SECTOR-WIDE CIRCULARITY ASSESSMENT of CONSTRUCTION SECTOR

Deliverable 2.2

Metabolism of Cities

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Deliverable lead	Metabolism of Cities (MoC), info@metabolismofcities.org
Authors	Executive summary: Carolin Bellstedt, Aristide Athanassiadis; Apeldoorn report: Rob de Groot, Adriaan Hellemans; Bodø report: Carolin Bellstedt, Shamita Chaudhry, Gerardo Ezequiel Martín Carreño, Aristide Athanassiadis; Høje-Taastrup report: Carolin Bellstedt, Aristide Athanassiadis; Mikkeli report: Vuokko Malk; Roskilde report: Carolin Bellstedt, Aristide Athanassiadis; Seville report: Santiago Rodriguez, Pedro Cruces;
Reviewers	Carolin Bellstedt, Metabolism of Cities Aristide Athanassiadis, Metabolism of Cities Nikolai Jacobi, ICLEI
Abstract	This current Sector-Wide Circularity Assessment report provides contextual information on the six different CityLoops cities and their construction sectors under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations of the data used and offers recommendations on how to make this sector more circular. The assessment was carried out by the cities themselves after receiving extensive training on data collection and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.
Keywords	Material flow analysis; sector-wide circularity assessment; circular sector; Urban metabolism;
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Executive Summary

This document contains five separate reports of the Sector-Wide Circularity Assessments (SCA) of the construction sector that were carried out by six different cities of the CityLoops project: Apeldoorn (the Netherlands), Bodø (Norway), Høje-Taastrup (Denmark), Mikkeli (Finland), Roskilde (Denmark) and Seville (Spain). The SCA was carried out by the cities themselves, based on the SCA method that was developed by Metabolism of Cities and after receiving extensive training on data collection and data processing.

Carrying out the SCA

Through a first course, cities were trained to properly undertake the data collection process necessary to conduct a SCA. Each session explained what type of data is important in contributing to a comprehensive understanding of circularity at a sector level. By the end of the course, cities had developed skills in gathering and uploading data for their own city data portal. Numerous insights can be found in the individual Data Hubs of each city. Metabolism of Cities (MoC) ran this moderated version of this course for the CityLoops cities, in which there was live support and weekly online class sessions with a group of participants. (The course ran for 8 weeks from Feb-March 2021.)

In a second moderated course, which Metabolism of Cities ran for 10 weeks from April-June 2021, the cities learned how to take the documents and datasets collected during the first course, which were in different formats such as excel sheets, pdf, shapefiles and csv among others, and convert them into a standardised, machine-readable format. That enabled for the interactive visualisation of data into the centralised and accessible CityLoops Data Hub. Through this process, the cities learned how to create interactive maps and graphs that helped visualise their data in any way they chose.

Lessons learned

The development of the SCA method, its translation in online courses and its application by city officials and practitioners brought forward numerous insights that are essential to be shared in the context of circularity assessment of cities, but also in terms of capacity building in this complex topic of circular economy. While the lessons learned are already being taken into account for the remaining project trajectory of CityLoops, they are mainly useful beyond the CityLoops context: These insights can be relevant for researchers (in terms of developing a scientifically rigorous yet easy-to-use method, but especially for building upon this existing work here and the very method), for city officials (to get familiar with the necessary steps to measure circularity), and for policy makers (to determine means to increase capacity building and streamline circularity assessments).

Overall, it was observed by the cities, as well as the SCA method developers that this entire process proved to be fairly challenging for several reasons:

- **End result:** While a very clear idea of the outcome was formulated by MoC before its implementation by cities, it was hard to showcase it beforehand, as the method was tailor made for the CityLoops project. As such, it was sometimes unclear for cities what they would achieve at the end of the analysis.

- **Data:** The availability of and accessibility to data quickly became an issue for all the cities. For some it was an “unpleasant surprise” that they did not have good local data and that national data for downscaling made up a considerable share of the data. The possibility for the picture not to be representative or misleading because of that made some cities a bit uncomfortable. This meant that they were not so keen on the use of national data, which was often the only way to arrive at some results. This element also showcases the need for a data infrastructure and knowledge by cities, as cities do not have any data on the very system that they want to change. Ideally, this data infrastructure would be embedded in a harmonised data governance approach that is shared by (European) cities.

- **Importance of the assessor:** Connected to the data gathering as well, it also turned out that it mattered who was in charge of conducting the method. In some cities, it was an administrator from the city itself, in others it was a consulting company or even a university. Some city governments did not want to ask companies for their data, whereas this was not a problem for a university, for example. Different assessors also have different “circular economy” and “data analysis” fluency levels, which radically altered the level of in-depth analysis.

- **Capacity building:** The objective of WP4 was and is to support cities in their efforts of measuring circularity by developing accounting methods and helping cities to apply them. As such, capacity building was one crucial component of WP4. Nevertheless, most city officials/administrations are under permanent time scarcity. For that reason, most analytical or new types of work are generally outsourced. This approach links to a fundamental decision that local governments are taking in many areas of their responsibility, whether or not to build in-house capacity or outsource any technical work. A recommendation around what is more suitable to do in terms of circularity monitoring cannot be made, since these differing circumstances, the various governance and working forms, plus staff availability, expertise, interest and resources don’t allow for that. This is to say that all forms that cities have evolved to function as and operate in, are deemed legitimate and need to be engaged with accordingly. In practice, when it came to carrying out the SCA work, a number of cities were reluctant to apply the method themselves and even build capacity internally. Tied to this, there was misalignment of tasks in the sense that some cities had understood that the analysis was to be carried out by MoC in WP4, rather than by themselves in WP2 and 3, respectively.

- **Purpose:** Linked to the first point of end results and to the previous one on capacity building, one of the most challenging points within the SCA development and application was for cities to understand its utility in their everyday tasks. Indeed, most cities (within the CityLoops consortium, but also more widely in the EU context) are preoccupied with implementing a circular economy through specific demonstration actions. Knowing their status quo (in terms of circularity) as well as knowing how to propose systemic actions and policies come at a second order of priority. As such, while the utility of the SCA was increasingly understood by the cities over the course of the project, it was difficult for them to place it at the same level of importance as the demonstration actions. However, to understand the impact of these demonstration actions, and circular economy interventions in general, it is necessary to have established a status quo that they can be related and compared to. Therefore, the status quo, revealed by the underlying material flow analysis, serves as a baseline for which impact assessments as well as time series can be connected to. It is recommended that the importance of this relationship is made evident to those wanting to improve their city's or sector's circularity.

Aside from these reasons, there were possibly others at play that made carrying out the SCA for the first time challenging (both from the development and the application sides). However, it also needs to be stressed that many cities committed to the work, put in a lot of effort and produced in-depth analysis that can enable them to draft policies and actions to make their sector(s) more circular.

Meta-impression

The sector-wide circularity assessment provided a framework to develop a solid data and knowledge foundation for cities to kickstart or solidify their circularity journey. As mentioned in the previous part, different cities included different levels of engagement in this process and had different levels of data quality. Therefore, different levels of insights can be extracted from each of the sector-wide circularity assessment reports. In addition, the entire method was not developed with benchmarking or comparison in mind. On the contrary, it was focusing on providing contextual information and insights. Nevertheless, some general insights can be summarised when looking at the work from all cities side-by-side. For instance, different circularity pathways exist depending on the local resources, local actors and infrastructures. Indeed, in most cases local extractive, productive and waste treatment activities are situated just outside the city boundaries.

Scope and use of reports

Each Sector-Wide Circularity Assessment report provides contextual information on the three different CityLoops cities and their construction sectors under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations of the data used and offers recommendations on how to make this sector more circular.

The reasons and benefits of carrying out the SCA method (taken from "Sector-Wide Circularity Assessment Method", Deliverable 4.3, page -A-):

- **"Make data visible:** At its most basic level, the SCA makes data that cities have or have access to visible, by digging them out of drawers and locally stored files on computers and putting them in a centralised place.

- **Break silos:** Looking for and making data visible also opens up silos that city departments often operate in due to their organisational nature and working structures. Breaking silos (of information) can uncover data that other departments were not aware of, can benefit from and potentially allow for better communication around data needs. It can also highlight areas where it is possible to start collaborating on, ideally creating synergies, but that is its own point.

- **Put material into context:** The materials that the cities deal with in the Demonstration Actions are, on their own, not representative of the whole sector that they are in. By analysing a number of other material (flows) that in this group embody the sector better and gaining information on the sizes of those, the material of interest to a single city or DA can be seen in context and its significance understood.

- **Understand the big picture:** By studying a number of materials, along various elements of the value chain, throughout a sector, and ideally over more than a year, cities will, possibly for the first time, see the big picture of a sector in their city. They will also gain insights about the sectors' complexities, main challenges and efforts that are needed to be carried out in order to achieve their objectives and goals.

- **Establish a status quo:** If they do create this big picture for the first time, they will simultaneously establish a first status quo. This baseline will give them a starting or reference point for their analysis, efforts and policy making in the future and also for the evaluation framework in CityLoops that the assessment is primarily designed for.

- **Inform policy making:** With the status quo and the big picture, a city is given a basis from which they can optimise planning and develop policies that are holistic, context-specific, and informed and supported by hard values. In an iterative process, they could even carry out the assessments over and over to track the efficacy of their implemented policies.

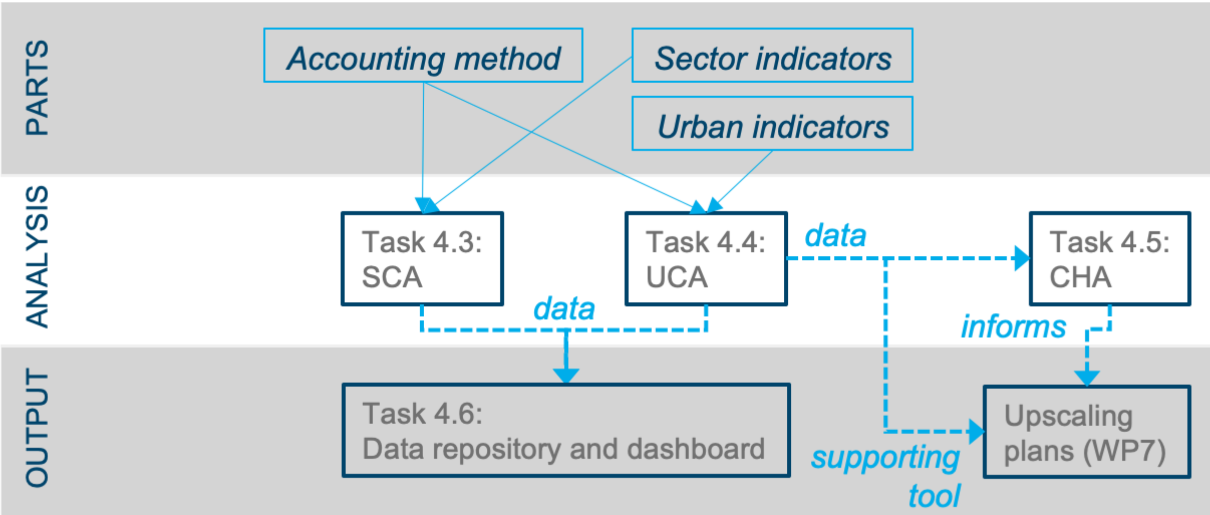
- **Put DAs into context:** Aside from having the materials in a larger context, the DAs themselves also need to be understood as part of a larger "ecosystem". This ecosystem is made up of stakeholders and supply chains that are uncovered through the SCA, by spatialising and disaggregating as much as possible the metabolic flows and stocks and economic activities, infrastructures, and actors associated with them.

- **Upscale DAs:** By obtaining insights on both the material and waste flow sizes and the economic landscape in the city, cities will be able to develop informed circularity upscaling plans (WP7). They will be able to determine where the DAs can be further expanded and how much capacity there is. It may also help to directly support the implementation of the demonstration actions themselves through indicating relationships and pressure points.

- **Unlock circular hotspot analysis:** Determining the circularity of a single sector lays the groundwork and unlocks the ability to do a "circular hotspot analysis" (later in WP4). The hotspot analysis will uncover the sectors to be prioritised, since one of their material flows or part of the value chain is significant, either in terms of size or economic importance, and very linear."

Connection to other CityLoops work

"The SCA is not an analysis that stands on its own in the CityLoops project nor within WP4 which focuses on Circularity Assessment of Cities as a whole. In addition to the SCA, there will be the development of an Urban Circularity Assessment (UCA) and a Circularity Hotspot Analysis (CHA) method, later in the CityLoops project. The SCA, UCA and CHA are in fact connected and complementary analyses which help to further advance cities towards their circular economy journey until they can develop their own circularity roadmap" (cited from "Sector-Wide Circularity Assessment Method", Deliverable 4.3, page 5).



These three types of analyses co-exist and should be employed depending on a city's starting points or needs.

- SCA and UCA both take advantage of material (flow) accounting (MFA). MFA is a heuristic tool for a city to embark or go further in their journey to the circular economy transition. The results produce overall insights and supply in-depth figures and operational elements for cities. As such, the SCA and UCA aim to initiate this process, to determine where cities stand and then empower them in moving to the next step.
- The SCA, which is independent of UCA and CHA, is specific to the construction and/or biomass sectors, usually the most critical ones in a city. On the CityLoops project level, it provides more context to and informs the demonstration actions. For any other city that has identified the importance of these sectors as well, more than others in their municipal economy, they can conduct a SCA to get an overview of the sector.
- The UCA is recommended when a city does not know where to start in their circularity journey. It provides an urban wide understanding beyond sectors, with a focus on materials of the entire economy and therefore unveils a "big picture". Going from big to small, from the UCA overview to sectors, certain economic activities or even single

materials can then be followed and focused on next. (The SCA is not needed to carry out the UCA for a city.)

- The CHA is considered as an extension, using results from the UCA to inform decision making on where to take action on circularity hotspots by planning and implementing context-specific best practices and policies. With the UCA results as a prerequisite to carry out the CHA, it is not a standalone analysis.

A city does not have to use all three methods or any of them. If it knows its status quo and where it needs or wants to act, i.e. where there is a circularity hotspot within its administrative boundaries, they can begin with the carrying out of a demonstration action or follow an informed circularity roadmap.

If they are not aware of their situation or status, it is recommended to conduct an analysis first. The UCA, SCA and CHA can be used in a complementary way to integrate the insights with each other to make the overall circularity approach coherent and easiest for cities to work with.

Indicator glossary

The indicators used for the SCA were the following eight. The methodology of indicator assessment is described in the linked metadata of each indicator. These indicators are all related to the construction sector specifically and do not account for the urban economy as a whole.

Indicator	Description
Domestic material consumption (DMC)	The total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. See Eurostat.
Circular Material Use rate	The circular material use rate (CMU), also called Circularity rate, measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. A higher Circularity rate value indicates more secondary materials substituting for primary raw materials i.e. avoiding the environmental impacts of extracting primary material.
EU self-sufficiency for raw materials	Measures how much the city is independent from the rest of the world for several raw materials.
EOL recycling rate	The End-of-Life Recycling Rate (EoL RR) measures the efficiency with which the mass contained in End-of-Life products is collected, pre-treated, and finally recycled.
Amount of sector specific waste that is produced	Total mass of waste for sector.
EOL processing rate	The End-of-Life Processing Rate (EoL PR) measures the efficiency of the end-of-life processing process.

Incineration rate	Mass percentage of waste which is incinerated.
Landfilling rate	Mass percentage of waste which is landfilled.

Online resources

These reports can also be found online, with interactive graphics and PDF download option per city:

- Apeldoorn;
- Bodø;
- Høje-Taastrup;
- Mikkeli;
- Roskilde;
- Seville;

(The italic texts in this report were written by Metabolism of Cities' Carolin Bellstedt and Aristide Athanassiadis. They provide relevant general information and serve as connecting elements of the single report parts. They are the same texts in every single city report and marked italic to avoid duplicated reading.)*

Contents

Acronyms and Abbreviations

CBS	Centraal Bureau voor de Statistiek (in English: Netherlands Statistics)
CDW	Construction and Demolition Waste
CHA	Circularity Hotspot Analysis
CMU	Circular Material Use rate
DA	Demonstration Actions
DEU (DEI)	Domestic Extraction Used (in the Mikkeli report “DEI” is mistakenly used.)
DMC	Domestic Material Consumption
EoL	End-of-Life
EoL-RR	End-of-Life Recycling Rate
EU	European Union
GVA	Gross Value Added
ICA	Andalusian Institute of Statistics and Cartography
IMP	Import
INE	Instituto Nacional de Estadística (in English: National Institute of Statistics Spain)
LMA	Landelijk Meldpunt Afvalstoffen (in English: Netherlands nationwide waste reporting)
MFA	Material Flow Analysis
MoC	Metabolism of Cities
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (in English: Statistical Classification of Economic Activities in the European Community)
NUTS	Nomenclature of Territorial Units for Statistics
PRODCOM	PRODuction COMmunautaire (Community Production)
PWE	Provinciale Werkgelegenheid Enquete (in English: Provincial Employment Survey)
SCA	Sector Circularity Assessment
UCA	Urban Circularity Assessment

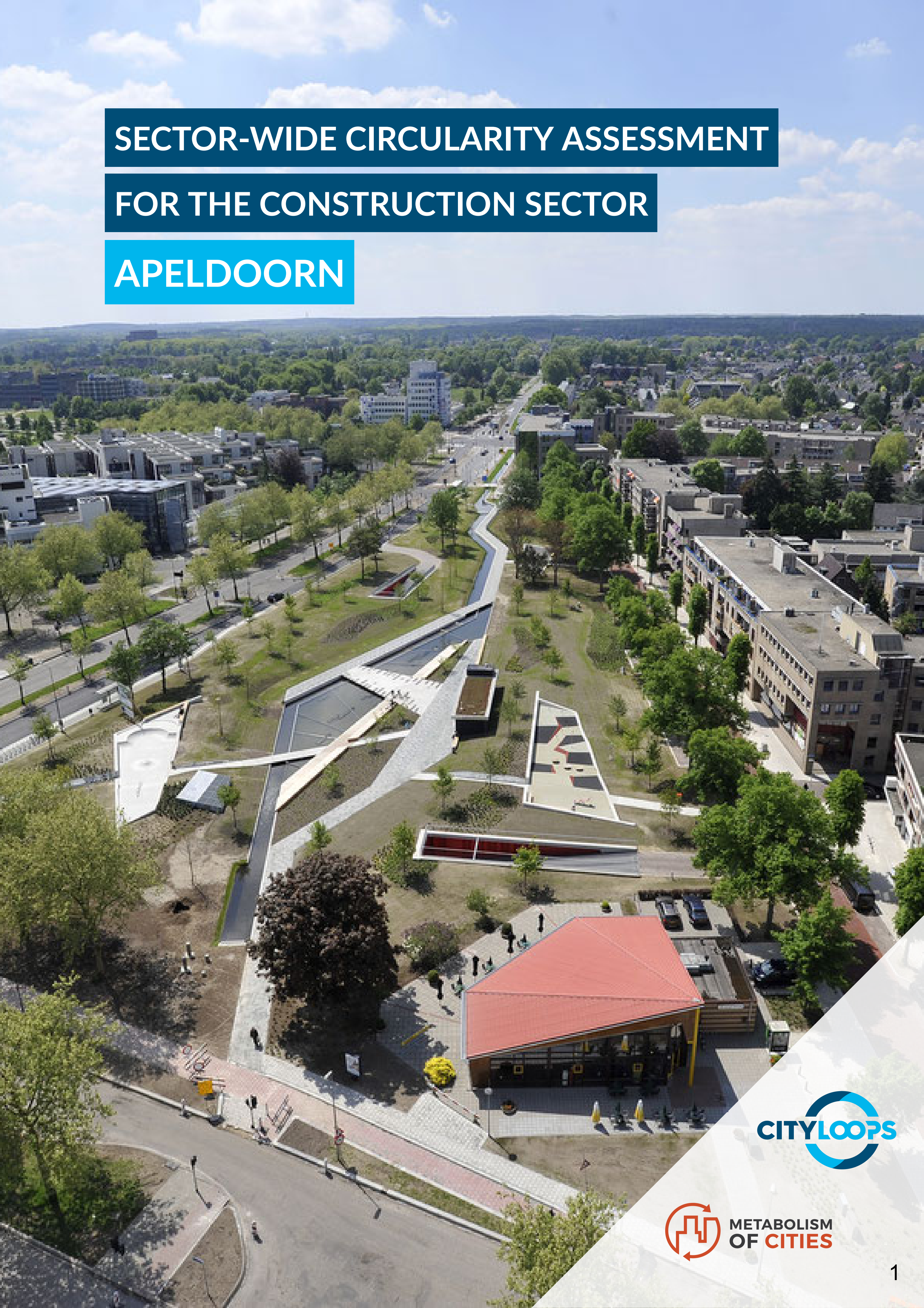
Glossary

CDW	Construction and demolition waste is the waste generated during construction, renovation, or demolition of buildings, structures, roads, and other infrastructure. Wastes from concrete, bricks, wood, metal, asphalt, plasterboard, glass, plastic, insulation, and other construction materials typically make up this category.
CHA	Circularity Hotspot Analysis is a method for cities to identify urban circularity hotspots that are defined by strategic objectives, material flows and their weights for four material categories: biomass, metal ores (gross ores), non-metallic minerals, and fossil energy materials/carriers. The aim of the method is to assist cities in this process, by providing them with a method, to apply on their own, to reveal and understand circularity hotspots and take action on them by planning and implementing context-specific best practices and policies. See more on CHA in D4.5
Circular Sector	A circular sector is a sector that advances in all four circular city vision elements, which are (1) collaboration between stakeholders, (2) circular business models and behaviour patterns, (3) closing material loops & reducing harmful resource use, and (4) improving human well-being and improving environmental quality, in line with the SDGs. See more on Circular Sector in D4.3
DA	Demonstration actions assess the technical and economic viability of new or improved technologies, products, processes, services, or solutions in an operational environment (or near operational environment), whether industrial or otherwise, which includes, if necessary, a larger scale prototype or demonstrator, which involves activities directly aimed at producing new, modified or improved products, processes, or services, plans and arrangements. (In the CityLoops project there are 10 demonstration actions.)
EoL	The term "End-of-Life" refers to the stage of a product's life cycle, in which it has reached its useful end and no longer functions.
Lifecycle stage	Lifecycle stage refers to the various phases a product goes through from its extraction of raw materials, manufacturing and production, distribution and consumption, and finally end-of-life. These stages are typically defined as a product's lifecycle.
MFA	Material Flow Analysis is a material accounting method (one of the most widely used) that takes a systems perspective and quantifies the relevant

	inputs and outputs for these systems. MFA relies on the principles of mass balancing as a way to verify that the model is complete and accurate.
SCA	Sector-wide Circularity Assessment is a method that combines material flow accounting and key “circularity” indicators to assess circularity in economic sectors. SCA seeks to create an understanding of an urban sector, its economic significance, material flows and stocks, related infrastructure, and stakeholders to capture, assess and present its situation around closed material loops and harmful resource use. It quantifies metabolic flows and stocks of a sector and links them to economic activities and actors. Sectors are analysed on their own and for this assessment construction or biomass sectors are evaluated.
Sector (construction)	Sector is a general term used to describe a group of establishments engaged in similar kinds of economic activity. The construction sector is made up of 11 representative materials and associated economic activities.
Stock	Stock is a term in material flow accounting and represents any material that is in the system for more than one year. It is constituted of the accumulation or stockpiling of materials in various stages of the product life cycle. It can be categorised as material stock, built environment stock, product stock, or e-waste stock. Material stock can be raw materials, processed materials, or waste material and built environment stock refers to the materials that are used in buildings, infrastructure, or other constructed assets that have a long lifespan with significant material stock.
UCA	Urban circularity assessment is an urban material flow and stock accounting method paired with system-wide indicators to assess the material circularity of a city. The material flows are accounted economy-wide for two years, applying the Mayer et al. (2019) framework, which in itself builds on the EW-MFA method, including the wide material scope, while optimised for a circular economy assessment. The developed UCA method seeks to find a balance between scientific rigour and comprehensiveness on the one hand, and operability by urban policymakers and practitioners on the other.

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

APELDOORN



CITYLOOPS

METABOLISM OF CITIES

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Apeldoorn are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Aluminium

Bitumen / asphalt

Bricks

Concrete

Glass

Gypsum

Insulation

Iron (steel)

Sand and gravel

Soil

Timber

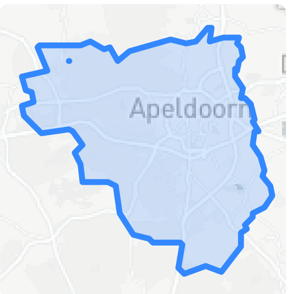
The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

(The italic texts in this report were written by [Metabolism of Cities](#)' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

Urban context

To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.



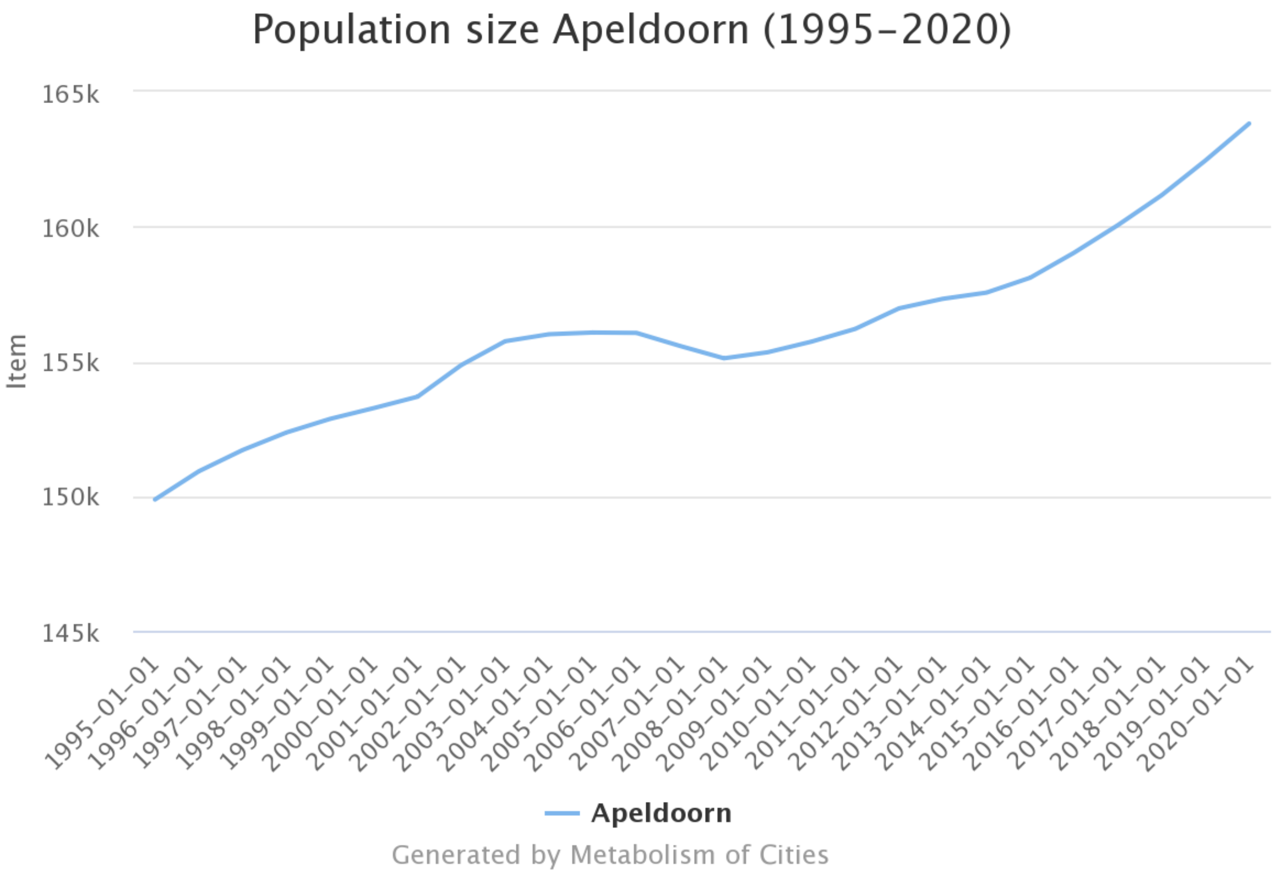
Apeldoorn
164,781
341 km^2

Veluwe
700,975
1,860 km^2

Gelderland
2,096,603
5,136 km^2

Netherlands
17,475,415
41,543 km^2

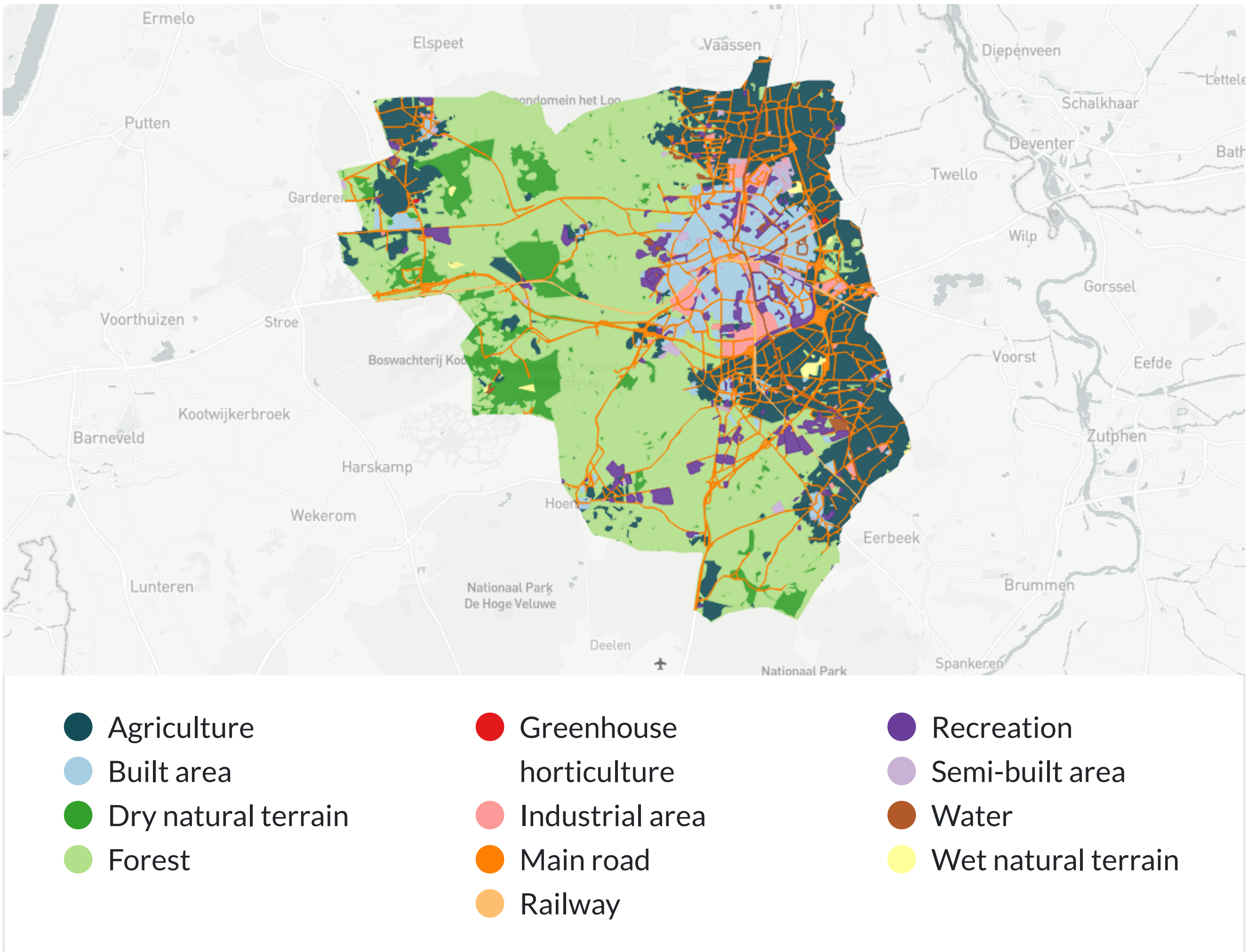
Population of Apeldoorn



Data source

The population of Apeldoorn has been increasing significantly over the past decades. The population grew from 149,869 inhabitants in 1990 to well over 163,818 in 2020, a growth of 9.3%.

Land use



The land use of the municipality of Apeldoorn is dominated by forests, agricultural use and built-up area. About half of Apeldoorn's area is covered by forests, and even becomes well over half of the area, when including other natural terrains. The city itself has a strong urban character, which mainly consists of residential areas and business parks. The rural area of the municipality combines forested and agricultural lands with various smaller towns that are all part of the municipality.

Economic context of construction sector

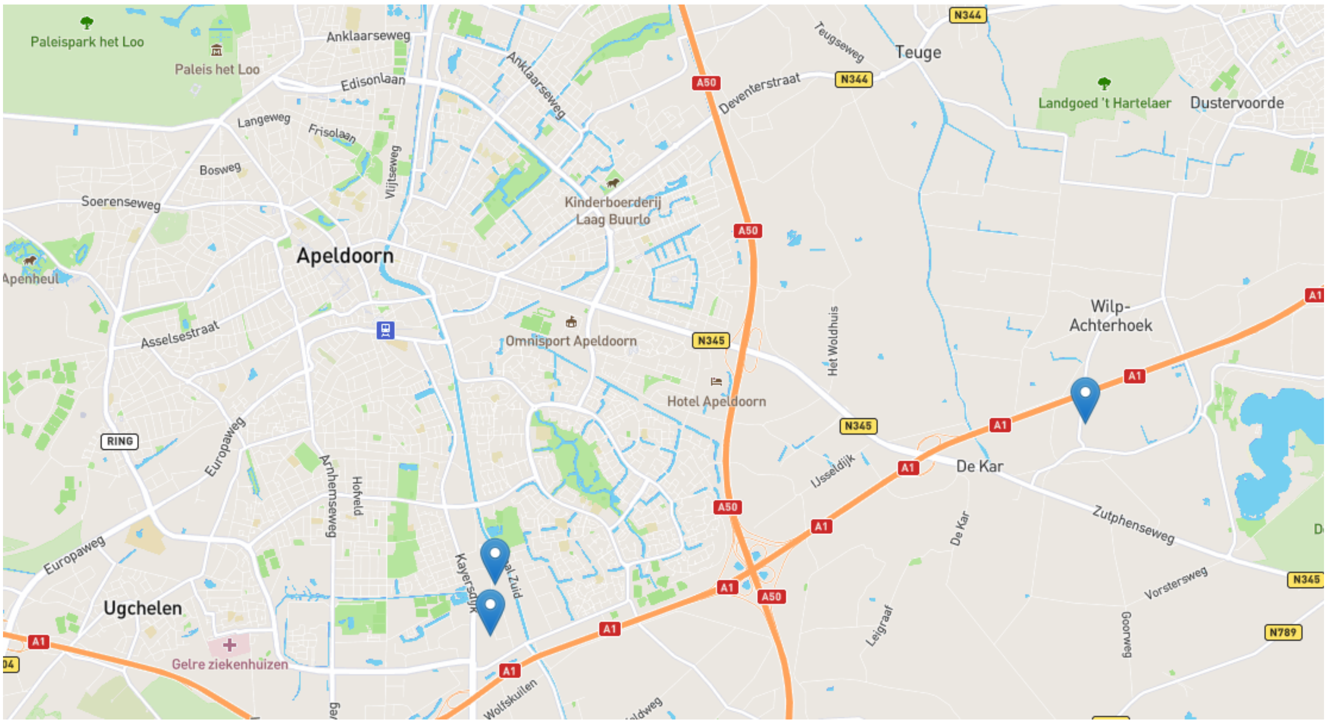
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	GDP (monetary value, in €)	Employees
Apeldoorn	950,000,000	4,200
Veluwe	4,720,000,000	18,900
Gelderland	9,675,000,000	42,800
Netherlands	75,225,000,000	332,800

The construction sector in Apeldoorn

The local construction sector is one of the smaller economic branches in the municipality of Apeldoorn. The biggest sectors in terms of employment are healthcare, wholesale and retail and administrative and support services in Apeldoorn. Important to note is that also not all companies in the construction sector are all active (solely) locally, as well as that there are also various actors active in the region that are not located within the region (Circulaire Atlas Gelderland, 2019).

The actors of the construction sector



Data source

There are no raw material extraction companies in Apeldoorn, making Apeldoorn highly dependent on imports from the region, the Netherlands, or the rest of the world. This is a characteristic of the Netherlands as a whole as more raw materials (minerals, biomass, metals and fossil materials) are imported rather than extracted locally.

There are three local waste collection sites: Circulus-Berkel, SITA Recycling and Atterro Wilp. Circulus-Berkel is the company that collects all household waste in the municipality of Apeldoorn. From that location, the materials are redistributed to other companies where they are treated (recycling, incineration, landfilling etc.). A few companies treat non-hazardous waste, and most companies are active in the recovery of sorted materials. It is important to note, that these are all companies categorized under the NACE-codes 37, 38 and 39. These NACE-codes are non-material specific and therefore some companies might not be active in the collecting or treating waste from biomass or construction sector.

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level). However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	853,422.03	Tonnes/year
39	Circular Material Use Rate	-26.55	%
48	EU self-sufficiency for raw materials	0.73	%
55	EOL-RR (End of Life Recycling Rate)	9.28	%
57	Amount of sector specific waste that is produced	44,314.46	Tonnes/year
58	End of Life Processing Rate	30.00	%

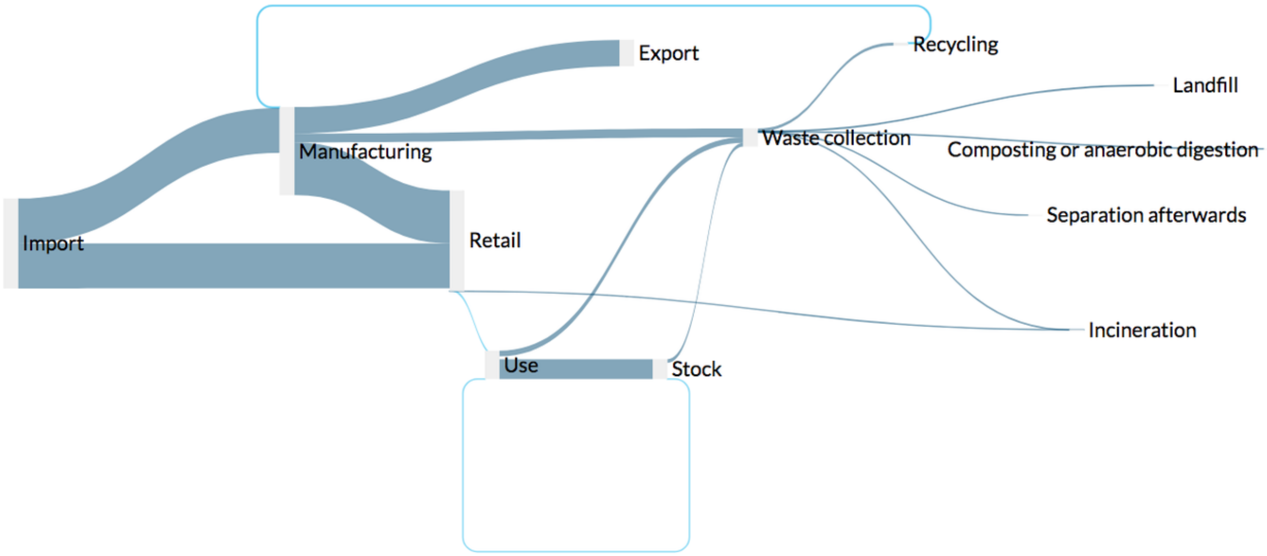
Indicator number	Indicator	Value	Unit
59	Incineration rate	4.77	%
61	Landfilling rate	11.63	%

The indicator table above describes calculated values for the mandatory indicators for the Sector-wide Circularity Assessment. There is no information on the indicator values over time, as there was only data collected, processed, and analysed for one year: 2018. However, these indicator values can be compared to values from other geographical scales. It is especially relevant to compare per capita or percentage values from the Netherlands level to those of Apeldoorn. In comparing these values, multiple issues arose. In many cases. the data from Apeldoorn was significantly different from those of the values of Netherlands as a whole. It is difficult to pinpoint whether Apeldoorn is truly performing on these indicators with the presented values or that the calculated values of the material flows are just not representative for Apeldoorn.

DMC is in Apeldoorn 853,422 tonnes. The per capita value for this is around 5.2 tonnes of domestic (construction) material consumption. For the Netherlands, this value that includes metal ores, non-metallic minerals and fossil energy materials/carriers is around 5.8 tonnes per capita. This indicates that Apeldoorn is performing slightly better in terms of material consumption. However, the stated material consumption of the Netherlands comprises more materials than only construction materials. Therefore, it is likely that Apeldoorn is consuming more non-biomass materials per capita than an average citizen in the Netherlands. Then, the value for the Circular Material Use rate (39) is -27% which is unlikely, as the Dutch CMU rate is 30 percent. It is unclear what could explain the minus value for CMU.

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



[Data source]

The Sankey diagram clearly shows that the municipality of Apeldoorn relies solely on import when it comes to construction materials. A significant portion of the data that is visualized here is based on statistics for the Netherlands, using the population or employment numbers as proxies to create estimates. This is the case for Use , Imports, Exports and Waste Processing. Also note that there is no outflow from Retail, as there is no data available at the moment.

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.

Rating	*Reliability*	*Completeness*	*Temporal correlation*	*Spatial correlation*
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Extraction/Harvesting			All data from 2018	Only country level data
Manufacturing			All data from 2018	Only country level data
Retail	No data	No data	No data	No data
Use			All data from 2018	Only country level data
Stock			'Real time' information (2021)	
Waste collection			All data from 2018	Only country level data

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Landfill			All data from 2018	Only country level data
Incineration			All data from 2018	Only country level data
Recycling			All data from 2018	Only country level data
Anaerobic digestion	No data		No data	No data
Composting	No data		No data	No data
Imports			All data from 2018	Only country level data
Exports			All data from 2018	Only country level data

The data collection process was difficult due to various reasons. First of all, there is almost no information on material flows collected locally. Therefore, Netherlands Statistics (CBS) was the primary source for gathering data (also the source that delivers Dutch data on Eurostat statistics). However, the scale of information was therefore almost always national which means that the **spatial correlation** was often low and in almost all cases downscaling needed to be performed. Secondly, information on companies e.g. manufacturing or waste produced is often estimated through surveys with companies as well as information derived from annual environmental reports, this data is therefore often estimated rather than measured resulting in medium **reliability**.

Thirdly, the **completeness** of the data is also very limited. Information was very often only be found on sector level, and sometimes it was also difficult to pinpoint at which lifecycle stage the datasets were providing information about. The material categories used in the collected datasets or for the proxies were not the same as for this course (e.g. Eurostat's MFA uses raw material categories, and for this MFA also products were used, making it difficult to find information on materials per lifecycle stage). Additionally, the municipality of Apeldoorn also did not want ask companies for data on material use. In the Netherlands a strict division between governmental organisations and companies is desired and it is unlikely that individual companies will provide much information on their material use on a public website. Then, for waste collection and processing there is some information for governmental organisations available (LMA, nation-wide waste reporting) as it is mandatory for companies to register waste collection and treatment. However, the information is highly confidential and it is not allowed to publish this information unless it is aggregated so that no individual companies can be extracted from the information.

Unfortunately, all these reasons have resulted in a rather red and orange coloured data quality matrix. Only the temporal correlation was high, as most data was present from the year 2018. Partly because CBS acquires much of their data on a yearly basis and for half of the lifecycle stages the same dataset was used; Eurostat's Material Flow Accounts.

Data gaps and assumptions

As described before there were quite some data gaps in terms of the *completeness* of the data (level of detail in which information was obtained) as well as on which *spatial scale* information could be collected.

Material and lifecycle stage information

- There is **no difference made between use and retail** in the material flow accounts of Eurostat and therefore data on retail is lacking. It was decided that, due to the uncertainty in choosing which material category of Eurostat would have to be linked to the SCA material categories, the information would be summed to the sector level. Also, **waste data** as well as information on how waste is processed was difficult to estimate as it depends on the type of waste how it is processed and the information on waste treatment was only found on total company waste level.
- In terms of **stock information** there is a local dataset called GBI which collects information on all locations in Apeldoorn that are subjected to maintenance performed by (contracted companies of) the municipality of Apeldoorn. However, the information is mainly collected in the unit of 'metres' or square meters or 'items'. This could not be properly recalculated to a number of tonnes, and therefore it was decided to leave this information out and only deal with the information present in tonnes, the amount of concrete roads in Apeldoorn.

Proxy information

- **Forested area:** there was no information on which amount of the forested area in Apeldoorn is being managed to produce wood flows. This information was left out of the assessment.
- **Employees:** local employee data was obtained from the Provincial Employment Survey (in Dutch, Provinciale Werkgelegenheid Enquete, PWE). It was required to round up/off the number of employees to tens (10, 20, 30 etc.), so there might be some results that are not fully representative for Apeldoorn. Then, in using the employees as a proxy for the sector as a whole also resulted in using some employees multiple times which in reality is of course not the case. NACE-codes only specify on the economic activity that it entails, and not per

se on the type of materials that are being dealt with. Especially for wholesale and retail and imports and exports, this was problematic.

- **Downscaling:**In all cases, except for household waste and material stock (which is incomplete), national data was used which required downscaling to estimate the size of material flows for Apeldoorn. The problem was, however, that the Eurostat MFA only uses raw materials and only a couple of materials in product forms. This was particularly difficult for the construction sector, as various materials share the same raw materials and in some cases the Eurostat categories comprised multiple materials that were not part of this SCA.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector

The municipality of Apeldoorn has a binding contract with a single concrete processor/provider, located in Nijmegen. For demolishing, the realisation of pathways, roads, etc. or other infrastructural projects there is a multitude of contractors both situated inside and outside of Apeldoorn, any of which will be selected through procurement.

Apeldoorn has it's own land bank, providing contractors with soil/sand if necessary. Contractors will need to acquire concrete through Apeldoorn's concrete processor, other materials can be freely imported. Reuse/recycle requirements per project are defined by Apeldoorn's procurement officers, this is specified in e.g. tonnes of concrete/asphalt that needs to be made from recycles materials. Responsibility of further recycling/reuse of materials is put in the hands of the contractors themselves. While steps have already been taken to ensure a certain reuse/recycling minimum, there is a demand for upcycling methods of CDW materials into higher-value products, which could prove to be a more efficient reuse method.

Connection to and upscaling of demonstration actions

A number of videos (1, 2) have been made in the past, explaining exactly the plans for the near future of Apeldoorn. It is important that inhabitants as well as stakeholders get a say in this process. Saxion University has taken upon itself the task of generating a 3D visualisation of a neighborhood and how improvements can be made on its' circularity. This visualisation will be embedded in the open source platform OpenStad.

During the planned procurement of increasing circularity for this neighborhood, citizen input will be taken into account. The goal is to reach an as-high-as-possible score of circularity. Afterwards this pilot will be evaluated and it will serve as a learning experience, where the municipality aims to incorporate lessons learned into future decision-making processes.

Recommendations for making the construction sector more circular

The main recommendations are as follows:

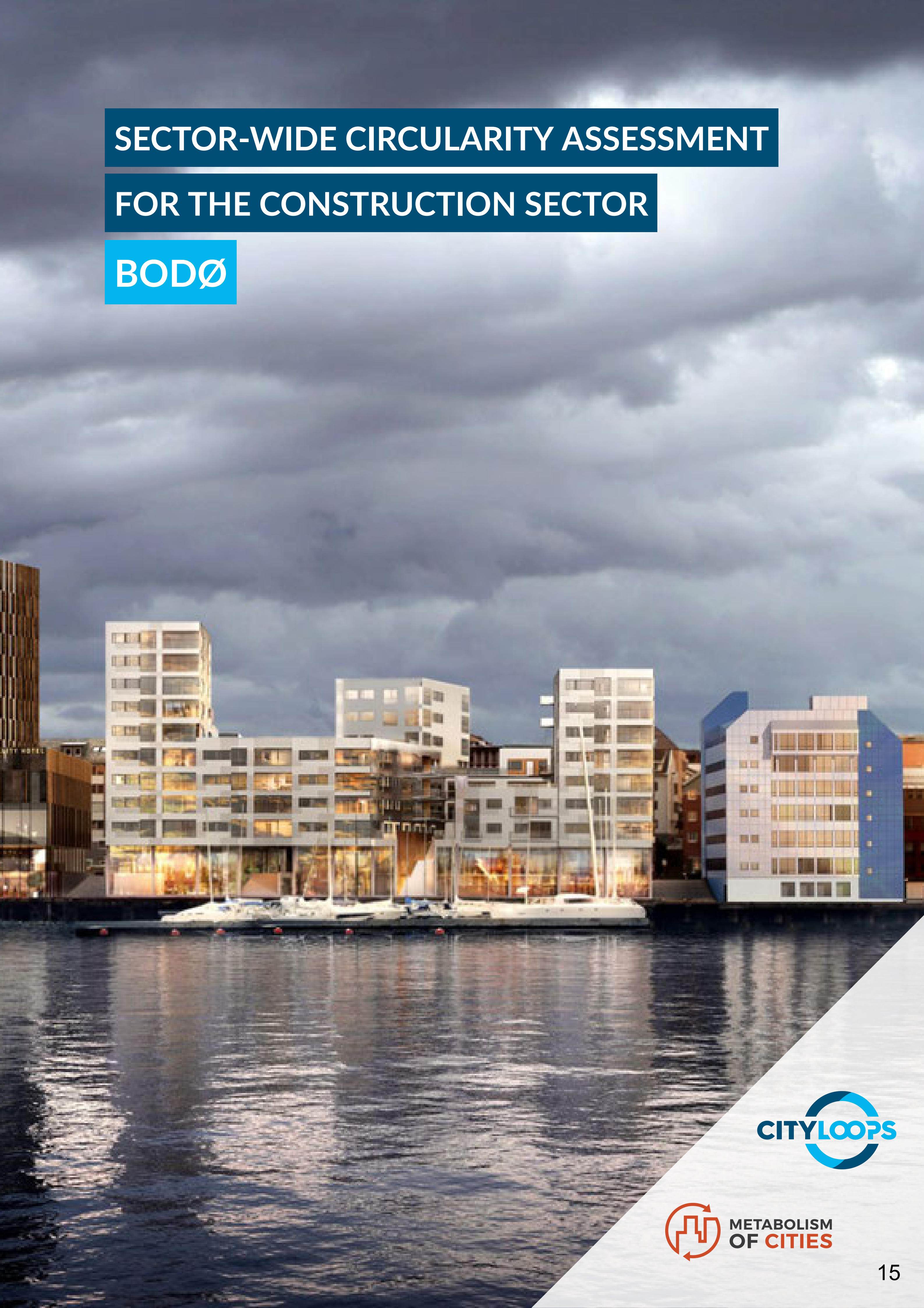
1. Start *measuring material flows locally*, in categories and units that are relevant for the municipality. Perhaps begin at the level of the demonstration actions and scale up based on those results. Simultaneously, set specific and measurable goals for circularity which in the initiation phase can be based on national values. Over time, these goals need to be re-evaluated and specified to the local situation.
2. Investigate the role of *import and export* of materials in Apeldoorn's sectors. Many materials produced in Apeldoorn are not consumed locally which can partly be caused by the fact that the economic character of the Netherlands is based on throughflow and export of materials, as well as the fact that companies are not per se city oriented but often operate at larger scales in the region or country.
3. Choose on what scale(s) the municipality has and wants to have *influence* on obtaining circularity. Is it possible and realistic to create industrial metabolisms and connect companies or even sectoral flows to one another or should the municipality focus more on what kind of materials go in and out of and are consumed in the municipality. Then, the municipality can decide on setting more circular demands on the materials that they use in biomass (e.g. greening) or construction projects.
4. Evaluate the *circularity of sustainability initiatives* and the *sustainability of setting demands for circularity*. Potential trade-offs exists if issues of material flow monitoring and actions linked to them are not viewed holistically. Who and what benefits of certain decisions, and who or what bears the losses? In the transition towards circular and sustainable societies, quick win-wins might overshadow relevant questions and processes that demand more time.

References

- Netherlands
- Gelderland
- Veluwe
- Apeldoorn population (1995-2020) line graph
- Land use Apeldoorn 2015
- Apeldoorn construction sector actors map

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

BODØ



CITYLOOPS

METABOLISM OF CITIES

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Bodø are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Aluminium	Bitumen / asphalt	Bricks
Concrete	Glass	Gypsum
Insulation	Iron (steel)	Sand and gravel
Soil	Timber	

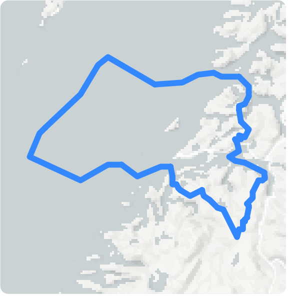
The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

(The italic texts in this report were written by Metabolism of Cities' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

Urban context

To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.



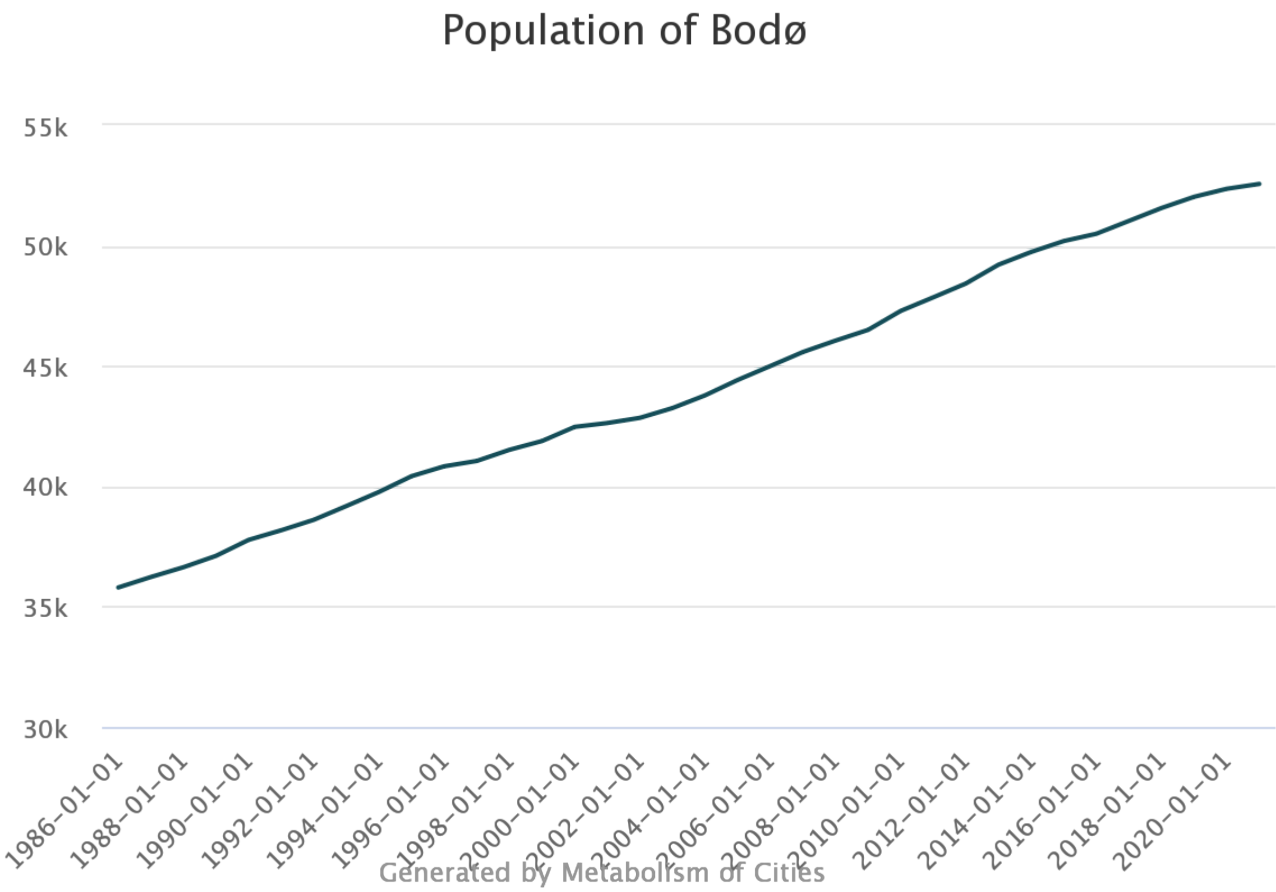
Bodø
52,560
1,395 km^2

Nordland
240,559
38,155 km^2

Nord-Norge
482,839
112,975 km^2

Norway
5,398,804
385,207 km^2

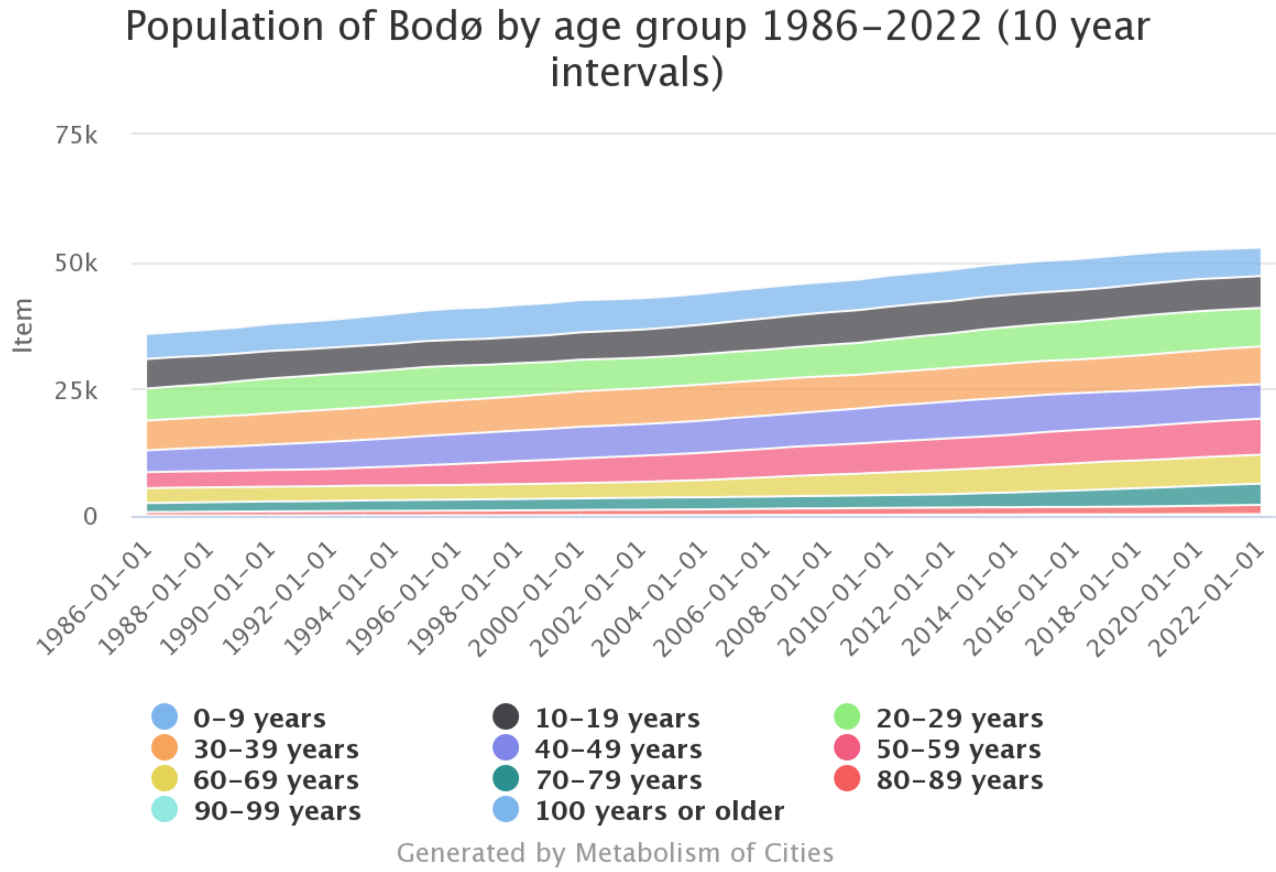
Population of Bodø



Data source

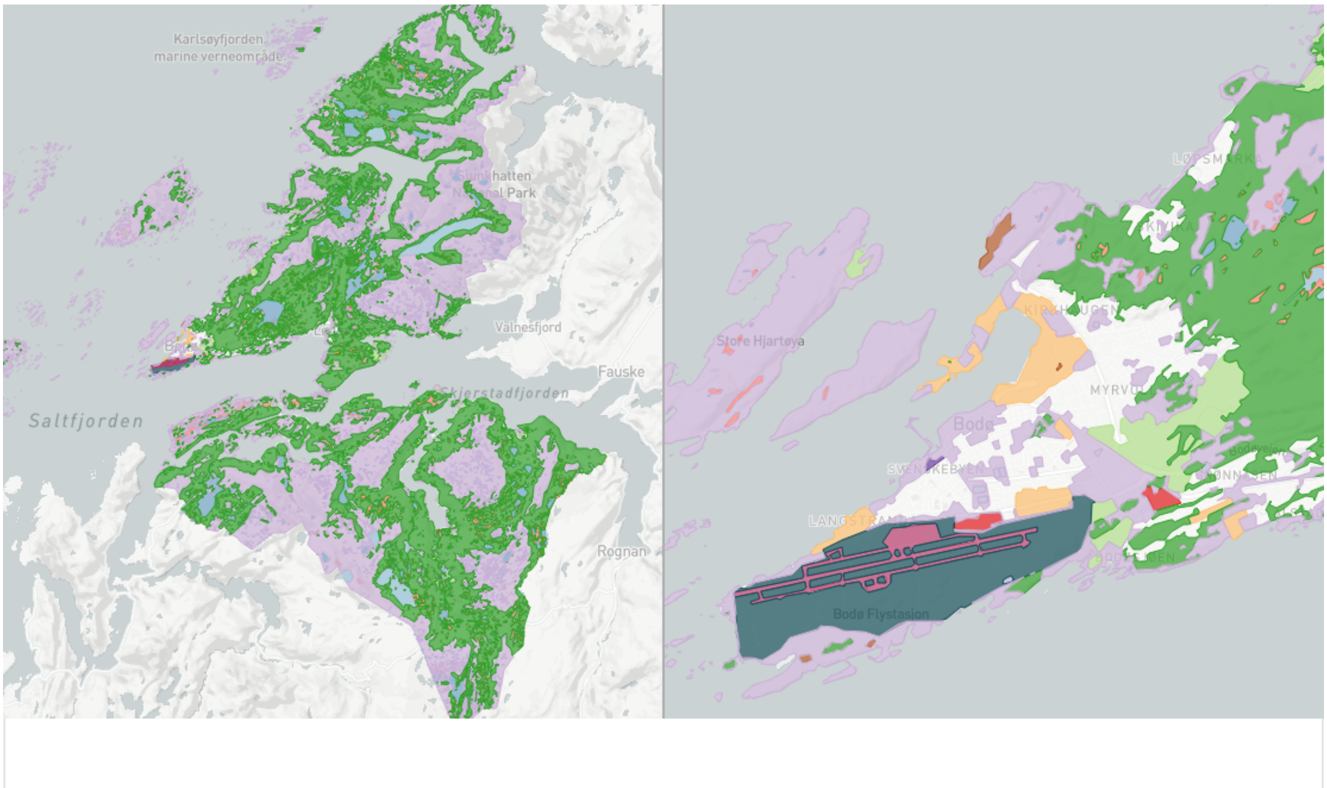
The population of Bodø was 52,560 in 2021. Over the last 35 years, it has been increasing significantly, namely by 46.8%, where there were only 35,792 inhabitants in 1986. On average, the municipality grew by 471 people each year over the last 10 years. The population density is quite low with 40 inhabitants per km^2 of land area in 2020.

As can be seen in the graphic below, the population is comparatively young with 51% of them being younger than 40 years.



[Data source]

Land use



Data source

Bodø is a town and a port located on the tip of a peninsula in the traditional region of Salten in Nordland Country, Norway. It consists of several small islands off the peninsular coastline as well. Due to its strategic location and its popularity as a trading port, it was established as a town around 200 years ago.

Its landscape was historically dominated by natural birch vegetation, but over the past 4,500 years, it has developed into an open and mostly treeless landscape (Moe, 2011).

This is evident even today as the dominant land use in Bodø are Open Area (~47%) and Forests (40%) corresponding to approximately 650 sqkm and 560 sqkm respectively. The urban built up area, in contrast, is merely 5 sqkm (0.35%) of which the airport comprises 3.5 sqkm (0.25%), industrial area comprises 1.4 sqkm (0.1%) and residential areas comprises 0.02 km.

Economic context of construction sector

This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

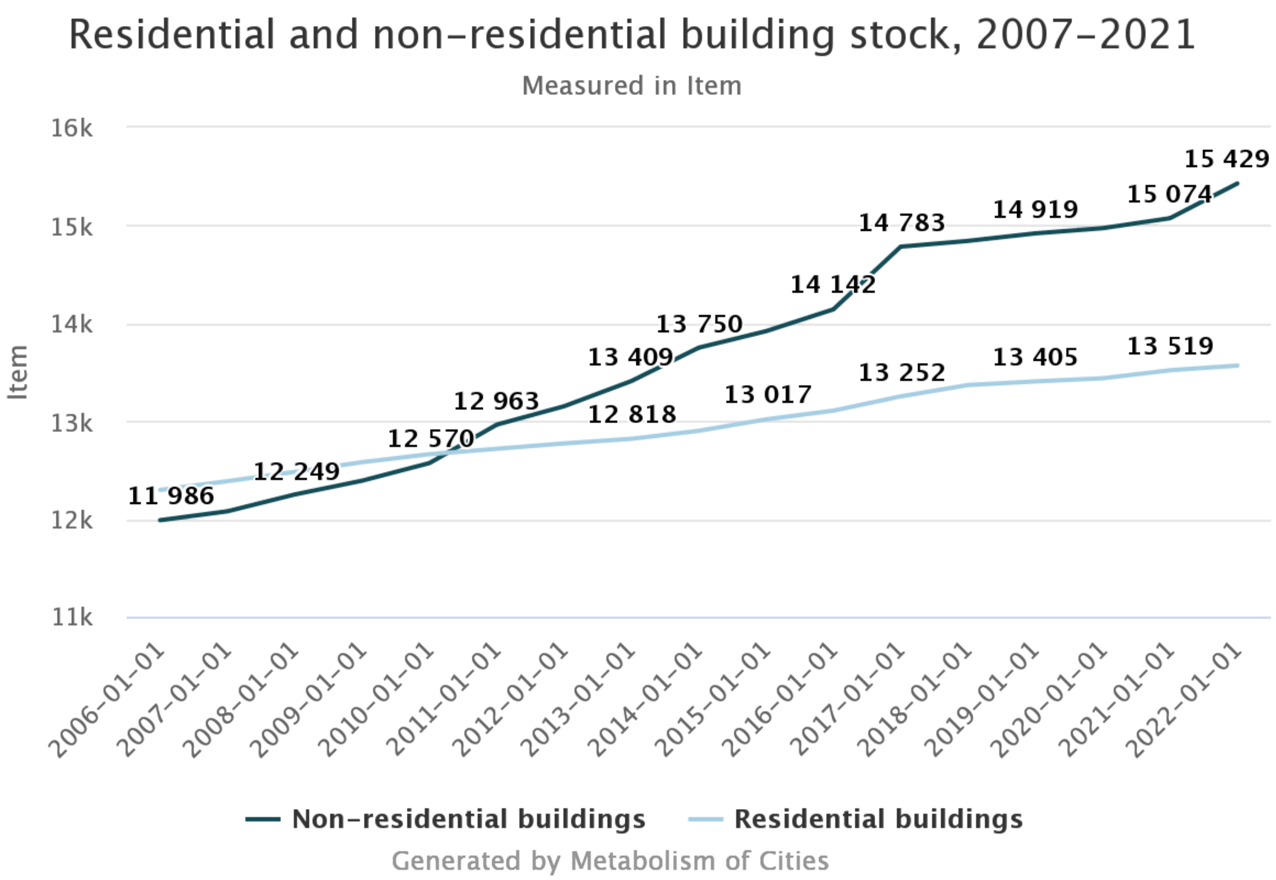
	Turnover (monetary value, in kr)	Employees
Bodø	8,154,000	2,249
Nordland	161,592,100,000	10,508
Nord-Norge	327,060,000,000	104,918
Norway	626,851,800,000	260,560

The construction sector in Bodø

The construction sector in Norway is the second-largest employer in the country after wholesale and retail trade according to Statistics Norway, providing employment to approximately 16% of employees. In comparison, the construction sector employs only 8% of employees in Bodø. In 2019, the annual turnover of the construction sector in Norway was NOK 626,851.8 million, while in Nord-Norge (Northern Norway) it was NOK 327,060 million and in Nordland was NOK 161,592.1 million.

The construction sector in Bodø is quite small compared to Norway in total, when considering activities around new buildings. In the year 2020, the number of construction applications processed in Bodø were merely 440, which is 0.5% of the 80,584 construction applications processed for the whole of Norway. (Data source).

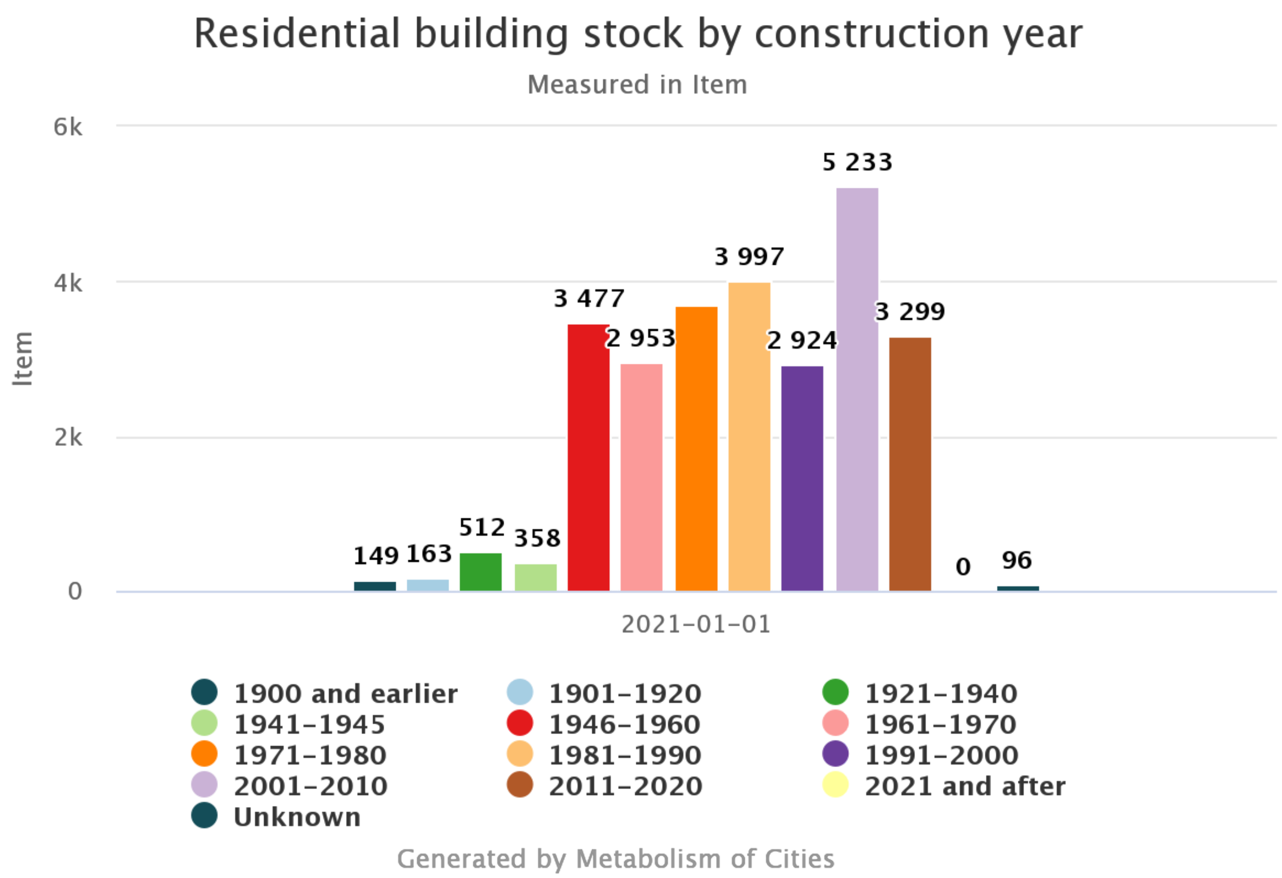
In Bodø, the building stock is fairly equally distributed between residential and non-residential buildings. 47% of the buildings are residential (source), of which 4% are municipally managed housing (source) and remaining 43% are private housing. 53% of buildings are non-residential (source). As is shown in the graphic, from 2006 to 2022, the total building stock of Bodø has gradually been growing. Until 2011, the number of residential and non-residential buildings were nearly the same, but after that the number of non-residential buildings grew while the residential stock remained fairly steady.



Data source

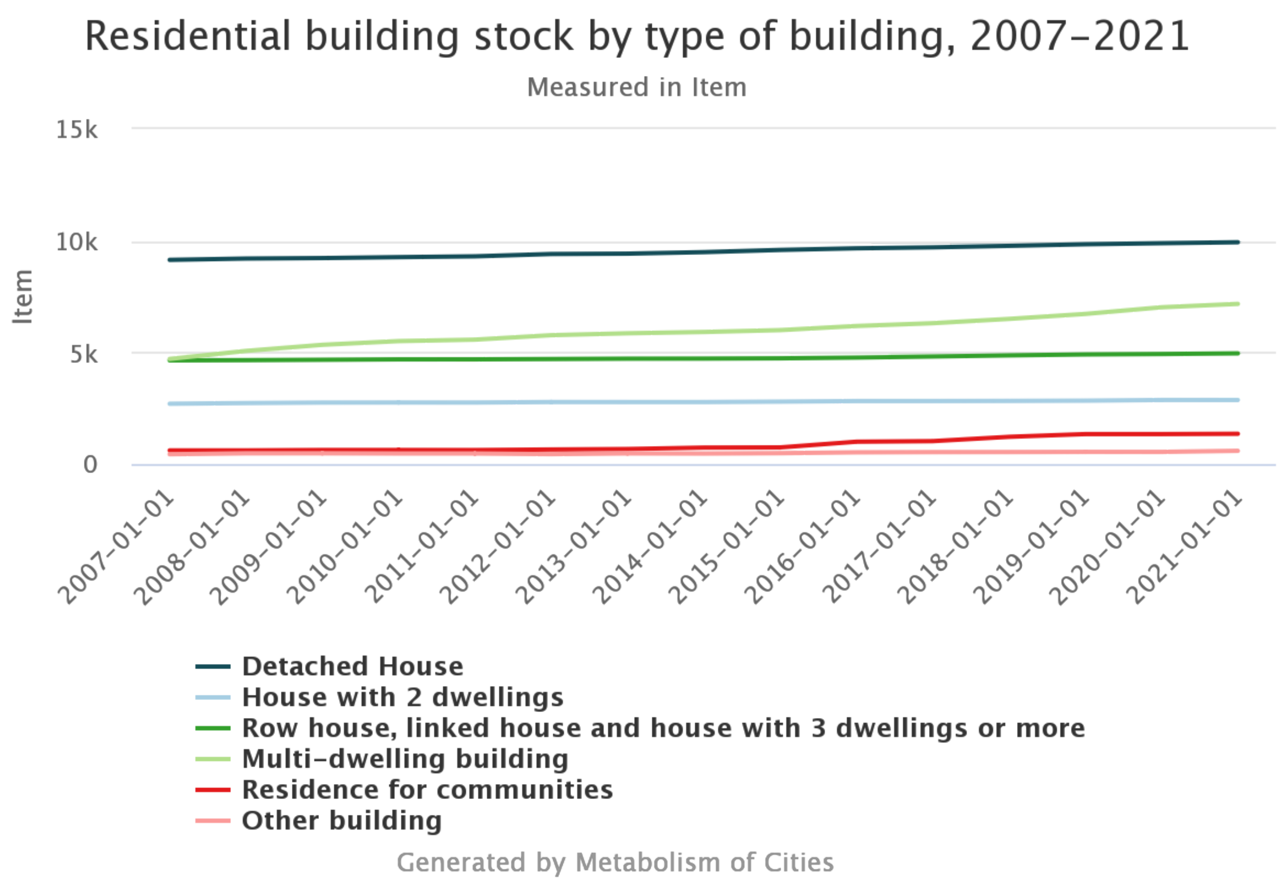
The 13,519 residential buildings comprise 26,861 dwellings. These dwellings can be further categorised by the year of construction and into six different housing typologies. The graphic here shows the number of buildings that were built in different groups of years, counting in decades from 1961 onwards. Considering the age of buildings is relevant from a circular economy perspective. With the age of buildings, their renovation needs, as well as the materials that become available when houses are demolished can be anticipated.

For the situation in Bodø, it can be seen that while there was a boost in construction activity between 2001 and 2010, the majority of the dwellings existing today were built already before that time, after the second world war. This means that depending on the quality of the built stock, the expectations of the residents with regards to comfort and design trends, these buildings will, at a minimum, face renovation activities or will be replaced by new buildings, triggering the production of CDW and the consumption of new or secondary raw materials.



Data source

Aside from the age, the distribution by typology can also be considered. The following two charts illustrate the data for 2007 to 2021, and data focused on 2021, respectively. The graph illustrates that the 'detached house' is the most prevalent with 37%, followed by the 'multidwelling house' and the 'row house, linked house and house with 3 dwellings or more', with 27% and 18% respectively. It is interesting to note that even though the number of residential buildings has largely remained constant, there has been a notable increase in the number of dwellings. This can largely be attributed to the increase in the number of multidwelling houses.



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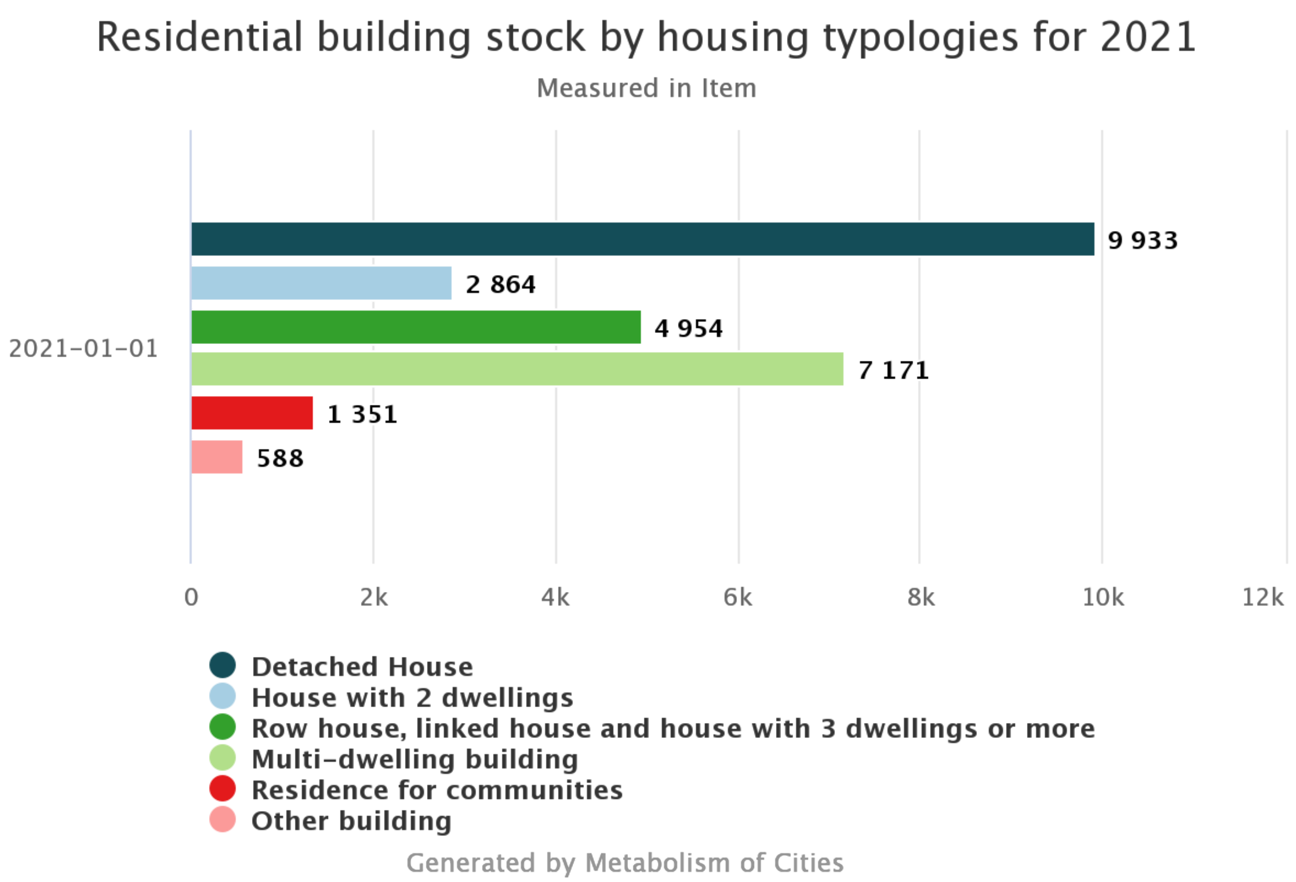
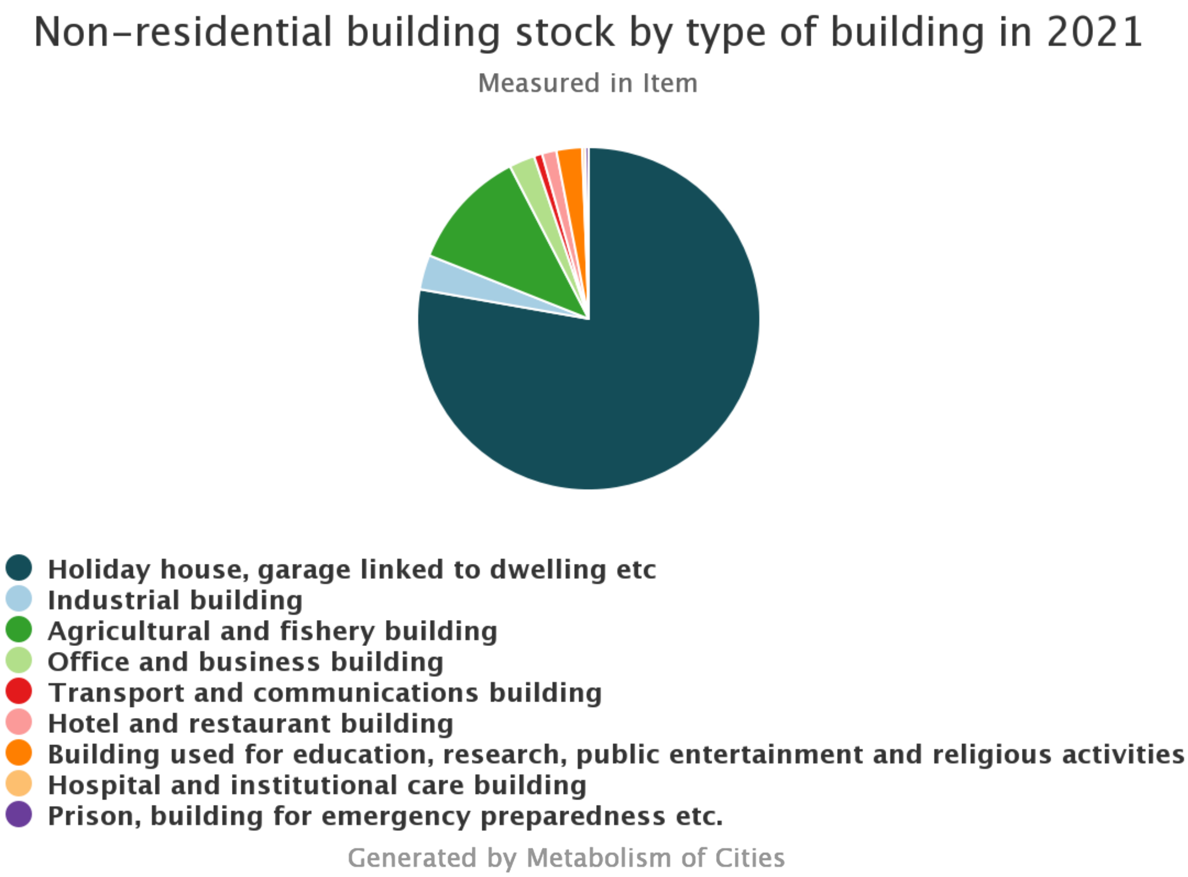


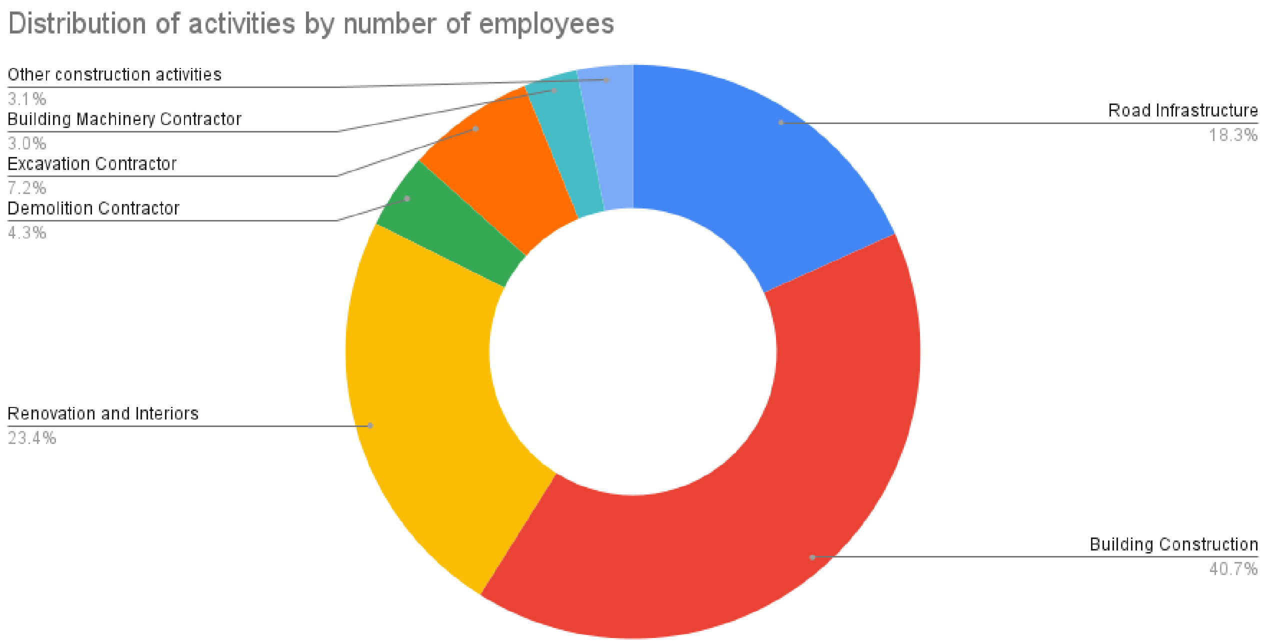
Data source

As for the non-residential building stock, the 15,074 buildings that existed in 2021 can also be further explored by the type of building. For this stock, nine different typologies exist, as can be seen in the chart. It shows that holiday homes are dominant with 78%, although they are in practice also used by residents, just not as permanent dwellings. The other dominant non-residential building types are agricultural and fishery buildings and industrial buildings that comprise 11% and 3% of the total non-residential building stock respectively.



Data source

The actors of the construction sector



Data source

There are 4,812 construction companies in Nord-Norge as of 2019 (source), with 2,398 of them situated in Nordland (source) and about 489 in Bodø (source). Of those in Bodø, 34 companies were identified to be of particular importance and which in turn were further analysed.

The construction companies in Bodø are pretty much clustered and close to the city. The actors are construction companies, contractors, entrepreneurs, and construction consultants. The primary actors associated with material flows in the construction sector are: Nordasfalt AS, Gunvald Johansen Bygg AS, Boligbyggelaget Nobl AS, Byggmester Fritzøe AS, Byggmester Erling Skipnes AS, Nordanlegg AS, Veinor AS, and Gunvald Johansen Support AS. As for waste management companies, there are two main ones in Bodø: Retura-Iris and Østbø.

Extraction

There is no extraction of building materials currently being done in Bodø. Up until recently, gravel mines were being operated by two companies in Bodø - Nordland Betong AS and Nordasfalt AS.

Nordland Betong, one of Nordland's largest concrete producers and established in 1947 in Bodø, operated two gravel mines in Bodø, in Vika i Misvær and in Kvikstad, see map below. These are now almost closed. According to Mr. Tore Mosand, the General Manager of Nordland Betong, the mine in Vika i Misvær still has at least one million tonnes of sand (grade 0-8) left in it, but the land owner does not want more to be removed.

Nordasfalt AS, established in 1988, which works in road and highway construction, also operated a gravel mine until 2018, however its mine is no longer operational.

Data source

Manufacturing

Manufacturing of construction materials and products in Bodø spans asphalt, concrete, glass, and insulation materials, along with products such as prefabricated concrete pipes and fire-safety doors. There are 7 major companies involved in manufacturing.

Nordasfalt AS and Nordland Betong, have been mentioned under extraction as well, and manufacture asphalt for road and highway construction, and ready-concrete and concrete products respectively. They also work in the production and laying of asphalt, milling, rehabilitation of concrete structures, tunnel washing, production of bitumen etc. Loe Bodø Betong AS also produces concrete products such as prefabricated pipes.

Bodø Glass & Ramme AS and Glassproffen AS are both glass manufacturers. Bodø Glass & Ramme AS was established in 1981 and operates a glass and aluminium workshop in Bodø. It provides interior solutions using mainly these two materials. Glassproffen AS also has a workshop in Bodø, and provides interior solutions in glass, plexiglass (acrylic) and lexan (polycarbonate). They also offer repair and replacements of broken glass.

Løvold Industri AS is a company that was established in 1950 and currently produces fish-packaging boxes and building insulation in EPS-expanded polystyrene under the brand name Termopor.

Rapp Bomek AS manufactures heavy-duty door, window, and wall safety solutions for applications where security is important. Their products are used in commercial buildings, airports, banks, embassies, prisons, hospitals, etc.

Retail

Bodø has several actors selling building materials and products. Some of these are outlets of larger chains operating nation-wide, while some are Bodø-based. Some of the latter manufacture or extract the building materials as well.

Companies such as Bygger'n Bodø, Byggmakker, XL-BYGG Kåre Abelsen and Julius Jakhelln AS are building material and hardware stores, of which the last is a locally owned store. Specialised retailers operating in Bodø are Asak Miljostein selling concrete products, Acrylicon Nord-Norge AS selling flooring, Byggesystemer Bodø AS selling scaffolding, and Ventistål AS selling ventilation and plumbing.

The manufacturers retailing their products include Løvolds industri AS selling insulation, Bodø Glass Og Ramme AS selling glass and aluminium solutions, and Nordasfalt AS selling gravel and crushed stone.

Use

The list of construction actors responsible for the use of materials in Bodø is quite long. These actors can be broadly categorised into four major activity groups - construction, renovation & interiors, excavation & demolition, and construction machinery.

Nordasfalt AS which constructs roads and highways for public and private projects is the largest construction employer in Bodø with 180 employees. It delivers approximately 200,000 tonnes of asphalt for public and private projects annually.

Then there is Gunvald Johansen Bygg AS which is one of Nord-Norge's leading construction companies developing residential, commercial and public buildings and employing 152 people.

Boligbyggelaget Nobl is a housing society that builds and manages housing across the country since 1946 and currently employs 43 persons. They assist over 290 housing companies across the country with financial, technical and legal management as well.

Byggmester Fritzøe AS is a dealer for Systemhus in Bodø with 31 employees. It was founded in 2002 and specialises in interior and exterior carpentry work for home construction.

Nordanlegg AS is a local Bodø contractor with 22 employees. They own machines and equipment that allow them to perform a variety of activities such as excavations, building construction, as well as renovation.

Amongst renovation and interiors companies, Byggmester Erling Skipnes AS is an important one that specialises in carpentry and woodwork. They are a subsidiary of Norgeshus and employ 27 people in Bodø.

VeiNor AS is one of the largest excavation and demolition contractors in the Salten Region with 40 employees. They recently purchased all the shares in Bernhardsen Entreprenør AS, another prominent demolition contractor in Bodø.

Aside from the listed and described companies that engage in the use of construction materials, there are certainly a great many more of them in the municipality. However, for this report, only the main players as specified by the Bodø Kommune were included.

Waste collection and treatment

Construction and demolition waste in Bodø is largely handled by three companies, Iris Salten IKS (and its subsidiaries), Østbø AS and Bodø Energi Varme AS. (The companies and their collection and/or treatment facilities are shown on the map below.) While Bodø municipality is a local waste authority and has the formal responsibility for waste disposal in the municipality, it rents services from Iris Salten.

Iris Salten IKS is an inter-municipal waste management company with its head office in Vikan outside the city of Bodø. It serves the nine municipalities in Salten, which also own the company. The company's main activity is the collection and treatment of both household and corporate waste, through three subsidiaries that have been established to perform this service; Iris Service AS, Iris Produksjon AS, and Retura Iris AS. However, the final waste treatments are left to their partners.

- Iris Service AS, founded in 2001, focuses on household renovation and operation of the environmental squares. It also operates all of Iris "Miljøtorg", two of which are in Bodø. Miljøtorg Bodø is not relevant for CDW collection, as it accepts wastes from other categories. However, Miljøtorg Vikan is relevant for CDW, and especially for wood waste.

- Iris Produksjon AS handles all waste that comes through the Iris Group and operates Salten's only landfill. At this location, they also prepare waste for the local district heating plant, for energy recovery.

- Retura Iris AS, a wholly owned subsidiary of the Iris Salten IKS Group, is a part of the national franchise chain called Retura Norway, a waste management company. Retura Iris offers waste solutions to companies and institutions. It offers complete waste solutions, from waste planning to collection and treatment of the waste throughout the Salten region. It offers rental services for waste containers for different types of waste streams such as industrial, hazardous and CDW. It also provides courses and sorting guides to corporations.

Østbø AS is Nord-Norge's largest commercial waste and environmental company. It offers total waste services throughout northern Norway and provides the following services: Business renovation, household renovation, industrial service, environmental mapping and environmental remediation, transportation, transport of dangerous goods, consultancy, car wreck reception in Bodø and Fauske, and solutions for the oil and gas industry as well. The waste categories they deal with are hazardous waste, iron and metals, and electronic waste.

Bodø Energi Varme AS is a subsidiary company of the Bodø Energi group. The company is headquartered in Bodø and 100% owned by Bodø Municipality. Bodø Energy Varme AS supplies heat from the Keiseren Bio plant at Rønvikjordet to the district heating system in the municipality that has been in place since 2015 (source). The biomass heating plant uses locally recycled wood (pallets, demolition wood, kitchen fittings, etc.) as feed, which it receives in about equal parts from the two waste management companies, Retura Iris and Østbø. After four years of operation, by 2019, 96% of Bodø's energy needs in 2019 (i.e. 53,859 MWh of energy) were met by bioenergy.

Data source

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level).

However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	15,065.60	Tonnes/year
39	Circular Material Use Rate	0.02	%
48	EU self-sufficiency for raw materials	0.91	%
55	EOL-RR (End of Life Recycling Rate)	0.0009	%
57	Amount of sector specific waste that is produced	141,182	Tonnes/year
58	End of Life Processing Rate	80.00	%
59	Incineration rate	14.80	%
61	Landfilling rate	86.85	%

The indicators chosen for the SCA of the construction sector in Bodø are focused on construction materials, their end-of-life treatment, sectoral circularity, and resilience in the sector.

Domestic material consumption (DMC) of Bodø is the sum of total building raw materials extracted within and imported into Bodø, minus the building raw materials exported by the municipality. It amounts to 15,065.6 tonnes or 0.28 tonnes per capita. This value is significantly lower than the DMC of 13.4 tonnes per capita for EU-28 in 2019 and even lower relative to the 25 and 31.6 tonnes per capita for neighbouring countries Denmark and Finland, respectively.

Circular Material Use rate (CMU) for Bodø is 0.02% which indicates that there is very little circularity in the sector currently. Its CMU value is much lower than the 2019 CMU of EU-28 at 12.4% and also lower compared to the 2019 CMU values of 7.6% and 6.3% for Norway's neighbouring countries Denmark and Finland respectively.

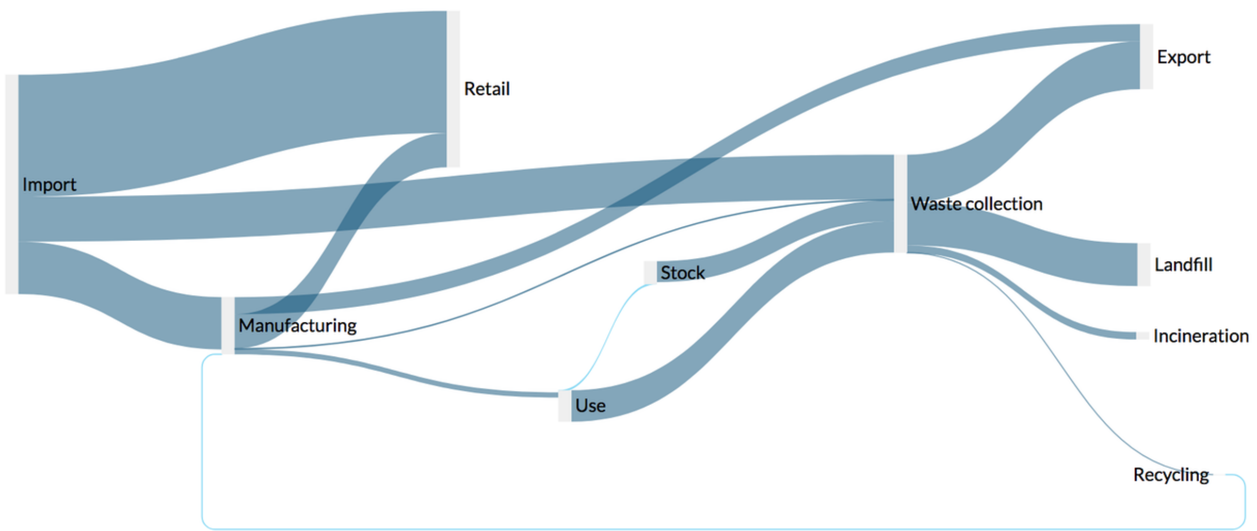
EU self-sufficiency for raw materials measures how independent a city is from importing raw materials from the rest of the world. Bodø's self-sufficiency indicator is very low with 0.91%. Unfortunately, there is no national value to compare it to. And since the data completeness was lacking in terms of differentiation of the single materials, this indicator couldn't be calculated for them individually to determine the various self-sufficiency levels.

EOL recycling rate (EOL RR) for Bodø is negligible at 0.0009%. The **EOL Processing Rate** here has been assumed to be 80%. The low EOL RR can be attributed to the fact that reliable recycling data was only available for insulation materials that are produced in very low quantities (3 tonnes) compared to the total EOL mass collected (260,680 tonnes). EOL RR should potentially be higher as high recycling rates were reported by the local waste management company Iris, however, quantitative values for those are unavailable as well. What would increase this value is the inclusion of metals in this calculation. However, data on those were not made available.

Amount of sector-specific waste that is produced is 141,182 tonnes. This waste is largely incinerated or landfilled. The **incineration rate** is 14.8% while the **landfilling rate** is extremely high at 86.85%. These add up to more than 100% as they also include the imported waste.

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



Data source

The Sankey diagram is built from the data collected from Bodø's actors, Norwegian statistics, and the indicators that have been derived from them. Therefore, one needs to take into account that the data quality influences how close to actuality and informative the Sankey is for present-day Bodø. In addition to the data quality, so-called allocation values also have an impact on the data behind the visualisation. These allocation values were employed to estimate the amounts of materials that "flow" between the single life cycle stages, since these relationships and quantities were in most cases unknown, except for waste collection going to waste treatment.

Overall, the Sankey diagram for Bodø shows that quite a lot of materials are moving around in the construction sector system of 2019.

It can be observed that there is no **extraction** that takes place in Bodø. This was confirmed by the *Directoratet for Mineralforvaltning* or the Directorate of Mineral Management for Norway as well as Nordland Betong, which was previously operating gravel mines in Bodø.

Bodø relies heavily on raw material **imports** for its construction sector. 584,990 tonnes of materials imported were for the sole input for manufacturing (comprising 24% of total imported material). Of this imported material, the majority (56%) went to retail, while a large quantity (20%) also went to waste collection.

60% of the **manufacturing** flow in Bodø were allocated towards retail, 30% were allocated to exports, 9% were allocated to be used directly (without passing through retail) in local construction projects, and 1% was allocated as waste.

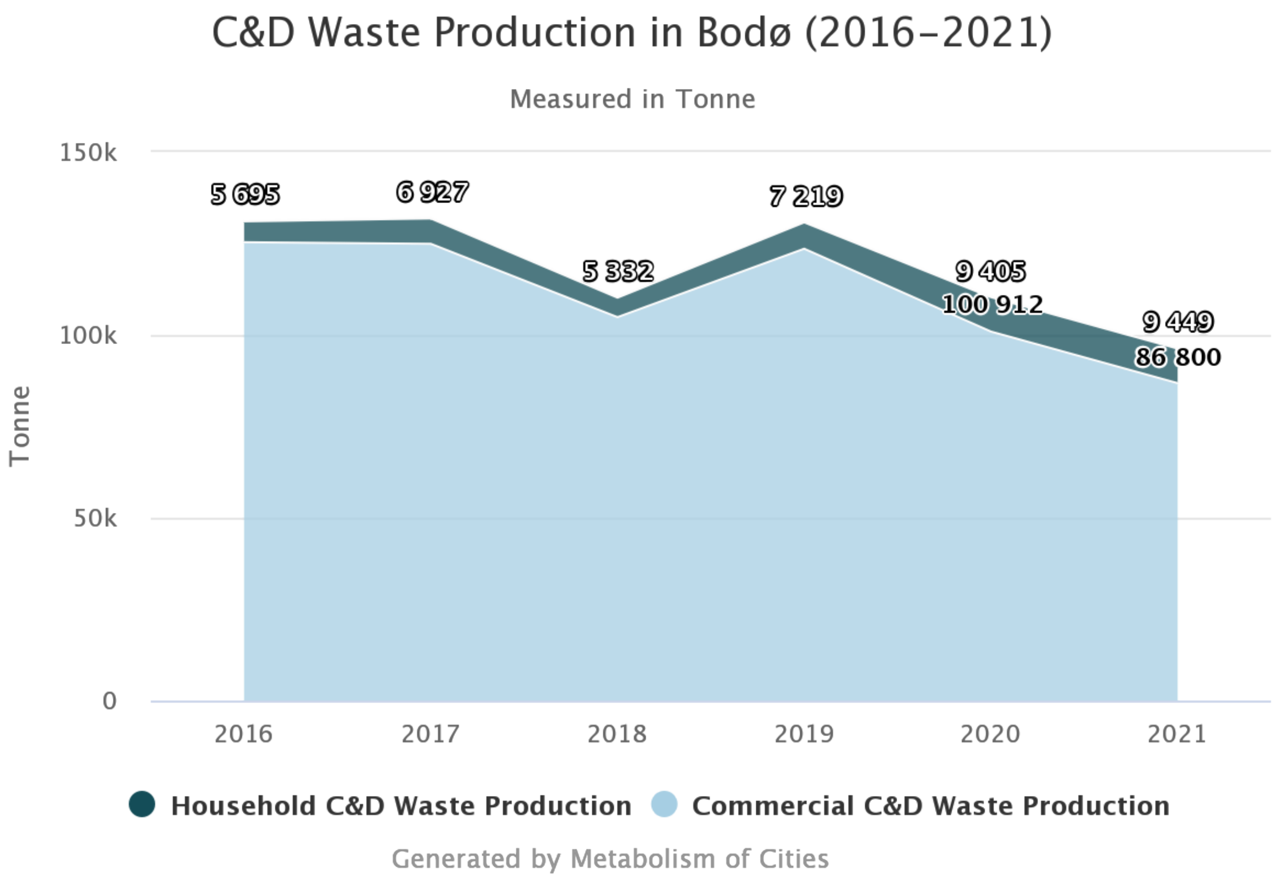
With regards to **retail** in Bodø, it was estimated that 22% of the materials came from local manufacturing, while the remaining 78% were imported from outside of the municipality.

A data gap existed for **use** and therefore there is no relationship between use and stock, for materials which are needed to realise construction activities. However, through an interview with the waste management company Iris, the information was received that 5,840 tonnes of concrete were resold for reuse to other construction sites and so a reverse flow of material, from stock to use, can be observed.

Although it seems that most of **stock** goes to waste collection and a little bit gets reused, this is only true in terms of the amount of *flows*. It might seem that all buildings and infrastructure get demolished again, but this of course is not the case. It is just that the Sankey diagram does not depict the stocks, the materials that stay in a system for over a year, but only the flows from the single stages.

The **waste collection** in Bodø, in 2019, was quite large compared to other flows. Of the total CDW collected, about 130,777 tonnes, only 5% originated from households while the remaining 95% originated from commercial sources. Although this ratio has remained almost constant since

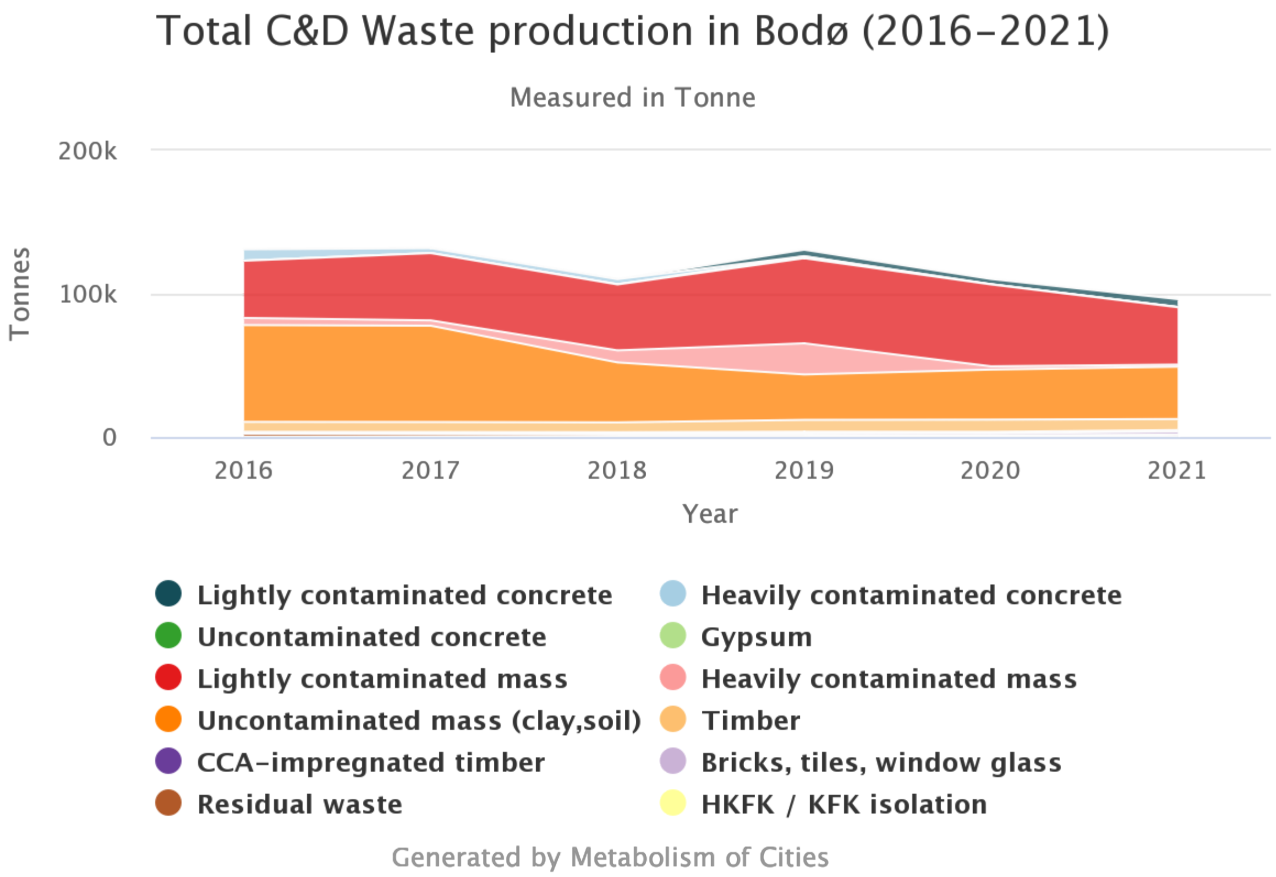
2016, it can be seen that the production of CDW from households has increased to 10%. It is worth noting that, contrary to other regions or countries, households pay significantly less for waste disposal than commercial entities have to.



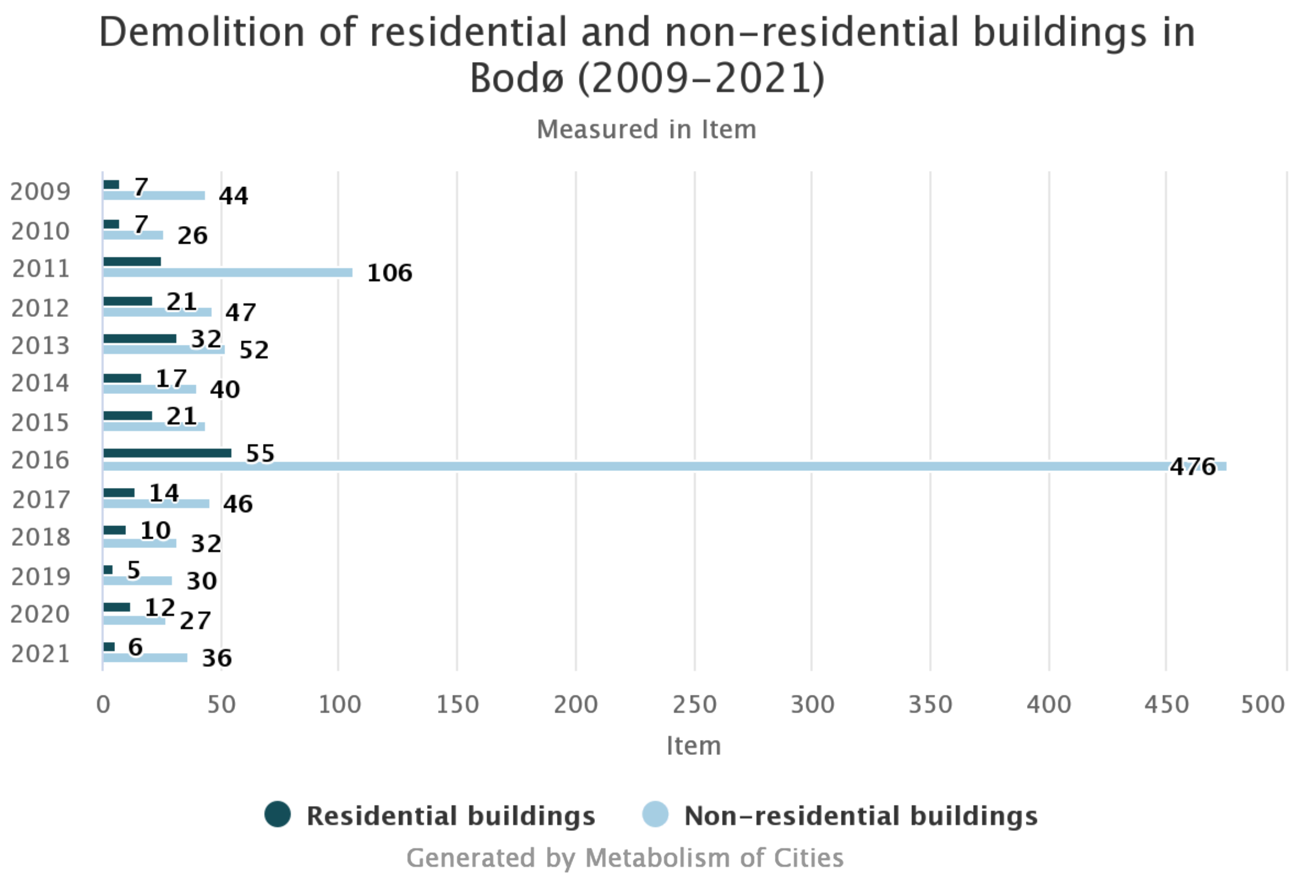
Data source

Aside from the distinction by waste source, in order to better understand the waste collection flows, the waste can also be broken down into materials. The most common type of CDW generated in Bodø by mass is composed of uncontaminated, lightly contaminated and heavily contaminated mass. These materials alone accounted for a combined 86% of the materials collected in 2019. As can be seen in the following graph, lightly contaminated mass is the predominant CDW, accounting for 45% of the total and showing a slightly increasing trend from 2016 to 2019, with an increase from about 40 kt to about 60 kt. However, in this same period, a significant decrease in the production of uncontaminated mass can be seen. It can also be observed that in 2019, the production of heavily contaminated mass increases considerably, quadrupling its 2016 value.

The next CDW fraction in Bodø is concrete, accounting for 5% of the total in 2019. As with mass, concrete is also collected with varying degrees of contamination. According to the waste collection company Iris, from 2019, there was a change in the regulation with regards to reusing concrete, to encourage more recycling and reuse of contaminated concrete. Nevertheless, it seems that this measure has had no effect so far, because the quantity remains constant.

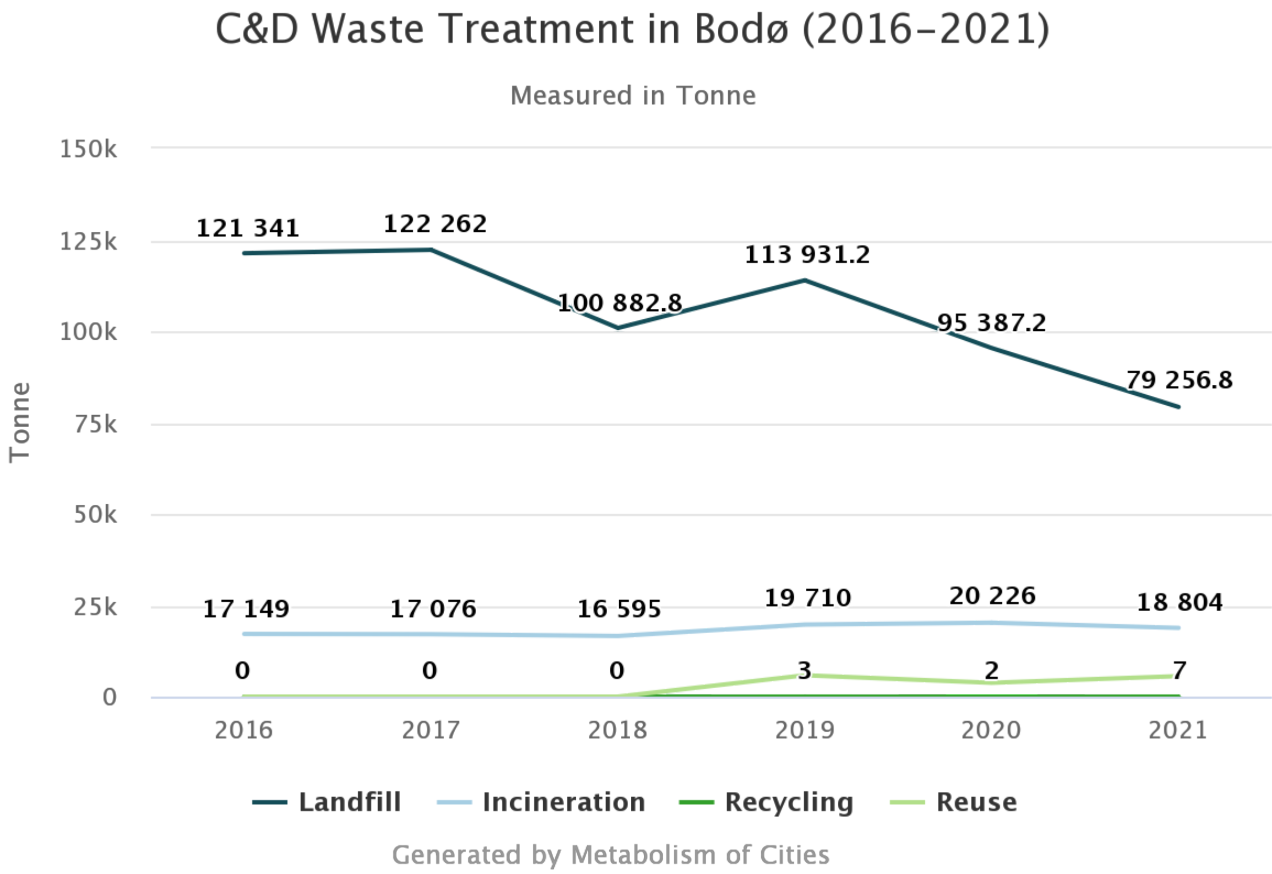


Data source



Data source

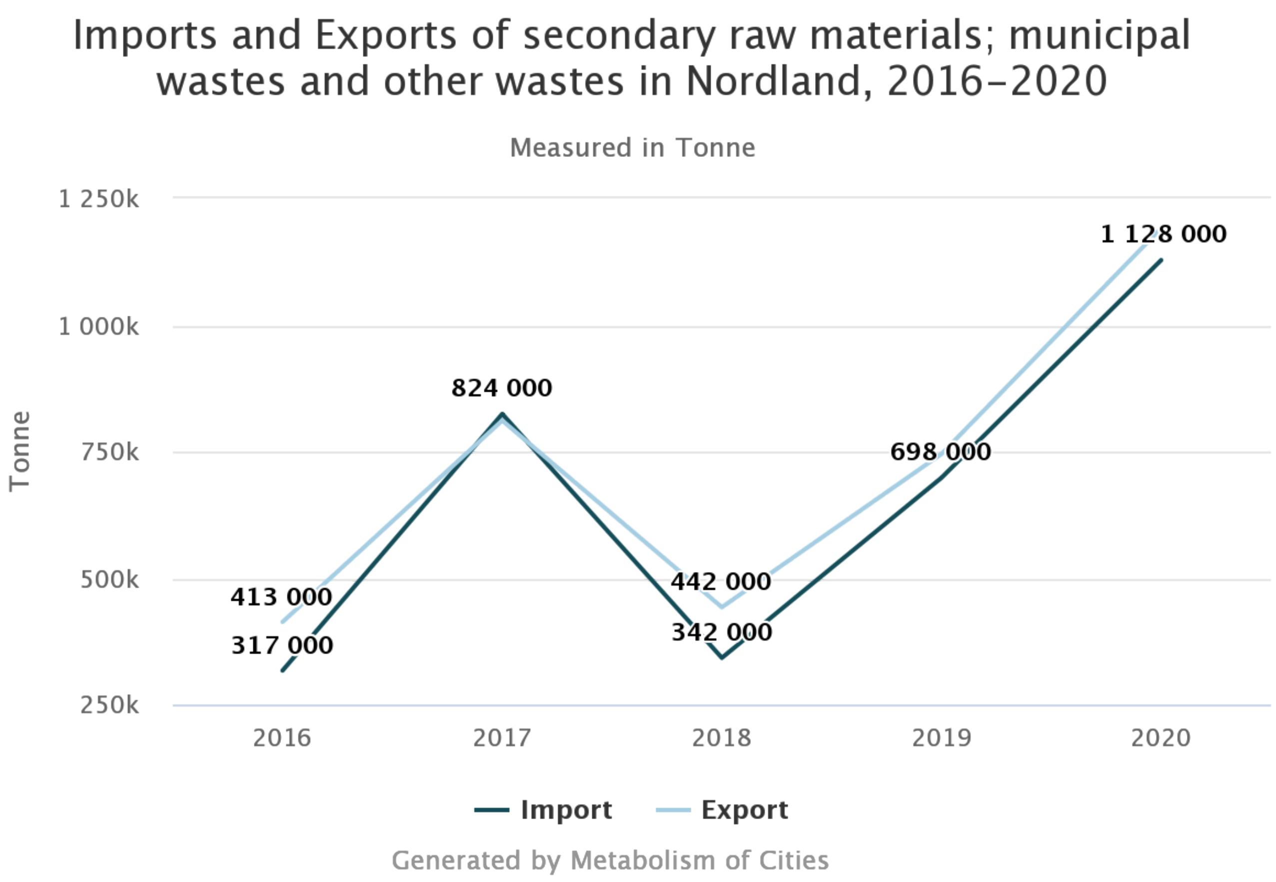
The *demolition of building stock* contributed to 21% of the total CDW. As can be seen in the below graph, in the year 2019, 30 non-residential buildings and 5 residential buildings were demolished, which were calculated to amount to 55,942 tonnes of CDW. In summary, 32% of the collected CDW originated from construction and rehabilitation projects. The remaining 45% were imported waste and a meagre 0.5% also originated from manufacturing.



Data source

Following waste collection and the paths of materials to the right, it can be seen that the close majority of waste (49%) is exported. The other half is subjected to **waste treatment** locally. The two major waste treatment methods for CDW in Bodø are landfilling and incineration (energy recovery). A significant share of materials was sent to the landfill, the majority being made up of "mass", which is basically soil, followed by bricks. Overall, it seems, however, that landfilling is on a downward trend in Bodø, when comparing it to the other years (see graph below). A smaller flow, with two important CDW fractions from the CDW, residual waste and timber, was subjected to **energy recovery** by the district heating plant in Bodø BE Varme AS. The residual waste, under which plastics from construction are also classified, is sorted roughly before it is ground, sieved, pressed and packaged. The timber, which also includes CCA-impregnated timber, is ground into wood chips, before being sent for energy recovery. Finally, as last waste treatment option, some of the waste is sent to **recycling**, however its scale is currently negligible, with only 3 tonnes of insulation being recycled every year. This value was doubled in 2021, as can be seen in the graphic below, but it still pales in comparison to the other end-of-life processes. It can be noted that for some materials different waste treatments apply, depending on their condition. For example, regarding the CDW treatment of concrete, there are three pathways. If the concrete is lightly contaminated, it is crushed, sorted, and resold and if the concrete is uncontaminated, it is resold for reuse directly to other construction sites. In the case that the concrete is heavily contaminated, it is also sent to landfill.

For the rest of the **exports** that are not waste materials, there should be flows from other lifecycle stages leaving the municipality, however, these are could not be allocated appropriately and therefore not be determined. They do make up significant flows however, because the total almost equals that of imports. Finally, with regards to **imports and exports** in Nordland, it shows that cross-boundary trade of secondary raw materials, municipal waste, and other waste materials in Nordland, between 2016 to 2020, has been increasing. As can be seen in the graph below, both imports and exports follow a similar trend, with imports being marginally lesser than exports for the most part. It could be interesting to determine the materials that are behind these amounts and if there are solutions for them to reuse them locally to avoid the trade and environmental consequences thereof.



Data source

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.

Rating	*Reliability*	*Completeness*	*Temporal correlation*	*Spatial correlation*
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Extraction/Harvesting	Not applicable.			
Manufacturing			2019	

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Retail	Data was not determined.			
Use	Data could not be determined.			
Stock			2021	
Waste collection			2019	
Landfill			2019	
Incineration			2019	
Recycling			2019	
Imports			2019	
Exports			2019	

The data gathered for this report is a combination of public, company, and municipal data. Most of the data has been modelled and/or downscaled from higher spatial scales and therefore the accuracy is somewhat compromised.

As can be seen in the data quality matrix above, the **overall quality of the data is relatively low**:

- The temporal correlation is very good for all lifecycle stages (LCS), as the data was almost always from the reference year (2019). The GDP and employee data was used for 2019, while the waste and stock data were more recent with 2020 and 2021 respectively.
- The spatial correlation is still fairly good. However, it does suffer, especially in manufacturing where national data was used and in imports and exports where NUTS3 level data were employed.
- The reliability of the data is ok. For almost half of the LCS, the data were measured, while the other half was estimated or provisional.
- The completeness of data scores medium for all LCS, except one. This is mostly because the data either only exists for some single or for some economic activities, but not both and not all materials are differentiated.

- Finally, one LCS did not require any data and two LCS are missing entirely. This situation is explained in more detail below.

Data gaps and assumptions

Since most of the gathered data is only available on a larger level than the local level of Bodø, considerable data gaps existed. This means that downscaling and modelling of higher spatial scale data have been necessary to get an indication on how these values apply to Bodø. The following paragraphs describe how sources, assumptions, and calculations were used for each lifecycle stage to close the gaps.

Extraction

For extraction, it was found out from the Map of the Directorate of Mineral Management for Norway that two active mines exist in Bodø. The respective company (Nordland Betong) was contacted and shared that the mines are practically not operational anymore and therefore they could not share any extracted quantities. With the data for Nordland (NUTS3) available, the goal was to downscale the data for other years based on persons employed in the sector. However, according to the statistics on "Employed persons by place of work, by industry", there are zero people working in any mining or quarrying activities in Bodø. Only 2009 was the last year, where a total of three people were employed in mining. Clearly, people were active in the mines up until recently, since these were operative, but it is possible that employees are not classified as such for statistical purposes, if they e.g. are not working in this position full-time or as their primary capacity. Instead, they are likely included in construction employment statistics, which did not provide a reliable coefficient for downscaling.

Manufacturing

The manufactured amounts were derived from the Norwegian national statistics called "10455: Sold production of goods in the manufacturing industry, by 8-digit Prodcom code 2008 - 2020". The relevant produced materials were selected and then calculated from kilograms to tonnes. Thereafter, employment numbers in that sector were used as a proxy to downscale the values from Norway to Bodø. Although the materials are available on a very detailed material level, they were not classified to the sector specific construction materials, but grouped into one, which is why they are considered low in terms of completeness for the data quality. In addition, since the volume of concrete production was provided by Nordland Betong, its mass was determined and added, while all concrete related materials were then subtracted from the national statistics calculation. While Nordland Betong is one of the main concrete producers in Bodø, it is recognised that the value for concrete is smaller than it is in reality.

Retail

In the case of retail, the data gap could not be closed. While the value could be derived by subtracting exports from production, the data quality of both of those parts is already quite poor overall that deriving a number through calculation of them would not have produced any valuable numbers. The issue around data in that area and level was confirmed by a recent study, albeit focused on Denmark, entitled “Cities as organisms: Urban metabolism of the four main Danish cities” (p.3), which stated that “it should be noted that inflows of construction materials and goods could not be quantified due to unavailability of public data at the city level.” It goes on in saying that “data on construction material inflow is difficult to obtain at the city level, if existing at all. Worth mentioning here is the current development of dynamic built environment stock studies that might help get a better understanding on the size of construction material flows entering cities” (p. 13). Their findings could be confirmed for the inflows represented by the lifecycle stages of retail and use, for which the data was not obtained.

Use

As mentioned under “retail”, data for the use lifecycle stage could not be derived. Although the "Total construction applications processed (number)" exists, it does not specify what the applications are for, e.g. building typology, renovations etc. In addition, the use of materials for infrastructure such as roads etc. is unknown too. While in principle possible to determine it indirectly, namely by applying the DMC (Domestic material consumption) formula (Domestic extraction used + Imports - Exports), this calculation was not possible because the domestic extraction value is missing. The concrete that is manufactured in Bodø could have been added to the use stage. However, it would have been the only material out of eleven, greatly underrepresenting the total flow. Furthermore, it was unknown how it is allocated to the various other LCS, e.g. how much of the concrete is actually used in Bodø.

Stock

For the stock, the materials in the building were determined with the following stock calculation methodology.

Data

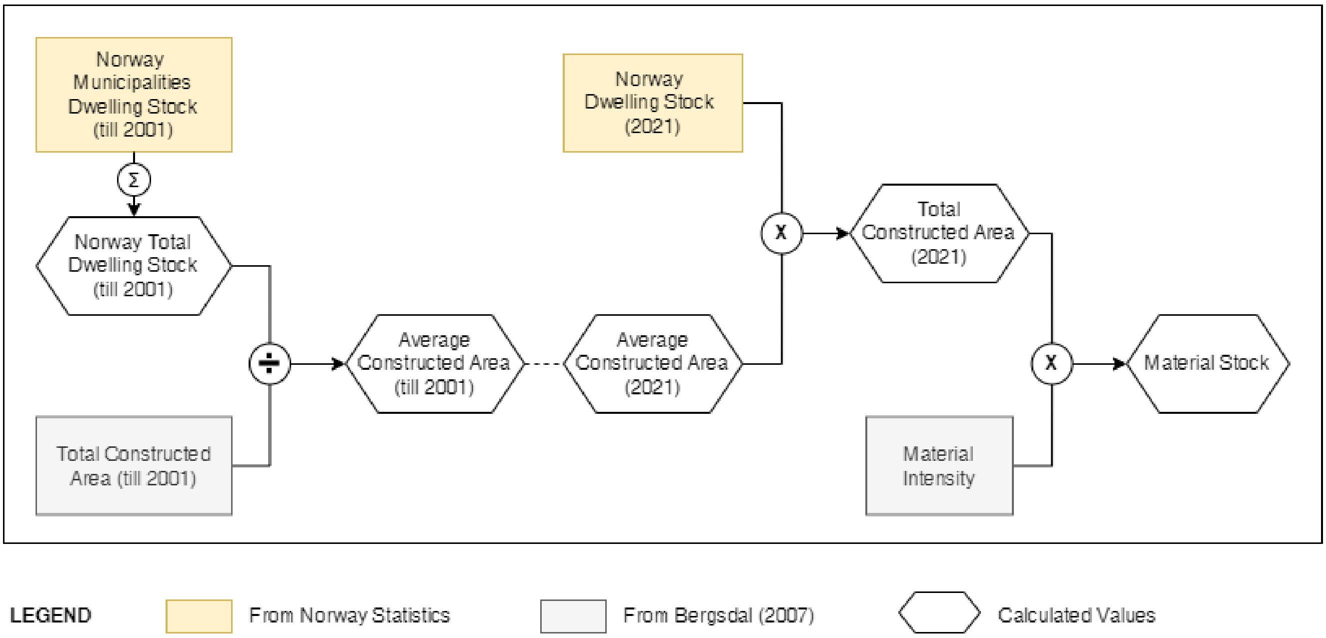
For the calculation of the building stock, two data sources were mainly used, namely, the StatBank data from Statistics Norway and a research paper by Bergsdal et al. (2007) titled ‘Dynamic material flow analysis for Norway's dwelling stock’.

While Norwegian statistics provided information on the total number of residential and non-residential buildings, disaggregated by the municipality, type of building, and cohort (timeframe of construction), the national statistics do not provide the total constructed area. The statistics showed that in the year 2021, 64% of the buildings in Bodø were residential and 36% were non-residential.

From Bergsdal et al. (2007) material intensity values (kg per sqm) were obtained for the two most prominent materials in Norwegian building construction - concrete and wood. The total constructed area was extracted from the paper as well. These figures were disaggregated by cohorts up until 2001 and by housing type as well.

Methodology

It was decided to focus on the dwelling stock alone, as there was little information to be found on non-residential buildings. The objective for the stock calculation was to find the average constructed floor area for each housing type and cohort. This would be used as a multiplier to get the total constructed floor area of different housing types and cohorts in 2021. Further, when multiplied by material intensities of various materials (concrete and wood in this case) the total stock of these building materials in the region could be derived as well. See Figure for a visual representation of this methodology, which is also defined as steps in the text below.



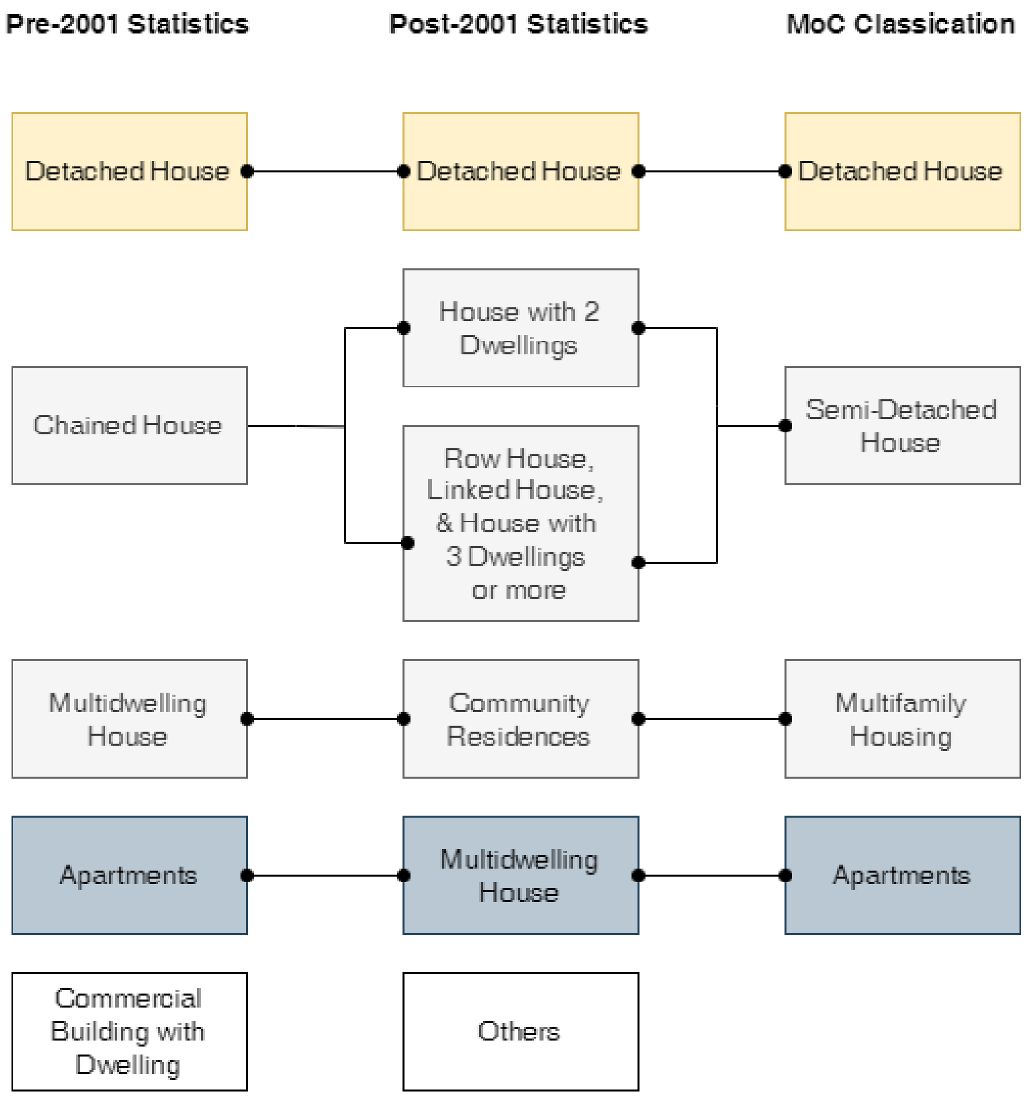
[Data Source]

Step 1: Cleaning up the data

Bergsdal (2007) used the Norwegian statistics dated before 2001, up until when the housing classification was different. The housing was classified into 5 categories - Detached house, Chained house, Multidwelling house, Apartments, and Commercial buildings with dwellings, as can be seen in Figure . Post 2001, Statistics Norway classified its dwellings into 6 categories - Detached house, House with 2 dwellings, Row house, linked house, and house with 3 dwellings or more, Multidwelling house, Community residences, and Others.

On clarification with Statistics Norway, it was learnt that some categories were clubbed together post 2001. To match the numbers from the research paper and the current statistics, four housing categories were created: Detached house, Semi-detached house, Multi-family house, and Apartments, which correspond to both pre and post-2001 housing classifications as shown in Figure 2. Commercial buildings with dwellings, and Others, as they were ambiguous categories, and occupied less than 2% of the dwelling stock, were left out.

Apartments in the research paper were buildings with 3 or more floors, whereas multidwelling houses were defined as buildings with less than 3 floors. This made them structurally very different, which was also evident from their vastly different material intensities. However, in the post-2001 statistics, there is no classification for apartments, but rather a 'multidwelling house' and community residences as a separate category. This was slightly confusing, but after some deliberation and trial-and-error, the pre-2001 multidwelling houses were corresponded with post-2001 community residences, and the pre-2001 apartments with post-2001 multidwelling buildings.



Data Source

Step 2: Calculating the Multiplier

After sorting the data from both papers into the four new categories, Norway's total dwelling stock until 2001 was calculated and disaggregated by cohort and typology. This was then divided by the Total Constructed Area until 2001 to get the Average Constructed Area until 2001 for each cohort and housing typology.

Step 3: Adjusting the Tables

These averages for the year 2021 were projected manually to get the multiplier for each cohort and housing typology. The same was also done for the material intensity data.

Step 4: Calculating Total Constructed Area This could then be multiplied by the present-day dwelling stock statistics available with the StatBank for the year 2021, to get the Total Constructed Area 2021.

Step 5: Calculating Material Stocks

With the total constructed area now available, the material intensity was multiplied to get the stock of materials per cohort and per typology. The amounts were summed up to get total stock for each material.

Waste collection and treatment

The data for waste collection and treatment were obtained from Iris Salten, one of the two main local waste companies. Therefore, it is not complete and fully representative of the total waste amounts. The data were provided for the years of 2016 to 2021 and in tonnes, so they could be used directly. While the collected waste is broken down into various material groups, these are understandably different from the eleven materials that make up the sector in this assessment, while data for some materials (e.g. metals) were missing entirely. In addition to the classification by materials, the data also differentiated by the origin of waste, namely if it is from household or commercial sources. Iris does not distinguish from which activity the waste stems from, i.e. from construction, renovation or demolition.

Imports and Exports

For imports and exports, national road freight transport data for unloading and loading regions (NUTS3) respectively, from 2019 were used. The data is in tonnes, so it doesn't suffer in quality through conversion. However, an estimation needed to be made for the share of materials used in construction. For this, it was estimated that 80% of the materials for selected categories from the NUTS3 imports are used for the construction sector. The same applied to export.

There is additional data on rail, maritime and air transport. However, this does not help in the assessment, because only an overall number is given without a breakdown in materials. The estimation of the share of materials used for construction, plus downscaling from NUTS2 would provide values too rough to be of any use.

To summarise overall, the data gaps stemmed from, (1) some data only being available on a national level and not a municipal level and (2) large amounts of data being unavailable due to lack of reporting and/or trade secrets. These barriers gave valuable insights into the nature and availability of data surrounding the construction sector. The lessons learned from this exercise help lay the groundwork for a better understanding of what kind of data is most meaningful to show the impact of circular activities.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector

This report provides information on the construction sector, its size, actors and materials handled in the municipality of Bodø. Based on that it can be summarised that the construction sector in Bodø is quite small compared to the national average. The most number of employees are engaged in building construction, followed by renovation and interior activities. A few actors are regionally and nationally important as well. The largest local companies in the municipality have been established for well over 30 years and have consistently contributed to the development of Bodø, as well as Northern Norway in some cases.

Bodø heavily relies on imports as there is no extraction occurring in its jurisdiction and little circularity in the building material value chain. Apart from direct reuse of lightly contaminated and uncontaminated concrete, and the recycling of recovered insulation, the material flows in the industry are quite linear. The rate of landfilling is quite high and overall, the municipality of Bodø still has a long way to go to make the material flows of their construction sector circular.

Connection to and upscaling of demonstration actions

The municipality of Bodø has three demonstration actions (DA) planned to showcase its intent to encourage circularity in the construction sector in Bodø. These three DAs revolve around a major urban development project called *'New Airport / New City'* that is being undertaken by the Bodø Kommune. This involves demolition of the old military airport, creating a new city district in its place, and constructing a new airport in a new location.

Through the DAs, the city will become a living lab, where tools and methods are developed and tested to boost circularity in urban development.

- **DA 1**: DA 1 involves demolition of the existing military airport with **circular material management**. The circular strategy is to **repurpose existing structures** as much as possible and perform **selective demolition and reuse** of construction materials where repurposing is not possible. This first stage involves laying the groundwork by **mapping** existing structures and materials on site, **assessing** quality and pollution, **identifying** recycling and reuse potential, establishing **intermediate storage** and treatment facilities for CDW. This stage also involves tools such as a life cycle CO2 calculator, construction materials passport, databanks, and a secondary materials marketplace, to name a few.

- **DA 2**: DA 2 is the stage for involvement of professional stakeholders (construction consultants, entrepreneurs, architects) and citizens in the city development process. At this stage, people and stakeholders are **engaged in dialogue** on how to repurpose and **prolong the lifetime** of existing buildings and materials when designing the new city, as well as technical dialogue on practices of screening and selective demolition. Using 3D GIS visualisation tools and the CityLab stakeholder platform, DA 2 stimulates imagination and opinions of people by showing 3D visualisation of future Bodø along with sustainability indicators for different options.
- **DA 3**: DA 3 is the final stage of embedding **circular strategies into the planning** of the new city district.

The tools and methods developed through Bodø's DAs have the potential to be scaled regionally, nationally and internationally. Guides (standard operating procedures) can help other cities adopt Bodø's methods on data gathering, data visualisation, and scenario development to make informed decisions. It will also be described how mapping of resources on the demonstration area is done, how information is distributed to a databank and to a market place for reused materials. Quantifying the potential for upscaling is difficult to do, as in the case of the airport, the project is very specific to this situation and because DA 2 and 3 are rather qualitative.

Recommendations for making the construction sector more circular

In order for the construction sector to become more circular, the **successes and methods** behind the actions striving for that need to be made as visible as possible. This will ensure replicability and that the barrier of knowledge gaps, in terms of how to build with circularity on a purely practical level, are reduced. As per the waste hierarchy, prevention of waste is the strategy that is most favourable from a circular economy perspective, while recycling and energy recovery are the least, barring the landfill.

It can also be recommended to **increase engagement and collaboration with local players** that already have circular initiatives and solutions, for example:

- Nordland Betong AS, a concrete manufacturer in Bodo, is a partner in collaborative research initiatives such as the Concrete Innovation Cluster, a national innovation project aiming for a **carbon-neutral concrete industry** by 2030, and Circulus a research project between the UiT Norges Arktiske Universitet and major industry partners, that aims to achieve 75% **reuse and recycling of concrete structures** and 75% **reduced energy consumption**. It has also tested the use of Recycled Concrete Aggregate (RCA) in their production process to make their products more circular. Further, they are working on the reduction of sludge produced during the concrete production process, which right now is a waste material.
    - Collaborative efforts between industry and academia need to be further encouraged to increase the uptake and implementation of cutting edge innovation in the field.

    - Concrete users and concrete product manufacturers, specifically, need to look into replacing virgin aggregate with RCA to the maximum extent possible.
- Gunvald Johansen Bygg AS is Bodø's largest locally owned group in the construction industry and one of the region's largest contractors. Their goal is to have at least [80% **source sorting**] of waste.
    - Bodø Kommune should support other construction companies to have such ambitious waste sorting goals as well. One way to do this is to provide graded incentives based on the percentage of source sorting the companies do. This could be in the form of publicity, tax rebates, fiscal incentives, etc.
- Byggpartner AS build cabins and also provide their customers options to **renovate and rehabilitate** their old homes. They recently renovated a 100 year old house to modern standards wherein they replaced the roof, cladding and windows and also re-insulated the home.
    - Such efforts not only increase the lifespan of the building materials and reduce pressure on mining of virgin resources, but also preserve the heritage value of a place. Bodø has more than 300 homes which are over 100 years old. The Kommune could incentivise the **renovation** of such homes to today's modern standards to promote circularity in the construction sector and prevent waste.
- Byggesystemer Bodø AS is one of Norway's largest construction machines rental company and scaffolding contractor. According to them, "**rental** and efficient utilisation of the equipment reduces the total carbon footprint due to higher utilisation of machinery and equipment by 30% to 50%, depending on use and equipment" (source).
    - The Kommune should promote circular business models such as these, which support rental services over ownership (Product as a Service or PaaS) and maximise the utility of a product while being profitable.
- Grassproffen AS is a glazier which offers **repair and replacements** of broken glass in windows and frames to its customers.
    - Broken window panes fall under the 'Window glass, roof tiles, bricks, porcelain and tiles' category. Of these, insulating glass panes containing PCBs, chlorinated paraffin and phthalates are covered by a separate return scheme and the remaining waste goes to landfill. Repair and replacement of broken glass is a great alternative provided by Glassproffen AS, that can be offered by other glass manufacturers in the region as well. This increases the lifespan of the window and should be promoted by the Bodø Kommune to divert waste from the landfill.
- Egna is a thrift store based in Bodø. It **sells items** that are made from sustainable materials, recycled, refurbished, redesigned, and ready for reuse. In terms of CDW, Egna **accepts furniture and "interiors" items**. For its new store in Bodø Storsenter, Egna is collaborating with the architectural firm Rintala and Eggertsson Bodø. Their vision is to be "organic, inclusive, and different", with the construction largely done using recycled materials. For this, they are collecting second-hand building materials from people. Some of the materials they have listed on their website are - wood, OSB boards, plywood, old parquet flooring, wooden doors, tin roofing, metal plates, copper pipes etc. (Data Source)

    - This could serve as a model construction project that can inspire new constructions in Bodø to follow suit and build using sustainable, recycled materials.

Finally, it is recommended that the **data availability and quality** are improved on, so that the region can determine its true potential of available resources and wastes per year. This way, the potential for upscaling the demonstration actions could be better analysed and a circularity process for the sector developed, containing main objectives and an action plan.

References

- Norway
- Nord-Norge
- Nordland
- Population of Bodø 1986-2021 line graph
- Bodø land use map
- Distribution of activities by number of employees

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

HØJE-TAASTRUP

CITYLOOPS

METABOLISM OF CITIES

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Høje-Taastrup are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Aluminium	Bitumen / asphalt	Bricks
Concrete	Glass	Gypsum
Insulation	Iron (steel)	Sand and gravel
Soil	Timber	

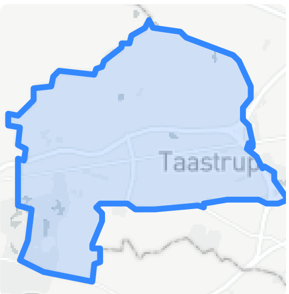
The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

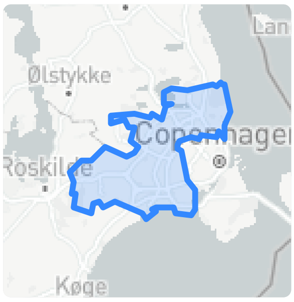
(The italic texts in this report were written by Metabolism of Cities' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

Urban context

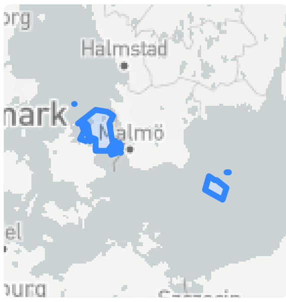
To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.



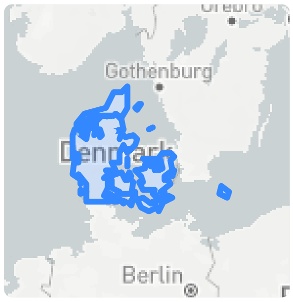
Høje-Taastrup
50,759
78 km^2



Københavns omegn
548,370
342 km^2

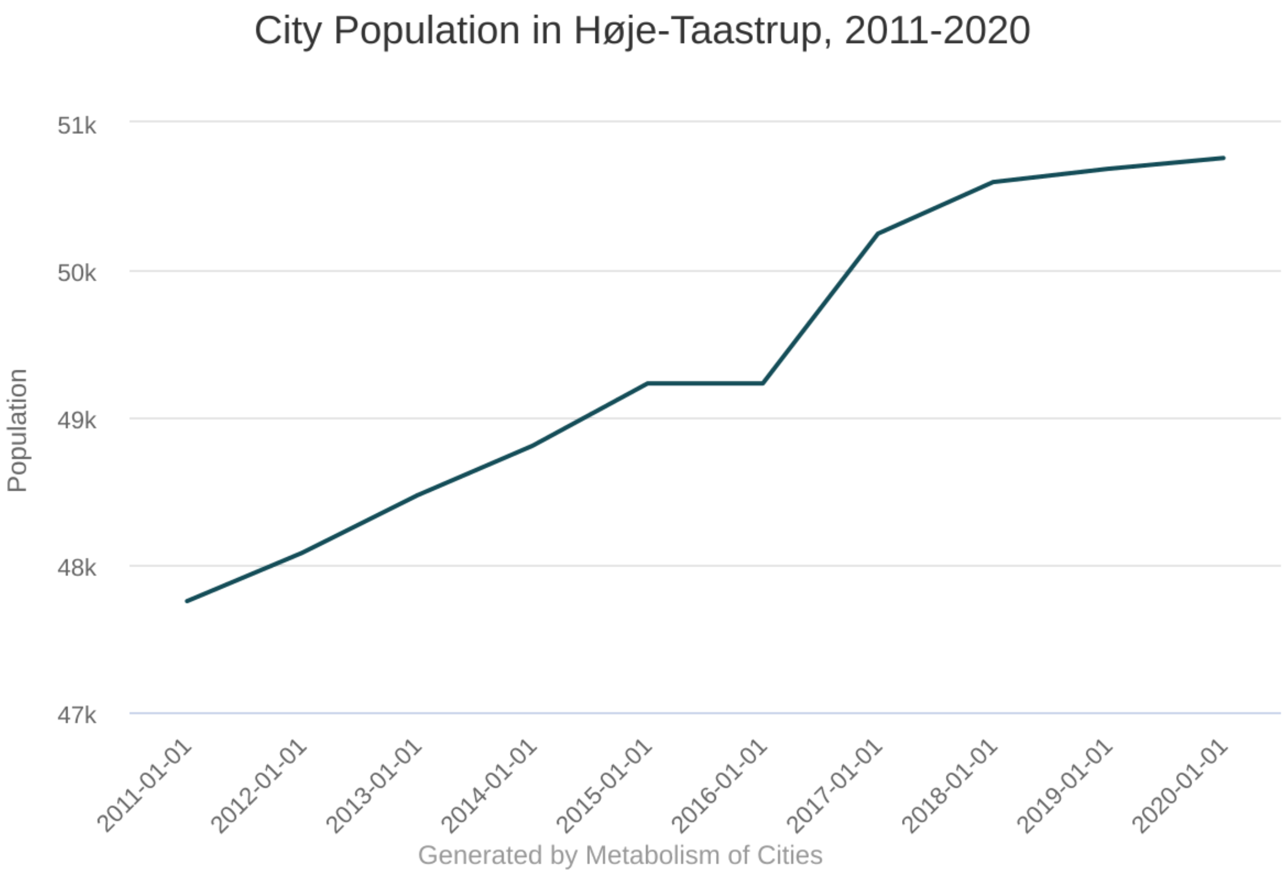


Hovedstaden
1,846,023
2,568 km^2



Denmark
5,822,763
42,933 km^2

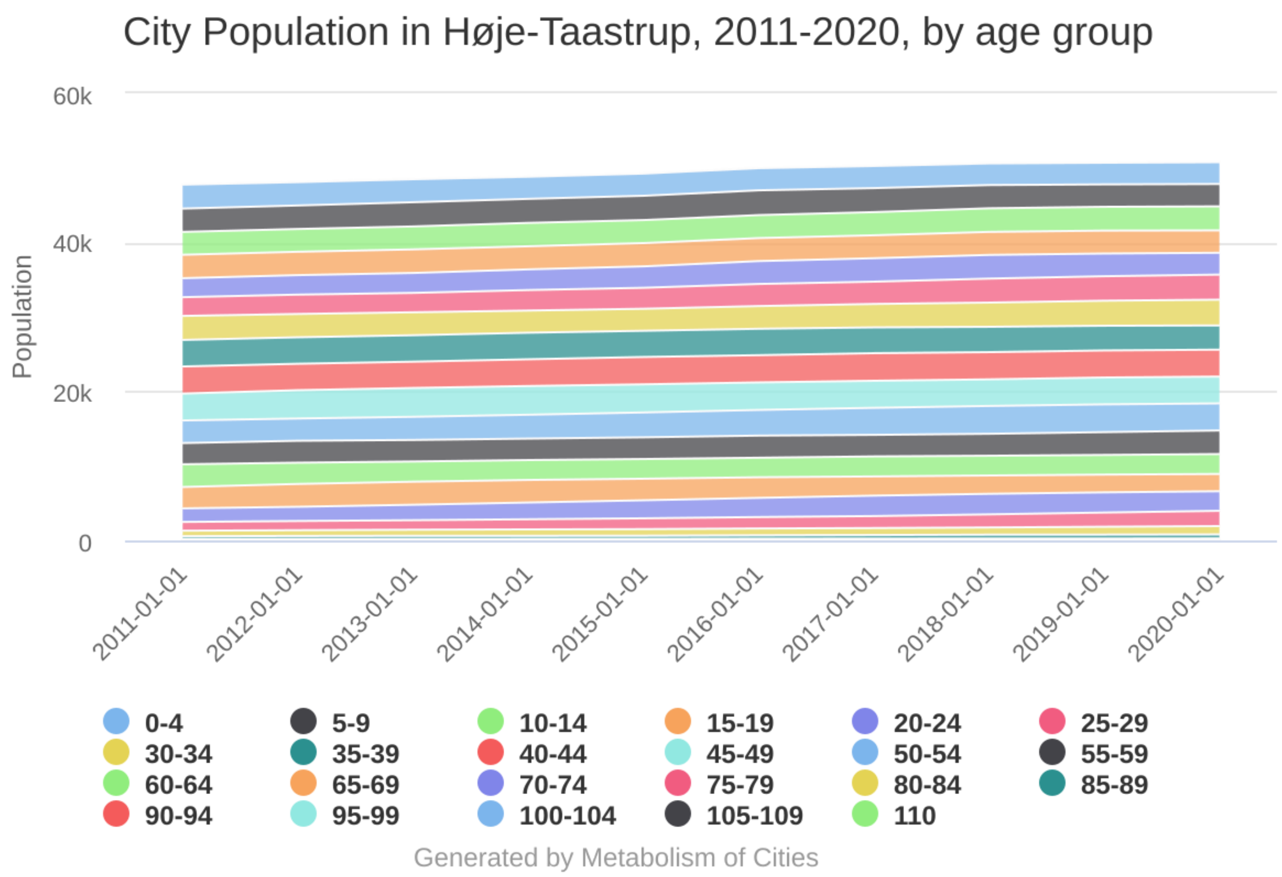
Population of Høje-Taastrup



Data source

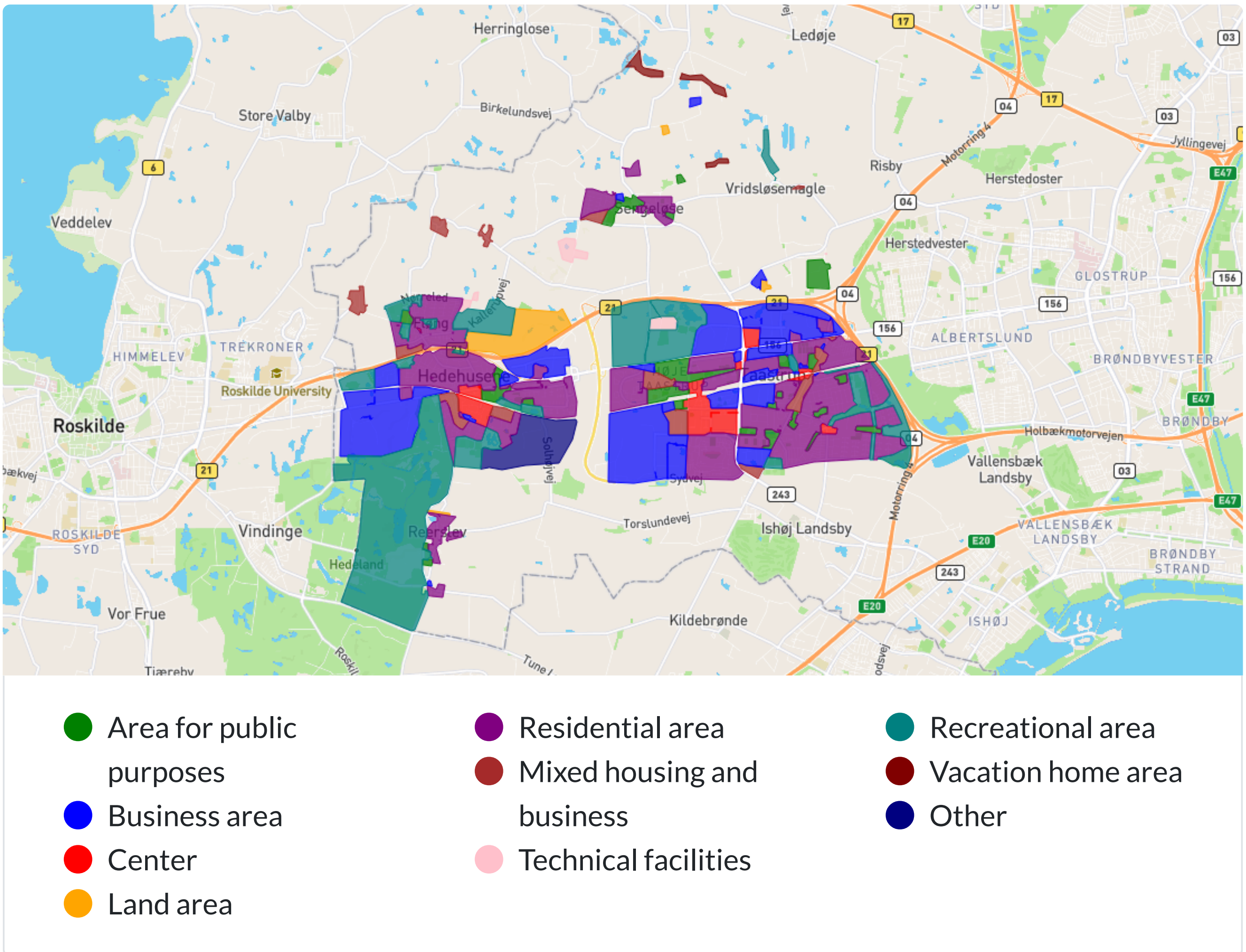
The population of Høje-Taastrup has been slightly increasing, namely by 6.3%, from 47,753 inhabitants in 2011 to 50,759 in 2020. There were a total of 21,645 households in 2020. Due to urban development measures, the population is expected to further increase to about 60,000 - 65,000 inhabitants in the course of the next 10 years.

As can be seen in the graphic below, the population is comparatively young with half of the population 49.6% of them being 39 years and younger.


City Population in Høje-Taastrup, 2011-2020, by age group
60k
40k
20k
0
Population
2011-01-01
2012-01-01
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
2020-01-01
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-99
100-104
105-109
110
Generated by Metabolism of Cities

Data source

Land use



Data source

The municipality of Høje-Taastrup has two main urban areas, namely Taastrup/Høje-Taastrup and Hedehusene/Fløng. It is in these areas where the main part of the population lives. In addition to these urban areas, there is a large part of the municipality that is rural, with agriculture as well as nature areas.

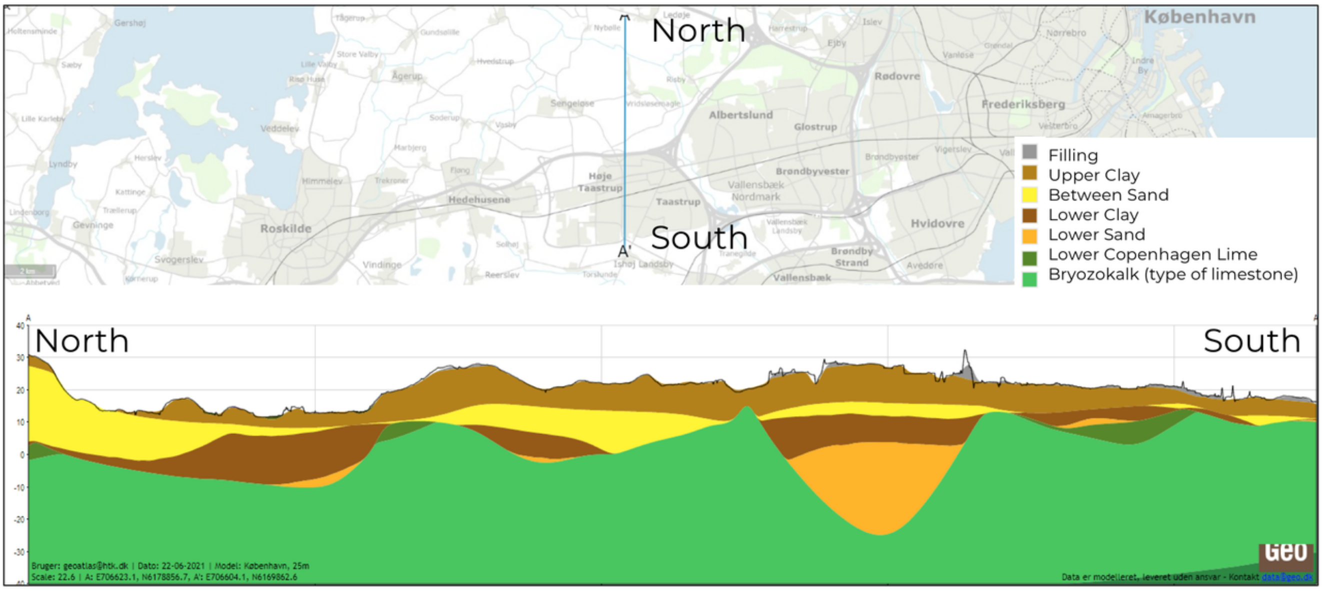
The land use map of Høje-Taastrup shows 10 different types of land use. It needs to be noted that those are the ones represented in the municipal planning framework of 2014, which do not account for the entire area of the municipality (78 km2), but for 45% of it (34.9 km2). These land uses include general and specific types of residential, business and public purpose areas. The largest share of land is used for residential areas and makes up 10.6 km2 (30.4% of total municipal planned land). The use for recreational purposes is followed by a close second (28.3%) with 9.9 km2. Finally, the business area makes up the third largest share with 21%, while the remaining uses (mixed housing and business, area for public purposes, technical facilities, land area, vacation home area, center, and other) are all below 5%.

With regards to the larger geographical context, "Høje-Taastrup Municipality is located west of Copenhagen and is one of the largest municipalities in the capital area. The municipality covers an area of 78 km2 and has no coastline. In the areas around Hedehusene, Fløng, Taastrup and Høje-Taastrup in the central and south-eastern part of the municipality are densely populated with an extensive road network and are intersected by the Holbæk motorway.

Høje-Taastrup Municipality is one of the capital area's greenest municipalities. 2/3 of the area consists of forest, meadow field and lakes with a number of protected areas, including Vasby Mose, Sengeløse Mose and Porsemosen. In many places, especially between Baldersbrønde and Høje Taastrup, around Vridsløsemagle, Sengeløse and Soderup in the north and south of Hedehusene, you can still experience smooth, slightly hilly moraine landscape created by the recent ice age. Smeltevandsdalen Store Vejeådal between Høje-Taastrup and Albertslund municipalities forms an 11 km long green wedge.

The area between the railway and the Holbæk motorway is approx. 20-40 meters above sea level. It then falls to the southeast, north and northwest and is interrupted in several places by meadows and bogs, which in an arc extend from east to west and are drained by Hove Å and its tributaries to Nybølle Å, which flows to the north and forms boundaries to respectively Roskilde and Egedal municipalities.

From Hedehusene, the landscape gradually rises to the south through Reerslev and Stærkende and culminates in the 69 m high Maglehøj. It was for a long time the municipality's highest point, but is today surpassed by the artificial, 81 m high hill Flintebjerg in Hedeland. Where the landscape south of Hedehusene and west of Reerslev and Stærkende previously formed a continuous moraine plain, extensive gravel excavation in the 1960s and 1970s as well as subsequent re-establishment subsequently created a strongly hilly landscape with artificial hills and lakes. Today, the area is Hedeland Nature Park, which extends into Roskilde and Greve Municipality.



[Data source]

Høje-Taastrup municipality is intersected by a watershed that lies from east to west in a line around the Holbæk motorway. The northern part of the municipality is drained by streams that run northwest to Roskilde Fjord and the southern part of streams that run southeast to Køge Bay. Høje-Taastrup municipality is therefore located at the source of the river systems and therefore has far fewer problems with floods from rivers than the downstream municipalities" (Anja Kiel Groth, groundwater employee of Høje-Taastrup).

Economic context of construction sector

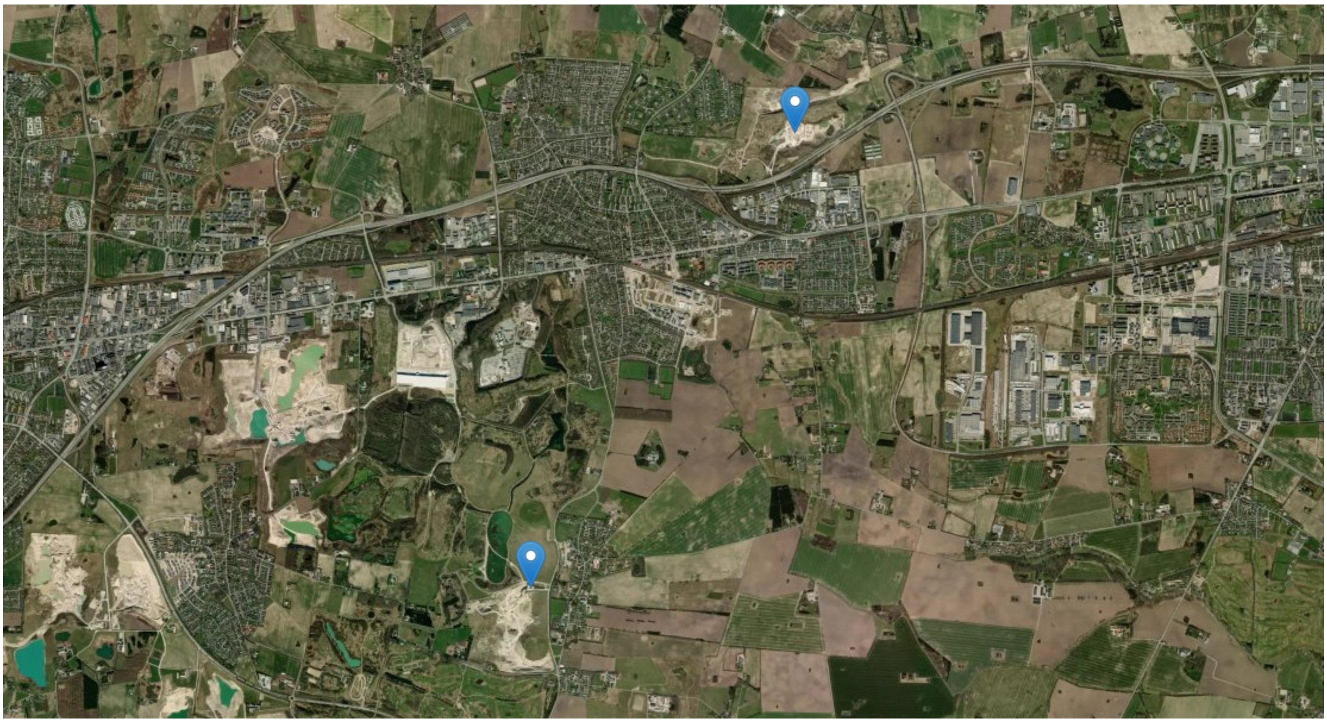
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	GDP (monetary value, in kr.)	Employees
Høje-Taastrup	7A	2,739
Københavns omegn	8A	28,764
Hovedstaden	9A	9B
Denmark	10A	178,864

The construction sector in Høje-Taastrup

The number of people employed within the construction sector in Høje-Taastrup is slightly increasing. Høje-Taastrup is undergoing urban development in primarily two larger areas but also in other areas in the municipality. Therefore, a lot of construction is taking place. The high construction activity does not necessarily correspond directly to increased local employment in the construction sector as many workers commute to the building sites from other municipalities.

The actors of the construction sector



Data source

The primary actors associated with material flows in the construction sector are: Kallerup Grusgrav, NCC Reerslev Grusgrav, IBF Hedehusene, Tscherning, Lind & Risør A/S, F.J. Poulsen's Anlægsgartneri A/S, John Jensen A/S, Dansk Miljøforbedring, Vestforbrænding.

Extraction

Extraction in Høje-Taastrup is handled by two companies, both depicted in the map just above. The first, Kallerup Grusgrav is a company that operates a gravel mine and has been in existence since 1971. The company's purpose is to extract raw materials from hill materials, among other things for filling / securing roads or backfilling around houses. They also accept concrete and bricks for recycling. The crushed concrete is used just like ordinary stable gravel and bricks are used such as drainage layers at the bottom of riding arenas. They also sell topsoil and lime.

NCC Reerslev Grusgrav is another company operating a gravel pit and is part of NCC, one of Denmark's largest construction and contracting companies. At their site, raw soil, sand, gravel and stone have been extracted for a long time. In the beginning of 2021, NCC Reerslev Grusgrav closed down their activities in the gravel pit, as the area is fully exploited.

Manufacturing

IBF Hedehusene is a large concrete manufacturer, which produces concrete sidewalk tiles, roof tiles, paving stones, retaining walls and ready-mix concrete amongst other things.

Tscherning is a company that operates both locally and nationally and deals with demolition, construction work, environmental remediation and machine rental.

Tarkett A/S is a wood flooring company. They work on the manufacturing and wholesale of flooring. They do have 25 employees at the registered location in Høje-Taastrup, however, only their headquarter office is located in the municipality, but none of their 30 factories. Tarkett currently has approx. 11,000 employees in over 100 countries and had a turnover of approx. 2.5 billion Euro in 2013.

Lastly, there are three companies that deal with the "manufacture of metal structures and parts of structures". Schrøders Metal A/S is a metal product factory that works as a subcontractor to relevant industries. Established in 1997 and working with 12 employees today, their focus is on the processing of metal sheets, pipes and profiles with the following materials: steel, aluminum, titanium, messing, copper and plastic.

K.S. Smede og Montage A/S, founded in 1986, is a 16 employee large company today. They work on steel and aluminum constructions, handling forging as well as assembly tasks. With their workshop and office facilities in Taastrup, they carry out work for customers, as well as act as a subcontractor to several of the country's largest construction companies.

The third metal working shop is the one of Ebbes Kleinsmedie ApS with 21 employees. It was founded in 1973 and specializes in blacksmithing, sheet metal work, iron constructions and copy cutting, handling iron, stainless steel and finer metals. They are also a regular supplier to the elevator industry with elevator shafts, compartments, frames and doors, as well as industrial painting, assembly and maintenance.

Retail

The main actor within the category of "Retail sale of hardware, paints and glass in specialised stores" is Silvan City2 with 11 employees. The company is a part of a large retail chain of building materials and sells to private and professional craftsmen.

As for the "retail sale of furniture, lighting equipment and other household articles in specialised stores", IKEA is the largest player in the municipality. Although the company sells a lot of articles, it can be assumed that most of their products are exported into the municipality and that for example, wood is not sourced from the area for their products.

Use

The largest actor for the construction of residential and non-residential buildings is Lind & Risør A/S with 250 employees. Lind & Risør is a 100% Danish family-owned full-service architect and construction company that has built commercial and residential houses since 1980. It provides construction services to customers throughout Denmark. Therefore, it is not known how much construction activities they engage in in Høje-Taastrup.

With regards to the construction of roads and motorways NCC Danmark A/S is a large player, with 19 employees declared. However, as with the other companies engaged in the use phase of construction, their material use (rate) is unknown.

“Landscape service activities” are another activity where construction materials are used. A big actor (around 70 employees) is F.J. Poulsen's Anlægsgartneri A/S. Starting in Roskilde with a horticultural business and nursery in the 1930s and evolving into landscape gardening for private as well as tender business, the company eventually relocated to Taastrup in 2007, to have more space. Nowadays, the company engages in all types of landscape and construction work (sewer, local rainwater diversion, and cloudburst protection, pruning and top cutting, BIO cleaning of lakes, roof gardens and green roofs, concrete crushing & sale of recycled materials, private gardens and driveways, artificial turf and multi-lanes, carpentry, harped topsoil). From a resource reuse perspective, their crushing of concrete and sale of recycled materials are especially relevant. The company purchased a crushing plant in 2004 for crushing concrete rubble and tiles, in order to reduce the use of raw materials such as bottom protection and stable gravel.

Aside from those actors in the basic construction part, there are several companies related to installation services, such as the installation of plumbing, heating, joineries, and roofing.

John Jensen A/S, VVS Installationer was established in 1962 and employs around 200 people today. With their main work revolving around plumbing work, John Jensen VVS A/S services public and private organisations, pharmaceutical and food industry, business and production companies, district heating and housing companies John Jensen A/S 2021](https://www.jj-vvs.dk/om-os/).

SH Installation A/S is another plumbing installation company, based in Hedehusene. It has 69 employees and handles different services from single installations to turnkey contracts in plumbing for heat, water and sanitation.

Wicotec Kirkebjerg A/S, though headquartered in Copenhagen, has regional offices in Taastrup with 400 employees. It offers a broad spectrum of services: Electrical and mechanical Services, piping and plumbing services, HVAC services, district heating, fire and protection, building automation, and service & maintenance across numerous industries such as hospitals, pharmaceuticals, education & research, energy supply and district heating, infrastructure, and commercial- and Residential Buildings.

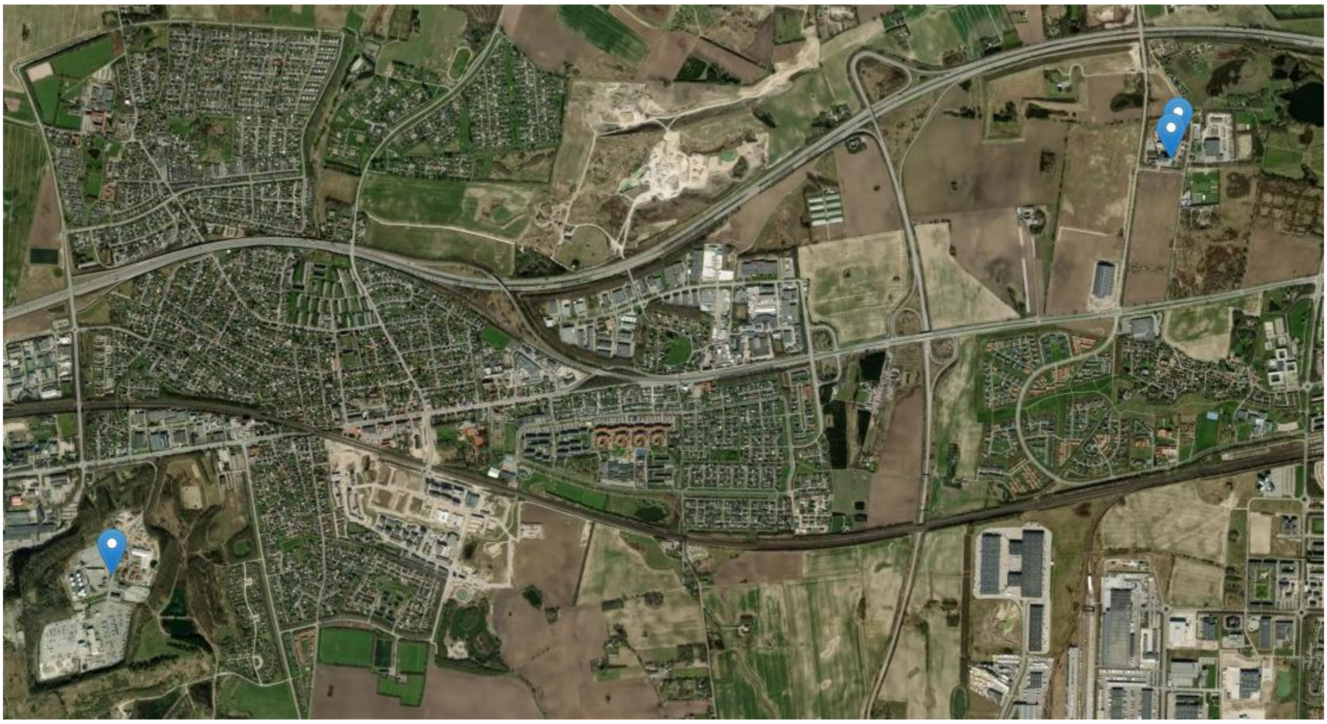
As for joinery installation, Deko P/S is a big employer with 214 employees. The company works on the design, production and installation of partitions of glass, wood, and aluminium. However, it seems that the production site is not actually in Taastrup, but that the location serves as office and storage facility.

Finally, there is one main actor connected to “roofing activities”, namely NimTag ApS. The company, having 30 years of experience, has 40-50 employees, a number of subcontractors and handles various roof tasks such as roofing felt, roof insulation, membrane laying, service inspection and the establishment of green roofs, just as the installation of skylights and fire ventilation NImTag ApS 2021.

Aside from the listed and described companies that engage in the use of construction materials, there are certainly a great many more of them in the municipality. However, for this report, only the main players, those with the largest employee numbers, were included.

Waste collection and treatment

The waste collection and treatment in Høje-Taastrup is generally organised by the municipality itself, which takes care of waste collection for private households, but neither for companies nor demolition waste. For the purpose of the SCA only demolition waste was relevant, which is handled by private haulers. The private haulers need to be officially registered, but it is not the municipality that handles this, but a national system. And the waste depots and recycling drop-off centres are run by private companies, some of which are owned by groups of municipalities. In the construction and demolition waste, the following needs to be separated: natural stone (granite, flint); unglazed bricks and roof tiles; concrete; mixtures of the aforementioned materials; iron and metal; gypsum; fiberglass insulation; soil; asphalt; mixtures of concrete and asphalt. Glass and wood are typically also separated. Waste treatment takes place in the one major waste treatment facility in Høje-Taastrup, the incineration plant. Otherwise the waste is treated in regional facilities, or in only very rare circumstances is it exported.



Data source

As for the waste actors, two main ones with three facilities exist, as can be seen on the map just above. Dansk Miljøforbedring and Vestforbrænding are both waste collection facilities. Dansk Miljøforbedring primarily handles construction waste from large construction projects. The recycling station (Genbrugsstationen) is operated by Høje-Taastrup municipality in collaboration with I / S Vestforbrænding and is geared towards local inhabitants, businesses and smaller constructors doing minor renovations. (Companies can deliver a maximum of 200 kg per year.) At the Vestforbrænding site, 30 different types of waste are collected for recycling and some waste also gets incinerated. Smaller amounts can more easily be collected there. For example, citizens can dispose of up to ten roofing sheets without declaring it at www.bygningsaffald.dk, the national notification form for construction waste. (It should be noted that this website is an optional portal for notification of construction and demolition waste, operated by a consultancy company. There are other systems for notifications of construction and demolition waste, but Høje-Taastrup employs that one.)

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level). However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	338,309.13	Tonnes/year
39	Circular Material Use Rate	52.04	%
48	EU self-sufficiency for raw materials	1.26	%
55	EOL-RR (End of Life Recycling Rate)	14.90	%
57	Amount of sector specific waste that is produced	633,982.50	Tonnes/year
58	End of Life Processing Rate	22.77	%
59	Incineration rate	0.78	%
61	Landfilling rate	19.20	%

The domestic material consumption (DMC) is calculated by adding “Domestic extraction used” to “Imports” and subtracting “Exports”. For Høje-Taastrup, it amounts to 338,309.13 tonnes and 6.67 tonnes per capita. This value is very low compared to the total DMC of 13.4 tonnes per capita for EU-28 in 2019 and even lower relative to the 24.98 tonnes per capita in all of Denmark. However, those latter two also do take into account the **total** DMC and not just the materials used in the construction sector. Since it goes beyond the scope of this work to determine the share of construction materials in the total economy, it will not be further assessed. It does seem unrealistic that the DMC of Høje-Taastrup is only about a quarter of the national value, as construction materials do usually take up more of the DMC than that. This distorted value could likely origin from the estimation of the export values.

The CMU value of indicator 39 is extremely high with 52%, compared to the 12.4% for EU-28 in 2019 and 7.6% for Denmark. This could be due to the very high domestic recovery value (385,208.04 tonnes), relative to that of extraction (583,198.75 tonnes). The first value, in this case, actually only represents the materials that were subjected to recycling and not of how much was actually recovered. This value was in turn used as a recovery value, as the actual amount that was recovered from recycling is unknown. Another difficulty that is added to this indicator is that it was originally designed for metals. Since now materials from different categories are bundled up, it skews the image of the circularity of materials.

The EU self-sufficiency for raw materials indicator is very low with 1.26%. Unfortunately, there is no national value to compare it to. And since the data completeness was lacking in terms of differentiation of the single materials, this indicator couldn’t be calculated for them individually to determine the various self-sufficiency levels.

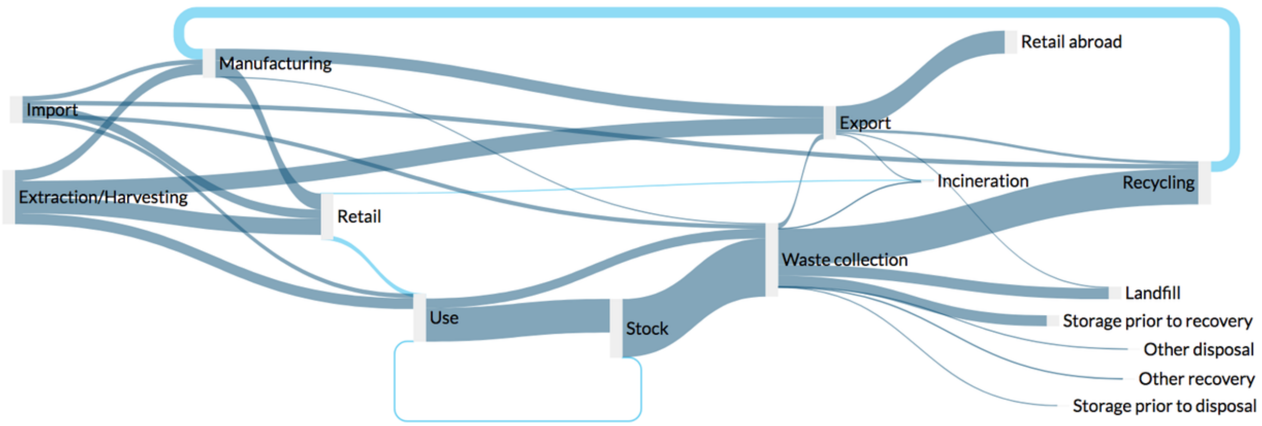
The EOL recycling and processing rates are still considerably low with about 15% and 23% respectively. While 19% of materials are still subjected to disposal and 81% to recovery, the efficiency of recovery could still be improved. There is however uncertainty in those values, as the amounts derived from recycling had to be estimated.

The incineration rate is very low with less than 1%. This is somehow surprising, on the one hand as Høje-Taastrup has its own incineration plant. On the other hand, construction waste materials are usually not subjected to a large extent to those facilities.

Finally, the landfilling rate is still quite high at 19%. The numbers came from the waste statistics and can be considered reliable, thus there is no uncertainty there. Either the municipality really still landfills quite a lot of waste, or the values are influenced by a lack of classification or differentiation of waste use on landfills as “alternative daily cover”.

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



[Data source]

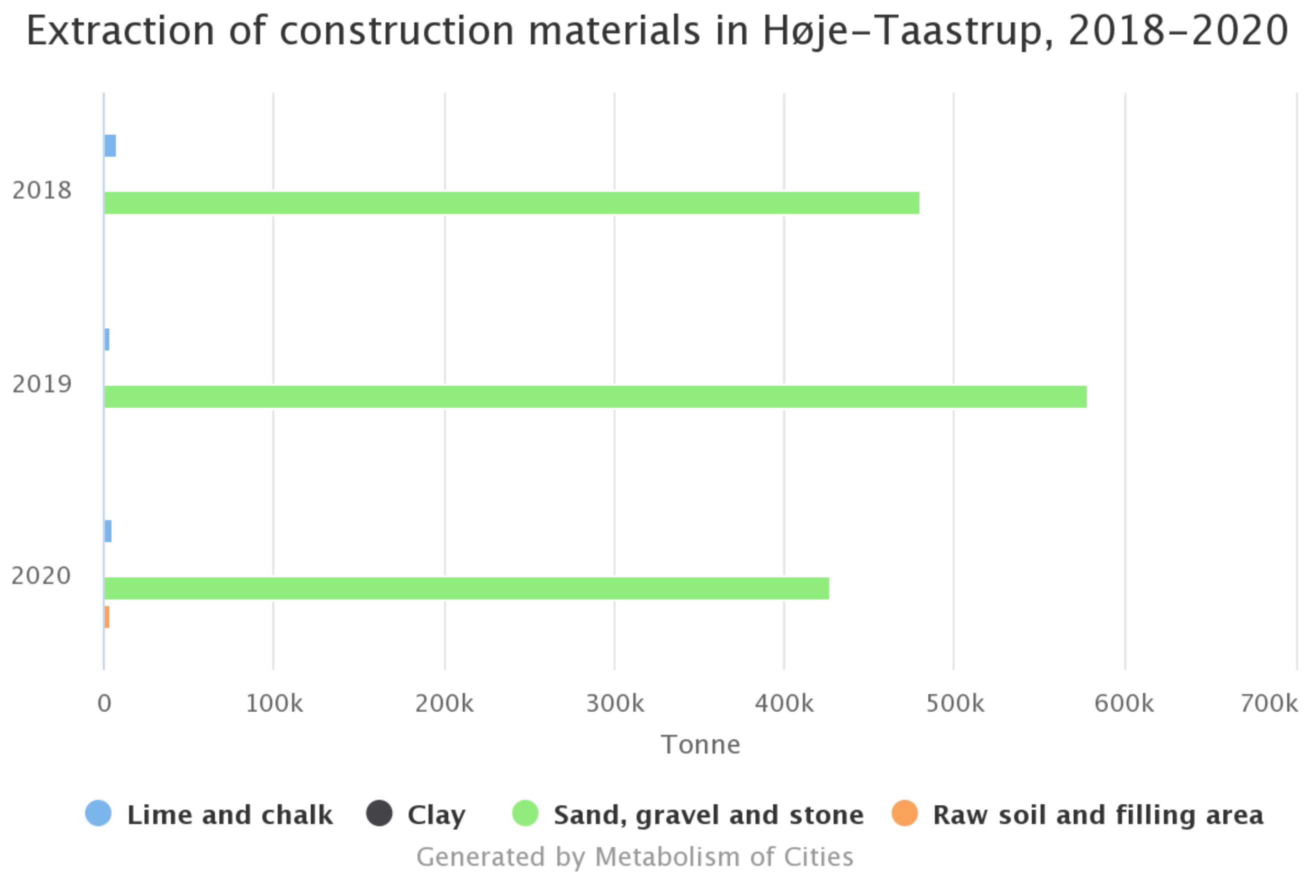
The Sankey diagram builds of course on the collected data that also the indicators have been derived from. Therefore, it needs to be taken into account that the previously discussed data quality influences also the quality and informative value of the Sankey diagram. In addition to the data quality, so-called allocation values also have an impact on the data behind the visualisation. These allocation values were employed to estimate the amounts of materials that “flow” between the single lifecycle stages, since these relationships and quantities were in most cases unknown, except for waste collection going to waste treatment.

Overall, the Sankey diagram for Høje-Taastrup shows that quite a lot of materials are moving around in the construction sector system. The share for **extraction** is quite significant. The total amount sums up the four material groups that are extracted in the municipality:

- Lime and chalk
- Clay
- Sand, gravel and stone
- Raw soil and filling area

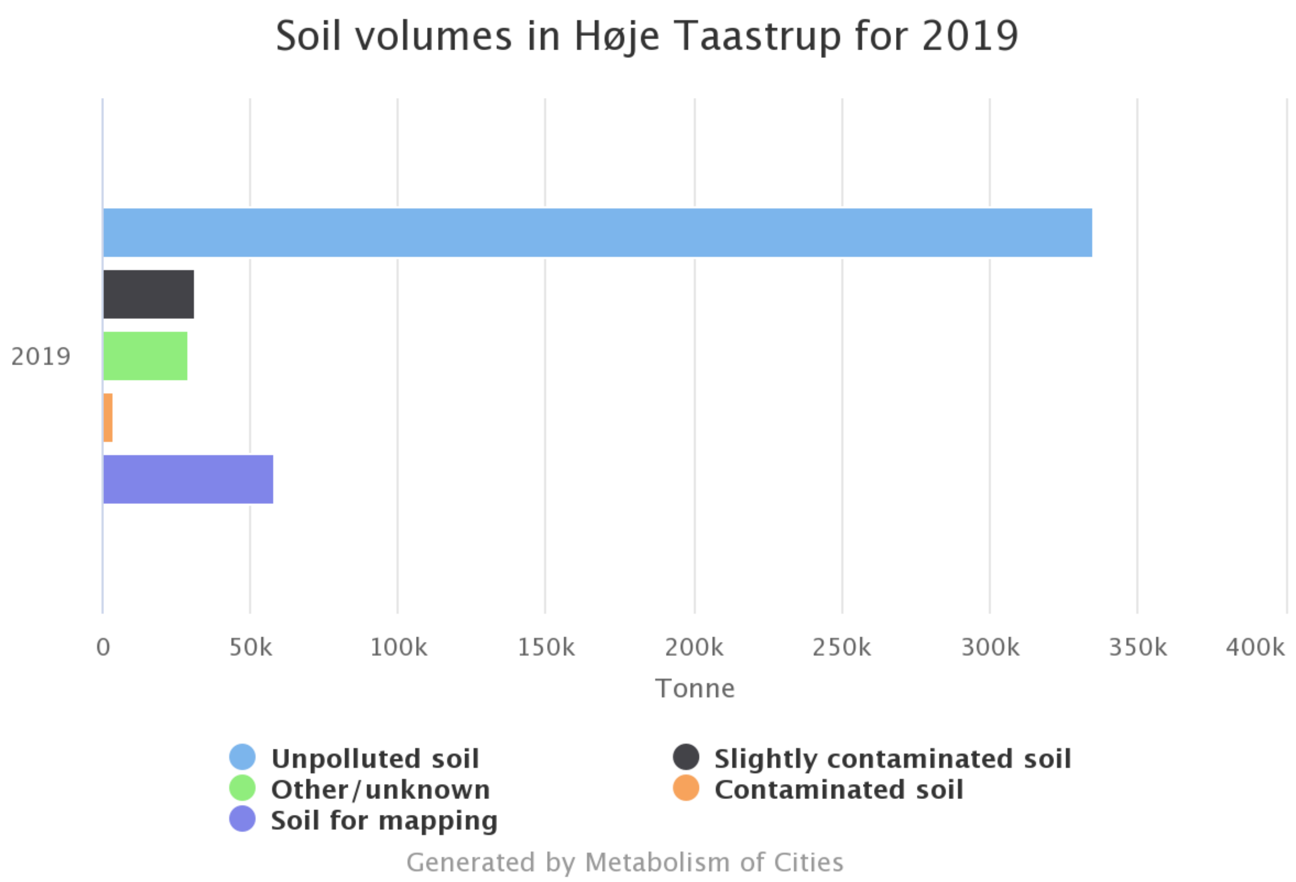
It can also be seen that a lot of the extracted materials get exported to retail outside of the municipality.

The graph just below shows that the amounts of sand, gravel and stone are clearly and consistently making up the larger shares of all excavated materials. Of the two companies engaging in the extraction activities, NCC Industry A/S dominates with over 90% of the total sand, gravel and stone in each year. Their contribution will decrease tremendously, if not amount to zero, in the next few years, since the gravel pit has been exploited and the company closed down their extraction activities in the beginning of 2021.



Data source

It should be noted that although soil can also be extracted and some data on soil was available from an inventory that registers that transported amounts, it was excluded from the Sankey diagram. This is because it is unknown where the different kinds of soil come from, literally and with respect to the stage in the supply chain and what happens to them. For example, they could be stored, recycled, or undergo a remediation process. For completeness, the amounts are nevertheless depicted in the chart below.;



Data source

As for **import and export**, while smaller than extraction, they are both fairly similar in size. **Manufacturing** sees a large inflow of materials from recycling and **retail** is fed with new materials from extraction, import and manufacturing, as well as secondary materials from incineration and use. This latter return flow from use back to retail could be surplus materials from construction sites that are labelled for reuse.

Going forward in the diagram from left to right, it can be seen that there is a data gap from the outgoing materials from **retail** to all other lifecycle stages. This reflects on the gap in the data availability described above.

Use is being fed by imported and extracted materials, although the majority would likely origin from retail. Most of the materials from use end up in stock, as constructed materials. Although it seems that most of **stock** goes to waste collection and a little bit gets reused, this is only true in terms of the data of flows. It might seem that all buildings and infrastructure get demolished again, but this of course isn't the case. It is just that the Sankey diagram does not depict the stocks, the materials that stay in a system for over a year, but only the flows from the single stages.

While the **waste collection** node does receive most materials from the stock, it also gets inflows from imports, manufacturing and use. The diagram shows that the main share of materials leaves to **recycling**, which is also fed by imports and which has a large outflow as return flow to manufacturing. As for the other waste treatment options, **landfill** is quite high and very similar in size to **storage of materials for recycling**. Finally, a significant stream is from **export** to **retail abroad**.

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.

Rating	***Reliability***	***Completeness***	***Temporal correlation***	***Spatial correlation***
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Extraction/Harvesting				
Manufacturing				
Retail	no data			
Use				
Stock				
Waste collection				
Landfill				
Incineration				
Recycling				
Imports				
Exports				

As can be seen in the data quality matrix above, the overall quality of the data is relatively high. The temporal correlation is very good for all lifecycle stages (LCS), as the data was almost always from the reference year (2020) or from 2019. The spatial correlation is still fairly good. However, it does suffer, especially in manufacturing where national data was used and in use, imports and exports where NUTS3 level data were employed. The reliability of the data is ok. For over half of the LCS, the data was measured, while the other half was estimated or provisional. Finally, the completeness of data scores medium for all LCS. This is mostly because the data either only exists for some single or for some economic activities, but not both and not all materials are differentiated.

Data gaps and assumptions

Aside from data often being available, there were still some gaps in local data or the data was not in the right form. The following paragraphs describe how sources, assumptions, and calculations were used for each lifecycle stage.

Extraction

The data for extraction was obtained from the Capital Region of Denmark, as authority of extraction of virgin materials, which provided it for each of the two operating companies of the municipality for the year 2018-2020. It was broken down by materials and measured in cubic meters. To get to the correct unit (tonnes), coefficients from the Eurostat Handbook were used for conversion. All of them stem from this handbook, except soil, which comes from this source.

Manufacturing

The manufactured amounts were derived from the Danish national statistics called "VARER3: Manufacturers' sales by main SITC groups". The relevant materials were selected and then calculated in tonnes with a conversion sheets for conversion from DKK 1,000 to tonnes. Thereafter, employment numbers in that sector were used as a proxy to downscale the values for Høje-Taastrup. Since the materials are only on a 2-digit level, they are considered medium in terms of completeness for the data quality.

Retail

In the case of retail, the data gap could not be closed. The issue around data in that area and level was confirmed by a recent study entitled "Cities as organisms: Urban metabolism of the four main Danish cities" (p.3), which stated that "it should be noted that inflows of construction materials and goods could not be quantified due to unavailability of public data at the city level." It goes on in saying that "data on construction material inflow is difficult to obtain at the city level, if existing at all. Worth mentioning here is the current development of dynamic built environment stock studies that might help get a better understanding on the size of construction material flows entering cities" (p. 13). Their findings could be confirmed for the inflows represented by the lifecycle stages of retail and use, for which it could either not be obtained at all or it was estimated indirectly, respectively (see "use").

Use

As mentioned under "retail", data for the use lifecycle stage could only be derived indirectly, namely by applying the DMC (Domestic material consumption) formula (Domestic extraction used + Imports - Exports). With the help of the imports and exports data, it was calculated how much materials were used. Since the imports and exports data is from NUTS3 level and it can be considered a rough estimation, the score in the data quality matrix is low for reliability accordingly.

Stock

The amounts for stock came from a report called “Prognose for sekundære råstoffer” *(English: Forecast for secondary raw materials)* which was carried out for the municipalities of Høje-Taastrup and Roskilde in 2021. The report provides information on a forecast for the expected production of recyclable (secondary) raw materials of concrete and bricks from buildings, as well as concrete, asphalt and gravel from paving that result from demolition and renovation projects. The values could be used as they were.

Waste collection and treatment

The data for waste collection and treatment were extracted from the Danish “Affaldsdatasystemet (ADS)” *(English: waste data system)* by the municipality, using the sources of “"Affaldsproduktion i Danmark fordelt på kilde og kommune (R026) (Branchegruppe)" *(English: Waste production in Denmark by source and municipality (R026) (Industry group))* and “Affaldsproduktion i Danmark fordelt på behandling og kommune (R019) (R/D)” *(English: Waste production in Denmark by treatment and municipality (R019) (R / D))*. The data is for 2019 and in tonnes, so it could be used directly. In principle, the completeness of waste data is also pretty good. The issue here is that although it is detailed per material, it is not known by which economic activity or lifecycle stage they are produced.

Imports and Exports

For imports and exports, national road freight transport data for unloading and loading regions (NUTS3) respectively, from 2019 were used. The data is in tonnes, so it doesn’t suffer in quality through conversion. However, an estimation needed to be made for the share of materials used in construction. For this, it was estimated that 80% of the materials for selected categories from the NUTS3 imports are used for the construction sector. The same applied to export.

To summarise overall, the data gaps stemmed from:

- Some data only being available on a national level and not a municipal level.
- Large amounts of data being unavailable due to lack of reporting and/or trade secrets.
- Certain data that is available, but only behind a paywall. It was not possible to access this data, because it required to be extremely precise about exactly what data needs to be retrieved. As the SCA process and method were still under development, a precise enough formulation of which data was needed was not possible to be conveyed to a level that was satisfactory to those who were to retrieve the data, during the time when the people in the municipality had resources to do so.

These barriers gave valuable insights into the nature and availability of data surrounding the construction sector. It became clear to the municipality that they are not the correct actor to perform a SCA based on the skill-sets and data that are available to a municipality. It is clear that Høje-Taastrup is too small on a Danish scale to make a representative Sankey diagram, and that examining things on a regional or national level would provide much more meaningful, accurate and rich information. Since the municipality is so relatively small, most flows are in and out of the municipality and very few are contained within municipal borders.

The lessons learned from this exercise help lay the groundwork for a better understanding of what kind of data is most meaningful to show the impact of circular activities in Høje-Taastrup. A focus on totally avoided raw material extraction could, for example, be a good approach. This could be measured both as a total, where an increase over time could be tracked, and as a proportion to total material use in construction, where the trend would show an increasing (but overall miniscule in the next 5 years) proportion over time. Most of the raw materials used in building projects in Høje-Taastrup come from other municipalities, so the increase in total avoided material extraction could also be measured in terms of reduced total transport distance of the materials.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector

This report provides a lot of information on the construction sector, its size, actors and materials handled in the municipality of Høje-Taastrup. Based on that it can be summarised that the construction sector plays an important economic role in the municipality. Various actors and industries are represented here, including some national and international companies. Many of the local companies have been in the municipality for well over 50 years and consistently brought business to and made available job positions in the region.

It was seen that the area is also well suited for extraction of sand and gravel due to its geological history. Since not all of the materials are needed locally, a lot of those are exported.

The current situation of the construction sector with regards to its circularity is hard to determine due to limitations in data availability and quality. The direct reuse of materials is quite low and while the amount of waste subjected to recycling is high, the recycling efficiency is not known, which would help in determining the amount of secondary materials available. It is, however, already commendable that there is a focus on waste sorting, though mostly in the interest of removing hazardous substances from the waste stream and recycling non-hazardous materials lower on the waste hierarchy than where they started.

Overall, the municipality still has a long way to go to make the material flows of their construction sector more circular.

Connection to and upscaling of demonstration actions

The demonstration actions have shown that it is feasible to maintain the value of materials post-demolition and avoid an unnecessary downgrading on the waste hierarchy. The current scale of the amount of avoided waste and avoided extraction of virgin materials is too small to detect the relative impact to the total waste produced and virgin materials used on a municipal level. Hopefully, with greater momentum in coming years, the sector will transform such that there is a more obvious flow of materials directly from site to site, rather than the linear trend that is more often seen today.

In terms of the flow of soil, a great potential to reduce the overall flow of soil in conjunction with building projects can already be seen. The municipality has observed that just by taking soil management into account in the planning of a large building project, it is possible to reduce the need for transport of soil to and from the site by over 90%. With further planning, it is possible to ensure that the soil is only transported locally rather than the sometimes long distances we see today. This has a great potential to reduce the carbon footprint from transportation associated with building projects and with it, noise, dust and road wear and tear on local roads.

Recommendations for making the construction sector more circular

In order for the construction sector to become more circular, the **successes and methods** behind the actions striving for that need to be made as visible as possible. This will ensure replicability and that the barrier of knowledge gaps, in terms of how to build with circularity on a purely practical level, are reduced.

The municipality would also be greatly helped by **legal measures** that would incentivise circularity. These include higher fees for virgin resource extraction and higher fees for waste disposal. Greater possibilities of certifying and guaranteeing used materials are also essential to reduce the perception of risk associated with using used materials.

It can also be recommended to **increase engagement and collaboration with local players** that already have circular initiatives and solutions, for example:

- F.J. Poulsen's Anlægsgartneri A/S describe their initiative around their "Crushing of concrete and sale of recycled materials". For this, they invested in a concrete crusher and now collaborate with skilled haulers to "take care of picking up, transporting and crushing concrete from pavements, foundations, retaining walls and other "clean" concrete. The concrete must be free of asphalt, plastic, wood and similar foreign objects. All broken concrete from the project is driven to its own place and crushed for recycling and used as a support layer in other projects." The company recognises that by using recycled materials, they can help delay the depletion of raw material depots in Denmark.

    - The municipality of Høje-Taastrup could support this business by promoting it and direct business there. It could possibly facilitate determining if the concrete crusher as a resource is used at full capacity and if that isn't the case how that could be achieved, e.g. in the form of a public-private partnership with them or bringing business together.
- Tarkett, the flooring company state that they have a "Circular Collection", where all floors of that collection are recyclable, meaning that they (1) "have routines for collecting old floors all over the country", (2) "transport the collected material to a recycling plant" and (3) "the old floors are recycled as raw material in new floors".
    - The municipality of Høje-Taastrup could promote this business. In addition, it seems to be an opportunity to include this company in procurement processes, for when the municipality itself requires new flooring.

Certainly, other **circular initiatives** could be discovered and mapped in Høje-Taastrup, or it could be learned from, adopted and build on the "14 Danish cases on resource efficiency in small and medium-sized enterprises", which can be a recommendation in and of itself.

It can also be recommend that the municipality guards and finds measures to **take care of local resources**. Although the area is predestined for extraction of construction materials, especially with its many gravel pits, these materials are nevertheless still finite. Recognising that private businesses engage in their extraction and that it is economically important, the resources should be sourced responsibly, as the avoidance of virgin materials use has the highest priority in a circular economy.

Finally, it is recommended that the **data availability and quality** are improved on, so that the region can determine its true potential of available resources and wastes per year. This way, the potential for upscaling the demonstration actions could be better analysed and a circularity process for the sector developed, containing main objectives and an action plan.

References

- Denmark
- Hovedstaden
- Københavns omegn
- Population of Høje-Taastrup, 2011-2020 line graph
- Municipal planning framework 2014
- Static map of extraction companies in Høje-Taastrup

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

MIKKELI

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Mikkeli are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Aluminium	Bitumen / asphalt	Bricks
Concrete	Glass	Gypsum
Insulation	Iron (steel)	Sand and gravel
Soil	Timber	

The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

(The italic texts in this report were written by [Metabolism of Cities](#)' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

Urban context

To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.

Mikkeli

53,134

3,229 km²

Etelä-Savo

144,615

19,130 km²

Pohjois- ja Itä-Suomi

1,278,237

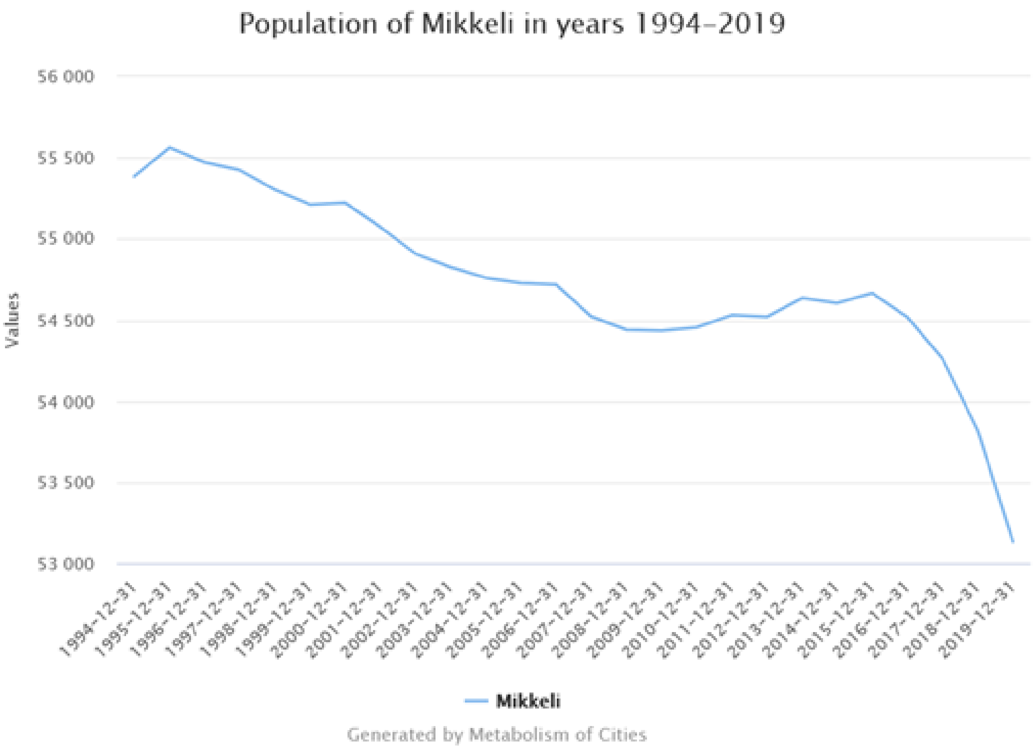
236,450 km²

Finland

5,525,292

390,908 km²

Population of Mikkeli

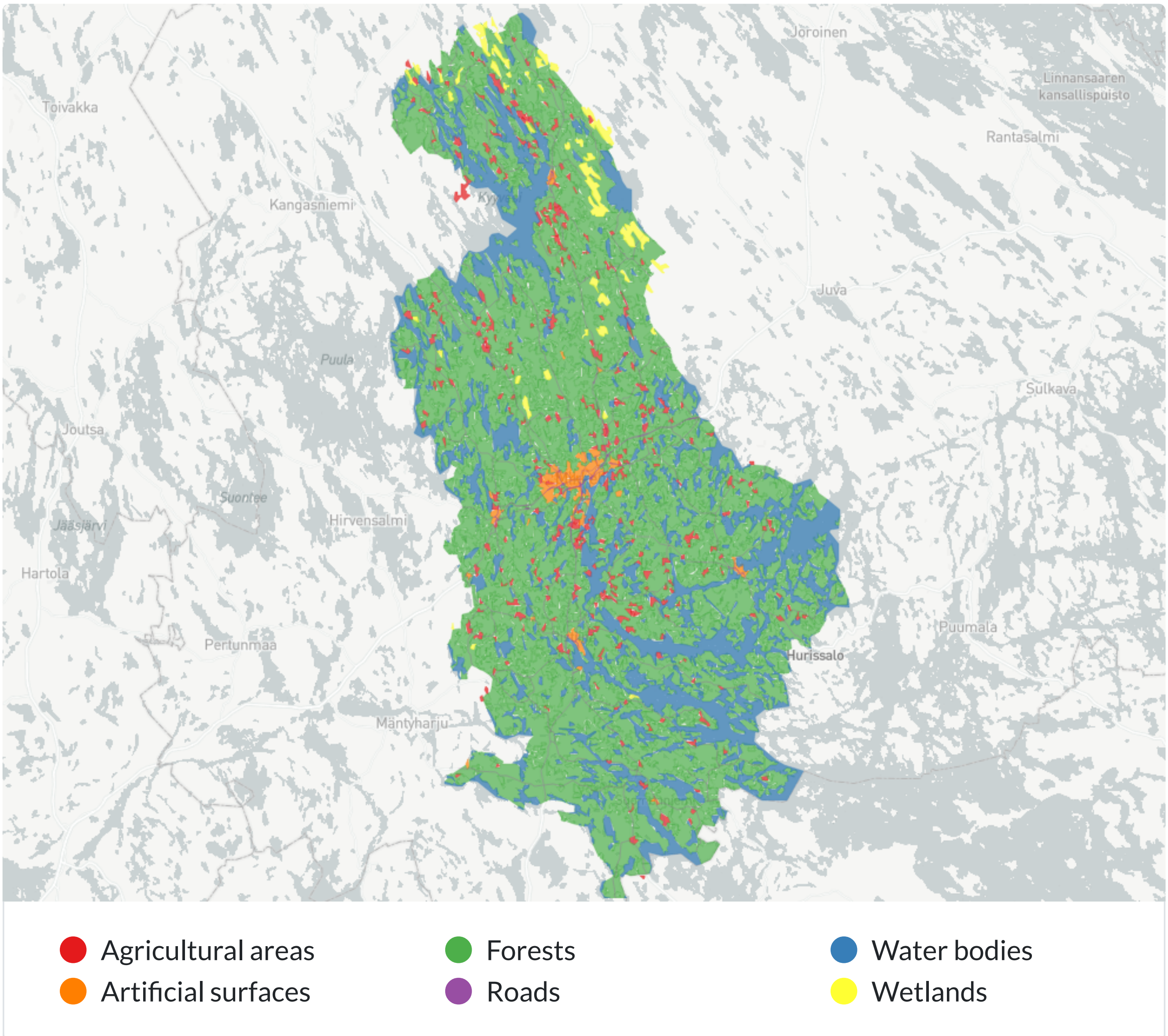


Data source

In year 2019, there was 53 130 inhabitants in the city of Mikkeli, of which 13.9% were aged 0-14, 60.2% were aged 15-64 and 25.7% were over 65 years old. The population of the city of Mikkeli has been slightly declining in the 21st century, but since 2016 the population change has clearly accelerated and the city lost almost 1 400 people between 2016 and 2019. The negative demographic development of the city of Mikkeli is largely the result of two components: natural demographic change has accelerated slightly, but especially outward migration (particularly emigration of young adults) has increased considerable in 2016-2019. In 2019, Statistics Finland published a new population forecast for the city of Mikkeli. The city's population is predicted to decline by 11 % by 2040. (Kumpusalo 2020, Mikkeli Development Miksei Ltd)

In 2018, Mikkeli was the 18th largest city in Finland by population. (City of Mikkeli website)

Land use



There are various living environments in Mikkeli. These include a growing downtown area, developing agglomerations and the quiet of the rural area. Living in Mikkeli is divided in two main area types: city/agglomerations and dispersed habitat/rural area. There are numerous summer cottages at the lake- shores of the rural areas. There are around 700 lakes and ponds in Mikkeli and water covers 424.7 km2 (13 %) of the city. (Riihelä et al. 2015)

Forests and other natural areas account for 89.6% and agriculture for 5.8% of Mikkeli's land area. (Use of land in Mikkeli for extraction and harvesting, agriculture and forests 2018)

Economic context of construction sector

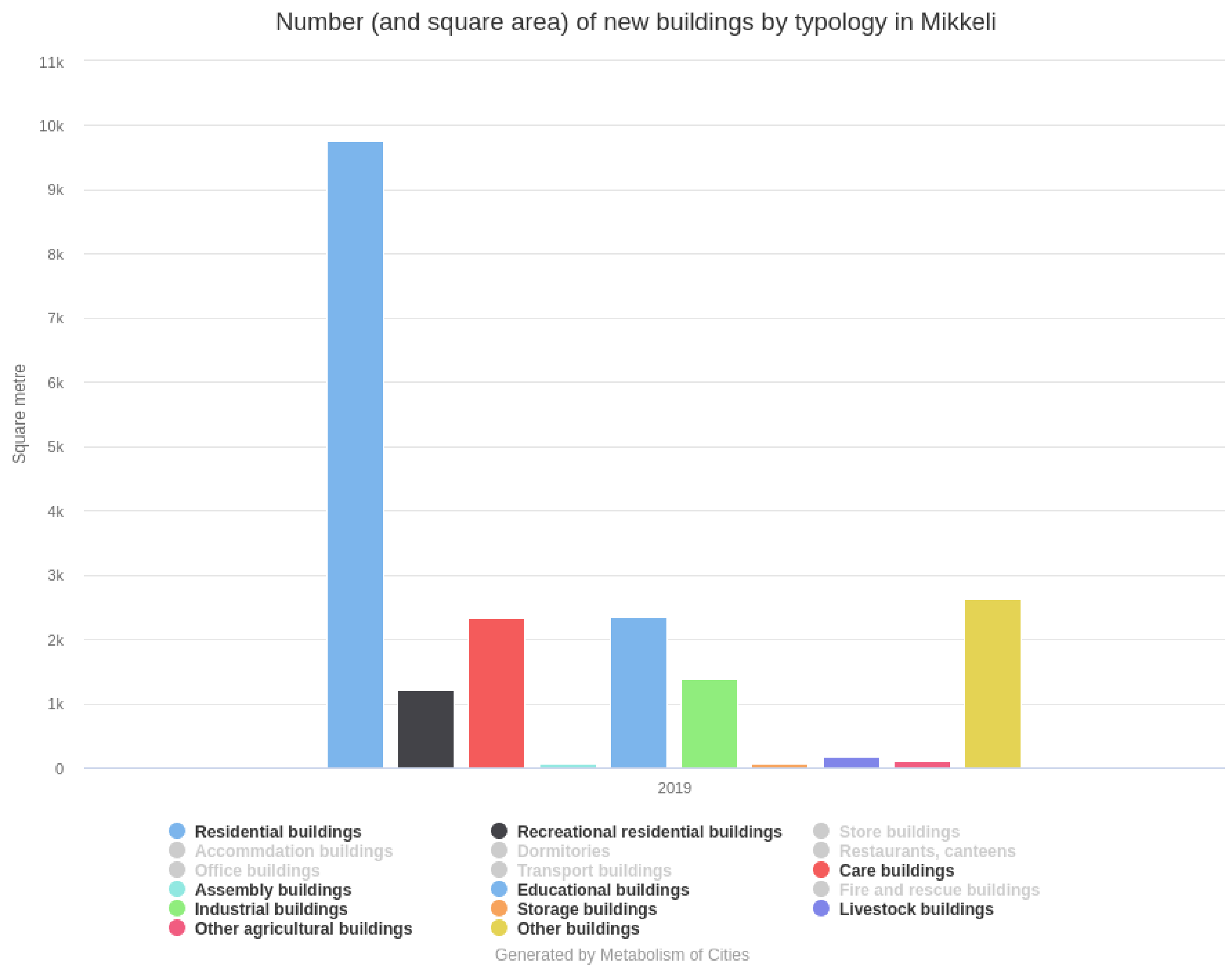
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	GVA (monetary value, in €)	Employees
Mikkeli	141,000,000	1,307
Etelä-Savo	272,000,000	3,515
Pohjois- ja Itä-Suomi	3,227,000,000	9B
Finland	14,978,000,000	167,861

The construction sector in Mikkeli

The construction sector employs 11,2% of employees in Mikkeli. The corresponding percentage for the whole country is (7%). The most significant employment sectors in Mikkeli are industry (22,6%) and wholesale and retail trade (17,6%). Construction accounts for about 10% of Mikkeli's net sales. Based on turnover, the most significant industries in Mikkeli are wholesale and retail trade (28%) and industry (26%). (Data of Statistics Finland on industries and employees in Mikkeli) Data is from year 2018 (GVA and employees data from reference year 2019 was not available).

In Mikkeli, the largest construction projects are often managed by national companies and employees can also come from outside the area. According to the 2019 statistics, the number of new buildings in Mikkeli was 171 and the total floor area was 19,994 m2. About half of the floor area (48 %) was residential buildings. 76% of the house types were detached houses, 21% terraced houses and 2% apartment buildings.



Number (and square area) of new buildings by typology in Mikkeli
Square metre
11k
10k
9k
8k
7k
6k
5k
4k
3k
2k
1k
0
2019
Residential buildings
Accommdation buildings
Office buildings
Assembly buildings
Industrial buildings
Other agricultural buildings
Recreational residential buildings
Dormitories
Transport buildings
Educational buildings
Storage buildings
Other buildings
Store buildings
Restaurants, canteens
Care buildings
Fire and rescue buildings
Livestock buildings
Generated by Metabolism of Cities

[Data source]

The actors of the construction sector

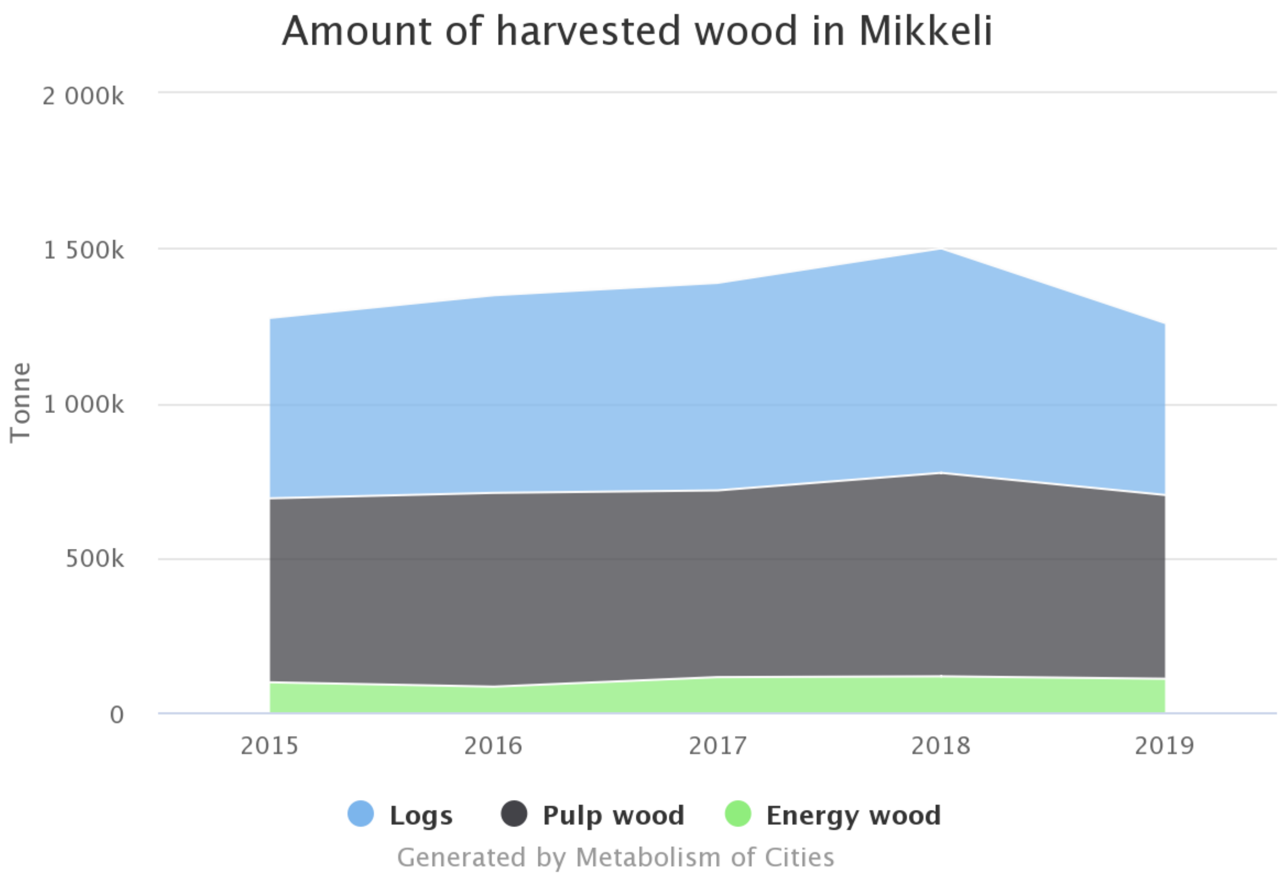
[Data source](#)

The actors of construction sector were listed by using data of Statistics Finland, where the total number of actors, employees as well as economical information are given by NACE-codes (EU classification of economic activities): (Industries and employees in Mikkeli 2013-2018).

Also A list of actors in Mikkeli by Nace codes was available. However, the list is not totally coverable and some important actors are missing from this listing. Information was collected from companies webpages as well.

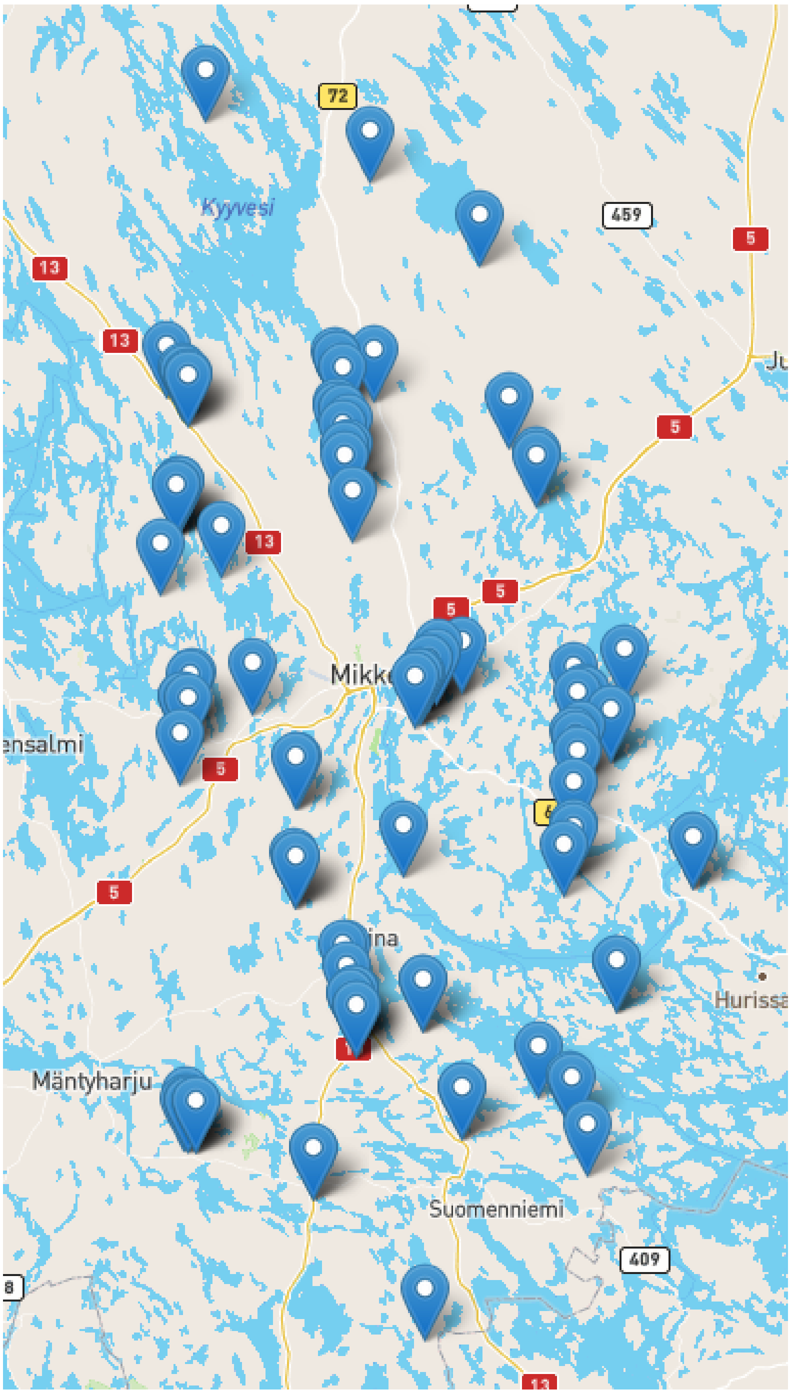
Extraction and harvesting

Forests and forest-based industries are very important source of economic well-being in Southern Savonia. The incomes from the harvesting of province´s forests are the highest in the country. The forests are mostly owned by private forest owners. (Metsäkeskus 2020)



Data source

Mikkeli has a total of 52 soil extraction permits for gravel and sand, 35 for stone materials and 8 for other materials. Materials are used for construction and for manufacturing of concrete. There are no statistics on actors available, but e.g. Metsähallitus, concrete manufacturers and earthwork companies own extraction sites. (Data on soil extraction pemits and amount of extracted rock and gravel in Mikkeli)


72
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13

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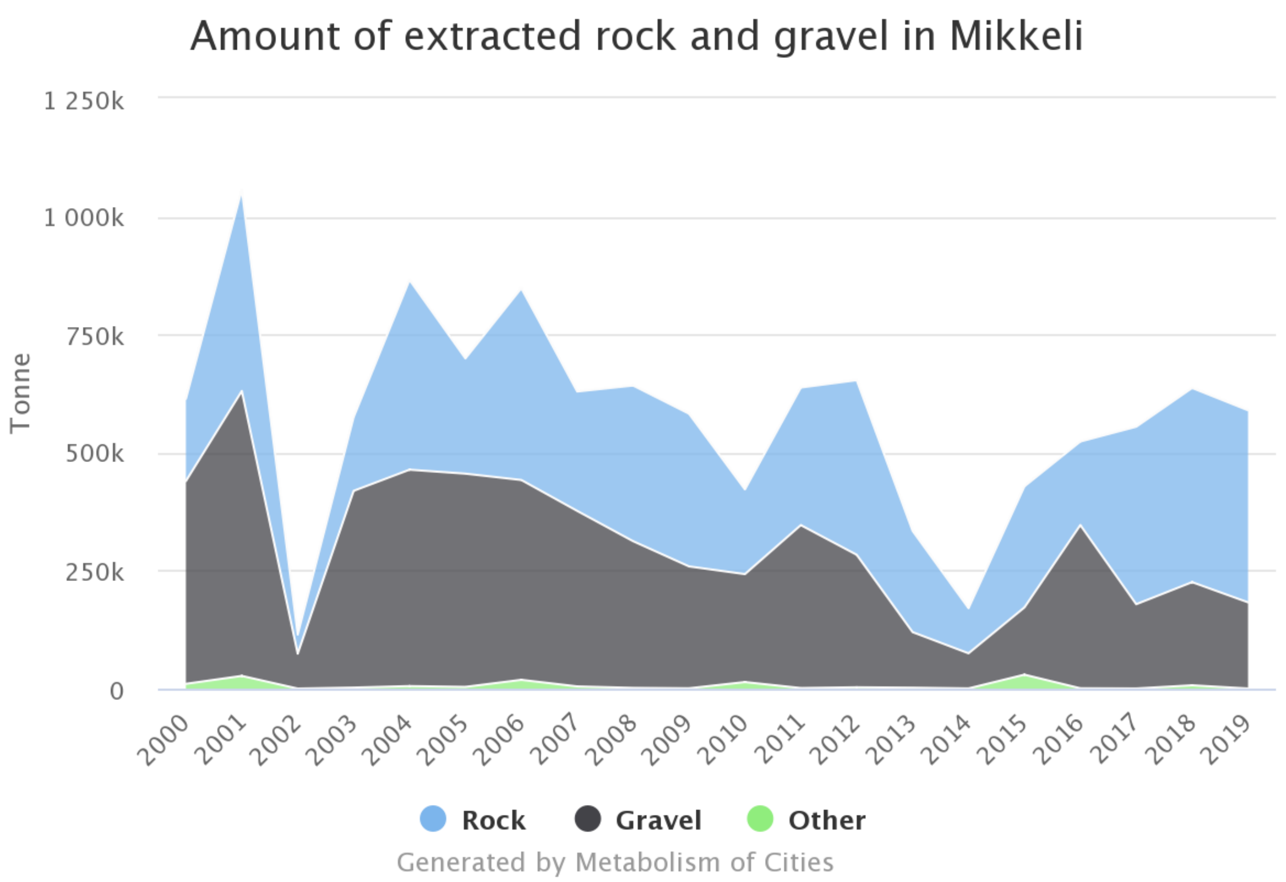


Data source

Manufacturing

Mikkeli has several actors manufacturing timber and concrete products for construction sector throughout Finland and for export.

Actors in timber manufacturing:

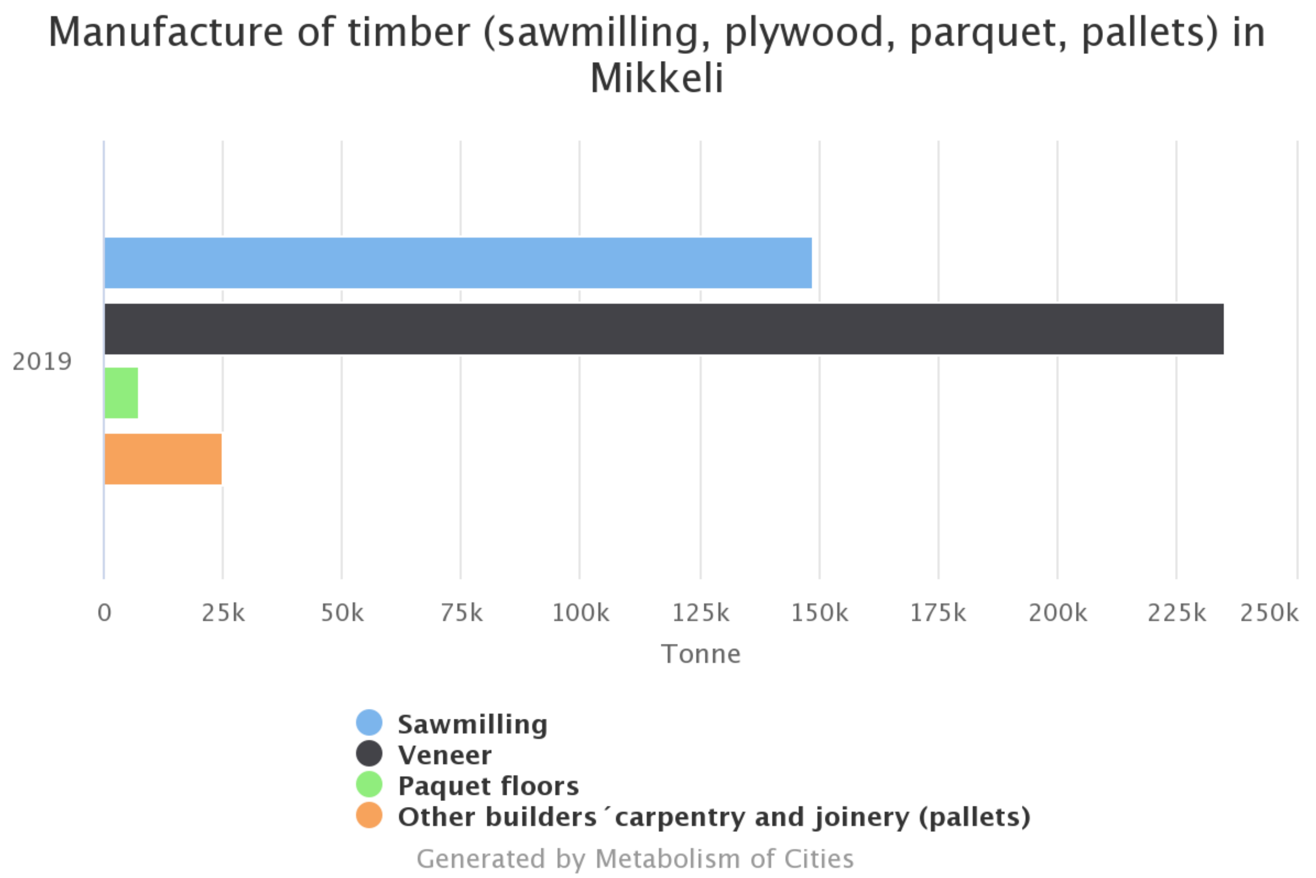
According to Statistics Finland, there were a total of 12 actors in the sawmilling and planing of wood, 1 actor in manufacture of veneer sheets and wood-based panels, 1 actor in manufacture of assembled parquet floors and 6 actors in Manufacture of other builders' carpentry and joinery in 2018. (Industries and employees in Mikkeli 2013-2018).

There were also 6 actors in Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials, 4 actors in Manufacture of kitchen furniture and 3 actors in Manufacture of other furniture. However, the role of these actors to the total material flows is assumed to be low. The most important actors in timber manufacturing are:

- UPM Pellos' plywood mill is Europe's largest plywood mill. It produces approximately 480,000 cubic meters of plywood per year from approximately 1.1 million cubic meters of Southern Savonia spruce logs for the Finnish and European markets. The factories employ about 600 people and are the largest industrial employer in Southern Savonia (Kumpusalo 2019, Mikkeli Development Miksei Ltd)

- Versowood Otava Ltd: The production capacity of spruce sawing is about 275,000 m^3 per year. 90% of production is exported.
- Misawa Homes of Finland Ltd is a sawmill which export spruce lumber to Japan.
- SWM-Wood Ltd manufactures heat-treated wood for the needs of the construction and carpentry industries and retailers. Company is the 2nd largest manufacturer of Thermowood® in Europe
- Oplax Ltd: manufacturing of pallets
- Parla Floor, Timberwise: manufacturing of parquet floors

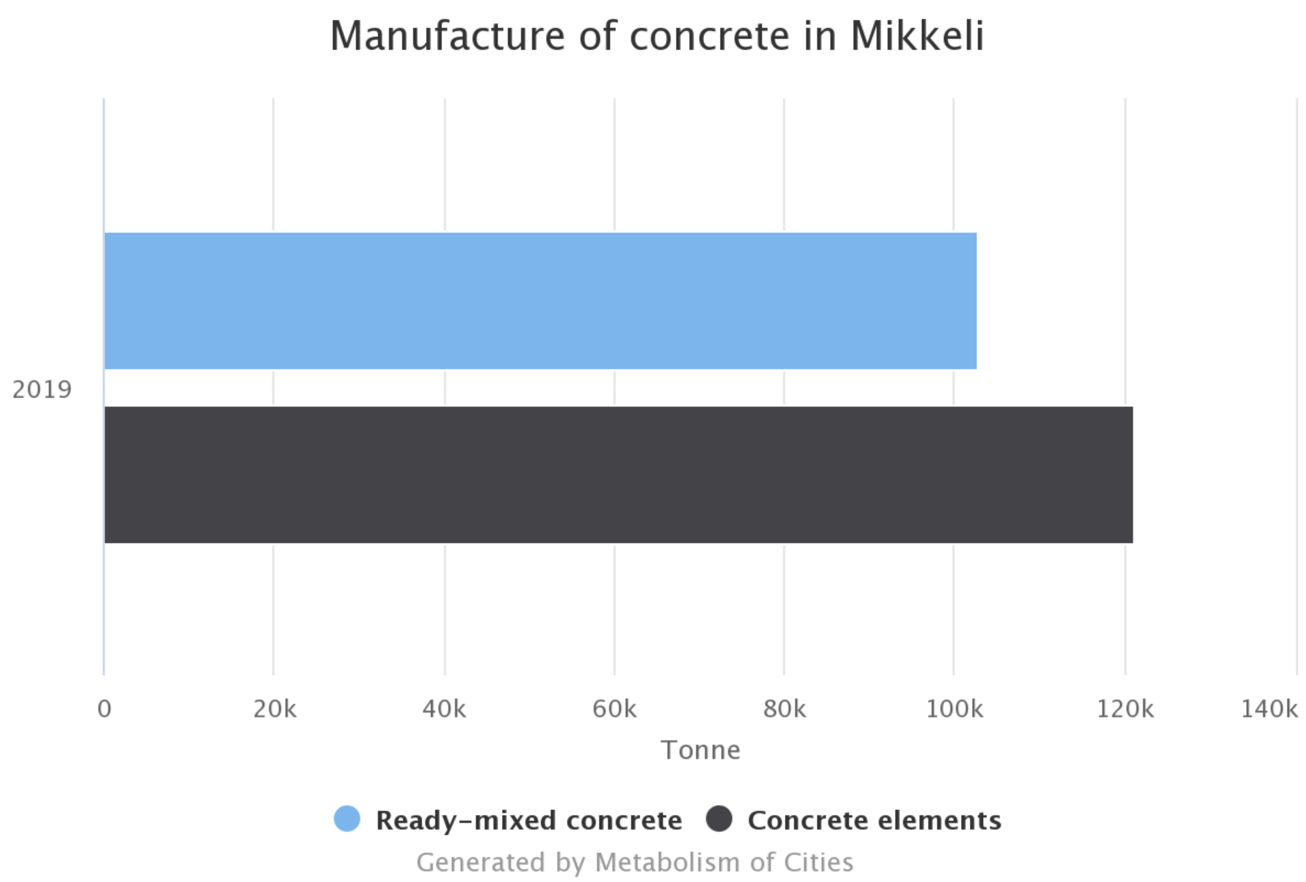
The production volumes of these companies were used to calculate material flows in manufacturing of timber products in Mikkeli.



Data source

Actors in concrete manufacturing:

- SBS Betoni Ltd´s plant in Tikkala, Mikkeli is the largest in Finland in terms of area and production capacity (Savon Sanomat 2014). The plant produces ready-mixed concrete and concrete elements.
- BetSet Ltd plant in Pursiala, Mikkeli manufactures wall elements and ready-mixed concrete. Concrete elements are manufactured for use in the construction industry throughout Finland.
- Sora ja Betoni V. Suutarinen Ltd´s plant in Suomenniemi, Mikkeli. The plant produces ready-mixed concrete and concrete elements.



Data source

There are also companies of metal industry in Mikkeli (17 actors in 2018) who manufacture metal products (metal structures and their parts, metal doors and windows, and perform metal processing and coating). (Industries and employees in Mikkeli 2013-2018)

Retail and wholesale

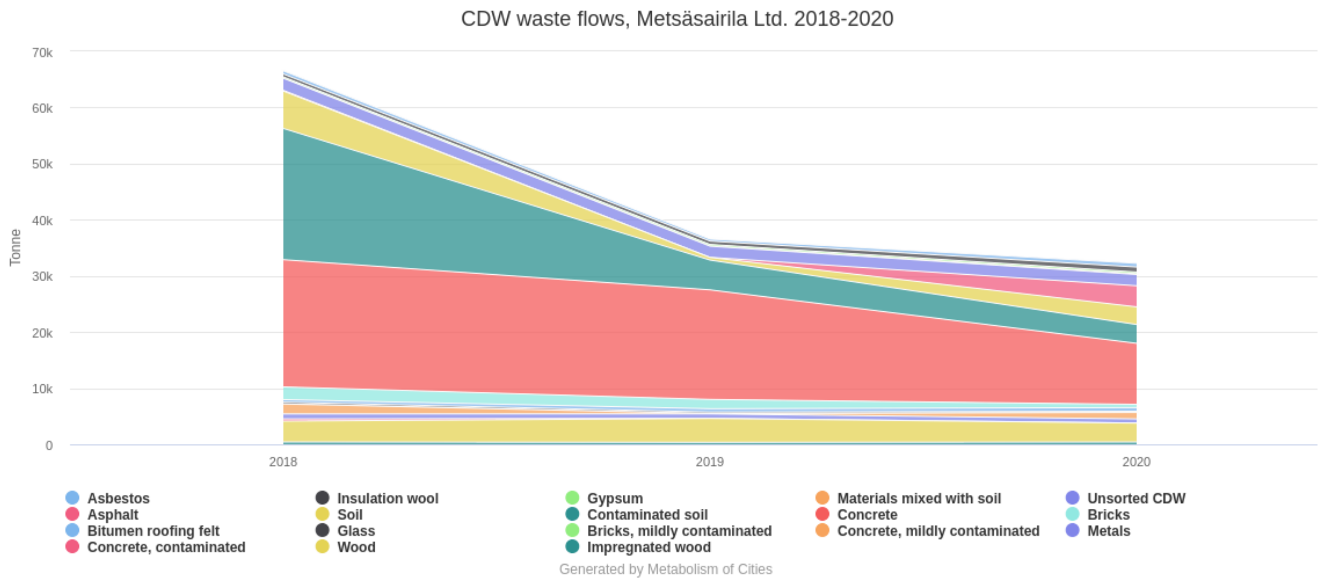
In 2018, Mikkeli had 45 actors related to the retail and wholesale of construction materials (NACE codes 46.73 Wholesale of wood, construction materials and sanitary equipment and 47.52 Retail sale of hardware, paints and glass in specialised stores). Some biggest actors are e.g. K-Rauta, Carlson and Stark. (Industries and employees in Mikkeli 2013-2018)

Use

There were 425 actors in the construction sector in Mikkeli in 2018 (Industries and employees in Mikkeli 2013-2018). Most of these are small companies. The largest construction projects are often managed by national companies such as YIT, Skanska and Destia.

Waste collection and treatment

The most significant operator responsible for waste collection and treatment in Mikkeli is the city-owned waste management company Metsäsairila Ltd. All construction and demolition waste generated from the City of Mikkeli's own sites is delivered to Metsäsairila. Private operators can deliver waste elsewhere, also outside Mikkeli, depending on the contractor. Otavan Metalli Ltd and Mikkelin Romu Ltd receive scrap metal in Mikkeli. Mikkelin Romu Ltd receive also construction, wood and demolition waste. According to environmental permits of companies, concrete and timber manufacturers treat (e.g. crush) waste fractions generated from their own production and deliver for recycling or incineration. Suutarinen Ltd can also crush concrete waste from the construction and demolition sites in their concrete plants in Tikkala and Suomenniemi. In addition, at least Mikkelin Autokuljetus Ltd has an environmental permit for crushing and receiving concrete waste. Mikkelin Toimintakeskus assoc. focuses on the re-use fixing and upcycling of goods and materials. They sells small quantities of materials from e.g. renovation and demolition sites to reuse.



Data source

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level). However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	561,715.39	Tonnes/year

Indicator number	Indicator	Value	Unit
39	Circular Material Use Rate	2.58	%
48	EU self-sufficiency for raw materials	4.91	%
55	EOL-RR (End of Life Recycling Rate)	25.26	%
57	Amount of sector specific waste that is produced	35,598.00	Tonnes/year
58	End of Life Processing Rate	97.27	%
59	Incineration rate	0.00	%
61	Landfilling rate	7.59	%

Due to deficiencies in data quality, not all indicators could be calculated with complete reliability.

Domestic material consumption

DMC is the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. Formula for domestic material consumption is: DMC = Domestic extraction used (DEI) + Imports (IMP) – Exports (EXP).

In the case of Mikkeli, DEI was calculated using reliable local or regional data on extraction of sand & gravel and soil (peat) as well as harvesting of wood. This value was allocated for manufacturing (50 %), retail (20 %), use (10 %) and waste collection (10 %). Assumed allocation values defined by Metabolism of Cities (MOC) were used.

Imports (IMP) were calculated using Finnish Customs data from Finland and downscaling it to Mikkeli by using employees of construction sector. This value was allocated for manufacturing (40 %), retail (40 %), use (0 %) and waste collection (0 %). Assumed allocation values defined by Metabolism of Cities (MOC) were used.

Amount of exports (EXP) are based on rough estimations and downscaling of national Finnish Customs data (see Chapter Data Quality).

The resulted DMC in Mikkeli is 561,715.39 tonnes per year and 10.6 tonnes per capita which is slightly better than the reference value 13.4 tonnes per capita for EU-28 in 2019 (Eurostat). Generally a decrease in the indicator value is beneficial to the environment and to the Green

Economy Source.

Circular material use rate

Formula for Circular material use rate is: (domestic recovery – imported waste for recycling – exported waste for recycling) / ((domestic material consumption + (domestic recovery – imported waste for recycling – exported waste for recycling)).

Domestic recovery is amount of collected waste that is recycled. In case of Mikkeli, the reliable data was obtained from the most important actor Metsäsairila Ltd but data does not cover all waste flows from private sector (see chapter Data Quality).

Imported waste for recycling is based on assumed allocation values defined by the Metabolism of Cities. Assumption is that 20 % of all imports are allocated to recycling. In case of Mikkeli, imports (IMP) were calculated using Finnish Customs data from Finland and downscaling it to Mikkeli by using employees of construction sector. From this value, 20 % was allocated to recycling

Exported waste for recycling is based on actual amount of metal waste that is collected by Metsäsairila and exported outside of Mikkeli for recycling. Data does not cover local private actors, who receive metal waste or other CDW and export it for recycling.

Calculation of Domestic Material Consumption has been described above. In case on Mikkeli there are many uncertainties due to downscaling, rough estimations and assumed allocation values.

The resulted Circular Material Use Rate CMU for Mikkeli is 2,58 % which is low compared to 12.4% for EU-28 or 6,3 % for Finland in 2019 (Eurostat). Low value means that less secondary materials have substituted for primary raw materials in Mikkeli than in EU or Finland. However, the data collection and quality should be developed to get more reliable value.

EU self-sufficiency for raw materials

Formula for EU self-sufficiency for raw materials is: Import Reliance (IR) = Net import / Apparent consumption = (1- (Import - Export)) / (Domestic production + Import - Export).

Import value is based on Finnish Customs data from Finland. Data has been downscaled to Mikkeli by using employees of construction sector.

Export value is based on rough estimations and downscaling the Finnish Customs data (see Chapter Data Quality).

Domestic production is the manufacturing of construction products in Mikkeli. Value is based on reliable local data on manufacturing of concrete and timber products and downscaled PRODCOM data of Statistics Finland for manufacturing of aluminum and iron (see Chapter Data Quality).

The resulted value for EU self-sufficiency for raw materials in Mikkeli is 4,91 %. The reliability of the value is weakened by the uncertainties of the import and export data. EU statistics (Eurostat) are given for individual materials (mostly metals) and e.g. timber and concrete are not listed in the statistics. EU self-sufficiency for e.g. aluminum for EU-28 was 9,8 % and for iron 28,2 % in 2018.

EOL Recycling Rate

For each material fraction, the End-of-Life recycling rate is defined as the End-of-Life mass recycled divided by the available mass of End-of-Life materials. It is the product of the Processing Rate and the Collection Rate (EoL RR = EoL PR x EoL CR). Formula is: EOL RR = EOL Mass recycled / EOL Mass collected x 100.

In case on Mikkeli EOL mass recycled include CDW collected by Metsäsairila Ltd which is recycled at Metsäsairila (e.g. concrete waste used in road, field and landfill structures) or exported to recycling (metals). Data does not cover CDW collection of private actors.

EOL mass collected is calculated by summing the following amounts:

- share of materials from "use" lifecycle stage that goes to waste collection (allocation value of Metabolism of Cities, 20 %). Data on use of construction materials is based on statistics of e.g. new buildings and roads in Mikkeli and there are many uncertainties in unit conversions of the data (see Chapter Data Quality).
- share of stock materials that goes to waste collection. In case of Mikkeli this is calculated by using amount of CDW collected by Metsäsairila and assumed allocation value defined by Metabolism of Cities, 99 %.
- share of imports that goes to waste collection. However, allocation value has not been given and the value is 0.

The resulted EOL Recycling Rate for Mikkeli is 25,97 %. There are many uncertainties and assumptions associated with calculating the value. If only the realised amount of CDW collected by Metsäsairila and CDW fractions recycled by Metsäsairila or exported to recycling are taken into account, the recycling rate is 80%. Through the EU Waste Directive, Finland was committed to utilizing at least 70% of the construction and demolition waste generated in the country as a material by year 2020. The aim of the CityLoops project is that the recycling rate of construction waste is close to 95 % in Mikkeli.

Amount of sector-specific waste that is produced

The amount of sector-specific waste that is produced was 35598 t. The amount is based on only data of Metsäsairila Ltd. Asbestos (376 t) and insulation wools (596 t) were removed from total CDW amount received by Metsäsairila Ltd. because they are not in scope of materials selected to SCA. (Materials included to SCA have been listed in the introduction part of this report. Insulation material included in SCA is only plastic based insulation.) Private sector can deliver CDW also to other local waste collectors or export it outside from Mikkeli. Mikkeli Development Miksei Ltd have studied waste management of CDW in Mikkeli (see report here). According to the study, it is estimated that about 70 % of all concrete and brick waste from big demolition projects (area of buildings >250 m2) are delivered to Metsäsairila. Consequently, the amount of sector-specific waste that is produced is bigger than amount calculated here.

End-of-Life Processing Rate

The End-of-Life Processing Rate measures the efficiency of the end-of-life processing process. The formula is: End-of-Life Processing Rate = End-of-Life mass recycled / End-of-Life mass collected for recycling x 100. The indicator shows only the local situation of the municipality and exported waste flows are not included in the calculation. This aspect helps with local circularity planning. Recycling waste elsewhere means that these materials aren't necessary available locally anymore.

In case on Mikkeli, EOL mass recycled include CDW collected by Metsäsairila Ltd which is recycled at Metsäsairila (e.g. concrete waste used in road, field and landfill structures).

EOL mass collected for recycling include CDW collected and recycled by Metsäsairila Ltd (e.g. concrete waste used in road and field structures) as well as metal waste which is collected by Metsäsairila but exported outside of Mikkeli for recycling.

The resulted EOL Processing rate is 97,27 %, which means that almost all of the waste collected by Metsäsairila Ltd for recycling, are also recycled at Metsäsairila area and only small part (metals) are exported elsewhere for recycling. In case of Mikkeli, most of CDW is utilised in Metsäsairila area in field, road and landfill structures. Data does not cover CDW collection of private actors.

Incineration rate

Incineration rate is mass percentage of waste which is incinerated. The formula used in SCA is: Incineration Rate = Incinerated waste / (Total waste + imported waste - exported waste) x 100. The indicator shows the local incineration only.

In the case of Mikkeli, the amount of local incineration is 0 because there is not waste incinerator in Mikkeli. Consequently, the incineration rate is also 0 %. The value is based on data from Metsäsairila Ltd. However, timber waste collected by Metsäsairila Ltd, is exported outside of Mikkeli for incineration and energy recovery. The proportion of timber waste exported for incineration from all collected CDW in Metsäsairila Ltd. is 12.9 %. Also energy waste fraction consisting e.g. paper/cardboard- and plastic based wastes (also plastic based insulation) are exported from Metsäsairila to incineration. However, the proportion of energy waste fraction coming from construction sector is not possible to distinguish from other energy waste from statistics.

Landfilling rate

Landfilling rate is mass percentage of waste which is landfilled. The formula used in SCA is: Landfilling rate = Landfilled waste / (Total waste + imported waste - exported waste).

In case of Mikkeli, landfilled waste consists of reject which cannot be sorted, materials mixed with soil and gypsum. Also asbestos waste and insulation wool are landfilled in Metsäsairila, but these fractions were not under the scope of sector-wide circularity assessment (Materials included to SCA have been listed in the introduction part of this report).

Total waste include the CDW collected by Metsäsairila Ltd. Data does not cover CDW collected by local private actors or CDW transported outside of Mikkeli.

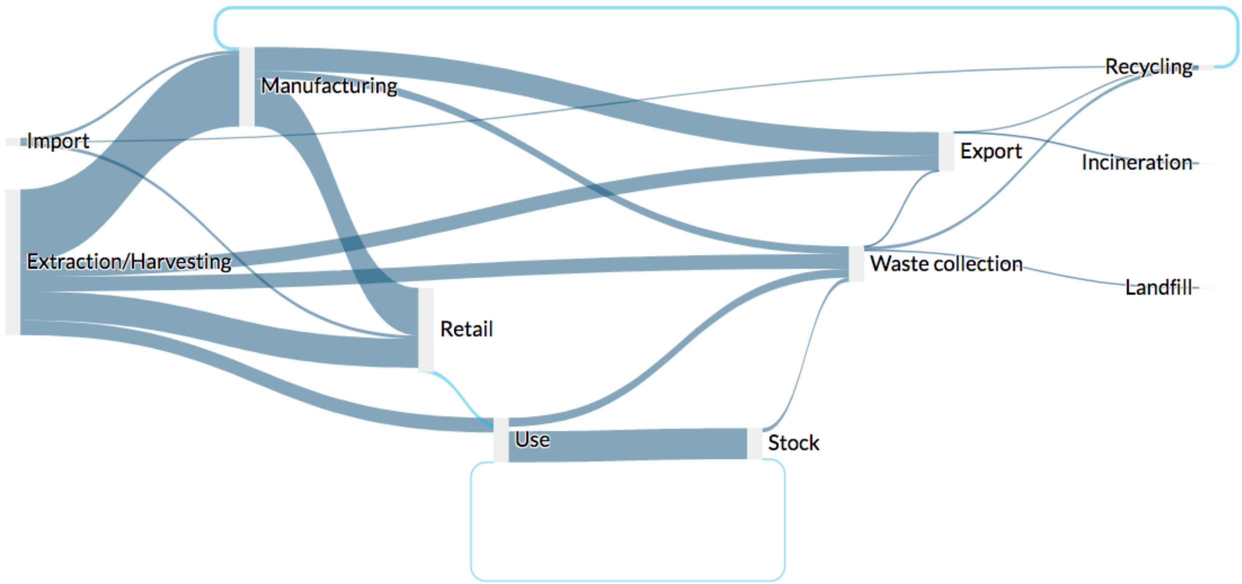
Imported waste is 0. Metsäsairila or other actors can receive waste also from nearby areas, but the data is not available.

Exported waste include metal and timber waste collected by Metsäsairila Ltd. Metal waste is exported for recycling and timber waste for incineration.

Landfilling rate of CDW received by Metsäsairila Ltd is 7.59 %.

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



[Data source]

The Sankey diagram describes well that the main flows of construction materials in Mikkeli are in extraction and harvesting and in manufacturing. The amounts of extraction and harvesting as well as manufacturing are also the most reliable and complete datasets, which were collected. These lifecycle stages include extraction of sand and gravel and wood. Also extraction of peat was included to “soil” material according to SCA method, although it is not utilized by construction sector in Mikkeli. However, the proportion of peat production in extraction and harvesting lifestage is only 7 %. There are lot of manufacture of timber and concrete products in Mikkeli and considerable part of manufacturing is also exported outside the area. Most probably the proportion of export from manufacturing is even larger than illustrated in the Sankey diagram. From timber products even 90 % of biggest sawmill and plywood plants are exported abroad according to companies webpages. In addition to timber and concrete manufacturers, there are also smaller companies manufacturing metal products in Mikkeli.

There were no local or national statistics of retails available in tonnes. The material flows of retail lifecycle stage illustrated in the Sankey diagram is based only on assumed allocation values. Due to this data gap, material flows from retail to other lifecycle stages have not been estimated.

The Sankey diagram shows that the proportion of recycling of construction materials is very small but diagrman also shows that big part of the treatment of collected waste is unknown. The amount of materials at waste collection phase has been calculated by using assumed allocation values (assumption that 10 % from extraction, 10 % from manufacturing, 20 % from use lifecycle stages goes to waste collection). According to calculation, approximately 300 000 tonnes of construction and demolition waste are collected which could be potentially circulated in the city.

Currently, the amount of material flow that goes to recycling, landfilling and incineration is based on actual statistics of municipal waste management company Metsäsairila Ltd. The proportion of waste collected by Metsäsairila Ltd is only 12 % from the calculated total amount of waste collection. According to statistics, Metsäsairila Ltd. recycles 78 % of CDW, that it receives, in field, road and landfill structures in the area. Proportion of landfilling is 6 % (mainly materials containing hazardous substances and also gypsum). Timber waste (13 %) is exported to incineration and metal waste (2 %) is exported to recycling. In addition to Metsäsairila Ltd. there are also some small local actors who receive CDW and deliver it for recycling, incineration or landfilling. Part of the CDW is transported directly outside of Mikkeli for treatment but the amounts are not known. Recycling and incineration of wastes from manufacturing is currently not included in the Sankey diagram but some information is available in environmental permits of factories. The main waste flows of concrete plants operating in Mikkeli are wood and concrete waste, which are treated at the plants. Crushed concrete is utilized in civil engineering and wood chips in energy production. Sawmills and e.g. plywood factory generate typically peel, chew and chips as a by-product. These are usually utilized for energy in local or plant´s own power plant. Some of the by-products of e.g. plywood plant also go for further processing.

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the *ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.*

Rating	***Reliability***	***Completeness***	***Temporal correlation***	***Spatial correlation***
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	**Reliability**	**Completeness**	**Temporal correlation**	**Spatial correlation**
Extraction/Harvesting				mostly local data
Manufacturing				mostly local data
Retail	Data gap			
Use	High uncertainties in unit conversions			local and NUTS2 data
Stock	High uncertainties in unit conversions			

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Waste collection		Only Metsäsairila Ltd data		
Landfill				
Incineration		Only Metsäsairila Ltd data		
Recycling		Only Metsäsairila Ltd data		
Anaerobic digestion	Not relevant for CDW			
Composting	Not relevant for CDW			
Imports	Uncertainties on downscaling data	Some materials missing		Country data
Exports	Rough estimations and downscaling			local and country data

Extraction and harvesting

Reliable local data was collected on sand & gravel extraction. Wood harvesting and peat extraction are based on regional South Savo data and downscaled to Mikkeli based on forest or wetland area. Sand & gravel used in concrete manufacturing was obtained from environmental permits of actors. There is no other extraction/harvesting in Mikkeli.

Manufacturing

Reliable data on manufacturing of concrete and timber products were obtained from environmental permits or webpages of companies. Data covers all concrete actors and the most important timber actors. Data on manufacturing of aluminium and iron (steel) products were obtained from country-level PRODCOM statistics of industry (Statistics Finland) and downscaled to Mikkeli based on employees on relevant NACE-code (25 Manufacture of fabricated metal products, except machinery and equipment). Employee's data was from year 2018 and PRODCOM data from year 2019.

Retail

Data in tonnes was not found. Statistic Finland has data on the trade turnover index which describes the development of the turnover of trade companies (source). However, it was not possible to convert this data to tonnes.

Use

Reliable data on floor area of new buildings was obtained from Mikkeli. Unit conversion to tonnes was based on data on realised masses of CDW fractions in buildings demolished recently in Mikkeli. The obtained values as t/m2 were based on four demolished public buildings and does not necessarily reflect material masses e.g. in detached houses. More reliable data for unit conversions from Finland was not found.

Reliable data on road pavements in kilometers were obtained from Eastern Finland. Many assumptions based on literature and statistics were made to convert kilometers to tonnes of bitumen/asphalt, which decrease data reliability. Data was downscaled to Mikkeli based on lengths of different road types.

Use of sand & gravel has been roughly estimated based on extraction. It was assumed that 80 % of extracted amount is used in Mikkeli and 20 % is exported to nearby areas.

Data does not cover e.g. use of concrete and metals in construction of bridges or railways. Also data on use of plastic based insulation is missing.

Stock

Reliable data on floor area of existing buildings and length of roads were obtained from Mikkeli. There are same uncertainties in unit conversions as explained for use data. Data does not cover e.g. stocks in bridges and tunnels, railways, summer cottages or smaller streets.

Waste collection

Reliable data on waste collection of the most important actor Metsäsairila Ltd was obtained (see data). Data covers all waste flows from construction and demolition projects of City of Mikkeli but not all waste flows of private sector. There are some local actors other than Metsäsairila who collect metal, concrete and other construction waste. Their waste flows are currently missing from the data. In addition, CDW may be exported outside area. Manufacturer of concrete and timber products treat considerable amounts of waste from their own production.

Imports and exports

Reliable country-level data on imports and exports of construction materials were obtained and downscaled to Mikkeli based employees on construction sector. This not necessarily give reliable approximation on imports to Mikkeli. There was also uncertainties on choosing relevant products for Mikkeli from the country-level data. Data was not obtained for all materials.

National import-export data does not reflect the export of materials from Mikkeli to other parts of Finland. Rough estimations were made e.g. on export of sand & gravel to nearby areas (20 %). Export of concrete and timber products were roughly estimated based on information obtained from companies web pages. It was assumed that about 50 % of concrete production (ready mixed concrete and elements) are exported outside of Mikkeli. Export of timber products covers only export to abroad and was estimated based on information on companies webpages.

Data gaps and assumptions

The only full data gap is on retail data. Searching data sources will be continued. Data quality and completeness related to use and stocks could be improved by collecting more data on materials in bridges, railways etc. Quality of unit conversions concerning amount of materials in buildings could be improved if more accurate data on typical masses of materials in Finnish buildings could be found. Waste collection flows of different actors in Mikkeli can be complemented if data is available or data can be estimated. Also import and export data will be complemented if more accurate data is available.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector

The detailed analysis of Sankey diagram and data and assumptions behind those have been described in the Chapter "Visualisations".

As a conclusion, there are lot of manufacture of timber and concrete products in Mikkeli and considerable parts of these are exported outside of the area. There are also lot of forests in Mikkeli and nearby areas, so raw wood is obtained from very close proximities. Virgin sand &

gravel and stone material is also easily available for concrete manufacturing and for construction of roads and buildings. However, other construction materials like metals, gypsum, bricks and insulation materials are imported to Mikkeli.

According to the calculation illustrated in Sankey diagram, approximately 300,000 tonnes of construction and demolition waste are collected from extraction, manufacturing and use lifecycle stages, which could be potentially circulated in the city. There are many circular flows in the city but when looking at the whole picture, the flows are quite small in mass. On the other hand, all the data related to CDW collection and treatment is not currently available. Even 80 % of CDW collected by the most important actor, municipal waste management company Metsäsairila Ltd is recycled, mostly on the road and landfill structures. Metal waste is exported to recycling and timber waste is exported to incineration and energy recovery. The greatest potential for developing circular economy of construction sector in the city is to utilise materials collected as waste in upcycled higher-value products, which could replace virgin materials in the construction sector.

There are still many assumptions behind the distribution of material flows visualised in the Sankey diagram. In the future, the information may be updated based on possible new and more detailed data.

Connection to and upscaling of demonstration actions

Mikkeli's demonstration in the CityLoops project involves the demolition of two public buildings Pankalampi Health Care Centre and Tuukkala hospital using circular material management methods, including digital tools. To carry out the demolitions with circular material management, the sites are scanned and a pre-demolition audit will identify potentially recoverable materials and their characteristics. After a selective demolition procedure, salvaged materials are incorporated into the digital databank and construction material marketplace. Miksei Mikkeli promote use of the marketplace by other construction sector actors, private and public, both to offer and to obtain secondary construction materials. After evaluation of the pilot demolitions, the learnings and experience will be incorporated into a circular demolition operations model and generic demolition contract that can be applied in further public projects.

Demonstration actions respond to the needs to develop documentation of material flows as well as upcycling of CDW which were also emerged in the SCA analysis.

Recommendations for making the construction sector more circular

Mikkeli has already many good practices on construction and demolition sector. However, in future CDW materials could be upcycled and reused more efficiently than at present. For example, furniture and building components could be sold more efficiently for reuse or utilised at the city's own sites. Wood waste could be reused as a building material instead of energy recovery. Bricks could be recovered and used in construction instead of crushing. Crushed concrete could be used on city´s construction sites instead of virgin soil material although virgin soil material is still readily available. New operating models for the recycling and reuse of materials should be developed and tested, and new business could be created so that the circular economy can become part of the normal way of operating in construction and demolition in Mikkeli in the future. In addition, developing of documentation and data collection can improve assessment of circularity. The CityLoops project plays an important role in the development of these models and tools in the city of Mikkeli.

References

- Finland
- Pohjois- ja Itä-Suomi
- Etelä-Savo
- Population of Mikkeli in years 1994-2019 line diagram
- CORINE Land Cover 2018, 25 ha, Mikkeli
- Waste collection and treatment facilities in Mikkeli map

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

ROSKILDE

CITYLOOPS

METABOLISM OF CITIES

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Roskilde are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Aluminium	Bitumen / asphalt	Bricks
Concrete	Glass	Gypsum
Insulation	Iron (steel)	Sand and gravel
Soil	Timber	

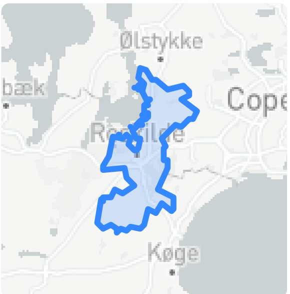
The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

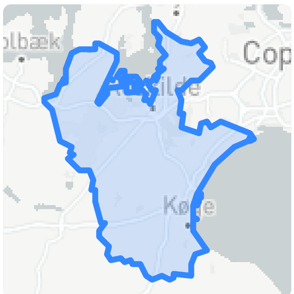
(The italic texts in this report were written by Metabolism of Cities' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

Urban context

To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.

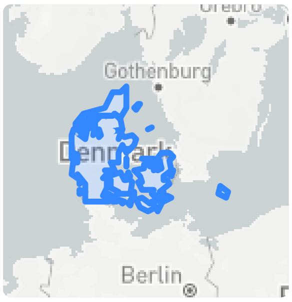


Roskilde
88,989
212 km^2



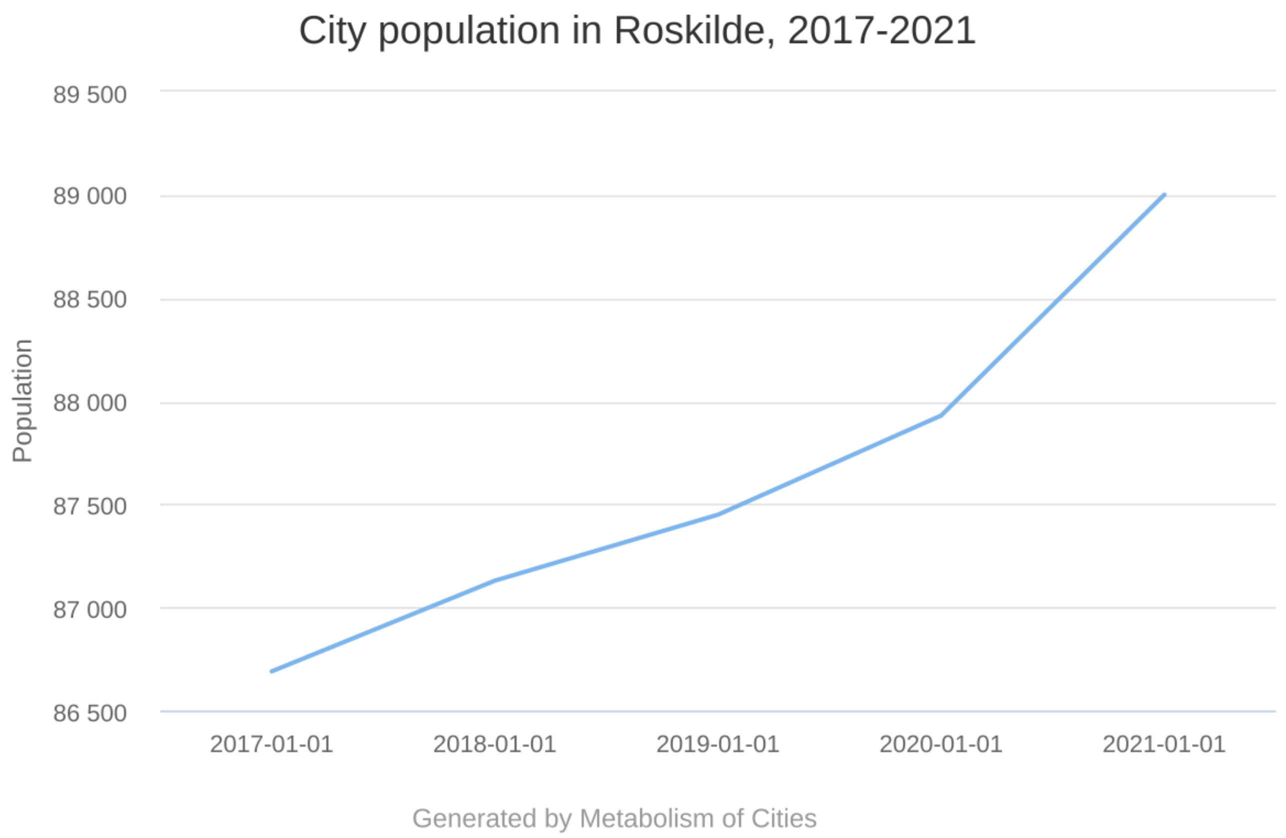
Østsjælland
253,321
808 km^2

Sjælland
2,659,634
9,789 km^2



Denmark
5,850,189
42,933 km^2

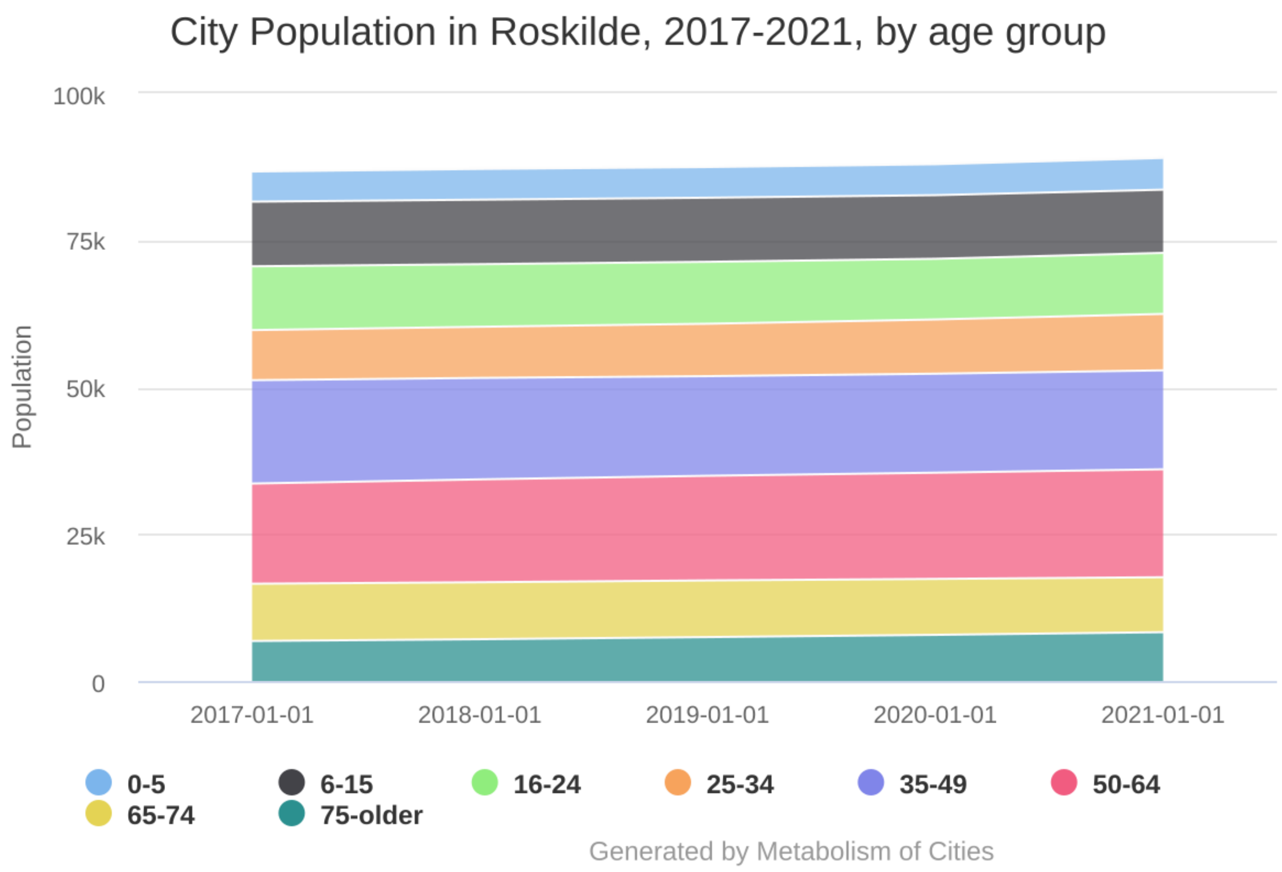
Population of Roskilde



Data source

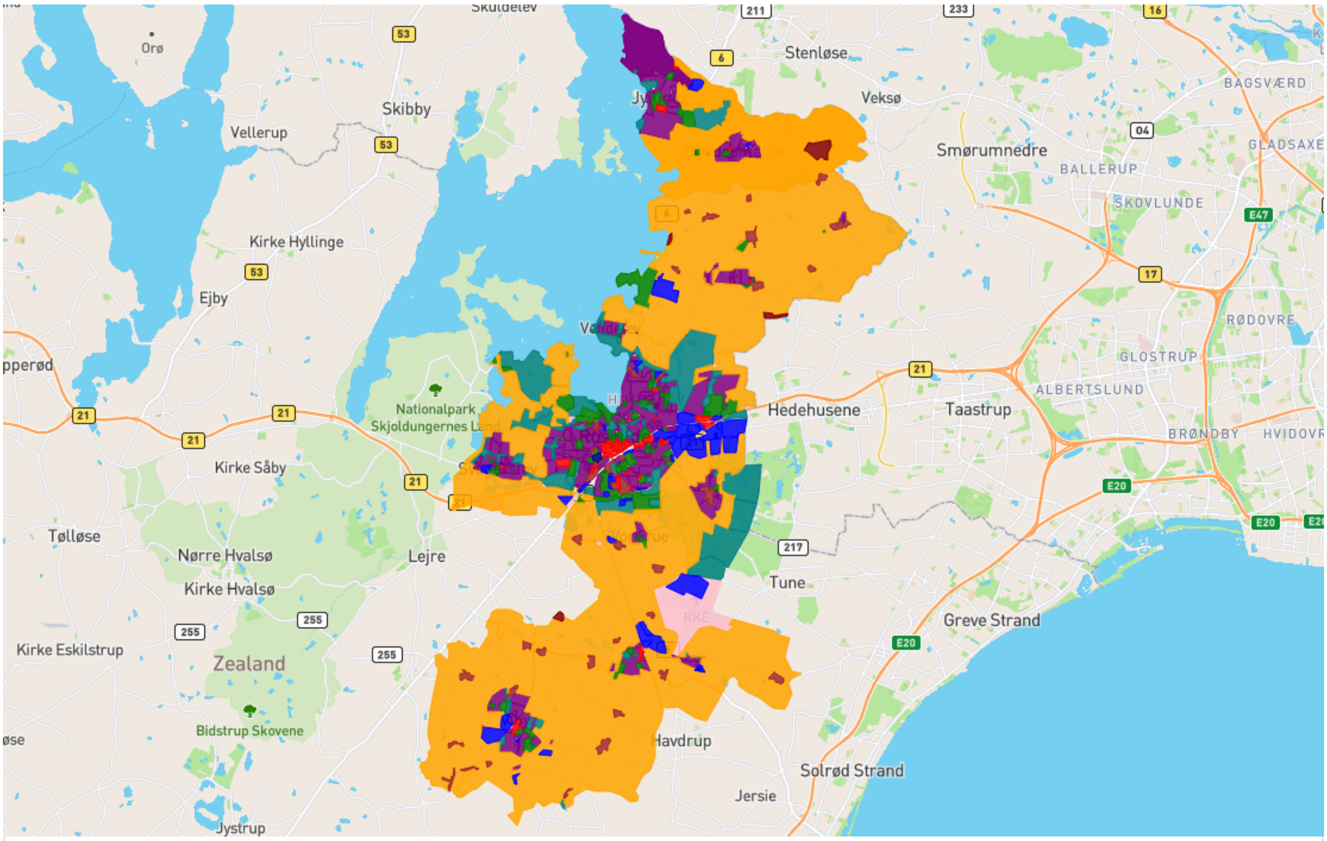
Roskilde municipality is characterised by a steady increase in population, namely by 2.67% from 86,689 inhabitants in 2017 to 89,001 in 2021. Roskilde is a popular settlement municipality and the city's relocation rate has been continuously increasing, for example by 1,200 people from 2019 to 2020. Expressed in households, there were a total of 40,102 in 2020. Roskilde municipality is characterised by a population that is largely represented by the fact that there are more than twice as many with a long higher education as in the rest of the Region Zealand. Also measured in short and medium-term higher education, Roskilde Municipality is above Region Zealand. Roskilde University attracts a number of new citizens every year and a portion of those stay in the municipality when they start working. This is balanced by a growing portion of elders in the population, since the number of deaths are increasing.

As can be seen in the graphic below, the population is comparatively young with about 40.6% (2021) of them being 34 years and younger, while the largest number of people are in the 50-64 year olds age group.


City Population in Roskilde, 2017-2021, by age group
Population
100k
75k
50k
25k
0
2017-01-01
2018-01-01
2019-01-01
2020-01-01
2021-01-01
0-5
6-15
16-24
25-34
35-49
50-64
65-74
75-older
Generated by Metabolism of Cities

Data source

Land use



- Area for public purposes
- Business area
- Center
- Land area
- Residential area
- Mixed housing and business
- Technical facilities
- Recreational area
- Vacation home area
- Other

Data source

The municipality is characterised by a mixed land use. Agriculture and nature fills up a significant part of the landscape. Low rise dwelling areas also dominate the land use. In 2021, there will be a special focus on changed land use, nature conservation and increased biodiversity on municipal land, cooperation on afforestation, further development of the nature areas close to the city, and improved access to nature.

Economic context of construction sector

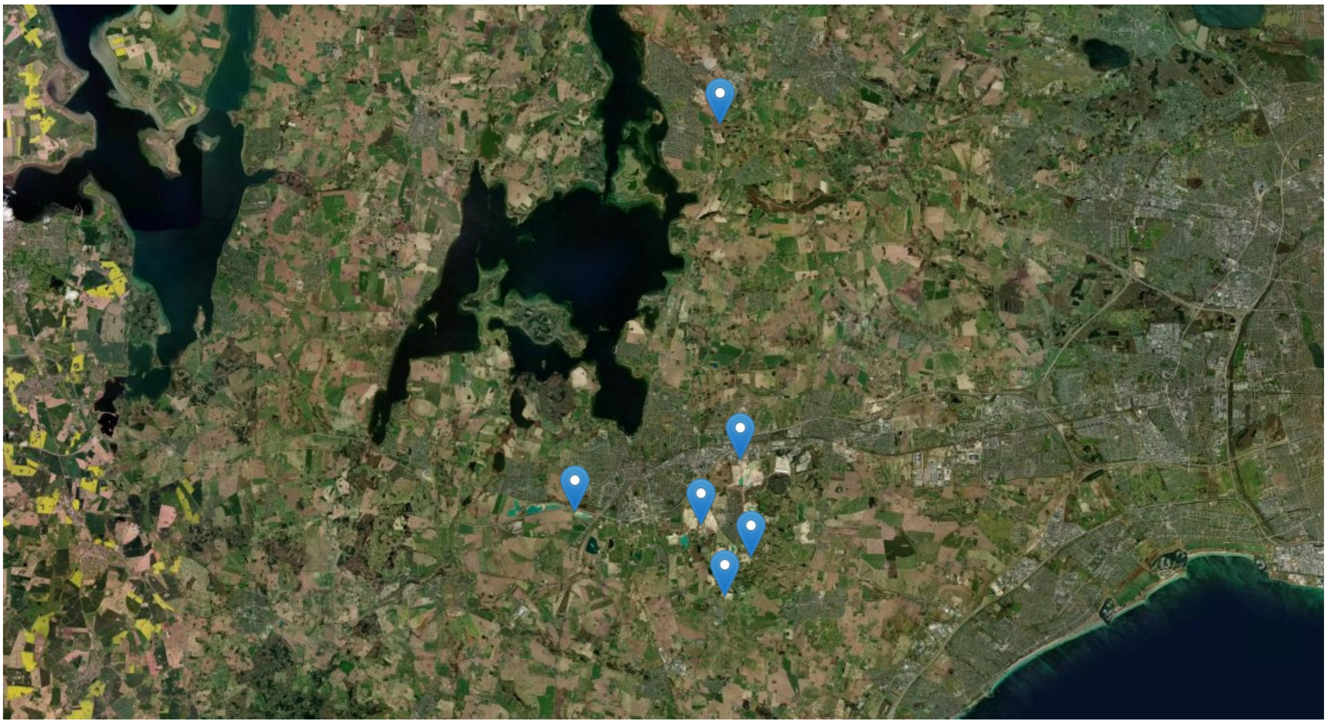
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	GDP (monetary value, in kr.)	Employees
Roskilde	708,000,000	3,113
Østsjælland	1,739,000,000	7,700
Sjælland	18,635,000,000	82,500
Denmark	40,375,000,000	178,505

The construction sector in Roskilde

The construction industry plays a key role as the second largest industry in the municipality and contributes to the economic activity overall. The construction industry accounts for 13% of the total industry. The construction sector of Roskilde is characterised by many small to medium sized companies in the construction sector. Most are associated with rawmaterial production and typical craftmen.

The actors of the construction sector



Data source

The primary actors associated with material flows in the construction sector are: Nymølle, Roskilde Sten & Grus ApS, Munck Asfalt, Betonelement, DK Beton, and ARGO.

Extraction

A number of actors that deal with extraction of raw construction materials can be found in Roskilde. As seen on the map, there are a total of six companies present, most of which are gravel pit operation sites. Nymølle Stenindustrier A/S and Roskilde Sten & Grus ApS are the largest companies by employees with around 70 and 45 people respectively in 2019, whereas the other four companies have less than five employees. The so-called "Hedehusene" gravel pit (see image), though in the municipal boundaries of Roskilde and operated by Nymølle, is the largest gravel pit of Denmark. In 2020, about 2 million tonnes of gravel were excavated from that site. For over 100 years, gravel has been sourced from this area with different levels of quality that the Danish construction and infrastructure industry are dependent on. These gravel deposits have been deposited by huge meltwater rivers during the last ice age and cover a vast area from Roskilde west and all the way to Hedehusene in the east, containing an unusually high content of stones. Therefore, the municipality is well suited to produce a wide range of high quality sand, gravel and stone products to fit many different purposes, e.g. foundation, road construction, construction projects, as well as a contract for asphalt and concrete production (Nymølle Stenindustrier A/S 2019).

Data source

Compared to Nymølle, Roskilde Sten & Grus ApS has not been in operation for so long, but also already for three generations. What began with the discovery of sand in their agricultural field in the 1970s and the initial operation of a gravel pit in Himmelev is nowadays a family-owned company that has excavated several areas in the vicinity of Roskilde. Since 1999, the primary excavation work has been at Øde Hastrup Vej (Roskilde). The area has since grown and the third generation, Anders Jensen, has taken over the day-to-day operations. The gravel pit delivers both for the very large construction and building projects, for the small craftsman, gardener, mason and contractor as well as for the private homeowner who has the opportunity to bring their own trailer and pick up materials (Roskilde Sten & Grus ApS 2021).

Manufacturing

The construction material related manufacturing industry in Roskilde is limited to two materials: bitumen/asphalt and concrete. For all other materials (aluminum, bricks, glass, gypsum, insulation, iron (steel), timber), there are no companies registered to be dealing with those in the municipality.

Asphalt

The main bitumen/asphalt company in terms of employees is Munck Asfalt with 27 people (2019). Founded in 1995, their business revolves around the manufacture of asphalt and the construction of roads and motorways. At the "Sjælland - Asfaltfabrik Svogerslev", the asphalt plant which is located between Svogerslev and Lejre, approx. 8 km west of Roskilde, new asphalt is mixed in a batch operation with a 4 tonne mixer and a capacity of approx. 240 tonnes per hour. The site also has a crushing plant that receives old, broken asphalt and electric slag for crushing.

Next to Munck Asfalt, there is also the Dansk Støbeasfalt, with officially 9 employees, which has existed under this name since 1986 and was owned and operated by Vagn Rask for 25 years. Since then, Dansk Støbeasfalt has had an administration and factory in Roskilde. Since the end of 2011, the company has been owned by and operated as a subsidiary of the DAB Group AB, which handles membranes, sealing layers, cast asphalt and concrete renovation. The local subsidiary itself focuses on casting asphalt and moisture insulation (Dansk Støbeasfalt 2021).

The third company registered in Roskilde municipality to handle asphalt is Sjællands Emulsionsfabrik I/S (SE). SE is a production company that produces various bitumen based products. Typically, the products are used in the production and laying of asphalt. Other areas of application for SE products are, for example, gluing, grouting, moisture protection, impregnation and sealing. (SE 2021).

Concrete

As for concrete, there are two actors, namely Betonelement and DK Beton.

Betonelement is a subsidiary of CRH Concrete A/S, which manages several brands and employs approximately 1,300 employees in 11 factories throughout Denmark. CRH Concrete A/S is part of the international group CRH plc (approx. 80,000 employees in 30 countries). The Betonelement company is located in the south of Roskilde municipality, in Viby Sjælland, where it has the production site, as well as the headquarters of Betonelement and CRH Concrete A/S. There, it produces concrete and lightweight concrete with a special focus on concrete building elements that it also designs and installs as a service. Betonelement supplies all types of elements, from prestressed structures, over facades, walls, columns and beams, to complete solutions in both industrial, domicile and residential construction. Since recently, they can also deliver filigree decks, double walls, tunnel elements and prestressed bridges (Betonelement 2021).

DK Beton is the other company manufacturing concrete in Roskilde. While a national supplier with 17 locations that supply ready mix concrete, two of those sites are in the municipality, namely in Roskilde and Gadstrup. The company delivers both traditional concrete, floating / vibratory and set concrete in all strengths. Floor concrete, curb concrete, joint concrete and gravel concrete are also part of their supply. daily concrete delivery. Their customers range from private individuals to large contractors.

Retail and wholesale

There was no information provided on the companies registered in Roskilde that are operating in the retail or wholesale related to the construction sector. Oftentimes, the manufacturing companies are engaged in direct sales to other companies or contractors, thus skipping the step of a retail middle person. Moreover, even if the company names are known, it is generally very difficult to obtain data on sales volumes of materials. Therefore, the actors of this supply chain stage are disregarded.

Use

As for the actors in the use stage, the share of companies or private persons employing construction materials for construction or renovation work is unknown. Although there are permits for such work, it is not stated who carries it out, no less which materials and quantities for it are employed. In all likelihood the number of actors, especially in the form of small companies, is quite large. However, there is no overview of those. Even if there was, the local contractors' shares of doing work within the boundaries of the municipalities vs. outside of it and those who aren't registered in the municipality, but still conducting work in it are unknown.

Waste collection and treatment

The four main actors dealing with waste collection and treatment in Roskilde are all concentrated to the east of the center of the municipality, in industrial areas, close to highway 21. ARGO, an I/S waste company that treats waste for citizens and companies in nine Zealand municipalities, dominates waste processing in Roskilde. The company's primary task is to ensure that waste is converted into resources. The prioritisation is as follows: reuse before recycling before energy utilisation before landfill. As much waste as possible must be reused and recycled, and energy utilisation must take place in an environmentally sound manner and with the greatest possible benefit in the form of electricity and district heating. In Roskilde, ARGO operates two sites: a recycling center and a combined heat and power plant (CHP) called Energitårnet (energy tower), whose construction was finished in the end of 2013. The energy tower rises as a landmark for Roskilde and is surpassed only by the monumental cathedral. The CHP, which cost 1.293 billion kroner (166.6 mio. Euro), uses the waste that cannot be reused or recycled and with a utilisation rate of close to 100 percent, generates heat for the production of electricity and district heating. The district heating is sold to the transmission company VEKS, whose transmission network extends from Roskilde to Copenhagen and along Køge Bay to Køge.

Data source

Aside from ARGO, there are three other actors: Solum Roskilde A/S, Hedehusene Product Handel A/S, and Stena Recycling. These primarily deal with waste collection, the two latter ones especially with iron and metals, which they also trade.

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level). However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	3,160,939.04	Tonnes/year
39	Circular Material Use Rate	9.01	%
48	EU self-sufficiency for raw materials	1.01	%
55	EOL-RR (End of Life Recycling Rate)	13.99	%
57	Amount of sector specific waste that is produced	683,520.42	Tonnes/year
58	End of Life Processing Rate	30.00	%
59	Incineration rate	1.75	%
61	Landfilling rate	25.03	%

The domestic material consumption (DMC) is calculated by adding "Domestic extraction used" to "Imports" and subtracting "Exports". For Roskilde, it amounts to 3,160,939 tonnes and 35.52 tonnes per capita. This value is quite high compared to the total DMC of 13.4 tonnes per capita for EU-28 in 2019 and still higher relative to the 24.98 tonnes per capita, in all of Denmark. However, those latter two also do take into account the **total** DMC and not just the materials used in the construction sector. Since it goes beyond the scope of this work to determine the share of construction materials in the total economy, it will not be further assessed. There are two main aspects that influence the DMC: (1) Probably the exported amount of extraction is under accounted for, meaning that not all that is extracted locally is also used locally, but likely transported to and used in other regions and (2) the "use", which was indirectly determined through this high extraction value becomes very high in return, especially since the exports are not that high. These uncertainties are definitely a shortcoming.

The CMU value of indicator 39 stands at 9% and compared to the 12.4% for EU-28 in 2019 and 7.6% for Denmark, seems to be in line. However, since this indicator also includes the DMC, it must be assumed that the value is negatively affected as well. Another difficulty that is added to this indicator is that it was originally designed for metals. Since now materials from different categories are bundled up, it skews the image of the circularity of materials.

The EU self-sufficiency for raw materials indicator is very low with 1.01%. Unfortunately, there is no national value to compare it to. And since the data completeness was lacking in terms of differentiation of the single materials, this indicator couldn't be calculated for them individually to determine the various self-sufficiency levels.

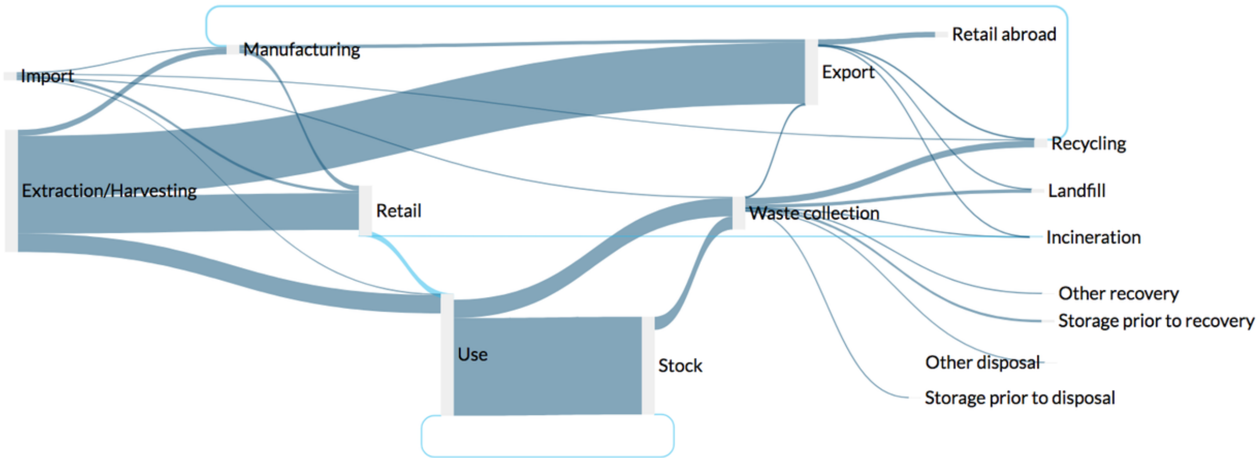
The EOL recycling and processing rates are still considerably low with about 14% and 30%, respectively. While 27% of materials are still subjected to disposal and 73% to recovery, the efficiency of recovery could still be improved. There is however uncertainty in those values, as the amounts derived from recycling had to be estimated.

The incineration rate is very low with only 1.75%. This is somehow surprising, as there is an incineration plant close by in Høje-Taastrup. On the other hand, construction waste materials are usually not subjected to a large extent to those facilities.

Finally, the landfilling rate is still quite high at 25%. The numbers came from the waste statistics and can be considered reliable, thus there is no uncertainty there. Either the municipality really still landfills quite a lot of waste, or the values are influenced by a lack of classification or differentiation of waste use on landfills as "alternative daily cover".

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



Data source

The Sankey diagram builds of course on the collected data that also the indicators have been derived from. Therefore, it needs to be taken into account that the previously discussed data quality influences also the quality and informative value of the Sankey diagram. In addition to the data quality, so-called allocation values also have an impact on the data behind the visualisation. These allocation values were employed to estimate the amounts of materials that "flow" between the single lifecycle stages, since these relationships and quantities were in most cases unknown, except for waste collection going to waste treatment.

Overall, the Sankey diagram for Roskilde shows that quite a lot of materials are moving around in the construction sector system. The share of materials for and from **extraction** really dominate the graph. About 30% of the materials (2 million tonnes) are extracted in the form of sand and gravel by one company, Nymølle Stenindustrier A/S, alone. The main share of it is subjected to export for retail outside of the municipality, while the other shares go to manufacturing, retail and direct use.

Compared to export, **import** plays a significantly smaller role. (It should be noted that the data quality and estimations of imports do have an impact on the image here, see the data quality section above.)

Manufacturing sees an inflow of materials from recycling and **retail** is fed with new materials from extraction, import and manufacturing, as well as secondary materials from incineration and use. This latter return flow from use back to retail could be surplus materials from construction sites that are labelled for reuse.

Going forward in the diagram from left to right, it can be seen that there is a data gap from the outgoing materials from **retail** to all other lifecycle stages. This reflects on the gap in the data availability described above.

Use is being fed by imported and extracted materials, although the majority would likely origin from retail, which can only be assumed due to the data gap. Most of the materials from use end up in stock, as constructed materials. While it may seem that quite a significant amount (677 kt) of the **stock** goes to waste collection and a little bit gets reused, this is only true in terms of the data of flows. It might seem that a lot of buildings and infrastructure get demolished again, but this of course isn't the case. It is just that the Sankey diagram does not depict the stocks, the materials that stay in a system for over a year, but only the flows from the single stages.

While the **waste collection** node does receive most materials from the stock, it also gets inflows from imports and use. The diagram shows that the main share of materials leaves to **recycling**, which is also fed by imports and which has a comparatively large outflow as return flow to manufacturing. As for the other waste treatment options, **landfill** is quite high and very similar in size to **storage of materials for recycling**. Finally, a significant stream is from **export** to **retail abroad**.

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.

Rating	*Reliability*	*Completeness*	*Temporal correlation*	*Spatial correlation*
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*

Rating	*Reliability*	*Completeness*	*Temporal correlation*	*Spatial correlation*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Extraction/Harvesting				
Manufacturing				
Retail	no data			
Use				
Stock				
Waste collection				
Landfill				
Incineration				
Recycling				
Imports				
Exports				

As can be seen in the data quality matrix above, the overall quality of the data is relatively high. The temporal correlation is very good for all lifecycle stages (LCS), as the data was almost always from the reference year (2020) or from 2019. The spatial correlation is still fairly good. However, it does suffer, especially in manufacturing where national data was used and in use, imports and exports where NUTS3 level data were employed. The reliability of the data is ok. For around half of the LCS, the data was measured, while the other half was estimated or provisional. Finally, the completeness of data scores medium for all LCS. This is mostly because the data either only exists for some single or for some economic activities, but not both and not all materials are differentiated.

Data gaps and assumptions

Aside from data often being available, there were still some gaps in local data or the data was not in the right form. The following paragraphs describe how sources, assumptions, and calculations were used for each lifecycle stage.

Extraction

The data for extraction was obtained from the Danish statistics on "RST01 Extraction of raw materials in Denmark by region and type of raw material", which has data for the years 2006-2020 and where it was used for 2019. Since it was only an amount for all construction materials, the coefficient 1.9 from the Eurostat Handbook was used to convert from cubic metres to tonnes.

Manufacturing

The manufactured amounts were derived from the Danish national statistics called "VARER3: Manufacturers' sales by main SITC groups". The relevant materials were selected and then calculated in tonnes with a conversion sheets for conversion from DKK 1,000 to tonnes. Thereafter, employment numbers in that sector were used as a proxy to downscale the values for Høje-Taastrup. Since the materials are only on a 2-digit level, they are considered medium in terms of completeness for the data quality.

Retail

In the case of retail, the data gap could not be closed. The issue around data in that area and level was confirmed by a recent study entitled "Cities as organisms: Urban metabolism of the four main Danish cities" (p.3), which stated that "it should be noted that inflows of construction materials and goods could not be quantified due to unavailability of public data at the city level." It goes on in saying that "data on construction material inflow is difficult to obtain at the city level, if existing at all. Worth mentioning here is the current development of dynamic built environment stock studies that might help get a better understanding on the size of construction material flows entering cities" (p. 13). Their findings could be confirmed for the inflows represented by the lifecycle stages of retail and use, for which it could either not be obtained at all or it was estimated indirectly, respectively (see "use").

Use

As mentioned under "retail", data for the use lifecycle stage could only be derived indirectly, namely by applying the DMC (Domestic material consumption) formula (Domestic extraction used + Imports - Exports). With the help of the imports and exports data, it was calculated how much materials were used. Since the imports and exports data is from NUTS3 level and it can be considered a rough estimation, the score in the data quality matrix is low for reliability accordingly.

Stock

The amounts for stock came from a report called "Prognose for sekundære råstoffer" *(English: Forecast for secondary raw materials)* which was carried out for the municipalities of Høje-Taastrup and Roskilde in 2021. The report provides information on a forecast for the expected production of recyclable (secondary) raw materials of concrete and bricks from buildings, as well as concrete, asphalt and gravel from paving that result from demolition and renovation projects. The values could be used as they were.

Waste collection and treatment

The data for waste collection and treatment were extracted from the Danish "Affaldsdatasystemet (ADS)" *(English: waste data system)* by the municipality, using the sources of ""Affaldsproduktion i Danmark fordelt på kilde og kommune (R026) (Branchegruppe)" *(English: Waste production in Denmark by source and municipality (R026) (Industry group))* and "Affaldsproduktion i Danmark fordelt på behandling og kommune (R019) (R/D)" *(English: Waste production in Denmark by treatment and municipality (R019) (R / D))*. The data is for 2019 and in tonnes, so it could be used directly. In principle, the completeness of waste data is also pretty good. The issue here is that although it is detailed per material, it is not known by which economic activity or lifecycle stage they are produced.

Imports and Exports

For imports and exports, national road freight transport data for unloading and loading regions (NUTS3) respectively, from 2019 were used. The data is in tonnes, so it doesn't suffer in quality through conversion. However, an estimation needed to be made for the share of materials used in construction. For this, it was estimated that 80% of the materials for selected categories from the NUTS3 imports are used for the construction sector. The same applied to export.

To summarise overall, the data gaps stemmed from:

- Some data only being available on a national level and not a municipal level.
- Large amounts of data being unavailable due to lack of reporting and/or trade secrets.
- Certain data that is available, but only behind a paywall. It was not possible to access this data, because it required to be extremely precise about exactly what data needs to be retrieved. As the SCA process and method were still under development, a precise enough

formulation of which data was needed was not possible to be conveyed to a level that was satisfactory to those who were to retrieve the data, during the time when the people in the municipality had resources to do so.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector

This report provides a lot of information on the construction sector, its size, actors and materials handled in the municipality of Roskilde. Based on that it can be summarised that the construction sector plays an important economic role in the municipality. Various actors and industries are represented here, including some national and international companies. Many of the local companies have been in the municipality for well over 50 years and consistently brought business to and made available job positions in the region.

It was seen that the area is also well suited for extraction of sand and gravel due to its geological history. Since not all of the materials are needed locally, a lot of those are exported.

The current situation of the construction sector with regards to its circularity is hard to determine due to limitations in data availability and quality. The direct reuse of materials is quite low and while the amount of waste subjected to recycling is high, the recycling efficiency is not known, which would help in determining the amount of secondary materials available. It is, however, already commendable that there is a focus on waste sorting, though mostly in the interest of removing hazardous substances from the waste stream and recycling non-hazardous materials lower on the waste hierarchy than where they started.

Overall, the municipality still has a long way to go to make the material flows of their construction sector more circular.

Connection to and upscaling of demonstration actions

The municipality of Roskilde has three demonstration actions (DA) planned to showcase its intent to encourage circularity in the construction sector in Roskilde.

- **DA 1: Demolition of Hall 11/12 area, preserving the building structure and facilitating reuse of CDW**
    - Hall 11 is a secondary building situated in the demonstration area. It will be demolished and materials from the demolition will be incorporated into other

construction projects. The function of hall 12 was and will remain a skate hall. Beams and pillars and the main steel structure of hall 12 will be preserved - therein lies the greatest savings in materials and CO2. The building will get a new roof, new façade and new interior. Hall 12 will be connected with a new multi-storey car park by a roof spanning 12 x 45 metres.

  - The buildings had a **pre-demolition screening** and **selective demolition** will take place, keeping reusable elements in storage for reuse in new buildings and creating material passports documenting their quality and possible use. A **virtual material bank** will be created through design for disassembly using Building Information Modelling (BIM) for information on regulations, quantities, material types, etc. LCA on selected materials will aid in decision making by revealing the carbon emissions impacts of different handling options. Roskilde will also try to implement circular soil strategies in the project by minimising soil movement and facilitating reuse on site.
  - A **material passport** will be created for selected materials from the demolished buildings. A virtual material bank is sketched and will be used for hall 11/12 - both for materials going out (in the selective demolition) and in the new, renovated hall. The first version consists of an Excel sheet for each material, describing its lifespan, what kind of testing it has to go through, and where it could end up in future uses.
  - The virtual material passport and databank are merged in one database. The circular procurement strategy includes use of the virtual material bank to source and supply secondary construction materials. The data is extracted from BIM models and kept in a database. Roskilde asks for the BIM in the tendering process for each building to be built at Musicon, to ensure such documentation is available for the future. Contractors need to provide a Revit/BIM model level of detail of each building with amounts/ types of materials.
- **DA 2: Construction of Car Park 2 'Indfaldet'**
  - Construction of Car Park 1 was finished in mid-2021. When Roskilde started digging in preparation for the car park, they discovered a large amount of concrete obstacles in the ground stemming from the site's concrete production function in the past. The concrete unearthed in CityLoops was kept on site and crushed into a mixed fraction. The mixed fraction was used for material layers below the concrete, replacing virgin gravel. Other concrete recovered from the digging was cleaned and crushed, to be mixed on site and used in new concrete. This has made a very positive business case.
  - A criterion in the tender for the new car park was that the developer foresee **design for disassembly**, including scenarios for future recycling. Consequently, a report was delivered by the contracted developer (MT Højgaard). They created the multi-storey car park with a steel skeleton, premade components assembled by bolts and a minimal use of concrete. They made calculations on CO2 for future reuse/ recycling and have documented the benefits on future use of materials from the car park. The local Parkour club is to finish/ furnish their area of the Car Park 1 with materials from the material bank at Musicon.
- **DA 2b: Construction of Car Park 2 'Pulsen'**

    - The second multi-storey car park will be built as a steel structure, and Roskilde is involving the market in **risk model analysis and testing.** 100% recycled coarse fraction and 50% recycled fine fraction of recycled concrete will go into the foundation for Car Park 2. It's a new construction, so circular strategies such as design for disassembly will be added. Roskilde will create a physical construction material bank in the ground floor of Car Park 2. There will be a roofed passageway between this car park and hall 12. The refurbishment of the old library in Roskilde has released a total of 128 big bags of used roof tiles. These roof tiles will be reused in the new car park on the facades.

Recommendations for making the construction sector more circular
In order for the construction sector to become more circular, the **successes and methods** behind the actions striving for that need to be made as visible as possible. This will ensure replicability and that the barrier of knowledge gaps, in terms of how to build with circularity on a purely practical level, are reduced.

The municipality would also be greatly helped by **legal measures** that would incentivise circularity. These include higher fees for virgin resource extraction and higher fees for waste disposal. Greater possibilities of certifying and guaranteeing used materials are also essential to reduce the perception of risk associated with using used materials.

It can also be recommended to **increase engagement and collaboration with local players** that already have circular initiatives and solutions, for example:

- DK Beton already has a "circular concrete" product. According to their information, this material employs 20% recycled concrete aggregate, 100% recycled water and a filler that replaces up to 30% cement.
    - The municipality of Roskilde could support this business by promoting it and direct business there. In addition, it seems to be an opportunity to include this company in procurement processes, for when the municipality itself requires concrete.
- Solum Roskilde, who on their "Our DNA is circular economy" page state that they want to be a 100% circular company and already engage in partnerships for that. "The Solum Group has e.g. together with STARK and Golder developed the idea behind GENTRÆ, which is wood waste from construction sites that are converted into recycled wood for the same purpose, rather than as before, ending up as waste on incineration. An idea that has won a prize at the Realdania Circular Construction Challenge." They have something on CE, might be interested to share it.
    - Roskilde could support this company and their ambition by facilitating a get together of like minded companies to create the possibility for partnerships. A smaller way to provide assistance could be in the form of drawing attention to such projects, by sharing it on the municipality website or a newsletter.

Certainly, other **circular initiatives** could be discovered and mapped in Roskilde, or it could be learned from, adopted and build on the “14 Danish cases on resource efficiency in small and medium-sized enterprises”, which can be a recommendation in and of itself. This would help with other **business potentials** e.g.:

- for higher value utilisation of materials: Development and testing of new concepts and business models as well as new and existing technologies and methods that support a higher value utilisation of materials
- of circular design and product development: Design of products and processes that underpin a more circular economy and new circular business models.
- of plastics recycling: Reducing and improving the recycling of plastics, including in particular plastic packaging across sectors as part of SMEs' exploitation of future business potentials in plastics recycling

It can also be recommend that the municipality guards and finds measures to **take care of local resources**. Although the area is predestined for extraction of construction materials, especially with its many gravel pits, these materials are nevertheless still finite. Recognising that private businesses engage in their extraction and that it is economically important, the resources should be sourced responsibly, as the avoidance of virgin materials use has the highest priority in a circular economy.

Finally, it is recommended that the **data availability and quality** are improved on, so that the region can determine its true potential of available resources and wastes per year. This way, the potential for upscaling the demonstration actions could be better analysed and a circularity process for the sector developed, containing main objectives and an action plan.

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- Static land use map of Roskilde
- Static map of extraction companies in Roskilde
- Header image: Mariusz Paździora, CC BY-SA 3.0, via Wikimedia Commons

SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

SEVILLA

CITYLOOPS

METABOLISM OF CITIES

Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of two central sectors of any city in terms of material flows, societal needs and employment, namely the construction and biomass sectors. Due to their sizes, they represent a considerable opportunity for cities to transform their metabolism and economy towards a more circular state.

Within this project, seven European cities, amongst those also the City of Sevilla are planning to implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their sector, a Sector-Wide Circularity Assessment method was developed. This method combines a circular city and circular sector definition, a material flow and stock accounting method, as well as circularity indicators. The sector itself was defined in terms of a number of representative materials that make up a large share of the sector and associated economic activities. The construction sector is made up of 11 materials, depicted as icons here, which were studied along the entirety of their supply chains. Altogether, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

- Aluminium
- Bitumen / asphalt
- Bricks
- Concrete
- Glass
- Gypsum
- Insulation
- Iron (steel)
- Sand and gravel
- Soil
- Timber

The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection (construction and biomass) and data processing. Numerous additional insights can be found in the individual Data Hubs of each city.

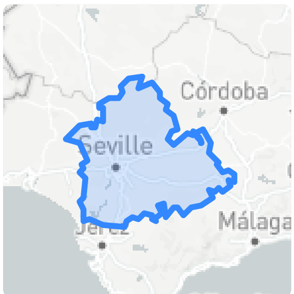
This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the limitations from the data used and offers recommendations about how to make this sector more circular.

(The italic texts in this report were written by Metabolism of Cities' Aristide Athanassiadis and Carolin Bellstedt. They provide relevant general information and serve as connecting elements of the single report parts.)*

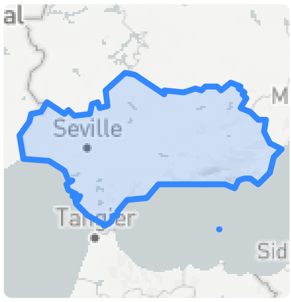
Urban context

To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to a city level.

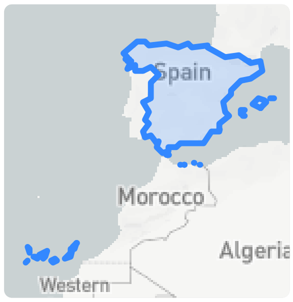
Sevilla
688,592
142 km^2



Sevilla
1,942,389
14,036 km^2

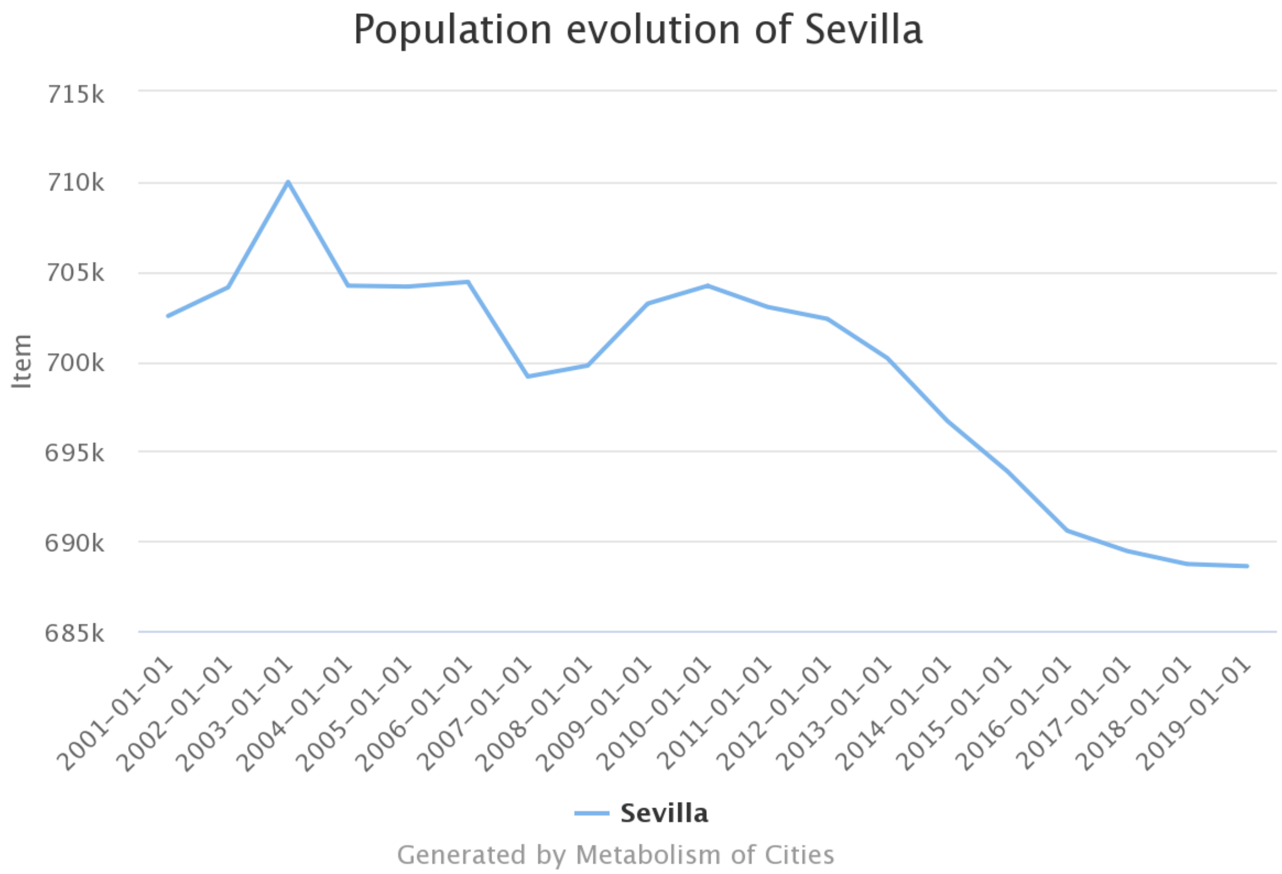


Andalucía
8,414,240
87,600 km^2



Spain
47,026,208
505,990 km^2

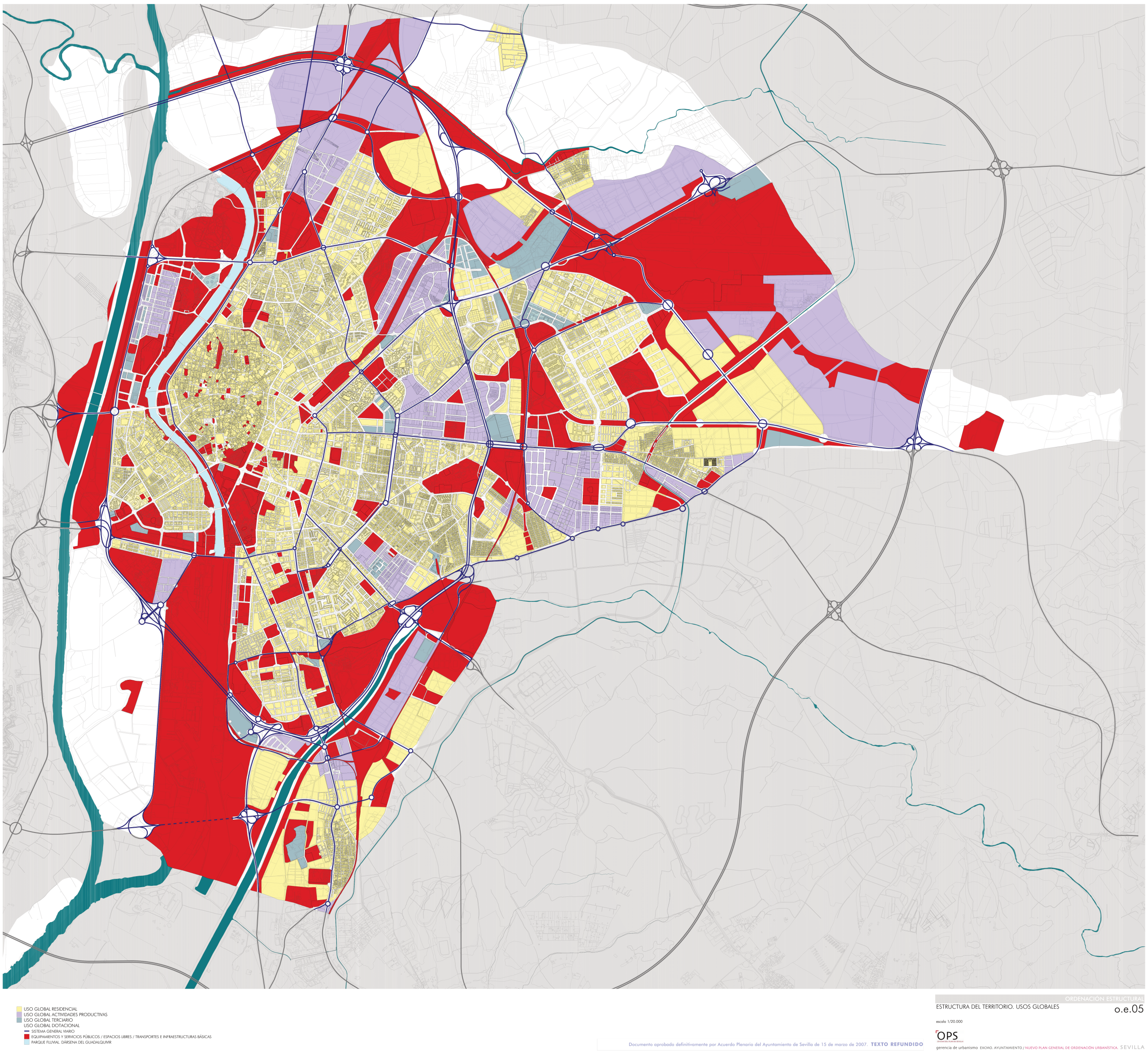
Population of Sevilla



Data source

The municipality of Seville is made up of 11 districts, which are administratively subdivided into 108 neighbourhoods and these, in turn, into 542 census sections. As of January 1, 2019, the population amounted to 688,592 inhabitants, which represents a loss of 10,098 people compared to January 1, 2017, with the South district being the one that loses the most inhabitants. If the comparison is made with respect to January 1, 2013, the loss of people is even greater, reaching 11,577 inhabitants i.e., 1.65% of the total population. The highest concentration of population is found in the East district, where there are 105,964 inhabitants registered. This population represents 15.10% of the total population of the city.

Land use



[Data source](#)

Seville's land use is urban and mostly classified as residential, but has public facilities, services, free spaces, transport and basic infrastructures. The historic area is composed of 3.9 km². The green spaces only occupy 1.8 km² of the territory.

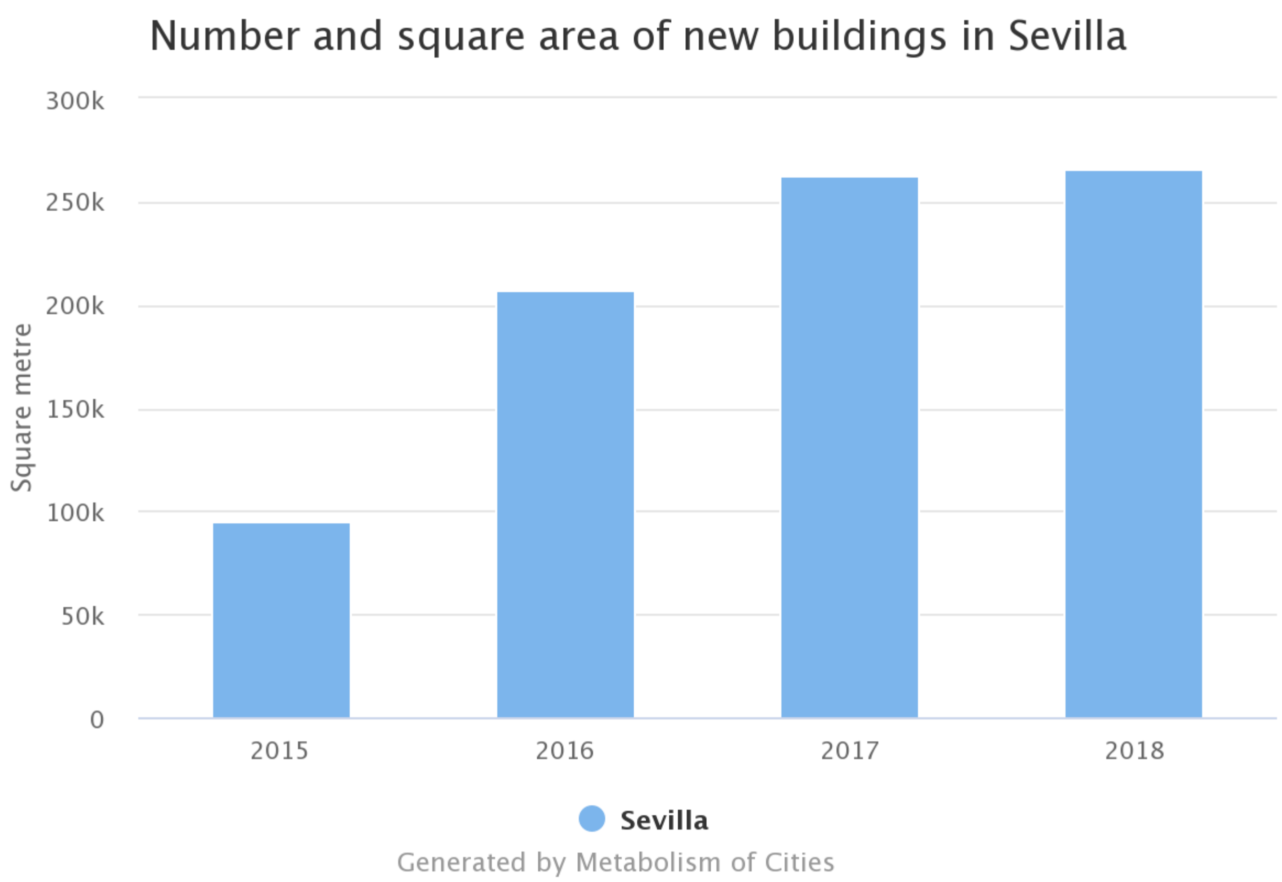
Economic context of construction sector

This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	GDP (monetary value, in €)	Employees
Sevilla	781,932,436	13,044
Sevilla	2,214,984,000	43,734
Andalucía	10,694,329,000	214,750
Spain	70,715,000,000	1,295,000

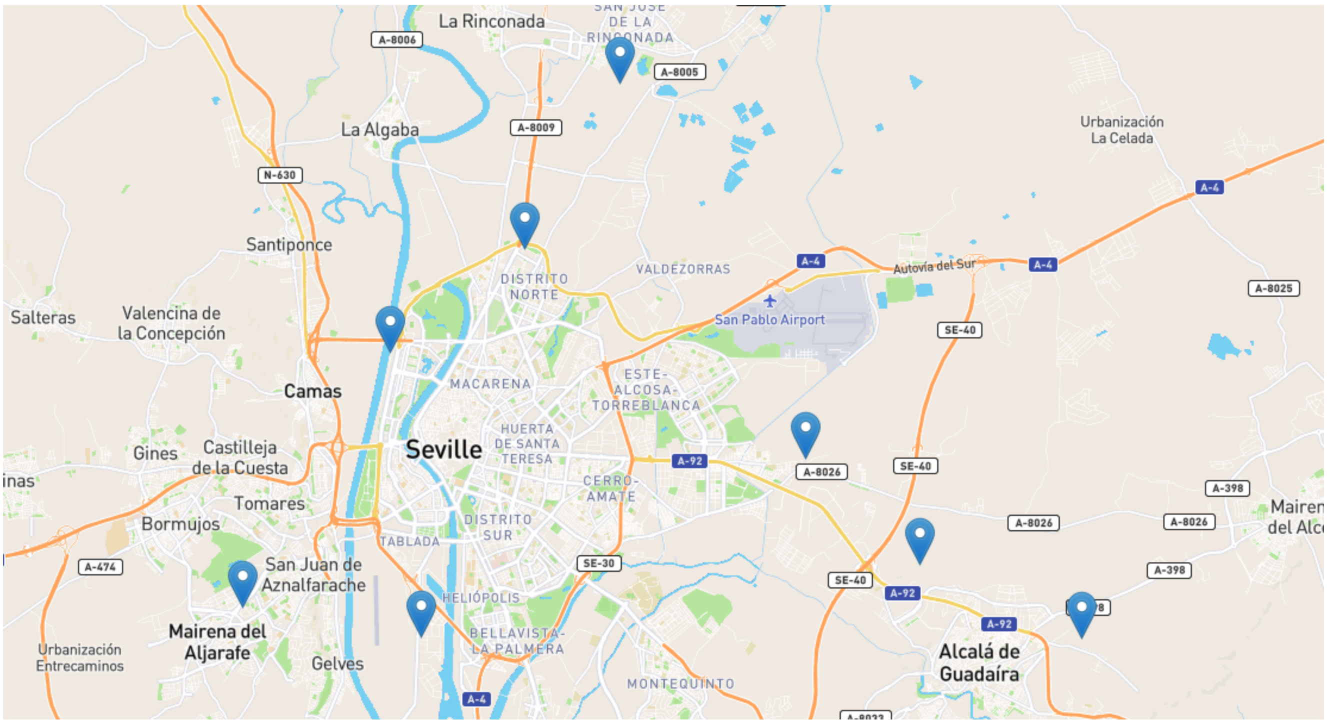
The construction sector in Sevilla

The construction sector employs 5.4% of employees in Seville. The corresponding percentage for the whole country of Spain is 6.4%. The most significant employment sectors in Seville are the Service sector (78.6%). Construction accounts for about 5.6% of Seville's GDP. Based on turnover, the most significant industries in Seville are wholesale and retail trade (11%) and the manufacturing industry (9.75%). (Data of Statistics Andalucia region) Data is from the year 2018 (GPD and employees data from the reference year 2019 was not available). In Seville, the largest construction projects are often managed by national companies and employees can also come from outside the area. According to the 2018 statistics, the number of new buildings Licenses in Seville was 1,602 and the total floor area was 266,266 m^2.



Data source

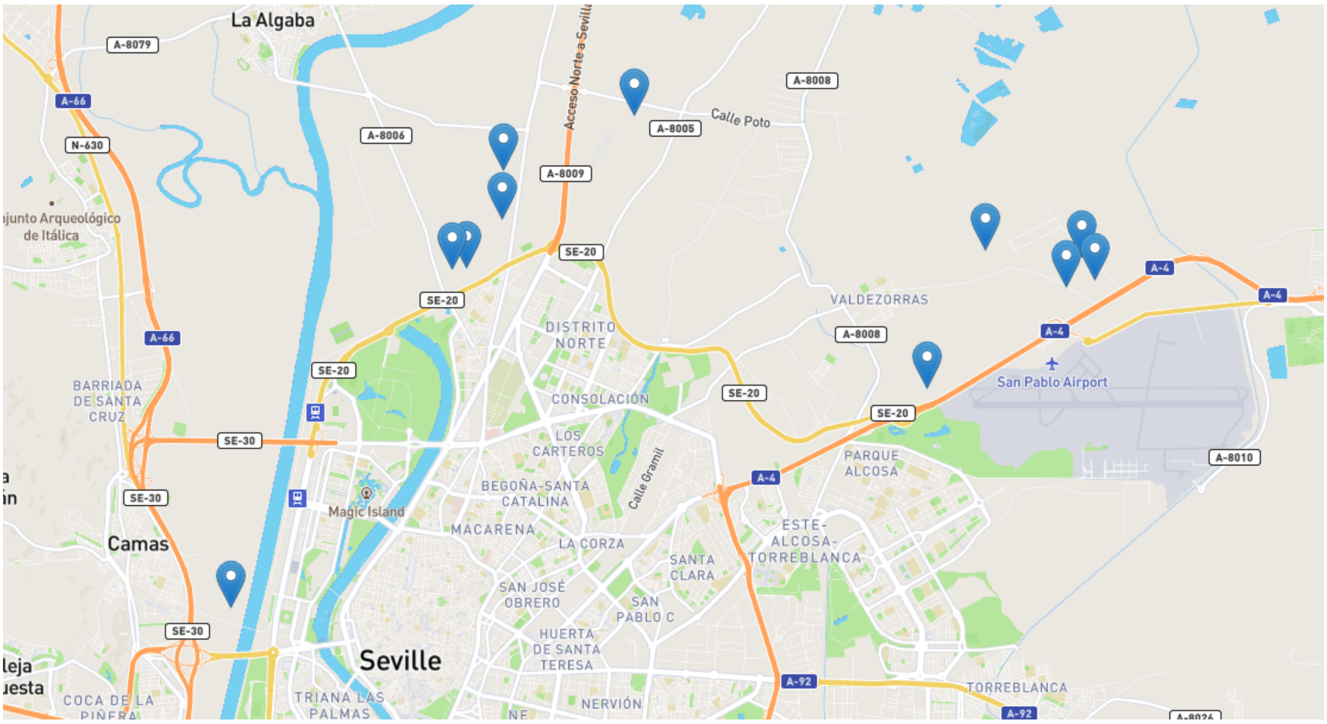
The actors of the construction sector



Data source

Seville shows 3,032 facilities focused on the construction sector, the corresponding percentage regarding the whole facilities (all economic sectors) located in Seville municipality is 6.5%. The construction facilities are mainly located in the metropolitan area of Seville and there are representatives of all the roles in the value chain i.e., extractive/harvesting, manufacture/use, waste collection and valorisation. The main actors showed in the figure are representative of the entire value chain.

Extraction activities



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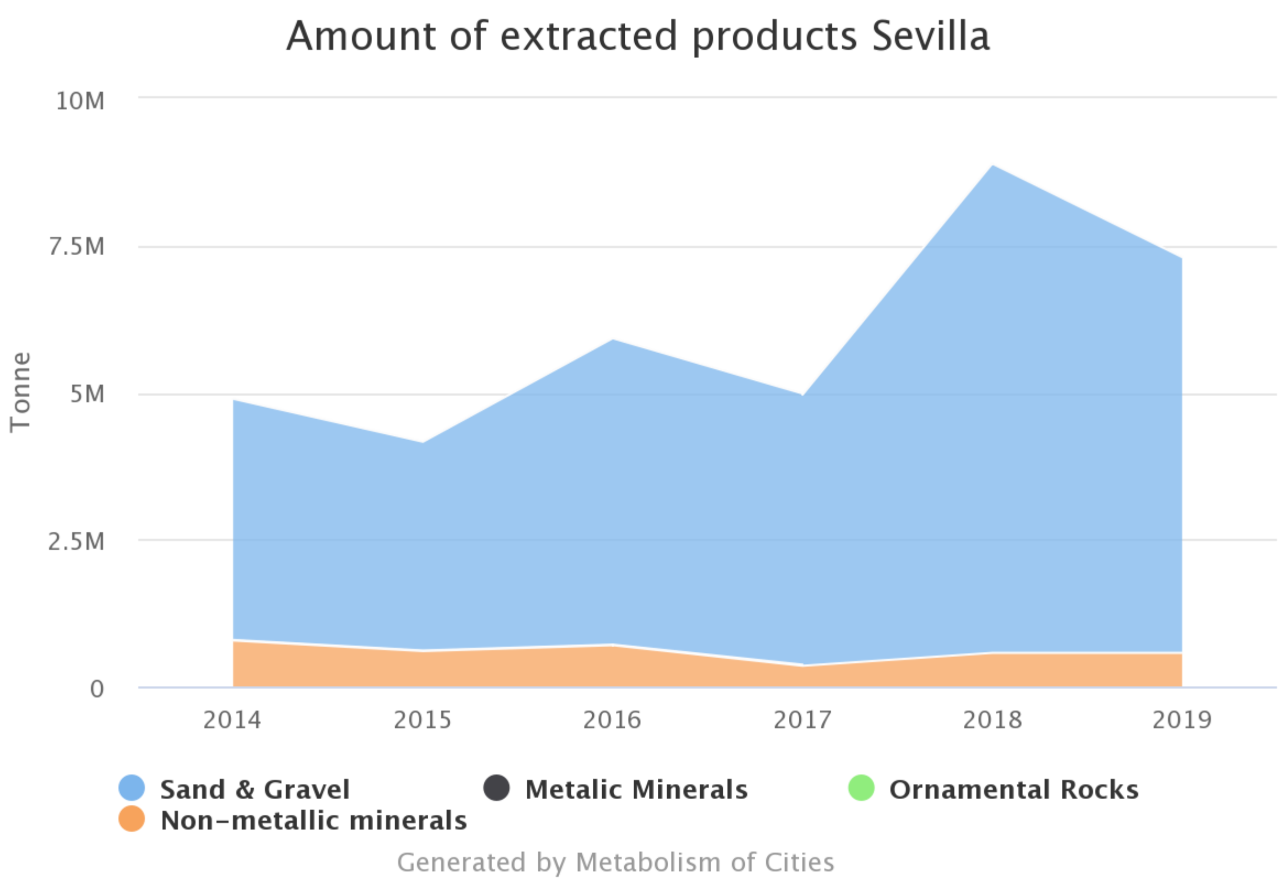

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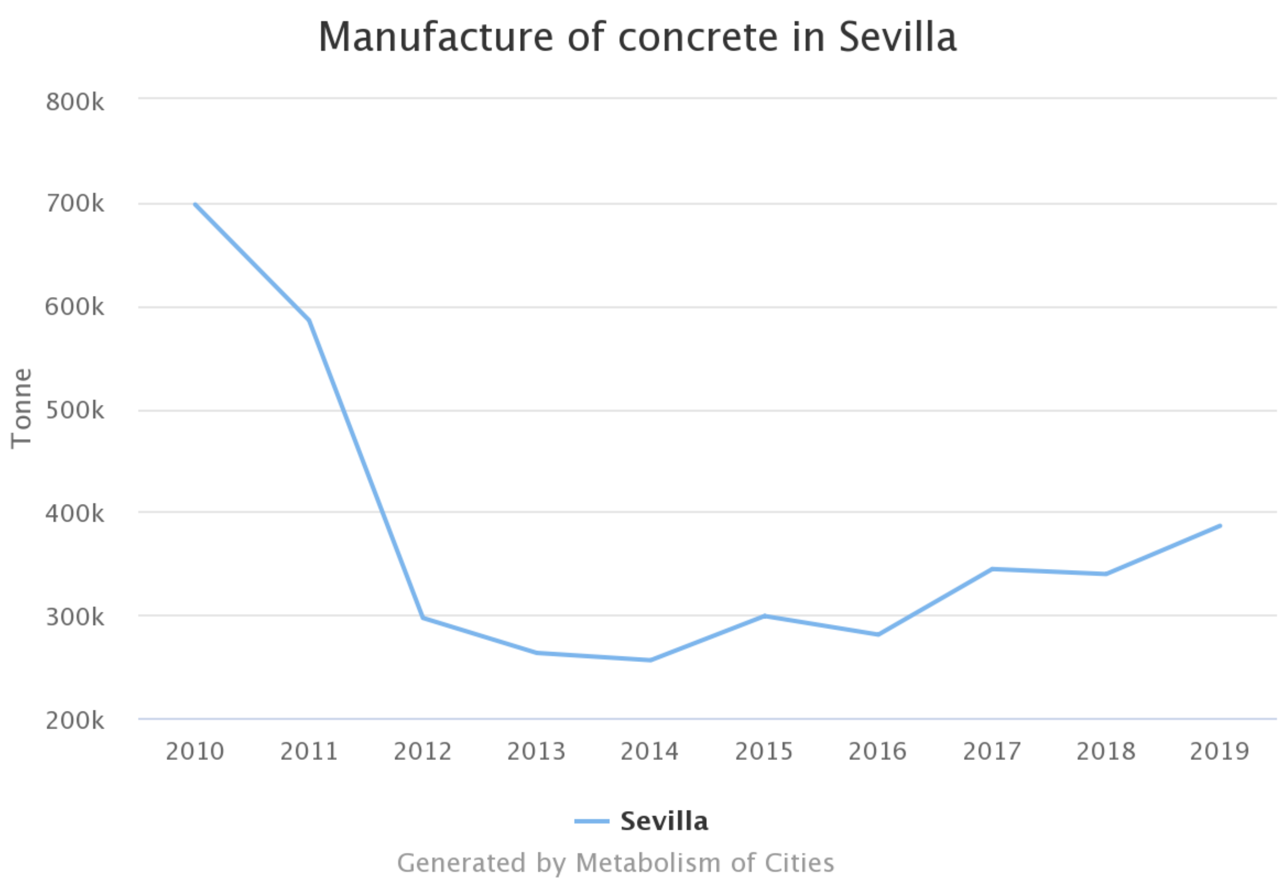

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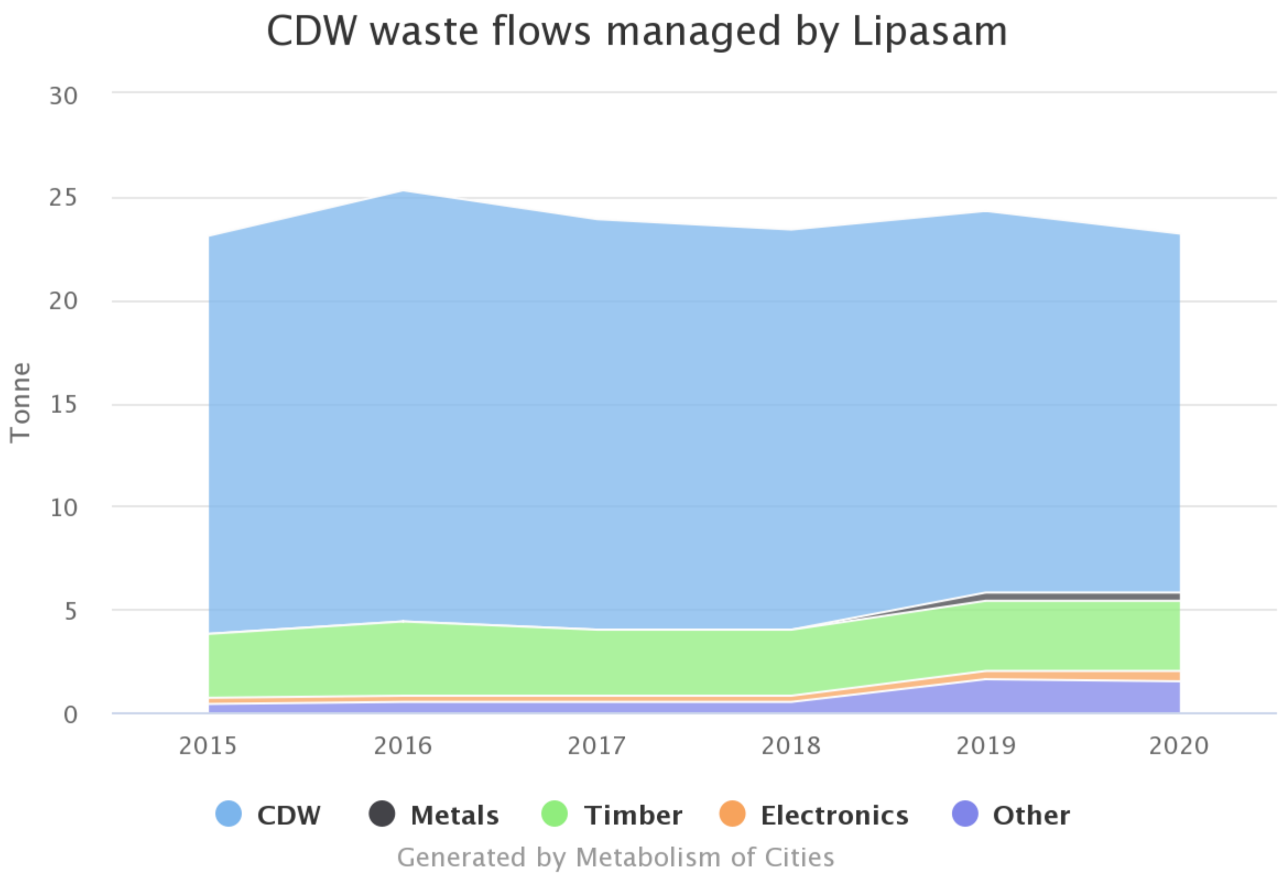


Data source

Indicators

To monitor the progress of this economic sector towards circularity, a number of indicators were proposed and measured. Altogether, these indicators depict several facets of circularity of the sector. As such, they need to be considered in combination rather than in isolation when assessing circularity. In addition, these indicators can be compared to other cities or spatial scales (such as the country level). However, this has to be done with great care and use of the contextual elements in the previous sections of the report. Finally, the value measured from these indicators can be traced over time to track the sector's progress towards circularity.

Indicator number	Indicator	Value	Unit
34	Domestic material consumption (DMC)	1,554,971.10	Tonnes/year
39	Circular Material Use rate	13.8	%

Indicator number	Indicator	Value	Unit
48	EU self-sufficiency for raw materials	1.09	%
55	EOL recycling rate	0.53	%
57	Amount of sector specific waste that is produced	445,041.76	Tonnes/year
58	EOL processing rate	566	%
59	Incineration rate	0	%
61	Landfilling rate	43.32	%

Indicators #34, #39, #48

- Domestic material consumption (DMC) (#34): 1,554,971.10 ton
- Circular Material Use Rate (#39): 13.80 %
- EU self-sufficiency for raw materials (#48): 1.09 %

DMC is the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. Formula for domestic material consumption is: DMC = Domestic extraction used (DEI) + Imports (IMP) – Exports (EXP).

The calculated DMC (#34) for Seville is 1,554,971.10 tons per year and 2.25 tons per capita, lower than the value for Spain (3.72 tons per capita). In the case of Sevilla, there are many uncertainties due to downscaling, rough estimations and assumed allocation values.

The Circular Material Use Rate (CMU) for Seville is 13.80 % which is similar compared to 12.4% for EU-28 in 2019 (Eurostat). This value means that secondary materials have substituted for primary raw materials in Seville proportionally to the EU rate. However, the data collection and quality should be developed to get more reliable value.

Formula for EU self-sufficiency for raw materials is: Import Reliance (IR) = Net import / Apparent consumption = (1- (Import - Export)) / (Domestic production + Import - Export).

Data is based on Spanish Statistics data from the Spain government and the Eurostat database. Data has been downscaled to Seville by using employees of the construction sector. The resulting value for EU self-sufficiency for raw materials in Seville is 1.09 %. The reliability of the value is weakened by the uncertainties of the available data which mostly have been downscaled to Seville due to a huge lack of local data.

Indicators #55, #57

- EOL-RR (End of Life Recycling Rate) (#55): 0.53 %
- Amount of sector specific waste that is produced (#57): 445,041.76 ton

For each material fraction, the End-of-Life recycling rate is defined as the End-of-Life mass recycled divided by the available mass of End-of-Life materials. It is the product of the Processing Rate and the Collection Rate (EoL RR = EoL PR x EoL CR). Formula is: EOL RR = EOL Mass recycled / EOL Mass collected x 100.

In the case of Seville EOL mass recycled include CDW collected by Lipasam which is recycled at Fermovert facilities. Data does not cover the CDW collection of private actors. The resulting EOL Recycling Rate for Seville is 0.53 %. There are many uncertainties and assumptions associated with calculating the value. If only the realised amount of CDW collected by Lipasam and recycled by Fermovert is taken into account, the value of these indicators is much lower than actually could be taking into account, the private sector.

The amount of sector-specific waste that is produced was 445,041 tons. This value is based on Spanish Statistics data from the Spain government and the Eurostat database. The private sector can deliver CDW also to other local waste collectors or export it outside from Seville. Consequently, there are some discrepancies that will be further studied during the development of the demo actions in the CityLoops project demonstration phase.

Indicators #58, #59, #61

- EOL processing rate (#58): 556 %
- Incineration rate (#59): 0.00 %
- Landfilling rate (#61): 43.32 %

The End-of-Life Processing Rate measures the efficiency of the end-of-life processing process. The formula is End-of-Life Processing Rate = End-of-Life mass recycled / End-of-Life mass collected for recycling x 100. The indicator shows only the local situation of the municipality and exported waste flows are not included in the calculation. This aspect helps with local circularity planning. Recycling waste elsewhere means that these materials aren't necessarily available locally anymore.

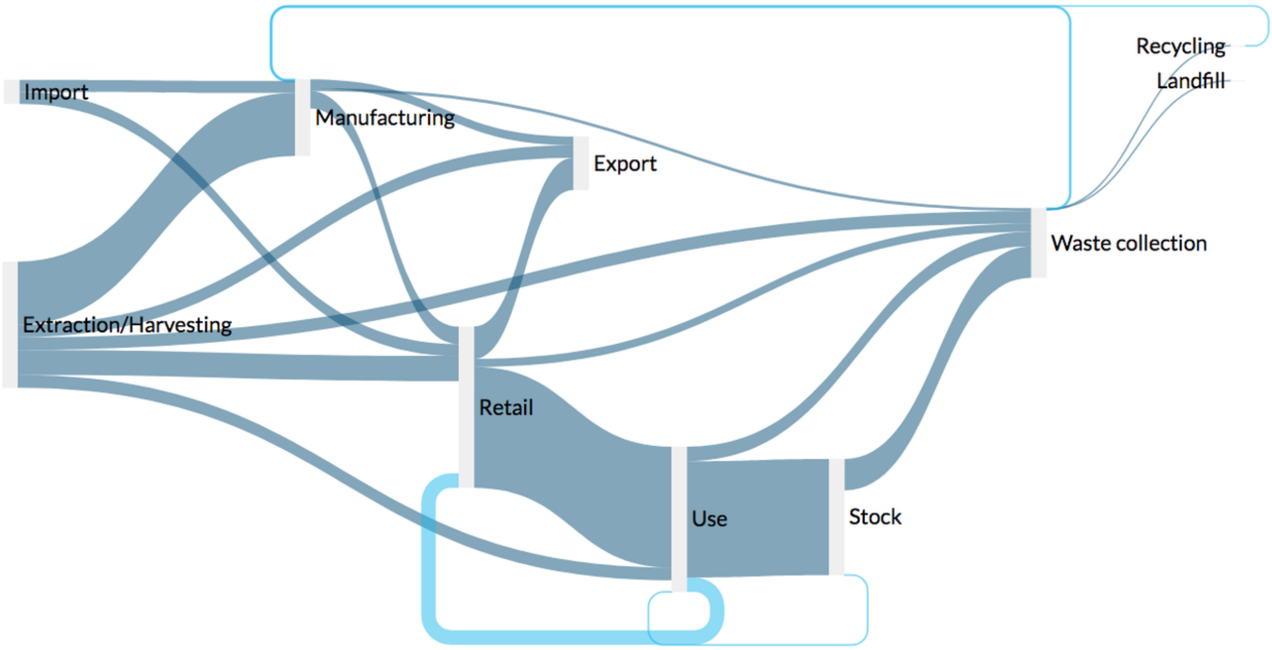
In the case of Seville, EOL mass recycled includes CDW collected by Lipasam (recycled at Fermovert facilities) and Private Sector (Data downscaled from Eurostat and Spanish statistics). The resulting EOL Processing rate is 555 %, which show weakness in the calculation and means that local available Data does not cover the CDW collection of private actors. Consequently, this indicator will be further studied during the development of the demo actions in the CityLoops project demonstration phase.

Incineration rate is the mass percentage of waste that is incinerated. The formula used in SCA is Incineration Rate = Incinerated waste / (Total waste + imported waste - exported waste) x 100. The indicator shows the local incineration only. In the case of Seville, the amount of local incineration is 0.

Landfilling rate is the mass percentage of waste that is landfilled. The formula used in SCA is Landfilling rate = Landfilled waste / (Total waste + imported waste - exported waste). In the case of Seville, landfilled waste consists of reject which cannot be sorted, materials mixed with soil and gypsum. Data cover CDW collected by local private actors or CDW transported outside of Seville.

Visualisations

Measuring circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the sector-wide circularity assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows from the studied economic sector are circulating from one lifecycle stage to another. The height of each line is proportional to the weight of the flow. This diagram therefore helps to quickly have an overview of all the materials flows that compose the sector and their respective shares. The flows that are coloured in light blue in the Sankey diagram, are return flows. This means that they flow in the opposite direction of the lifecycle stages and are subjected to reuse, redistribution, or remanufacturing. Their size relative to the others is a good indication for the materials' circularity.



Data source

The Sankey diagram describes the large Extraction/Harvesting of materials for the construction sector in Seville compared to the import. This means that for the City of Seville, materials required for the construction sector came from the metropolitan area of Seville especially regarding sand & gravel and gypsum & limestone. There is significant manufacture of concrete and bricks products in Seville. Most part of the imported materials goes to the manufacturing sector, mostly from iron and other metal products. Indeed, the metal industry in Seville is centennial. The Federation of Metal Entrepreneurs (FEDEME) holds the business representation in the negotiation of the four Collective Agreements of the Metal Sector in the province of Seville, affecting a total of 9,076 companies and 83,026 workers. The Sankey diagram shows significant activity in retail and uses in the construction sector mainly in bricks, concrete, gypsum/limestone sand & gravel and metals. The material flows of the retail lifecycle stage illustrated in the Sankey diagram is based only on assumed allocation values. Finally, considering the export, Seville mainly has the export from the retail sector. These numbers were estimated, because it wasn't found data that allows the inclusion of precise and accurate data for the City of Seville.

Data quality assessment

Numerous datasets were collected and considered in the sector-wide circularity assessment. In some cases, datasets were not available for some materials or for some lifecycle stages for the studied sector. Therefore, estimations need to be done by looking at data at higher spatial scales (region or country). This section qualitatively assesses how reliable the data used is.

Data quality

Before describing data gaps and assumptions, the overall data quality is considered. It is expressed through four data quality dimensions that are depicted in the data quality matrix: reliability, completeness, temporal correlation, and spatial correlation. Each dimension has its own criteria for the ranking of high (green), medium (yellow) and low (red), which is based on this Pedigree report and shown in the table below. There can be additional explanations in some cells, as supporting information.

Rating	***Reliability***	***Completeness***	***Temporal correlation***	***Spatial correlation***
high	*Reviewed or measured data*	*Data exists for all of the single materials and their respective economic activites*	*Data less than 3 years difference to the time period of the data set*	*City-level data*

Rating	*Reliability*	*Completeness*	*Temporal correlation*	*Spatial correlation*
medium	*Estimated data*	*Data exists for most single materials and most economic activities*	*Data less than 6 years difference to the time period of the data set*	*Regional-level data (NUTS 3)*
low	*Provisional data*	*Data exists for the sector only for the Life Cycle Stages*	*Data less than 10 years difference to the time period of the data set*	*NUTS 2 and country-level data*

Data quality matrix

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Extraction/Harvesting				
Manufacturing				
Retail				
Use				
Stock				
Waste collection				
Landfill				
Incineration				
Recycling				
Anaerobic digestion				
Composting				
Imports				

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
Exports				

EXTRACTION AND HARVESTING

Reliable local data was collected on sand & gravel extraction. The other data for harvesting and extraction are based on regional and national statistics i.e., National Institute of Statistics (INE) and Andalusian Institute of Statistics and Cartography (ICA).

MANUFACTURING

Data covers the main actors in the construction sector in Seville. Data on the manufacturing of metal products were obtained from the country and regional level (INE and ICA) and downscaled to Seville based on employees on relevant NACE-code. Employee data was from the year 2019.

RETAIL

Retail data were obtained by downscaling statistical data from INE and ICA and Eurostat only from some materials.

USE

Statistical data on food consumption, of the different biomass materials, were collected from INE and ICA at the country and regional scale. Data does not cover e.g., the use of concrete and metals in the construction of bridges or railways. Also, data on the use of plastic-based insulation is missing.

STOCK

Reliable data on floor area of existing buildings and length of roads were obtained from Municipal statistics and ICA. However, it was not possible to obtain or to convert this information into tons.

WASTE COLLECTION

Data on waste production were obtained from the country and regional level (INE and ICA) and downscaled to Seville. Reliable data on local waste collection was obtained from Lipasam. Data covers all waste flows from small construction and demolition projects in the City of Seville, but not all waste flows of the private sector. There are some local actors other than Lipasam who collect construction waste. Their waste flows are currently missing from the data. In addition, CDW may be exported outside the area.

IMPORTS AND EXPORTS

Reliable country-level data on imports and exports of construction materials were obtained and downscaled to Seville based employees in the construction sector. There were also uncertainties on choosing relevant products for Seville from the country-level data. Data was not obtained for all materials.

Data gaps and assumptions

Searching for data sources will be continued. Data quality and completeness related to use, retail and stocks could be improved by collecting more data involving private actors. Waste collection flows of different actors in Seville can be complemented if data is available or data can be estimated. Also, import and export data will be complemented, if more accurate data is available.

Data analysis

This section analyses the Sankey diagram developed in the previous section. It discusses and interprets the results for the sector-wide circularity assessment. It also reflects on how the current demonstration actions fit within the bigger picture of the sector, as well as how they could be upscaled to accelerate the transition towards a more circular sector.

Insights on status quo of the construction sector
The main conclusions from the Sankey diagram analysis are:

- Virgin sand & gravel, Gypsum & Limestone and other stone material are easily available for concrete manufacturing and for construction of roads and buildings.
- There are significant manufacture of bricks, metals and timber products in Seville and considerable parts of these are exported outside of the area.
- However, other construction materials like aluminium, glass and insulation materials are imported to Seville.

According to the calculation illustrated in the Sankey diagram, all the data related to local CDW collection and treatment is not currently available. The municipal waste management company Lipasam only collects CDW from small producers and citizens throughout the “Clean points”. Even almost the total amount of CDW collected by Lipasam is recycled, it shows a limited impact on the whole picture of the city. The greatest potential for developing the circular economy of the construction sector in the city is to utilise materials collected as waste in upcycled higher-value products, which could replace virgin materials in the construction sector.

There are still many assumptions behind the distribution of material flows visualised in the Sankey diagram. In the future, the information may be updated based on possible new and more detailed data.

Connection to and upscaling of demonstration actions

The CityLoops demonstration actions (DAs) in Seville is focused on the improvement of CDW management and valorisation.

DAs like the implementation of a methodology for the quality assessment of the CDW from the demolition activity of the pipeline's substitution works carried out by EMASESA will promote more circular destination and valorisation of generated CDW. From the results of this DA, the upscaling to other demolition activities by other actors could have a relevant impact on the circularity of the CDW management in Seville.

Another DA that could have a relevant impact regarding the upscaling of the CDW waste collection and valorisation is the IT software tool developed to optimise the waste collection management in the "Clean points" of Lipasam that collect CDW from small producer and citizens and that will be tested during the CityLoops demonstration phase. This IT software tool was designed to improve the CDW waste collection and valorisation to improve and increase the use of these "Clean points" by citizens and small producers.

Another DA that can improve the circularity in the CDW management is the launch of a campaign to disseminate the DAs under implementation in Seville and search for the commitment of citizens and small producers. The success of these campaigns could upscale the success of these DAs and have a relevant impact on the circularity of organic waste management, in the City of Seville.

Recommendations for making the construction sector more circular

- Promote the increase of furniture and building components reuse or utilised at the city's own sites;
- Promote the recovery of bricks and use in construction instead of crushing;
- Crushed concrete could be used on city´s construction sites instead of virgin soil material although virgin soil material is still readily available;
- New operating models for the recycling and reuse of materials should be developed and tested, and new business could be created so that the circular economy can become part of the normal way of operating in construction and demolition in Seville in the future;
- Disseminate the developed documentation and data collection to improve the assessment of circularity and the interest of the main stakeholders. The CityLoops project plays an important role in the development of these actions in the city of Seville.

References

- Spain
- Andalucía
- Sevilla
- Population of Sevilla line graph
- Land use
- Map of Sevilla Geo localisation of main actors construction sector Imagen

CITYLOOPS

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and organic waste (OW), where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and OW, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.