 1.5% of Denmark's primary plastic industry is employed in Vejle, the amount of plastics in resin form remains negligible in comparison to the volume of plastics in intermediate goods, packaging, or finished products.[94] As a consequence, the majority of environmental and health impacts associated with the production of resins needed for imported products almost exclusively burdens people and the planet beyond the city's boundaries.

Overall, it is estimated that the **upstream production** of fossil-fuel based polymers used for goods and raw materials by Vejle emits **more than 32,000 tons of CO_2** and uses 960 TJ of energy. To put these numbers into perspective, this is equivalent to the average annual CO_2 emissions of more than 5,000 Danish citizens.[95] These numbers should be treated as conservative estimates since they only refer to the 60% of identified polymers. Due to large uncertainties around the type of polymers used in the local industry, the total emissions from plastic imports are likely to be significantly higher. Excluding the unspecified polymers, polypropylene was identified as the most abundant polymer (4,500 tons) which is widely used across all product applications, such as packaging, durable consumer goods, and construction materials.

[94] In line with the industry definitions of Denmark, only the primary plastic industry consumes resins in raw material form
[95] Based on 2017 data on per capita CO_2 emissions from Our World in Data

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

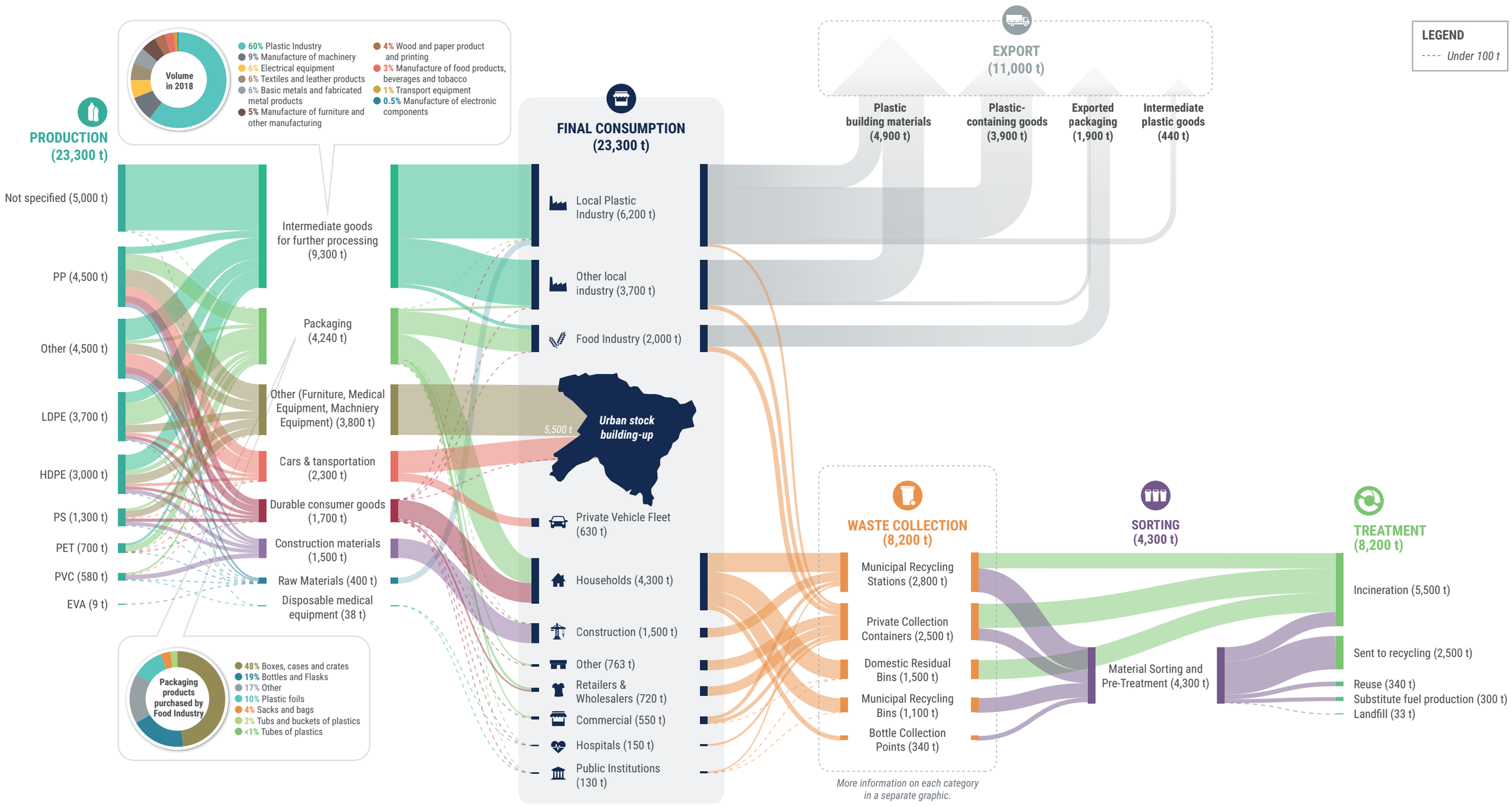


Figure 22: Plastic material flow analysis for the Municipality of Vejle (2018)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

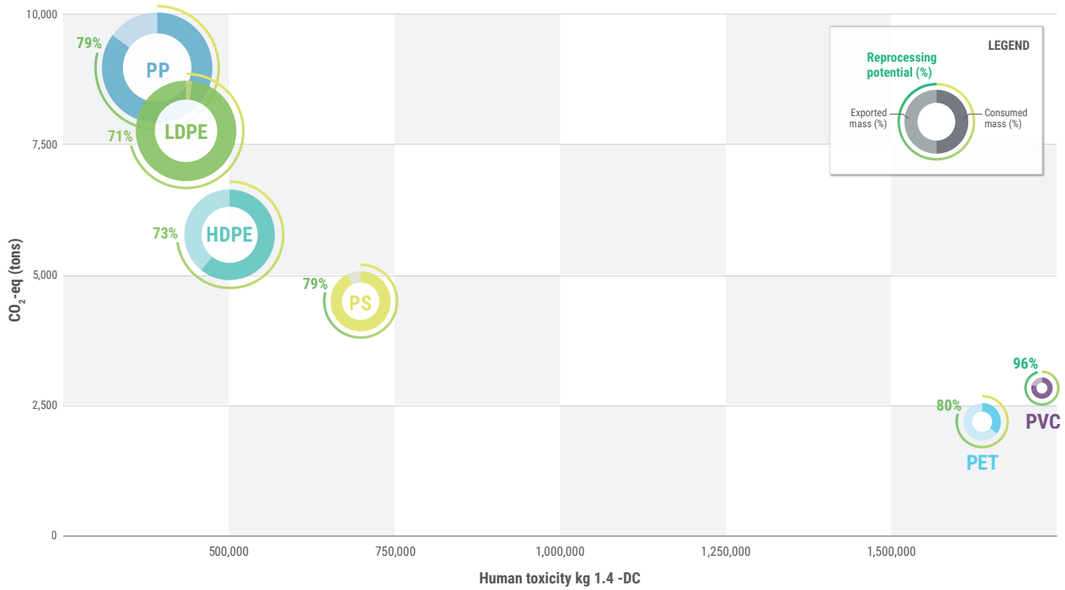


Figure 23: Absolute CO_2 emission and human toxicity related to production of key polymers used in Vejle[96]

Apart from carbon emissions, the production of resins imported into Vejle also contributes to air pollution and associated human health impacts in places of resin production. In particular the small volume of PVC used in the Vejle's healthcare sector, building industry, and other plastic products is disproportionately responsible for the emission of toxic air pollutants: around 86% of air emissions associated with the production of polymers imported into Vejle are linked to PVC.

[96] PP (polypropylene), LDPE (low-density polyethylene), HDPE (high-density polyethylene), PS (polystyrene), and PET (Polyethylene terephthalate). This graphic also shows the reprocessing potential of the respective polymers based on Faraca and Astrup (2019), as well as the assumed share of polymers which are exported as products, later on. Export shares can be significantly higher since most polymers purchased by industry are unknown and therefore do not show up in this graphic.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

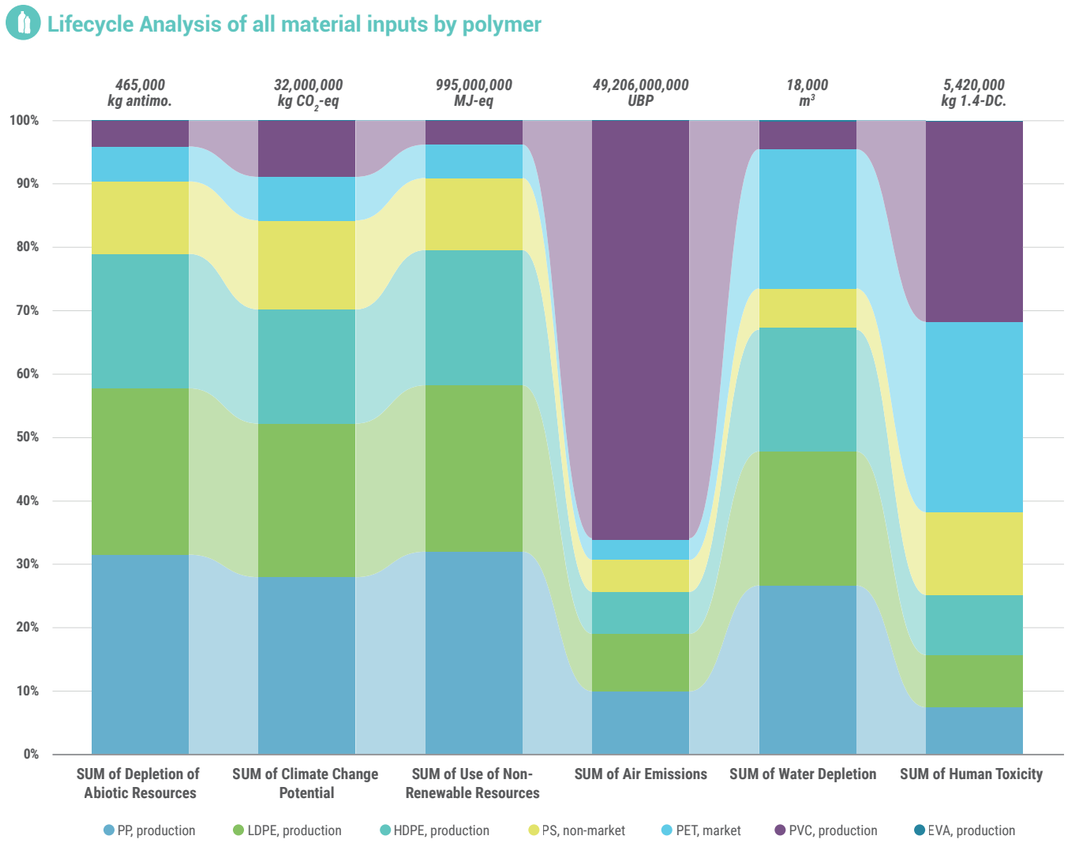


Figure 24: Relative contribution of different polymers to different environmental impact categories associated with the production of key polymers.[97]

The MFA further highlights the role of **local industry as hotspots of plastic consumption,** where intermediate goods and resins of largely unknown polymer composition are processed into plastic building materials and other plastic-containing goods (Figure 25). Overall, around 47% of plastics passing through the Municipality of Vejle are estimated to be attributed to plastic processed or produced for export into external markets. Based on the share of local industrial sectors from national industry, we can estimate that the **primary plastic industry alone may consume around 6,200 tons of plastic** goods and raw materials. This accounts for 60% of all intermediate plastic goods used by local industry. The second largest industrial consumer of plastic materials is the city's manufacturing industry of machinery. While the data available on industrial plastic imports is low, these estimates do reveal that the collaboration with local industrial players is an important leverage point to influence the transition of plastic value chains beyond the city of Vejle towards circularity.

[97] Data from ecoinvent

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Figure 25: Polymer composition of different product applications used in Vejle

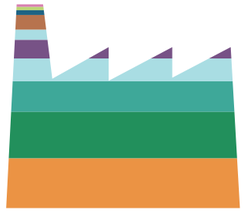
After industry, **private households are the largest identified end-consumer** of plastic products. In Vejle, households have used 4,300 tons of plastics as consumer goods and packaging, bought cars with around 630 tons of plastics, and further purchased an unknown share of plastics as furniture. Since fast-lived plastics packaging is one of the main concerns for the Municipality of Vejle, it is worth mentioning that households are responsible for the largest share of packaging that is managed by the city's waste management system.[98] In 2018, **private households used around 1,880 tons of plastic packaging** collected by the Municipality. As a comparison, plastic packaging used by municipal institutions only amounts to 14 tons, based on scaled down numbers from national waste data.

[98] Households consume around 44% of all packaging imported into the city. But 40% of packaging is estimated to be purchased by the local food industry for the export of food products.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

WASTE COLLECTION (8,600 t)

Types of plastic products sorted at Vejle's four recycling stations (Volume 2018)

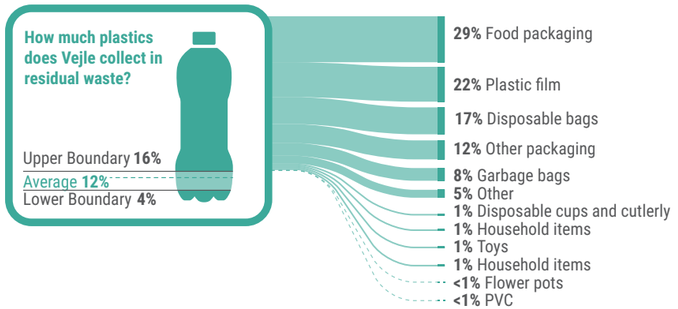


- Styrofoam **12**
- Bottles **15**
- Cables **22**
- Patio furniture **68**
- Plastic window frames **95**
- PVC **236**
- Foils **263**
- E-plastics **437**
- Hard plastic **663**
- Plastics in combustible waste **709**

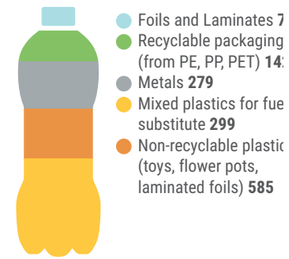
Waste Characterization of privately collected waste (Volume 2018)

- PVC **17**
- Plastic packaging **455**
- Non-packaging plastics **459**
- Plastics in combustible waste **1,825**

Waste Characterization: Plastics in Residual Waste (Volume 2018)



Types of plastics in Vejle's separately collected recyclables (Volume 2018)



- Foils and Laminates 7
- Recyclable packaging (from PE, PP, PET) 14
- Metals **279**
- Mixed plastics for fue substitute **299**
- Non-recyclable plastic (toys, flower pots, laminated foils) **585**

Figure 26: Detailed waste composition of privately and publicly collected waste of Vejle's four collection routes (1) recycling station drop offs, (2) private waste collection, (3) municipal residual waste collection, and (4) recycling curbside pick-up

Hotspots and insights in relation to the collection and end-of-life treatment of plastic waste from Vejle can be broken down into (1) municipally managed waste and (2) privately managed waste. With respect to municipally managed waste, 5,410 tons of plastic waste were collected or dropped off at recycling centers in 2018. A key insight is that from this municipally managed waste, only 6.4% gets directly reused via the national bottle deposit scheme and 35% of collected plastics via municipal pick-up or drop-off is recycled and subsequently reprocessed. This leaves the large majority of plastics ending up in incineration (59%) or used as a low-quality substitute for fuel production (5.5%).

Privately collected waste from businesses and industries are less well-known and had to be downscaled from national data, using Vejle's employment shares in respective sectors. Our analysis shows that the private waste collection contributed 2,800 tons of plastics to the city's total waste outputs, from which 66% was sent to incineration.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

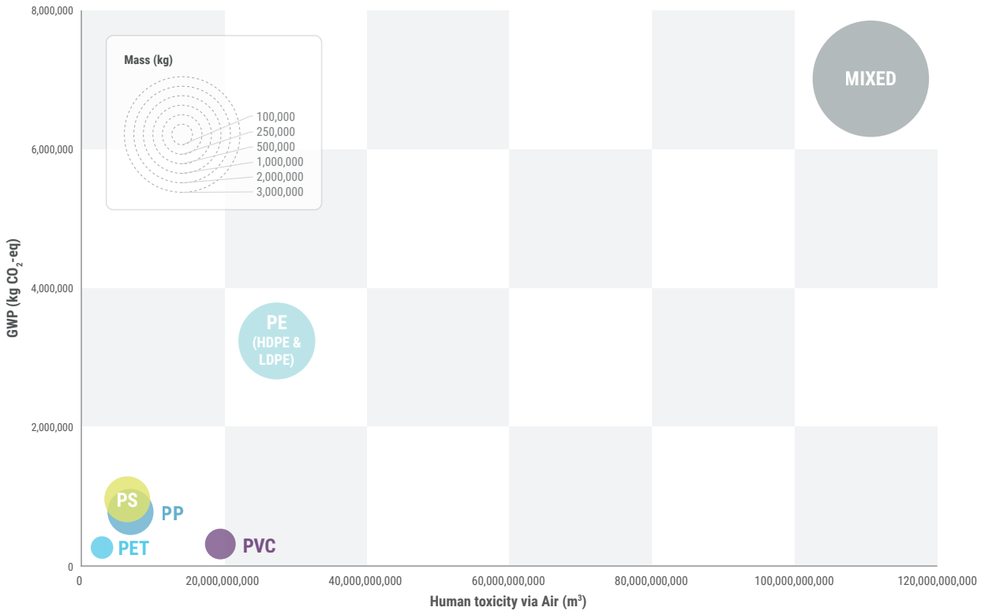


Figure 27: Absolute global warming potential and human toxicity resulting from the end-of-life treatment of Vejle's plastic waste.[99, 100]

Together, **incinerated plastics lead to the emissions of 4,072 tons of CO_2** -eq (Figure 27). The polymer with the highest climate change potential per kg at end-of-life is polystyrene, closely followed by polyethylene. Since polyethylene is significantly more abundant in Vejle's waste stream, recycling efforts should be targeted to recover PE waste (such as found in food packaging) from Vejle's residual waste (Figure 27). While not present in large volumes, also small amounts of incinerated PVC are a hotspot that should be addressed by the Municipality given the concerns of PVC burning for human toxicity and air pollution.

To tackle the identified hotspots and impacts of Vejle's current plastic streams, Vejle's vision for a circular economy for plastics needs to:

- Find **cross-cutting value chain solutions** to reduce the need for short-lived plastics.
- Significantly **increase the currently low reprocessing and reuse rates** of plastics, starting with packaging applications.
- Widen their scope of interventions to **reduce the upstream impacts** associated with the purchasing of plastics in local industries.
- Focus on the **removal of any remaining PVC**-containing products that are currently not sorted out from incinerable waste streams.

[99] Using MFA waste volumes for polymers sent to incineration
[100] Data from ecoinvent

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.2 Vision for a sustainable plastics sector in Vejle

A sustainable plastics economy can be defined as a system in which the production, consumption and end-of-life treatment of plastics is decoupled from environmental and human health impacts, as well as the use of finite resources.[101] **Plastics retain their value throughout their life cycle through measures of redesign, reuse, repurposing, and recycling** - made possible through the elimination of harmful and non-recyclable substances.

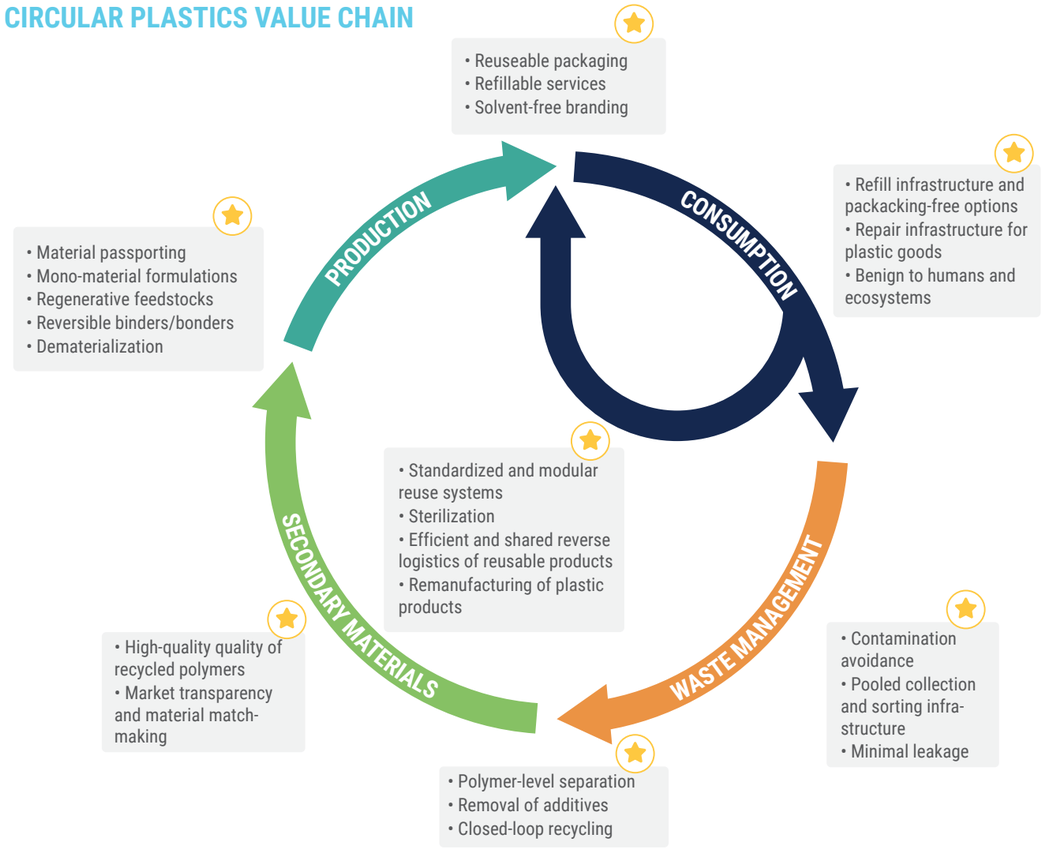


Figure 28: Circular plastics value chain

[100] The Ellen MacArthur Foundation. (2019). A Vision of a Circular Economy for Plastic.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

In line with National and European goals to create a sustainable and circular plastics sector, the City of Vejle is working towards the creation of methods and tools that support citizens, local companies, and the Municipality to **reduce virgin plastic production, eliminate waste, and increase recycling and reuse of plastic throughout the city.**

The Danish National plastics Action Plan[102] launched in 2018 contains 27 initiatives which aim to prevent plastic waste creation,[103] increase plastic recycling and recyclability, expand the deposit return system, and develop more circular consumption patterns of plastics in Denmark. In total the Danish government has allocated DKK 50 million in the course of four years to the plastics action plan. The National Climate targets[104] have set a requirement for 60% plastic recycling and sorting of 80% of Danish plastic from incineration by 2030.

In 2018, Denmark released the National Strategy for circular economy,[105] which outlines the transition pathway to a circular economy and its benefits for the competitiveness of Danish enterprises, consumers, and public institutions. DKK 4.1 million has been allocated to efforts regarding circular economy and chemicals in plastics aimed specifically at a follow-up to the EU Plastics Strategy. DKK 4 million has been allocated to having more products covered by the eco-label scheme along with efforts to increase knowledge about such schemes. DKK 6.1 million has been allocated to an effort supporting enterprises' innovation with regard to substitution of undesired chemicals in production and products such as PVC with better alternatives, among others to avoid chemicals in the plastics value chain with adverse effects on human health and the environment -that are currently a barrier to circular economy.

Based on our research on the current state and hotspots within the plastics sector in Vejle, we have developed five strategic focal areas the City and REFLOW pilot team can take on to contribute towards their vision of a sustainable and circular plastics sector, as well as contribute towards the Danish national goals and European Directives regarding plastics:

- **Tackling plastics in Vejle's food value chain** to reduce and eventually eliminate problematic and unrecyclable plastics that are used by the food industry and retailers in the city.
- **Ensuring the responsible and sustainable use of PVC in construction and healthcare** by promoting proper management of soft PVC and substitution of toxic and non-recyclable PVC elements in the two sectors.
- **Increasing the effectiveness of municipal waste management systems** through improved infrastructural and technical capacities of the recycling stations and promoting better waste sorting practices by citizens.

[102] Ministry of Environment and Food of Denmark. (2018). Plastics without waste - The Danish government's plastics action plan.
[103] Through actions such as ban on free plastic carrier bags and thin plastic carrier bags or criteria on reducing single use plastic at public events.
[104] Ministry of Environment and Food of Denmark. (2020). Klimaplan for en grøn affaldssektor og cirkulær økonomi (Climate plan for a green waste sector and circular economy).
[105] Ministry of Environment and Food and the Ministry of Industry, Business and Financial Affairs. (2018). Strategy for Circular Economy.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- **Building momentum for circular plastic use in businesses** in Vejle, spearheaded by the private sector and built upon transparent information on plastic consumption patterns by the local businesses in the city.
- **Building a culture of responsible plastics consumption** in Vejle which is co-created with citizens to equip "prosumers" to make environmentally sound consumption and purchasing choices.

3.3 Focus Area 1: Tackling plastics in Vejle's food value chain

3.3.1 Introduction

Based on the material flow analysis and impact assessment conducted for Vejle, unrecyclable, contaminated, and problematic food packaging emerges as a central leverage point to transition into a circular plastics economy. The embodied impacts associated with food packaging consumption in Vejle can be attributed to two main nodes along the food value chain.

First, **Vejle's local food industry purchases around 2,000 tons of plastic packaging** for the export of food items. With a local food industry dominated by five large players,[106] Vejle is uniquely positioned to reduce the upstream and downstream life cycle impacts of food packaging beyond the Municipality's boundaries.

Second, food retailers in Vejle continue to sell food products packaged in materials that cannot effectively be recovered by the Municipality's waste management system. Amongst the most problematic materials that are a priority to be phased out are **black plastics, multi-layer packaging, EPS trays** for meat and cheese, and small but relevant shares of PVC packaging. These packaging products are found in the 481 tons of food packaging that is incinerated as part of the Municipality's residual waste. Since **food packaging makes up a third of plastics in the residual waste**, it is one of the largest drivers behind the CO_2 emissions associated with the incineration of plastic waste, emitting 1,344 tons of CO_2-eq per year..

To tackle plastics in the food value chain, local industrial buyers of food packaging, retailers, and consumers need to collaborate. Three emerging strategic directions for a circular food packaging system and related key action items are presented below.

3.3.1 Strategic direction 1.1: Ensuring that non-recyclable, problematic, and toxic plastics are removed from food value chains

In order to increase recycling rates, enable high-quality recycling, and reduce the embodied impacts of incineration, problematic and non-recyclable plastic packaging should be substituted and removed from local food retailers.

Since black plastics, polystyrene packaging, PVC, and multi-layered films are amongst the most critical nuisances for local recycling systems, Vejle's actions should address these items first. Pilots within San

[106] Based on business data from virk.dk: These five players are: (1) Fertin Pharma, (2) DANPO A/S, (3) Danish Crown Foods, (4) DANE PORK and (5) DAN CAKE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Francisco and San Diego evidence that **bans on EPS, PVC packaging, and black plastics from products purchased through public procurement** can be an effective intervention pathway.[107] While such an effort in Vejle can become a key legislative measure taken by the City, it should be accompanied with a systematic search for better-performing alternatives.

To support local retailers and the dominant local meat processing industry in purchasing less black plastics, PVC, and multi-layered packaging, Vejle can strategically bring together members of local food outlets to share best practices in the procurement of recyclable alternatives across their in-house brands. Establishing a roundtable between the Municipality and industry before municipal ordinances are passed can ensure that retailers are educated about potential alternatives and the economic impact that a phasing out of these materials could have.

When creating a **city-wide roundtable of local retailers,** the Vejle pilot can build on its existing partnership with a local supermarket branch of REMA 1000.[108] With REMA's latest plastic strategy plan, the discounter has already committed to reduce the use of multi-layered components and non-recyclable packaging, and increase the procurement of recycled plastics used in their product line.[109] An **in-depth audit of REMA's** use of black plastics, PVC plastics, and unrecyclable multi-layered films, supplemented with an analysis of current barriers and opportunities for substitutions, is recommended to build knowledge before onboarding other retailers of the city.

Use-cases

- Sabic's Trucircle and Tesco partnership: The UK retailer uses the first recycled flexible packaging from materials returned by customers.
- Refucoat: EU project which develops fully recyclable food packaging as alternatives to modified atmospheric packaging.

[107] San Francisco banned all foam products, such as EPS, used in food containers.
[108] REMA 1000 is a leading discounter grocery chain in Denmark.
[109] REMA1000. (2018). Emballage- og plaststrategi 2018.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.3.3 Strategic direction 1.2: Reducing the need for single-use packaging in food value chains

Packaging-free solutions and new concepts of multi-use packaging play a key role in overcoming the challenges associated with single-use packaging in Vejle's food system. To date, the Vejle pilot has kicked off a partnership with REMA 1000 to test circular packaging solutions for candy tubs and flower pots, but to significantly reduce single-use packaging additional pathways for direct reuse need to be explored.

Building on the existing partnerships with REMA 1000, Vejle has a unique opportunity to finance more radical solutions for food distribution that make single-use packaging redundant. A key entry point which has already been successfully employed by other supermarket chains[110] could be the **trial of refill stations for dry goods and frozen vegetables, and the trial of reusable containers for fresh meat and cheeses.** Key in rolling out refill and reuse zones in local supermarkets is (1) winning user acceptance, (2) ensuring equal or lower prices to wrapped products, and (3) closely monitoring potential negative unintended consequences on additional food waste generation. UK grocery chain Asda[111] provides a food example on how to retain low prices and cooperate with suppliers in order to improve the model. Through targeted financial support for REMA 1000, Vejle can ensure the risk of introducing this new model is distributed between public and private partners. If successfully implemented, the Municipality can benefit from these investments through lower waste collection costs. To scale proven models, Vejle can **facilitate the cooperation and knowledge sharing between local food outlets.**

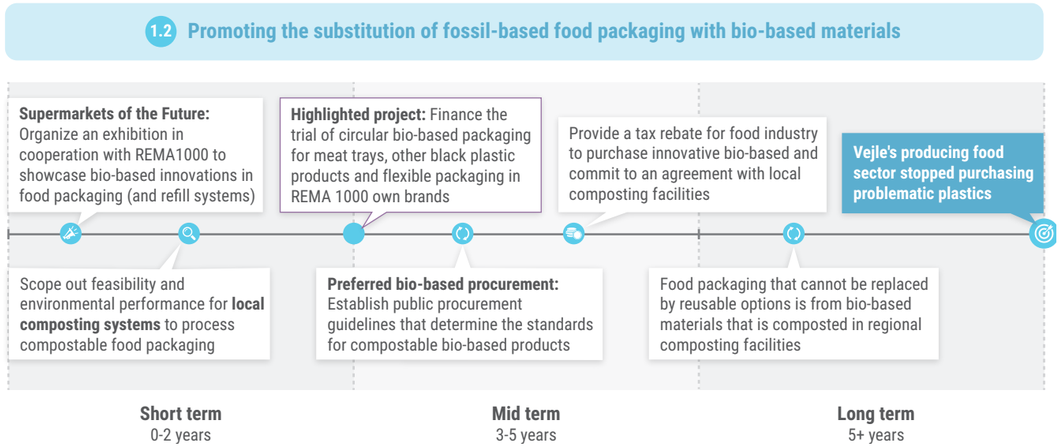
[110] Environmental Investigation Agency, G. (2021). Checking Out on Plastics III.
[111] ASDA. (2021). Asda Opens New Sustainability Store.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Since large-scale refill infrastructure requires the cooperation of upstream suppliers, the Municipality should work on identifying particular local and regional food value chains which may lend themselves well to test and scale reusable B2B or B2C packaging. Local and regional food value chains embrace those products that are produced, processed, and consumed in the close proximity to the city. Since Vejle's food industry is dominated by a few large food producers,[112] a **driving group to identify and experiment with reusable B2C and B2B packaging** should begin with these actors.

Use-cases

- Swap Box: Zero waste take-away system employed in five cities across the Netherlands and Belgium that does not require any deposits of extra fees for the consumers.
- Swedish Return System: A shared system of normed crates and pallets used across the Swedish food and drink industry.



3.3.4 Strategic direction 1.3: Assess potentials for substituting fossil-based food packaging with bio-based materials

Food packaging is largely composed of fossil fuel-based polymers which emit greenhouse gases during production and incineration, and accumulate in the environment due to their persistent properties.[113] To decouple plastic usage from fossil fuels, the substitution with compostable and biodegradable alternatives is gaining popularity. Bio-based packaging materials that do not use finite resources, do not contribute to marine and land littering, and can return nutrients to soils via composting. Under the right conditions, they can offer a viable pathway to reduce the environmental impacts of fossil-fuel based plastics. However, to

[112] DANE PORK, Danish Crown Foods, Danpo, and Arla Foods.
[112] FAO-UN; van Crevel, R. (2016). Bio-based food packaging in Sustainable Development: Challenges and opportunities to utilize biomass residues from agriculture and forestry as a feedstock for bio-based food packaging.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

reap the benefits of bio-based materials it is critical that Vejle carefully assesses and compares different waste management solutions.

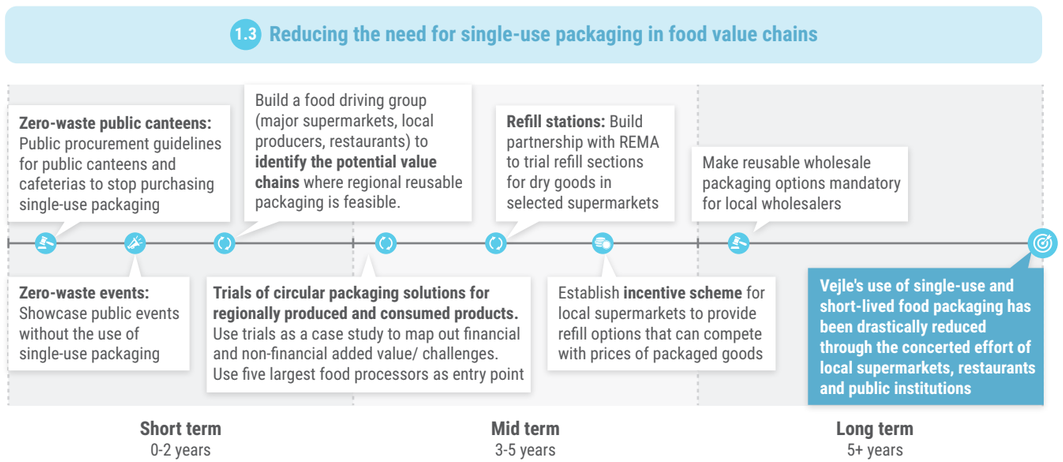
An indispensable first step for the City of Vejle, thus, is to conduct a **comparative life cycle analysis** that assesses the environmental benefits of (1) a composting scenario, (2) an advanced recycling scenario that can recover hard-to-recycle polymers, and (3) a baseline incineration scenario. This analysis could start with selected products, such as black plastics and EPS meat and cheese trays which are currently a significant nuisance to local recycling systems.

For those products where a shift to compostable materials is indeed environmentally beneficial, Vejle can use tax instruments and its procurement power to (1) incentivize the purchasing of non-fossil fuel packaging, and (2) to establish guidelines for public purchasing that prioritize bio-based materials where possible. Such a **"bio-preferred" purchasing program** was already implemented by San Francisco.[114]

Even long before legislative and large supply chain interventions can be realized, the Vejle pilot can already build momentum and public support towards sustainable bio-based food value chains. A visionary and engaging **exhibition that showcases the supermarket of the future,** for example, could build awareness about the multiple innovations in packaging that have already been trialed or adopted.

Use-cases

- Infarm: Infarm is a start-up providing vertical farming solutions for supermarkets, removing the need for non-recyclable flower and herb pots.
- Full Cycle Bioplastics: The bioplastics are waste-based and present a compostable plastic alternative.



[112] Ibid.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.4 Focus Area 2: Ensuring the responsible and sustainable use of PVC in construction and healthcare

3.4.1 Introduction

PVC - in particular soft PVC - is one of the most problematic polymers flowing through the Municipality of Vejle. While PVC only makes up around 2.5% of all polymers imported into the city (580 t in 2018), this share is responsible for two-thirds of air emissions generated in downstream production processes, and the **highest human toxicity potential** of all the known plastic polymers used in the city (Figure 27).

Two sectors, healthcare and construction, have emerged as hotspots of PVC consumption that targeted actions by the Municipality of Vejle can address. **The construction sector alone accounts for over 60% of all known city-wide PVC use,** and hence also their upstream environmental impacts. The majority of PVC building materials accumulate in the Municipality's building stock, especially PVC pipes for water and sewage which are not dug up during a demolition or renovation process and remain in the ground alongside new pipes. Thus, the expected impacts associated with the end-of-life treatment of PVC will emerge in the future.

Healthcare institutions are a hotspot since their albeit small volume of PVC carries a disproportionately large impact on human health and air emissions. The healthcare sector uses predominantly soft PVC in the form of disposable medical equipment, such as tubing, liquid solution bags, and blood bags. Soft PVC requires the addition of several plasticizers and additives during the production process which emit hazardous gases when incinerated.

To ensure responsible and sustainable use of PVC in Vejle, we propose two strategic directions that (1) support local healthcare facilities to improve the handling of PVC products through safe alternatives and innovative recycling schemes, and (2) build capacity in the local construction industry, including building material manufacturers, contractors, and builders to procure low-impact building products and substitute critical soft PVC.

3.4.2 Strategic direction 2.1: Ensure safe and responsible handling of healthcare PVC waste across the entire value chain

Soft PVC is one of the only remaining polymers that the Municipality of Vejle continues to send to landfill given the significant effects on air pollution associated with the production, use, and incineration of this material. Vejle's ambitions to move towards a sustainable and circular economy for plastics should be realized through actions that (1) support health care facilities to substitute PVC wherever feasible, (2) use their own procurement power in public health institutions to prioritize PVC- and DEHP- free medical products, and (3) encourage healthcare institutions to participate in **soft PVC recycling programs.**

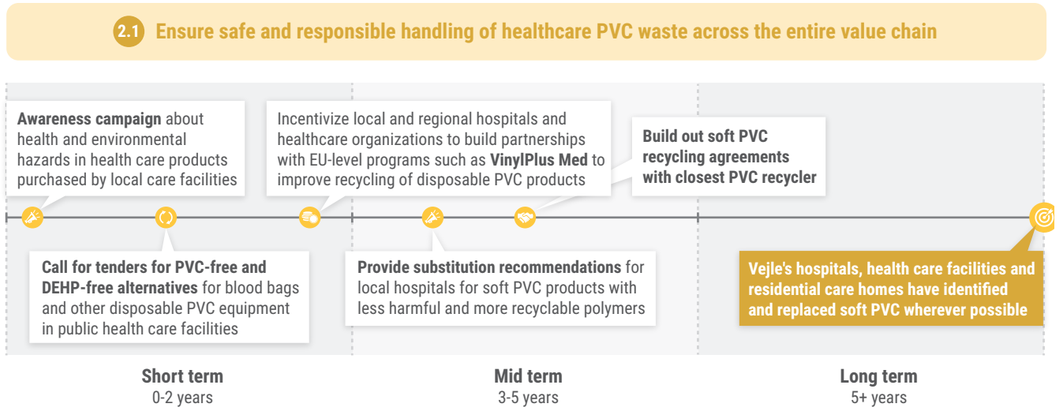
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

With respect to soft PVC substitution in medical healthcare products, Vejle Municipality first requires an in-depth understanding of which products currently contain PVC/ DEHP, and which viable substitutes exist. In publicly managed healthcare facilities, Vejle can identify those contracts ending in the near future, and submit **call for tenders for PVC- and DEHP- free solutions.**

While blood bags and PVC tubing are the product categories where PVC is most common, there are still very few market-ready solutions for alternatives. Therefore, parallel to the phasing out of harmful PVC products, Vejle's healthcare sector should also actively engage with national and EU-wide initiatives for soft PVC recycling, such as VinylPlus Med.[115]

Use-cases

- VinylPlus Med: VinylPlus and Europe Hospitals collaborated to develop a recycling scheme for single-use PVC devices.
- RecoMed: RecoMed is a UK recycling scheme that collects soft PVC from hospitals for reprocessing.



3.4.3 Strategic direction 2.2: Build capacity in local building industry to phase out soft PVC use

Vejle's local building sector is an important leverage point for ensuring the safe and responsible use of PVC. Which PVC-containing building products should be substituted by PVC alternatives, however, requires a careful comparative life cycle analysis. Existing analyses have indicated that the replacements of hard PVC in pipes,[116]

[115] Vinyl Plus. (2021). VinylPlus Med Accelerates Sustainability in Healthcare.
[116] Sustainable Solutions Corporation. (2017). Life Cycle Assessment of PVC Water and Sewer Pipe and Comparative Sustainability Analysis of Pipe Materials.

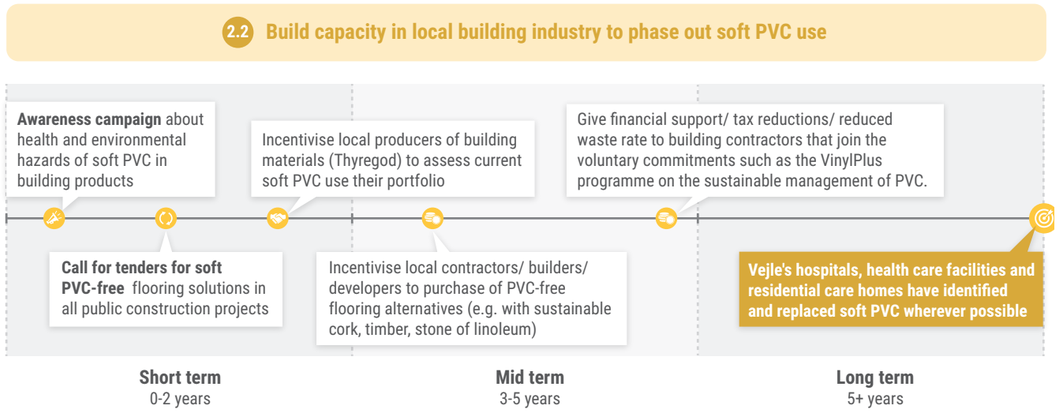
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

windows, gutters and shutters do not per se lead to lower environmental impacts compared to alternatives.[117] Environmental and human health impacts related to soft PVC are less ambiguous due to harmful additives and plasticizers, such as DEHP and phthalates, which are used in the production of soft PVC.[118]

Therefore, clear recommendations for phasing out all PVC from building products have to be designed with care. Instead, Vejle Municipality can support local contractors and producers of building materials to focus on phasing out soft PVC that may still be used in flooring or other building elements. A close **partnership with Thyregod**[119] - the Municipality's biggest producer of plastic building products - could serve as a starting point for assessing opportunities and barriers to phase of soft PVC from product portfolios.

Use-cases

- Building Green Knowledge Hub: The membership-based platform Building Green offers many educational resources, peer-to-peer support and product guidance, including information on PVC use and PVC alternatives.
- International Living Future Institute: The "Living Building Challenge" accreditation requires a strict standard for healthy and sustainable materials. To prepare building professionals to meet these requirements, the Living Future Institute provides in-depth guidebooks and databases on approved materials.



[117] Baitz, K., et al. (2005). Life cycle assessment of PV in product optimisation and green procurement.
[118] Jönsson, Å., et al. (1997). Life cycle assessment of flooring materials: Case study.
[119] Plastindustrien. (2021). Thyregod Bygningsindustri A/S | plast.dk.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.5 Focus Area 3: Increasing the effectiveness of municipal waste management systems

3.5.1 Introduction

An effective collection scheme is the first step towards improving the performance of the recycling network of Vejle. Based on the analysis of Vejle's waste management system, there are a number of drivers that currently reduce the environmental performance and effectiveness of current collection and recycling systems.

First, a large share of collected recyclables from households end up in incineration. In 2018, around 142 tons of PE, PP, and PET recyclables and 72 tons of recyclable foils were reprocessed by the city's contracted recycling partner. These two reprocessed streams, however, only constitute 19.5% of all collected plastic waste in the city's municipal curbside pick-up. An additional 300 tons of mixed plastics are recovered as a fuel substitute used for cement plants in Germany. This type of recycling is a downcycling measure, and leads to significant losses in material and economic value. Thus it is important the Municipality of Vejle prioritizes an alternative, higher-value recovery route for this stream. The remaining 53% of collected plastics in curbside recycling schemes are sent to incineration after sorting. This share of **mis-sorted, non-recyclable plastic waste generates around 1,370 tons of CO_2 emissions through incineration,** that is 11% of all greenhouse gas emissions associated with the incineration of Vejle's plastic waste.

Second, residual household waste collected from Danish households consists of around 12% plastic waste, including a large proportion of food packaging and non-food packaging (913 tons). To recover recyclable materials from residual waste, awareness raising campaigns need to focus their efforts on the current behavioural causes behind household waste sorting practices which lead to the mis-sorting of theoretically recyclable packaging. As an example, **food waste that is still in its packaging was found to make up 18% of Danish residual waste** - over half of this food packaging is made from plastics.[120] While not all food packaging is recyclable, food packaging composed of PET, HDPE, PP, and PS should be targeted for recovery in Vejle's recycling system since these polymers offer the highest potential to be reprocessed into food-grade and high-quality applications.[121] Vejle's strategy to build effective recycling systems, thus, should start with the user experience of **citizens to build knowledge on the bottlenecks and pressures** currently reducing the rate of reprocessed plastics into high-quality applications.

3.5.2 Strategic direction 3.1: Optimize sorting and recycling behaviour through citizen engagement

Citizen behaviour in sorting and recycling plays a central role in improving the effectiveness and performance of local recycling systems. The goal of this strategic direction is to (1) increase the amount of recyclable material recovered by reducing losses to residual waste streams, and (2) to reduce contamination and improve the quality of recovered recyclables in the Municipal recycling schemes.

[120] Edjabou, M. E. (2016). Composition of municipal solid waste in Denmark.
[121] Eriksen, M. K., et al. (2019). Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Engaging residents through awareness-raising and educational campaigns is already a central theme within the Vejle pilot. Based on our analysis and existing research, a few insights emerge that help to increase the effectiveness of these campaigns. As an example, studies on Danish household waste show that around **33% of all plastics in residual waste is food packaging.** Simultaneously, food waste that is still in its plastic packaging contributes over 9% to Danish household waste.[122] Thus, **targeting awareness campaigns** on food waste reduction, and on properly sorting out food waste from recyclable packaging can improve the quality of recovered materials - with the added side benefit of reducing the impacts associated with overproduction of food. Using **community-based norms in local campaigns** has been a proven approach to nudge pro-environmental recycling behaviour.[123]

To increase the quality of collected recyclates, Vejle is also encouraged to trial a separate food packaging collection system. **Sorting out food-grade plastics from non-food packaging can help to avoid contamination of high-quality polymers.**[124] This can ensure that high-quality polymers that are approved for food contact can retain their value, and become reintroduced into new packaging applications. A separate food packaging collection system could also be implemented at the retail level by implementing regulations for supermarkets that (1) ban the dumping of food waste in its packaging, and (2) require the sorting into food packaging and non-food packaging.

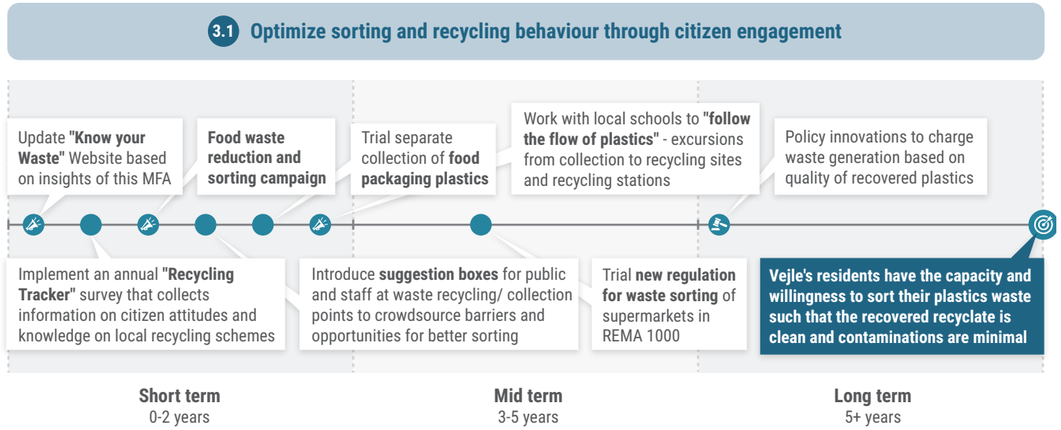
Over the long-run, Vejle's changes to local sorting systems paired with consumer awareness campaigns can result in **innovative waste fees** which are tied to the quality and degree of contamination of recovered polymers.

Use-cases

- Recycle Now: WRAP has launched a campaign in the UK aiming at increasing consumer awareness and changing recycling behavior.
- LeedsByExample: The city of Leeds has started a city-wide recycling campaign that successfully increased on-the-go recycling of citizens through the investment into recycling points and a local recycling reward system.

[122] Edjabou, M. E. (2016). Composition of municipal solid waste in Denmark.
[123] Linder, N., et al. (2018). Using behavioural insights to promote food waste recycling in urban households-evidence from a longitudinal field experiment.
[124] Eriksen, M. K., et al. (2019). Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



3.5.3 Strategic direction 3.2: Improve local infrastructure and technical capacity for short-loop recycling

Optimizing the infrastructure for post-sorting and recycling of plastic streams is another strategic direction to build out a circular plastic system for Vejle. To date, the city holds contracts with recyclers situated abroad which only **reprocess less than 20% of the city's plastic flows into high-quality resins.** While innovations in recycling infrastructure for current low-quality polyolefins exist, geographies and economies of scale are a barrier for a small municipality to develop advanced infrastructure for recycling. Thus, we recommend that the Municipality of Vejle pools their resources with surrounding municipalities, and starts with an in-depth comparative life cycle assessment of current collection and sorting schemes to identify potential optimization strategies.

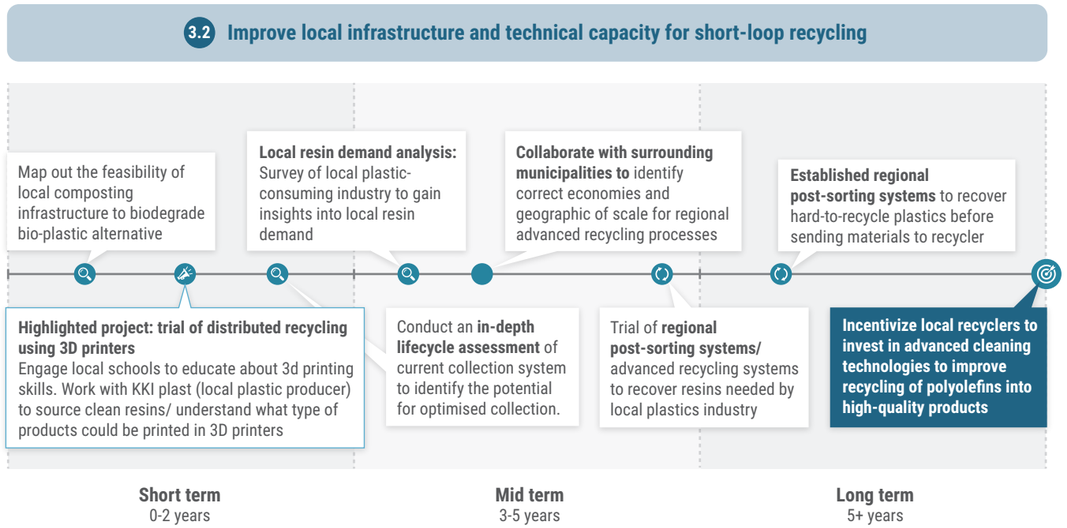
Two potential pathways to explore for the Municipality of Vejle are (1) the opportunity for short-loop recycling of polymers needed by the local industry, and (2) collaborate with surrounding municipalities for a joint waste solution that reaches economies of scale. Regarding the first pathway, Vejle can start with a **demand analysis of local industry** to identify which polymers a **regional post-sorting system** should ideally target. Based on selected partnerships with resin-purchasing industries, Vejle can subsequently trial how targeted polymers can be re-diverted and reprocessed into raw materials at a regional scale.

At a small scale, short-loop recycling can also be trialed as part of a citizen-driven education program on **3D-printers and their role in distributed recycling networks.** 3D printers have been used to recycle locally recovered resins into new products and support quick prototyping for local makers. KKI - a small company with expertise in plastic processing - could serve as an interesting partner in developing trials and experiments with short loop recycling via 3D printers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Use-cases

- Green Fablab Lorraine: The Green Fablab is an experimentation with closed-loop recycling of plastic waste collected from local secondary schools.
- Quality Circular Polymers: Through the investment of SUEZ and LyondellBasell, this state-of-the art closed-loop mechanical recycling facility that recovers high-quality PP and HDPE polymers from household packaging waste.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.6 Focus Area 4: Building momentum for circular plastic use in Vejle's businesses

3.6.1 Introduction

The transition towards circular plastic flows in Vejle calls for a close collaboration with local businesses and manufacturers. Vejle's private sector, including the local industry and other commercial enterprises, is dominated by many small to medium sized businesses. Since these stakeholders are not part of the Municipality's waste management system, information about the composition, volume, and type of plastic waste is lacking. It is estimated, however, that they jointly generate around 2,800 tons of plastic waste that is collected by private hauling and recyclers. Plastic shares in combustible and mixed waste from industry are assumed to amount to 9% and 14% respectively.[125] With around 1,830 tons of plastic sent to incineration, **plastics from the local industry are responsible for more than 30% of greenhouse gas emissions** from end-of-life treatment processes.

More uncertainty exists around the polymer composition of plastic products purchased for commercial uses or intermediate processing into exported goods. Figure 25 shows that around 98% of the unspecified and unknown polymers relate to those that industry further processes into goods and materials. An analysis of Vejle's local industry (excluding the primary plastic industry) suggests a great diversity in enterprises and manufacturers, increasing the difficulty to understand how much and what kind of polymers are purchased. Given the large amount of (unknown) plastics used by local industries, the life cycle assessment of the production phase in Figure 23 needs to be seen as a conservative estimation of embodied environmental impacts, showing the lower end of the possible impacts.

To reduce the emissions associated with the production and end-of-life treatment of plastics from the private sector, the Municipality of Vejle needs to build momentum amongst local businesses to ascribe to circular plastic consumption. As a public authority, Vejle's strategic directions to address private sector plastic consumption is twofold. First, the Municipality can increase the transparency and collective knowledge on the amount and types of plastics consumed by local businesses. Second, Vejle Municipality can support businesses to adopt circular plastic flows by building an enabling policy environment and strategically encouraging bottom-up innovation amongst businesses.

3.6.2 Strategic direction 4.1: Establish transparent information flows on plastic consumption in Vejle's private sector

Apart from a few larger industrial players, **Vejle's municipal economy is dominated by many small to medium-sized enterprises.**[126] Gaining knowledge on plastic consumption patterns and waste creation across Vejle's diverse SMEs and B2B value chains would allow the city to identify, and reutilize additional large commercial plastic streams that are currently unknown.

[125] Danish Environmental Protection Agency. (2019). Analyse af nationale plaststrømme i landbrug.
[126] Based on business registry virk.dk

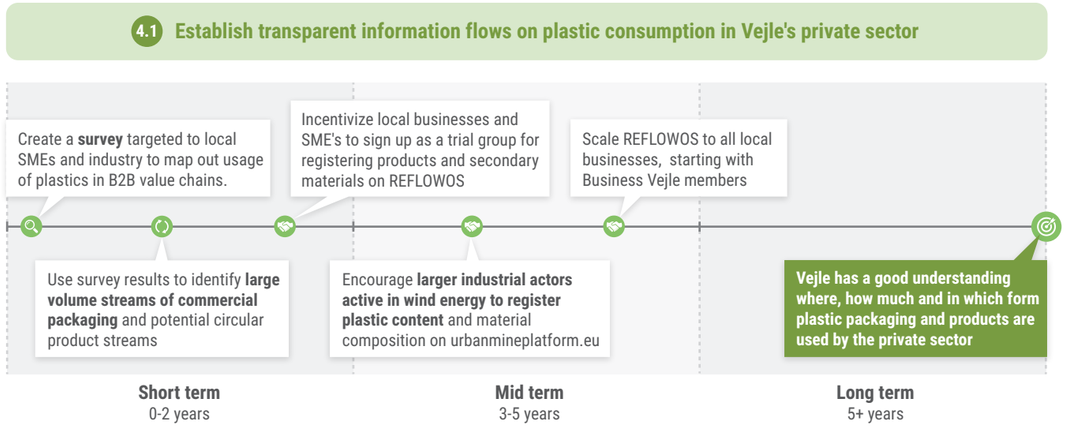
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

In the long-run, Vejle can **encourage local businesses and small industries to utilize REFLOWOS**[127] as a platform to support the creation of new partnerships, circular value chains and material exchanges. Before REFLOWOS is fully developed, Vejle can already work with selected local businesses to trial the operating system, and to **craft financial incentive schemes that encourage participation amongst businesses.** Vejle's local business association "Business Vejle"[128] can play a key role in building buy-in amongst its members to participate in REFLOWOS. A preparatory survey of business members that takes stock of large commercial plastic streams, for example, can help pave the way towards REFLOWOS to build initial information on plastic usage in the private sector.

Taking inventory of commercial use of plastics and plastic products can not only incentivize B2B material exchanges, it can also highlight where **municipal policy interventions** are needed to discourage the use of unrecyclable, problematic or single-use plastic products. As a hypothetical example, a survey of REFLOWOS may reveal a large-volume waste stream of plastic pallet wraps from wholesalers and retailers which the Municipality is currently unaware of. In this scenario, Vejle Municipality can directly provide financial support or reduced waste rates to companies willing to adopt reusable or better performing plastic alternatives.

Use-cases

- Urban Mine Platform: This open-source platform shows the material composition, and stock and flow of wastes of batteries, vehicles, and electronic equipment across the EU.
- US Materials Marketplace: The Marketplace is a platform for regional businesses and organizations to upload real-time data on available waste streams and by-products to support the matchmaking of material supply and demand.



[127] REFLOWOS (D2.2) is an operating system developed as part of the REFLOW project which should allow local communities to establish circular economic value chains between organizations within a municipality, region or city
[128] BusinessVejle. (2021). Forside - BusinessVejle.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

3.6.3 Strategic direction 4.2: Encourage local businesses to spearhead the transition towards circular plastics

Building transparency on plastic flows through the commercial and private sector is a starting point to encourage a transition towards more sustainable plastic consumption. But to reduce the environmental impacts of plastics originating from the private sector, the Municipality of Vejle needs to **build the technical capacity, awareness, and enabling networks amongst local businesses to increase the recovery and synergistic exchange of plastics.** Implementing an enabling regulatory environment that incentivizes local matchmaking between waste generators and recyclers is a critical step to begin with.

As part of awareness raising events in cooperation with Business Vejle, the Municipality can link local awards - such as the **"Well Done Award"**[129] - to best practices in plastics management adopted by the members of the association. To further build momentum amongst local businesses, Vejle can **financially support organizations to educate themselves** about problematic plastics in their portfolios, conduct **plastic audits,** and join global commitments such as the **Plastic-free Industry Commitment Mark.** Onboarding local waste service providers who exhibit expertise in the content and composition of business waste can help Vejle to offer targeted training sessions for local businesses.

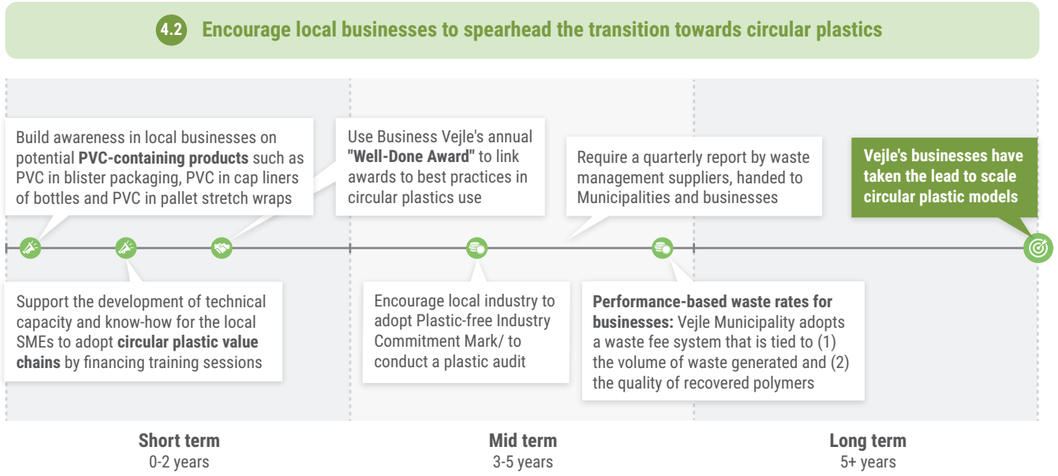
In the long-run, Vejle's actions in this strategic direction can aim to **adopt a hybrid waste fee system** that is tied to the quality (degree of contamination, percentage of low-quality polymers in recovered materials), and quantity of plastic waste sorted in local businesses. To enable sophisticated waste management policies, a close collaboration with private waste haulers and waste management suppliers is critical. **Diligent reporting on commercial waste characterization** and an ongoing dialogue between businesses and local waste haulers is a prerequisite for increasing the quality of recovered plastic streams.[130]

Use-cases

- The 3R initiative: The 3R initiative works towards higher recycling rates of corporate plastic waste via a plastic credit system that incentivizes companies to invest in plastic recovery and infrastructures.
- Plastic-free Certification Marks: A Plastic Planet developed two certifications that businesses can apply for in order to demonstrate their commitment to phase out their dependency on fossil-based plastics.

[129] Business Vejle gives out the annual "Well-done Award" to honor local companies for their good initiatives. BusinessVejle. (2021). Well-Done Prisen - BusinessVejle.
[130] Nilsson, H. (2020). Central upphandling av avfallstjänster.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



3.7 Focus Area 5: Building a culture of responsible plastics consumption

3.7.1 Introduction

Building a city-wide **culture of responsible plastic consumption** amongst citizens is key in achieving a circular plastic system in Vejle. Citizens are responsible for the largest share of plastic products and plastic-containing consumer goods imported into the Municipality of Vejle. Some of these plastic flows are fairly well-known, such as the composition and quantity of packaging that enters and leaves Vejle's households. Yet, there is still uncertainty around the types and exact amount of plastics contained in durable consumer goods, kitchen appliances, toys, furniture, and cars that are purchased by citizens (Figure 22). Despite these uncertainties, it is known that a significant amount of polypropylene (PP) ends up in durable consumer goods, cars, and transportation or other long-lasting products (in total 43%). PP contributes around 30% to the greenhouse gas emissions associated with the upstream production of known polymers consumed or processed in the Municipality. **Some plastic goods consumed by households are low in volume, but high in their impact.** For example, soft PVC - a highly problematic material that generates toxic air emissions during the production phase - can still be found in toys and flooring.

Consumption choices in supermarkets, local stores, and online have a direct effect on the overall embodied environmental impacts along the full life cycle from the production, consumption, and end-of-life management of consumer packaging and other lasting plastic goods. Reducing embodied impacts requires a shift in mindset and a significant transition of purchasing, consumption, and recycling behaviours amongst Vejle's citizens.

Three strategic directions emerge as a starting point to create a culture of responsible plastic consumption. First and foremost, Vejle can implement a set of actions that **create an inspiring narrative and a joint mission** to turn Vejle into a city with a circular plastic economy. Second, the **strategic education of citizens to become**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

responsible and aware "prosumers" can help citizens to make better, less environmentally harmful purchasing choices. Third, **citizens need to become an active part of shaping waste management systems** that meet their needs. For each of these three strategic directions, a suite of action items are suggested.

3.7.2 Strategic direction 5.1: Create an inspiring narrative and joint mission to move towards a circular plastics future for Vejle

While individual consumption choices in the supermarket or online affect the amount of plastics leaving Vejle's waste system, the **mission towards a circular plastics future for Vejle needs to be spearheaded by the Municipality itself.** By creating (and driving forward) a joint mission that frames plastic reuse and reduction as a common goal between public authorities, private companies, and citizens, Vejle can build an enabling environment for addressing plastic consumption systemically. The overarching goal in this direction is to systematically reduce the financial and mental threshold amongst businesses and citizens to purchase in line with the city-wide plastic mission.

Action items within this strategic direction aim at giving visibility to this joint narrative through targeted campaigns, and explicitly articulating the goals which the city seeks to achieve. The core messages communicated in this narrative should highlight that (1) a circular plastic economy requires partnerships between businesses, citizens, and public actors, (2) citizens can do their part by making use of incentives and infrastructure provided by the city, and (3) reducing and reusing plastics does not have to be more expensive nor inconvenient for citizens.

A starting point can be to **survey local grocery stores, bakeries, markets or other food outlets** on their willingness to accept reusable packaging options. The resulting list of businesses supporting Vejle's common mission can be consolidated as a public resource list, map, or website, as well as a "label" for participating businesses. Such a public initiative for packaging-free consumption in Vejle can follow a similar scheme as the Refill campaign that gives visibility to businesses offering free tap water refills.

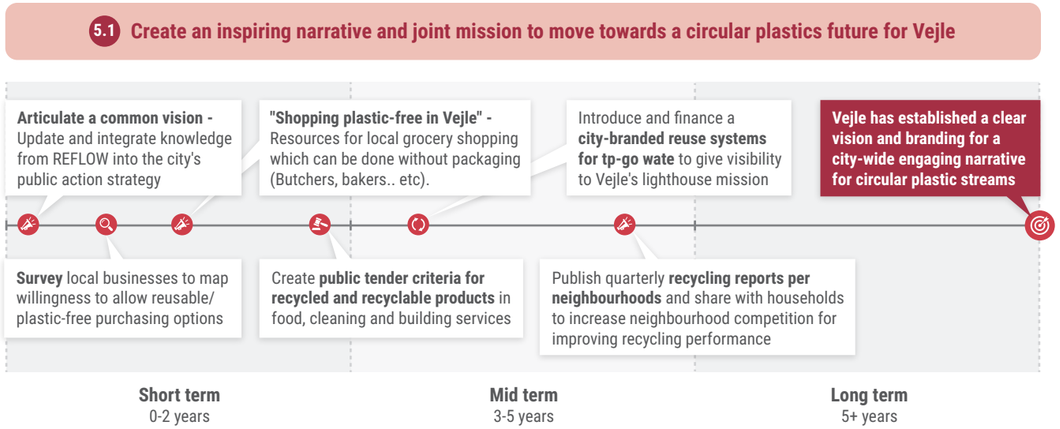
Vejle's joint mission towards higher recycling rates and less plastic usage can also profit from publishing **regular recycling reports at a neighbourhood scale.** Neighbourhood waste reports that comparatively illustrate the performance of each neighbourhood's recycling behaviour could serve a similar purpose as the already proven effect of friendly competition between neighbours to reduce energy consumption.[131, 132]

Use-cases

- CircularPP: CircularPP is using innovation procurement and capacity building to promote a circular economy and belongs to priority 1 "Capacity for Innovation" in the Baltic Sea Region.
- Refill: Refill is a global campaign against single use bottles which engage with local businesses eager to be a part of the Refill Revolution.

[131] Allcott, H. (2011). Social norms and energy conservation.
[132] Czajkowski, M., et al. (2019). Social norm nudging and preferences for household recycling.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



3.7.3 Strategic direction 5.2: Build citizen capacity to become responsible and aware prosumers of plastic products

The second direction in this thematic area focuses on building specific capacities in citizens to become responsible and aware prosumers of plastic products. Action items in this strategic direction highlight the need to **tackle plastic consumption in long-lasting applications,** such as kitchen appliances, toys, furniture, and building products which currently build up in Vejle's urban stock.

It should be noted that diverse socio-economic backgrounds as well as the absence of alternatives to plastics within some product categories limit the effectiveness of awareness raising on individual consumption choices. Nevertheless, Vejle can support citizens in extending the lifetime of long-lasting plastic appliances through targeted financial, infrastructural, and regulatory levers which facilitate citizen activities in **repair, reuse, and remanufacturing of consumer goods.**

Harnessing existing initiatives on repair and reuse, such as the Spinderlihallerne[133] Repair Workshop, Vejle Municipality can organize local repair events for used kitchen appliances, electronic devices or other plastic-containing consumer goods that often end up in local recycling stations. An interesting future pathway to explore is how the repair and upgrading of consumer goods can be financially incentivized via (1) **tax rebates** on repair and reuse services, or (2) the introduction of a local eco-credit system that awards the participation in reuse and repair schemes.

Vejle can also begin to set up local capacity to retrofit and upgrade some of those consumer products which are usually not considered part of the plastic challenge. For example, newly purchased cars and machines contain a significant amount of plastics that are currently building up in Vejle's urban plastic stock. While still

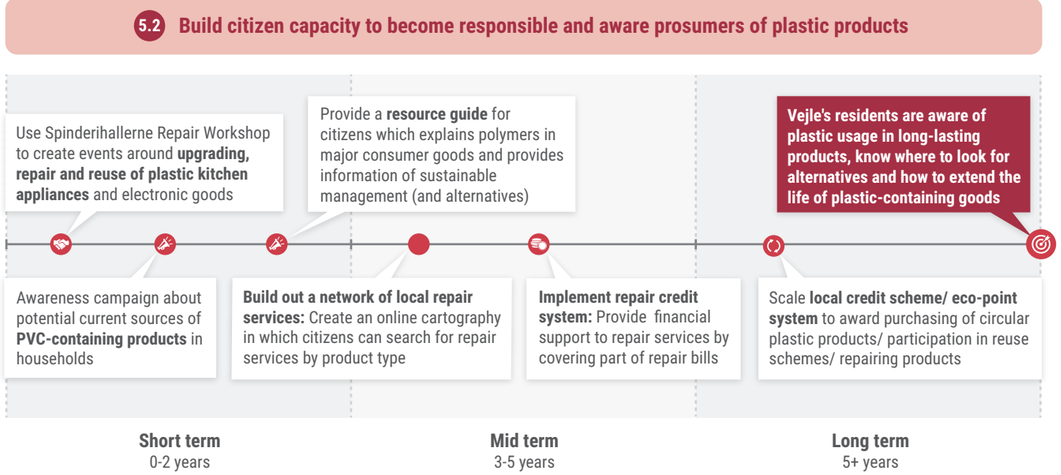
[133] Spinderihallerne.dk. (2021). Innovations- og udviklingsmiljø - Spinderihallerne.

in its infancy, a range of local businesses and technicians across the world[134] have started to retrofit old cars with electric engines, thus, both accelerating the shift to a renewable energy transition[135] and reducing the need of raw materials - including plastics - to manufacture new vehicles. By financing local businesses or initiatives to build out retrofitting capacity, and testing converted electric vehicles, Vejle would acknowledge that **shifting towards a sustainable plastic economy can further drive forth a more fundamental transition towards a low-carbon future.**

Simultaneously to the expansion of repair and reuse infrastructure, Vejle can also build citizen awareness on problematic and unrecyclable plastics in consumer goods and establish a list of resources with information on alternatives.

Use-cases

- CIRC4Life: The EU-funded project trials the effectiveness of an eco-credit scheme to achieve pro-environmental behaviour.
- Reparaturbon Vienna: Vienna created a city-wide network of repair services, and established a subsidy system that pays 50% (up to 100€) of the bills on repair activities. Participating businesses receive 50% as direct support from the city. Per year, the city saves around 880 tonnes of waste.
- Repair Café: The website provides examples of activities for repairing kitchen utensils.



[134] Examples of start-ups, businesses and DIY initiatives are IAN Motion, DIYev, or Complete Coach Works
[135] Aggarwal, A.; Chawla, V. K. (2021). A sustainable process for conversion of petrol engine vehicle to battery electric vehicle: A case study.

3.7.4 Strategic direction 5.3: Involve citizens in co-creating circular systems

A last key strategic direction for Vejle should emphasize activities that increase the participation of local residents in the development of effective and user-friendly circular systems for plastic materials. The goal of this direction is to **learn from citizens about current perceived barriers and opportunities** that would support them in purchasing less plastics, and to engage them directly in the optimization of local recycling systems.

Creating circular plastic flows require detailed knowledge of the current attitudes, barriers, and incentives which influence local citizen purchasing and recycling behaviour. An annual survey supplemented by suggestion boxes in key locations (e.g. local supermarkets, recycling centers, recycling bins) can be a good starting point to monitor how citizens respond to Vejle's interventions in local plastic waste management. Based on identified bottlenecks, concerns, and challenges concerning both plastic packaging consumption patterns and recycling, Vejle can subsequently **engage locals, students, and entrepreneurs** to find design-driven solutions via hackathons or competitions.

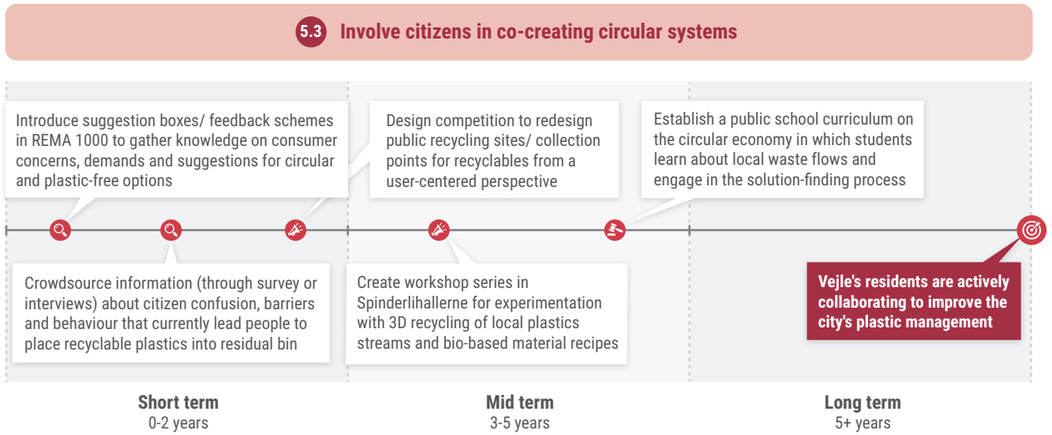
Existing analyses and interviews at the pilot site of Dem Gamle Gård can already provide initial material for citizen engagement in the user-friendly design of recycling sites. A local design competition for high-school students - or other target groups - can engage young people to develop a better understanding of current recycling practices and translate these into a design solution. On a larger scale, New York City has engaged in a similar design competition to collect proposals for the redesign of public waste bins. Targeting local schools is advantageous because they can integrate design challenges as part of a curriculum on waste management and urban metabolisms. Other activities in such a school program can (1) organize excursions that follow the flow of plastics throughout the city, and (2) a hands-on workshop component that teaches students biofabrication of alternative materials to plastics.[136]

Use-cases

- BetterBin Competition: New York City's competition was used to achieve their Zero Waste mission by crowdsourcing design ideas for a user-friendly recycling bin in public spaces.
- Materiom: Materiom is an open source platform with material recipes using abundant bio-resources and waste products.
- Circular Economy teaching materials: The Finnish Innovation Fund Sitra has compiled a range of resources to integrate circular economy skills into schools.

[136] Materiom's recipe database for biomaterials can be used as a resource for such activities.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



3.8 Relevance for pilot activities

The Vejle Pilot's action plan and Theory of Change outline the key activities that will be done during the period of the REFLOW project to promote and **achieve a reduction of plastic waste and an increase in plastic recycling in Vejle.** To communicate how and where Metabolic Institute's urban metabolism analyses and resulting recommendations directly support the Vejle pilot's planned activities, desired outcomes, and impacts, we mapped out all touchpoints between the Theory of Change and our proposed five focus areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

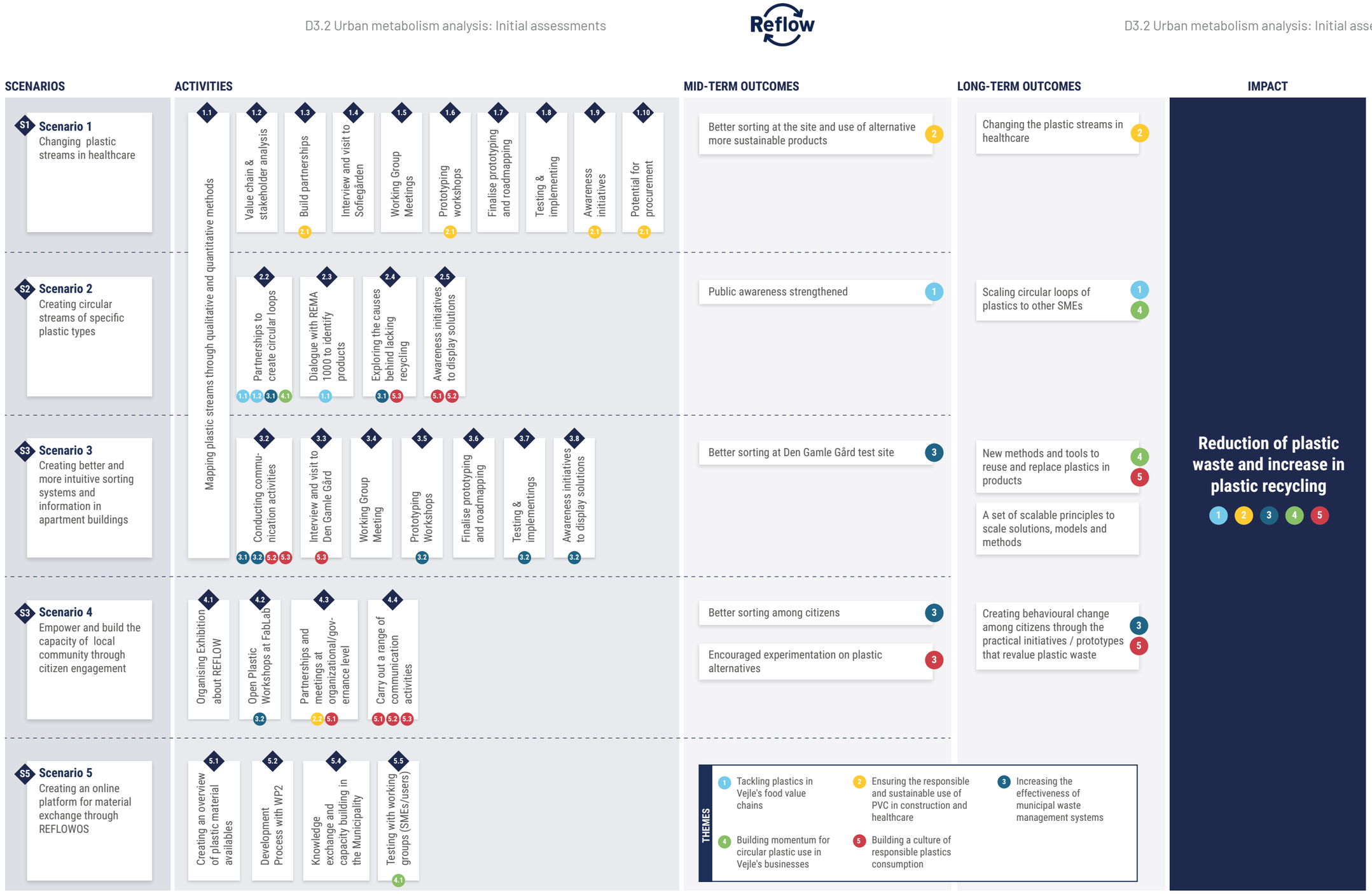


Figure 29: Touchpoints between the Vejle Pilot's Theory of Change and the proposed focus areas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

4. PARIS

4.1 Introduction to Paris' timber sector

4.1.1 Background and scope of the analysis

Paris is the capital of France, located in the center-north of the country. The city is the economic and political center of France. The Municipality hosts 2.15 million inhabitants, while the wider region (Ile-de-France) has a total of 12.28 million inhabitants, accounting for almost one fifth of the French population.

Paris is an international city, and one of the most visited destinations in the world, both for tourism and business. Over the last decade, over 30 million people visited the capital every year. Paris hosts many international events and professional fairs. This international host status will only be reinforced in the next few years as the capital will host the Summer Olympics Games in 2024. The event sector, although immobilized over the last year due to the Covid-19 pandemic, is therefore very large, considered to be a significant producer of waste, and represents an important logistical challenge for the City. The Paris pilot within REFLOW focuses on the wood waste generated from the event industry and temporary construction projects within the city. Currently, there is a lack of technical solutions, circular business models, and adequate regulation for the management of this waste.

Paris Municipality has developed its strategy towards a circular economy, aiming to create a "sustainable, cohesive, responsible and resilient city."[137] The plan revolves around five key areas: (1) planning and construction, (2) reduction, reuse, and repair, (3) support for actors, (4) public procurement, and (5) responsible consumption. The REFLOW Paris pilot works therefore in close relation to this city-wide strategy, exploring solutions in the management of wood waste produced from events and temporary construction taking place in the city. As a result, the City and REFLOW pilot share the common goal of transforming Paris' event sector by supporting circular events and circular temporary constructions.

During the implementation of the Paris REFLOW Action Plan, the policy landscape in France has evolved quite significantly in the domain of the circular economy. In January 2021, the so-called AGEC law,[138] an acronym roughly translating into "against waste for a circular economy," came into effect. The law expands the former Extended Producer Responsibility laws to new sectors, such as the construction industry -which is one of the largest wood waste producers at the national level. The law - targeting wood, mineral fractions, metal, glass, plastic, and plaster - demands newly quantified objectives and targets across these sectors for reuse, repair, recycling, and eco-design. The law includes incentive systems, such as visible labels for eco-design.

Within this context, the REFLOW Paris pilot is focused on qualifying and quantifying waste material flows in the event and temporary structure context, to be shared with reuse actors across the nascent circular economy

[137] MAIRIE DE PARIS. (2017). Circular Economy Plan Paris.
[138] Légifrance. (2020). LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

industry. Once identified and quantified, material flows can be captured by reuse actors and incorporated into sustainable, circular supply chains. The Paris pilot team also seeks to build a circular economy approach to event waste management by creating a tracking system to coordinate the use and reuse of materials involved in the trade fair sector and temporary structures. To gain insights into the event industry, the REFLOW team is partnering with the FIAC,[139] a large international annual art fair.

At a more practical level, the Paris pilot set out to focus on specific timber flows in the event and temporary construction industry to develop new models and digital tools to facilitate the reuse of wood materials and products and to accelerate the transition of these sectors toward circular models. The pilot aims to prototype and test digital tracking and scanning tools that leverage computational design techniques in their incubator Driven x REFLOW.[140] These tools will not only support the monitoring of wood materials, but facilitate their reintegration into manufacturing processes and extend their life cycles. Through their incubator, the pilot also aims to develop tools capable of generating databases of wood products to support the development of an agile digital marketplace to increase exchange between the event and temporary construction sectors. An important focus for the pilot team is to develop robust business models around digital tracking tools to support the nascent circular event industry. Through these circular digital wood innovations, and through the pilot's awareness-raising efforts among event industry actors, the pilot aims to drive the transition towards a circular event industry.

Scope and Method of the Material Flow Analyses (MFAs)

Metabolic Institute conducted two Material Flow Analyses (MFAs) in order to support the Paris pilot team in (i) assessing the city-wide and event-specific wood flows, and (ii) identifying high-potential interventions the City and the REFLOW Paris pilot can take on to improve the circularity of timber flows across the region and the event sector.

A city-wide timber MFA was developed by Metabolic Institute to map and quantify the flows of timber and wood products across the value chains that supply Paris and its wider region Ile-de-France with wood products. The analysis aimed to provide a first understanding of the state of the urban wood system. This MFA provided a top-down yet granular image of Paris' and Ile-de-France's wood system to support the Paris pilot in developing its different scenarios and intervention areas. The city-level material flow analysis is representative of annual wood flows in Ile-de-France, in 2017. The main data sources used to produced this MFA include:

- Local timber production in Ile-de-France from the Regional Forest and Timber Plan[141]
- Local timber processing and manufacturing, and timber products imports from a regionalized timber biomass flow model[142]

[139] Fiac! (2021). Foire internationale d'art contemporain, 21-24 octobre 2021, Paris, Grand Palais Éphémère.
[140] Driven. (2021). Driven by Volumes – Computational Design x Circular Economy.
[141] DRIAAF. (2020). Le programme régional de la forêt et du bois d'Île-de-France.
[142] Flux-biomasse.fr. (2021). Modèle forêt-bois 1.2 - France et Régions - Sankey + données au format excel.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- Urban mining model for Ile-de-France by Augiseau (2017)[143]
- A European furniture dataset from the European Environmental Bureau[144]
- Regional waste collection and treatment datasets and reports from ORDIF,[145, 146, 147] Ile-de-France region,[148] and ADEME[149]

Once the Paris pilot developed a strong partnership with FIAC, a second MFA was carried out by Metabolic Institute to provide a granular and bottom-up analysis of wood flows going through the FIAC event of 2019. The scope and focus of this second MFA was developed through a co-iterative and highly interactive process with the Paris pilot team and FIAC stakeholders to ensure strong alignment with the pilot's and its partners' core objectives. The temporal scope of the MFA was set to the duration of the FIAC 2019. As part of this process, and to improve the granularity and accuracy of the results, the FIAC provided bottom-up data, including:

- Procurement inventory of FIAC 2019 of all structures during the event (including origin of products, volumes, and separation rate at the end of the event)
- Technical descriptions of materials and products used in the event structures
- Sustainable certification documents for event structures
- Procurement inventory of FIAC 2019 of all furniture pieces
- Furniture products catalogue, with technical descriptions of each furniture piece
- Waste collection and separation surveys from FIAC 2019

The analysis benefited from multiple rounds of interviews with the event organizers, as well as frequent communication with FIAC suppliers.

Additionally, Metabolic Institute conducted a preliminary environmental analysis of the wood products flowing through the region, specifically looking at the carbon-storage capacity in the built environment, the current waste management practices at the city-level, and at problematic wood materials at the event-level. For the carbon calculation, the main sources included:

- A carbon analysis, with different GHG emissions projections from the Metropole du Grand Paris[150]

[143] Augiseau, V. (2017). La dimension matérielle de l'urbanisation. Flux et stocks de matériaux de construction en Ile-de-France.
[144] Forrest, A., et al. (2017). Circular Economy Opportunities in the Furniture Sector.
[145] ORDIF. (2013). Les DAE non dangereux produits en Île-de-France : Industrie, commerces, services.
[146] ORDIF. (2017). LA GESTION DES DÉCHETS MÉNAGERS ET ASSIMILÉS EN ÎLE-DE-FRANCE - DONNÉES 2017.
[147] ORDIF. (2014). LES DÉCHETS D ' ÉLÉMENTS D ' AMEUBLEMENT MÉNAGERS ET PROFESSIONELS.
[148] Ile-de-France (2019). Plan Régional de Prévention et Gestions des Déchets
[149] Guinard, L., et al. (2015). Évaluation Du Gisement De Déchet Bois Et Son Positionnement Dans La Filière Bois/Bois Énergie.
[150] Métropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- A report on the French wood construction sector and its evolution based on different scenarios by CODIFAB and France-Bois-Forêt[151]
- Local forest datasets from the Regional Forest and Timber Plan

For the environmental impact of problematic wood products in the FIAC event, the main sources were:

- Life Cycle Inventory from Ecoinvent 3.6[152]
- Several LCA reports available for alternative materials[153]
- ReCiPe characteristization factors from RIVM[154]

4.1.2 Current System and its Impacts

Material flow analysis for the Ile-de-France region

The city-level timber MFA has highlighted that the vast majority of wood products can be found in the urban stock as construction elements, with a total **46 Mtons of wood found in Ile-de-France.** An additional **2,000 Mtons** of wood is stored in the wooden furniture of the region's residents.

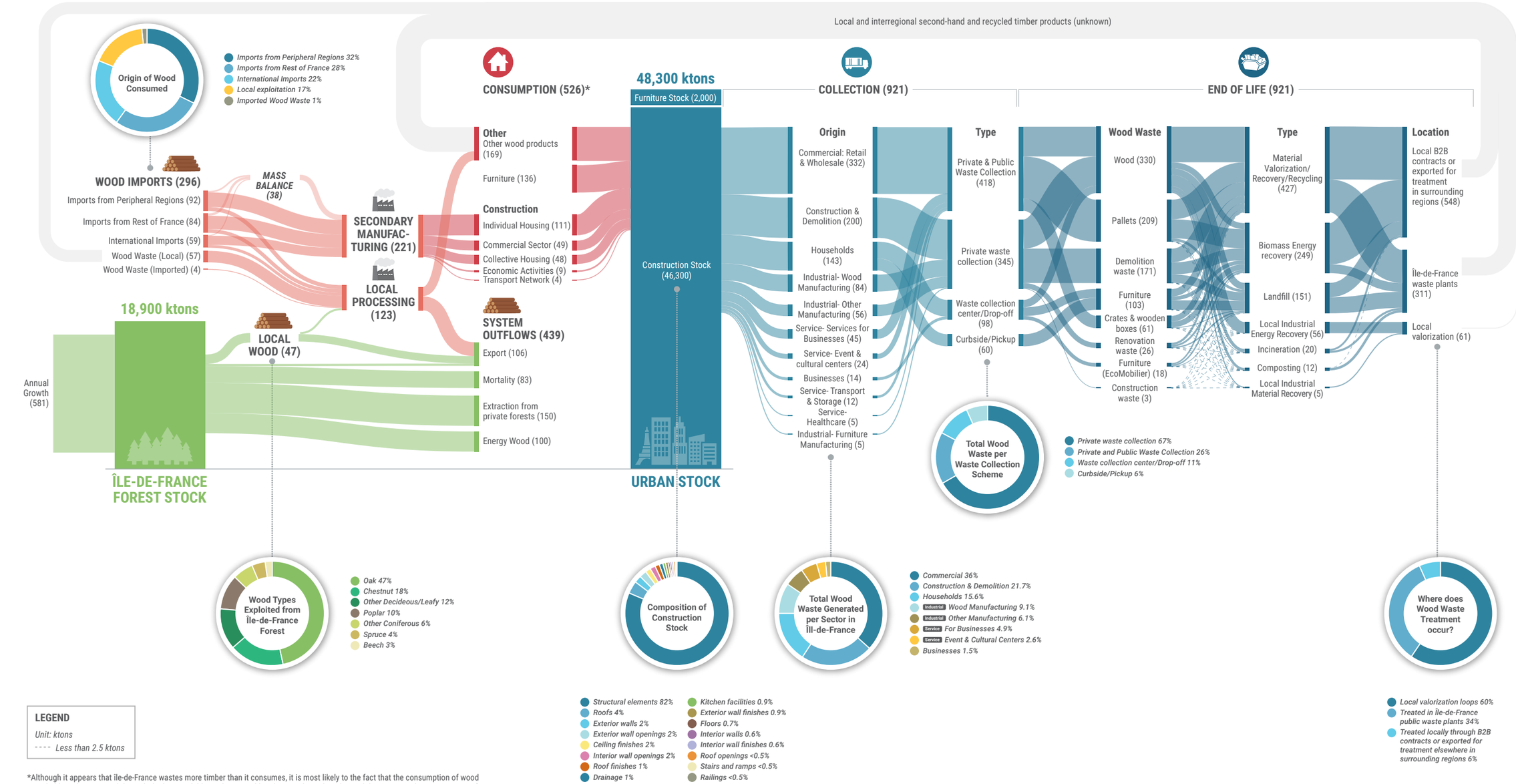
As the analysis focuses mostly on lumber wood and timber products, the very large quantities of wood for energy are not included in this sankey diagram. The inflow of wood elements and products for construction purposes represents one of the largest wood inputs into the region of Ile-de-France with at least **220,000 tons of wood for construction consumed on an annual basis.** The majority of wood elements (72%) for the construction sector are used to build both **individual and collective housing.** Around **136,000 tons of wood-based furniture** are purchased, mostly by the region's residents (82%), but also by local businesses (18%). At least **169,000 tons** of other wood products (including at least 39,000 tons of wood packaging) and goods are brought into the region (although this number is most probably underestimated due to very limited data on commercial consumption of packaging and other wood products (except furniture) at the regional level).

The MFA also includes the regional forest stocks and wood flows. The analysis has illustrated that the stock of wood in Ile-de-France forests is also significant, with **19 Mtons of standing wood biomass.** This represents about **40% of the volumes** of wood stored in Ile-de-France's buildings. The wood flow analysis from the forest highlights the low exploitation of Ile-de-France forest resources. Only a little more than half (~53%) of the annual biomass growth is harvested. From the harvested wood, half is harvested by private landowners to be used as wood fuel, a third is harvested by wood companies for biomass energy products (e.g., wood chips), and only 15% is harvested as lumber for wood products (i.e., furniture, wood construction products). **Most of the timber harvested (80%) is directly exported** to other regions of France or abroad for their primary

[151] Cellule Economique de Bretagne. (2019). Enquête Nationale De La Construction Bois.
[152] Wernet, G., et al. (2016). The Ecoinvent database version 3
[153] Ecoboard International bv. (2021). Personal Communication (April, 2021).
[154] Huijbregts, M. A., et al. (2016). ReCiPe 2016 - A harmonized life cycle impact assessment method at midpoint and endpoint level. Report I: Characterization.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments



*Although it appears that île-de-France wastes more timber than it consumes, it is most likely to the fact that the consumption of wood is probably underestimated due to little data available on the second-hand regional wood market and data gaps on the consumption of timber by the private sector. The second-hand flow of timber products is illustrated but not quantified due to little data.

Figure 30: Sankey diagram of Ile-de-France timber MFA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

processing. This is due to a major gap in the current wood industrial fabric of Ile-de-France, a lack of sawmills. In the 1970s, the region boasted around 60 sawmills, but their numbers dwindled to around 5 sawmills capable of processing large-diameter hardwood trees. In 1970, these sawmills processed around 100,000 m^3 of wood whereas in 2016, less than 2,000 m^3 of wood was processed.

In terms of wood waste collection, the **commercial sector** (mostly retail) produces the largest amount of wood waste, with **332,000 tons of wood waste,** or around a third of the total volumes of wood waste in the region, on an annual basis. The vast majority of wood waste (81%) from this sector is composed of wood pallets. The **construction sector** is the second largest sector with **22% of the volumes (200,000 tons),** the majority (85%) stemming from demolition sites. This is followed by **households** with 143,000 tons, of which almost **75% is discarded wooden furniture.** The different manufacturing sectors (145,000 tons) are also a notable contributor of wood waste, especially the wood manufacturing sector (84,000 tons). Services and healthcare represent relatively smaller amounts of wood waste, although it can be noted that the event and cultural sector generates around 24,000 tons of wood waste in the region.

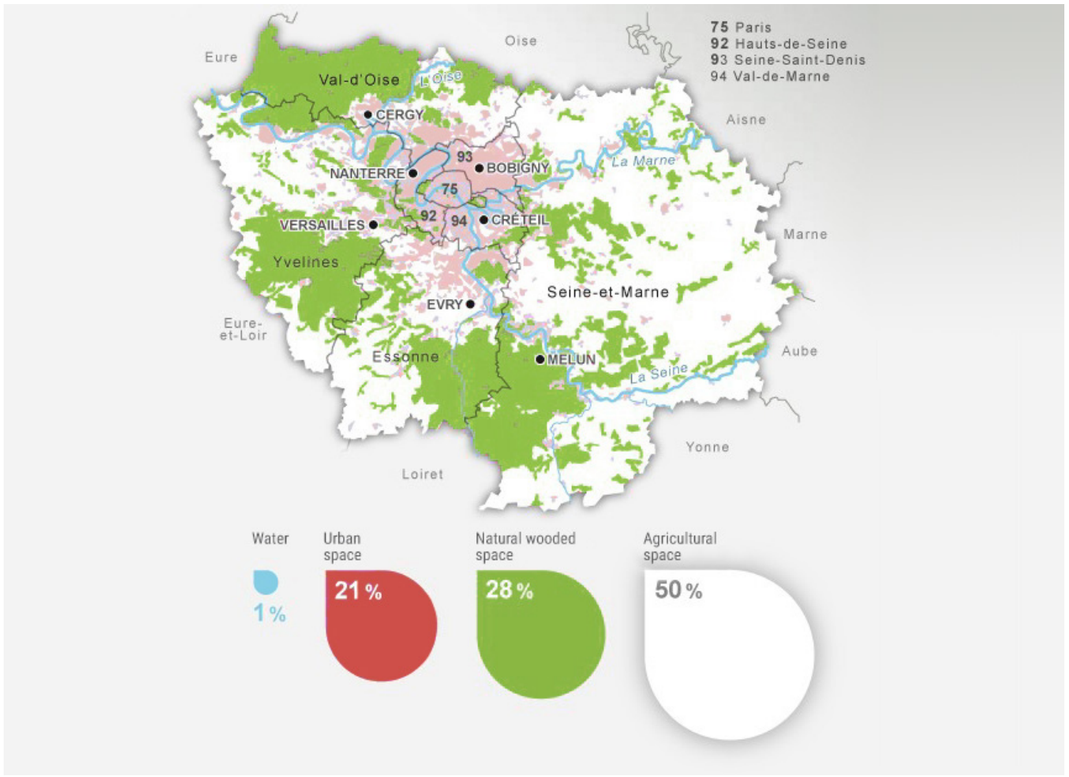


Figure 31: Ile-de-France region land cover types

From the **920,000 tons of annual wood waste** generated, **60%** is treated outside of Ile-de-France, in surrounding regions. In terms of waste treatment, almost half is downcycled into paper or shredded for future low-value wood products. **249,000 tons** of wood is **incinerated** to produce energy in waste-to-energy plants. **151,000 tons of wood waste still ends up in landfills.** 20,000 tons is incinerated without energy recovery, annually.

Ile-de-France Carbon Flows and Storage Analysis

Wood roughly consists of around 50% carbon, 44% oxygen, and 6% hydrogen, with traces of several other elements. [155] Thanks to the MFA, it was possible to conduct a carbon flow and stock analysis at the regional level. The goal of this analysis is to show the **carbon storage potential of the built environment in Paris and its region,** based on a variety of wood construction growth scenarios, and assess how much the wood construction sector can contribute to the region's climate targets, based on these different scenarios. The amount of CO_2 stored in wood can be calculated assuming the wood carbon content, the moisture content of wood and wood products, and using the molecular weight ratio between carbon and oxygen.[156]

The MFA illustrates that the Île-de-France forest contains around 19 Mtons of wood, mostly distributed across oak (sessile and pedunculate), chestnut, and resinous trees. The forest stores an estimated 34,302,000 tons of CO_2, with an annual CO_2 uptake of 1,100,000 tons (Figure 32). The release of CO_2 from the forest stock is mainly through trees being harvested for forestry products (79%), mostly intended for energy use, but also due to the annual tree mortality. A total 710,000 tons of CO_2 is estimated to be released during the energy use and the decaying process of the wood, meaning that a net-uptake of 390,000 tons of CO_2 is achieved by Île-de-France forests annually. In comparison, the urban stock adds an annual 810,000 tons of stored CO_2 in wooden products (assuming a moisture content of 15%) across construction materials (340 kt), furniture (210 kt), and other wooden products (260 kt). The Ile-de-France's urban stock stores an estimated 74 Mtons of CO_2, mostly in construction materials (71,000 kt), but also in furniture (3,000 kt) (Figure 32).

[155] Pettersen, R. C. (1984). The chemistry of solids.
[156] IPCC. (2006). Generic Methodologies Applicable to Multiple Land Use Categories.

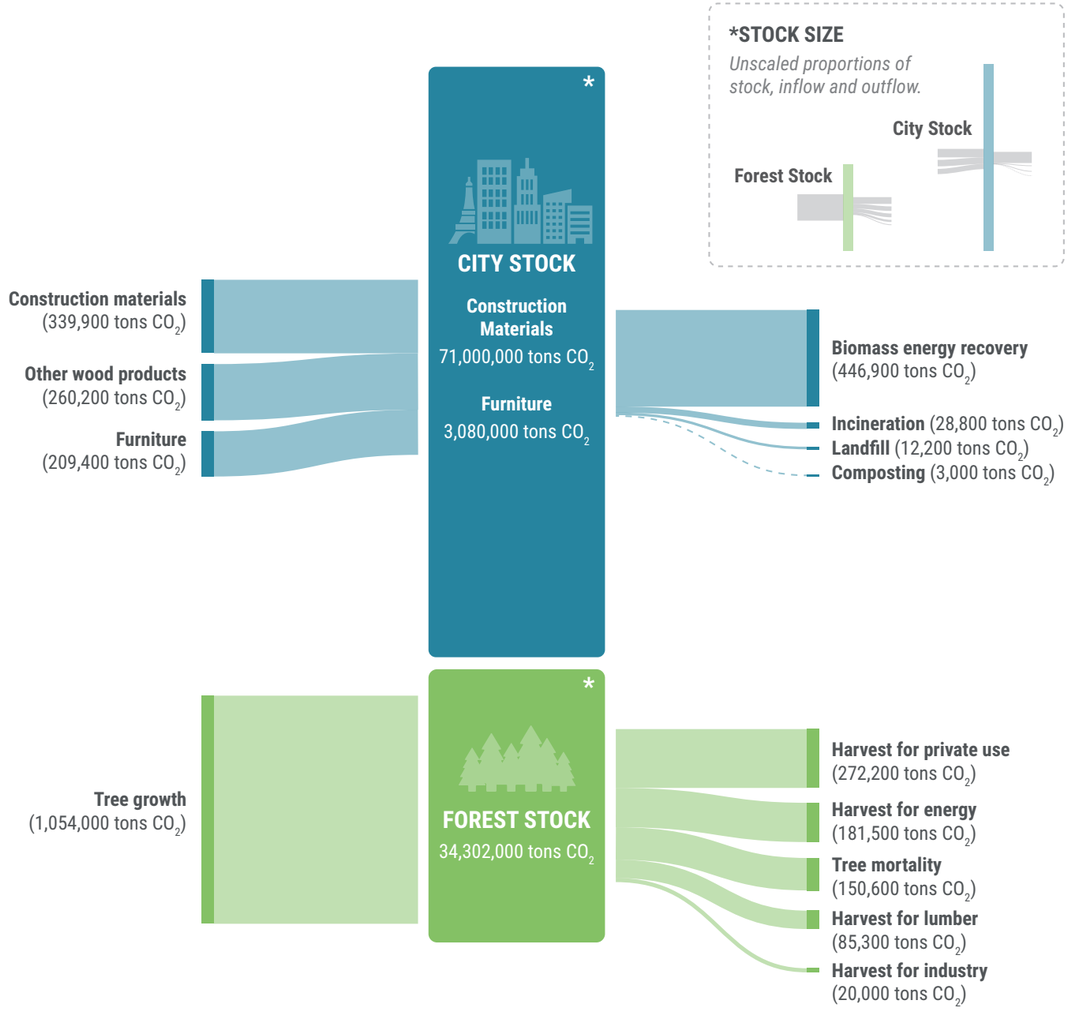


Figure 32: Carbon stocks and flows in Ile-de-France's forests and wood products and materials

Thanks to the MFA, the different volumes of wood waste and their treatment routes are known, which enables us to understand how much CO_2 is released during the end-of-life phase of wood waste in the region. Considering only the CO_2 directly released from the wood products[157] during the biomass energy recovery, incineration, composting, and landfilling processes, the total amount of CO_2 was quantified. The largest CO_2 release comes from the incineration in waste-to-energy plants of pallets, crates, and wooden boxes, representing

[157] Not during the different waste processes, thus excluding recycling and reuse.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

roughly **190,000 tons of CO_2-eq emissions** released. An additional 154,000 tons of CO_2-eq is released from the incineration with energy recovery (123 kton) and the simple incineration (23 kton) of wood waste. The wood waste from construction, demolition, and renovation activities, releases around **107,000 tons CO_2-eq** at the end-of-life stage, of which 103 kton CO_2-eq are released through **incineration** with energy recovery. Finally, furniture, which mainly comes from households, releases 43,000 tons of CO_2 while stored in landfill or incinerated.

With the wood-based construction sector in Ile-de-France[158] growing steadily in parallel to the French government pushing for an increasing amount of bio-based materials in the construction sector, wood construction is poised to play a key role in the construction and renovation sectors of Paris and its surrounding region.[159] It is therefore interesting to understand how it might affect the amounts of CO_2 stored in Ile-de-France's ever-evolving urban stock. Parallel to the wood construction sector growth, the region of Ile-de-France and the Métropole du Grand Paris, a regroupement of the largest municipalities in the region, have set ambitious targets for GHG emissions reduction from the built environment, focused on its Scope 1 and Scope 2 emissions.[160, 161] Their climate objectives are, by 2050, a reduction of:

- 75% of GHG emissions for the residential sector[162]
- 70% of GHG emissions for the industrial and private sector. With a more ambitious target of 75% for the services/tertiary sector[163]

At the national level, the construction industry has set a target to reduce 80% of the CO_2 impacts of its materials by 2050.[164] In essence, the carbon footprint of the construction sector represents the scope 3 emissions[165] of the Île-de-France and Métropole du Grand Paris emissions. The Metropole of Grand Paris concentrates more than half of the population and the majority of the GHG emissions.

[158] Cellule Economique de Bretagne. (2020). Enquête Nationale De La Construction Bois - Fiche Régionale: Ile-De-France.
[159] NECP France. (2020). Integrated National Energy and Climate Plan for France.
[160] Scope 1 (direct): Emissions of sources, which are owned and controlled by the company like for example the generation of electricity, heat or steam in owned or controlled boilers, emissions from physical or chemical processing, transportation of goods and fugitive emissions etc. The Greenhouse Gas Protocol. (2004). A Corporate Accounting and Reporting Standard (Revised Edition).
[161] Scope 2 (indirect): Emissions from the generation of purchased electricity consumed by the company, which occurs at the facility where electricity is generated. The Greenhouse Gas Protocol. (2004). A Corporate Accounting and Reporting Standard (Revised Edition).
[162] In comparison to 2005 baseline
[163] In comparison to 2005 baseline
[164] Daunay, J., et al. (2019). Neutralité & bâtiment - Comment Les Acteurs Du Secteur Peuvent S'Inscrire Dans Une Démarche Zéro Émission Netter.
[165] Scope 3 (indirect): All other indirect emission sources, which are caused by the activity of the company but not controlled by it, i.e. purchased materials or use of sold products. The Greenhouse Gas Protocol. (2004). A Corporate Accounting and Reporting Standard (Revised Edition).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

According to the climate monitoring report[166] of Métropole du Grand Paris, **there is currently a gap between their climate targets and their actual annual emissions** from the built environment (see Figures 33, 34). For example, based on the most probable emission scenario, the **emissions from the residential sector in 2024 will be 34% larger than the target for that year.**

As a result, Metabolic Institute investigated how much the wood-based construction sectors could contribute to bridge these emission gaps. Using four different scenarios for the evolution of the French wood construction sector by 2050[167] (see appendix B) we calculated the impacts of increasing wood construction in the region in terms of CO_2 stored in the urban area. We then compared these different volumes to the gaps in scope 1 and 2 emissions (target emission level vs actual emission level) of the Metropole of Grand Paris, for the years 2024, 2030, and 2050 for the residential and the service sectors. While this is a relatively simple approach to assess the mitigation role of the wood-based construction in the region, it helps further understand the order of magnitude of the role this sector could play in achieving climate mitigation targets.

In 2012, **the residential sector emitted more than 9 Mtons of CO_2-eq.**[168] Running the different scenarios, by 2024, all scenarios have similar impacts - with the annual wood construction and renovation flows helping bridge between 27% and 34% of the annual gap in GHG emissions, through the CO_2 stored in the wood structures. By 2030, the **business-as-usual (BAU) scenario,** which considers only current measures in place, would bridge only 11% of the annual emission gap anticipated in 2030, while **the ambitious scenario** (current + additional measures) would bridge 15%. **The carbon neutral scenario**, which considers aggressive measures to push the construction industry towards carbon neutrality and wood-based materials, would cover 15% of the annual emissions gap. The decrease of offsetting between 2024 and 2030 is due to an anticipated increased gap between the actual emissions and the target emissions in 2030. By 2050, the difference is more striking for each scenario. The BAU would only offset 15% of the gap, the ambitious scenario would cover 26% of the gap, and the carbon neutral scenario would cover **about 37% of the annual emission gap.**

[158] Métropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris.
[159] Cellule Economique de Bretagne. (2019). Enquête Nationale De La Construction Bois.
[160] Métropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

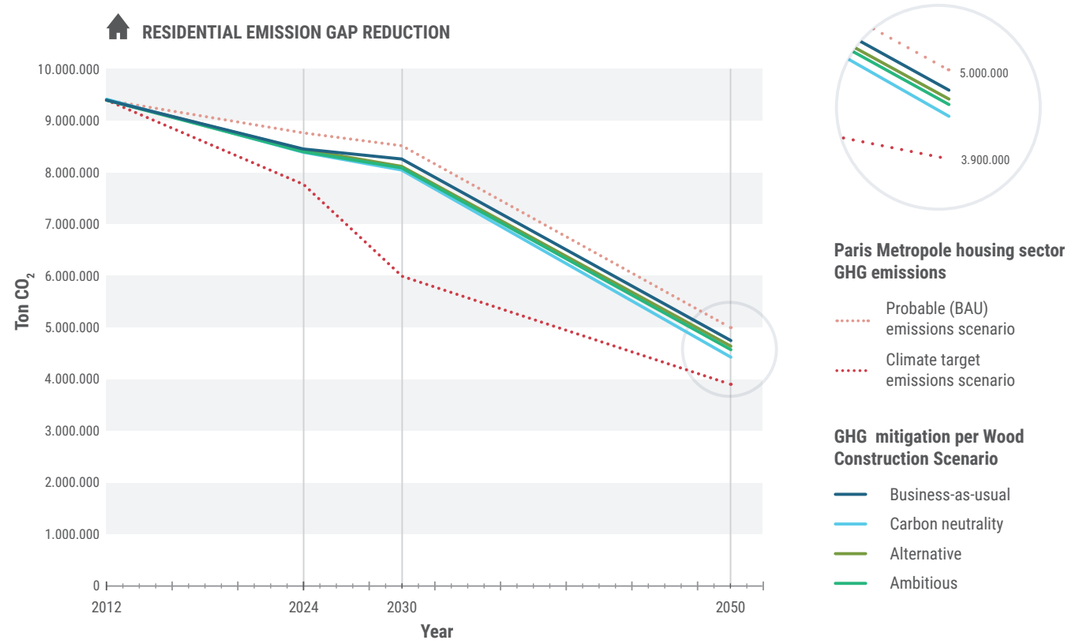


Figure 33: Residential building wood construction sector contribution in bridging Scope 1 and 2 emissions gap of Paris Metropole residential sector - depending on 4 scenarios for the wood construction sector

The buildings of the service sector emitted more than **5 Mtons of CO_2 in 2012.**[169] For the services sector, the reduction in the gap between the target and actual emissions of the business real estate in 2024 hover between 16% and 22%. By 2030, the **carbon neutral** scenario would fill 20% of the gap inemission, more than double than the **BAU** scenario (9%). By 2050 however, the **BAU** will only bridge 6% of the gap while the **carbon neutral scenario** will offset about **29% of scope 1 and 2 emissions** for offices and other business buildings.

[169] Métropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

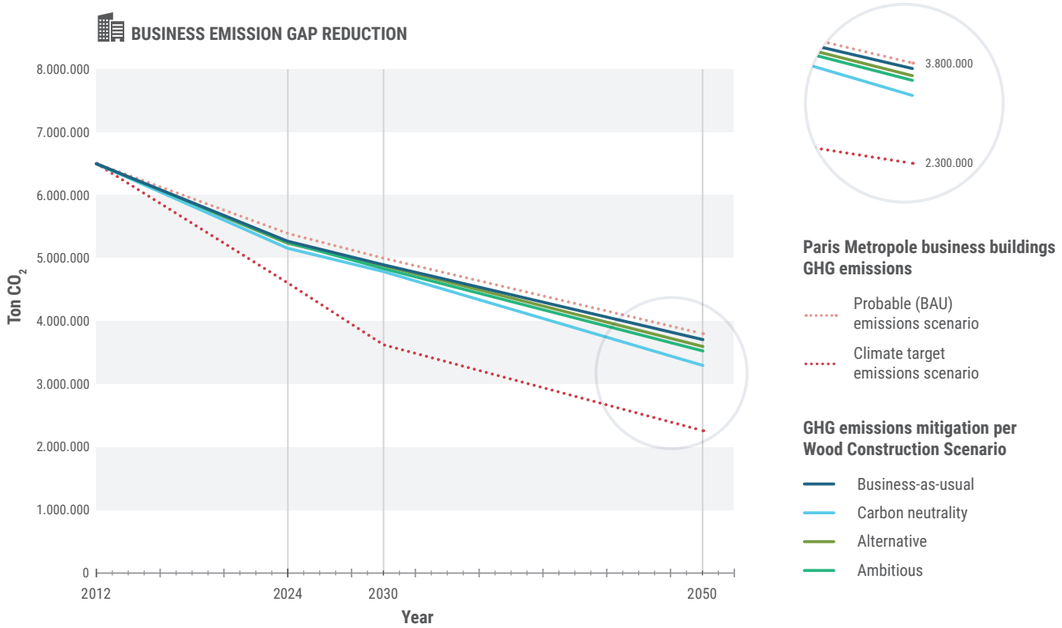
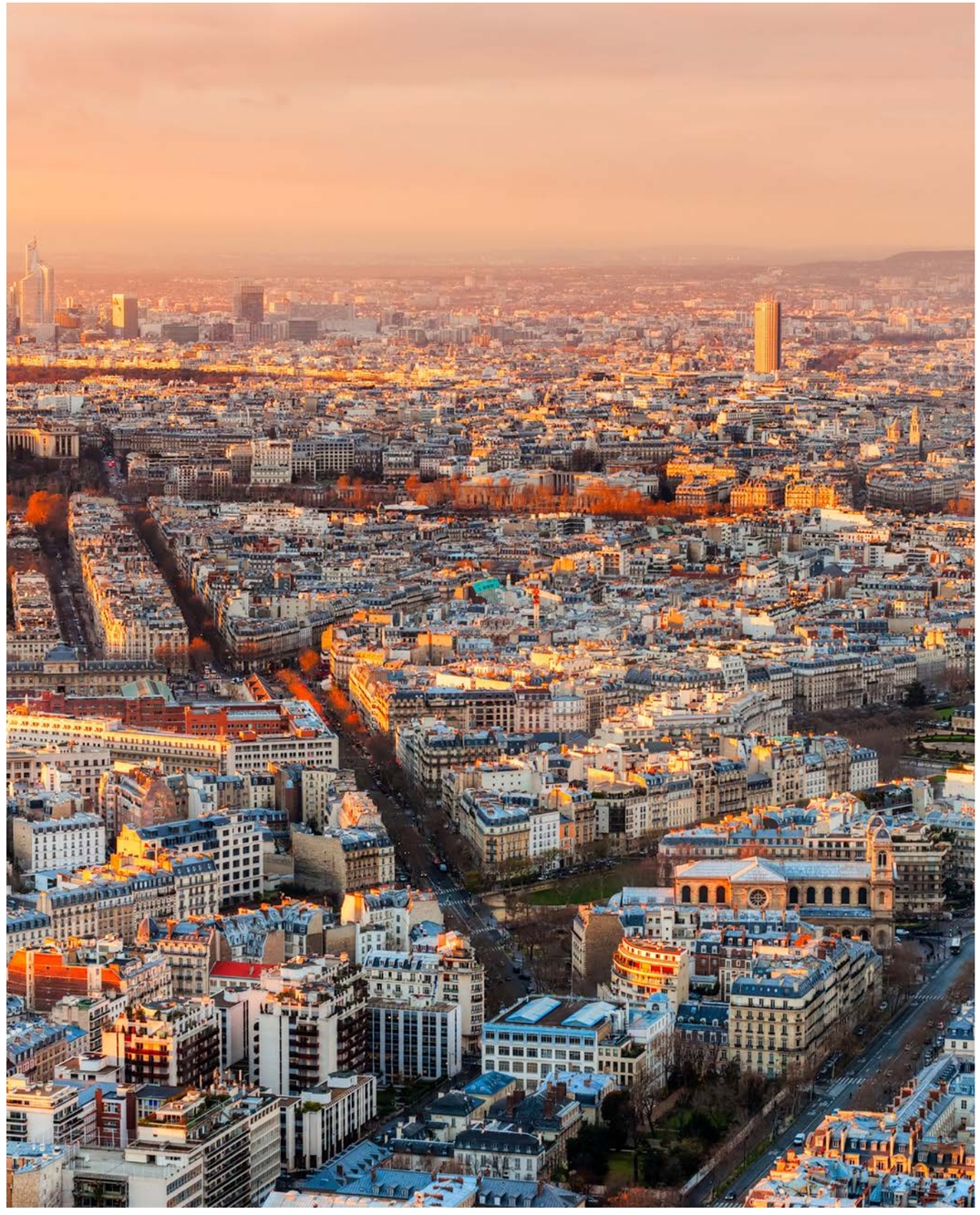


Figure 34: Business buildings wood construction sector contribution in bridging Scope 1 and 2 emissions gap of Paris Metropole business sector - depending on 4 scenarios for the wood construction sector

Regarding annual scope 3 emissions,[170] substituting concrete-based construction with wood-based ones will alleviate some of the annual scope 3 emissions from the residential and business construction sectors. In 2012, it was estimated that the scope 3 emissions of the construction sector in the Metropole Grand Paris amounted to roughly **6 Mtons of CO_2**. Considering the different scenarios, regional annual scope 3 emissions would be minimally reduced by 2024, and by 2030, only the **carbon neutral scenario** would offset the annual scope 3 emissions for one year[171] by avoiding almost 6 Mtons of GHG to be released. By 2050, the carbon neutral scenario would cumulatively avoid 22 Mtons of GHG, equivalent to **3.5 years of scope 3 emissions**[172] from the construction sector in the Metropole of Grand Paris, therefore reducing by 10% over the 35 year period (2015-2050). The **ambitious scenario** would help avoid about 6% of cumulative scope 3 emission between 2015 and 2050 (baseline 2012).

[170] The carbon emitted during the annual production of construction and renovation material.
[171] In comparison to 2012 as annual emission baseline
[172] In comparison to 2012 as annual emission baseline

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

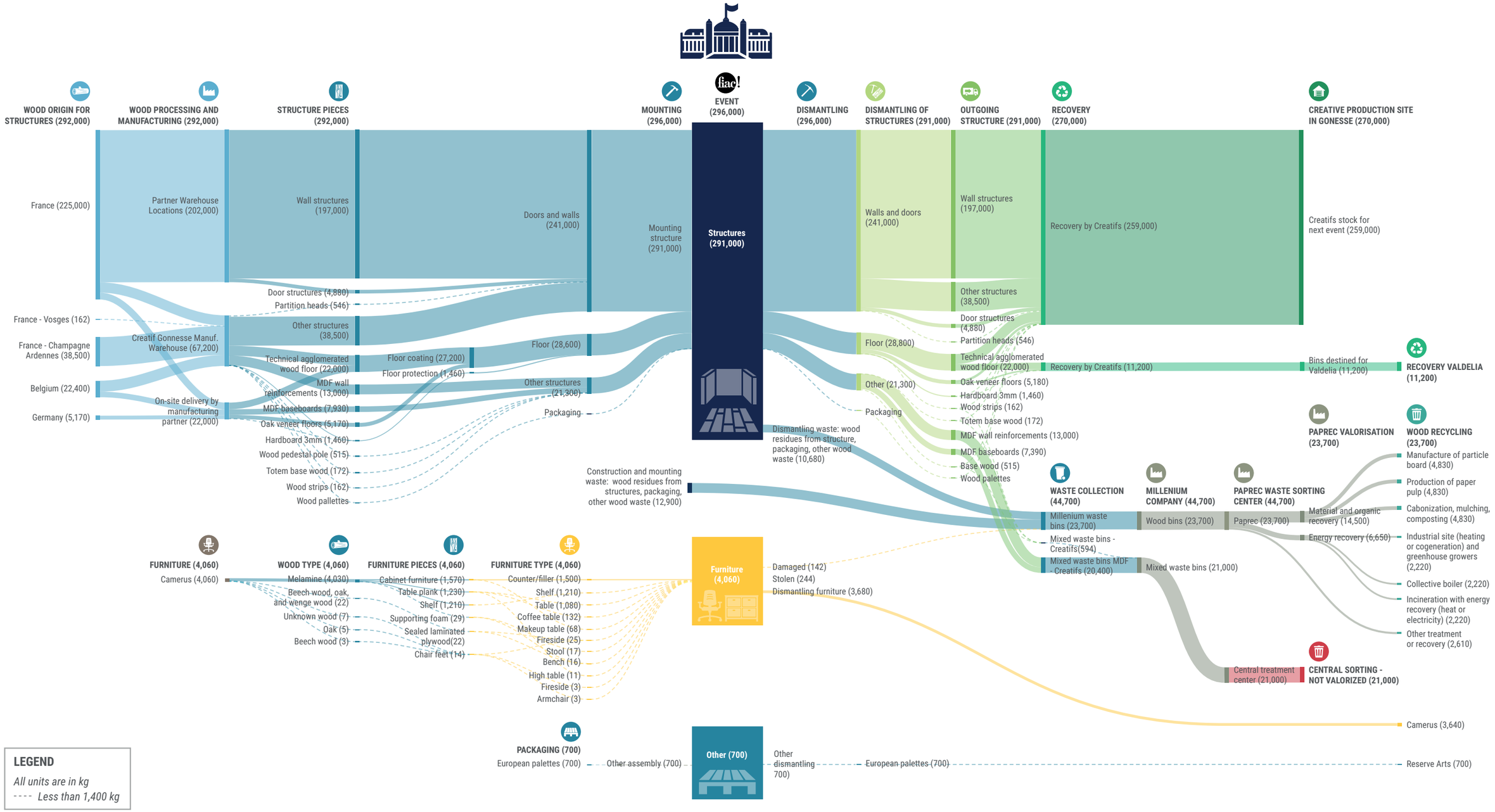


Figure 35: Sankey diagram of FIAC 2019 wood MFA

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Material flow analysis of the FIAC event in 2019

The International Contemporary Art Fair (Foire Internationale d'Art Contemporain, or FIAC)[173] is an annual art exhibition which showcases roughly around 200 exhibitors in the Grand Palais Éphémère location. In order to install artworks and sculptures the Grand Palais gets transformed into several exhibition rooms using wooden structures.

The MFA of the FIAC event quantifies the entire range of wood products that went through the event in 2019, with a total of **296 tons of wood products** identified and quantified. All other materials, such as carpets or metal structures were excluded to solely focus on wood flows. The main group of wood products are the wood structures (with the walls, ground layers, and various supporting elements), the furniture, and wood packaging, except the packaging from the exhibitors since no data was available. The wood packaging used by the FIAC exhibitors are custom-made structures specifically designed for the art pieces. Thus, they are all re-used at the end of the event to pack the art pieces.

The wood structures used to set up the different exhibition rooms for the FIAC constitute 98% of the entire volume of wood, with 291 tons. From this total volume of structure, the wall panels and doors (in medium density fibreboard (MDF)), and the structural elements supporting the walls (wood pine beams) of the FIAC exhibition represent 241 tons of wood, by far the largest flows into the event. The majority of the wood used in the structure originates from France or neighboring countries, such as Germany and Belgium. The wood elements (~28 tons) used for the flooring mostly constitute laminated wooden floors. The structures are brought onsite and built over three days. During the construction process, around 12 tons of wood waste is collected in a separated bin intended for wood recycling.

The wood furniture (i.e. tables, chairs, and cabinets) represents 4 tons of wood and since they were rented out most furniture pieces are recovered at the end of the event, with the exception of a few items too damaged or stolen during the event. Small amounts of wood palettes (< 1 ton) are used to move food products and flyers for the event.

At the dismantling stage, the wall, doors, and structural elements (241 tons) are taken down and cleaned. These elements are designed specifically for the FIAC event and are therefore 100% re-used for subsequent editions of FIAC and Paris Photo.[174] During the dismantling process, around 10 tons of wood waste is collected in a separated bin intended for wood recycling. The wood flooring are recovered and cleaned, 60% of the wood flooring is directly stored for subsequent use, while 40% is too weathered for a direct reuse into the event, and is therefore sent to La Réserve des Arts,[175] a circular organization that collects materials from the event industry for artistic projects.

[173] Fiac! (2021). The Fair.
[174] Parisphoto.com is an International art fair for photography, which is a sister event of FIAC and happens one week after the FIAC event every year
[175] LA RESERVE DE ARTS. (2021). Home | LA RESERVE DES ARTS.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Overall, due to the strong efforts by the event organizers and their suppliers, around 93% of all wood products avoid the residual waste stream. The vast majority gets re-used (86%) or recycled (7%), making the event from a wood perspective very circular. The wood waste in the recycling bins (22 tons) are sent to a recycling center, and are subsequently either shredded and downcycled or incinerated in waste-to-heat biomass plants.

Two key elements - reinforcement walls and baseboards - are made of MDF (amounting to 20 tons), cannot be reused, and are thrown in the residual bin to be subsequently incinerated, likely without energy recovery. MDF products are not recyclable due to the use of a toxic resin during their production process.

Environmental Hotspots of FIAC wood products

In the FIAC MFA, we identified around **223 tons** (326 m^3) **of MDF products** - primarily in wall panels (200 tons), reinforced wall panels (13 tons), baseboards (7 tons), and doors (5 tons) - a total of 210 tons of 8mm MDF sheets and 13 tons of 19mm MDF sheets. The MDF-based wood products therefore represent the largest volume per wood type used in the event.

The use of MDF is associated with **health risks** due to the use of **formaldehyde**,[176, 177] a resin used to glue together the wood chips of the board. It can be inhaled while cutting MDF and cause health issues, as the wood panels make exceptionally small particles while cutting.[178] Impacts on human health can be drastic, although shifting to MDF with less formaldehyde content can increase its performance considerably.[179] MDF is widely used in the event, furniture, and construction industry, and most materials come with various benefits and drawbacks. It is therefore key to assess different products that could perform the same function across a variety of impact indicators. As a result, a simplified environmental impact assessment using LCA methodology focusing on the production stage of MDF and MDF alternatives was carried out, focusing on climate change,[180] human toxicity,[181] terrestrial ecotoxicity,[182] and freshwater ecotoxicity impacts.[183]

During the FIAC, the MDF consumption is associated with **197 tons CO_2-eq emissions** in terms of global warming impacts. In terms of human toxicity, its equivalent to releasing **92 ton of 1,4 dichlorobenzene**[184] (14DCB-eq) into the urban air. From a freshwater ecotoxicity perspective, the production process of the MDF used for the event is responsible for emitting an associated **7.5 tons of 14DCB-eq into freshwater ecosystems.** Finally, regarding terrestrial ecotoxicity, 0.037 tons of 14DCB-eq is leached to industrial soil.

[176] Thetkathuek, A., et al. (2016). Respiratory Symptoms due to Occupational Exposure to Formaldehyde and MDF Dust in a MDF Furniture Factory in Eastern Thailand.
[177] Priha, E., et al. (2010). Exposure to and acute effects of medium-density fiber board dust.toms due to Occupational Exposure to Formaldehyde and MDF Dust in a MDF Furniture Factory in Eastern Thailand.
[178] Teixeira, R. L., et al. (2017). Evaluation of Airborne MDF Dust Concentration in Furniture Factories.
[179] Nakano, K., et al. (2018). Life cycle assessment of wood-based boards produced in Japan and impact of formaldehyde emissions during the use stage.
[180] IPCC (2013): climate change: GWP 100a (kg CO_2-eq)
[181] ReCiPe (2008) Midpoint (H) V1.13:human toxicity: HTPinf (kg 14DCB-eq)
[182] ReCiPe (2008) Midpoint (H) V1.13:terrestrial ecotoxicity:TETPinf (kg 14DCB-eq)
[183] ReCiPe (2008) Midpoint (H) V1.13:freshwater ecotoxicity:FETPinf (kg 14DCB-eq)
[184] Goedkoop, M., et al. (2009). ReCiPe 2008.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

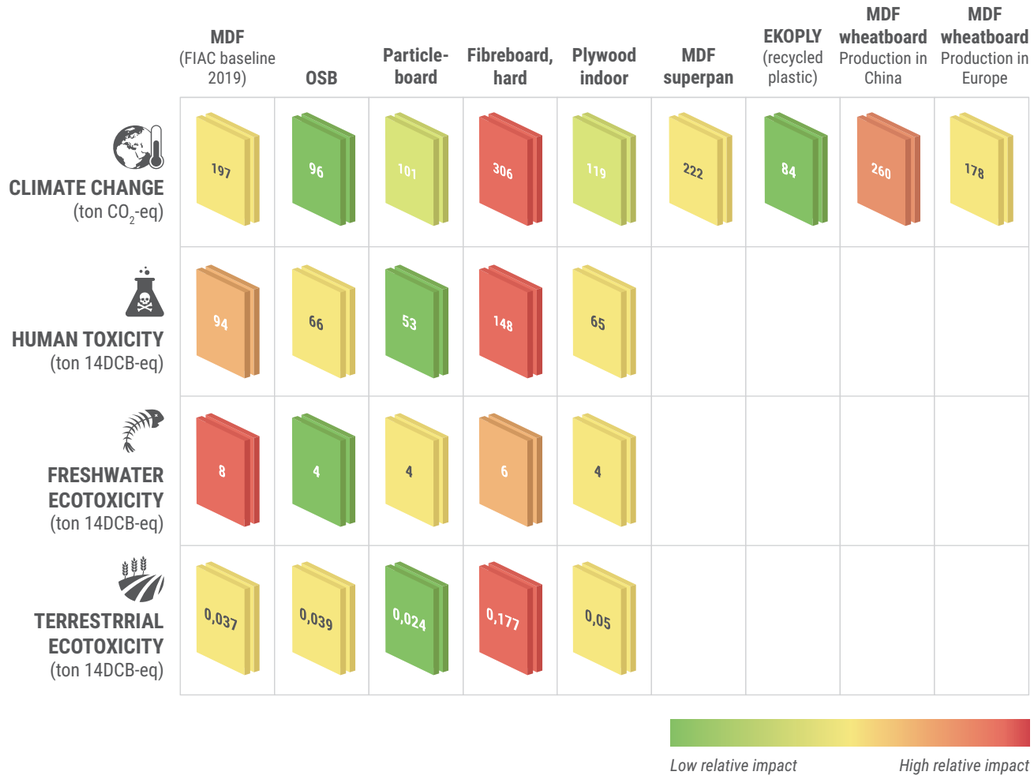


Figure 36: Comparative environmental impacts of MDF and alternative materials

Different possible alternative wooden boards were identified and compared to the MDF. Specifically four 'conventional' alternatives, namely Oriented Strand Board (OSB), particleboard, fibreboard (hard), and plywood (indoor). Three more novel products, namely MDF Superpan,[185] EKOPLY,[186] and MDF strawboard (ECOboard Standard)[187] were selected as potential candidates to replace the MDF. The last three options were only compared concerning their global warming impact, due to a lack of data. In terms of recyclability, OSB can be burned without emitting toxic fumes and generally contains less formaldehyde than plywood, MDF, and particleboard.[188, 189] Particleboard is generally non-recyclable, although technically recycling particleboard into

[185] FINSA. (2021). superPan.
[186] EKOPLY. (2021). EKOPLY - Market Leader in Recycled Plastic Sheets and Boards.
[187] ECOBoard international b.v. (2021). ECOBoard Standard – ECOBoard international bv.
[188] Lee, A. (2021). Is OSB an environmentally packaging/ crating material?
[189] Woodguide.org. (2021). Sustainability and OSB.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

MDF is possible, but not common.[190, 191] MDF cannot be recycled at the moment, but recent developments in the field of MDF recycling technologies using ohmic heating,[192] have opened the possibility to recycle MDF panels into new MDF panels. This innovation is expected to appear on the market in 2021/22.[193] Recycling opportunities for hard particleboards appear to be similar as for MDF. Plywood can be recycled into particleboards.[194] Ekoply is a recycled material and fully recyclable at its End-of-Life.[195]

The results show that every alternative has its strengths and weaknesses. From an environmental point of view, switching to fibreboard should be avoided since it is related to the highest emissions (306 ton CO_2-eq) and highest health impacts of all alternatives. Particleboard and MDF are not recyclable at the moment, and therefore would not solve FIAC's issue. OSB[196] and plywood[197] are related to smaller health impacts than MDF as well as lower CO_2 emissions. Moreover, due to health concerns while cutting MDF with high formaldehyde, **options with low formaldehyde contents should be favored,** such as MDF strawboard or OSB.

4.2 Vision for a sustainable timber sector in Paris

A circular and regenerative system for bio-based materials such as wood can be defined as a productive environment that mimics natural systems of regeneration so that waste does not exist, but is instead feedstock for another cycle, and that ultimately ensures the long-term health and biodiversity of its ecosystems.

To maintain a sustainable system, all renewable or biological resources, such as wood, must be extracted at rates lower than or equal to regeneration rates. At the end of their life cycle, wood products must be free from contaminants and can safely be returned to their ecological cycles to regenerate living systems, such as soil, which provide further renewable resources for the economy.[198] Such a transition towards a circular economy in bio-based sectors often depends on a cascade model for valorisation[199] which stipulates that the circular economy of wood should prioritize the highest possible value over the whole life cycle.[200, 201] As large amounts of resources such as energy go into producing wood-based products, the value of products should

[190] Antov, P.; Savov, V. (2019). Possibilities for Manufacturing Eco-friendly Medium Density Fibreboards from Recycled Fibres – a Review.
[191] Mantanis, G., et al. (2004). A New Process for Recycling Waste Fiberboards.
[192] Holmes, E. (2017). MDF recycling trials bring solution closer | Resource Magazine.
[193] MDF Recovery. (2021). Welcome to MDF Recovery.
[194] Weber, C.; Iwakiri, S. (2015). Utilização de resíduos de compensados, MDF e MDP para produção de painéis aglomerados.
[195] EKOPLY. (2021). EKOPLY - Market Leader in Recycled Plastic Sheets and Boards.
[196] Except terrestrial ecotoxicity, similar value as MDF
[197] Except terrestrial ecotoxicity, higher value as MDF
[198] Economic Commission for Europe, et al. (2019). Forests and the Circular Economy.
[199] Jarre, M., et al. (2020). Transforming the bio-based sector towards a circular economy - What can we learn from wood cascading?
[200] Kampelmann, S. (2020). Wood works: how local value chains based on urban forests contribute to place-based circular economy.
[201] Carus, M.; Dammer, L. (2018). The Circular Bioeconomy - Concepts, Opportunities, and Limitations.,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

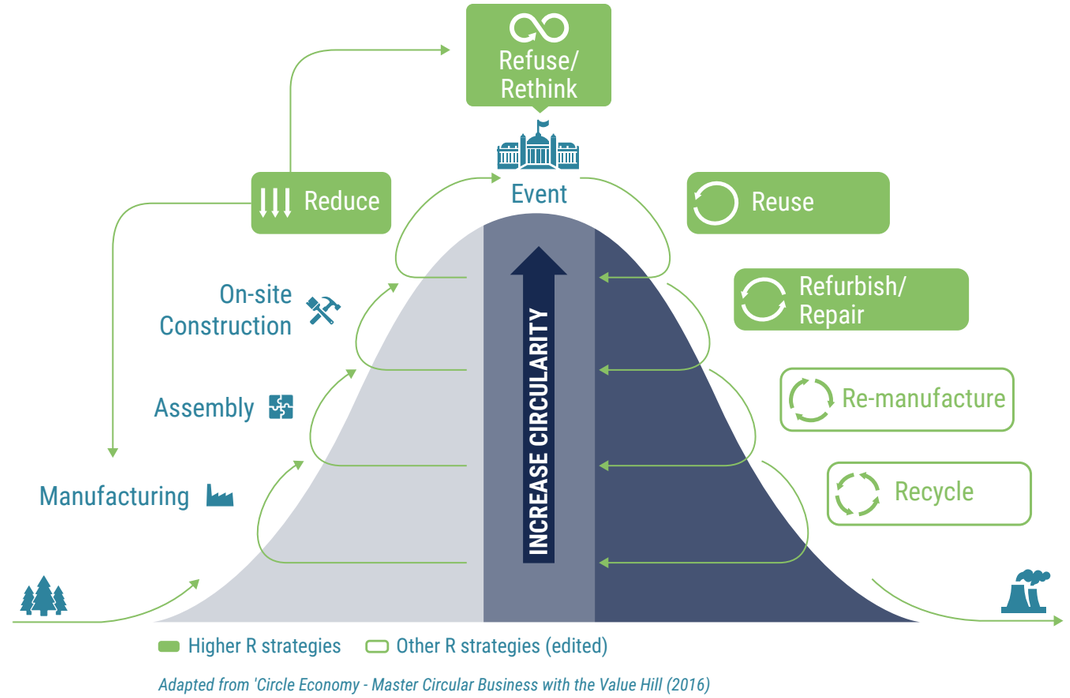
be maintained for as long as possible by extending their lifespan, ensuring reusability, and cascading waste at the maximum value, before being returned back to the soils or downgraded.

The EU Action Plan for the Circular Economy[202] lists biomass and bio-based products as a priority area, given that the bio-based sector is one of the most resource intensive in Europe. The Action Plan has set a target to recycle 30% of wood in the EU by 2030. Additionally, the City of Paris adopted its circular economy plan[203] in July 2017 which aimed to recover 70% of waste from construction and public works in the form of materials by 2020. This includes the integration of the principle of selective dismantling and reuse of building materials from structural and finishing works for renewal schemes. Following up on the national CE goals, the AGEC law[204] has been enforced in France which widens Extended Producer Responsibility (EPR) to the construction sector - one of the largest wood-waste producers in the country. The law also encourages the use of spare parts from the furnishment industry.

For public events, the City of Paris has established a Charter for Eco-responsible Events[205] that promotes eco-design at each stage of the event, from design to dismantling. The REFLOW Paris pilot shares the objective of creating a culture of circular events and circular temporary constructions, which relates to the city strategy and is contributing to the national and EU-level circular economy goals. Following circular economy principles, a circular event can be defined as an event that eliminates any toxic or non-recyclable materials, and that strives to reduce its material footprint. Material that cannot be reduced must be re-used at a high rate, and repaired to extend its life cycle. Materials and products not fit for their original purpose should be re-manufactured into high-value products. Finally, all products should be broken down into their material components and recycled into new feedstocks.

[202] European Commission. (2015). Closing the loop - An EU action plan for the Circular Economy.
[203] MAIRIE DE PARIS. (2017). Circular Economy Plan Paris.
[204] Légifrance. (2020). LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1).
[205] Paris.fr. (2018). Organisateurs d'événements, adoptez la nouvelle charte écoresponsable parisienne.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



Adapted from 'Circle Economy - Master Circular Business with the Value Hill (2016)

Figure 37: Value hill for circular events

Based on Metabolic Institute's research on the current state and hotspots within the timber sector and the events industry in Paris, three strategic focal areas have been developed as recommendations for how the City and REFLOW Paris pilot team can further contribute to its vision of a sustainable and circular timber sector, as well as contribute towards the National Circular Economy goals, and European Directives regarding wood:

1. **Increasing carbon storage in the built and natural environment** by promoting and developing the local hardwood-based construction industry, to help achieve climate targets and support local employment.
2. **Sustainable waste management of wood** by decreasing carbon sources and maintaining high value out of wood leveraged by better waste management data infrastructure in the city.
3. **Building a culture of responsible production and consumption of wood** through innovative ownership models, design for deconstruction, and the phasing out non-recyclable and toxic materials from the events industry.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

4.3 Focus Area 1: Increasing carbon storage in the built and natural environment

4.3.1 Introduction

The city-level timber MFA has shown that the vast majority of timber can be found in the urban stock as construction elements, with a total 46 Mtons of wood. The second largest stock of wood in the region consists of 19 Mtons of standing wood biomass in Ile-de-France's forest. These two stocks represent significant carbon sinks, with an estimated 70 Mtons of CO_2 stored in Ile-de-France urban stock and 34 Mtons for the regional forests and trees.

One of the largest inflows of wood into the region are wood products for the region's construction industry, representing more than 200,000 tons annually. The wood construction sector has been increasing at a steady-pace over the last decade in Ile-de-France. On the other hand, the MFA highlighted the low exploitation of Ile-de-France forest resources, with very little lumber wood harvested. The majority of harvested timber is exported due to little primary processing capabilities in the region, which has collapsed since the 1970s.

As a result, **the region is interested in supporting and growing its local wood industry, especially regarding timber wood for construction.**[206] Around 11,200 employees work in the wood industry in the region, albeit about half in the paper and cardboard industry. Less than 1,500 people work directly in the wood construction sector, across 327 companies. There are also a bit less than 2,500 people working in sawing and wood working, with the majority in woodworking, and very little in the primary processing sawing sector.[207] The region has developed a new strategy for the forest and wood industry development over the next decade.[208] Among its objectives, the region has a special focused on:

- Reinforcing the competitiveness of the regional wood industry and boosting employment in the sector;
- Raising awareness on career pathways in the regional wood industry, on forest management practices, and biodiversity.

There is therefore a key opportunity to sustainably harvest more of Ile-de-France local forests to grow the local industry and provide high-quality feedstock to the growing wood-based construction industry.

Lastly, as mentioned previously, the region of Ile-de-France and the Métropole du Grand Paris have set ambitious targets for GHG emissions reductions for the built environment in the residential and business sectors. Yet, according to their climate monitoring reports, there is currently a gap between their climate targets and their actual annual emissions from the built environment.[209] As shown in the impact section of this analysis, the construction sector, and specifically the wood construction sector, can play a significant role in storing more carbon in the urban stock and supporting the region and Paris to meet their target.

[206] Pécresse, V. (2017). Stratégie régionale pour la forêt et le bois 2018-2021.
[207] INSEE. (2012). La filière bois en Ile-de-France : un fonctionnement qui dépasse les limites régionales.
[208] DRIAAF. (2020). Le programme régional de la forêt et du bois d'Île-de-France.
[209] PMétropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Based on the findings stemming from the MFA and the impact assessment, to tackle climate change mitigation, and increase local employment opportunities through the local forestry and wood industry, three strategic directions have emerged. These directions will help spur a climate-proof and circular wood construction system for the region of Ile-de France.

4.3.2 Strategic direction 1.1: Support wood-based construction and renovation as a means to achieve carbon reduction goals (Scope 1, 2, and 3)

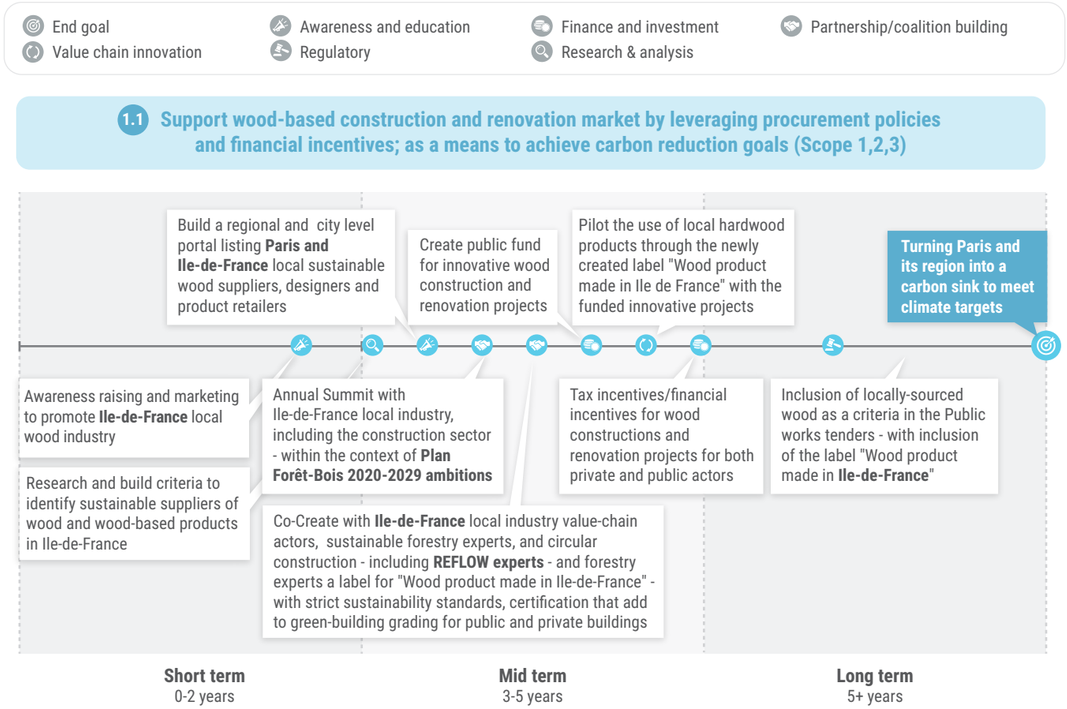
In order to achieve the ambitious climate targets of the Metropole of Paris and the surrounding region, wood-based construction must be encouraged across the region. As shown in the impact section, boosting the wood construction industry over the next decades, in line with a 'carbon neutral' ambition could greatly support the mitigation efforts of GHG emissions. To support its expansion, regional authorities and the City of Paris can run awareness and marketing campaigns about the local wood industry. A research effort must be conducted to survey and list sustainable suppliers of wood present within the region. To increase their visibility, an online portal developed by the region and supported by its municipalities would be the next step, with a strong focus on sustainable wood products and the local wood industry, showcasing investment opportunities and providing contact information of local SMEs. To launch such a portal, a summit regrouping actors from the local wood and construction industry could be organized into an annual event to support the **Plan Forêt-Bois 2020-2029 ambitions,** over the next decade. In collaboration with stakeholders, including REFLOW experts from the Paris pilot, a label to showcase sustainable local wood can be co-created to offer an added-value to green and wood construction projects, and further establish the local industry as a key player in the transition. Beyond raising awareness and local labels, **public and private investments are key instruments to spur the development of the industry.** An innovation fund, such as the Wood Innovations Program developed[210] in the USA could enable the piloting of innovative hardwood-based construction projects in the region. The pilot can support the development of the criteria system for the label. In the long run, this label could be included in the public procurement process for public construction projects.

Use-cases

- Wood Innovations Program: The US Wood Innovations Grants funding supports traditional wood utilization projects, expands wood energy markets, and promotes using wood as a construction material in commercial buildings.
- Smart City Sweden: The Swedish government has a National wooden building strategy and an alignment for wooden construction was introduced in 2018.
- Wood Innovation Design Centre (WIDC): WIDC, such as the one in Canada, serves as a gathering place for researchers, academics, and design professionals where ideas for innovative uses of wood can emerge.
- proHolz: The working group of Austrian timber industry encourages building with wood with best practice examples and specialist information.
- Timber Innovative Act: Resources are allocated to facilitate the use of innovative wood products in wood building construction in the United States.

[210] U.S. Department of Agriculture. (2020). Wood Innovations Grants | US Forest Service.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



4.3.3 Strategic direction 1.2: Encourage mainstreaming of hardwood-based construction products to increase flows of carbon from Ile de France forest to its urban stock

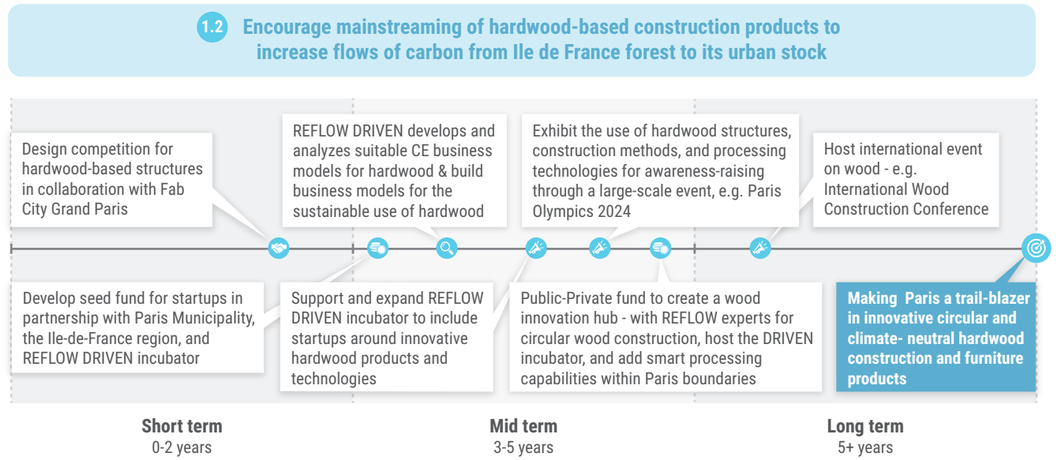
The local forestry and wood sector in Ile-de-France is challenged by the fact that less than 7% of the forest stock is made of softwood trees. Softwoods are usually the favoured wood feedstock for the construction market. Furthermore, hardwoods are harder to process, both at the primary and secondary stage, since they have a less standardized shape than softwood trees like pines. Therefore, the local wood industry faces the challenge of inadequate feedstock for mainstream wood construction products. This challenge opens opportunities for process and product innovation surrounding the hardwood industry.

In collaboration with Fab City Grand Paris, a REFLOW pilot partner, a design competition can be held to raise awareness around upcoming developments in the field and scout promising new innovations. The Driven x REFLOW incubator, in partnership with the City of Paris and the Ile-de-France region could develop seed funds for promising ideas. Aligned with their objectives, the incubator can develop circular business models surrounding the most promising innovations. The seed fund can then support the expansion of the incubator to include a new branch focused on startups developing new products and technologies in the hardwood industry. Paris' tenure of the Olympics event in 2024 could provide an opportunity to showcase the local

know-how and the potential of the incubated innovations for the construction sector. To further accelerate the development of local hardwood technologies and products, public and private investments can be sought to create a wood innovation hub, in collaboration with REFLOW experts. The hub could host the REFLOW Driven accelerator and provide R&D space for smart wood processing technologies in Paris.

Use-cases

- The Smile: The Smile Structure in London is the first large building/arc constructed only with large hardwood-Cross Laminated Timber structures, built as a showcase during the London Design Festival 2016.
- CLT Composite: The CLT Composite made from beech is a structurally bonded cross-laminated timber composite that has 40% better mechanical properties than regular softwood timber.
- Hardwood CLT building: The Maggie's Oldham building, constructed in 2017, is the first permanent building in the UK made from Cross Laminated Timber from sustainable sourced American tulipwood.



4.3.4 Strategic direction 1.3: Developing the hardwood industry in Ile de France: new employment opportunities

The region has the ambition of **creating 3,000 new jobs in the forestry and wood construction sectors, between 2018 and 2023.**[211] To truly support the growth of the industry and involve the local labor force and youth in its renewal, Paris Municipality, the region, and REFLOW partners have the opportunity to raise awareness about career paths in the industry and offer training opportunities. Local career fairs can help raise the profile of the industry to young people entering the job market while organizations such Driven x REFLOW can offer masterclasses, workshops, and training around wood processing technologies. To support job growth in

[211] Pécresse, V. (2017). Stratégie régionale pour la forêt et le bois 2018-2021.

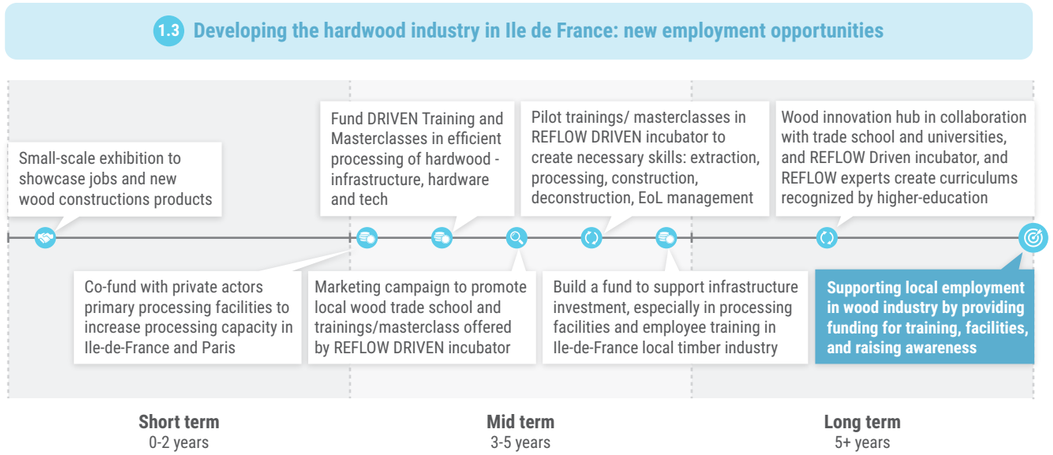
the sector, public and private investments are required to **re-establish primary processing facilities in the region.** This is a key step to maintain the lumber wood harvested within the region, create high-value wood products, and directly support employment opportunities in the region. In the longer term, a curriculum specialized in hardwood forestry could be developed in the wood innovation hub in partnership with the local wood industry and REFLOW partners. Local value chains based on peri-urban and urban forests can cement the sustainable bioeconomy as they provide attractive local jobs based on a carbon-neutral material that is naturally circular. The sustainable growth of the local forestry and construction sectors can have ripple effects by creating demand for business support specializing in urban wood companies over product design services to manufacturers offering tools and machinery adapted to the relatively small scale of urban and peri-urban wood operations.[212]

Use-cases

- Second Chance: The Baltimore organisation deconstructs buildings, salvages materials and sells retail space. They train and employ veterans, school dropouts and individuals returning from incarceration.
- European Neighborhood and Partnership Instrument Forest Law Enforcement and Governance Program (ENPI-FLEG): The initiative is funded by the EU and implemented by the World Bank, the International Union for Conservation of Nature, and the World Wide Fund for Nature. It helps participating countries develop sustainable forest sector policies and plans that attract investments, grow employment, and drive economic growth.
- Forest communities in Mexico: They have developed multiple commercial "community forestry enterprises" around timber and non-timber products providing relevant training and capacity building services in sustainable and economically viable practices.
- Humanim: The nonprofit enterprise trains disadvantaged workers in construction practices and deconstructing city-owned public housing amongst other trades.

[212] Kampelmann, S. (2020). Wood works: how local value chains based on urban forests contribute to place-based circular economy.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



4.4 Focus Area 2: Sustainable waste management of wood

4.4.1 Introduction

While wood is naturally a circular material, in Ile-de-France the flows of wood are not optimally made circular. From the 920,000 tons of annual wood waste, almost half is recycled into paper or downcycled into low-value wood products. In Ile-de-France, 151,000 tons of wood end up in landfills and 20,000 are incinerated annually.

The end-of-life (EoL) treatment of wood releases 490,000 tons of CO_2-eq annually. Landfilling and incineration combined release around 10% of the total CO_2 released. Landfilling and incineration (without energy recovery) should be avoided at all costs and wood material valorization - reuse, remanufacturing, recycling, biochemical cascading, and composting - should be favoured through cascading practices over direct waste-to-energy conversion.

The construction sector is the second largest sector in Paris with around 200,000 tons, but the recovery of wood waste from the construction and renovation sector is not optimal, with 25% of wood waste ending up in landfill, and around 40% of wood being downcycled, the rest being incinerated with energy recovery. There are still significant uncertainties surrounding construction wood waste. The construction sector constitutes an interesting source of wood waste products, such as wooden windows, wood beams, wooden structural elements, and wood floors. Households are the third largest producer of wood waste, with 143,000 tons, mostly consisting of furniture. **The recovery of furniture is still very low,** with a bit more than half of wood-based furniture ending up in landfills, equivalent to around **47,000 tons of wooden furniture landfilled.**

The lack of coverage in terms of wood waste, both in terms of temporal coverage for the private sectors and in terms of granularity of wood type, represents a challenge for the MFA. Little data exists for the second-hand market, since there is very little traceability of secondary wood waste streams. The waste flows from the different sectors (residential, industries, services, retail, construction) and for different wood waste

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

streams (furniture, wood, construction waste) and their EoL treatment processes are often compiled in silos. These data silos have various time coverage and granularity, which requires complex data processing, with high uncertainties in certain sectors (e.g., construction) and important data gaps (i.e., second-hand sector).

Through the analysis of the wood waste streams leaving the urban stock of Ile-de-France, three strategic directions have emerged.

4.4.2 Strategic direction 2.1: Avoid the incineration of wood to increase CO_2 stock in the built environment - encourage wood product reuse or valorization to keep CO_2 stored in the urban environment

To accelerate climate change mitigation goals, it is key to increase the size of carbon sinks as much as possible. A method to achieve this is to ensure that wood waste is valorised to its highest value. This can be achieved by redirecting reusable wood away from incineration and landfill towards reuse, as from a carbon-perspective wood products are most useful when they store carbon for a longer period of time.[213, 214] Currently 249,000 tons of wood are incinerated annually to produce energy in waste-to-energy plants in the region which can be redirected to become a carbon sink instead of a carbon source.

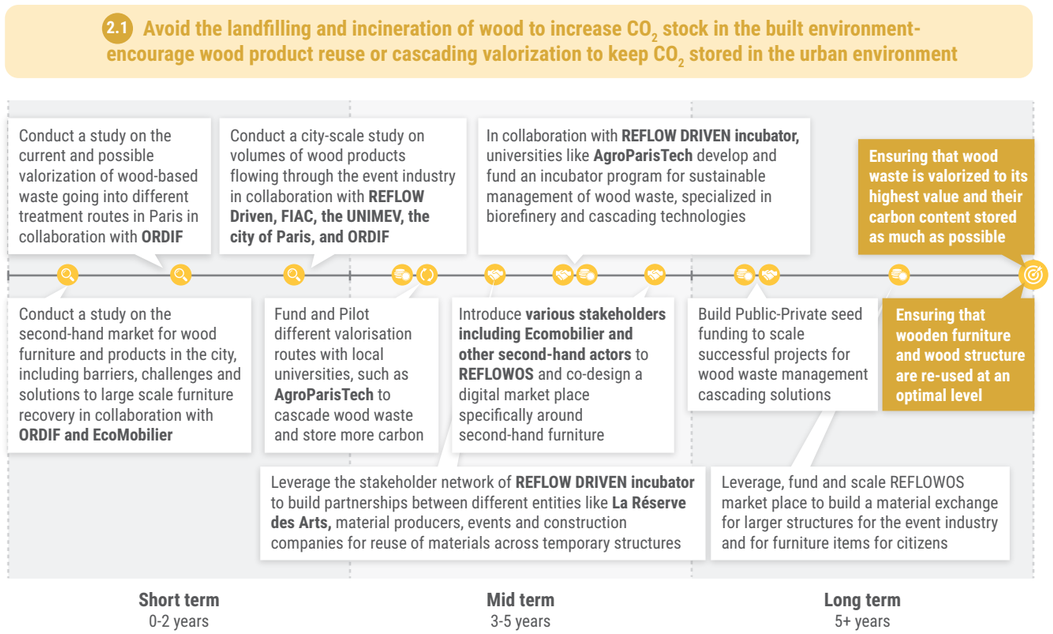
As a starting point, studies need to be conducted on the valorisation potential of wood-based waste going into different treatment routes in Paris and the second-hand markets for wood products such as furniture. These studies can inform the future actions necessary to ensure that all urban wood (including structures, construction elements, and furniture) in the region can **contribute towards carbon storage.** Insights from these studies can build a foundation of piloting and scaling valorisation pathways including reuse markets developed through REFLOWOS. Such actions will require partnerships between public and private actors including ORDIF,[215] EcoMobilier,[216] FIAC, UNIMEV,[217] La Reserve des Arts, and AgroParisTech[218] amongst others.

Use-cases

- ReWood: The upcycling technology uses wood waste from construction to create new facades and acoustic panels.
- Carbon-Smart Wood: The initiative sources wood from urban wood waste - trees that fall within metropolitan areas in US Cities independent of any wood harvest initiatives.
- Construction practices with recovered and reused wood waste:
  - Upcycle studios: The Danish development uses existing frames and panels and the offcuts from the local wood manufacturers.
  - Superuse Studio: The Dutch VIIIa was revalorised upcycled wood from cable reels into a facade which would usually be downcycled into particle boards or incinerated.

[213] Johnston, C. M.; Radeloff, V. C. (2019). Global mitigation potential of carbon stored in harvested wood products.
[214] Kazulis V., et al. (2017). Carbon storage in wood products.
[215] ORDIF. (2021). L'institut Paris région - Observatoire régional des déchets.
[216] Eco-mobilier. (2021). Tous mobilisés pour offrir une nouvelle vie à vos meubles usagés !
[217] Unimev. (2021). Union française des métiers de l'événement.
[218] AgroParisTech. (2021). Un partenariat fertile.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



4.4.3 Strategic direction 2.2: Improve wood-based waste traceability across the construction, furniture, event, and household sectors

To enhance recovery, reuse, and valorisation of wood-based products, setting up a transparent and traceable information system is a vital step. In the timber and temporary construction industry this equates to digital and infrastructural tools that can help actors to follow products throughout their life cycle and to generate a database of material available for reuse. The REFLOW Paris pilot is developing such tools and integrating REFLOWOS as the platform for pooling information on available stock of products.

To generate **wider adoption of digital tools for labelling and tracking of products** as well as waste monitoring at events and construction sites, suitable business models are required. Entrepreneurs developing such solutions within the REFLOW x DRIVEN incubator can partner with event organisers such as FIAC to trial **digital tracking of wood structures and products.** A demonstration pilot can help in bringing onboard relevant stakeholders and for generating funding for scaling up the technological solutions currently in development. For enhanced waste monitoring solutions, a baseline study can be conducted on the current waste data infrastructure in the Ile-de-France region in partnership with ORDIF to identify the intervention points for digital solutions.

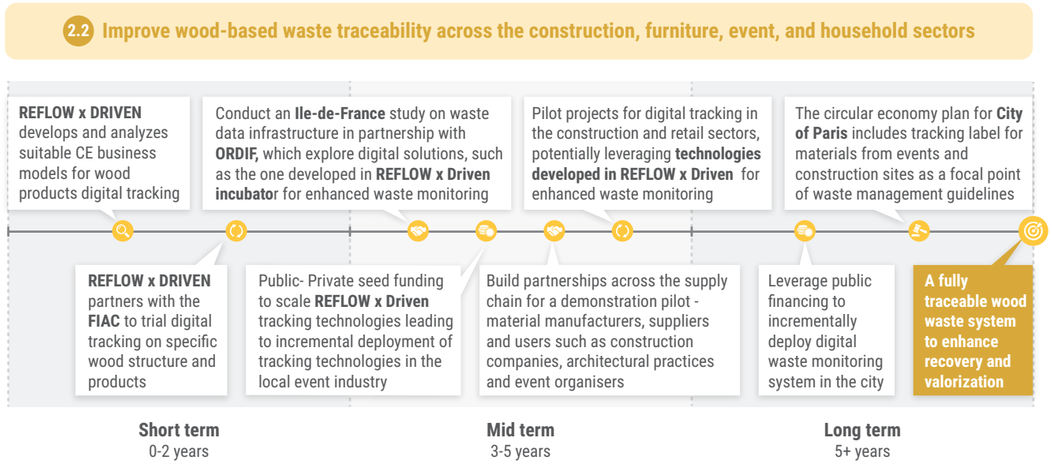
Insights from the pilot and the baseline study can inform Paris' circular economy action plan and the waste management guidelines to adopt the use of track and trace methods to qualify wood waste based on quality, quantify the amount of wood products circulating in the secondary reuse markets, and manage waste from

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

construction and the events industry. Scaling up the tracking and labeling solutions would require cooperation throughout the supply chain: material manufacturers, suppliers, retailers, and users such as construction companies, architectural practices, and event organisers. Developing such partnerships will also be vital to the implementation and adoption of the solutions developed within REFLOW.

Use-cases

- Elements: The company uses RFID tags for construction material tracking. It provides data documenting wood characteristics throughout the life cycle for optimal reuse.
- Chain of Custody (CoC): CoC is a system in Liberia that tracks timber from forests to the point of export through barcodes and data forms. The system helped secure more than $27 million in net tax revenue for the state in 2008–2012.



4.4.4 *Strategic direction 2.3: Develop urban mining of wood structures: promote deconstruction practices*

The inflow of wood for construction purposes represents one of the largest wood inputs into the region of Ile-de-France with at least 220,000 tons of wood consumed for construction on an annual basis. Urban mining is the process of recovering and reusing materials from buildings, infrastructure, and products that are no longer needed.[219] Only a small amount of construction and demolition waste goes back into buildings, whereas most of the material recovered from structures is downcycled and loses value. Reusing the 46 Mtons of wood currently available in Paris' **"urban mine" for new construction projects would shorten supply chains,** increase resilience, and maintain the value of wood-based products for a longer period - contributing to the carbon

[219] Blok, M. (2021). Urban mining and circular construction – what, why and how it works.

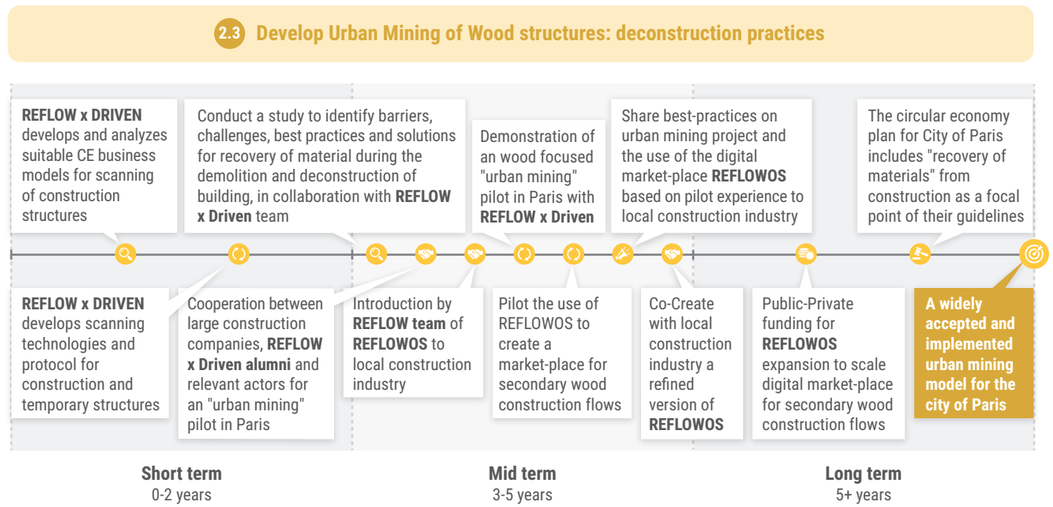
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

sink of the region. A major barrier in achieving this reuse is **the deficit in existing technology and protocols for scanning existing structures to understand what material can be extracted for reuse.** Developing these protocols and technologies will be an important step towards the implementation of an urban mining system.

A wood-focused urban mining pilot in Paris can be established with partners from the local construction industry as a demonstration, bringing interested actors onboard for a pilot which can inform a larger movement towards material recovery and reuse in the city. REFLOWOS can be expanded as a digital marketplace for the wood-based construction material reclaimed in the urban mining pilot. Similar platforms such as RE-SIGN[220] also help match the supply and demand requests for reclaimed construction materials in Italy.

Use-cases

- RE-SIGN: RE-SIGN is a platform allowing the exchange of materials, ideas, and networking of circular economy key actors.
- Werflink: The online sharing platform is designed for construction sites and companies to share equipment, materials, resources, freight space and facilities. The platform has been set up in collaboration with the Flemish Construction Confederation, construction company BESIX, Circular Flanders and FLOOW2 to create a more circular construction sector.



[220] RE-SIGN. (2021). RE-SIGN SOCIETA' BENEFIT S.R.L..

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

4.5 Focus Area 3: Building a culture of responsible production and consumption of wood

4.5.1 Introduction

To transform the wood system of Paris and the surrounding region, it is necessary to build a strong culture of responsible production and consumption practices.

A recurrent issue in the wood waste system is the presence of toxic and non-recyclable wood products, which generate environmental and human health issues at the production and use phases. They also do not allow for energy recovery at EoL due to their toxicity. These wood products, such as MDF must therefore be removed from product systems to allow for a fully circular wood sector to thrive. In the material of the FIAC, structural elements made of MDF (around 20 tons) that could not be re-used were thrown in the residual bin, to be subsequently incinerated, likely without energy recovery. To avoid the issue of MDF waste, it is key to remove these toxic and non-recyclable materials from the wood streams flowing through the event.

Through the FIAC MFA, it was uncovered that **around 93% of all wood products are getting re-used (86%) or recycled (7%),** making the event from a wood perspective, particularly circular. A large part of the success of the circular use of wood in the event was found to be the use of leasing ownership models. The event organizers either rent wooden furniture for the event or lease wood structures over long-periods of time. **The leasing/rental models incentivize event suppliers to keep and repair products to extend their life cycle.** For the wood structures, FIAC has had a long-term agreement with their wood structure supplier for almost seven years. This contract could be extended a further three years, bringing the leasing of the highest volumes of wood structures to almost a decade. The wood structures have been custom-made for the event, the long-term contract incentivizes their clean dismantling, careful maintenance, and storage for subsequent events. Additionally, since the structures belong to FIAC's supplier, and even though these are custom-made structures, they can be used in other events. The ownership system of wood structures therefore has impacted dramatically the circularity of the wood products flowing through the event studied.

At the Ile-de-France level, the forest stock represents an interesting source of hardwood for the lumber and construction industry. The Ile-de-France forests are a patchwork of private and public forests, therefore it is difficult to unilaterally engage a single management model. Nonetheless, the region has the ambition to increase its lumber production to encourage the development of the local wood industry.[221] With around **61% of the forests** constituted of **high value oak and chestnut trees,** it is key to ensure that the forests are sustainably managed to preserve the value of its ecosystems. To encourage and build a strong culture of sustainable practices around the production and consumption of wood, three strategic directions emerge for the pilot.

[221] DRIAAF. (2020). Le programme régional de la forêt et du bois d'Île-de-France.

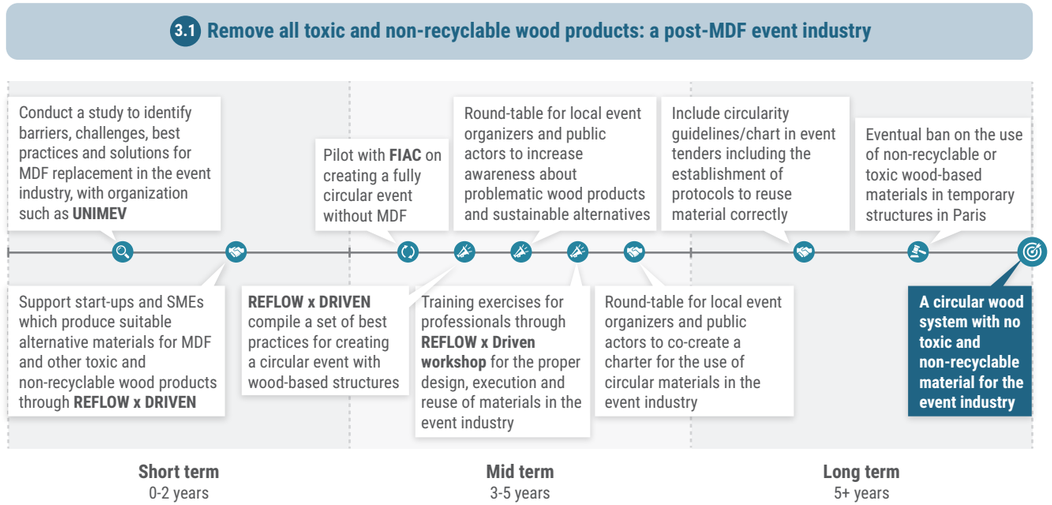
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

4.5.2 Strategic direction 3.1: Phasing out toxic and non-recyclable wood products in the event industry and consumer goods

To address the problematic use of MDF in the event industry, research must be conducted to identify the challenges and opportunities arising from the transition to alternatives. Building on this research, the REFLOW x Driven incubator can identify and support existing startups and SMEs that provide sustainable alternatives to MDF. Once strong partners and solutions are identified, the FIAC can be a testbed for a MDF-free event, enabling the REFLOW x Driven incubator to collect best practice. Through roundtable discussions, REFLOW partners can raise awareness about the issue of MDF and other toxic and non-recyclable materials in the event industry and present potential solutions. Training and design workshops could follow-up these discussions and further train event organizers and suppliers interested in learning more about sustainable alternatives.

Use-cases

- Eureka MDF: The technology uses post-harvest rice residue MDF panels with non-toxic adhesive.
- WOODOO: The recyclable molecularly enhanced advanced wood materials uses the transformation of low-grade wood into high-performance materials by replacing lignin with a bio-based polymer.
- XSTRAWDINARY: The material/flooring is made with agricultural residues, with similar characteristics as wood.
- Ecoboard: The advanced MDF board is composed of wheat residue panels glued with eco-friendly adhesive (MDI).
- Green Ultimate: The bio-based adhesive for wood elements replaces petroleum-based resins.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

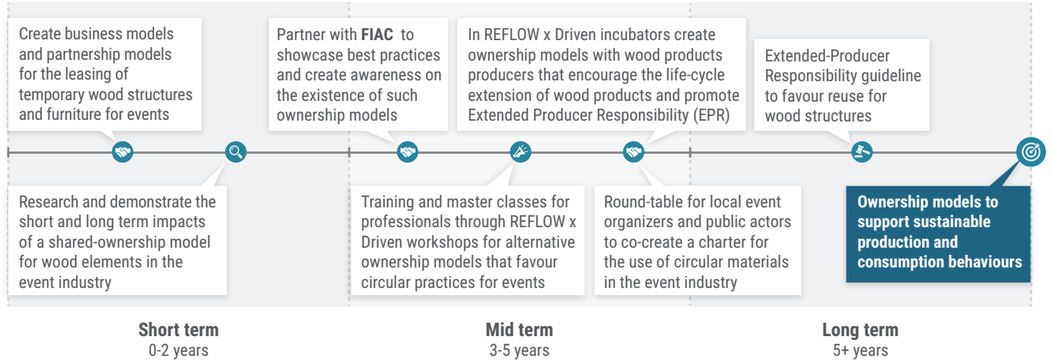
4.5.3 Strategic direction 3.2: Leasing model for temporary wood structures

Specific ownership and leasing models can have drastic effects on the use patterns of wood products and drive forward their circularity. Conducting **in-depth research on leasing models in the event industry** is a key next step to assess the variety of contracting and supplying models available and their associated benefits. The REFLOW pilot team can partner with FIAC suppliers to identify best practice and showcase the management of wood structures. Best practices can then be incorporated into Driven x REFLOW masterclasses and training on the sustainable management of materials, catered to event industry actors. The REFLOW team, through its incubator, can also work with SMEs and startups producing wood products for the event industry to develop strong circular business models that **promote Extended Producer Responsibility.**

Use-cases

- Arhend (Furniture as a service (FAAS)): The furniture company Arhend and the Ellen McArthur Foundation piloted a FAAS model to promote circularity, reduction in material usage and carbon emissions, and a more secure materials supply chain for office furniture.
- "Buy-back" schemes: This scheme applies to building blocks used by infrastructure companies in the Netherlands. The scheme involves a pre-agreed price for the buying-back and a deposit system.

3.2 Change in ownership models for wood elements



4.5.4 Strategic direction 3.3: Design temporary wood structures for efficient disassembly and future use

In line with the AGEC law[222] which brings Extended Producer Responsibility into the French construction sector, designing for disassembly ensures that stakeholders involved in the design of wood-based construction

[222] Légifrance. (2020). LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

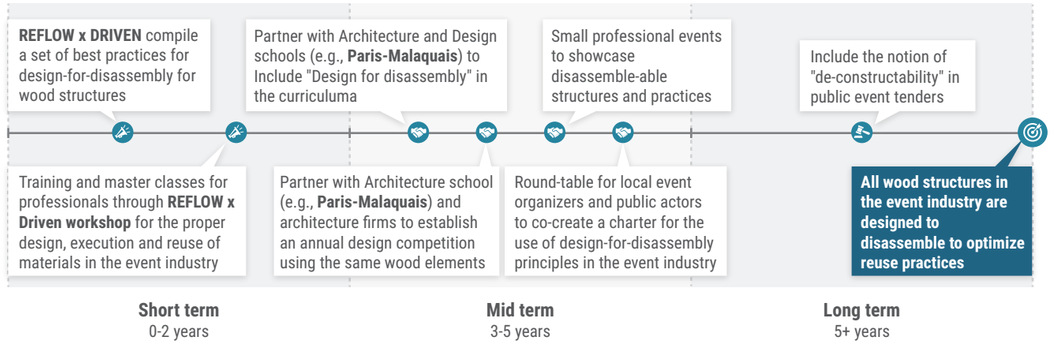
materials (manufacturers, architects, construction companies) play an active role in the management of the waste generated.[223] For this to be achieved, the above mentioned stakeholders should use instruments such as modular design, mono-material composites, product disassembly guidelines, and adhesive-free assembly.[224] To further enable reusability of materials in events and the urban mining of buildings in Paris, structures need to be designed keeping disassembly in mind.

The City of Paris can incentivise local architectural schools to **launch design competitions** for "design for disassembly," results of which can be used to showcase possible structures and practices at a professional level. REFLOW x Driven workshops can be leveraged to train professionals in design for disassembly and reuse of materials in the event industry. Training can include skills such as BIM or other digital tools to determine suitable connection systems for wooden structures.[225] The workshops can introduce innovative design techniques to professionals such as Wave Layered Timber, which is a glue-free building system that utilises the wave shape to lock together self-tightening wood components. Local event organisers and public actors in Paris can co-create a **charter for the use of circular construction principles** in the event industry, and eventually propagate the **inclusion of "disassemblability" as a criteria in future public event tenders.**

Use-cases

- Wave layered timber (WLT): To demonstrate circular design strategies in temporary structures, the city of Aarhus showcased a 1:1 wooden structure Dome of Vision 3.0 using disassemblable elements.
- ModulaR3 and Sylcat: Many manufacturers of wooden construction systems have also developed solutions for disassembly such as ModulaR3 and Sylcat.

3.3 Design for Disassembly: temporary wood structure are designed for efficient disassembly for future use



[223] Shooshtarian, S., et al. (2021) Extended producer responsibility in the Australian construction industry.
[224] Ibid.
[225] Pozzi, L. E. (2019). Design For Disassembly With Structural Timber Connections.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

4.5.5 Strategic direction 3.4: Sustainable management of Ile de France forest

To create a sustainable local wood production sector in Ile-de-France, it is important to assess the forest's natural capacity and **define a sustainable annual rate of extraction for wood.**[226] This analysis can guide the implementation of criteria to identify sustainable suppliers of local wood in the region who are trained in the basics of sustainable wood and forest management, such as the Certified Green Dealer[227] initiative in the US. Products originating from Ile-de-France forest can be labeled or certified to create a narrative around place-based circular economies[228] which can then be integrated into the tracking and tracing pilot.

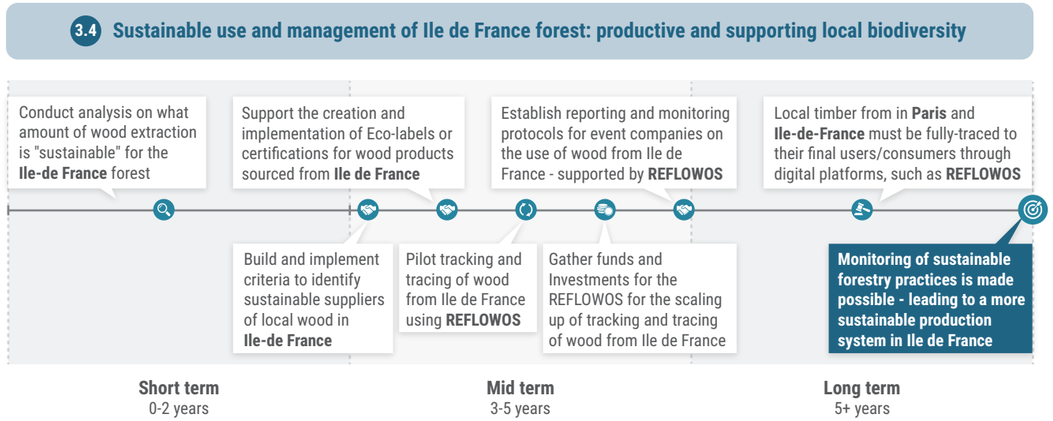
Central governments and industrial forestry players are often not highly active in urban timber value chains. Thus, changes in forest governance such as: (i) grouping smaller forest landowners into economic and environmental interest groups,[229] (ii) decentralising forest management,[230] and (iii) using locally controlled forestry[231] practices have been recommended for urban local forests. Insights from local value chains based on urban forests in other European regions can also inform policy options, circular economy practices,[232] and business models associated with locally-governed forest and forest-product management.[233] Such practices have the potential to create regenerative urban landscapes within the Ile-de-France region.[234]

Use-cases

- GDi GISDATA: The localised forest monitoring tools can support sustainable forest management practices.
- Forest's Contracts: The Lombardy Region Forests developed the Contracts as a participatory management tool for local communities.

[226] which complies with the National Forest Accounting Plans and the FRL (Forest Reference Levels) estimated for France estimated at -55.40 $MtCO_2eq$ for the period 2021–2025 and -57.29 $MtCO_2eq$ for the period 2026–2030
[227] Ecolabel Index. (2021). Certified Green Dealer.
[228] Kampelmann, S. (2020). Wood works: how local value chains based on urban forests contribute to place-based circular economy.
[229] CITEPA, et al. (2019). The National Forestry Accounting Plan of France including the Forest Reference Level (FRL) for the 2021- 2025 and 2026-2030 periods.
[230] Hajjar, R.; Molnar, A. (2015). Decentralization and community-based approaches.
[231] Macqueen, D.; Demarsh, P. (2015). Enabling investment for locally controlled forestry.
[232] Economic Commission for Europe, et al. (2019). Forests and the Circular Economy.
[233] Kampelmann, S. (2020). Wood works: how local value chains based on urban forests contribute to place-based circular economy.
[234] Marin, J.; Meulder, B. de. (2018). Urban landscape design exercises in urban metabolism: Reconnecting with central limburg's regenerative resource landscape.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



4.6 Relevance for pilot activities

The Paris Pilot's action plan and Theory of Change outline the key activities that will be done during the period of the REFLOW project to promote and achieve a city with a culture of circular events and circular temporary construction. To communicate how and where Metabolic Institute's urban metabolism analyses and resulting recommendations directly support the Paris pilot's planned activities, desired outcomes, and impacts, we mapped out all touchpoints between the Theory of Change and our proposed three focus areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

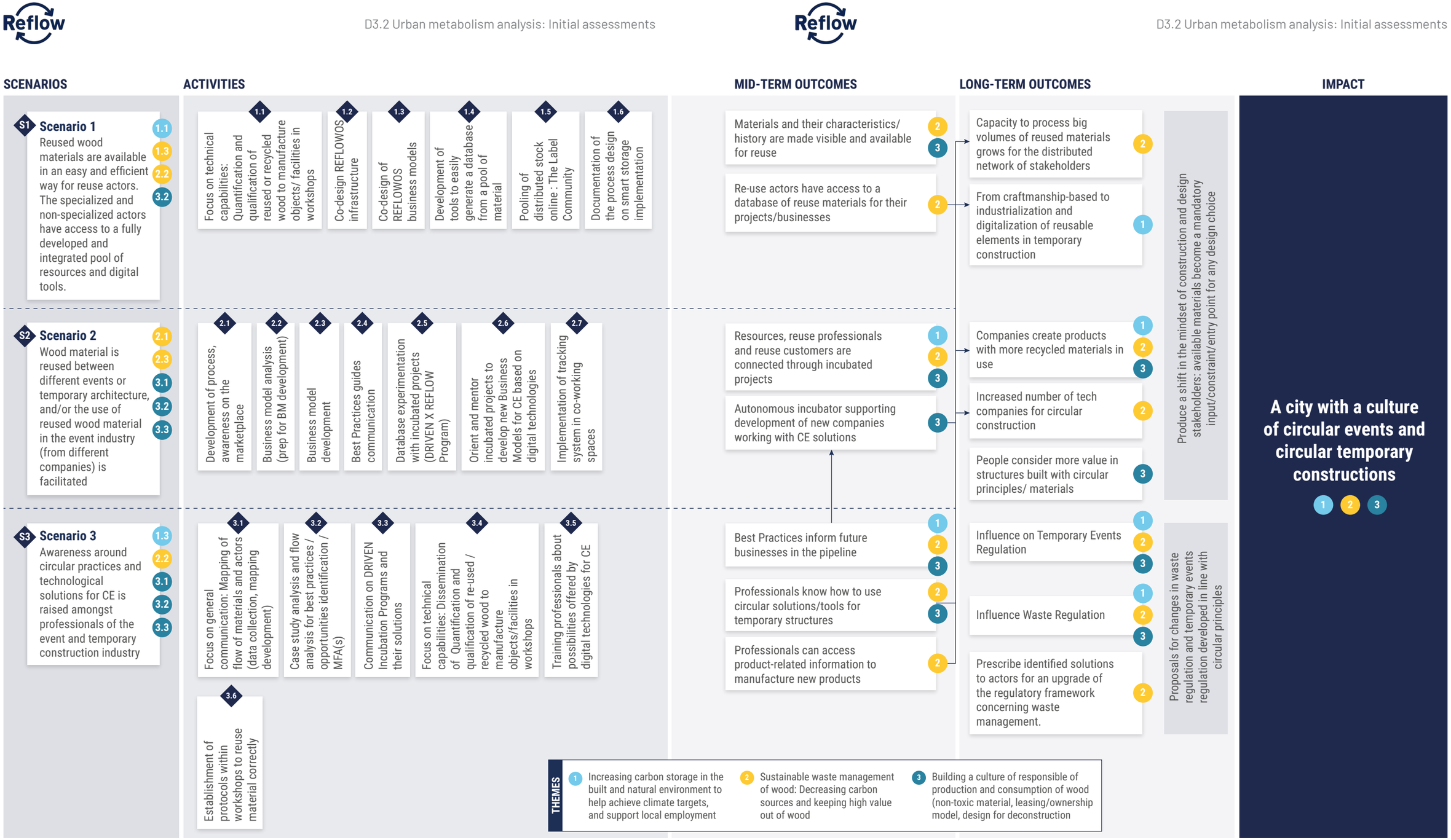


Figure 38: Touchpoints between the Paris Pilot's Theory of Change and the proposed focus areas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

5. CLUJ-NAPOCA

5.1 Introduction to Cluj-Napoca's energy sector

5.1.1 Background and scope of the analysis

Introduction to Cluj-Napoca

The City of Cluj-Napoca is located in the north-western part of Romania, 450 kilometres from Bucharest. Cluj-Napoca is the capital of Cluj County and the unofficial capital of the historical province of Transylvania. The City is one of the largest cities in Romania, with the broader metropolitan area of Cluj-Napoca accounting for 392,000 people.

Cluj-Napoca is growing both economically and demographically and, in recent years, has become an important economic center for Romania. Moreover, Cluj has become known as the "capital" of the IT sector in the country. Cluj's recent developments have led to significant changes in the social and economic life of Cluj and has generated a constant inflow of population. A recent study by the World Bank has revealed that housing needs for the next ten years is over 100,000 homes, while the building pace in the last years was around 7,000 homes/year.[235]

Challenges associated with Cluj-Napoca's fast-pace growth have been addressed within an Integrated Strategic Plan[236] which organises the development framework for the whole Metropolitan Area of Cluj-Napoca until 2030. In regards to energy consumption, local and regional strategies follow the guidelines of the National Energetic Strategy for 2030, which sets the main strategic objectives as: energy security, sustainable development and competitiveness. The Municipality's Action Plan aims to reverse the city's increasing energy consumption by introducing more efficient and circular solutions in district heating and electricity usage. A key direction for intervention identified thus far is the implementation of investment projects aimed at increasing energy efficiency and mitigating climate change with the help of EU funding. To date, the Municipality has successfully accessed some funding for increasing energy efficiency, promoting low carbon public transportation, and disseminating the need to be energy efficient to the local community.[237]

Within REFLOW, the aim of the Cluj-Napoca pilot is to build on top of the city's existing programs by focusing on improving the energy efficiency of public buildings and residential homes throughout the city. Objectives set by the pilot team include: assessing how the measures taken to date by the City have impacted the energy efficiency of selected buildings; to involve local stakeholders in implementing and furthering these measures; and to encourage different actors in the ecosystem to propose new ideas regarding renewable energy sources to be integrated in the City's strategy for a circular economy. All objectives will be complemented by educating citizens on the circular economy, its benefits and possibilities.

[235] Parisi, C., et al. (2020). H2020 REFLOW Deliverable 1.2: Cities' Circular Action Plan.
[236] Consisting of the city and the surrounding 18 communes.
[237] Parisi, C., et al. (2020). H2020 REFLOW Deliverable 1.2: Cities' Circular Action Plan.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Scope and Method of the Energy Flow Analysis (EFA)

In order to support the Cluj pilot team in assessing (i) the current energy efficiency of municipal assets, and (ii) high-potential interventions the City can take on to improve its energy efficiency, Metabolic Institute conducted an Energy Flow Analysis (EFA). The EFA focuses on energy consumption within the municipal boundaries of Cluj-Napoca in the year 2020. The analysis focuses on electricity consumption for all municipal assets. These assets include buildings as well as public lighting. The EFA focuses mainly on electricity consumption as detailed consumption data was available. Additionally, gas and heat consumption are estimated using the available data. In order to calculate the emissions due to energy consumption, the country of origin and source (eg. wind, solar, natural gas) are included in the analysis.

Metabolic Institute took a highly iterative approach with the Municipality and REFLOW pilot team to produce the EFA. As part of this process, and to improve the granularity and accuracy of Metabolic Institute's results, the Municipality of Cluj provided bottom-up data, including:

- A total of 2,062 Excel files that contained hourly electricity use in KWh for each consumption point in 2019 and 2020. The Excel files cover 1,137 consumption points.
- An overarching dataset that included the total consumption per month in 2018, 2019, and 2020 for each consumption point.
- A total of 22 scanned PDF documents of energy certificates. Each energy certificate included energy labels, construction years, floor area, and building type for one or multiple buildings.

In addition to municipal data sets, the Metabolic Institute team leveraged a series of external datasets to develop the EFA, including:

- The Europe Energy Buildings Database[238] to understand the energy efficiency of existing buildings in Romania.
- The EuroStat energy consumption sankey[239] to model the different types of energy sources (gas, hydro, solid fuels, etc.) used in Romania and to map their country of origin to account for imports, exports, and production in Romania.
- Data from the EIA[240] (Energy Information Administration) to supplement the Eurostat consumption data to provide more detail on the types of energy sources (gas, hydro, solid fuels, etc.) used in Romania.
- The 2017 Version of the CoM Default Emission Factors for the Member States of the European Union[241] provided by the Joint Research Commission of the European Union to calculate the emissions associated with energy consumption in Cluj-Napoca.

[238] European Commission. (2021). EU Buildings Database | Energy.
[239] Eurostat. (2021). Energy flow diagrams.
[240] U.S. Energy Information Administration (EIA). (2021). Dataset.
[241] data.europa.eu. (2021). CoM Default Emission Factors for the Member States of the European Union - Version 2017.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Metabolic Institute undertook several methodological steps to develop the EFA. The whole workflow is modelled in Python to increase transparency and replicability. The point of departure for the EFA is the overarching dataset that the Municipal of Cluj provided which includes the total electricity consumption per month in 2018, 2019, and 2020 for each consumption point. The first step was to process this dataset to calculate the electricity consumption in MWh per month for every consumption point in 2020. Subsequently, each consumption point, for instance "Gradinita cu Program Prelungit Floare de Iris - 594040100000136425 Gradinita cu Program Prelungit Floare de Iris OASULUI 131" is classified into a building type. In the case of this example the building represents a kindergarten. The classification scheme was iteratively produced and verified with the Municipality of Cluj-Napoca.

Based on the electricity consumption per building type, the amount of gas and heat are estimated using Romanian averages. This calculation is performed using conversion factors derived from the Europe Energy Buildings Database.[242] Next, the energy source (gas, hydro, solid fuels, etc.) and origins (production in Romania, import and export from other countries) are modelled using the EuroStat[243] and EIA[244] data. Finally, emissions (ton CO_2eq/MWh) are calculated for electricity, gas, and heat using emission factors derived from the CoM Default Emission Factors for the Member States of the European Union.[245]

Based on the EFA, Metabolic Institute has derived a series of insights. These insights reveal disproportionate consumption or emissions for some building types and assets. Next to the derived insights, time series analysis is conducted on the hourly data provided by the Municipality of Cluj-Napoca. In order to conduct the time series analysis, all 2,062 Excel files are aggregated and loaded into an SQL-database. Subsequently, each entry is classified to derive building types for each consumption point. Finally, the Prophet Library is used in Python to perform the actual time series analysis on the hourly data.

5.1.2 Current System and its Impacts

The Energy Flow Analysis (EFA) of Cluj-Napoca's public assets was developed using monthly electricity consumption data for each individual public building and the public lighting network. Gas and heat consumption were estimated based on the building type of each individual building. The total energy consumption of Cluj-Napoca's municipal buildings and assets in 2020 equals 20,800 MWh.

The EFA highlighted that Cluj-Napoca's public energy consumption is dependent on an energy grid that still relies heavily on fossil fuels - with 66% of the energy consumption based on gas (40%) and solid fuels (26%). Nuclear power provides a significant amount of energy, with almost 20% supplied to the Romanian grid, on which Cluj-Napoca relies. Renewable energy supplies the remaining 14% of Cluj-Napoca's public energy demand. Hydropower constitutes two-thirds of the renewable energy power (9% of total, with 1900 MWh).

[242] European Commission. (2021). EU Buildings Database | Energy.
[243] Eurostat. (2021). Energy flow diagrams.
[244] U.S. Energy Information Administration (EIA). (2021). Dataset.
[245] data.europa.eu. (2021). CoM Default Emission Factors for the Member States of the European Union - Version 2017.
[246] PROPHET. (2021). Prophet | Forecasting at scale.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This is followed by wind, solid biofuels, and solar photovoltaic, providing a combined 5% of the energy used in the City's public buildings.

The majority of the energy consumption from public utilities can be attributed to electricity consumption with a total 14,400 MWh consumed annually (69% of the total energy consumption). It can be noted that 2020 electricity consumption within public buildings appears to be lower than in previous years, most likely due to increased working from home due to the Covid-19 pandemic. In the previous 5 years, the average electricity consumption was around 19,000 MWh. Most of the electricity consumed in Cluj-Napoca's public utilities was produced in Romania (see text box below), with only 11% imported from Bulgaria, Hungary, Serbia, Ukraine, and Switzerland. A quarter of the energy is consumed in the form of gas (predominantly natural gas for gas boilers and for heaters), and the rest (7%) in the form of district heating.

Romanian electricity sector

The Romanian electricity sector is fragmented across seven companies producing most of the electricity, 6 main distributors (that also supply energy), and more than 20 additional active suppliers. The entire transmission network is managed by Transelectrica, a state-owned company.[247]

Electricity in Cluj-Napoca

Most of Cluj-Napoca's electricity comes from the distributor Electrica Distributie Transilvania Nord. 80% of Electrica's customers are domestic clients living in residential buildings, households, and municipal buildings. However, the company is also supplying electricity for public lighting and public utilities. Electricity for Cluj-Napoca is mainly generated by three gas-operated cogeneration power plants (37.5 GWh/year). Locally, no electricity is generated from hydropower, biomass or wind renewable sources, and there are currently only a few photovoltaic systems operating.[248] Nonetheless, imported electricity from renewable energy is present in Cluj-Napoca's grid, as highlighted in the EFA.

District heating and gas consumption in Cluj-Napoca

Hot water and thermal energy in Cluj-Napoca are provided by the Regia Autonomă de Termoficare Cluj (RATCJ), an autonomous public company in which Cluj-Napoca City Hall is the main shareholder. The district heating network is made up of a thermal plant of 143 MW with 109 sub-plants and 300 boilers, and a cogeneration plant. Heat is generated by both cogeneration plants and thermal power stations. The system is split between neighborhood heating plants where each facility is serving 20 to 40 residential buildings. 90% of the natural gas necessary to generate hot water is purchased from Petrom, the largest Romanian oil company and a natural gas producer. The gas pipelines have been directly linked to RATCJ since 1962.

[247] TRACE. (2017). Improving Energy Efficiency in CLUJ-NAPOCA Romania.
[248] Ibid.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

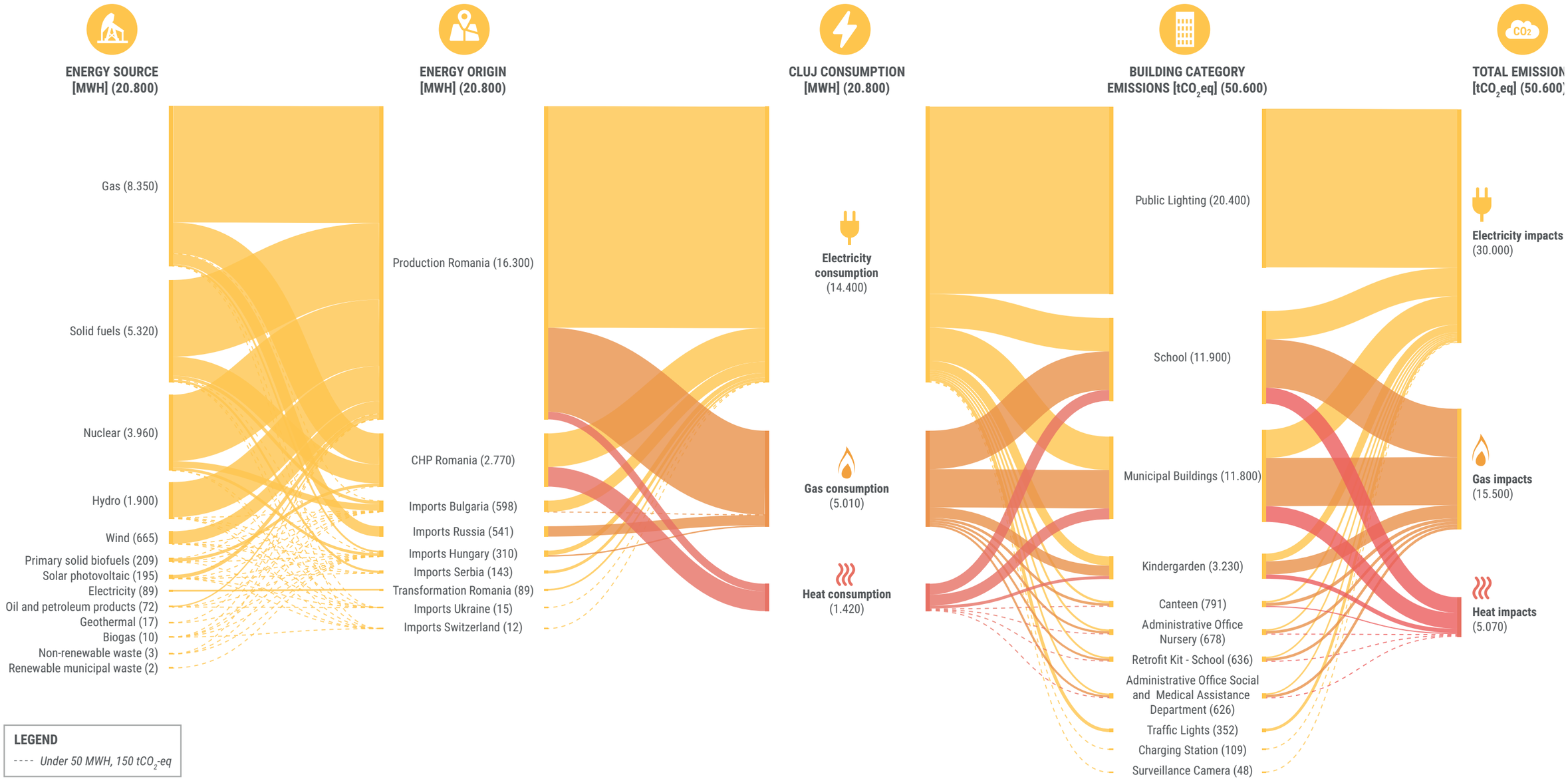


Figure 39: Energy Flow Analysis of Cluj-Napoca's public assets

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

The lion's share of the electricity supplied to public utilities is consumed by the public lighting network, representing 68% for the electricity annually consumed. Municipal buildings and schools complete the top 3, with almost identical annual consumption, each representing 12% of the total electricity consumed by the City's public infrastructures. These two building types also have very similar gas consumption patterns, covering 80% of the entire annual demand for gas. Kindergartens are also notable users of gas, consuming 10% of the total volume.

A total of 50,600 tons of greenhouse gas emissions (GHG - expressed in CO_2 equivalent) are emitted during the electricity or heat production process or directly emitted while burning gas. The electricity consumed by Cluj-Napoca public infrastructure accounts for approximately 60% of the total CO_2eq-emissions from the public assets' total energy consumption, while gas is responsible for about 30%, and heat 10%. Overall, public lighting accounts for approximately 40% of the CO_2eq-emissions. School's and municipal buildings both account for around 23% of CO_2eq-emissions. Most of these impacts are caused by gas consumption. The Retrofitted building accounts for 1.26% of total CO_2eq-emissions.

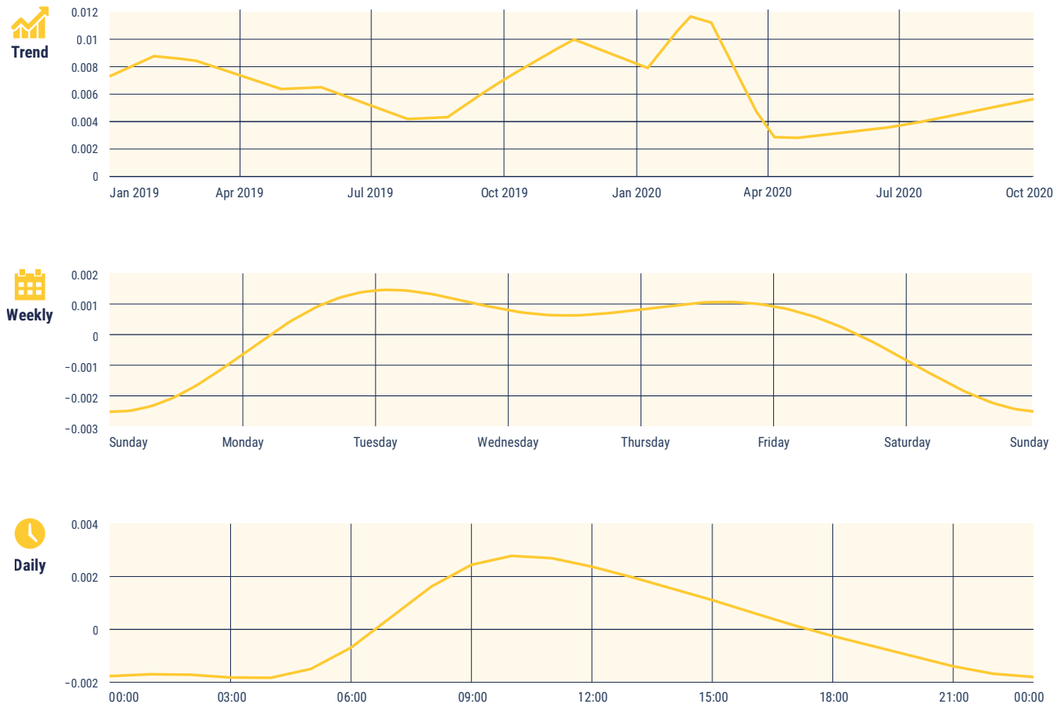


Figure 40: Monthly, weekly, and daily electricity consumption in Cluj-Napoca's public assets

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

While the EFA provided the annual energy consumption for Cluj-Napoca public infrastructure, Metabolic Institute conducted a more granular analysis on consumption patterns at the weekly and daily level. The trend visualisation above shows the electricity consumption from January 2019 to October 2020. Since only data for 2019 and 2020 was available it is not possible to derive insights into seasonal trends. As expected, consumption appears to be lower during the summer months, both due to low heating requirements and longer days, reducing the time public lighting is on. Moreover, a significant drop in consumption within public buildings can be observed in February-April 2020, corresponding to the beginning of the Covid-19 pandemic. The Weekly visualisation shows as expected low consumption on the weekends, and a peak on Tuesday. The peak on Tuesday corresponds to the prolonged workday that is common in Romania. The Daily visualisation shows low consumption during the night, which starts rising around 04:00am, until its peak at around 10:00am. After 10:00am consumption gradually decreases until around midnight.

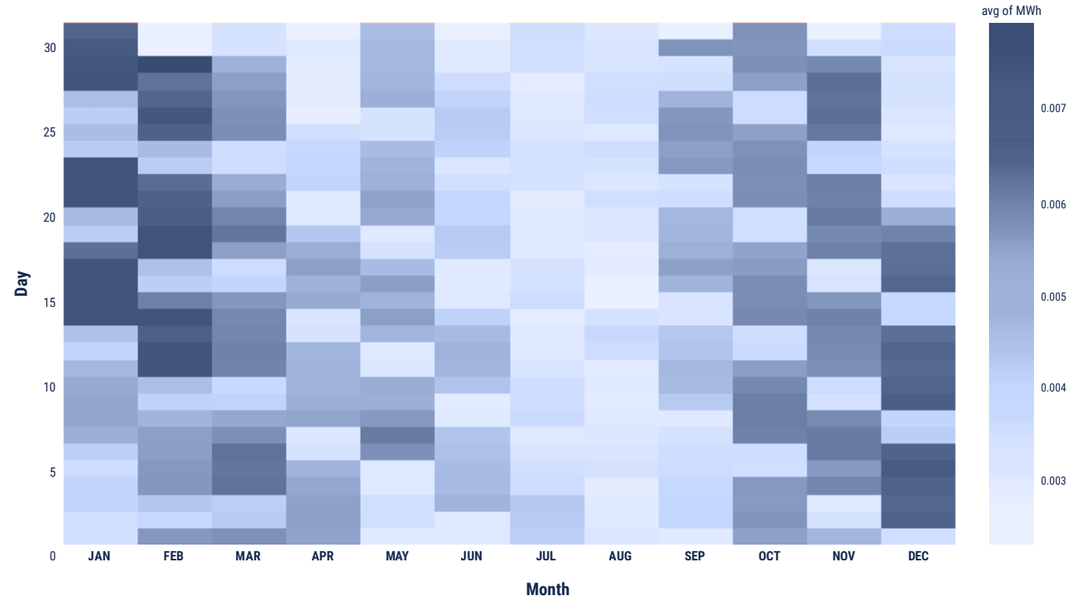


Figure 41: Heatmap of electricity consumption trends in 2020, Cluj-Napoca

The heatmap illustrates the electricity consumption trends for 2020 per day - the darker colors represent a higher electricity consumption. Electricity consumption is highest during the winter, and especially during weekdays. Weekends generally have low electricity consumption in all seasons, since public buildings are mostly empty. Yet, the weekends in winter still demand more energy than some weekdays in high summer.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

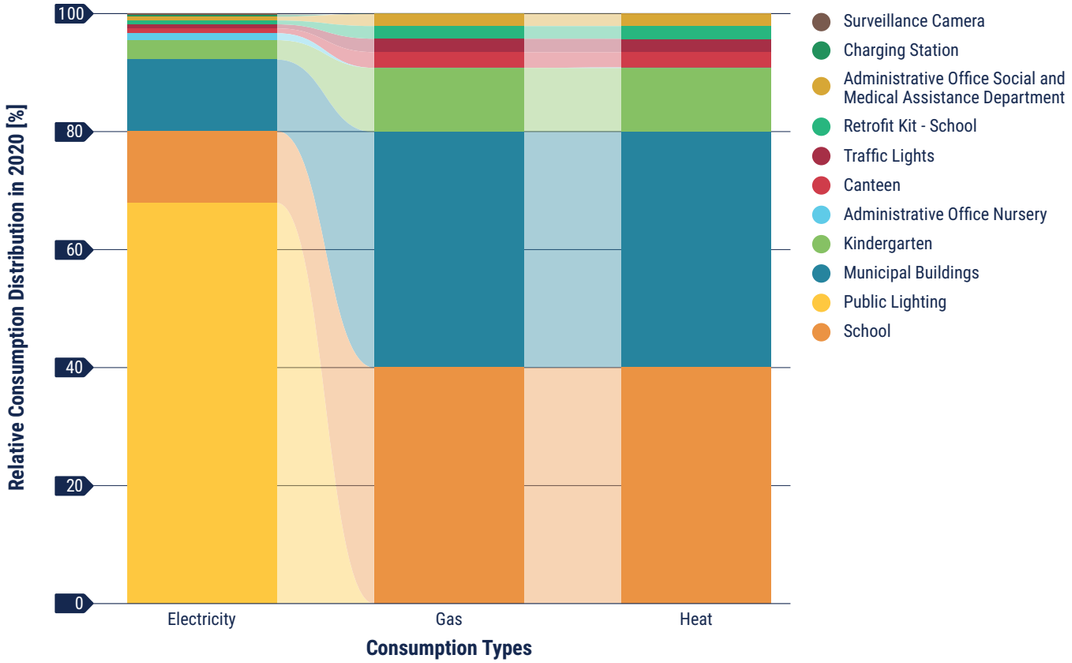


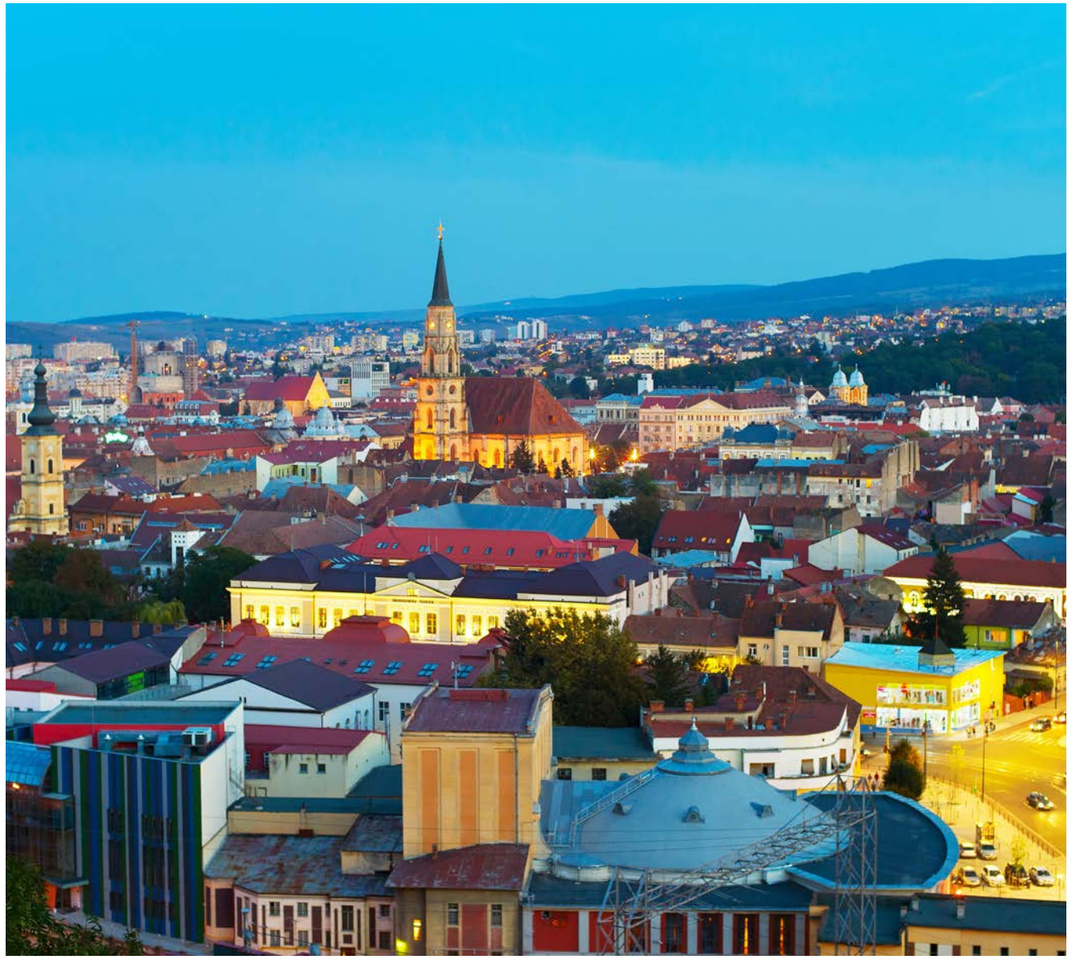
Figure 42: Relative contribution of public asset types to the total public consumption of electricity, gas, and heat

The analysis has highlighted key hotspots regarding Cluj-Napoca's public utilities energy consumption - illustrating specific building and asset types that consume the most energy, and therefore offer the best opportunities to reduce the City's energy consumption. The flow diagram shows the relative consumption distribution between different assets. Gas and Heat show an equal relative distribution as they are both derived by applying a conversion factor to the electricity consumption. But in fact the gas consumption is approximately 3.5x larger than the heat consumption. When it comes to electricity consumption, public lighting is the largest consumer by far with a total of around 68%, spread across 300 individual consumption points. Therefore, **solutions targeting the efficiency of the lighting system can significantly reshape the City's energy consumption profile.**

In terms of building types owned by the Municipality, schools and municipal buildings represent around 25% of the electricity consumption. These sources are not as diffuse as the public lighting, but situated at specific locations. It is possible, however, that there are multiple consumption points within a school or municipal building. Additionally, when it comes to gas and heat consumption, schools and municipal buildings are by far the largest consumers. As they account for 46% of total GHG emissions, both **schools and municipal buildings provide good opportunities to reduce energy consumption, and therefore GHG emission.**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Metabolic Institute assessed the 1,137 consumption points spread across Cluj-Napoca's municipal buildings to assess which buildings may provide the best potential for GHG impact reduction. Figure 43 below pinpoints which buildings and assets are responsible for the largest GHG impacts as a result of their high energy consumption points. The figure illustrates the top 20 consumption points and assets that, together, account for a disproportionately large 25% of the total GHG impacts. Thus, **these consumption points provide good opportunities for focused interventions.** More specifically, the municipal building named **"Municipal-Cluj-Napoca"** accounts for 3 of the 20 consumption points, thus presenting a perfect profile for energy efficiency interventions. Additionally, the technical schools - **Colegiul Tehnic** and **Liceul Tehnic** - also provide good opportunities for interventions as they totalize 5 energy consumption points over the top 20 consumption points.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

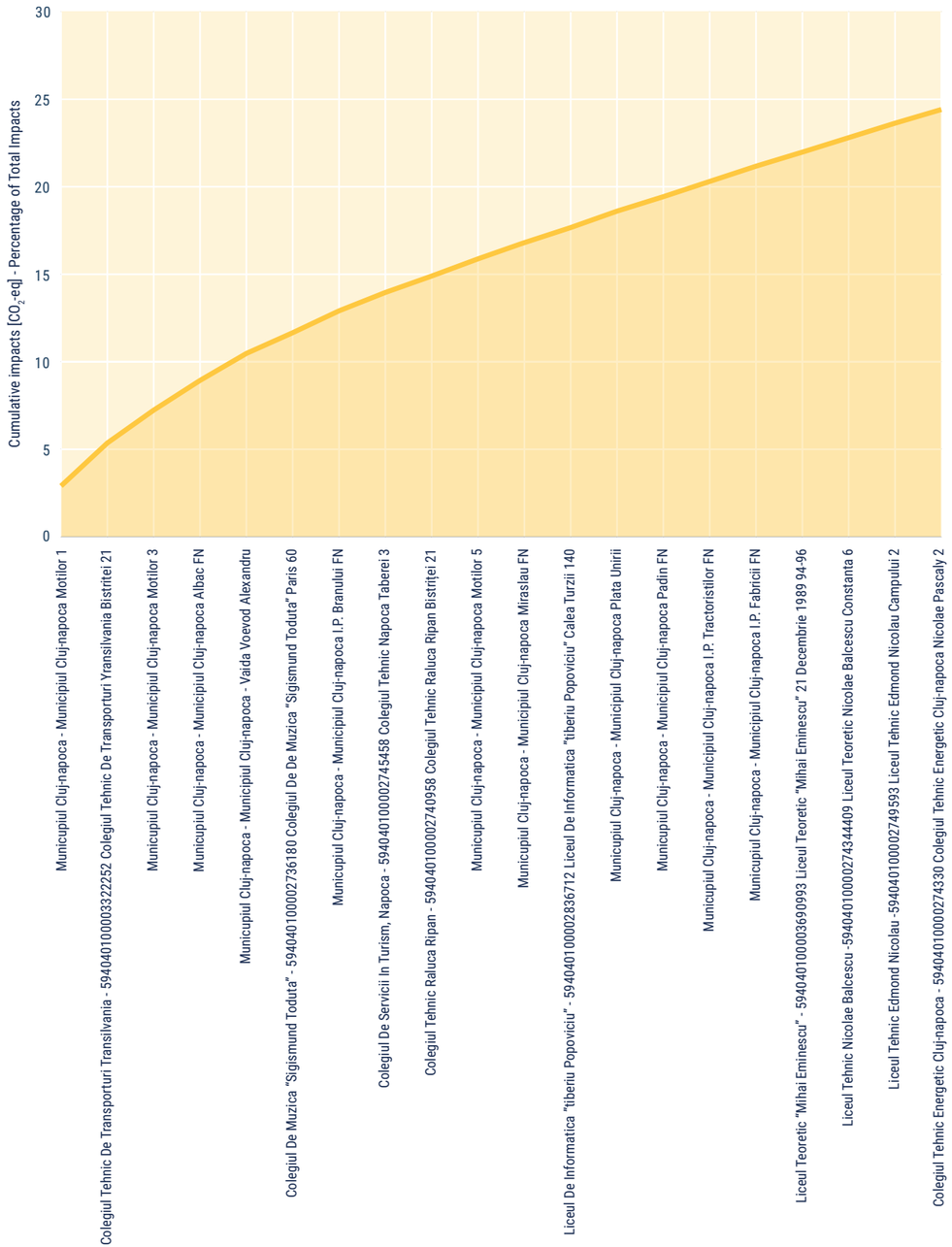


Figure 43: Top 20 largest GHG emitting consumption points in Cluj-Napoca public assets portfolio

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

5.2 Vision for a sustainable energy sector in Cluj-Napoca

Following the European Union's accession to the Paris Agreement, the Union has taken a leading role in leveraging sustainable energy for the fight against climate change with five prime dimensions: energy safety, decarbonisation, energy efficiency, the energy internal market, and research, innovation and competitiveness. The Union has committed to leading the global energy transition by achieving the Paris Agreement targets and focusing on the supply of clean energy throughout the Union. To do so, the Union has established energy and climate targets for 2030:

- A 40% reduction in domestic greenhouse gas emissions (compared to 1990)
- 32% renewable energy consumption
- 32.5% increase in energy efficiency
- 15% electricity interconnection

To ensure these targets are achieved, EU Member States must submit an Integrated National Energy and Climate Plan (INECP) to the European Commission for the period 2021-2030. Romania's INECP[249] includes the following 2030 targets:

- Romanian emissions are reduced by 44% (compared to 2005)
- Share of energy from renewable sources reaches 30.7
- Primary consumption decreases by 45.1% and final consumption by 40.4%
- Internal energy sources are increased and a diversified energy mix is ensured:[250] 30.3% hydro (7,593MW); 21.0% wind (5,255MW); 20.2% solar (5,054MW); 11.8% natural gas (2,958MW); 7.9% solid fuels (1,980MW); 7.9% nuclear energy (1,975MW); 0.4% crude oil and petroleum products (100MW); 0.5% biomass (137MW)

In regards to the energy transition, the Cluj-Napoca's Municipality Action Plan focuses on reversing the City's increasing energy consumption and waste by introducing more efficient and circular solutions in district heating and electricity usage. To date, the Municipality has successfully implemented a series of energy efficiency pilots, promoted low carbon public transportation, and disseminated the need to be energy efficient to the local community. The aim of the Cluj-Napoca pilot is to build on top of the city's existing programs by focusing on improving the energy efficiency of public buildings and residential homes throughout the city. By achieving this main goal, a series of broader achievements can be met:

- Improving the quality of life of city residents
- Increasing resource savings (both from an economic and ecological perspective)
- Improving collaboration between the City Hall and local stakeholders
- Positioning Cluj-Napoca as a lighthouse city in Romania
- Increasing the involvement of local communities across Romania in replicating best practice more broadly

[249] Government Romania. (2020). The 2021-2030 Integrated National Energy and Climate Plan.
[250] Based on a 25,052 MW total.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Based on our research on the current state and hotspots within the energy sector in Cluj-Napoca, we have developed two strategic focal areas the City can take as an initial focus to contribute towards their vision of a sustainable energy sector, as well as contribute towards the Romanian national and European goals in regards to the energy transition:

1. **Increase the energy efficiency of public buildings and assets in Cluj-Napoca:** The Cluj-Napoca Municipality should aim to reduce scope 1 emissions[251] by retrofitting existing public buildings and assets, first focussing on public lighting and energy efficiency measures that reduce gas consumption in schools.
2. **Prepare Cluj-Napoca for a future decentralized, renewable energy system:** The Cluj-Napoca Municipality should aim to reduce scope 2 emissions[252] by increasing on-site energy energy generation, as well as accelerating the development of local renewable energy production capacity.

5.3 Focus Area 1: Increase the energy efficiency of public buildings and assets

5.3.1 Introduction

A staggering 75% of buildings in the European Union are estimated to be energy inefficient.[253] Investing in energy efficiency at the municipal level will only lower the carbon footprint of EU Member States, but create important cuts in energy consumption expenditure at the national level.

The total energy consumption of Cluj-Napoca's municipal buildings and assets in 2020 equals 20,800 MWh. The majority of this energy consumption can be attributed to electricity consumption, with a total 14,400 MWh. A large portion of electricity is consumed by **public lighting** and a select number of municipal buildings - with **schools** and **municipal office buildings** representing almost half of electricity consumption combined. When it comes to gas and heat consumption, schools and municipal office buildings are by far the biggest consumers.

Based on the EFA insights, **schools** - especially **"Colegiul Tehnic"** and **"Liceul Tehnic"** - and **municipal office buildings** - especially **"Municipal-Cluj-Napoca"** - provide good opportunities to reduce energy consumption. Cluj-Napoca Municipality should target these buildings and apply the REFLOW pilot's retrofit kit or other cost-effective energy efficiency upgrades, such as: replacing light bulbs and radiators/boilers, increasing insulation, and sealing air-leaks. The City should aim to reduce scope 1 emissions[254] by retrofitting existing buildings and assets, first focussing on public lighting and energy efficiency measures that reduce gas consumption in schools. Within this track, the City could aim to achieve an energy label A for all municipal property in 2030.

[251] All Direct Emissions from the activities of an organisation or under their control. Including fuel combustion on site such as gas boilers, fleet vehicles and air-conditioning leaks.
[252] Indirect Emissions from electricity purchased and used by the organisation. Emissions are created during the production of the energy and eventually used by the organisation.
[253] European Commission. (2020). Energy efficiency in buildings.
[254] All Direct Emissions from the activities of an organisation or under their control. Including fuel combustion on site such as gas boilers, fleet vehicles and air-conditioning leaks.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

In addition to these targeted building interventions, the City can adopt **Smart City Practices** and transition towards automated building management systems. Moreover, the City can leverage existing public lighting maintenance schedules to install **high-efficiency lighting.**

5.3.2 Strategic Direction 1: Apply the REFLOW pilot's retrofit kit

The Municipality, in collaboration with the REFLOW pilot team, should apply the retrofit kit and/or additional upgrades on all public buildings and assets. This work can begin by auditing municipal buildings and assets with the aim to identify high energy consumption assets. For each asset, complete a detailed audit to identify main causes of inefficiency and identify key interventions. Such an asset audit should cover: type of lighting, age and type of heating systems, age and type of boiler, existence of double glazed windows, amount and type of insulation, etc. Upon completing each audit, the REFLOW pilot team can identify which assets their retrofit kit can contribute the most to. For those assets which the retrofit kit cannot support, additional energy efficiency upgrades should be identified. With an intervention strategy per asset in place, inclusive of the retrofit kit and complementary measures, the City can work with its university partner to calculate the potential cost effectiveness (MWh reduction per € spend) of applying the upgrades. Based on the absolute reduction potential per euro spent, the City can prioritize and apply interventions with the highest potential. For each intervention, a monitoring process should be implemented to measure actual impact over time. It will be important to measure the impacts of the retrofit kit and upgrade interventions over multiple years in order to account for yearly and seasonal variability compared to a baseline year.

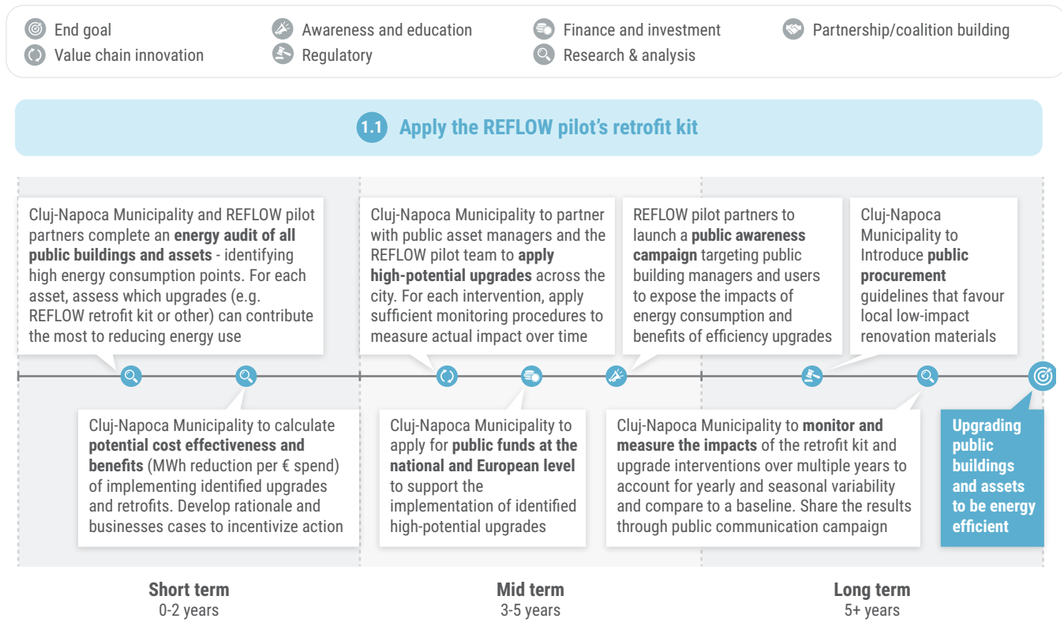
In parallel to conducting the upgrade audit, the Municipality should run an awareness raising campaign targeting municipal building managers and users. Through a communication campaign, the City and REFLOW pilot partners can raise awareness amongst public building managers and users on the issues and benefits of energy efficiency. The asset audit can be leveraged here to expose the amount of energy consumed by different assets and where opportunities and benefits are for increasing efficiency. The potential financial savings associated with the retrofit kit and complimentary upgrades, calculated per municipal asset by the City and its partnering university, can be communicated to building managers and users to further incentivize uptake. Annual results from the City's upgrades and monitoring processes can be published to further evidence the benefits of upgrades and garner further support.

Lastly, the City can introduce public procurement guidelines that favour local low-impact building materials during the retrofitting and upgrade measures. This work should begin by mapping the materials required for planned upgrades, working with local experts to identify sustainable materials, and then mapping local supply chains to identifying local suppliers.

Use-cases

- Paris School Retrofit Project: As part of Paris Climate Plan, the Project aims to retrofit 600 schools with a target of 65GWh of energy savings per year.
- RE:FIT Programme: In London, the Programme has a goal to cut carbon emissions from London's public buildings.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



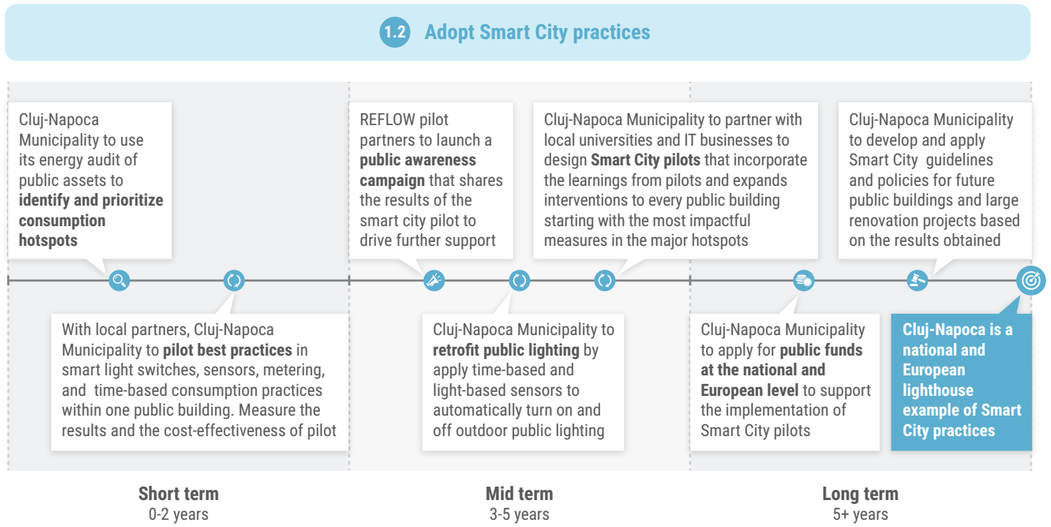
5.3.3 Strategic Direction 2: Adopt Smart City practices

Through an energy efficiency audit of municipal buildings and assets, the Municipality in collaboration with REFLOW pilot partners can identify specific assets that are consumption hotspots. For those assets identified, the City can create a partnership with local universities and IT companies to design pilots that leverage and test Smart City practices. Such practices can include: applying time-based and light-based sensors to automatically turn on and off outdoor public lighting. Moreover, the Municipality could identify specific municipal buildings to pilot best practices in smart light switches, sensors, metering, and time-based consumption practices. Smart pilots should be closely monitored over a predetermined time frame in order to measure the results and the cost-effectiveness of solutions. If the implementation of Smart City practices reveals positive outcomes, the Municipality can expand interventions across all relevant public buildings -starting with the most impactful measures and major hotspots. Lastly, the Municipality should collect and disseminate results and best practice of its pilots through Smart City guidelines and policies that can be used to guide the future development of public buildings and large renovation projects. By disseminating such guidelines more widely, Cluj-Napoca Municipality can position itself as a frontrunner and share best practices with other Romanian municipalities and public building managers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Use-cases

- Spectral: In ArenApoort, Spectral will develop a smart grid system to mitigate the possible stain in the power grid caused by rapid expansion.
- Energy Save: The Energy Management Solution is based on Artificial Intelligence and provides solutions for monitoring, reporting, control, and automation. It allows energy savings of more than 30%.



5.3.4 Strategic Direction 3: Install high-efficiency lighting

The lion's share of the electricity supplied to public utilities in Cluj-Napoca is consumed by the public lighting network, representing 68% of the electricity consumed annually. Overall, public lighting accounts for approximately 40% of the CO_2eq-emissions within the city. Therefore, **solutions targeting the efficiency of the lighting system can significantly reshape the city's energy consumption profile.** Within this work, the Municipality should partner closely with Siemens Austria -the private company responsible for the street lighting infrastructure and maintenance work within Cluj-Napoca. Siemens conducts this work through two of its energy saving companies: Siemens Elin Austria and Siemens Gebäudemanagement & Services GmbH.

The Municipality can begin this work by conducting a city-wide evaluation of all existing lighting poles in parallel with an assessment of running and maintenance operations (in collaboration with Siemens Austria, Siemens Elin Austria, and Siemens Gebäudemanagement & Services GmbH). From this evaluation, the Municipality can create an overview of the maintenance schedules for the existing network and identify which districts within the city should be addressed as priorities for upgrades. Understanding the existing maintenance staff and schedule will be important for the Municipality, as these can be leveraged and optimized to complete

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

upgrades. Key upgrades to prioritize will be **replacing public lighting with LED bulbs and implementing a smart timing program and LED bulbs.** The outcomes of the evaluation and the resulting upgrade plans should be communicated to the public alongside the benefits of shifting to a more efficient lighting system.

Upon completion of its evaluation, the Municipality should implement a **smart street lighting timing** and **sensor-based program.** With such a program, street lighting can be adjusted for specific needs in a particular area, according to varying weather and activity levels. Currently in Cluj-Napoca, local authorities start the street lighting network from a central system – someone turns on the entire system when they decide it is sufficiently dark outside. The current system does not allow for adjusting light intensity based on how dark it is outside, or based on the time of the day (e.g., in the early hours, like 2:00am, there is no need to have as much light in the city as in the late afternoon). By making street lights adjustable and automating the system, street lights can be dimmed to varying levels throughout the day, instead of turning off the lights at certain times of the day.[255] Moreover, by implementing motion-sensors within the light network, the Municipality can ensure lights only turn on when someone is walking by and that they stay off when nobody is there. The attractive aspect of this program is that it can be tailored to the specific lighting needs of each area. Such smart street lighting programs are quite simple, inexpensive methods of reducing electricity consumption. In a previous study, TRACE calculated that such a system would require an initial capital investment of $100,000 over a year. This investment would prompt between 100,000 and 200,000 kwh in energy savings.[256]

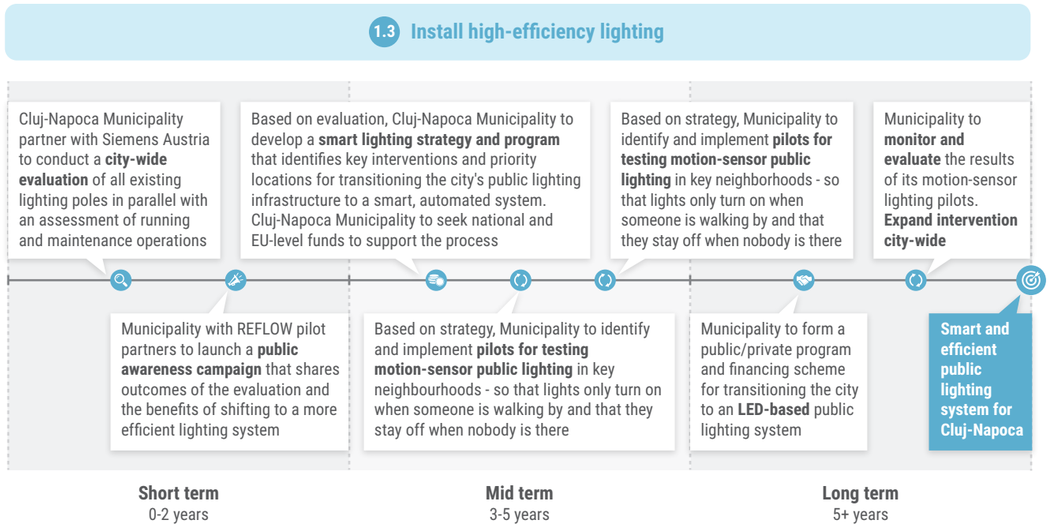
Lastly, the Municipality should transition to LED-based public lighting. It is widely acknowledged that environmentally friendly LED lamps are more efficient than vapor-sodium ones. Because this transition can be quite a costly solution, we recommend the Municipality develops a partnership or a joint venture between the city government and a private entity to accomplish this goal. For example, the city of Los Angeles in partnership with the Clinton Climate Initiative is developing the largest streetlight retrofit undertaken by a city to date. Within the project, the city is replacing traditional street lights with environmentally friendly LED lights. The project is estimated to reduce CO_2 emissions by 40,500 tons and save $10 million annually through reduced maintenance costs and 40% energy savings.[257]

Use-cases

- Copenhagen LED's: Copenhagen has installed more than 19,000 networked LED's with sensors and remote controls. Energy savings are more than 75% with the new lighting system.
- Chennai Public Lighting: 70% of the public lighting in Chennai has been replaced with a LED-based lighting system resulting in large energy savings.

[255] For example, lights can switch to 100% at 7PM, after that dimming to 75% at 10PM, and then to 50% at midnight.
[256] TRACE. (2013). Improving Energy Efficiency in CLUJ-NAPOCA Romania.
[257] TRACE. (2013). Improving Energy Efficiency in CLUJ-NAPOCA Romania.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



5.3.5 Strategic Direction 4: Increase consumer awareness

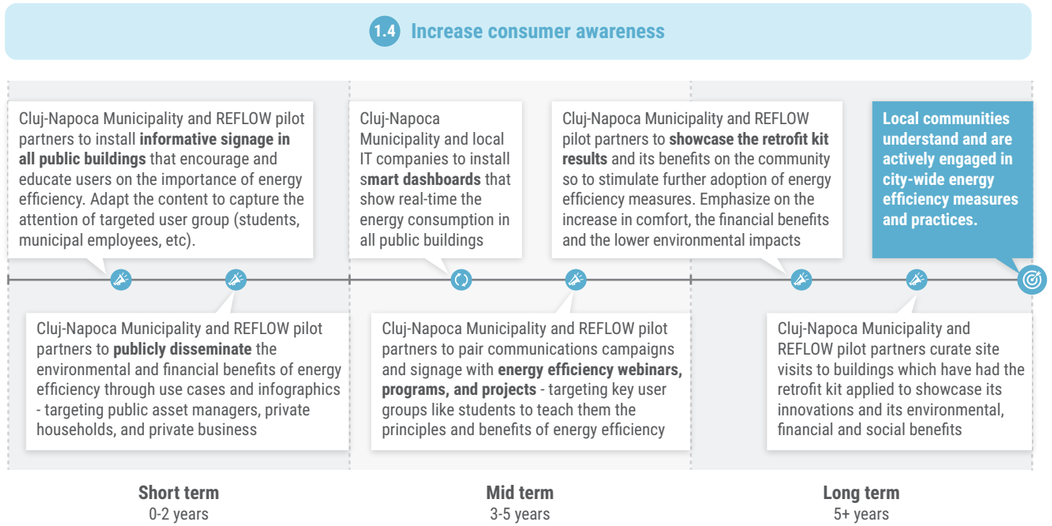
In parallel to technical pilots for retrofitting and upgrading, it is important for the Municipality and REFLOW pilot partners to engage closely with citizens on the topic of energy efficiency. Impacts associated with energy consumption are not just associated with construction, but closely connected to how people use and behave within buildings. Therefore, a highly public awareness raising and education campaign should be curated by the Municipality that focuses on local residents. While the scope of Metabolic Institute's analysis within REFLOW is energy efficiency of Cluj-Napoca public assets, it is encouraged that this campaign focuses on energy efficiency within public buildings as well as private residential and commercial buildings. A first measure here is to showcase the retrofit kit being applied by Cluj-Napoca REFLOW pilots partners - its interventions, benefits, and the actual results of specific pilots. Showcase the retrofit kit can stimulate further adoption of its use and of energy efficiency measures within the city more broadly. Retrofit kit pilots can be used to practically evidence and emphasize the economic and environmental savings and how such savings directly benefit local city residents (e.g. the increase in comfort, the financial benefits, and the lower environmental impacts).

In municipal buildings under management by the City, the Municipality can design and install informational signage that educates users of best practice for energy efficiency and the associated benefits -for example by placing stickers at each light switch reminding users to use power responsibly. Posters can be designed to display informative environmental and financial benefits of energy efficiency -this content can be adapted per building to capture the attention of different target user groups (e.g. students, municipal employees, etc.). Within schools, such signage can be accompanied by seminars and/or projects that teach users principles of energy efficiency. Lastly, the Municipality can install dashboards within municipal buildings that display the real-time energy consumption (and generation) of a building.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Use-cases

- EMPOWERING Project: The project provided consumers with useful information to save both energy and money. It managed to do this by developing a comprehensive, flexible approach to billing, while creating open source software tools.
- Ecorys Energy Efficiency Campaign: The campaign aimed to encourage and empower household consumers to improve their energy efficiency status through visuals shared on various media and platforms.



5.4 Focus Area 2: Prepare Cluj-Napoca for a future decentralized, renewable energy system

5.4.1 Introduction

Cities are responsible for 75% of global greenhouse gas emissions, meaning the transition to a sustainable economy will be won or lost in our cities. In Europe, buildings are responsible for 40% of energy consumption, and 36% of greenhouse gases.[258] Total annual emissions of Cluj-Napoca municipal buildings and assets is 50,600 t CO_2eq. Electricity consumption accounts for approximately 60% of the total CO_2eq-emissions, while gas is responsible for about 30% and heat for 10%. The City should aim to reduce scope 2 emissions[259] by increasing on-site energy generation, as well as accelerating the development of local renewable energy

[258] European Commission. (2020). Energy efficiency in buildings.
[259] Indirect Emissions from electricity purchased and used by the organisation. Emissions are created during the production of the energy and eventually used by the organisation.

production capacity. The EFA highlights that only a small fraction of the energy consumed by Cluj-Napoca comes from renewable sources, almost none of which is produced within the Municipality. Increasing local renewable energy production provides a major opportunity to lower the GHG emissions of public buildings and assets. Thus, it is key to develop a robust understanding of the renewable energy production capacity of the territory -this can create the basis of a transition plan for Cluj-Napoca's local energy system.

A decentralized approach to renewable energy production is a natural next step for the Municipality to complement the energy received from the centralized national grid. The IT sector of Cluj-Napoca, a partner of the REFLOW pilot team, can support the trialing of the approach in key areas of the city. For example, the energy and GHG analysis have highlighted 20 high energy consumption points (~25% of total GHG emissions) across Cluj-Napoca existing public assets. Three locations, two schools and a municipal building account for 8 out of 20 of these consumption points, and are therefore potentially suitable renewable energy production pilots.

The transformation of the Cluj-Napoca energy system must be grounded in a collaborative approach, where Cluj-Napoca joins forces with other cities across Europe and beyond to accelerate the energy transition of cities as a whole. Being part of an international city network will ensure that Cluj-Napoca has access to the right tools and funds to structurally support its ambitions.

5.4.3 Strategic Direction 2.1: Assessing Cluj-Napoca potential for renewable energy

The Municipality of Cluj-Napoca must conduct an in-depth survey of its renewable energy capacity. To do so, Cluj-Napoca should partner with the Technical University of Cluj-Napoca to develop spatially-explicit analysis that illustrates what type of renewable energy is available and where. For example, Dublin has partnered with a local energy consultancy to create an interactive google map highlighting the renewable energy sites in Dublin.[260] Cluj-Napoca Municipality can map the areas of the city best suited for renewable energy production (including heat recovery), and quantify their potential energy production (based on different energy technologies). This analysis will ensure that any future energy project realistically considers the amount of renewable energy available for a given technology. This type of study would also provide the opportunity to acquire additional bottom-up data on the heating and gas consumption of Cluj-Napoca buildings. It is key to quantify heating and gas demand across the city to uncover potential heat recovery and renewable energy projects among the city's districts.

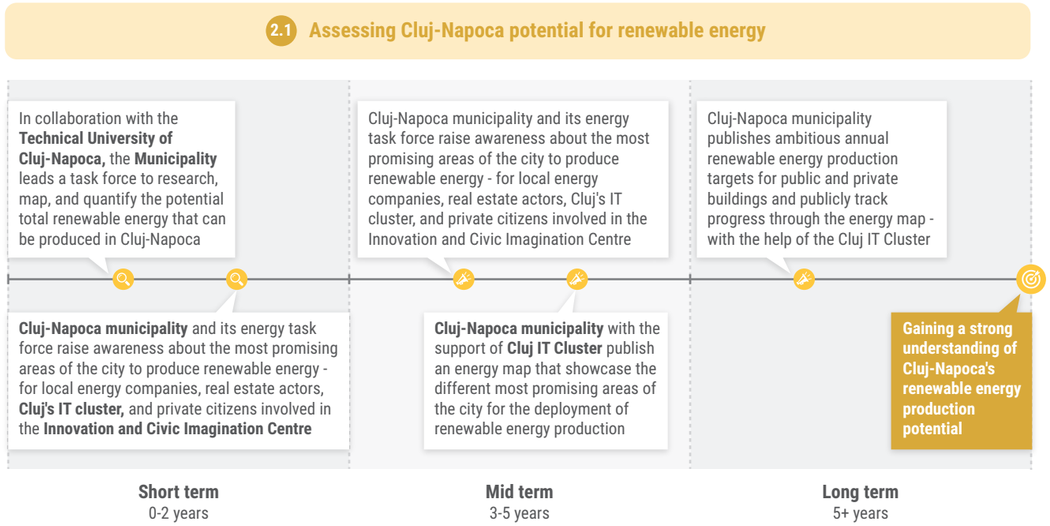
With greater clarity on its potential local energy capabilities, Cluj-Napoca can then set robust targets on how much renewable energy production capacity to install in new projects, annually. To organize this coordinated effort, a task force should be created in the Municipality, regrouping key public building managers, the city's IT sector, Romanian renewable energy providers, and citizen representatives. For a successful deployment of renewable energy technologies, it is key to assess the different requirements that must be met by the City to shift to a cleaner energy system - be it financial, policy, stakeholder engagement, environmental considerations, space, grid limitations, and current infrastructure. Raising awareness and specifying strategies

[260] Energy Cities. (2018). Mapping renewable energy potential.

to meet each requirement will be important to realise the potential of renewable energy within Cluj-Napoca and expedite the transition of Cluj-Napoca's energy system.

Use-cases

- Dublin Renewable Energy Potential Maps: Dublin Energy created interactive Google maps highlighting renewable energy production sites.
- Amsterdam Energy Atlas: Amsterdam's Energy Atlas stimulates the use of renewable energy by increasing citizen's awareness of their energy usage.



5.4.3 Strategic Direction 2.2: Establish the foundation of a decentralized, renewable energy system for Cluj-Napoca

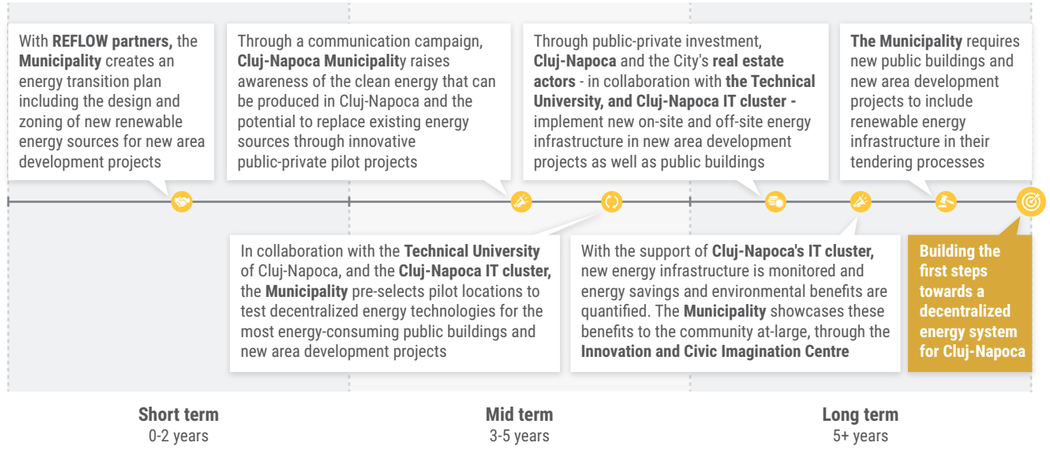
Based on the robust understanding of Cluj-Napoca public assets - their energy consumption and related GHG impacts - as well as novel understanding of the City's renewable energy capacity, the Municipality should develop renewable pilot programs across the city that prioritize the most impactful buildings. After prioritizing high impact public buildings, key stakeholders in the Cluj-Napoca IT sector should be selected and energy production technologies assessed. Beyond existing public buildings, the Municipality can take advantage of the city's new area development projects to pilot selected technologies in new developments -avoiding new areas becoming locked-in into the centralized grid. This will require strong partnerships with real estate developers. To incentivize public and private building managers and real estate developers to engage in renewable pilot projects, the City can develop incentive schemes, on the model of Cluj-Napoca's "Green Building" law which eliminates local taxes for corporate buildings that enforce green building standards. By focusing on both

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

existing public assets and newly built areas, the City can support the deployment of a decentralized energy system at scale -building up key knowledge and expertise in the process. Additionally, Cluj-Napoca can seek the support of the European Local Energy Assistance (ELENA)[261] to receive guidance and expertise from energy experts. Finally, the City can seek European, such as the European Energy Efficiency Fund,[262] to financially support renewable pilot projects.

Use-cases

- Solar Rooftops in Greater Chennai's Corporate Buildings: Solar rooftops were installed in Greater Chennai's Corporate Buildings to meet close to 80% of their energy needs.
- Mandora Eco-village: The Dutch Eco-Village contains 36 energy-efficient houses with more than 30 using gasless heat pumps and all using independent solar energy systems.
- Solar Policy Delhi: In Delhi, the challenge of building new distribution infrastructures is offsetted by the self-consumption of rooftop solar energy.
- Boulder's Climate Action Plan (CAP): The Boulder's Climate Action Plan is a city-funded initiative aiming at reducing greenhouse gas emissions and mitigating climate change.



[261] European Investment Bank. (2021). ELENA – European Local ENergy Assistance.
[262] European Investment Bank. (2021). European Energy Efficiency Fund.

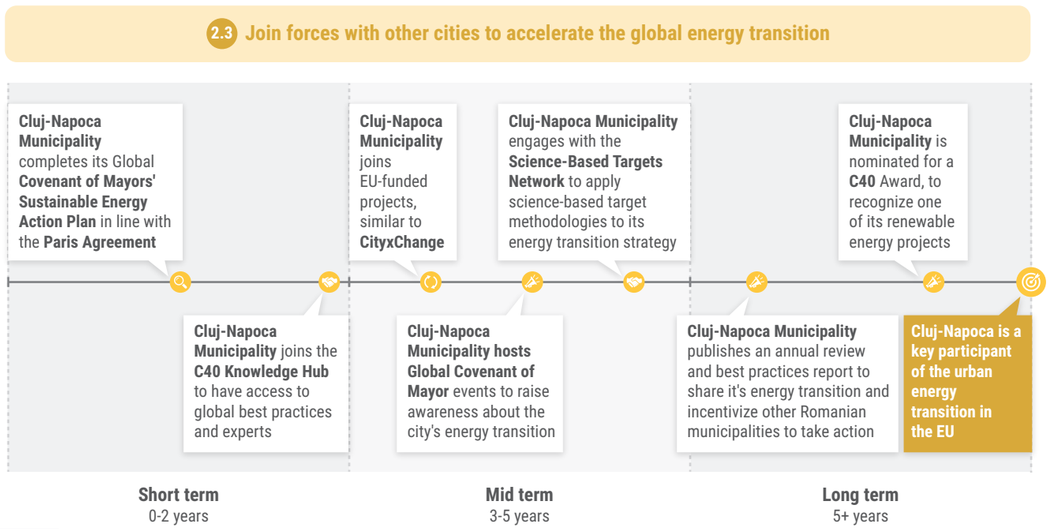
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

5.4.6 Strategic Direction 2.3: Join forces with other cities to accelerate the global energy transition

To support Cluj-Napoca's ambitions to become a lighthouse city for the energy transition in Romania, a natural next step is to join forces with other cities across the world, through international cities networks. Benefits from joining such networks include access to tools, such as those developed by the **Science-Based Targets Network.** Moreover, they add to local momentum for different energy projects. Increasing its engagement as a member of the **Global Covenant of Mayors** is a good place to start -initially by submitting an updated Sustainable Energy Action Plan. Additionally, the City can join an international city network, such as the **C40 initiative.** As a member of C40, Cluj-Napoca can access its Knowledge Hub of best practices and world-leading expertise. At the European level, the Municipality can also join EU-funded projects focused on the deployment of decentralized clean energy systems. For example, CityxChange[263] involves seven medium and small-sized EU cities working on deploying positive energy blocks and districts. Acting as a pilot within such projects will enable Cluj-Napoca to accelerate its transition by learning from other cities, gaining access to innovation funds, and sharing progress and lessons learned on the European stage. Finally, Cluj-Napoca can play an active role by hosting events for these networks (i.e., Global Covenant of Mayors; C40) and raising awareness on the global stage about the city's energy transition challenges and solutions.

Use-cases

- Science-Based Targets Network: The Network provides cities with guidance to stabilize all Earth's systems.
- Covenant of Mayors: Network of local governments committed to implementing EU climate and energy goals.
- C40 Cities: A network of cities with the common goal of tackling climate change through knowledge sharing.
- CityxChange: H2020 EU-funded projects focused on positive energy districts in medium-size cities

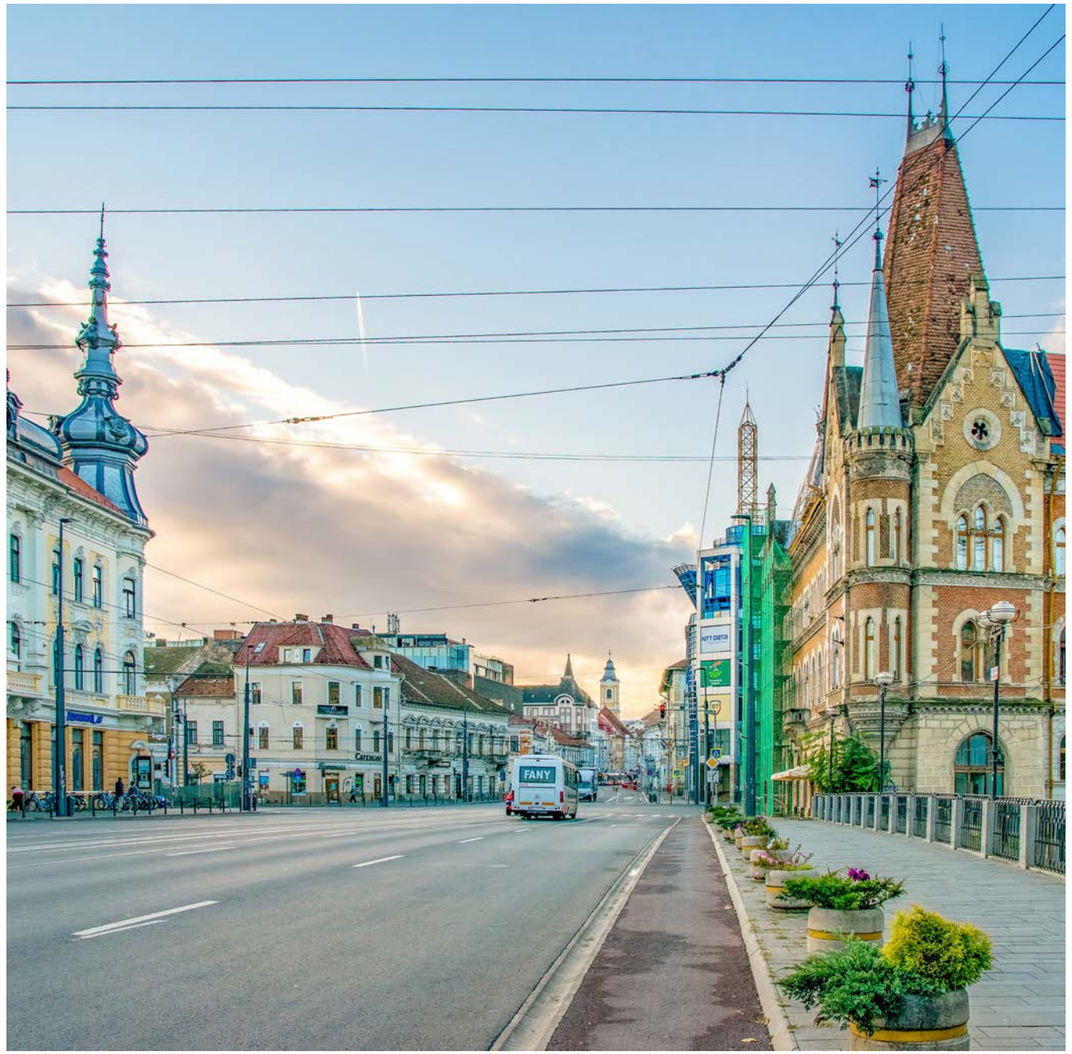


[263] +CityxChange. (2021). Lighthouse Cities and Follower Cities.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

5.5 Relevance for pilot activities

The Cluj Pilot's action plan and Theory of Change outline the key activities that will be done during the period of the REFLOW project to promote and increase energy efficiency in Cluj. To communicate how and where Metabolic Institute's urban metabolism analyses and resulting recommendations directly support the Cluj pilot's planned activities, desired outcomes, and impacts, we mapped out all touchpoints between the Theory of Change and our proposed two focus areas.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

Figure 44: Touchpoints between the Cluj-Napoca Pilot's Theory of Change and the proposed focus areas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

6. AMSTERDAM

6.1 Introduction to Amsterdam's textile sector

6.1.1 Background and scope of the analysis

Introduction to Amsterdam

Located in the province of North Holland, Amsterdam is the capital and largest city of the Netherlands with a population of 872,680 within the city and 2,410,960 in the metropolitan area. Amsterdam is well known as the Netherlands' cultural and commercial capital. Ranked as one of the world's most liveable and most innovative cities,[264] Amsterdam attracts people and businesses alike. With a motto "learning by doing", Amsterdam encapsulates its innovative spirit with the ambition to continue developing in a way that ensures a thriving and equitable environment for its citizens and visitors.

Amsterdam has set a specific focus on wellbeing next to welfare. The City described sustainability as one of its top priorities and has set a clear goal of reducing waste and transitioning fully to a circular economy. By 2025, Amsterdam aims to enable recycling or reuse of 65% of all household waste, by 2030, the use of primary raw materials should be reduced by 50%, and by 2050 the entire city economy should become circular.[265] To achieve these goals, the City actively promotes new ways of thinking and close cooperation between knowledge institutes, businesses and citizens.[266] The overall circular economy strategy for the years 2020-2025 has been developed based on the Doughnut Economics model by Kate Raworth, aiming to create a holistic umbrella for environmental, social, and economic priorities. The support from the City and a conductive climate for circular innovation and implementation of circular principles have already reaped benefits – over the last few years, there have been more than 70 projects completed that contributed to circular economy implementation in Amsterdam.[267]

Increasing the circularity of urban textile industries can play an important role in reaching the overall sustainability and circularity goals of the EU. Textiles are one of the main points of focus for the Dutch government and Amsterdam city – e.g. through the government-supported initiative Dutch Circular Textile Valley, which supports initiatives around circular textiles in four regions in the Netherlands, including Amsterdam region. Under the national Circular Economy Pact, signed by Amsterdam in 2019, the City is also renewing its textile collection procedures, focusing on better strategies for executing the collection.

Within the REFLOW project, the Amsterdam pilot focuses on textiles used by citizens, how these textiles are discarded and reused, and how textiles as resources can be brought back into the material flow. By supporting

[264] Innovation Cities. (2019). Innovation Cities Index 2019.
[265] City of Amsterdam. (2020). Policy: Circular economy - City of Amsterdam.
[266] Raworth, K. et al. (2020). The Amsterdam City Doughnut.
[267] Ibid.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

more diverse strategies for the collection of textiles, the project can aid the provision of feedstock for recycling industries, increase the demand for recycled textile and support the supply of newly produced products out of recycled resources for other stakeholders. The goal is to increase the number of textiles collected through empowering citizens to become the change makers – by taking active part in the behavioural change unfolding in Amsterdam, they can further educate and empower others.

To facilitate the shift towards more circular textile material streams in the region, the Amsterdam pilot is implementing a strategy consisting of two complementary scenarios. The short-term scenario aims to achieve impact by saving textiles from being discarded. By raising awareness and inducing behavioural change among citizens, home textiles and clothing can be collected in a more efficient way for recycling.

Scope and Method of the Textile Material Flow Analysis (MFA)

Within Amsterdam, textiles were selected by the REFLOW pilot team as the core material flow to be mapped throughout the city. To map the flows of textiles going through Amsterdam on a yearly basis, Metabolic Institute first mapped the entire supply chain of the industry – from raw material extraction to the end-of-life (EOL) processes (i.e., waste treatment), including every critical step in between (spinning, weaving, dyeing, finishing, transport, use, and collection).

As often in urban metabolism studies, municipal waste data (provided by the City's waste department) represented an important starting point to understand the magnitude of textile outflows of the city.[268] The consumption patterns of private households were determined thanks to a recent Dutch-based study on clothing consumption from households.[269] The EOL treatment options of textile waste were determined thanks to the same study as data directly from Amsterdam was not available. The composition of the textile flows was estimated thanks to a European-wide study performed by the Joint-Research Center.[270] The fiber breakdown was reviewed and adjusted based on feedback from two Dutch textile experts.[271] The inflows of textile into the city's boundaries proved a difficult step, as in many urban metabolism studies. Because distribution, wholesale, retail, and local production are reported at the national level, municipal figures are calculated based on downscaling national figures. Therefore, the textile consumption between different economic sectors of Amsterdam (e.g., private house, hospitality, manufacturing sector) are mostly based on input-output national tables, which inherently creates some uncertainties.[272] Therefore, after discussion with Dutch textile experts, it is noted that the figures for the hospitality sector may be underestimated due to the high density of hotels in Amsterdam relative to the national average.

[268] Gemeente Amsterdam (2019). Sorteren Analysis.
[269] Maldini, I., et al. (2017). Measuring the Dutch Clothing Mountain.
[270] Beton, A., et al. (2014). Environmental Improvement Potential of textiles (IMPRO Textiles).
[271] Ger Binks of BMA Techne and Antoine Luiken of Alcon Advies - lecturers at Saxion University of Applied Sciences
[272] Timmer, M. P., et al. (2016). An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release.
[273] Beton, A., et al. (2014). Environmental Improvement Potential of textiles (IMPRO Textiles).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

By using municipal and national databases alongside an iterative review by local experts, Metabolic Institute was able to construct an accurate picture of the textile flows reaching Amsterdam and leaving the city as waste. The environmental impacts of these textile flows can be traced back at every step along their life cycle. The environmental impacts were assessed using the life cycle normalized data from the JRC European report on textile consumption.[273] Although the system's boundaries are larger, this report provides the most comprehensive order of magnitude of environmental impacts by fiber type to date.

6.1.2 Current System and its Impacts

The key findings from the textile MFA have yielded many insights into Amsterdam's textile sector as well as the environmental and social impacts of the global textile industry.

From a global point of view, textile dyeing and finishing accounts for 17-20% of industrial water pollution. From a fiber perspective, cotton accounts for 4% of nitrogen fertilizers and phosphorus consumed globally, 16% of global insecticides usage, 7% of global herbicides usage, and 2.5% of global agricultural land. From an environmental perspective, **95% of impacts occur between the *raw materials* & *production* phase and the *consumption* phase.** The largest impact categories are: eutrophication, land occupancy and use, and land transformation. Human health impacts occur ~ 50% in the raw materials and production phase and 50% during the consumption phase. Laundering also has a significant impact. Worldwide, washing accounts for 50% of water usage impacts across the whole life cycle of textiles. Freshwater, human, and marine toxicity factors are overwhelmingly caused by detergents (74%, 69%, 64% respectively). The release of micro-plastics during the wash of synthetic textiles is also an emerging and critical issue. Last, emissions are high and climbing. Apparel and footwear industries account for 8.1% of global CO_2-eq impact. In 2015, the global textile industry's CO_2 emissions equated to 1,715 Mtons. The industry's CO_2 emissions are projected to increase by more than 60% to nearly 2.8 billion tons per year by 2030.

Amsterdam Textile Material Flow Analysis (MFA)

From Metabolic Institute's MFA, it is clear that Amsterdam is not producing most of its textiles. In fact, 98% come from abroad. The largest fiber type is cotton, followed by polyester, and usually they come together in different forms of blends. On average, clothes travel about 10,000 kilometers by container ship and about 600 kilometers by trucks to reach Amsterdam.

The **main producers of textile waste are private households.** This is logical as they also represent the largest consumers of textile products with **65% of all textile bought going to households.** The majority of household textile waste is not being separated -rather it's disposed of within the residual waste system and ultimately incinerated. There is a buildup of stock in Amsterdam households of 1,400 tons (13% of their consumption). There is little textile productive capacity within the city's boundaries, therefore the manufacturing sector is rather secondary in Amsterdam in terms of textile flows. In Amsterdam, **municipal collection is the primary textile waste collector,** with 71% of textile waste captured by these channels. Separated textile collection via city drop-off containers is secondary, with about 20% of all textile waste.

[273] Beton, A., et al. (2014). Environmental Improvement Potential of textiles (IMPRO Textiles).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

In Amsterdam, incineration is king, **67% of textile waste ends up at the incineration plant.** However, there is an interesting potential in Amsterdam's textile waste stream: from the 67% that is being incinerated, **28% could be re-used as clothing, 51% could be re-used as material,** and only the remaining 21% would ultimately have to be treated as waste.

MFA: Production Phase Impacts

The **overwhelming majority of impacts in the textile chain come from primary production and processing. 56,000 hectares** of agricultural and pasture land are used to produce the clothing and home textiles consumed within Amsterdam. Most of this is pasture land for wool, but thousands of hectares are also used for cotton production. This land mass represents 2.4 times Amsterdam's current surface area. Roughly 5,600 olympic swimming pools - or **15 million cubic meter** - of freshwater is consumed to produce Amsterdam fibers and fabrics. Moreover, the production of clothing and home textiles consumed within Amsterdam generates **61 million cubic meters** of industrial wastewater. In comparison, Amsterdam produces roughly 54 million

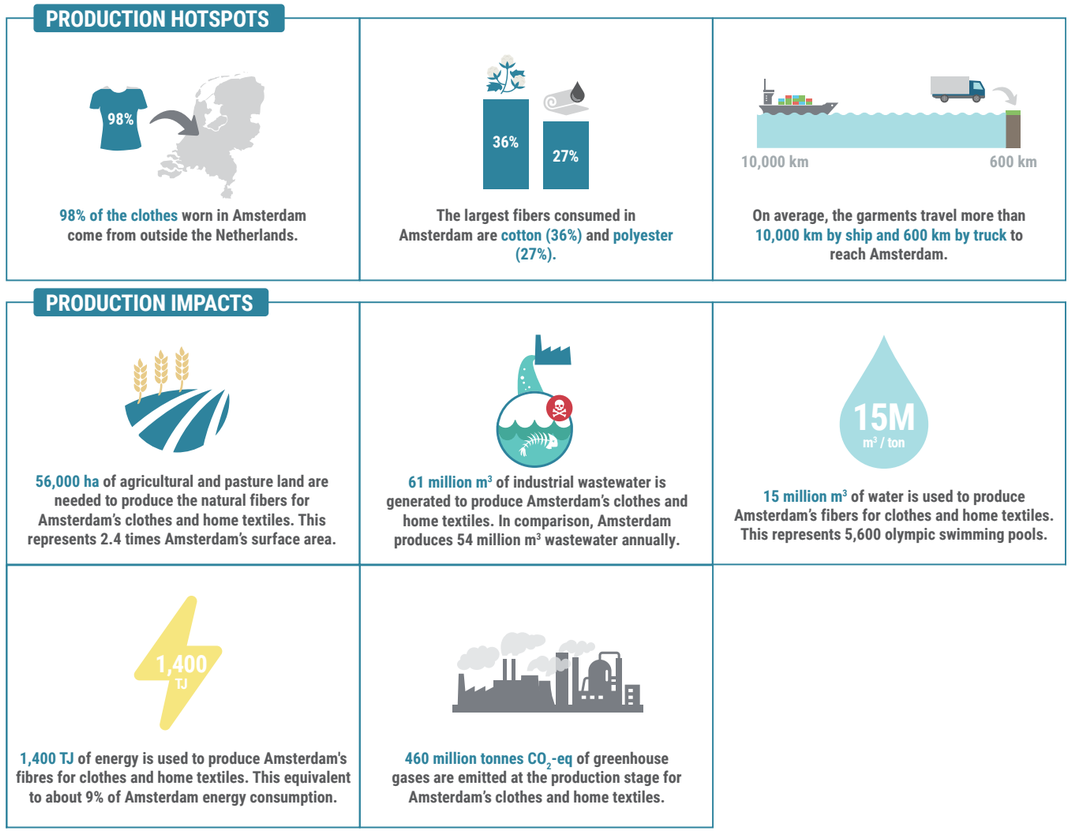


Figure 45: Production impacts associated with Amsterdam's annual textile consumption

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

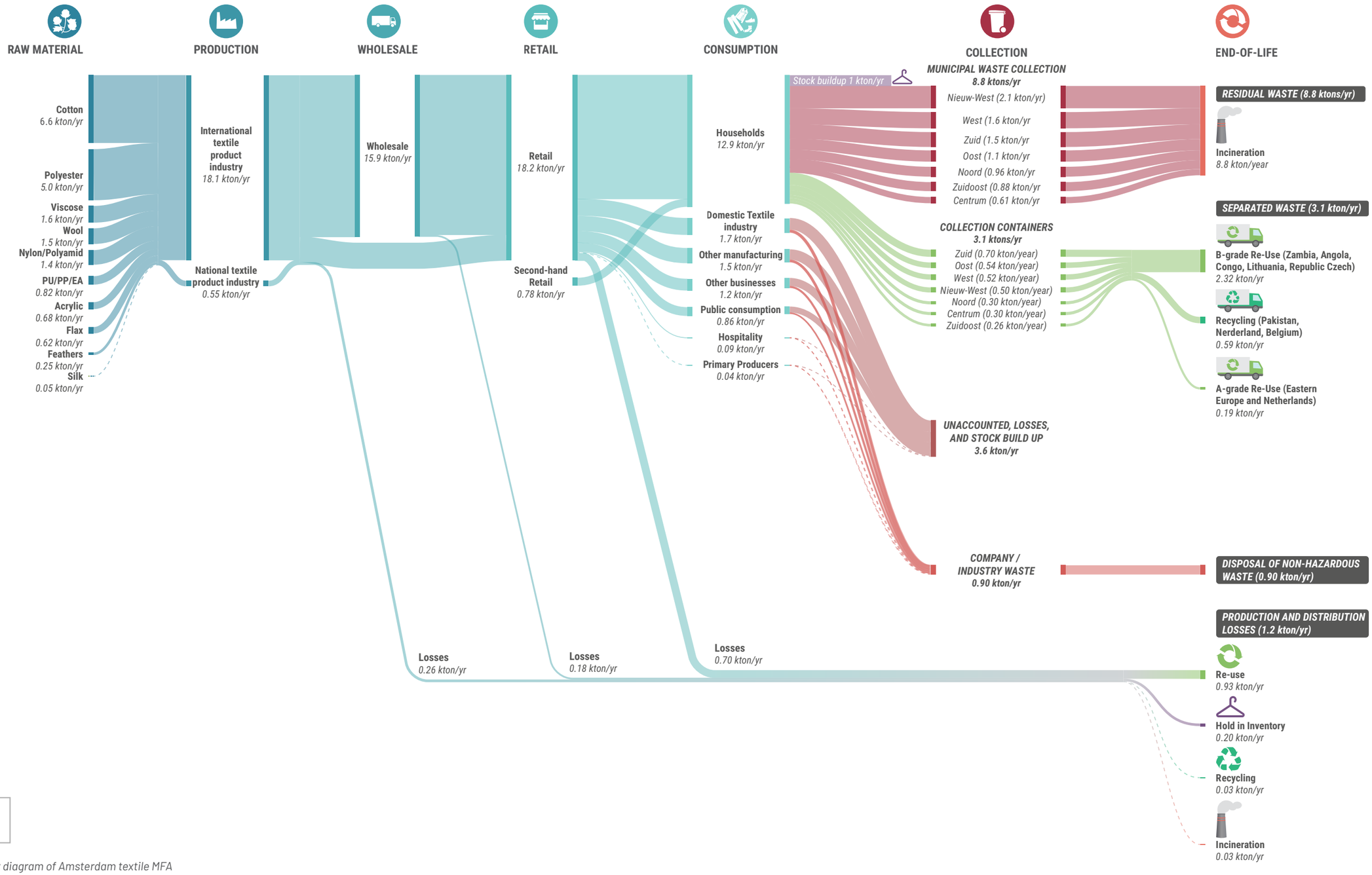


Figure 46: Sankey diagram of Amsterdam textile MFA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

cubic meters of wastewater -meaning the annual wastewater produced by all households, businesses, and industries within Amsterdam combined is less than what is generated from the production phase of the textiles consumed within the city. These insights help to emphasize how important it is for the City of Amsterdam to **account for the indirect impacts associated with those materials consumed within the city** that are produced elsewhere when developing its circularity strategies and action plans.

The energy inputs to produce the clothing and home textiles consumed within Amsterdam are also significant. **1,400 TJ** of energy is required to produce the clothes and home textiles consumed within the city -this figure equates to roughly 9% of the total energy consumption of Amsterdam households. Finally, a great deal of air pollution occurs at the production phase: **460 Mtons of CO_2** is emitted upstream throughout the production of the clothing and home textiles consumed by Amsterdam. These emissions are occurring upstream - unseen by Amsterdam residents - the majority being displaced in Southeast Asia and Northern Africa.

MFA: Consumption Phase Impacts

The main consumers of textiles within Amsterdam are households, with **more than two-thirds of the total textile volume** being consumed by households. There is a certain buildup of textile stock within Amsterdam, with about a quarter of the total consumed volume being stored in households and other economic sectors.

In terms of consumption impacts, more than **6,000 TJ of energy** are used by Amsterdam households annually to wash and dry clothing and home textiles -this is about 4% of the current energy consumption of households in the city. The washing of clothes and other textiles consumes 4.6 million cubic meter of water annually, which is 12% of the annual water consumption of households.

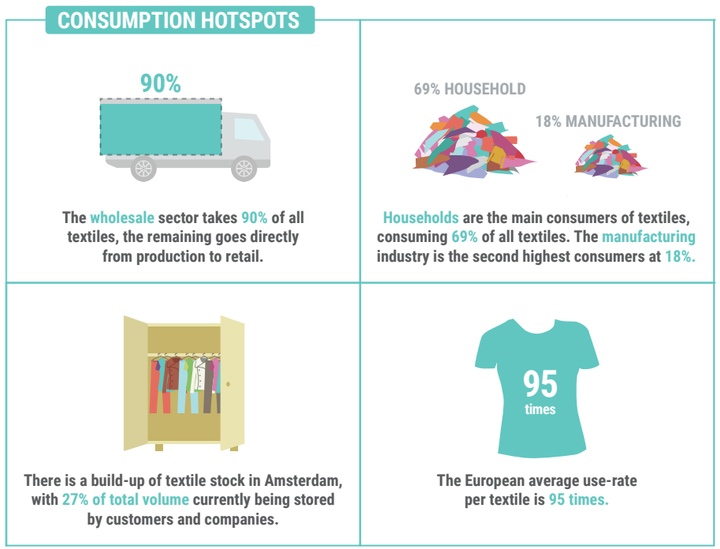


Figure 47: Use-phase hotspots associated with Amsterdam's annual textile consumption

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

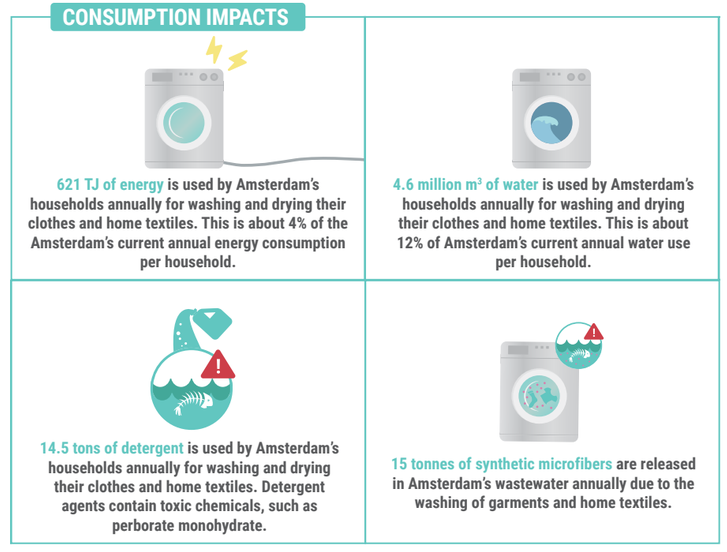


Figure 48: Use-phase impacts associated with Amsterdam's annual textile consumption

The use of detergent is also a major hotspot in terms of environmental impact, especially regarding eutrophication impacts and water pollution impact. In Amsterdam, about **14.5 tons of detergent** are poured into residential washing machines and then into wastewater annually to wash clothes. Regardless of recent innovations, many detergents still contain toxic chemicals.

Lastly, a major issue surrounding clothing consumption worldwide, and therefore also taking place in Amsterdam, is the production of microfibers that cannot be effectively filtered out of waterways by wastewater treatment plants. In Amsterdam, about **15 tons of plastic microfiber** are released into Amsterdam's water due to the washing of textile products.

MFA: End of Life Phase Impacts

The large majority of textiles waste collected in Amsterdam is done so through the municipal waste collector. Roughly **two-thirds is collected through residual waste collection,** and 24% is collected separately through city drop off containers. **70% of textile waste in Amsterdam is being incinerated** and one quarter is exported. Out of the 70% of textiles currently being incinerated, **51% could be recycled into high-grade feedstock for use by local manufacturers and designers, and 27% could be reused as clothing.** From the 24% that is exported, 6% is sold as high-grade, second-hand textiles mostly in Eastern Europe. The bulk of it - 70% - is sent to Lithuania, the Czec Republic, and several African countries -downcycled and sold as B-grade, or low-quality textiles. The rest gets recycled in Belgium, Pakistan, and also a little bit in the Netherlands. In regards to the 24% of textiles collected through the separated textile bind -13% of textiles that enter the separated collection bins are too polluted to be re-used or even recycled. This is an issue because it contaminates the rest of the textile being collected.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

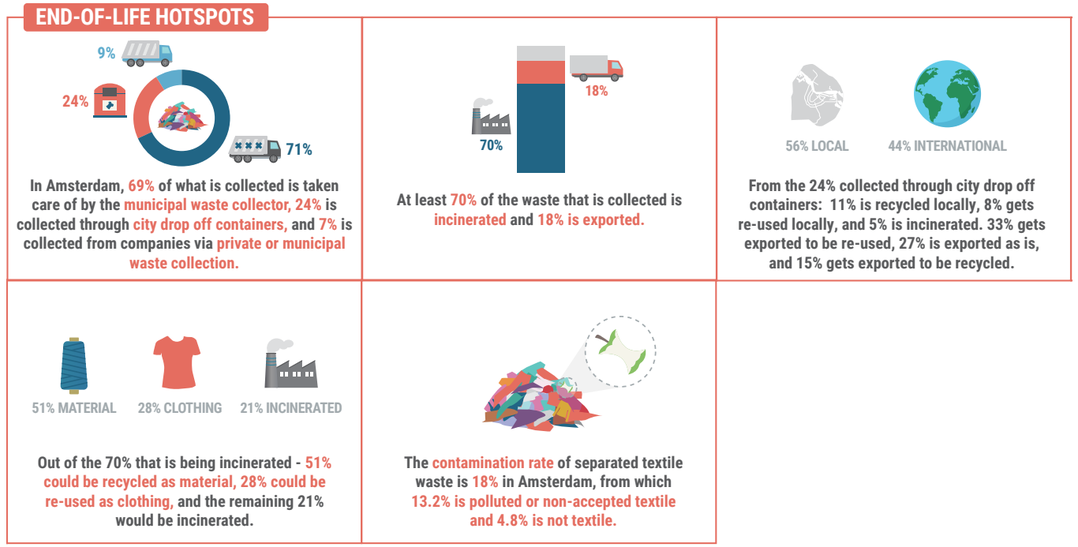


Figure 49: End-of-life impacts associated with Amsterdam's annual textile waste

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

The incineration of textiles within Amsterdam generates significant CO_2 emissions, which could be greatly reduced if textiles were reused or recycled. **11 Mtons of CO_2-eq** is emitted from Amsterdam's textile waste incineration. Additionally, 7.5 tons of particulate matter (PM <2.5um) is released into the environment contributing to **local air pollution**. By diverting reusable clothing from incineration, **2,500 tons of textiles could be circled back** into Amsterdam -avoiding the use of virgin feedstocks and generating roughly 10 million euros in second-hand retail sales. By diverting recyclable clothing from incineration, about **4,500 tons of textiles could be saved from incineration** and turned into recycled feedstock -substituting virgin textile material and generating roughly 1 million euros in sales to recyclers.

Amsterdam Neighborhood Analysis

In order to support the Amsterdam REFLOW pilot team's engagement with local communities, Metabolic Institute conducted a spatial analysis of Amsterdam neighborhoods to better understand the different patterns of waste generation and collection in relation to the unique socio-economic demographics of each neighborhood. The analysis covered an assessment of textile waste containers present across the city, district-specific socio-economic demographics provided by public records, and textile waste data identified within the textile MFA. Metabolic Institute analyzed the different neighbourhoods of Amsterdam based on the total amount of textile waste they produced, how much waste is collected separately, and how much textile waste is thrown into the residual trash bins. Key socio-economic and socio-demographic datasets were collected from municipal and national public databases.

In terms of absolute volume of textile waste produced (both collected separately and via residual waste), the **Nieuw West neighborhood produced the largest amount of textile waste,** with 22.5% of the total volume (~12 kton), while being home to 18% of Amsterdam residents. It also **has the lowest share of separation,** with only 18.6% of textile waste being separately correctly. On the other hand, Zuid, Oost, and Centrum have a separation rate of 32%. Overall, Oost produced the least textile waste (13.8%) with a population similar in size to Zuid and West (each between 16.3 and 16.9% of the overall population).

The following maps display different socio-economic parameters for each neighborhood. For each map, it can be observed that each polygon represents a neighborhood of Amsterdam. The height of each polygon represents the total amount of textile waste collected in the residual trash. As a result, one can see that Nieuw West produces the largest amount of textile in the residual waste, illustrated by its polygon significantly higher relative to the other ones. A quarter of all textiles (~2.2 ktons) found in Amsterdam's residual waste stream comes from Nieuw West. Centrum contributes the least amount of textile waste in the residual waste stream (7%), although it may be noted that it has a smaller population share (10%).

The dots on the maps represent the geographic locations of textile containers where Amsterdam residents can bring their separated textile waste to be recycled and reused. The shades of green of the dots illustrate the total amount of separated textile recovered in each district. Each green shade is specific to a district as the colour scale was set to compare each district with one another. The darker green a district-specific group of dots is, the larger the total (absolute) amount of collected textile waste is in the neighbourhood. Thus, the Zuid neighbourhood (where the darkest dots are visible) has collected the most textile waste, with

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

around 23% of all collected textile coming from this neighbourhood. As visible with the lightest colour dots, Zuidoost contributes the least in terms of absolute amounts of separately collected textile (8% or ~0.26 ktons), although it is only home to 9.5% of the Amsterdam population. Nieuw West contributes 16% to the total amount of collected textile, behind West and Oost, while both have, respectively, 2% and 5% less population than Nieuw West. Finally, the size of the dots reflects the total amount of sorted textiles an individual container has collected in a year - thus the larger the dot, the larger the amount of textile waste collected annually by this container (base year 2018). For example, in Zuidoost, a single container located on the southern end of the neighbourhood seems to collect most of all textile waste in the neighbourhood, as shown by its very significant size relative to the other dots surrounding it.

Last, the color of the polygons illustrate a social-economic or demographic parameter. The following paragraphs will cover several indicators, such as population density, income, household size, children population share, number of businesses, and house value.

Population density

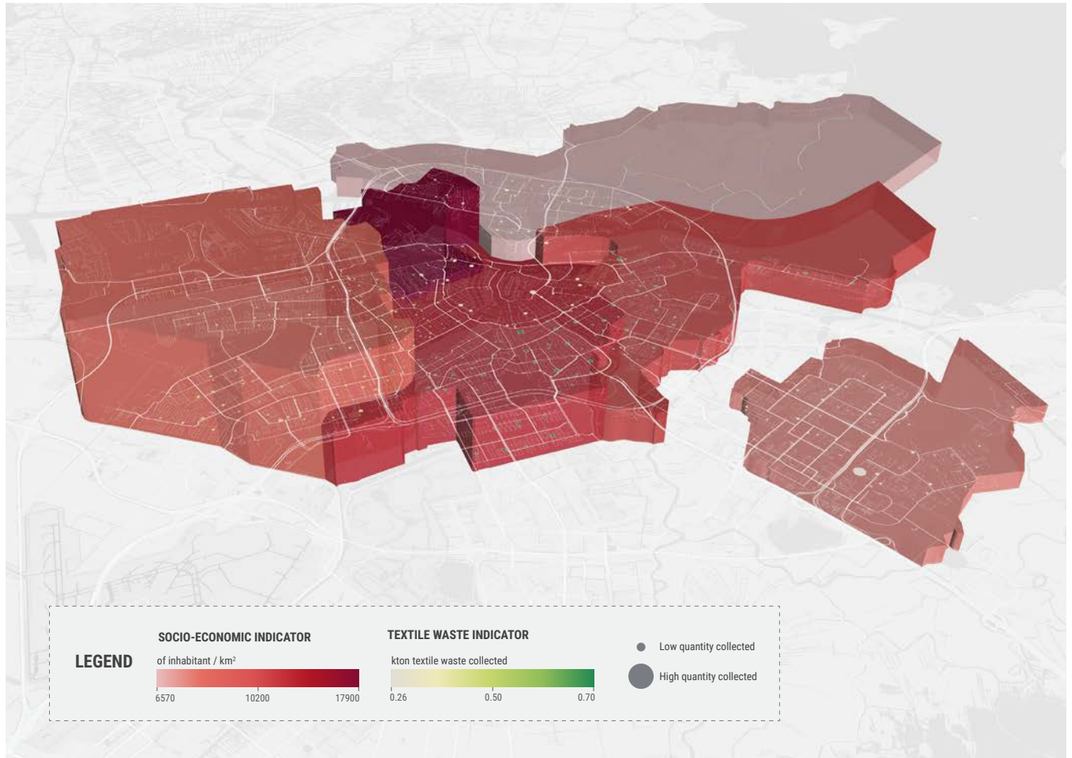


Figure 50: Population density across Amsterdam districts

The darker the red shades the more densely populated a neighborhood is. Therefore, the most dense neighbourhoods in Amsterdam are West and Centrum with, respectively, 15,440 and 13,818 inhabitants per km². Nieuw West and Zuidoost are less densely populated with around ~4,500 inhabitants per km². There is no visible correlation between the density of a neighbourhood and the total amounts of textile waste produced. The densely populated Centrum produces the smallest amount of textile waste (7.6%) for a population share of 10%, while West (most densely populated) produces 17.7% of all total textile waste with 16.9% of the population. Conversely, Zuid's population is almost the same as the West, and is equally responsible for a little over 18% of all textile waste, but Zuid's density is smaller by a third compared to the West, with 9, 447 inhabitants per km².

Income

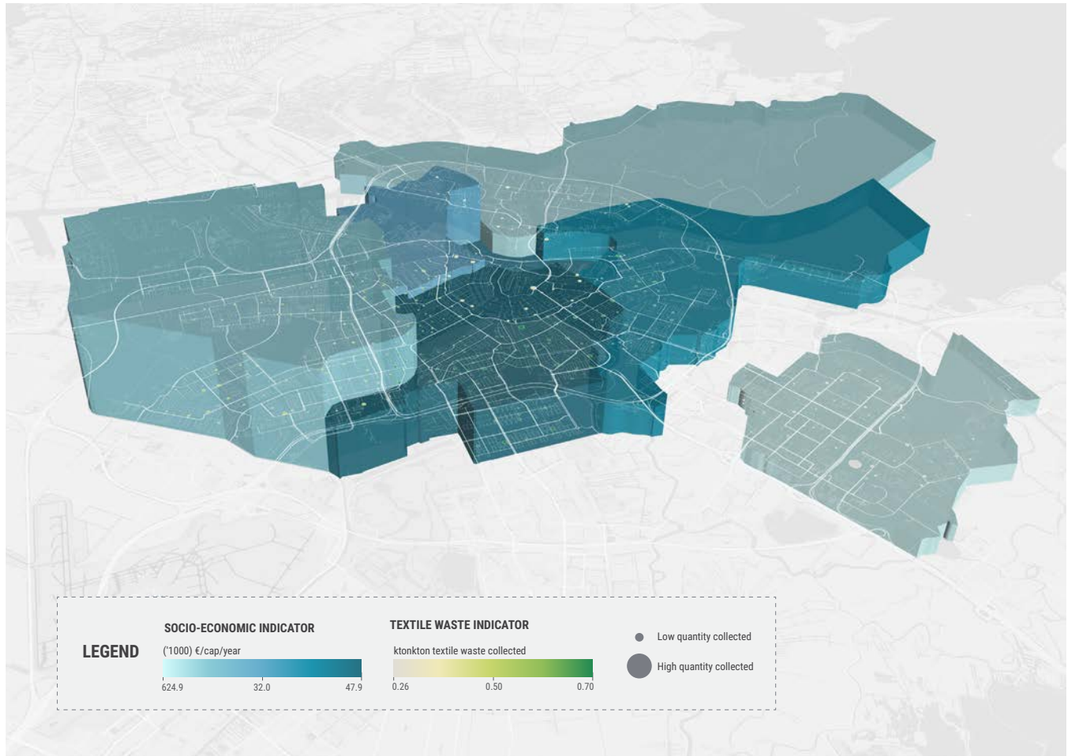


Figure 51: Average per capita annual income across Amsterdam districts

The darker the blue shades the higher the average personal income a neighborhood has. Therefore, Zuid and Centrum are the neighbourhoods with the highest personal income (47,900 and 45,000 €/yr, respectively), followed by Oost and West, around ~35,000€/yr, which correspond to the city-wide average. Nieuw West and Zuidoost are below the average with, respectively 28,000 and 24,000 €/yr. It should be noted that **the neighbourhoods with the lowest average incomes (North, Nieuw West, Zuidoost) also have the lowest shares of textile waste separation,** with respectively, 23.7%, 18.6%, and 22.5%, while the three richest neighbourhoods (Zuid, Centrum, and Oost) have separation rates above 32%.

Household Size

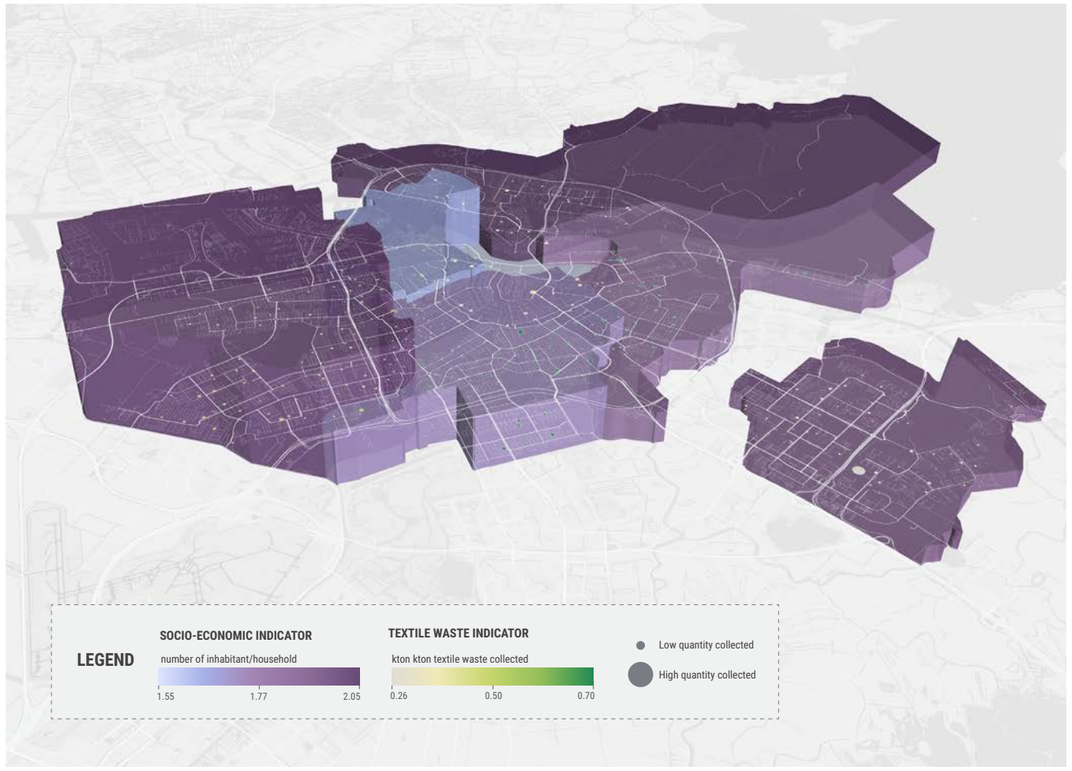


Figure 52: Average household size across Amsterdam districts

The darker the purple shades the higher the average number of people per household a neighborhood has. Therefore, North is the neighbourhood with the largest households (above 2 people per household), followed by Nieuw West and Zuidoost, in a similar range. It should be noted that **those neighbourhoods with the highest household size and lowest income (North, Nieuw West, Zuidoost) have the lowest shares of textile waste separation,** with respectively, 23.7%, 18.6%, and 22.5%. In terms of total waste production, North and Zuidoost produce much less waste relative to their population compared to Nieuw West (around ~8 and 14% for a respective population share of ~10 and 16% for North and Zuidoost against 23% and 18% in population share for Nieuw West). Neighbourhoods with smaller household sizes have higher separation rate, although West has a relatively small collection rate (24.7%) compared to its small household size, while Oost hosts, in average, marginally larger households in average, but has a separation rate above 32%.

Presence of Children in Household

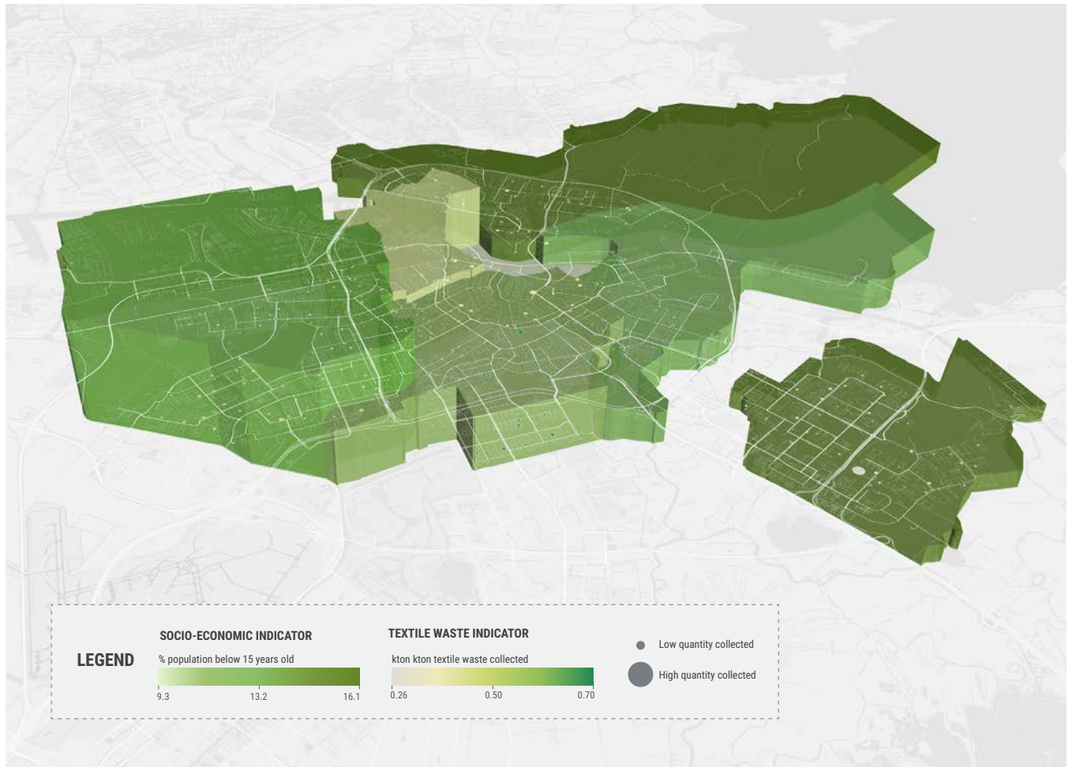


Figure 53: Share of children among the households of each Amsterdam district

The darker the green shades the higher the average number of children per household a neighborhood has. Therefore, the demographic parameter is similar to household size. North is the neighbourhood with the most children per household (16% of the population), followed by Nieuw West and Zuidoost. There is no clear visible correlation between children and the total amounts of textile waste produced, although we can find similar patterns discussed above in the household size map section: **the neighborhoods with the largest number of children have the lowest separation rate.**

House Value

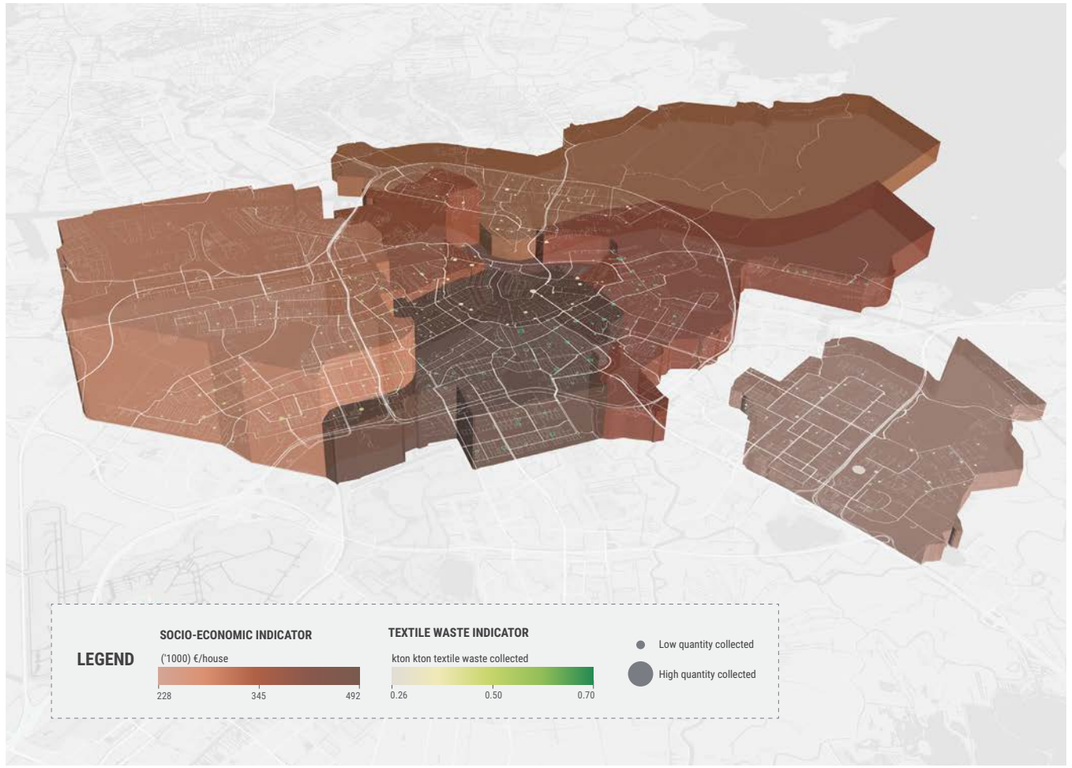


Figure 54: Average house value across Amsterdam districts

The darker the brown shades, the higher the average house value a neighborhood has. Therefore, Centrum and Zuid are the neighbourhoods with the highest house value in Amsterdam, followed by Oost and West. Zuidoost is the neighborhood with the lowest house value. There is no clear visible correlation between house value and the total amounts of textile waste produced. Nonetheless, it should be noted that **the neighbourhoods with the lowest house value (North, Nieuw West, Zuidoost in decreasing order) have the lowest shares of textile waste separation,** with respectively, 23.7, 18.6%, and 22.5%.

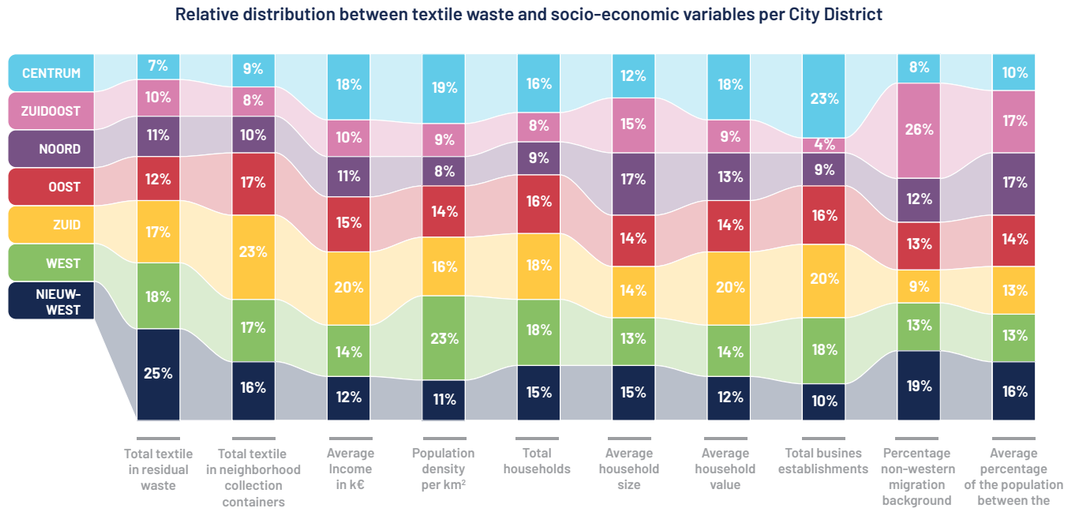


Figure 55: Comparative summary of Amsterdam districts across socio-economic and textile waste indicators

Figure 55 summarizes the results of Metabolic Institute's spatial analysis in relative terms to compare each neighborhood with one another.

Amsterdam Neighborhood Analysis: A deep dive into Nieuw West, Zuidoost, and Zuid

Based on Metabolic Institute's spatial neighborhood analysis, three neighborhoods were selected by the Amsterdam REFLOW pilot team - Nieuw West, Zuidoost, and Zuid - for further research based on their socio-economic makeup, their textile waste separation rate, and the amounts of textile waste produced. Based upon this selection, a more granular analysis was performed by Metabolic Institute to understand further the layout of each neighborhood in terms of the type of buildings and their use, and the location of specific textile containers.

In the maps below, each building use type has a specific colour code, whether the building is used for residential purposes, industrial use, a shop, a business, a school, by a sport facility, or even an event center. The location of textile containers are illustrated by the red dots. Their size indicates how much textile waste the specific container has collected in one year (2019).

Nieuw West

Nieuw West is predominantly residential with around 64% of its surface allocated to housing. The healthcare sector is the second largest user of space in the district with almost 8% of the total surface area. Event centers, industrial buildings, and offices cover similar surface areas, ranging between 4.5% and 5.5%. School and education centers amount to 4.1% of Nieuw West, while shops cover around 3.5% of its surface. Finally, shelters and other buildings cover around 4% of the district, and sport centers only 0.75% of Nieuw West. Nieuw West has about 68 textile containers. In 2019, these containers collected about 0.5 kton of textiles.

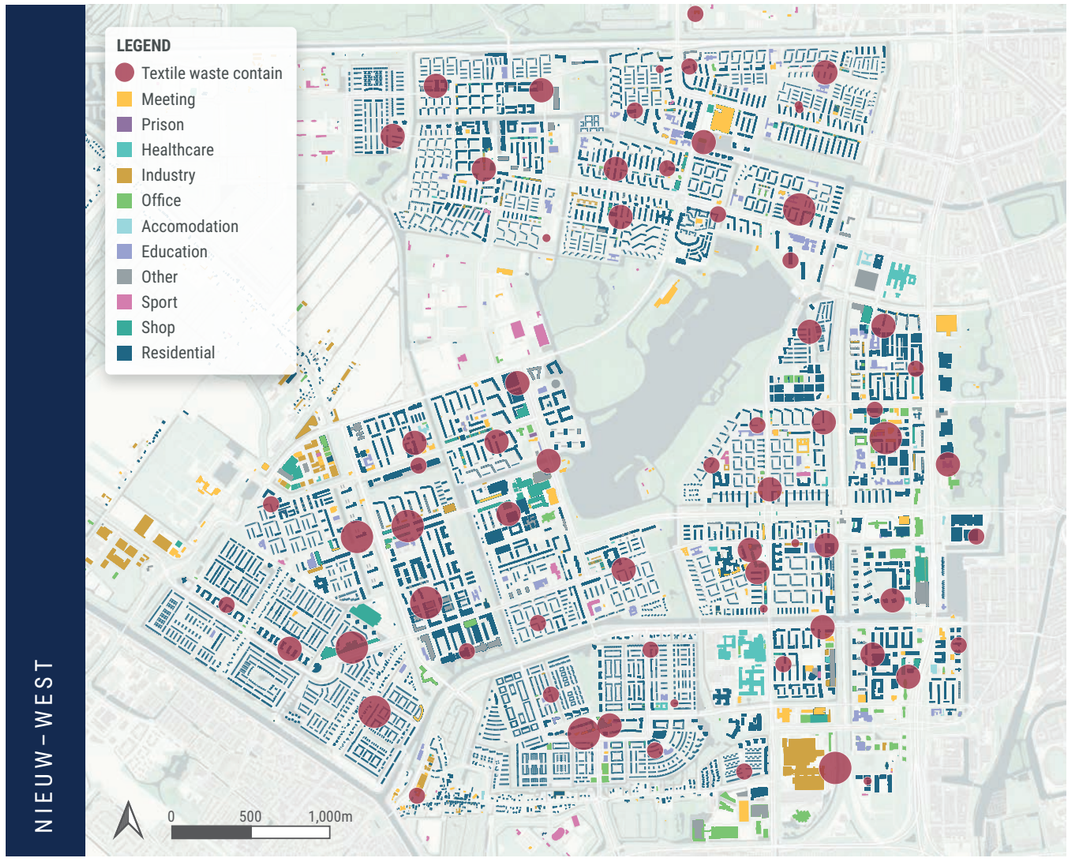


Figure 56: Nieuw-West district building types and textile bins location

Zuidoost

Zuidoost is a mixed-use area, composed of 44% of residential buildings, and 17% of office space. The healthcare sector is also an important share of the surface area of the district, with 10.5%. Around 8% of the district is dedicated to industrial use. Similarly, schools and education centers take up around 8% of the Zuidoost surface area. Event centers and shops cover around 5% each of the surface area, and finally sports centers, prisons, shelters and other buildings cover about 4% of the district. Zuidoost has 37 textile containers across the entire neighbourhood, mostly located in residential areas . In 2019, these containers collected about 0.25 kton of textiles.

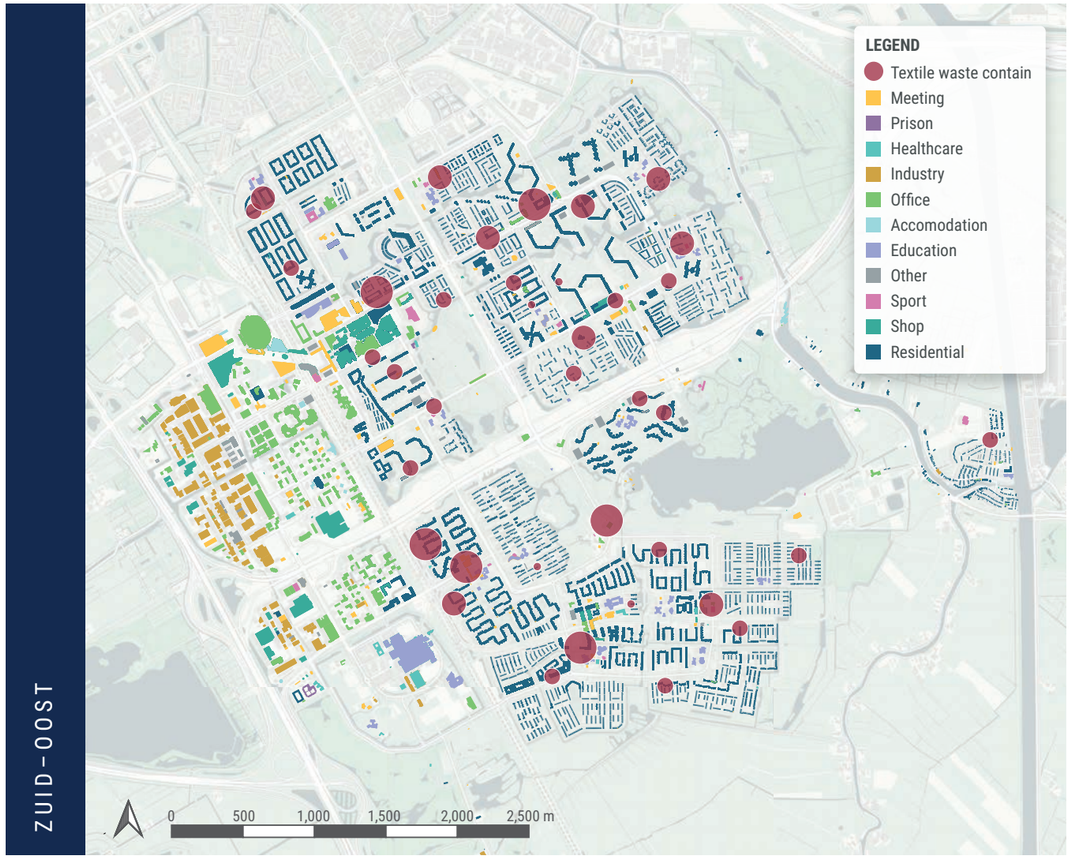


Figure 57: Zuid Oost district building types and textile bins location

Zuid

Half of the Zuid district is dedicated to housing and residential spaces. Nonetheless, office spaces cover a significant portion of the neighbourhood with almost 20% of the surface area. Event centers also hold a significant share of the overall building use in the district, with 10% of the built-up surface areas intended for events and conferences. School and education centers amount to 6.3% of Zuid's surface area, while shops cover around 4% of its surface. Each of the healthcare and industrial sectors cover around 2%. Finally, shelters and other buildings together cover around 6% of the district, and sport centers only 0.6% of Zuid. Zuid has 55 textile containers, dispersed throughout the entire neighbourhood. In 2019, these containers collected about 0.7 kton of textiles.

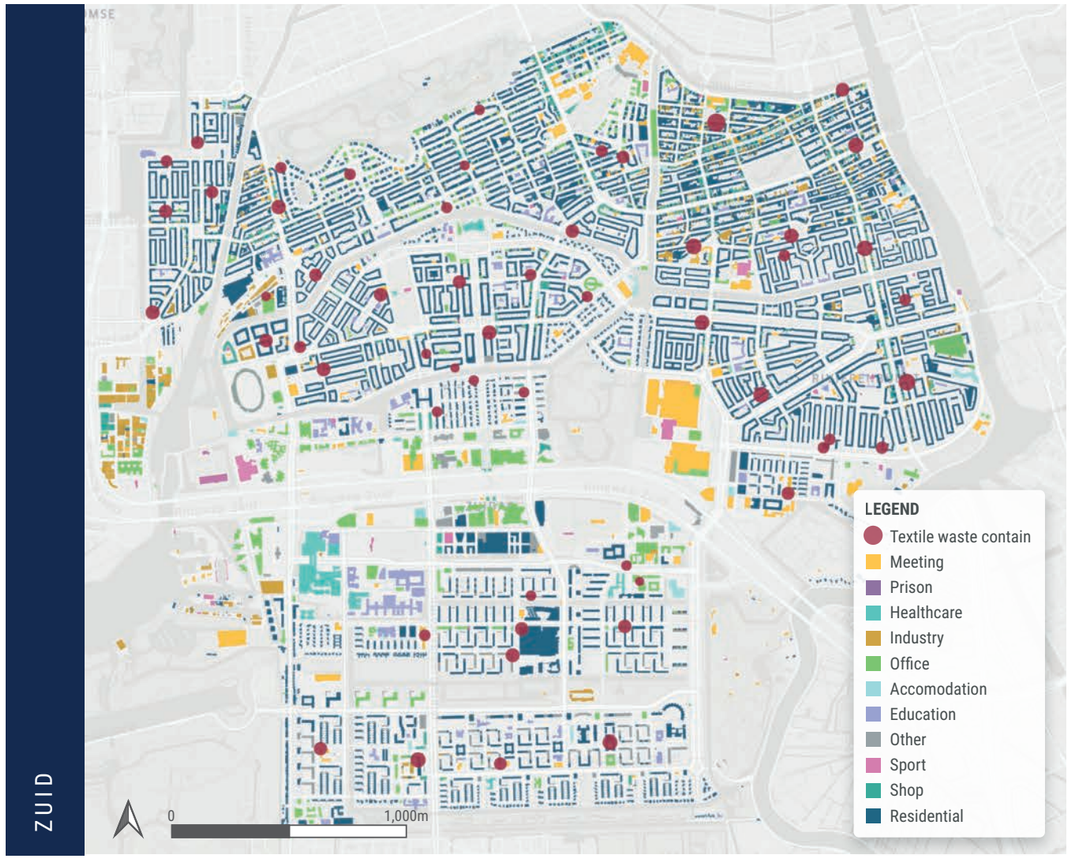


Figure 58: Zuid district building types and textile bins location

In summary, **Nieuw West is an interesting district for the REFLOW pilot to engage with as it is the district with the lowest separation rate that produces the largest amount of textile in the residual bins.** It's a very residential district, with large families, therefore the pilot will need to engage with residential communities. Zuidoost also shows a low-separation rate, but differs from Nieuw West as its a mixed-use area with a large share of its surface dedicated to offices, the healthcare sector, and schools. Zuidoost is home to the lowest average income in the city. Conversely, Zuid is a high-income, mixed-use neighbourhood with a high separation rate and where the largest amounts of separated textile are collected. It could be interesting for the REFLOW pilot team to engage in this neighbourhood to continue improving upon good practice and further optimize the separation rate.

6.2 Vision for a sustainable textile sector in Amsterdam

In a circular textile system, all materials are continuously cycled at their highest-value through loops of reuse, repair, remanufacture, and recycling. Optimal circulation of materials is ensured from the very beginning -by designing fabrics and garments so that fibers can be easily separated at the recycling phase. Moreover, textile products are designed and manufactured to last -durability and repairability are foundational design principles across the industry. Business models keep products at their highest value - with many leveraging leasing, lending, and reuse models. Where relevant, products are enhanced or replaced by virtual alternatives such as digital collections or virtual showrooms. Moreover, businesses empower users with the necessary knowledge, tools, and services to maintain the physical and emotional appeal of textile products. Textile products are collected and sorted to be reused, remade, recycled, and — after maximum use — composted. Landfill, incineration, and waste to energy have been made obsolete by the circular system. Naturally-derived materials enter biological loops at the end of life through composting or anaerobic digestion in ways that generate additional value, for example by increasing the health and carbon content of soil.

Renewable energy powers the entire chain - from manufacturing and distribution, to sorting and recycling. The health of people and ecosystems is protected by ensuring materials are free from hazardous substances, the use of products does discharge hazardous substances into the environment, and microfibres that may cause harm are prevented from reaching the environment. Governments support effective collection infrastructure, facilitate the establishment of related self-sustaining funding mechanisms, and provide an enabling regulatory and policy landscape.

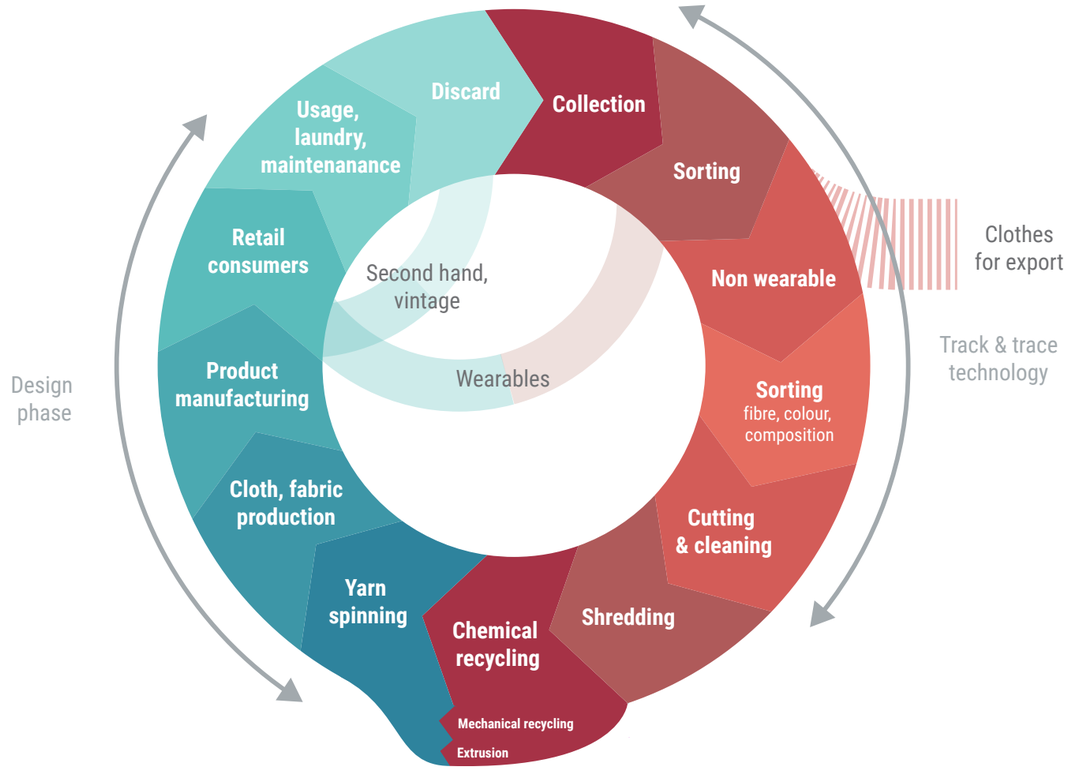


Figure 59: Circular textile value chain

Based on Metabolic Institute's research on the current state of Amsterdam's textile sector and its major impact hotspots, two strategic focal areas have been developed as recommendations for how the City can further realise its vision for a sustainable and circular textile sector, as well as contribute towards municipal, national, and European circularity goals:

1. **Collect more and collect better:** Rapidly increase the rate of separated textile collection in Amsterdam and reduce contamination while extending the life cycle of products and materials.
2. **Fuel recovery and reuse:** Build, enhance, and incentivize local reuse and remanufacturing value chains.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

6.3 Focus Area 1: Rapidly increase the rate of separated textile collection and extend the life cycle

6.3.1 Introduction

The overwhelming majority of impacts in the textile chain come from primary production and processing. 95% of impacts occur between the (i) raw materials and production phase and (ii) consumption phase of the textile chain. Thus, one of the most impactful things Amsterdam Municipality can do is reduce its consumption of virgin fibers by (i) rapidly increasing the rate of separated textile collection in Amsterdam and reducing contamination rates, while (ii) extending the life cycle of textile products and materials.

Yet, current separation and collection rates within the city aren't great. Firstly, most textiles - roughly 69% -end up in residual municipal waste and are then incinerated. 24% is collected through city drop off containers. The remaining 7% is collected from companies via private or municipal waste collection. Secondly, the amount that does get separated, has a high contamination rate. The contamination rate of separated textile waste is 18%, from which 13.2% is too polluted to be re-used or even recycled. This is an issue because it contaminates the rest of the textile being collected. The Amsterdam textile sector will simply not become circular as long as this low separation rate continues. In Amsterdam, the main producers of textile waste are private households. Thus the City should focus on increasing the separation and collection of textiles at the household-level, as households are the largest consumers of textiles within the city.

We recommend the Municipality increases the rate of separated textile collection and its reuse by innovating between the public and civic sectors. Firstly, intervening within municipal contracts and practices for separated textile collection. This can take the form of a close collaboration with Sympany - the textile collection company which oversees textile collection in Amsterdam - and other local stakeholders to optimize the location and functionality of separated collection containers while incentivising collection-to-reuse practices and logistics. Secondly, the Municipality should work with citizens at the neighborhood level to increase and improve separated textile collection and re-use practices. It is important to work at the neighborhood level as our research has shown that all neighborhoods are unique - with different consumption, separation, and waste patterns - and should be engaged with accordingly.

We recommend placing a starting focus on the Nieuw West neighborhood. While home to 18% of Amsterdam residents, Nieuw West produces the largest amount of textile waste by neighborhood, with 22.5% (~ 2.7 ktons) of the total volume of textile waste in Amsterdam (~12 kton). Nieuw West also produces the largest amount of textile in the residual waste. A quarter of all textiles (~2.2ktons) found in the city's residual waste streams (~8.7 kton) come from Nieuw West. Nieuw West also has the lowest share of separation, with only 18.6% of textile waste being separated correctly. Compare this to Zuid, Oost, and Centrum which each have a separation rate of 32%. Our research found that the rate of separated textile collection in Amsterdam correlates to a series of socio-economic factors at the neighborhood level. Neighbourhoods with the lowest house value; the largest number of children per household; lowest average income; and highest household size all correspond to having the lowest shares of textile waste separation. The neighborhood of Nieuw West is representative of all of these socio-economic factors -showing a clear connection between separated textile rates and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

socio-economic demographics. Therefore, Nieuw West is an interesting district for the REFLOW pilot team to engage and prioritize within its activities.

6.3.2 Strategic Direction 1: Incentivise a culture of reuse and repair amongst Amsterdam citizens to increase separated textile collection and re-use rates.

The City should focus on increasing the amount of home textiles being separately collected for repair and reuse across the city by educating and incentivizing citizens. To do so, the City can implement awareness raising campaigns to inspire citizens to think differently about the value of their textile waste and show them practically how it can be reused and re-circulated. These events can be done in collaboration with local organisations such as Pakhuis de Zwijger, Fashion for Good, and Waag Society's Textile Lab. Citizen workshops can begin first with a focus on the Nieuw West and Zuidoost neighborhoods.

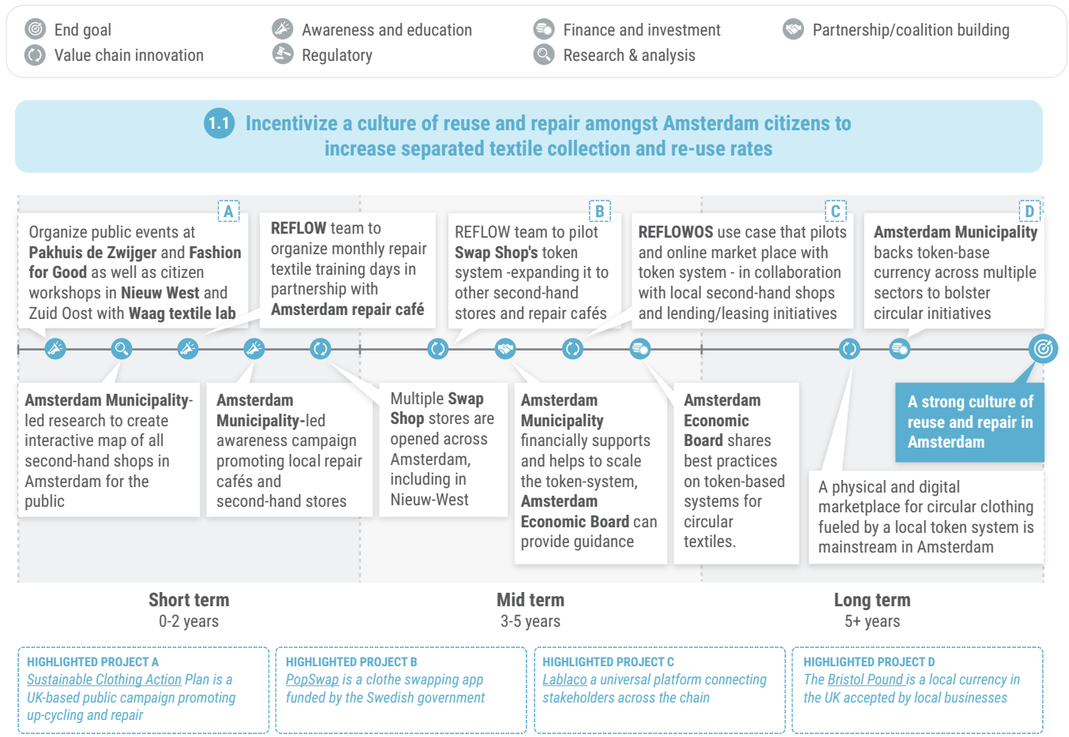
The City can also incentivize citizens to reuse textiles at the local level. For example by enabling local Repair Cafes or similar community-based initiatives through subsidizing the necessary community spaces and equipment, and providing training opportunities at low or no cost. This work can begin through the organization of repair days in partnership with Amsterdam's repair cafes. The City can also incentivize citizens to reuse textiles by better connecting and amplifying the city's local second-hand shops and pre-existing leasing and lending models with community consumption/disposal practices and innovative incentive schemes. To begin this work the City could run an exhaustive survey of all second-hand shops in Amsterdam - identifying key collaboration opportunities and making a citizen-friendly map of textile donation/drop off locations. Another key starting point would be to scale the city's existing SwapShop initiative[274] and pilot the expansion of its token system. For this we recommend connecting the SwapShop initiative and it's token system to the emergent REFLOWOS digital marketplace as well as extending the use of tokens from the Swap Shops to other local businesses (e.g. cafes, grocers, etc.). We recommend focusing first on key neighborhoods like Nieuw West.

Use-cases

- Circular Textile Days: Amersfoot organises a Circular Textile Days event where sustainable circular solutions are discussed and where actors in the industry can meet.
- Fibershed Learning Center: The learning center in California offers workshops, training, and show and tell sessions focused on circular textiles.
- Sustainable Clothing Action Plan: The British action plan contains a community campaign providing a series of materials aimed at better care of clothing (upcycling and repair) and re-use of 'preloved' items.
- Swap shop at recycling centers (Denmark): In 2016, Copenhagen did an experiment to collect textiles at local recycling centres. Those centres have a swap shop where citizens can exchange their used items.
- Bristol Pound: In Bristol, tokens are offered for multiple actions citizens or businesses are doing for carbon reduction. Tokens can be exchanged at multiple locations in the municipality.

[274] The SwapShop. (2021). The SwapShop.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



6.3.3 Strategic Direction 2: Improve municipal separated textile collection infrastructure and processes.

The Municipality should develop a targeted strategy for optimizing its separated collection infrastructure and processes. Firstly, the City can create an awareness raising campaign to educate and incentivize citizens to improve practices in relation to separated textile bins. Workshops should educate citizens on the importance of better separated textile collection and what best practice looks like, with a particular focus on how to avoid contamination. As part of this campaign, the City can host a city-wide Recycling Textile Week and place signage in key neighborhoods (e.g Nieuw West) that lead to textile recycling bins. In parallel to this campaign, the City should also incentivize citizens to use separated textile bins rather than the residual bin to dispose of textiles. As part of this work, the Municipality can collaborate with REFLOW pilot partners and Sympany to pilot a tokenized reward system in the Nieuw-West neighborhood that incentivizes the collection of textile waste in dedicated Sympany textile bins. The system can be based on a local or municipal token currency, potentially leveraging the token system already developed and in place in Amsterdam Swap Shops.

In addition to public educational campaigns, the Municipality should work in collaboration with Sympany to improve the city's network of separated textile bins. This work can begin with in-depth research in collaboration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

with REFLOW partners to identify the key challenges, barriers, and successes of using the network of separated textile bins in Amsterdam with the goal to improve the coverage of the bins network and the pick up rates of bins. Existing use-cases have shown that sensors placed on bins can enhance the monitoring of bin capacity and make more efficient pick up rates and waste management practices. The City should also work to improve the signage on bins with a focus on reducing contamination rates by making clear what should and shouldn't be placed within the bin. The City should also consider 'smart' bins[275] that can enable pre-sorting of textile waste. By implementing bins that have a pre-sorting function that separates reusable textiles from non-reusable textile scraps, the City could cut down post-collection separation processes and reduce lag times between collection and reuse by local partners. The build up of textile waste throughout the Covid-19 pandemic was a key lesson-learned that collection-to-reuse logistics need to be improved upon within the city. The City should also incentivize citizens to use separated textile bins rather than the residual bin to dispose of textiles. To do so, the REFLOW pilot team could deploy a token or credit system in conjunction with smart bins that have a QR code functionality.

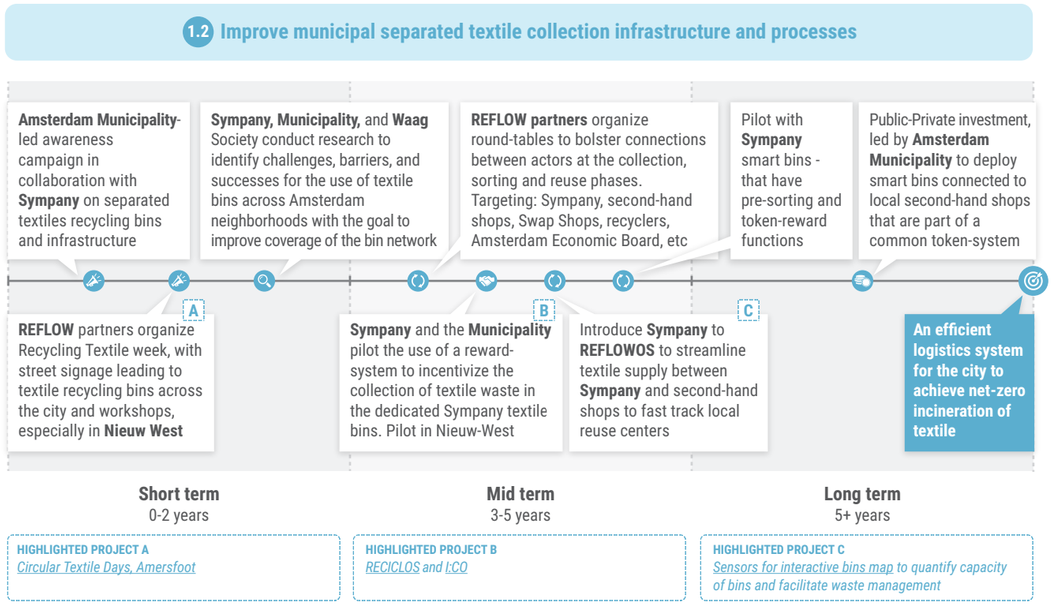
Lastly, the City should work to optimize logistics along the local collection and reuse chain. The majority of separated textiles collected by the City are leaving Amsterdam. Moreover the Covid-19 pandemic has shown us that a stock build up of separated textiles is prone to occur within Amsterdam leading to the incineration of reusable textiles. The City should look to create stronger connections between actors facilitating separated textile collection, sorting, and reuse of textiles within Amsterdam. For example, local actors including the Municipality and the Amsterdam Economic Board can leverage REFLOWOS to facilitate closer connections between Sympany, recyclers, Swap Shops, and local second-hand shops in Amsterdam. Through REFLOWOS the Municipality can streamline textile supply from separation through to reuse, fast-tracking and fueling local reuse centers and markets.

Use-cases

- Copenhagen TV campaign: The Danish Red Cross and a TV company collaborated to launch an awareness campaign encouraging citizens to return and recycle their textiles. Improved signage was also added to collection bins.
- Sweden residual bins study: A study in Sweden revealed that more bins installed close to residual bins beside multi-apartment houses led to 50% more textile recycling from people who didn't recycle before.
- Sensors for interactive bins map: Sensoneo digitilised Ekocharita container inventory allowing the quantification of the bin's capacity and waste management.
- RECICLOS: RECICLOS is a plastic recycling program where the user scans its products before putting them in a bin where a QR code is scanned. Virtual tokens are collected and can be exchanged on social projects.

[275] SENSONEO. (2021). Digitalisation of textile waste infrastructure.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



6.3.4 Strategic Direction 3: Double down on reducing primary consumption of the most impactful fibers: cotton, polyester, acrylic, and viscose.

Not all textile fibers are created equal in terms of social and environmental impacts. Therefore, in pursuit of reducing its direct and indirect impacts, the City of Amsterdam should prioritize reducing primary consumption of the most impactful fibers, including: cotton, polyester, acrylic, and viscose. Cotton is by far the most impactful fiber type from a production phase perspective. It's also the largest fiber consumed in Amsterdam with 6.6 ktons consumed each year, equalling 36% of all fiber consumption in the city. For every kg of cotton produced: 952 ha of land are used and the equivalent of 1.986 liters of water is consumed. Cotton accounts for 4% of nitrogen fertilizers and phosphorus consumed globally, 16% of global insecticides usage, 7% of global herbicides usage, and 2.5% of global agricultural land. **Reducing virgin cotton consumption and optimizing the collection and reuse of cotton in Amsterdam is of critical importance.** The third most consumed fiber in Amsterdam is viscose, at 1.6 kton per year. For every kg of viscose fiber produced, 1,429 ha of land is used. **Optimizing the recycling and reuse of viscose within the city is key to Amstedam reducing its indirect impacts** -in particular reducing pressures on land use and land transformation. Lastly, 0.68 kton of acrylic is consumed each year in Amsterdam. Despite this relatively low volume, acrylic fibers have a disproportionately significant impact. For every kg of acrylic fiber produced the equivalent of 0.99 kg of dichlorobenzene is released into surrounding freshwater systems and the equivalent of 37.7 kg of CO_2 is emitted. For every kg of acrylic fiber laundered within Amsterdam the equivalent of 5 kg of dichlorobenzene is released into surrounding freshwater systems. Reducing virgin acrylic production by optimizing the recycling and reuse of acrylic is **key to mitigating impacts associated with climate change and improving human and freshwater health.**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

The City should develop high-profile recovery schemes for its most impactful fibers. The City's on-going Denim Deal[276] focused on cotton recovery and reuse is a good example, with such an initiative expanding to include other similarly impactful fiber types. Amsterdam Municipality-supported recovery and reuse campaigns can run in partnership with organizations such as Fashion for Good and the Dutch Circular Textile Valley.

In parallel to initiating high-profile recovery schemes, the Municipality should encourage the use of recycled feedstocks and optimal recovery of these fibers within the city's textile sector. The REFLOW pilot team can leverage REFLOWOS to connect recovery, reprocessing, and remanufacturing stakeholders within the value chains of these fibers. A REFLOWOS pilot can be used, firstly, to monitor to what extent local industry is using recycled feedstock and optimally recovering these fibers at the end of their life. Secondly, such a pilot can be used to identify key points within the value chain in need of further support. Key actors to involve in such a pilot would be Sympany, local Swap Shops, Wieland Textile, and local designers.

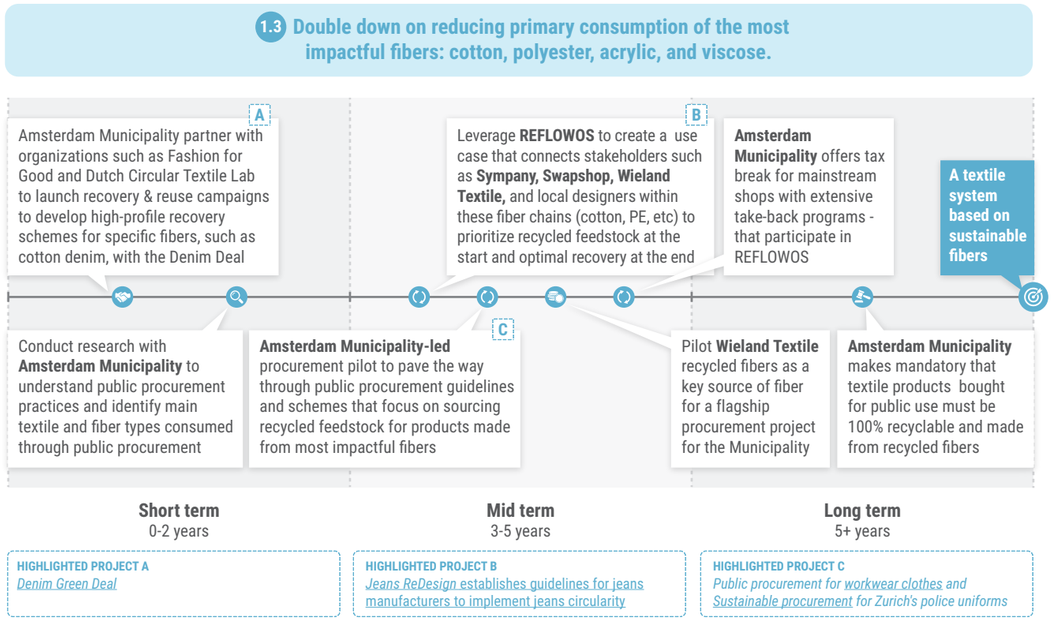
Lastly, the Municipality can pave the way through public procurement guidelines and schemes that focus on sourcing recycled feedstock for products made from cotton, polyester, viscose, and acrylic fibers. The Municipality could run a procurement pilot in collaboration with Wieland Textile focused on sourcing products made from recycled feedstock. Ultimately, the Municipality should mandate within its procurement guidelines that all textile products procured by the City must be made from 100% recycled feedstock and should be fully recyclable at the end of their life using the infrastructure found within the city. This work can begin by REFLOW pilot partners conducting research with Amsterdam Municipality to understand public procurement practices and identify main textile and fibre types that the City consumes through public procurement.

Use-cases

- Denim Deal: The Denim Deal tackles the use of cotton in denim by working with leading parties across the denim value chain to close the loop.
- Worn Wear - Used Patagonia Clothing & Gear: Patagonia offers discounts when used clothes are returned. The second-hand clothes are repaired or directly sold on their website.
- The Jeans ReDesign Guidelines: The guidelines are targeted to jeans manufacturers to implement circularity in jeans design.
- Green public procurement for work wear clothes: A municipality in Denmark has adopted a three-year leasing contract for their employees' workwear. After the contract, there is a buy-back possibility, else the uniforms are kept by the leasing company.
- Sustainable procurement for police uniforms: The City of Zurich has implemented sustainable procurement guidelines for the police uniforms where the fabrics must comply with Eco-Tex Standard 100 Class II or equivalent.

[276] Kühnl, S. (2020). Sustainability: What is the Amsterdam 'Denim Deal' all about?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



6.4 Focus Area 2: Build, enhance, and incentivize local reuse and remanufacturing value chains

6.4.1 Introduction

As seen by Metabolic Institute's MFA and impact analysis, one of the most impactful things Amsterdam Municipality can do is reduce its consumption of virgin fibers. Alongside promoting better separated collection, the City should also rapidly increase the recovery and reprocessing rates of textiles within the Amsterdam system -turning recovered fibers back into high-value feedstock for use in local industries.

Yet, current recovery and remanufacturing practices within the city are not great and mostly focus on downcycling and incineration. At least 70% of the textile waste that is collected by the City is incinerated. More than 11 ktons CO_2-eq is emitted from current incineration practices. Additionally, 7.5 tons of particulate (PM <2.5um) is released into the environment contributing to local air pollution. The 24% of separated textiles collected through city drop off bins are exported to Lithuania. From that total stock, 6% is sold as A-grade second-hand textile in the Netherlands and Eastern Europe, 75% is sold as B-grade second-hand textile in Lithuania, Republic Czech, and several African countries, and 19% gets recycled between Belgium, Pakistan, and the Netherlands. Metabolic Institute's research has shown that even when Amsterdam textiles are sorted separately, they are being exported abroad and most often downgraded. Within the current system very

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

little if any textile material is staying within Amsterdam for reuse. Meaning **the current textile system within Amsterdam is very linear, with the absence of any major loop to bring textiles back into the urban system at high value.**

In Amsterdam, valuable textiles are currently being incinerated and downcycled that could be reused and remanufactured by local actors and fed back into Amsterdam's economy for high-value use. This presents a large untapped potential for local remanufacturing. The incineration of clothes generates significant amounts of CO_2, which could be greatly reduced if these textiles were reused and remanufactured by local actors. Out of the 70% of textiles being incinerated, 51% could be recycled as material and 28% could be reused as clothing. By diverting reusable clothing from incineration, 2,500 tons of clothes could be circled back into Amsterdam -avoiding the use of virgin materials. By diverting recyclable clothing from incineration, about 4,500 tons of textile materials could be used as substitution for virgin feedstock. If the current reusable clothes and home textiles were diverted from incineration, their sales as second-hand textile products could generate up to 10 million EUR. If the current recyclable clothes and home textiles were diverted from incineration, their sales to textile recyclers could generate up to 1 million EUR.

It is **key that the Municipality and REFLOW pilot partners seed local markets capable of closing the loop in high-value ways.** Out of the 70% of textile currently being incinerated, half of it could be recycled as feedstock for local manufacturers and designers in Amsterdam. The manufacturing industry is the second largest consumer of textiles in Amsterdam, currently consuming 23% of textiles within the urban system. Making the **manufacturing sector** a key target for the REFLOW pilot to spur the production and use of recycled feedstock from local waste streams. The REFLOW pilot team should focus on increasing the rate of collected textiles being brought back into local loops by way of recycled feedstock. The City can use collected textile waste to provide feedstock for the recycling industry and ensure this recycled feedstock is getting to local producers to create new, high-value products.

6.4.2 Strategic Direction 2.1: Invest in the production and technological capacity needed to enable a textile (re)manufacturing sector within the city region

The City of Amsterdam should support the development of a local remanufacturing sector -both by providing local training and up-skilling opportunities as well as by providing the production and technological capacity needed to enable a textile remanufacturing sector within the city region.

This work could begin by hosting roundtables with remanufactures and designers operating within Amsterdam in order to collectively identify the manufacturing and recycling technology requirements of the local textile sector. These roundtables could be led by REFLOW pilot partners such as Waag Society in collaboration with local industry organisations including the Circular Textile Valley and Wieland Textile. The City should facilitate public/private investment in critical technical capabilities needed by the local sector -with the aim to scale core technologies like Fibresort[277] and Re:newcell[278] and integrate such capabilities within Amsterdam's

[277] Fibersort. (2021). The Fibersort project.
[278] Re:newcell. (2021). Technology.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

public waste treatment centers (AEB). Such interventions can help to make Amsterdam a center for textile recycling and remanufacturing and, ultimately, make incineration obsolete. Public investments in equipment and infrastructure should be done in ways that ensure the acquired technology can be made available and accessible to all relevant actors within the Amsterdam textile sector - both large and small companies alike - in flexible and agile ways.

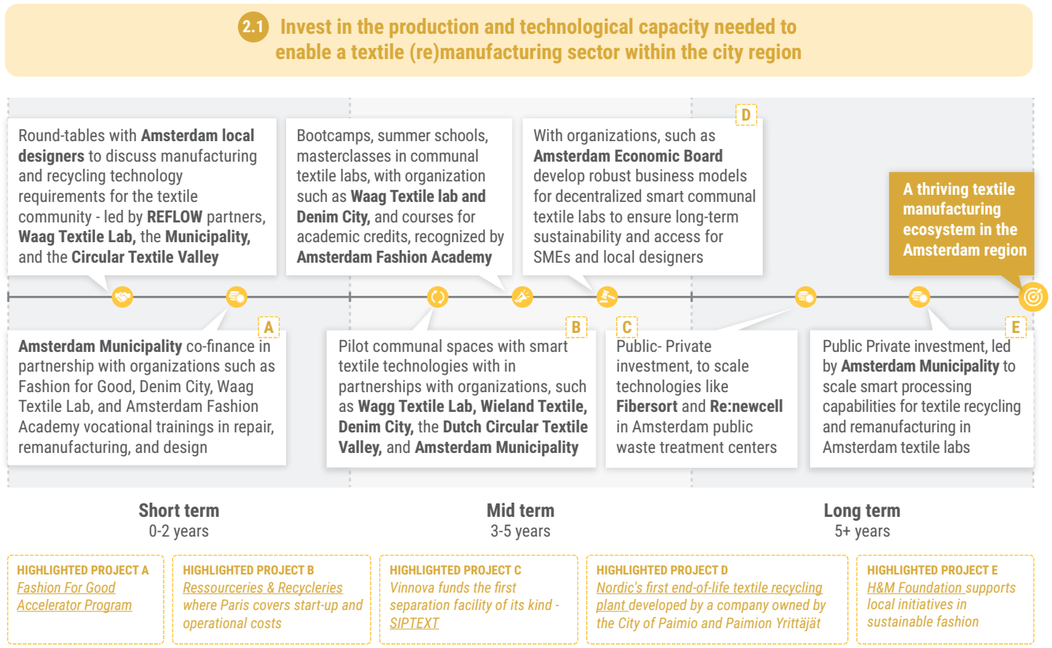
Moreover, the City could pilot communal production spaces equipped with smart and agile textile remanufacturing technologies. The pilots should implement and test the optimal equipment mix for such agile and shared production spaces. Importantly, these pilots could work with the Amsterdam Economic Board to develop robust business models for operating decentralized, smart communal textile labs that ensure long-term sustainability and access for SMEs and local designers. Pilots could be delivered in partnership with local organizations such as Waag Society's Textile Lab, Wieland Textile, Denim City, and Made Up North.

Lastly, the City could work with local vocational training centers to provide summer schools, masterclasses, and vocational training at low to no cost in topics such as repair, remanufacturing, and reproduction. With such training courses, the City can help to develop a local remanufacturing economy that's future-proofed with a highly skilled workforce. Courses could be partly delivered in the communal textile lab pilots and led by local partners including Fashion For Good, Denim City, Waag Textile Lab, and the Amsterdam Fashion Academy.

Use-cases

- Fashion For Good Accelerator Program: Each year, 10-15 startups are invited to join an intensive global programme with the goal of making all fashion "good".
- Ressourceries and Recycleries: Paris has the goal of having 20 Recycleries operating by 2020 where textiles will be repaired and resold. The City will assist in finding suitable locations for them in the city, and provide start-up financial support and financial support for operations for a three-year trial period.
- The Renewal Workshop: The zero waste system recovers the full value out of what has already been created by taking discarded apparel and textiles and turns them into Renewed products, upcycled materials or recycling feedstock. The second factory was built in Amsterdam in 2019.
- Nordic's first end-of-life textile recycling plant: The recycling plant was developed by a company owned by City of Paimio and Paimion Yrittäjät: Its goal is to develop the Paimio region.
- European Union's Horizon 2020 (i.e. Resyntex): Supports raw material innovation by funding circular economy initiatives (sustainable processing, reuse, recycling, recovery schemes).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



6.4.3 Strategic Direction 2.2: Connect and incentivize exchange amongst stakeholders across the chain through digital tools

By piloting digital tools like REFLOWOS, the REFLOW pilot team can support the Municipality of Amsterdam to empower a local market of remanufactured goods. Connecting and incentivizing exchange between stakeholders along the chain will be key to generating an effective and efficient local textile remanufacturing economy in Amsterdam. The REFLOW pilot team can play an influential role in this regard by leveraging REFLOWOS as a B2B connection and exchange platform where local recyclers, fiber (re)producers, textile (re)manufacturers, and designers are connected through a digital marketplace. REFLOWOS can facilitate the multi-step transformation process whereby textile waste is processed into recycled feedstock and finally into new products - ultimately increasing the amount of feedstock available for and used by the local urban economy.

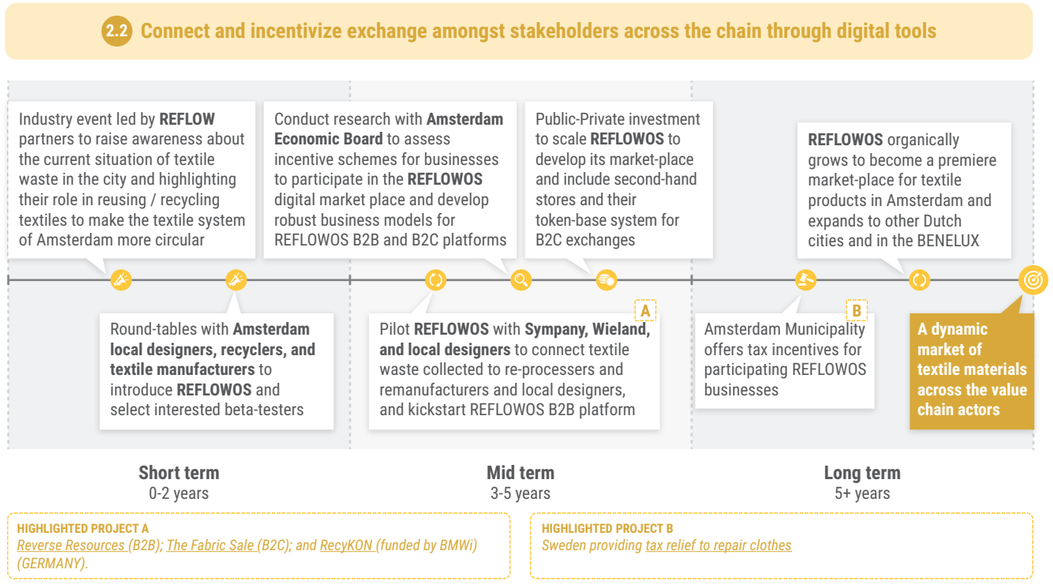
This work can begin with a series of awareness raising webinars that inform local manufacturers and designers about the current state of textile waste in the city - highlighting its negative impacts and the potential role local industry can play in making the textile system more circular. Off the back of such webinars, the REFLOW pilot team can host a series of roundtables with local designers, recyclers, and textile manufacturers to introduce REFLOWOS, explore practical use-cases, and select interested beta-testers. One immediate such pilot of REFLOWOS could be with Sympany, Wieland, and local designers at Denim City whereby REFLOWOS facilitates the collection, reprocessing, and remanufacturing of cotton waste as part of the public Denim Deal campaign.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

In parallel, the REFLOW pilot team could conduct research with Amsterdam Economic Board to identify and assess possible incentive schemes that increase the rate of engagement and adoption of REFLOWOS by local businesses. Beyond the piloting phase, public/private investment could be committed to scaling REFLOWOS as a digital marketplace more broadly - expanding its remit to include second-hand stores. Through such scaling, REFLOWOS has the potential to become the premiere digital marketplace for recycled textile products not only in Amsterdam, but cities across the Netherlands and the BENELUX region more broadly.

Use-cases

- Reverse Resources (B2B): Reverse Resources is an online platform where flows of textiles are tracked by connecting brands, manufacturers, waste handers, and recyclers/spinners.
- The Fabric Sale (B2C): The Fabric Sale is an online and in-person fabric shop where creators can have access to recycled high-designers fabrics. Sewing workshops are offered in-person.
- RecyKON: The network is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) where the aim is to bridge the gap from pre-processing and preparation itself to new end products.
- Study on policies driving textile circularity in Sweden: PlanMiljo and IVL Swedish Environmental Research researchers estimated the economic, environmental and social impacts of three circular measures; a wage subsidy, a knowledge hub, and a start-up/transition fund.
- Tax relief in Sweden to repair clothes: Sweden has reduced the VAT tax for repairs on clothes, bicycles, fridges, and washing machines.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

6.4.4 Strategic Direction 2.3: Promote principles of sustainable design and design for recovery

To ensure a circular textile manufacturing industry in Amsterdam, the City must go beyond simply providing the necessary tools, spaces, and exchange platforms. To ensure circularity, the REFLOW pilot team should collaborate with the Municipality of Amsterdam to promote a culture of circular production and incentivise the adoption of sustainable design principles and practices. To begin this work, the REFLOW pilot team could compile best practice for sustainable design and design-for-recovery. In collaboration with local actors, such as Denim City, Fashion for Good, and the Dutch Center for Circular Textile, this inventory of best practice can be integrated into a series of master classes that target and train professionals within the textile industry about how to design for recovery and reuse. In parallel, the REFLOW pilot team can work with local organisations, such as the Amsterdam Fashion Academy, to ensure modules such as "Design for Disassembly" are included into the curriculum of local trade schools.

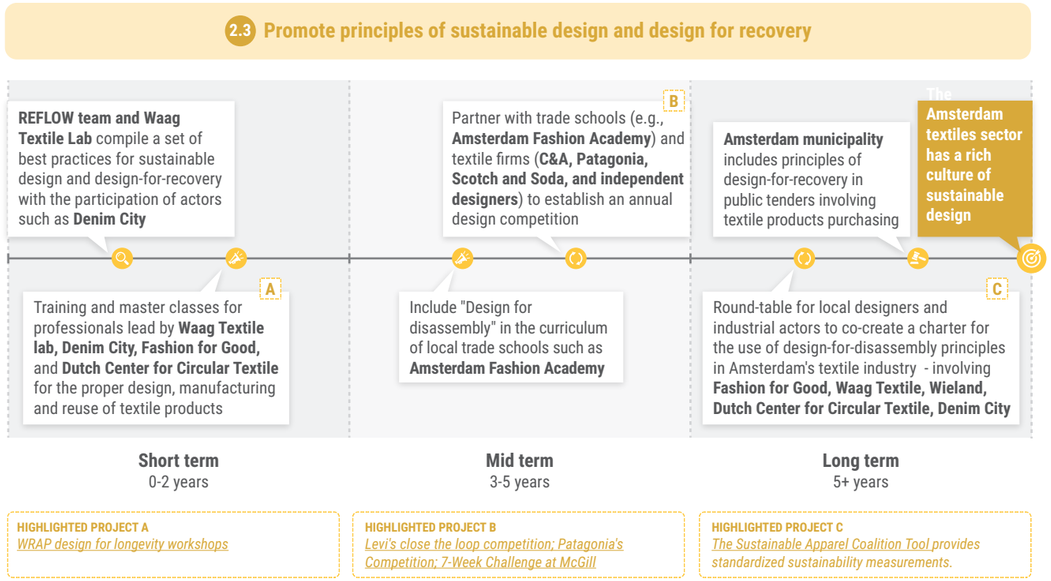
Alongside vocational training, the City can facilitate industry-driven initiatives. For example, partnering with trade schools and textile firms (e.g. C&A, Patagonia, or Scotch and Soda) to establish an annual design competition that showcases and awards best practice in circular design. Moreover, REFLOW pilot partners could host a working group of local designers and industrial actors with the aim of co-creating a charter for the use of circular design principles and design-for-disassembly principles within the Amsterdam textile industry. This work could include local actors such as Fashion for Good, Waag Society, Wieland, Dutch Center for Circular Textile, and Denim City.

Lastly, the City of Amsterdam can play a key role in seeding the demand for circular textile products within the city. The Municipality can incentivize locally remanufactured textile products made from recycled content through public procurement programs and guidelines. The best practice identified by pilot partners (e.g. circular design, design-for-recovery, etc.) can become key features of public tenders and procurement guidelines.

Use-cases

- WRAP design for longevity workshops: As part of the WRAP Design for Longevity initiative, the Sustainable Consumption research group at Nottingham Trent University (NTU) ran a series of workshops to engage industry effectively.
- Levi's Sustainability Undergraduate Case Competition to close the loop: Sustainable fashion design students were invited to participate in the competition to create innovative solutions on how Levi Strauss can "close the loop profitably".
- Patagonia Case Competition: The annual student competition tackles current sustainability issues. Last year's challenge was to find a way to reduce textile waste by shifting consumer behavior and innovation throughout the entire life cycle of their products.
- Sustainable Apparel Coalition Measurement Tools: The Higg Product Tools empower the industry to use life cycle assessment data to create more sustainable products.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.



6.5 Relevance for pilot activities

The Amsterdam Pilot's action plan and Theory of Change outline the key activities that will be done during the period of the REFLOW project to promote and increase the circularity of the Amsterdam textile sector. To communicate how and where Metabolic Institute's urban metabolism analyses and resulting recommendations directly support the Amsterdam pilot's planned activities, desired outcomes, and impacts, we mapped out all touchpoints between the Theory of Change and our proposed two focus areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

D3.2 Urban metabolism analysis: Initial assessments

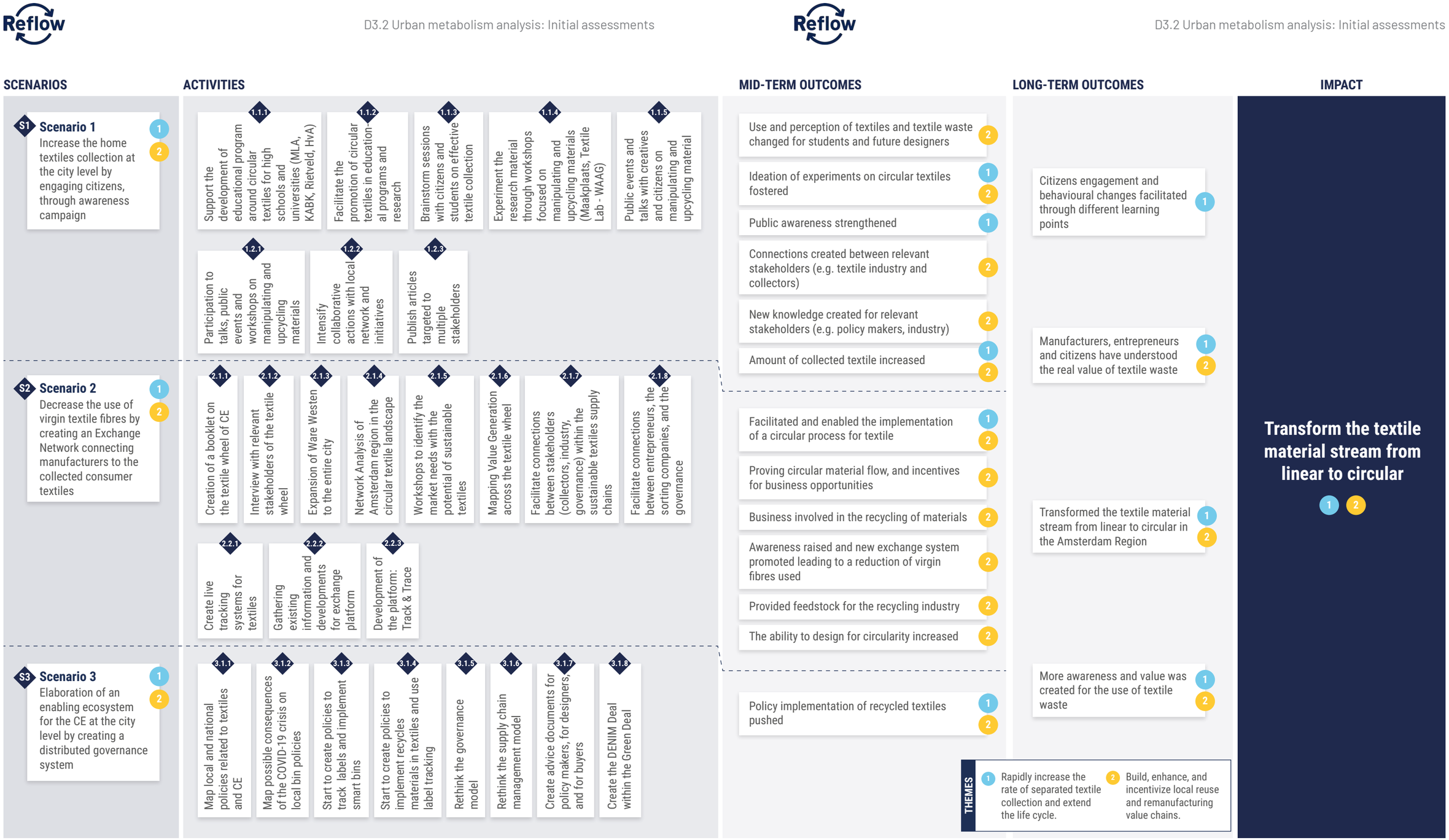


Figure 60: Touchpoints between the Amsterdam Pilot's Theory of Change and the proposed focus areas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

7. CONCLUSION

This report presents the process and outcomes of each REFLOW piloty city's urban metabolism assessment, as performed by WP 3 within the first 24 months of the project. The first section introduces the role in which urban metabolism analysis plays within the broader context of REFLOW, the following sections share the methodologies and outcomes of each REFLOW pilot city's assessment.

Key takeaways and insights have emerged through these activities which help evidence the complexity of the REFLOW ambition and method, the differences and similarities between pilot cities, and how the various theoretical and technical building blocks of the REFLOW concept may be best aligned to support the project's objectives going forward. Key takeaways include:

- The city-wide MFAs (e.g. the Vejle and Amsterdam MFAs, etc.) have provided valuable snapshots of how linear REFLOW cities currently are. The majority of REFLOW cities still operate within a make-take-waste paradigm where goods enter the city and leave as waste after short use cycles. Incineration, and even landfill, is still very much present within REFLOW cities -the identification and implementation of more sustainable measures (e.g. repair, reuse, remanufacture) should be treated as priority.
- The city-wide MFAs and the focus areas shared within this report highlight the importance of EU cities becoming (once again) productive places with the tools and knowledge needed to recover and remanufacture urban products and materials. Separated waste is regularly exported rather than treated within the boundaries of REFLOW cities. Recycling materials and products within city boundaries should be seen as an economic, social, and environmental priority -as this leads not only to new employment opportunities, but the ability to reduce a city's dependency on virgin materials. Cities must provide the resources and incentives to enable local remanufacturing, repairing, and refurbishing of materials and products at scale.
- The site-specific MFAs (e.g. the FIAC and SoGeMi market MFAs) have provided REFLOW pilot teams more granular understanding of value chain-specific resource flows and key stakeholders needed to increase the effectiveness of interventions. These MFAs have enabled pilots to identify and engage "on the ground" stakeholders (e.g., event organizers and timber suppliers in Paris; food wholesale market managers and regional food suppliers in Milan) and gain practical insights on the (in)efficiencies and impacts within and between supply chains which may otherwise go undetected. These MFAs have highlighted how local industry leaders (e.g. SoGeMi in Milan and FIAC in Paris) can play a pivotal role spearheading the transition of their industry towards a circular economy. SoGeMi, for example, can become a central figure in Milan's urban food system.
- By taking a whole-life-cycle approach to each city's environmental impact analysis, it became clear that the impacts associated with the resource flows of each REFLOW city are often not directly felt within the city itself. When assessing the circularity of an urban system, it is critical to apply a holistic and systemic lense. Not only through the identification of environmental, social, and economic impact factors, but also in the identification of upstream and downstream impacts.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

- Data on urban resource flows remains a key barrier within the MFAs and environmental impact analyses. Localized consumption data and greater insight into the supply chain and waste practices of private companies is a key bottleneck to increasing the granularity and accuracy of urban metabolism assessments. Municipalities should take a more active role in incentivizing data sharing amongst public and private urban actors and providing secure data exchange platforms that can facilitate the process.

In the next phase of the project, WP 3 partners will work closely with each pilot city to support them in leveraging these results within their respective Circular Action Plans and on-going intervention.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

REFERENCES

1. +CityxChange. (2021). Lighthouse Cities and Follower Cities, from https://cityxchange.eu/.
2. Aarhus Universitetshospital. (2019). Gentænk Plast - på vores hospitaler, from https://www.auh.dk/siteassets/om-auh/driftsafdelinger/teknisk-afdeling/miljo/gentank-plast.pdf.
3. Abdou, K., Aubin, J., Romdhane, M. S., Le Loc'h, F., & Lasram, F. B. R. (2017). Environmental assessment of seabass (Dicentrarchus labrax) and seabream (Sparus aurata) farming from a life cycle perspective: A case study of a Tunisian aquaculture farm. Aquaculture, 471, 204–212, DOI:10.1016/j.aquaculture.2017.01.019.
4. Aggarwal, A., & Chawla, V. K. (2021). A sustainable process for conversion of petrol engine vehicle to battery electric vehicle: A case study. Materials Today: Proceedings, 38, 432, from https://doi.org/10.1016/j.matpr.2020.07.617
5. AgroParisTech (2021). UN PARTENARIAT FERTILE - AgroParisTech, from http://www2.agroparistech.fr/UN-PARTENARIAT-FERTILE.html.
6. Allcott, H. (2011). Social norms and energy conservation. Journal of Public Economics, 95 (9-10), 1082–1095, from https://doi.org/10.1016/j.jpubeco.2011.03.003
7. Alvelal. (2021). Asociación AlVelAl | Agroecología, from https://www.alvelal.net/.
8. Amsa. (2008). Il termovalorizzatore Silla 2, from http://mediagallery.comune.milano.it/cdm/objects/changeme:22577/datastreams/dataStream4311256567056991/content.
9. Anderson, J. L., Asche, F., Garlock, T., & Chu, J. (2017). Aquaculture: Its role in the future of food. Frontiers of Economics and Globalization, 17, 159–173, from https://doi.org/10.1108/S1574-871520170000017011.
10. Antov, P., & Savov, V. (2019). Possibilities for Manufacturing Eco-friendly Medium Density Fibreboards from Recycled Fibres – a Review, from https://www.researchgate.net/publication/338015478_Possibilities_for_Manufacturing_Eco-friendly_Medium_Density_Fibreboards_from_Recycled_Fibres_-_a_Review.
11. ASDA. (2021). Asda Opens New Sustainability Store, from https://corporate.asda.com/newsroom/2020/10/20/asda-opens-new-sustainability-store.
12. Augiseau, V. (2017). La dimension matérielle de l'urbanisation. Flux et stocks de matériaux de construction en Ile-de-France, from https://www.researchgate.net/publication/325575077_La_dimension_materielle_de_l%27urbanisation_Flux_et_stocks_de_materiaux_de_construction_en_Ile-de-France.
13. Baitz, M., Kreissig, J., & Makishi, C. (2005). Life cycle assessment of PVC in product optimisation and green procurement - Fact-based decisions towards sustainable solutions. Plastics, Rubber and Composites, 34 (3), 95–98, from https://doi.org/10.1179/174328905X55461.
14. Beton, A., Dias, D., Farrant, L., Gibon, T., Le Guern, Y., Desaxce, M., et al. (2014). Environmental Improvement Potential of textiles (IMPRO Textiles). Report EUR 26316 EN, from http://europa.eu/.
15. Blok, M. (2021). Urban mining and circular construction – what, why and how it works, from https://www.metabolic.nl/news/urban-mining-and-circular-construction/.
16. Bondad-Reantaso, M. G., Subasinghe, R. P., Arthur, J. R., Ogawa, K., Chinabut, S., Adlard, R., et al. (2005). Disease and health management in Asian aquaculture. Veterinary Parasitology, 132(3-4 SPEC. ISS), 249–272, from https://doi.org/10.1016/j.vetpar.2005.07.005.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

17. Bräutigam, K. R., Jörissen, J., & Priefer, C. (2014). The extent of food waste generation across EU-27: Different calculation methods and the reliability of their results. Waste Management and Research, 32(8), 683–694, from https://journals.sagepub.com/doi/pdf/10.1177/0734242X14545374.
18. BusinessVejle. (2021). Forside - BusinessVejle, from https://businessvejle.dk/.
19. BusinessVejle. (2021). Well-Done Prisen - BusinessVejle, from https://businessvejle.dk/om-businessvejle/well-done-prisen/.
20. Calle Lobo, S. (2016). A Life Cycle Assessment of Gilt-head Seabream (Sparus aurata L.) aquaculture using different fish feeds, from http://lup.lub.lu.se/student-papers/record/8892610.
21. Carus, M., & Dammer, L. (2018). The Circular Bioeconomy - Concepts, Opportunities, and Limitations. Industrial Biotechnology, 14(2), 83–91, from https://doi.org/10.1089/ind.2018.29121.mca.
22. Cellule Economique de Bretagne. (2018). Enquête Nationale De La Construction Bois, from https://www.biblio-bois.info/wp-content/uploads/2019/12/Enquête-nationale-de-la-Construction-Bois-2018.pdf.
23. Cellule Economique de Bretagne. (2020). Enquête Nationale De La Construction Bois - Fiche Régionale: Ile-De-France, from https://www.fibois-idf.fr/sites/default/files/inline-files/Enquête Nationale de la Construction Bois IDF_1.pdf.
24. CITEPA, IGN, MTES, & MAA. (2019). The National Forestry Accounting Plan of France including the Forest Reference Level (FRL) for the 2021- 2025 and 2026-2030 periods, from https://www.ecologie.gouv.fr/sites/default/files/National Forest Accounting Plan France 2019 with explanary note VEN.pdf.
25. City of Amsterdam. (2020). Policy: Circular economy - City of Amsterdam, from https://www.amsterdam.nl/en/policy/sustainability/circular-economy/.
26. City of Baltimore. (2021). Food Environment Maps | Department of Planning, from https://planning.baltimorecity.gov/baltimore-food-policy-initiative/food-environment
27. Comune di Milano. (2018). The Food System in Milan - Five priorities for a sustainable development, from https://www.foodpolicymilano.org/wp-content/uploads/2015/04/Milan_food_system_EN1.pdf.
28. Comune di Milano. (2020). Economia circolare del cibo a Milano, from https://www.comune.milano.it/documents/20126/6143581/Economia+circolare+del+cibo+a+Milano+-+edizione+settembre+2020.pdf/907ef284-8222-d96c-a5a0-ab126d910a3e?t=1608477646111
29. Czajkowski, M., Zagórska, K., & Hanley, N. (2019). Social norm nudging and preferences for household recycling. Resource and Energy Economics, 58, 101110, from https://doi.org/10.1016/j.reseneeco.2019.07.004.
30. Danish Environmental Protection Agency. (2019). Analyse af nationale plaststrømme i landbrug (No. 9788770380706) Miljøstyrelsen, from https://www2.mst.dk/Udgiv/publikationer/2019/05/978-87-7038-070-6.pdf.
31. Daunay, J., Dugast, C., Bachelet, L., & Schmitt-Foudil, H. (2019). Neutralité & bâtiment - Comment Les Acteurs Du Secteur Peuvent S'Inscrire Dans Une Démarche Zéro Émission Netter, from https://ile-de-france.ademe.fr/sites/default/files/neutralite-carbone-batiment.pdf.
32. Downing, P., Consulting, I., & Roberts, M. (2019). Recycling Tracking Survey 2019 Behaviours, attitudes and awareness around recycling. Wrap. (March), from https://www.wrap.org.uk/sites/files/wrap/Recycling Tracker Report 2019_.pdf.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

33. DRIAAF. (2020). Le programme régional de la forêt et du bois d'Île-de-France, from https://driaaf.ile-de-france.agriculture.gouv.fr/Le-programme-regional-de-la-foret.
34. Driven by Volumes. (2021). Driven by Volumes – Computational Design x Circular Economy, from https://drivenbyvolumes.io/.
35. Eaternity. (2021). Eaternity Datenbank, from https://eaternity.org/foodprint/database.
36. EC. (2019). EUR-Lex - 32019L0904 - EN - EUR-Lex, from https://eur-lex.europa.eu/eli/dir/2019/904/oj.
37. Echeverría-Sáenz, S., Mena, F., Pinnock, M., Ruepert, C., Solano, K., La Cruz, E. de, et al. (2012). Environmental hazards of pesticides from pineapple crop production in the Río Jiménez watershed (Caribbean Coast, Costa Rica). Science of the Total Environment, 440, 106–114, from https://doi.org/10.1016/j.scitotenv.2012.07.092.
38. ECOBoard international b.v. (2021). ECOBoard Standard – ECOBoard international bv, from https://ecoboardinternational.com/ecoboard-standard-2/.
39. Ecolabel Index. (2021). Certified Green Dealer, from http://www.ecolabelindex.com/ecolabel/CertifiedGreenDealer.
40. EcoMobilier. (2021). Working together to give new life to old furniture! - Eco-mobilier, from https://www.eco-mobilier.fr/page/working-together-to-give-new-life-to-old-furniture/.
41. Economic Commission for Europe, & Food and Agriculture Organization. (2019). Forests and the Circular Economy, from http://www.fao.org/3/nb032en/nb032en.pdf.
42. Edjabou, M. E. (2016). Composition of municipal solid waste in Denmark (No. June), from https://backend.orbit.dtu.dk/ws/portalfiles/portal/124242212/Maklawe_Essonanawe_Edjabou_PhD_thesis_WWW_Version.pdf.
43. Edjabou, M. E., Petersen, C., Scheutz, C., & Astrup, T. F. (2016). Food waste from Danish households: Generation and composition. Waste Management, 52, 256–268, from https://pubmed.ncbi.nlm.nih.gov/27026492/.
44. EKOPLY. (2021). EKOPLY - Market Leader in Recycled Plastic Sheets and Boards, from http://www.ekoplysheets.co.uk/#:~:text=EKOply sheet is manufactured from,recyclable at end of-life.
45. Energycities. (2018). Mapping renewable energy potential | Energy Cities, from https://energy-cities.eu/best-practice/mapping-renewable-energy-potential/.
46. Environmental Investigation Agency & Greenpeace. (2021). Checking Out on Plastics III (No. January), from https://www.greenpeace.org.uk/wp-content/uploads/2021/01/Checking-Out-on-Plastics-III-FINAL.pdf.
47. Eriksen, M. K. (2018). Quality and Recyclability of Plastic from Household Waste, from https://backend.orbit.dtu.dk/ws/portalfiles/portal/178411474/Thesis_online_version_Marie_Kampmann_Eriksen.pdf
48. Eriksen, M. K., Damgaard, A., Boldrin, A., & Astrup, T. F. (2019). Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste. Journal of Industrial Ecology, 23(1), 156–168, from https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.12822.
49. European Commission - Energy Department. (2020). In focus: Energy efficiency in buildings | European Commission, from https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-feb-17_en.
50. European Commission. (2015). Closing the loop - An EU action plan for the Circular Economy, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614.

51. European Commission. (2020). Energy efficiency in buildings, from https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-feb-17_en.
52. European Commission. (2021). EU Buildings Database | Energy, from https://ec.europa.eu/energy/eu-buildings-database_en.
53. European Investment Bank. (2021). ELENA – European Local ENergy Assistance, from https://www.eib.org/en/products/advising/elena/index.htm.
54. European Investment Bank. (2021). European Energy Efficiency Fund, from https://www.eib.org/en/products/equity/funds/european_energy_efficiency_fund.
55. European Network for Rural Development. (2012). Local Food and Short Supply Chains, from https://enrd.ec.europa.eu/sites/default/files/E8F24E08-0A45-F272-33FB-A6309E3AD601.pdf.
56. Eurostat. (2021). Energy Flow Diagrams, from https://ec.europa.eu/eurostat/cache/sankey/energy/sankey.html?geos=RO&year=2019&unit=KTOE&fuels=TOTAL&highlight=_&nodeDisagg=0101000000000&flowDisagg=false&translateX=0&translateY=0&scale=1&language=EN
57. FAO-UN, & van Crevel, R. (2016). Bio-based food packaging in Sustainable Development: Challenges and opportunities to utilize biomass residues from agriculture and forestry as a feedstock for bio-based food packaging. FAO Report. (February), from http://www.fao.org/forestry/45849-023667e93ce5f79f4df3c74688c2067cc.pdf.
58. Faraca, G., & Astrup, T. (2019). Plastic waste from recycling centres: Characterisation and evaluation of plastic recyclability. Waste Management, 95, 388–398, from https://www.sciencedirect.com/science/article/abs/pii/S0956053X1930426X?casa_token=_zrVlewdrvIAAAAA:rc4ncaQkPv8JmII7GLKekH1LVu98_esP4q1qKy_ALMrV83_fKbh7H0u825-MJNcAAkDROXclsMc.
59. Faraca, G., Edjabou, V. M., Boldrin, A., & Astrup, T. (2019). Combustible waste collected at Danish recycling centres: Characterisation, recycling potentials and contribution to environmental savings. Waste Management, 89, 354–365, from https://www.sciencedirect.com/science/article/abs/pii/S0956053X1930220X?casa_token=4vaDkZ1DeA0AAAAA:dqQNz3N8J109dRgJMyXT2mzEQ4-6QaKYt5q-sLRsgRjPLpVYMn8Ga4n7J6B7FVqVok-_hIORzA#f0025.
60. fiac!. (2021). Foire internationale d'art contemporain, 21-24 octobre 2021, Paris, Grand Palais Éphémère, from https://www.fiac.com/.
61. fiac!. (2021). The Fair, from https://www.fiac.com/en-gb/about/the-fair.html.
62. Fibersort. (2021). The Fibersort project, from https://www.fibersort.eu/.
63. FINSA. (2021). superPan, from https://www.finsa.com/cs/Satellite?d=Touch&idiomaNav=en_UK&pagename=FN_CatalogoProductos/CP_Producto_C/CP_PTProductoDetalle&cid=1426689834052.
64. FIWARE. (2021). Foodko: Empowering Food Producers & Allowing Smart Logistics - FIWARE, from https://www.fiware.org/2016/07/15/foodko-empowering-food-producers-allowing-smart-logistics/.
65. flux-biomasse.fr. (2021). Modèle forêt-bois 1.2 - France et Régions - Sankey + données au format excel, from https://www.flux-biomasse.fr/resultats/sankey_bois/Ile_de_France.
66. Food and Agriculture Organization. (2021). Home | Food and Agriculture Organization of the United Nations, from http://www.fao.org/home/en/.
67. Food and Agriculture Organization of the United Nations. (2021). FAO Major Fishing Areas, from http://www.fao.org/fishery/area/search/en.

68. Forrest, A., Hilton, M., Ballinger, A., & Whittaker, D. (2017). Circular Economy Opportunities in the Furniture Sector. European Environmental Bureau (EEB), from https://eeb.org/library/circular-economy-opportunities-in-the-furniture-sector/.
69. Fresh Plaza. (2019). Italy: Retailers use Blockchain and QR Codes for traceability, from https://www.freshplaza.com/article/9135207/italy-retailers-use-blockchain-and-qr-codes-for-traceability/.
70. Gallo, A., Accorsi, R., Baruffaldi, G., & Manzini, R. (2017). Designing Sustainable Cold Chains for Long-Range Food Distribution: Energy-Effective Corridors on the Silk Road Belt. Sustainability, 9(11), 2044, from http://www.mdpi.com/2071-1050/9/11/2044.
71. García, B. G., Jiménez, C. R., Aguado-Giménez, F., & García, J. G. (2016). Life cycle assessment of gilthead seabream (Sparus aurata) production in offshore fish farms. Sustainability (Switzerland), 8(12), 1228, from www.mdpi.com/journal/sustainability.
72. Gemeente Amsterdam (2019). Sorteren Analysis, Personal communication to Metabolic Institute.
73. Global Safety Net 1.0. (2021). Global Safety Net, from https://www.globalsafetynet.app/viewer/.
74. Goedkoop, M., Heijungs, R., Huijbregts, M., Schryver, A. de, Struijs, J., & van Zelm, R. (2008). ReCiPe 2008, from http://www.pre-sustainability.com/download/misc/ReCiPe_main_report_final_27-02-2009_web.pdf.
75. Good Fish. (2021). Compact VISwijzer - VISwijzer, from https://www.goodfish.nl/en/small-viswijzer/.
76. GOODR (2021). Goodr, from https://www.goodr.co/.
77. Government Romania. (2020). The 2021-2030 Integrated National Energy and Climate Plan, from https://ec.europa.eu/energy/sites/ener/files/documents/ro_final_necp_main_en.pdf.
78. Guinard, L., Deroubaix, G., Roux, M., Levet, A., & Quint, V. (2015). Évaluation Du Gisement De Déchet Bois Et Son Positionnement Dans La Filière Bois/Bois Énergie, from https://www.ademe.fr/sites/default/files/assets/documents/evaluation-gisement-bois-201505-synthese.pdf.
79. Hajjar, R., & Molnar, A. (2015). Decentralization and community-based approaches. Forests, Business and Sustainability, from https://www.taylorfrancis.com/chapters/edit/10.4324/9781315771397-15/decentralization-community-based-approaches-reem-hajjar-augusta-molnar.
80. Hofste, R., Kuzma, S., Walker, S., Sutanudjaja, E., Bierkens, M., Kuijper, M., et al. (2019). Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators. WRI Publication, from https://www.wri.org/research/aqueduct-30-updated-decision-relevant-global-water-risk-indicators.
81. Holmes, E. (2017). MDF recycling trials bring solution closer | Resource Magazine, from https://resource.co/article/mdf-recycling-trials-bring-solution-closer-11621.
82. Hubbard, R. (2017). Why are Mediterranean Fisheries Failing, while Atlantic Fishing Improves? – Our Fish, from https://our.fish/news/why-are-mediterranean-fisheries-failing-while-atlantic-fishing-improves/.
83. Huijbregts, M. A., Steinmann, Z. J. N., Elshout, P M F M, Stam, G., Verones, F., Vieira, M. D. M., et al. (2016). ReCiPe 2016 - A harmonized life cycle impact assessment method at midpoint and endpoint level. Report I: Characterization. National Institute for Public Health and the Environment, 194, from https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf.
84. Innovation Cities. (2019). Innovation Cities Index 2019, from https://www.innovation-cities.com/index-2019-global-city-rankings/18842/.

85. INSEE. (2012). La filière bois en Ile-de-France : un fonctionnement qui dépasse les limites régionales, from http://www.epsilon.insee.fr/jspui/bitstream/1/14234/1/alap394.pdf.
86. IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf.
87. IPCC. (2006). Generic Methodologies Applicable to Multiple Land use Categories, from https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf.
88. ISPRA. (2019). Produzione nazionale » Produzione regionale » Produzione provinciale della regione Lombardia » Produzione comunale della provincia di Milano » Produzione del comune di Milano, from https://www.catasto-rifiuti.isprambiente.it/index.php?pg=mDetComune&aa=2017&regidb=03&nomereg=Lombardia&providb=015&nomeprov=Milano&regid=03015146&nomecom=Milano&cerca=cerca&&p=1&width=1920&height=1080.
89. IUCN. (2016). The Conservation Status of Sharks, Rays and Chimaeras in the Mediterranean Sea, from https://www.iucn.org/sites/dev/files/content/documents/brochure_medredlist_sharks.pdf.
90. Jarre, M., Petit-Boix, A., Priefer, C., Meyer, R., & Leipold, S. (2020). Transforming the bio-based sector towards a circular economy - What can we learn from wood cascading?: Elsevier B.V. Forest Policy and Economics, from https://doi.org/10.1016/j.forpol.2019.01.017
91. Johnston, C. M., & Radeloff, V. C. (2019). Global mitigation potential of carbon stored in harvested wood products. Proceedings of the National Academy of Sciences of the United States of America, 116(29), 14526–14531, from www.pnas.org/cgi/doi/10.1073/pnas.1904231116.
92. Jönsson, Å., Tillman, A. M., & Svensson, T. (1997). Life cycle assessment of flooring materials: Case study. Building and Environment, 32(3), 245–255, from https://www.sciencedirect.com/science/article/abs/pii/S0360132396000522.
93. Kampelmann, S. (2020). Wood works: how local value chains based on urban forests contribute to place-based circular economy. Urban Geography, 41(6), 911–914, from https://www.tandfonline.com/doi/abs/10.1080/02723638.2020.1786330.
94. Kazulis, V., Muizniece, I., Zihare, L., & Blumberga, D. (2017). Carbon storage in wood products. Energy Procedia, 128, from https://www.sciencedirect.com/science/article/pii/S1876610217338511.
95. Koffi, B., Duerr, A., Iancu, A., Kona, A., & Janssens-Maenhout, G. (2017). CoM Default Emission Factors for the Member States of the European Union - Version 2017 - Data Europa EU, from https://data.europa.eu/data/datasets/jrc-com-ef-comw-ef-2017?locale=en.
96. Kühnl, S. (2020). Sustainability: What is the Amsterdam 'Denim Deal' all about?, from https://www.the-spin-off.com/news/stories/Sustainability-What-is-the-Amsterdam-Denim-Deal-all-about-15643.
97. LA RESERVE DE ARTS. (2021). Home | LA RESERVE DES ARTS, from https://www.lareservedesarts.org/en_GB/.
98. Leclercq, C., Arcella, D., Piccinelli, R., Sette, S., & Le Donne, C. (2009). The Italian National Food Consumption Survey INRAN-SCAI 2005-06: Main Results: In terms of food consumption. Public Health Nutrition, 12(12), 2504–2532, from https://aceitedepalmasostenible.es/wp-content/uploads/2017/06/The-Italian-National-Food-Consumption-Survey-INRAN-SCAI-2005-06-main-results-in-terms-of-food-consumption-C-Leclercq-et-al.pdf.

99. Lee, A. (2021). Is OSB an environmentally packaging/ crating material?, from https://www.packnetltd.com/is-osb-an-environmentally-packaging-crating-material/#:~:text=Both OSB and Plywood are,and use it for landscaping.
100. Légifrance. (2020). LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1), from https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000041553759?r=rogReURdUk.
101. Linder, N., Lindahl, T., & Borgström, S. (2018). Using behavioural insights to promote food waste recycling in urban households-evidence from a longitudinal field experiment. Frontiers in Psychology, 9(MAR), 352, from https://doi.org/10.3389/fpsyg.2018.00352.
102. Lulijwa, R., Rupia, E. J., & Alfaro, A. C. (2020). Antibiotic use in aquaculture, policies and regulation, health and environmental risks: a review of the top 15 major producers (No. 2): Wiley-Blackwell. Reviews in Aquaculture, from https://onlinelibrary.wiley.com/doi/full/10.1111/raq.12344.
103. Macqueen, D., & Demarsh, P. (2015). Enabling investment for locally controlled forestry. Forests, Business and Sustainability, from https://www.taylorfrancis.com/chapters/edit/10.4324/9781315771397-14/enabling-investment-locally-controlled-forestry-duncan-macqueen-peter-demarsh.
104. MAIRIE DE PARIS. (2017). Circular Economy Plan Paris, from https://cdn.paris.fr/paris/2019/07/24/38de2f4891329bbaf04585ced5fbdf0f.pdf.
105. Maldini, I., Duncker, L., Bregman, L., & Piltz, G. (2017). MEASURING THE DUTCH CLOTHING MOUNTAIN: Data for sustainability-oriented studies and actions in the apparel sector Measuring the Dutch Clothing Mountain View project User-object relationships in open design View project, from https://www.researchgate.net/publication/319902973.
106. Mantanis, G., Athanassiadou, E., Nakos, P., & Coutinho, A. (2004). A New Process for Recycling Waste Fiberboards. 38th International Wood Composites Symposium, 119-122, from https://www.researchgate.net/publication/234102123_A_New_Process_for_Recycling_Waste_Fiberboards.
107. Marin, J., & Meulder, B. de. (2018). Urban landscape design exercises in urban metabolism: Reconnecting with central limburg's regenerative resource landscape. Journal of Landscape Architecture, 13(1), 36–49, from https://www.tandfonline.com/doi/abs/10.1080/18626033.2018.1476031.
108. Marine Stewardship Council. (2021). Sustainable Fishing | MSC | Marine Stewardship Council, from https://www.msc.org/.
109. MDF Recovery. (2021). Welcome to MDF Recovery, from http://www.mdfrecovery.co.uk/.
110. Medfish. (2021). Medfish: Fisheries moving towards sustainability – Rigorous and comprehensive analysis of French and Spanish Mediterranean fisheries using the MSC Fisheries Standard as a benchmark for sustainability, from http://www.project-medfish.com/.
111. Metabolic. (2018). Advancing aquaponics at the Metabolic greenhouse, from https://www.metabolic.nl/news/advancing-aquaponics-metabolic-greenhouse/.
112. Métropole du Grand Paris. (2018). Plan climat air énergie métropolitain de la Métropole du Grand Paris, from https://www.metropolegrandparis.fr/sites/default/files/2019-01/Syntèse_PCAEM.pdf.
113. Milan Urban Food Policy Pact. (2019). Local Food Waste Hub, from https://www.milanurbanfoodpolicypact.org/wp-content/uploads/2020/12/FW-Milan_2019.pdf.
114. Milan Urban Food Policy Pact. (2015). The Milan Pact - Milan Urban Food Policy Pact, from https://www.milanurbanfoodpolicypact.org/the-milan-pact/.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

115. Miljø- og Fødevareministeriet. (2018). Plastik uden splid, from https://mfvm.dk/fileadmin/user_upload/MFVM/Miljoe/Plastikhandlingsplan/Regeringens_plastikhandlingsplan_web_FINAL.pdf.
116. Ministry of Environment and Food and the Ministry of Industry, Business and Financial Affairs. (2018). Strategy for Circular Economy - Ministry of Environment and Food of Denmark, from https://en.fvm.dk/focus-on/circular-economy/strategy-for-circular-economy/.
117. Ministry of Environment and Food of Denmark. (2017). Affaldsforebyggelse i byggeriet - Forprojekt, from https://www2.mst.dk/Udgiv/publikationer/2017/02/978-87-93529-66-3.pdf.
118. Ministry of Environment and Food of Denmark. (2020). Affaldsstatistik, from https://www2.mst.dk/Udgiv/publikationer/2020/05/978-87-7038-183-3.pdf.
119. Ministry of Environment and Food of Denmark. (2020). Klimaplan for en grøn affaldssektor og cirkulær økonomi (Climate plan for a green waste sector and circular economy), from https://mfvm.dk/fileadmin/user_upload/MFVM/Pressemeddelelser/Aftaletekst_-_affald.pdf.
120. Ministry of Environment and Food of Denmark. (2018). Kortlægning af PVC i Danmark 2018, from https://www2.mst.dk/Udgiv/publikationer/2018/11/978-87-7038-000-3.pdf.
121. Ministry of Environment and Food of Denmark. (2018). Plastics without waste - The Danish government's plastics action plan, from https://en.mfvm.dk/fileadmin/user_upload/ENGLISH_FVM.DK/Regeringens_plastikhandlingsplan_UK.pdf.
122. Ministry of Environment and Food of Denmark. (2019). Preliminary assessment of plastic material flows in Denmark - Technical Report, from https://www2.mst.dk/Udgiv/publications/2019/06/978-87-7038-082-9.pdf.
123. MUFPP Secretariat. (2021). Milan Urban Food Policy Pact, from https://www.milanurbanfoodpolicypact.org/.
124. Nakano, K., Ando, K., Takigawa, M., & Hattori, N. (2018). Life cycle assessment of wood-based boards produced in Japan and impact of formaldehyde emissions during the use stage. International Journal of Life Cycle Assessment, 23(4), 957–969, from https://link.springer.com/article/10.1007/s11367-017-1343-6.
125. NECP France. (2020). Integrated National Energy and Climate Plan for France, from https://ec.europa.eu/energy/sites/ener/files/documents/fr_final_necp_main_en.pdf.
126. New Sea Aps. (2021). FAO Fishing Areas, from https://www.newsea.dk/info/fao-fishing-areas.
127. Nilsson, H. (2020). Central upphandling av avfallstjänster, from http://circularpp.eu/wp-content/uploads/2020/12/Waste-manegment-pre-tender-Malmö-Swedish.pdf.
128. NYC Health. (2021). Green Carts - NYC Health, from https://www1.nyc.gov/site/doh/health/health-topics/green-carts.page.
129. OCEANA. (2016). Mediterranean Sea - A Key EU Fishing Region in a Bleak State of Overfishing, from https://europe.oceana.org/sites/default/files/oceana_fs_med_overfishing.pdf.
130. Openagri. (2021). Openagri – Openagri, from https://open-agri.it/openagri/.
131. ORDIF. (2014). LES DÉCHETS D ' ÉLÉMENTS D ' AMEUBLEMENT MÉNAGERS ET PROFESSIONELS, from https://www.ordif.fr/fileadmin/DataStorageKit/ORDIF/Etudes/pdf/DEA_-_Rapport_2014.pdf.
132. ORDIF. (2013). Les DAE non dangereux produits en Île-de-France : Industrie, commerces, services, from https://www.ordif.fr/fileadmin/DataStorageKit/ORDIF/Etudes/pdf/Les_DAE_non_dangereux_produits_en_Ile-de-France__Industrie__commerces__services.pdf.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

133. ORDIF. (2019). LA GESTION DES DÉCHETS MÉNAGERS ET ASSIMILÉS EN ÎLE-DE-FRANCE - DONNÉES 2017, from https://www.eco-mobilier.fr/page/working-together-to-give-new-life-to-old-furniture/.
134. ORDIF. (2021). L'institut Paris région - Observatoire régional des déchets, from https://www.ordif.com/.
135. Paris.fr. (2018). Organisateurs d'événements, adoptez la nouvelle charte écoresponsable parisienne, from https://www.paris.fr/pages/organisateurs-d-evenements-adoptez-la-nouvelle-charte-ecoresponsable-parisienne-4005/.
136. Parisi, C., Beye, A., Bekier, J., & Keremis, A. (2020). H2020 REFLOW Deliverable 1.2: Cities' Circular Action Plan, https://zenodo.org/record/3872703/files/REFLOW-D1.2-Cities%20Circular%20Action%20Plans%20v%201.0.pdf?download=1.
137. PBL Netherlands Environmental Assessment Agency. (2018). CONSTRUCTION OF REGIONAL TRADE-LINKED SUPPLY AND USE TABLES FOR THE EU28, from https://www.pbl.nl/sites/default/files/downloads/PBL2018_Construction-of-regional-trade-linked-supply-and-use-tables-for-the-EU28_3313.pdf.
138. Pécresse, V. (2017). Stratégie régionale pour la forêt et le bois 2018-2021, from https://www.iledefrance.fr/sites/default/files/medias/rapports/RAPCR2017-185RAP.pdf.
139. Peliccia, M. (2020). Young farmers apply ancient agroforestry practices in the heart of Sardinia, from https://news.mongabay.com/2020/01/young-farmers-apply-ancient-agroforestry-practices-in-the-heart-of-sardinia/.
140. Pelletier, N., Tyedmers, P., Sonesson, U., Scholz, A., Ziegler, F., Flysjo, A., et al. (2009). Not all salmon are created equal: Life cycle assessment (LCA) of global salmon farming systems. Environmental Science and Technology, 43(23), 8730–8736, from https://pubs.acs.org/sharingguidelines.
141. Pettersen, R. C. (1984). The chemistry of solids, from https://www.fpl.fs.fed.us/documnts/pdf1984/pette84a.pdf.
142. Plastics Europe. (2018). Plastics - the Facts 2018, from https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf.
143. Plastindustrien. (2021). Thyregod Bygningsindustri A/S | plast.dk, from https://plast.dk/medlemmer/thyregod-bygningsindustri-as/.
144. Pozzi, L. E. (2019). Design for Disassembly With Structural Timber Connections, from https://repository.tudelft.nl/islandora/object/uuid:c8b85050-cd11-45eb-b3ac-c3624259654f/datastream/OBJ/download.
145. Priha, E., Pennanen, S., Rantio, T., Uitti, J., & Liesivuori, J. (2010). Exposure to and acute effects of medium-density fiberboard dust. Journal of Occupational and Environmental Hygiene, 1(11), 738–744, from https://doi.org/10.1080/15459620490520774.
146. Project Drawdown. (2021). Refrigerant Management | Project Drawdown, from https://drawdown.org/solutions/refrigerant-management.
147. PROPHET. (2021). Prophet | Forecasting at scale, from https://facebook.github.io/prophet/.
148. Provolo, G., & Sarteel, M. (2015). Good practices to reduce nutrient loss in the Lombardy region (Italy), from https://ec.europa.eu/environment/water/water-nitrates/pdf/leaflets/Leaflet_Lombardy_EN.pdf.
149. Raworth, K., Krestyaninova, O., Eriksson, F., Feibusch, L., Sanz, C., Benyus, J., et al. (2020). The Amsterdam City Doughnut, from https://assets.amsterdam.nl/publish/pages/867635/amsterdam-city-doughnut.pdf.
150. Re:newcell. (2021). Technology, from https://www.renewcell.com/en/section/our-technology/.

151. Regeneration International. (2021). Our Network - Regeneration International, from https://regenerationinternational.org/our-network/.
152. REMA1000. (2018). Emballage- og plaststrategi 2018, from https://rema1000.dk/wp-content/uploads/2019/02/REMA-1000-plast-og-emballagestrategi-02-2019.pdf
153. REMA1000. (2021). REMA 1000, from https://rema1000.dk/.
154. RE-SIGN. (2021). RE-SIGN SOCIETA' BENEFIT S.R.L, from https://re-sign.it/.
155. Roberson, L. A., Watson, R. A., & Klein, C. J. (2020). Over 90 endangered fish and invertebrates are caught in industrial fisheries. Nature Communications, 11(1), 1–8, from https://doi.org/10.1038/s41467-020-18505-6.
156. SENSONEO. (2021). Digitalisation of textile waste infrastructure, from https://sensoneo.com/reference/textile-waste-digitalisation/.
157. Shooshtarian, S., Maqsood, T., Wong, P. S., Khalfan, M., & Yang, R. J. (2021). Extended producer responsibility in the Australian construction industry. Sustainability (Switzerland), 13(2), 1–20, from https://doi.org/10.3390/su13020620.
158. SogeMi. (2021). I Mercati all'ingrosso di Milano - Sogemi Spa, from https://www.sogemispa.it/.
159. spinderihallerne.dk. (2021). Innovations- og udviklingsmiljø - Spinderihallerne, from https://www.spinderihallerne.dk/.
160. Statistics Denmark. (2018). Statistics Denmark: Total Construction 2018 (net floor area, by region), from https://www.statbank.dk/statbank5a/default.asp?w=2560.
161. Statistics Denmark. (2021). Statistics Denmark - Geography, Environment and Energy, from https://www.statbank.dk/10294.
162. Sustainable Solutions Corporation. (2017). Life Cycle Assessment of PVC Water and Sewer Pipe and Comparative Sustainability Analysis of Pipe Materials, from https://www.uni-bell.org/files/Reports/Life_Cycle_Assessment_of_PVC_Water_and_Sewer_Pipe_and_Comparative_Sustainability_Analysis_of_Pipe_Materials.pdf.
163. SWAG Project. (2021). SWAG Project – Growing Food. Building Community, from https://swagproject.org/.
164. Tamburini, E., Turolla, E., Fano, E. A., & Castaldelli, G. (2020). Sustainability of Mussel (Mytilus galloprovincialis) farming in the Po River delta, northern Italy, based on a life cycle assessment approach. Sustainability (Switzerland), 12(9), 3814, from www.mdpi.com/journal/sustainability.
165. Teixeira, R. L., Da Silva, J. R. M., Fiedler, N. C., Lima, J. T., Trugilho, P. F., & Neri, A. C. (2017). Evaluation of Airborne MDF Dust Concentration in Furniture Factories. Floresta e Ambiente, 24(0), 86514, from https://doi.org/10.1590/2179-8087.086514.
166. The Ellen MacArthur Foundation. (2019). A Vision of a Circular Economy for Plastic, from https://www.saplasticspact.org.za/wp-content/uploads/2020/01/npec-vision.pdf.
167. The Greenhouse Gas Protocol. (2004). A Corporate Accounting and Reporting Standard (Revised Edition), from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.
168. The Rockefeller Foundation. (2021). 100 Resilient Cities - The Rockefeller Foundation, from https://www.rockefellerfoundation.org/100-resilient-cities/.
169. The Swapshop. (2021). Home - The Swapshop, from https://www.the-swapshop.com/nl/.

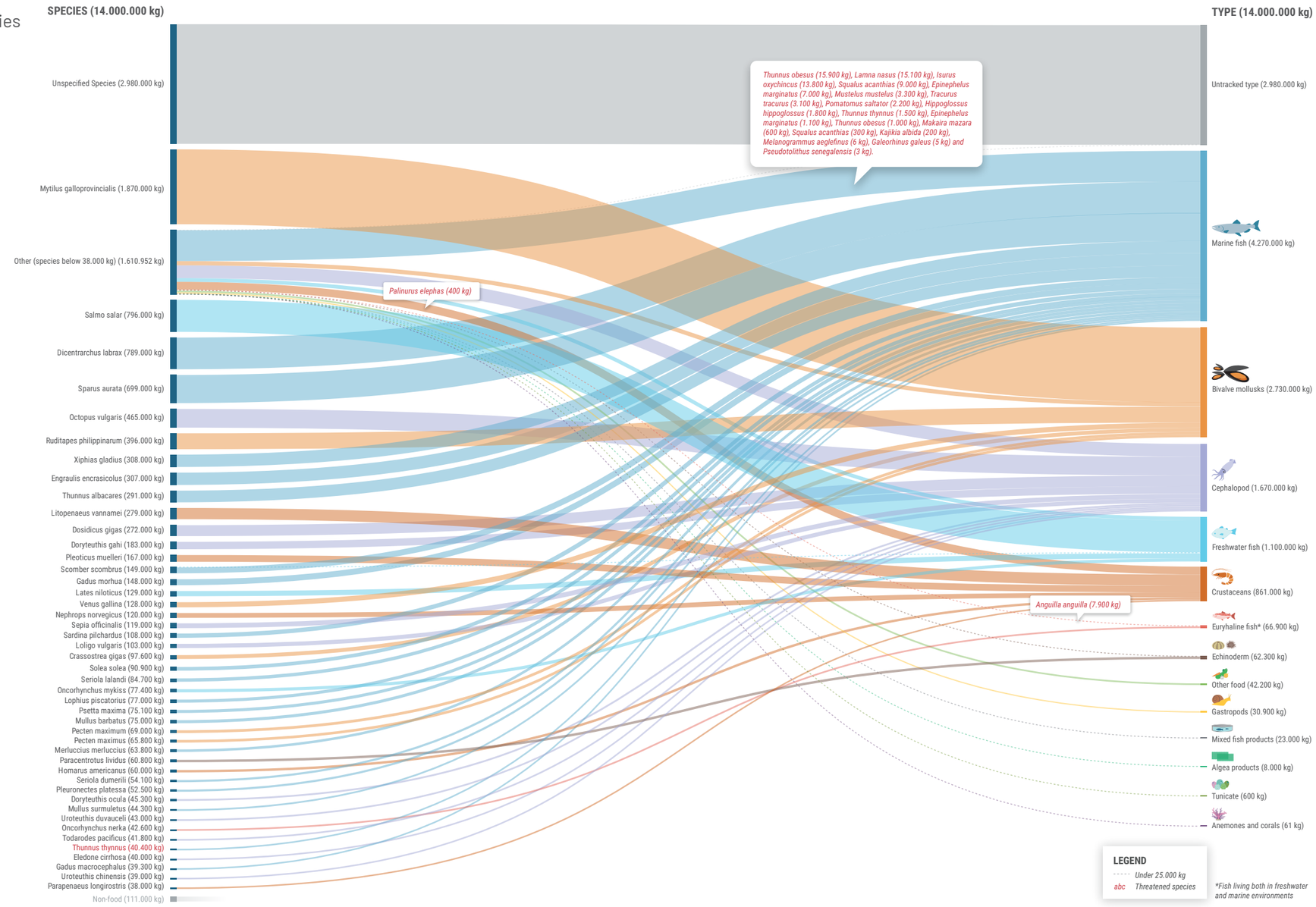
170. Thetkathuek, A., Yingratanasuk, T., & Ekburanawat, W. (2016). Respiratory Symptoms due to Occupational Exposure to Formaldehyde and MDF Dust in a MDF Furniture Factory in Eastern Thailand. Advances in Preventive Medicine, 2016, 1–11, from /pmc/articles/PMC5227115/.
171. Timmer, M., Los, B., Stehrer, R., & Vries, G.J. (2016). An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release*, from https://www.rug.nl/ggdc/html_publications/memorandum/gd162.pdf.
172. TRACE. (2013). Improving Energy Efficiency in CLUJ-NAPOCA Romania, from https://esmap.org/sites/esmap.org/files/DocumentLibrary/TRACE_Romania_CLUJ NAPOCA_Optimized.pdf.
173. TRACE Genomics. (2021). Corporate Partners, from https://tracegenomics.com/who-we-serve/corporate-partners/.
174. Trends.Earth. (2018). Trends.Earth — Trends.Earth 1.0.2 documentation, from http://trends.earth/docs/en/.
175. Tsagarakis, K., Palialexis, A., & Vassilopoulou, V. (2014). Mediterranean fishery discards: Review of the existing knowledge (No. 5): Oxford University Press. ICES Journal of Marine Science, from https://academic.oup.com/icesjms/article/71/5/1219/638845.
176. Turolla, E., Castaldelli, G., Fano, E. A., & Tamburini, E. (2020). Life cycle assessment (LCA) proves that Manila clam farming (Ruditapes philippinarum) is a fully sustainable aquaculture practice and a carbon sink. Sustainability (Switzerland), 12(13), 5252, from www.mdpi.com/journal/sustainability.
177. U.S. Department of Agriculture. (2020). Wood Innovations Grants | US Forest Service, from https://www.fs.usda.gov/science-technology/energy-forest-products/wood-innovations-grants.
178. U.S. Energy Information Administration (EIA). (2021). Dataset, from https://www.eia.gov/international/data/world.
179. UN Trade Statistics. (2016). Country Code (ISO 3166-1 alpha-3), from https://unstats.un.org/unsd/tradekb/Knowledgebase/50347/Country-Code.
180. UNIMEV. (2021). Union Française des Métiers de l'Événement - Accueil, from https://www.unimev.fr/.
181. Urban Farm Milano. (2021). Urban Farm Milano – Benvenuti in Urban Farm Milano, from http://www.urbanfarmmilano.it/.
182. Urban Innovative Actions. (2021). OpenAgri - New Skills for new Jobs in Peri-urban Agriculture | UIA - Urban Innovative Actions, from https://www.uia-initiative.eu/en/uia-cities/milan.
183. Vázquez-Rowe, I., Moreira, M. T., & Feijoo, G. (2012). Environmental assessment of frozen common octopus (Octopus vulgaris) captured by Spanish fishing vessels in the Mauritanian EEZ. Marine Policy, 36(1), 180–188, from https://doi.org/10.1016/j.marpol.2011.05.002.
184. Vejle Kommune. (2016). Vejle's Resilience Strategy, from https://resilientcitiesnetwork.org/downloadable_resources/Network/Vejle-Resilience-Strategy-English.pdf.
185. Vinyl Plus. (2021). VinylPlus® Med Accelerates Sustainability in Healthcare, from https://vinylplus.eu/community/vinylplus-med.
186. Virk. (2021). Virk | Data, from https://data.virk.dk/?pk_vid=89fc03befb84d75e1609680574c6f2d8.
187. Vittersø, G., Torjusen, H., Laitala, K., Tocco, B., Biasini, B., Csillag, P., et al. (2019). Short food supply chains and their contributions to sustainability: Participants' views and perceptions from 12 European cases. Sustainability (Switzerland), 11(17), 4800, from www.mdpi.com/journal/sustainability.

188. Weber, C., & Iwakiri, S. (2015). Utilização de resíduos de compensados, MDF e MDP para produção de painéis aglomerados. Ciencia Florestal, 25(2), 405–413, from https://doi.org/10.5902/1980509818460
189. Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The Ecoinvent database version 3, from https://www.ecoinvent.org/database/ecoinvent-371/ecoinvent-371.html.
190. Woodguide.org. (2021). Sustainability and OSB, from https://www.woodguide.org/guide/osb/.
191. World Permaculture Association. (2021). World Permaculture Association - We Believe In Abundance! from https://worldpermacultureassociation.com/.
192. World Resource Institute. (2021). Aqueduct | World Resources Institute, from https://www.wri.org/initiatives/aqueduct.
193. WWF. (2012). Smart Fishing Initiative: Comparison of Wild-Capture Fisheries Certification Schemes, from http://awsassets.panda.org/downloads/wwf_report_comparison_wild_capture_fisheries_schemes__2_.pdf.
194. WWF. (2021). Sustainable seafood guides | WWF, from https://wwf.panda.org/act/live_green/out_shopping/seafood_guides/.
195. Zucali, M., Tamburini, A., Sandrucci, A., & Bava, L. (2017). Global warming and mitigation potential of milk and meat production in Lombardy (Italy). Journal of Cleaner Production, 153, 474–482, from https://doi.org/10.1016/j.jclepro.2016.11.037.
196. Zurück zum Ursprung. (2021). Zurück zum Ursprung: Bio, das weiter geht. | Zurück zum Ursprung, from https://www.zurueckzumursprung.at/.

APPENDICES

Appendix A: Milan

SoGeMi fish market seafood species sold in 2019



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

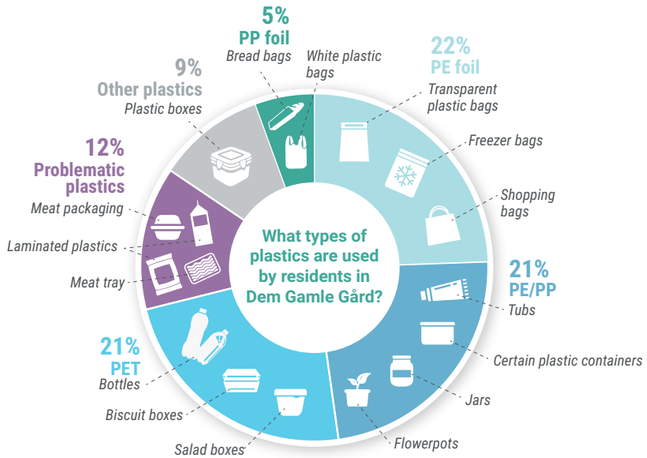
D3.2 Urban metabolism analysis: Initial assessments

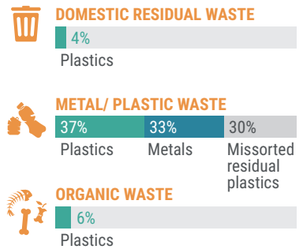
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Appendix B: Vejle

The following four visualisations show the bottom up data collected from the four REFLOW test sites of the Vejle pilot: Dem Gamle Gård (public housing), Sofiegården (Public nursing home), REMA1000 (Supermarket) and Ungdoms Center (School).

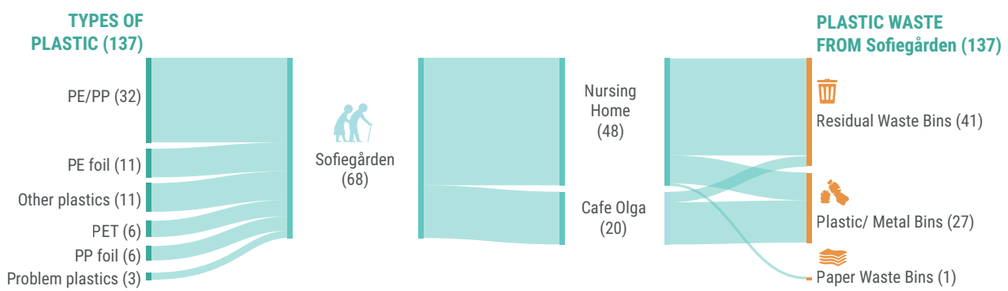
PUBLIC HOUSING: Dem Gamle Gård





PUBLIC NURSING HOME: Sofiegården

How much plastics does Sofiegarden generate in 2 weeks?



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

SUPERMARKET: REMA 1000

Plastic waste shares in REMA 1000(t)

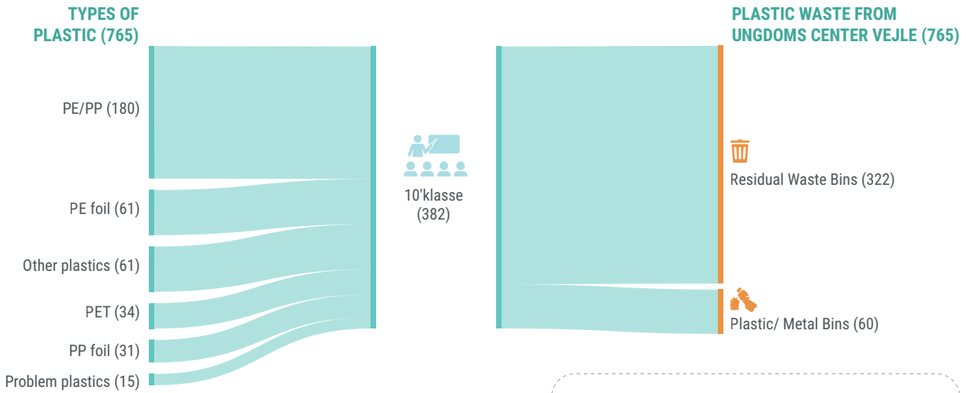
REMA 1000 generates around 3.5 tons of plastic waste annually. The majority of plastic waste consists of candy tubs, packaged food that could not be sold as well as around 600kg of plastic bags which people brought to the Bottle Collection Point.

Employees in 2019 (Discounter Supermarkets)

REMA 1000 employed around 6.5% of people working in discounter retail, in 2019. If other local discounter chains generate similar amounts of plastics, Vejle's discounters together produce around 54 tons of plastics annually.

SCHOOL: UngdomsCenter Vejle

How much plastics does UngdomsCenter Vejle generate in 2 weeks?



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

Appendix C: Paris

Four wood construction scenarios were used for the carbon stock and flow analysis of Ile-de-France. These four scenarios were developed by BIPE and FCBA in their report on the future of the wood construction industry in France. These scenarios are used to calculate the annual inflow of wood products for the construction sector in Ile-de-France.

Business-as-usual:

Scenario based on existing measures for the timber construction sector. This scenario is mainly based on the housing market projections to extend the observed construction market trends and freezes market shares for timber in construction at their level of 2015.

Ambitious:

Scenario that aims at a sharp reduction in GHG emissions with additional measures, and takes into consideration a more dynamic and larger market for the energy renovation of buildings. The projection of market shares take into consideration technological innovations, defined with industry experts, resulting in a scenario with high potential for development of
wood products.

Carbon neutrality:

Scenario which, like the Ambitious scenario, is based on the additional measure to drastically reduce GHG and higher renovation estimate. The market shares projections were built with the French Ministry of Ecological Transition with the objective of achieving sufficient volumes of wood for the construction sector to fulfil its sectoral contribution to achieving carbon neutrality.

Alternative

Scenario that takes into account the resumption of the construction cycle, as well as the implementation of new measures defined with industry experts. The market share projections are obtained from experts, on the basis for the development of new technologies, yet taking into account factors that can slow down their dissemination, thus constituting an intermediate scenario for the projection of market shares between the business-as-usual and the maximum development potential of wood products.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.