

SECTOR-WIDE

CIRCULARITY ASSESSMENT

CONSTRUCTION SECTOR



**METABOLISM
OF CITIES**

Version	3* (2021-12-31) *Third iteration of the Sector-Wide Circularity Assessment report.
WP	2
Dissemination level	Public
Deliverable lead	Metabolism of Cities
Authors	<u>Executive summary</u> : Carolin Bellstedt, Aristide Athanassiadis; <u>Apeldoorn report</u> : Rob de Groot, Adriaan Hellemans; <u>Høje-Taastrup report</u> : Carolin Bellstedt, Aristide Athanassiadis; <u>Mikkeli report</u> : Vuokko Malk; <u>Roskilde report</u> : Carolin Bellstedt, Aristide Athanassiadis; <u>Seville report</u> : 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;
License	 This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0). See: https://creativecommons.org/licenses/by/4.0/

Executive Summary

This document contains five separate reports of the Sector-Wide Circularity Assessments (SCA) of the construction sector that were carried out by five different cities of the CityLoops project: Apeldoorn (the Netherlands), 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*

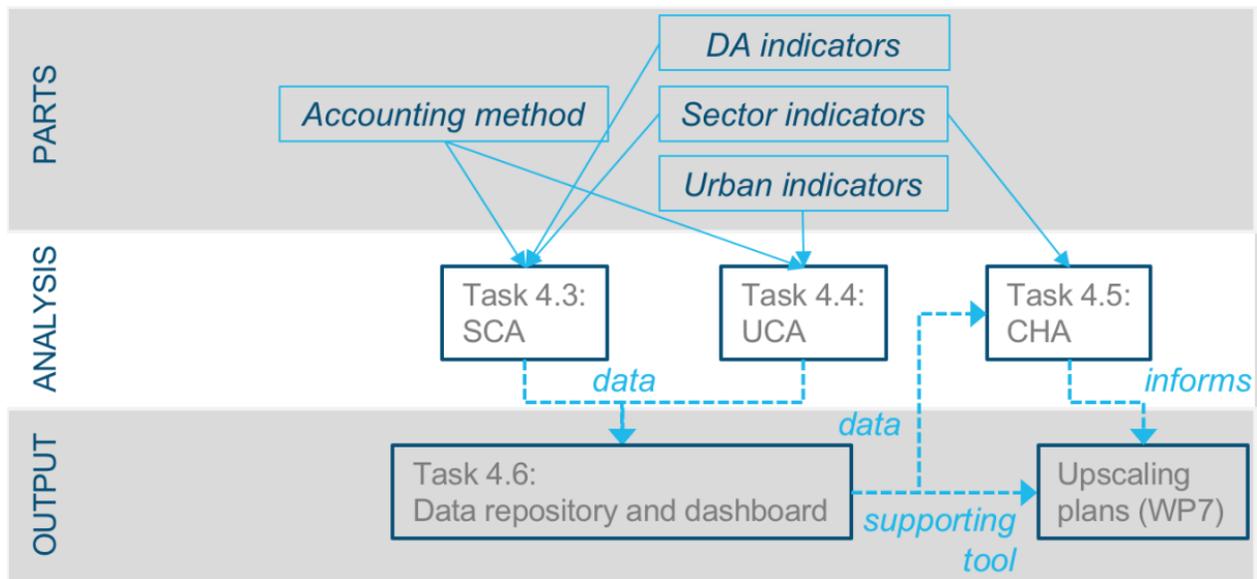
areas where it is possible to start collaborating on, ideally creating synergies, but that is its own point.

- **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). To some extent the information output of one method will become input for the next analysis, but the SCA is not needed to carry out the UCA for a city. These three types of analyses still co-exist in a complementary way, and some of the work and insights can be integrated with each other to make the overall approach coherent and easiest for the 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:

- [Apeldoorn](#);
- [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

Executive Summary	_____	ii
Sector-Wide Circularity Assessment for the Construction Sector of Apeldoorn	_____	1
Sector-Wide Circularity Assessment for the Construction Sector of Høje-Taastrup	_____	15
Sector-Wide Circularity Assessment for the Construction Sector of Mikkeli	_____	39
Sector-Wide Circularity Assessment for the Construction Sector of Roskilde	_____	66
Sector-Wide Circularity Assessment for the Construction Sector of Seville	_____	87

SECTOR-WIDE CIRCULARITY ASSESSMENT

FOR THE CONSTRUCTION SECTOR

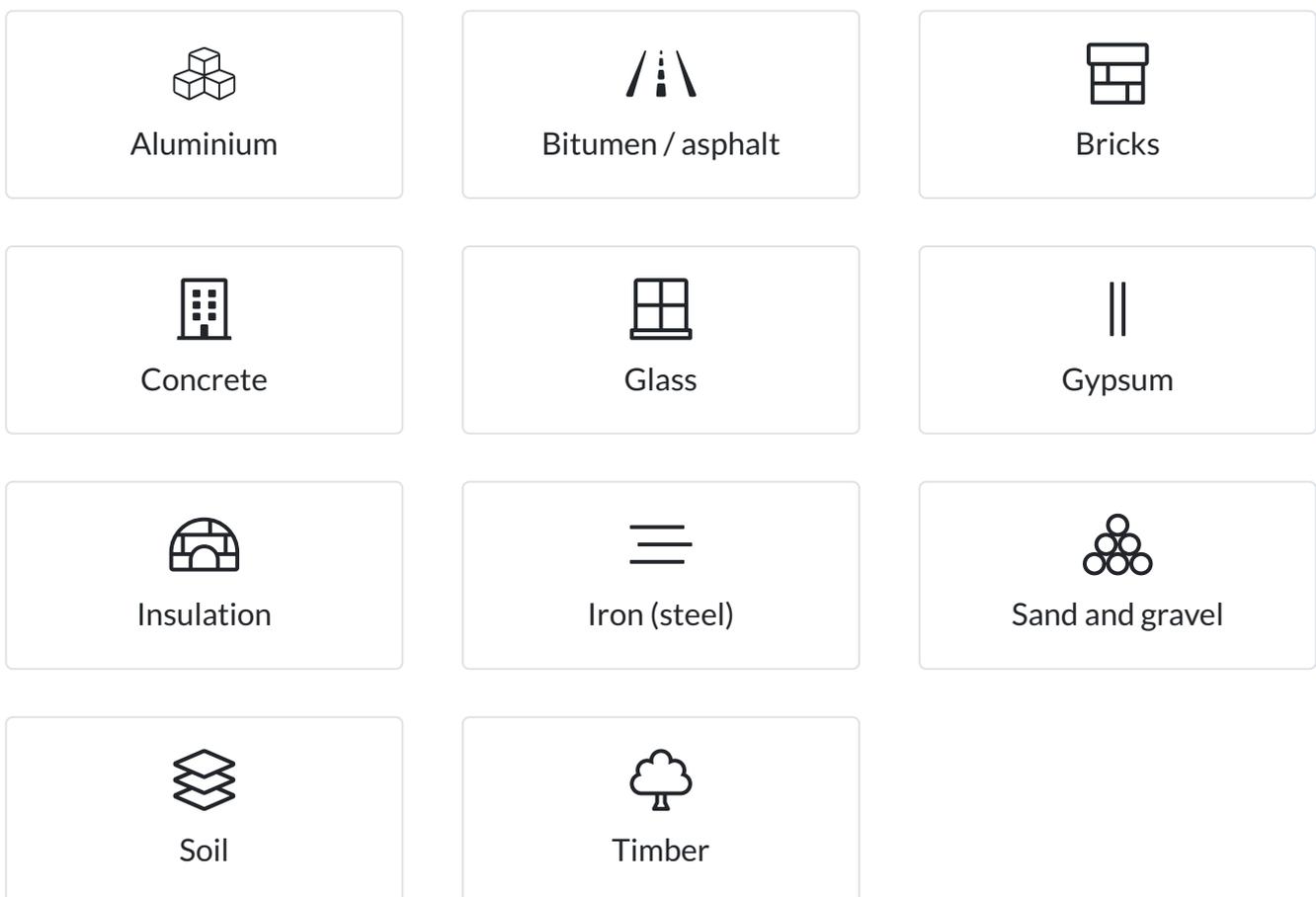
APELDOORN



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.



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 km²



Veluwe

👤 700,975

📏 1,860 km²



Gelderland

👤 2,096,603

📏 5,136 km²



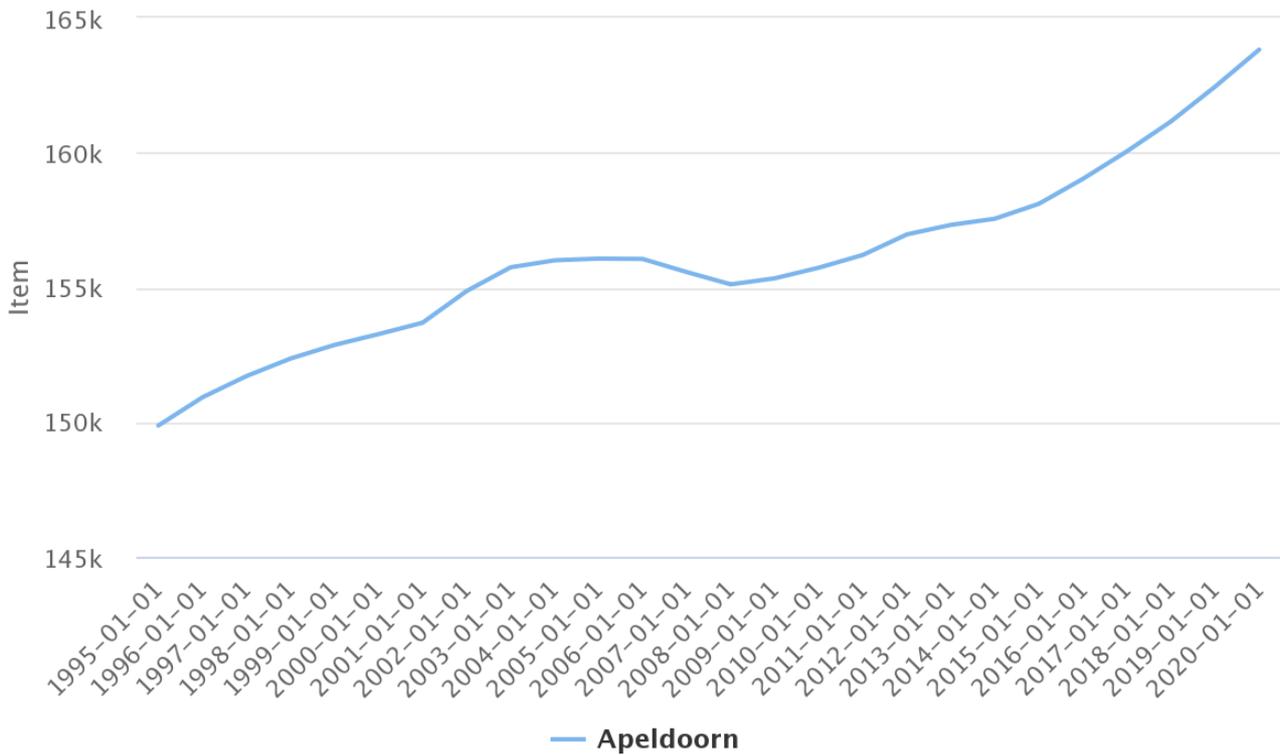
Netherlands

👤 17,475,415

📏 41,543 km²

Population of Apeldoorn

Population size Apeldoorn (1995-2020)

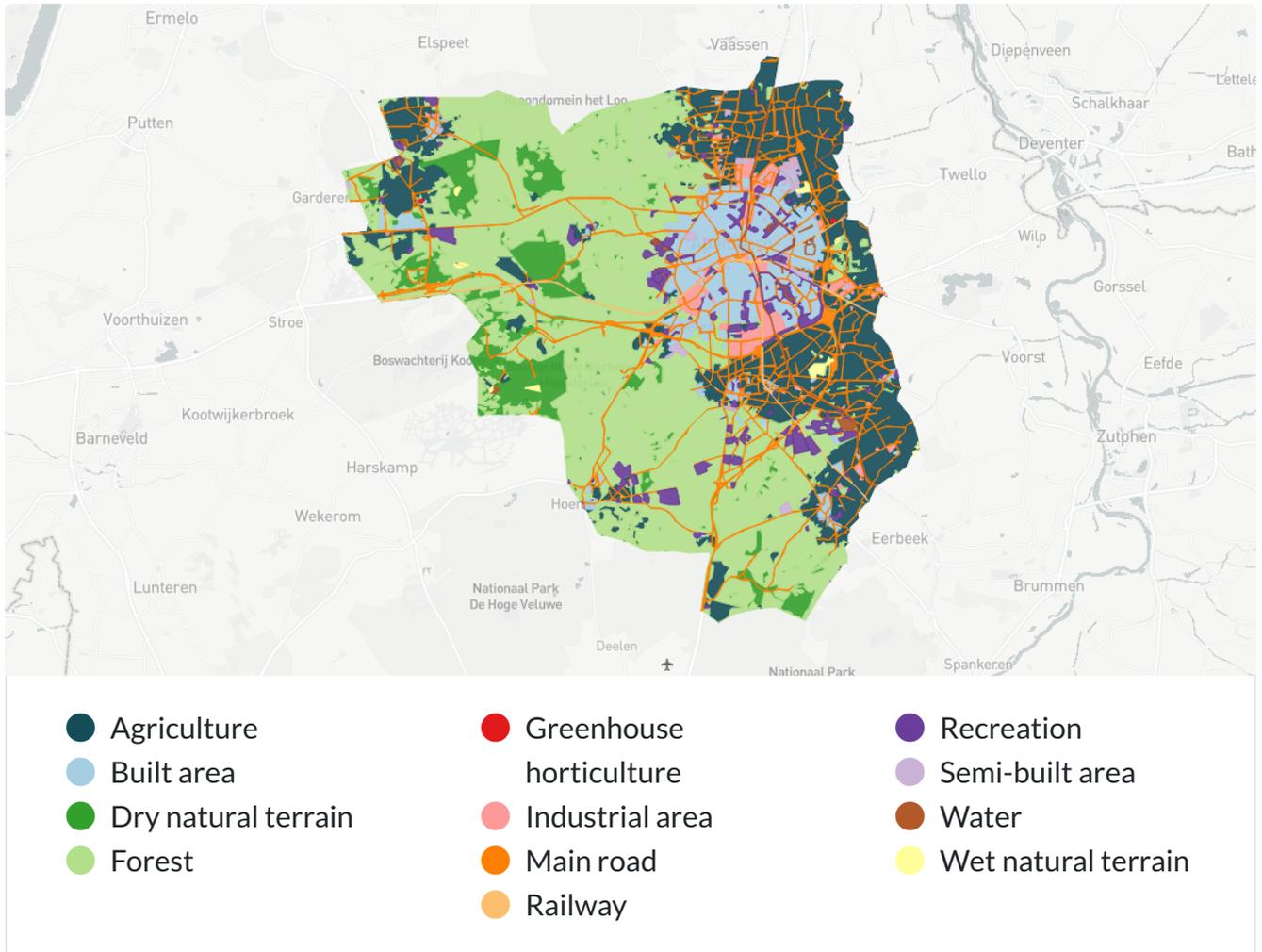


Generated by Metabolism of Cities

[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

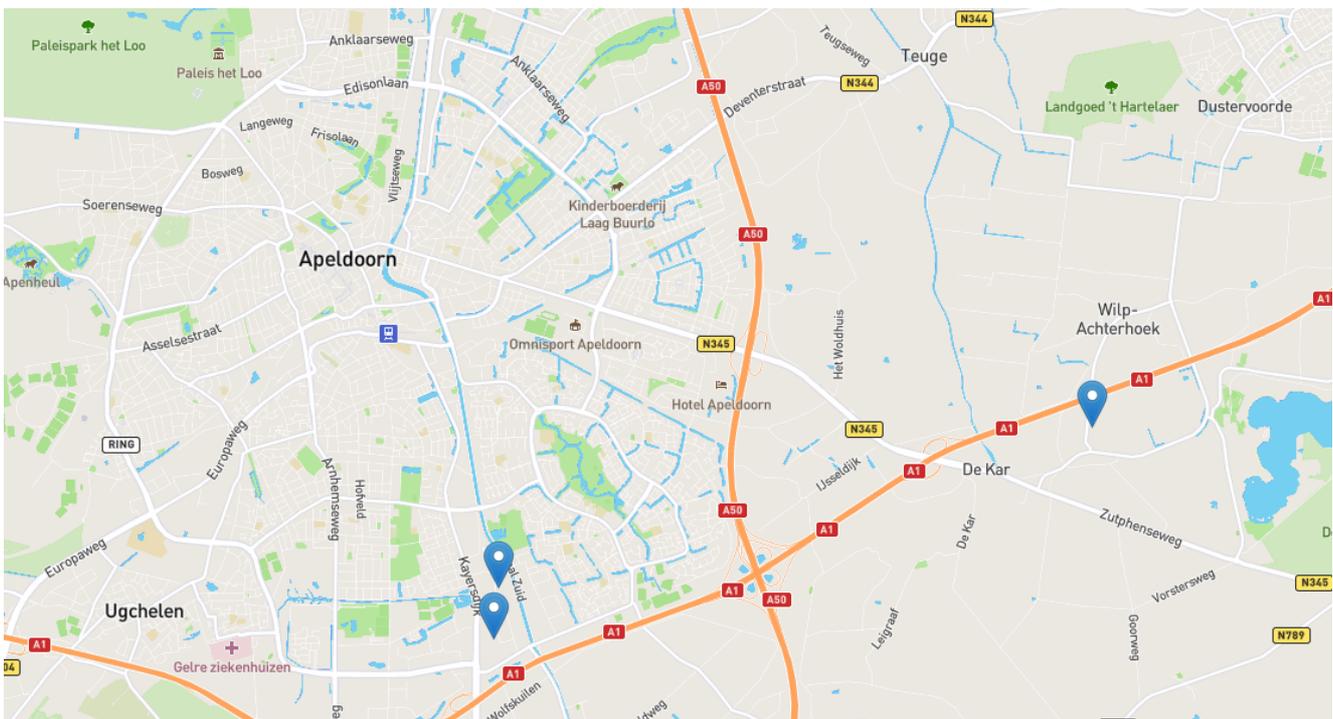
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	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	%

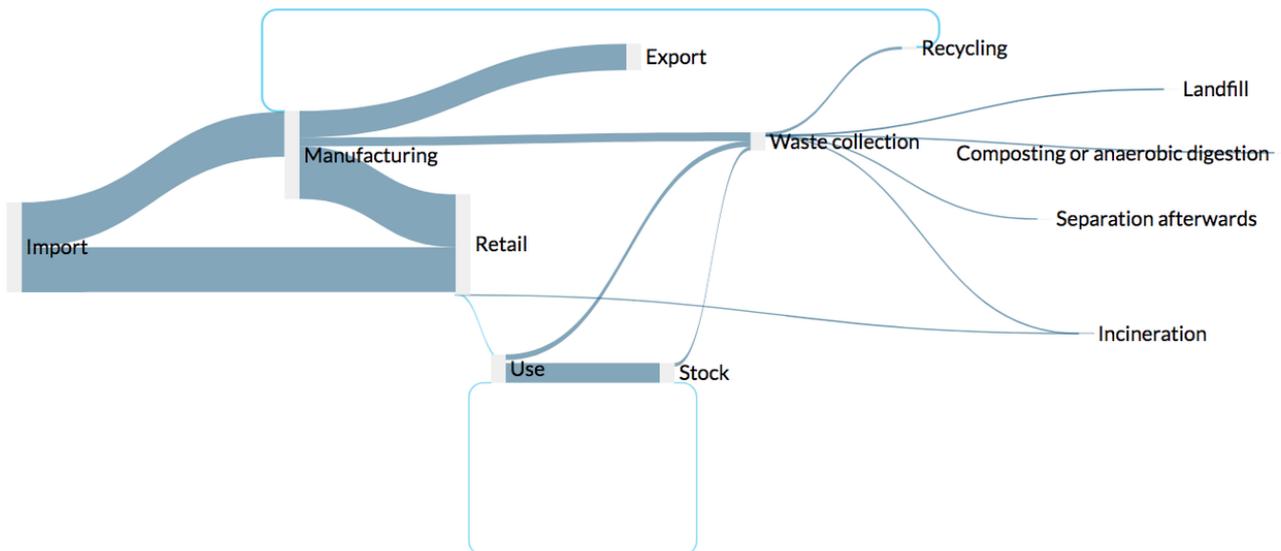
The indicator table above describes calculated values for the mandatory indicators for the Sector-wide Circularity Assessment. There is no information on the indicator values over time, as there was only data collected, processed, and analysed for one year: 2018. However, these indicator values can be 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.

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

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	Medium	Low	All data from 2018	Only country level data
Incineration	Medium	Low	All data from 2018	Only country level data
Recycling	Medium	Low	All data from 2018	Only country level data
Anaerobic digestion	No data	No data	No data	No data
Composting	No data	No data	No data	No data
Imports	Medium	Low	All data from 2018	Only country level data
Exports	Medium	Low	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 its 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 recycled 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

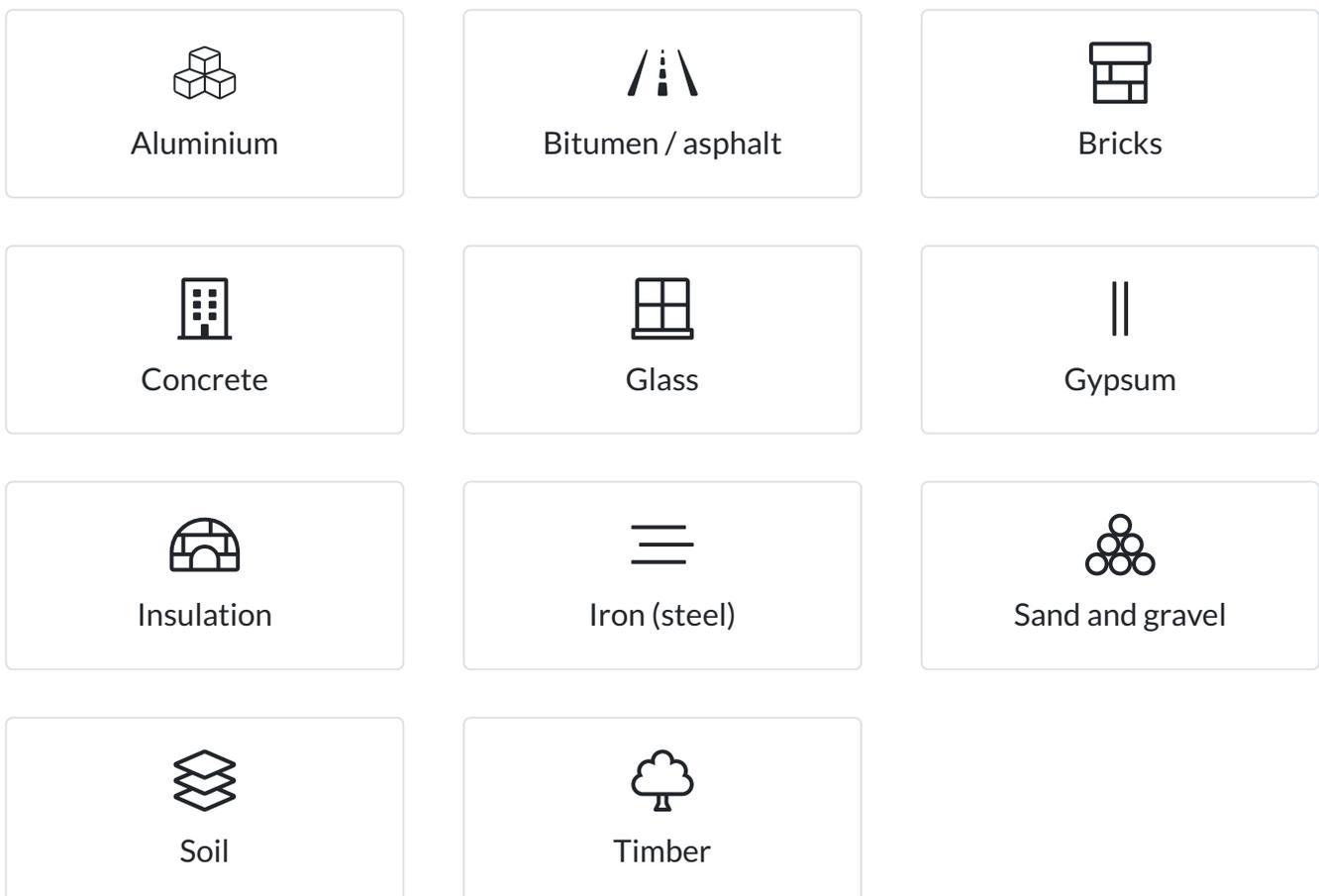
HØJE-TAASTRUP



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.



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

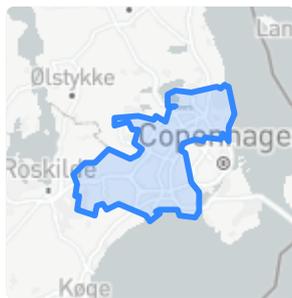
To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were 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 km²



Københavns omegn

👤 548,370

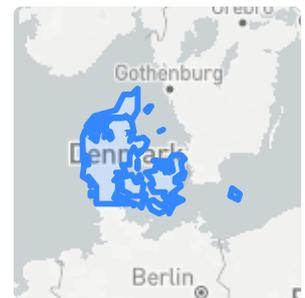
📏 342 km²



Hovedstaden

👤 1,846,023

📏 2,568 km²



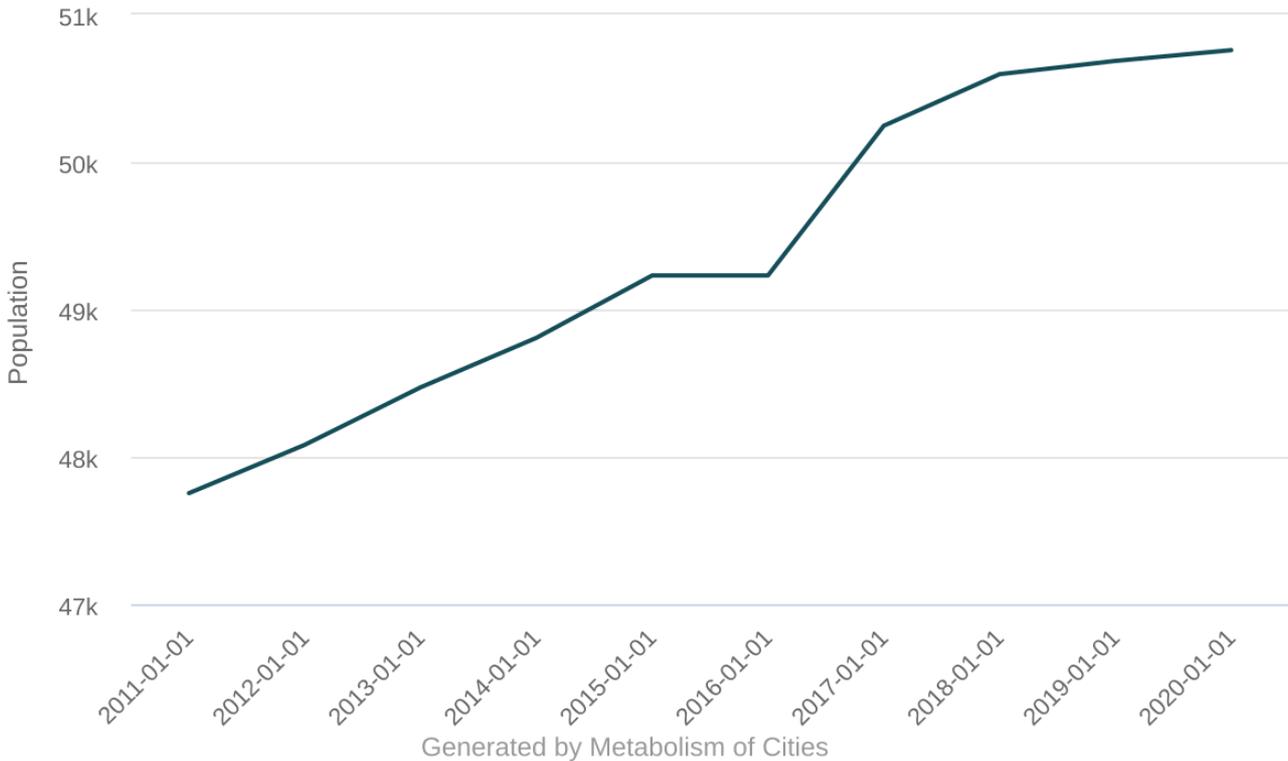
Denmark

👤 5,822,763

📏 42,933 km²

Population of Høje-Taastrup

City Population in Høje-Taastrup, 2011-2020

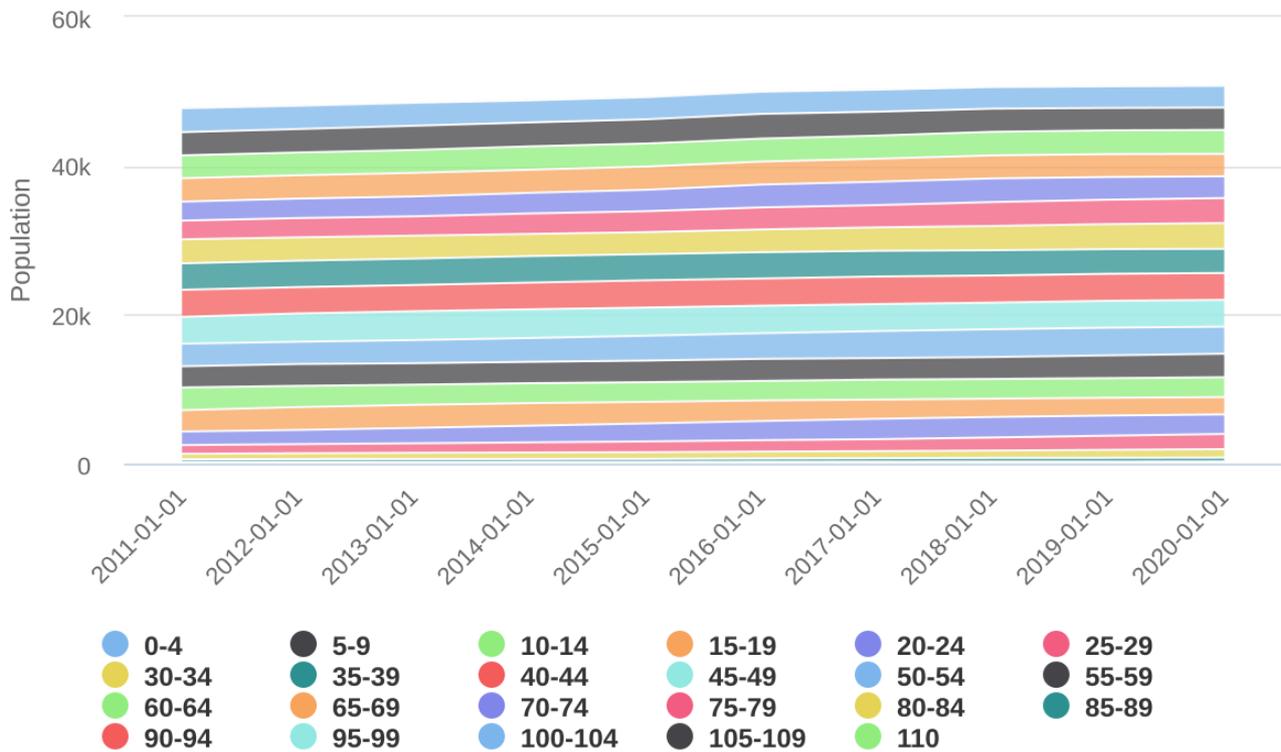


[Data source](#)

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.

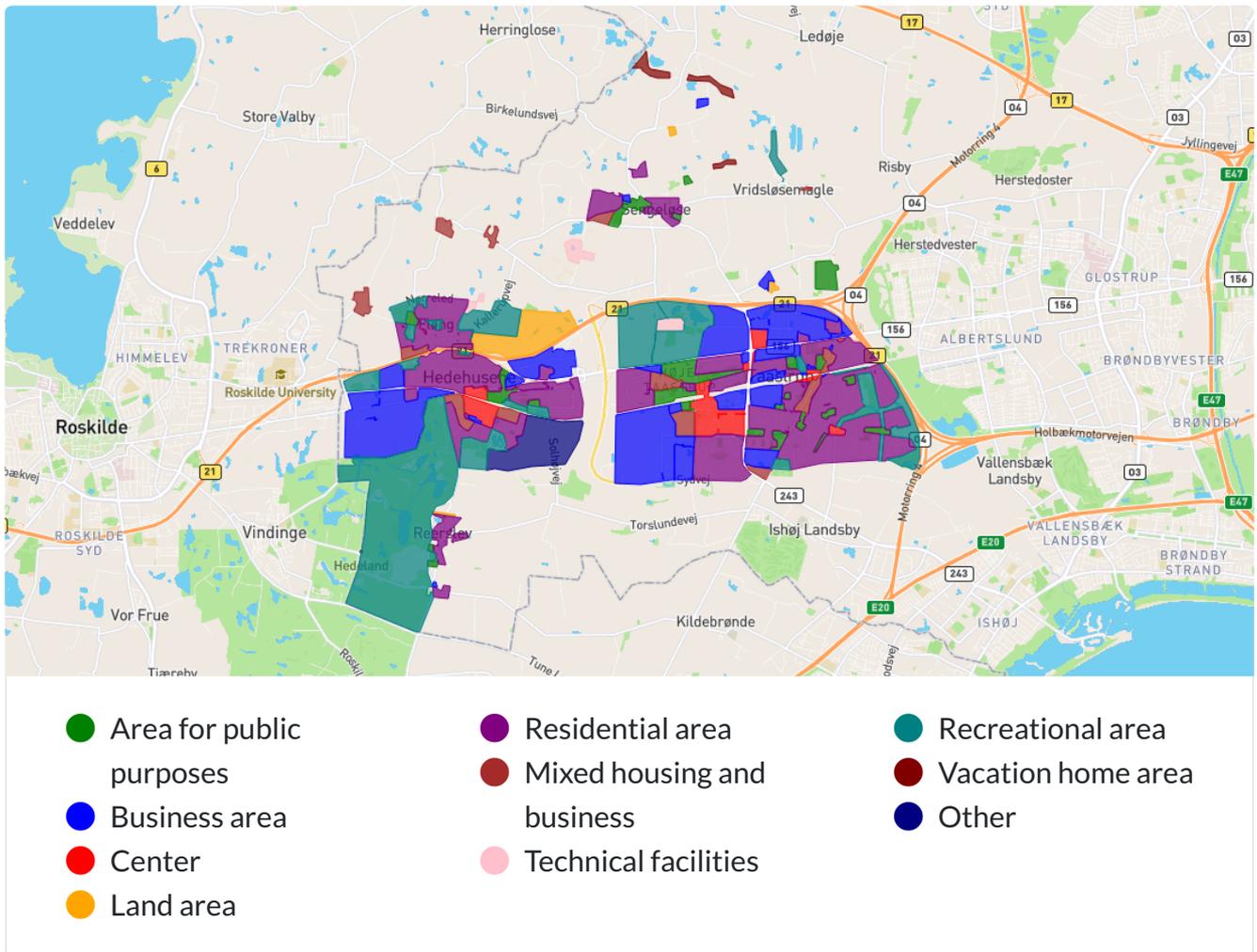
City Population in Høje-Taastrup, 2011-2020, by age group



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.

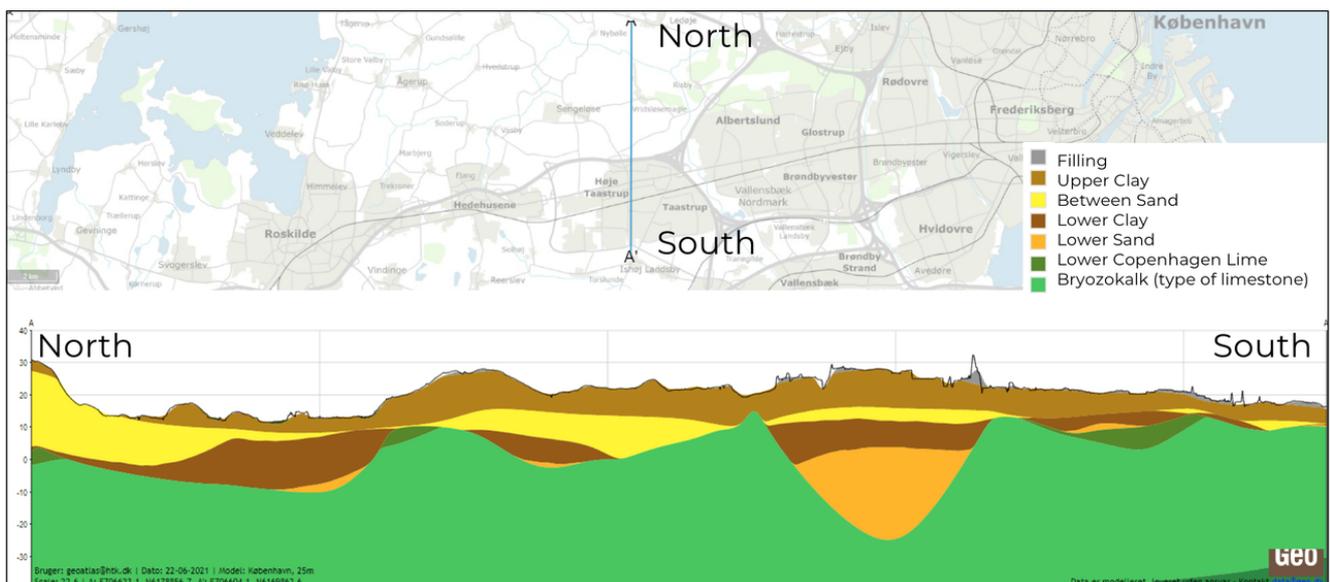
The land use map of Høje-Taastrup shows 10 different types of land use. It needs to be noted that those are the ones represented in the municipal planning framework of 2014, which do not account for the entire area of the municipality (78 km²), but for 45% of it (34.9 km²). These land uses include general 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 Baldersbrønne 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

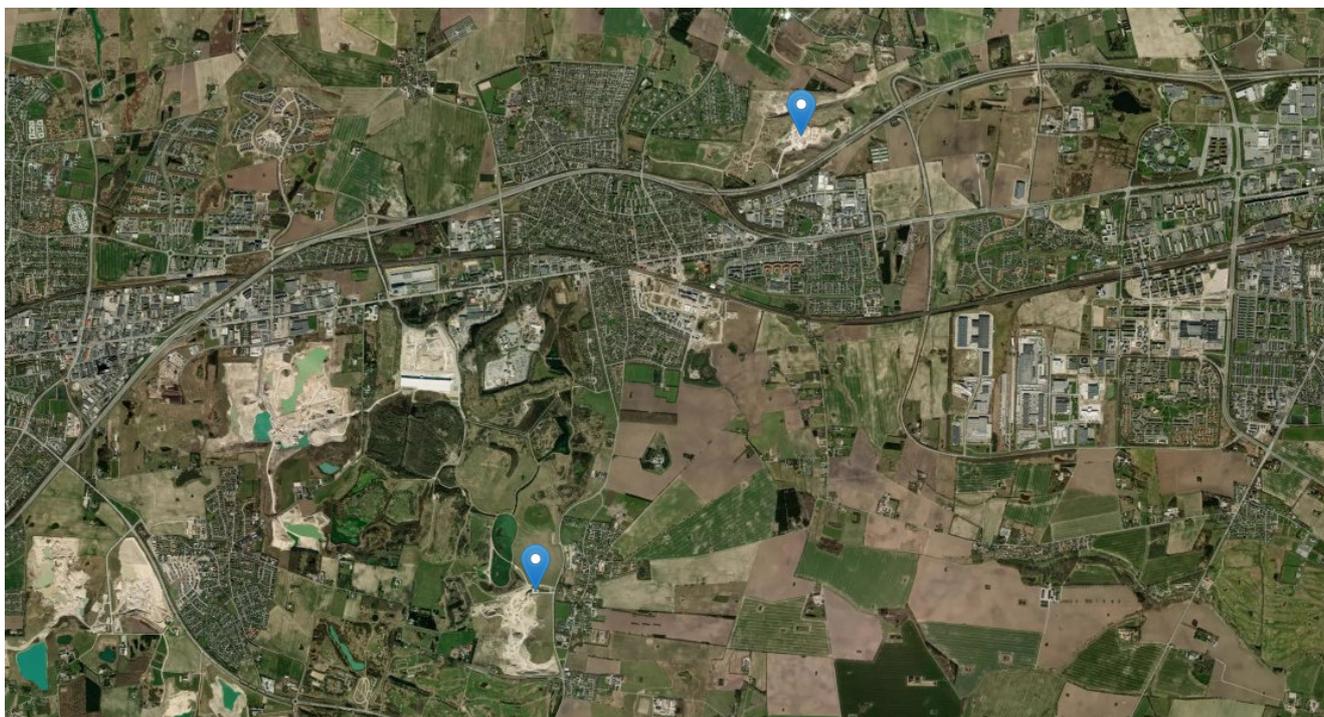
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector’s materials) are.

	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.

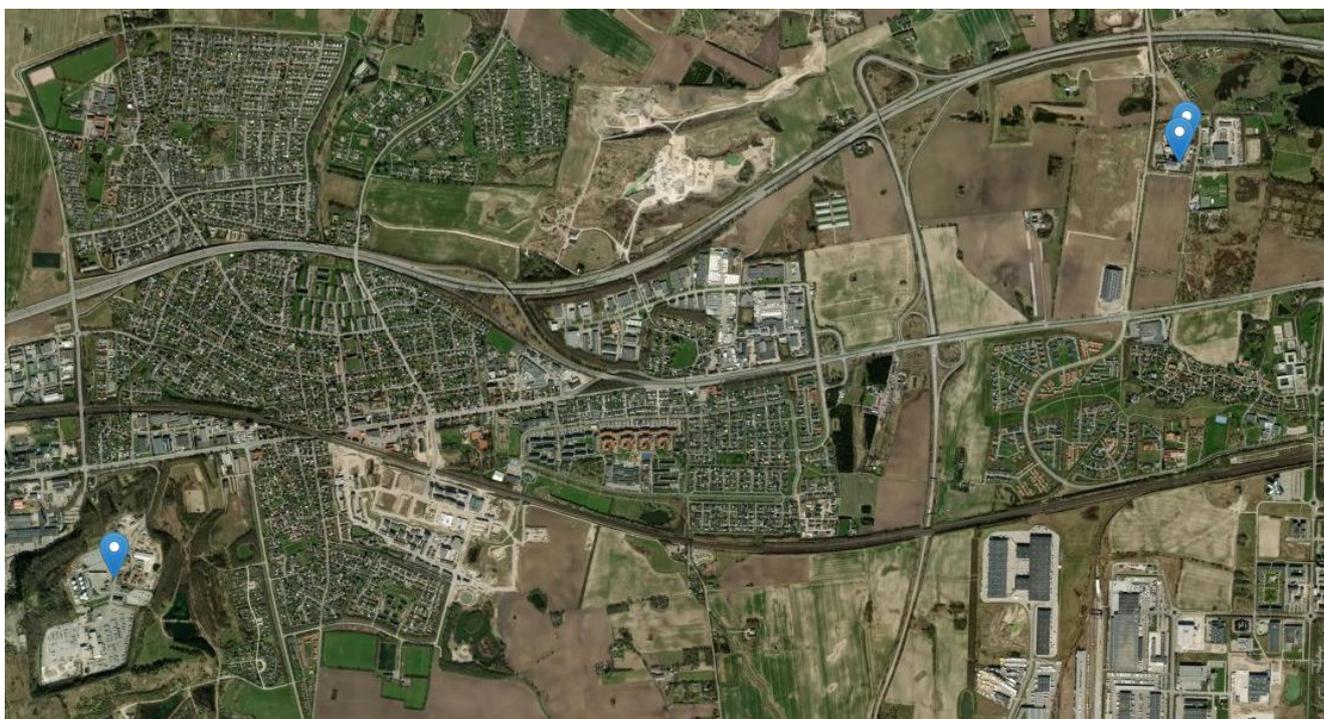
As for joinery installation, [Deko P/S](#) is a big employer with 214 employees. The company works on the design, production and installation of partitions of glass, wood, and aluminium. However, it seems that the production site is not actually in Taastrup, but that the location serves as office and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

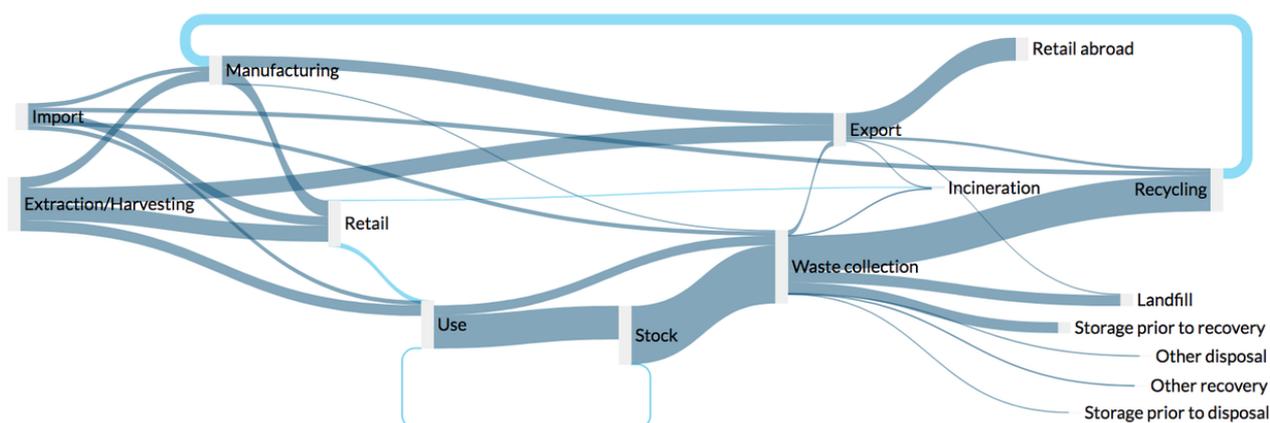
The EOL recycling and processing rates are still considerably low with about 15% and 23% respectively. While 19% of materials are still subjected to disposal and 81% to recovery, the efficiency of recovery could still be improved. There is however uncertainty in those values, as the amounts derived from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

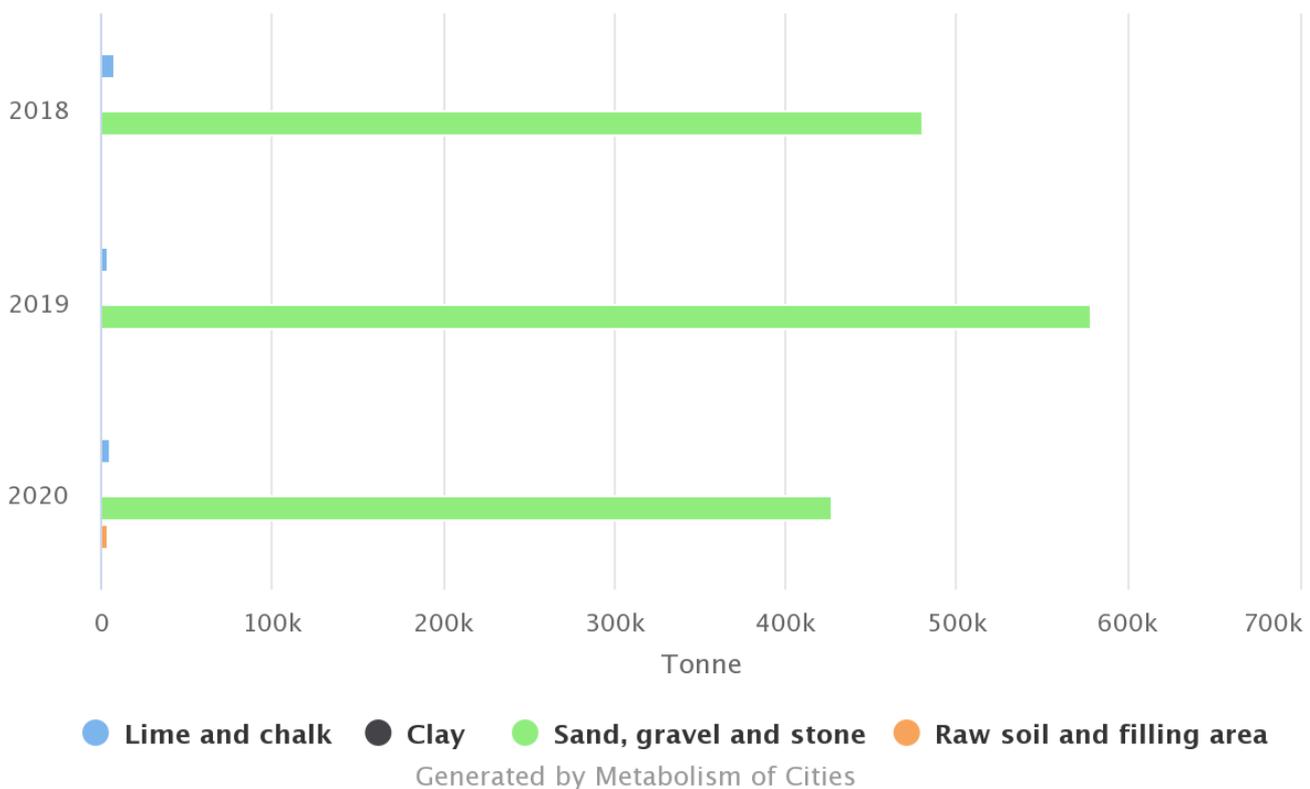
Overall, the Sankey diagram for Høje-Taastrup shows that quite a lot of materials are moving around in the construction sector system. The share for **extraction** is quite significant. The total amount sums up the four material groups that are extracted in the municipality:

- 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.

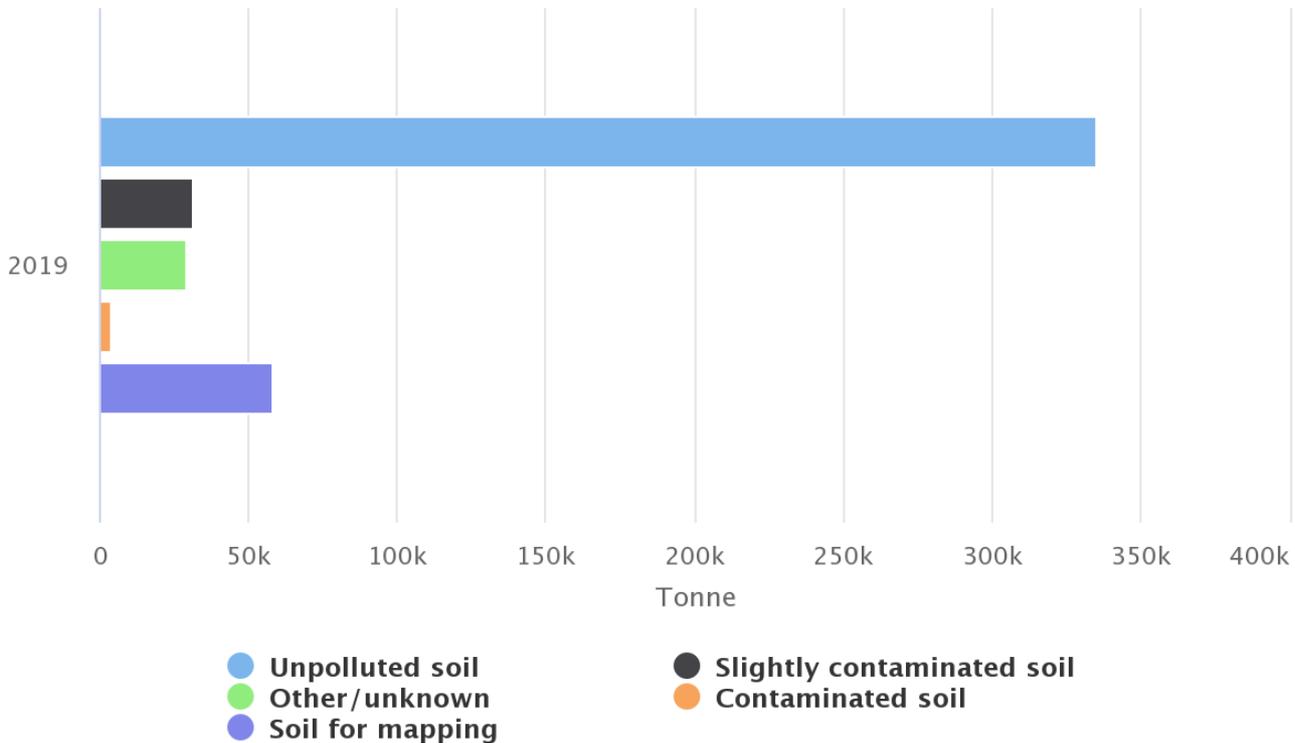
Extraction of construction materials in Høje-Taastrup, 2018–2020



[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.;

Soil volumes in Høje Taastrup for 2019



Generated by Metabolism of Cities

[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 activities	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	Good	Medium	Very Good	Very Good
Manufacturing	Good	Medium	Very Good	Poor
Retail	no data			
Use	Poor	Medium	Very Good	Medium
Stock	Medium		Very Good	
Waste collection	Good	Medium	Very Good	
Landfill	Good	Medium	Very Good	
Incineration	Good	Medium	Very Good	
Recycling	Good	Medium	Very Good	
Imports	Poor	Medium	Very Good	Medium
Exports	Poor	Medium	Very Good	Medium

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.

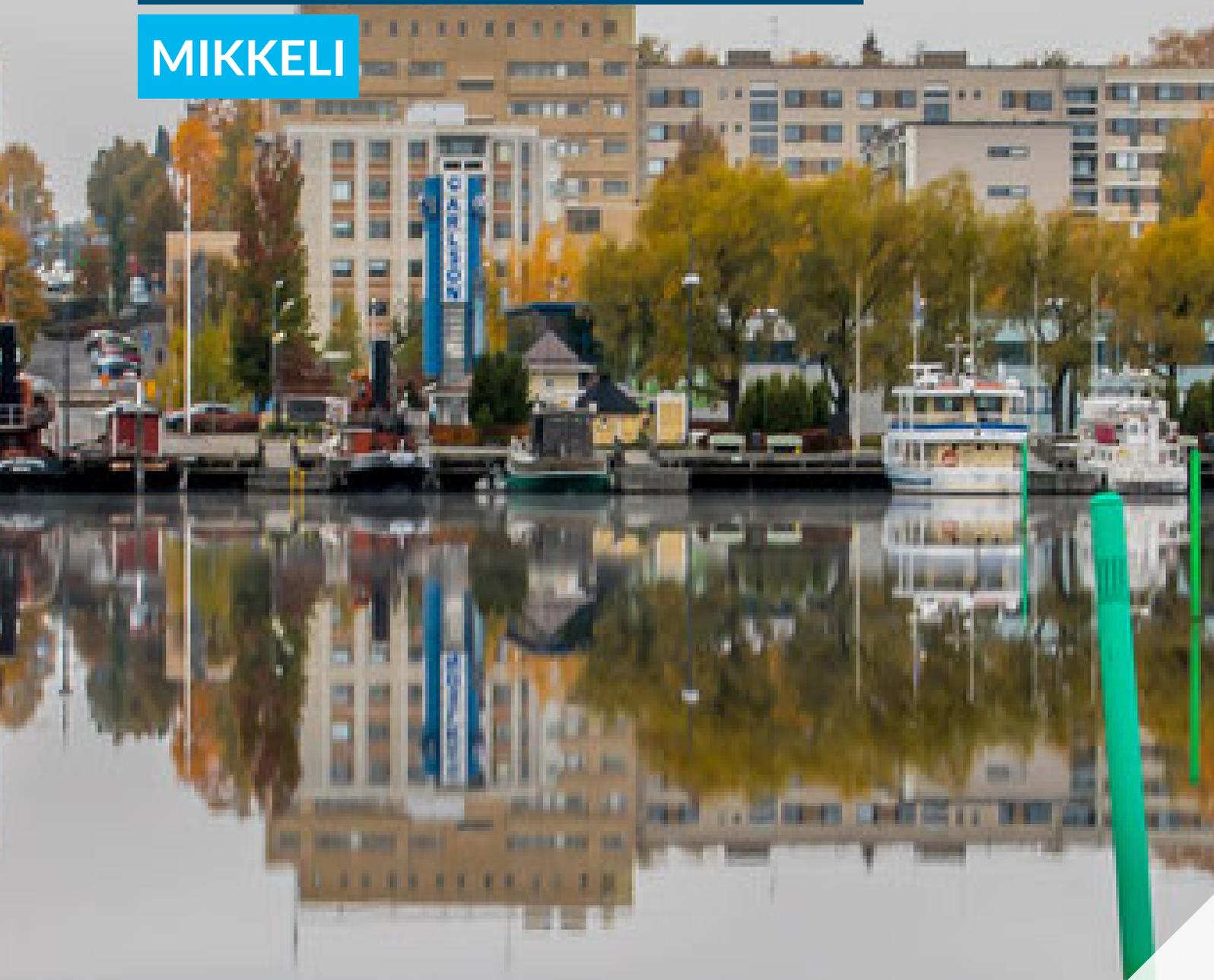
References

- [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

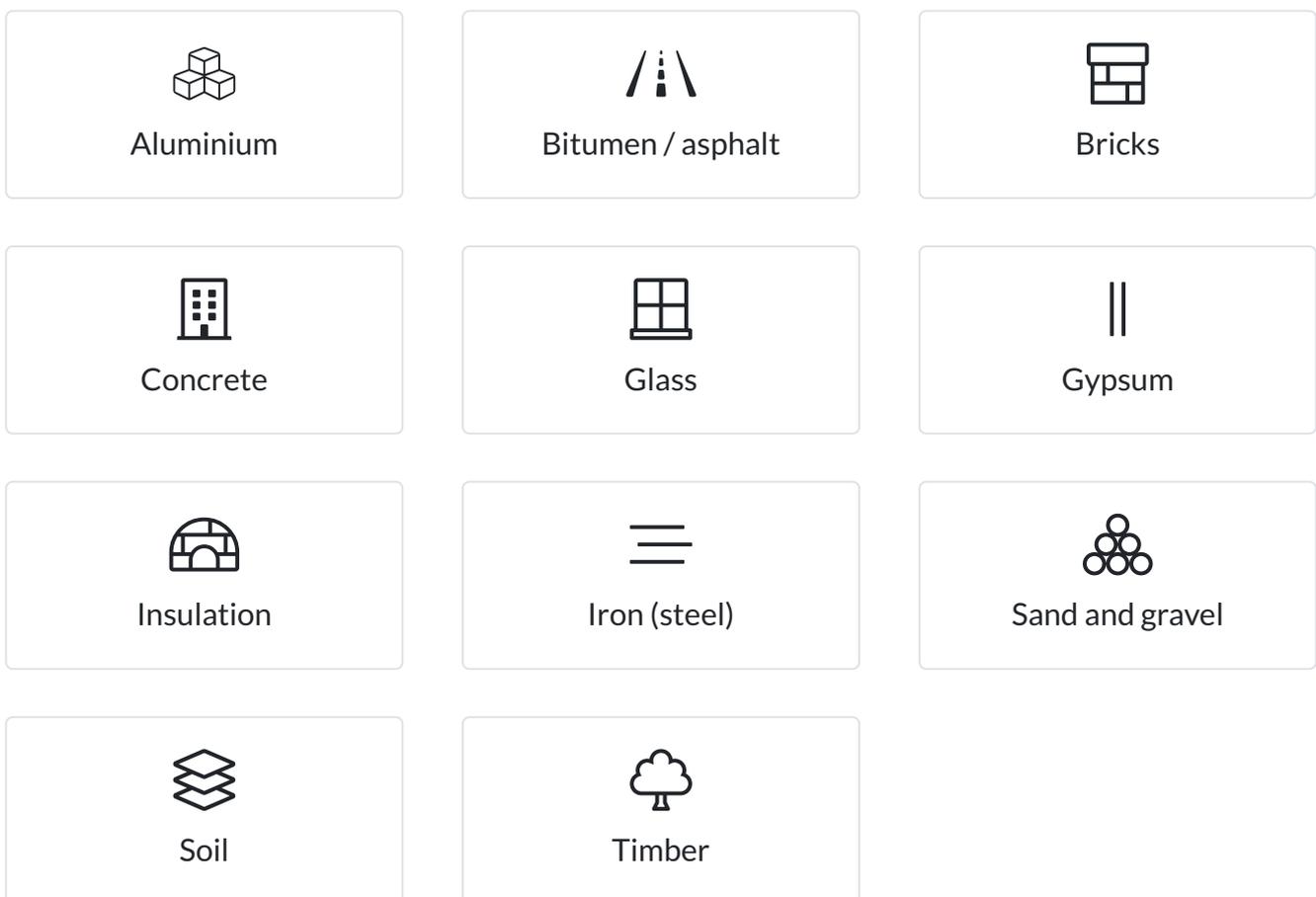
MIKKELI



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.



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

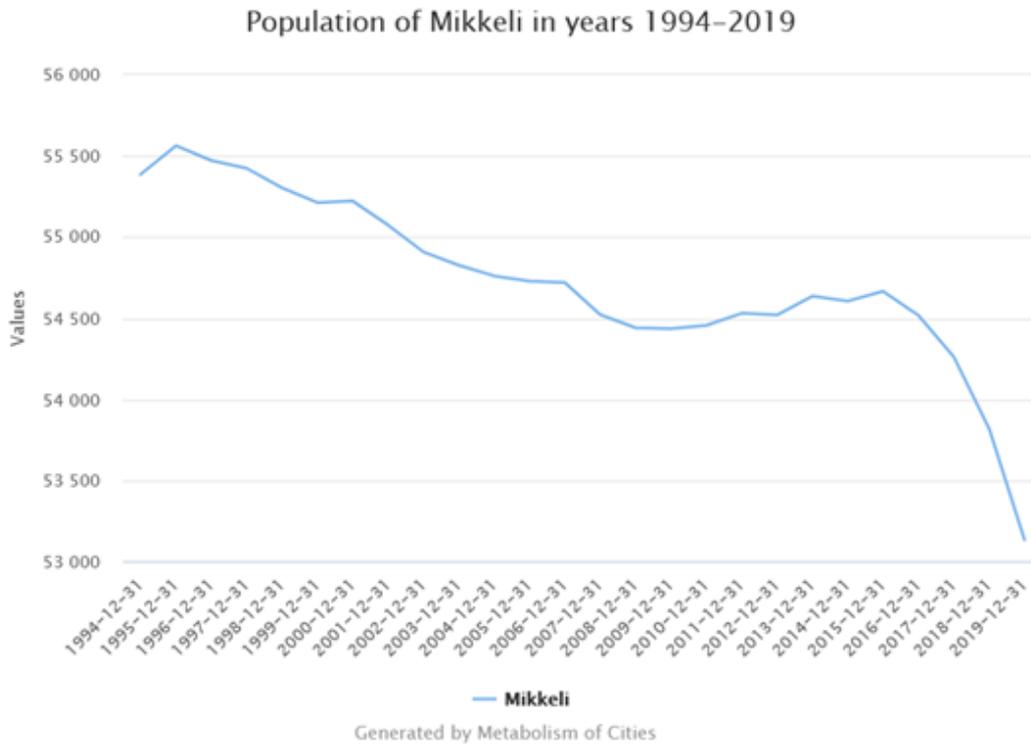


Finland

👤 5,525,292

📏 390,908 km²

Population of Mikkeli

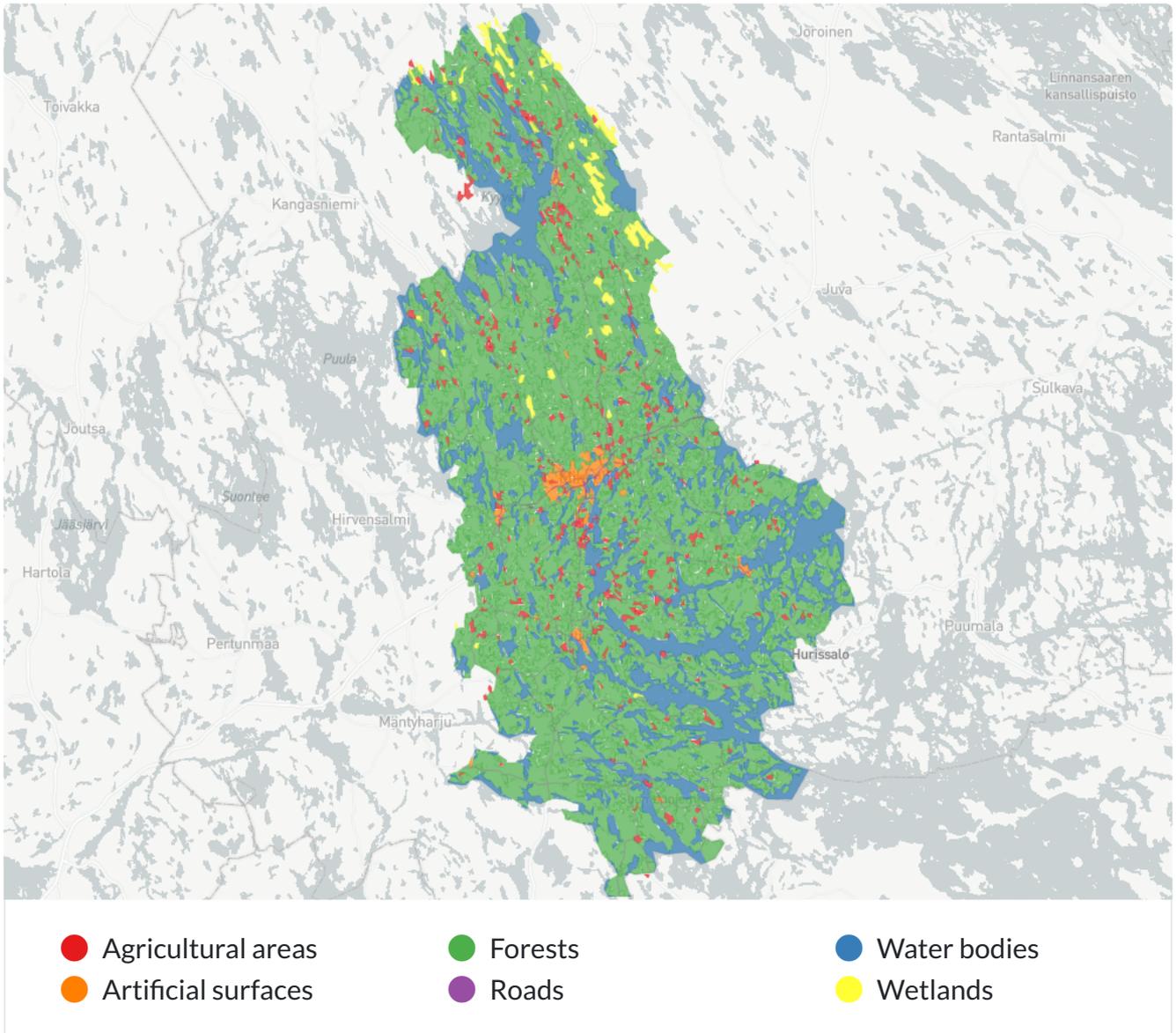


[Data source](#)

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.

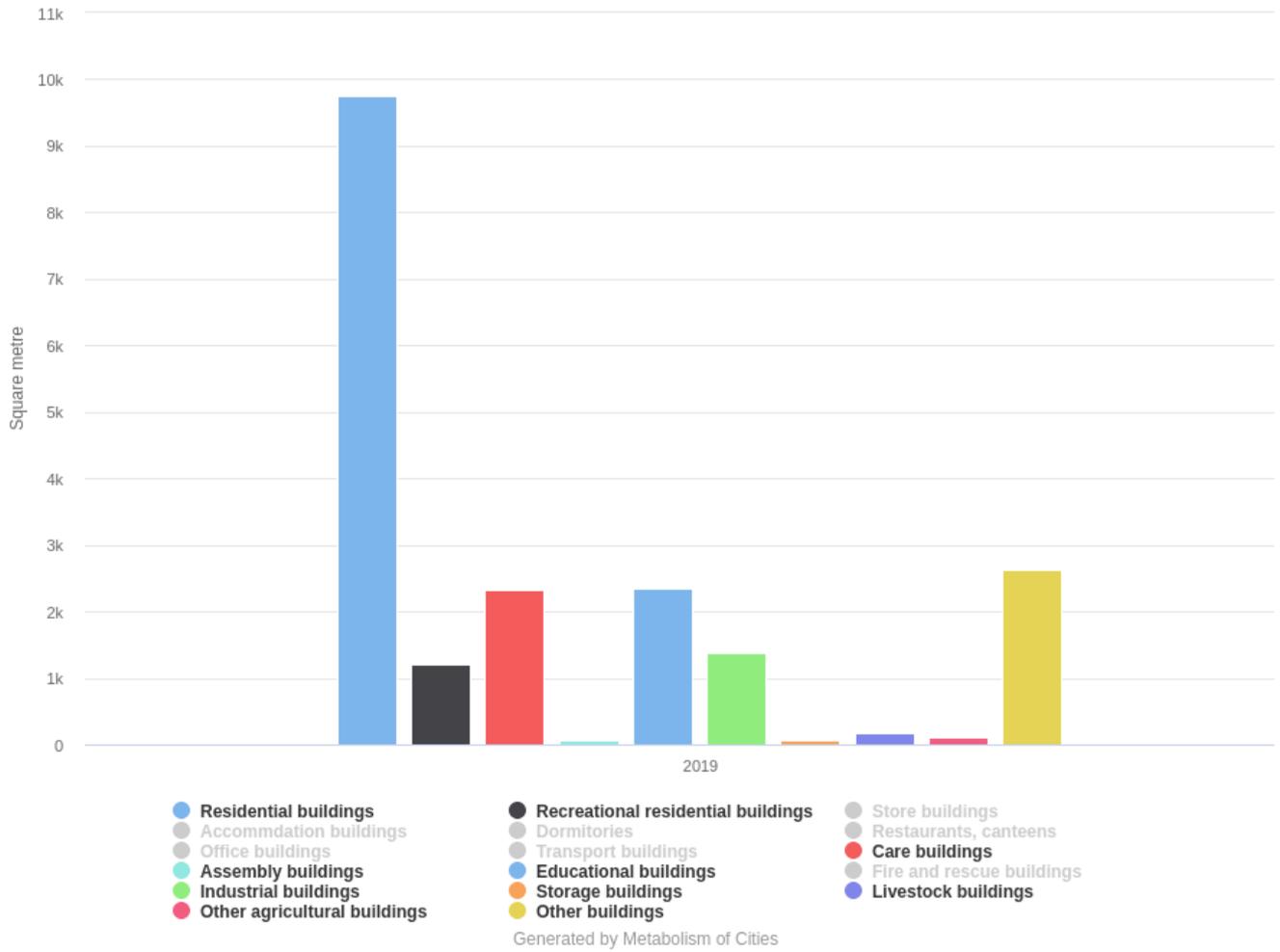
	GVA (monetary value, in €)	Employees
Mikkeli	141,000,000	1,307
Etelä-Savo	272,000,000	3,515
Pohjois- ja Itä-Suomi	3,227,000,000	9B
Finland	14,978,000,000	167,861

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



[Data source](#)

The actors of the construction sector



Data source

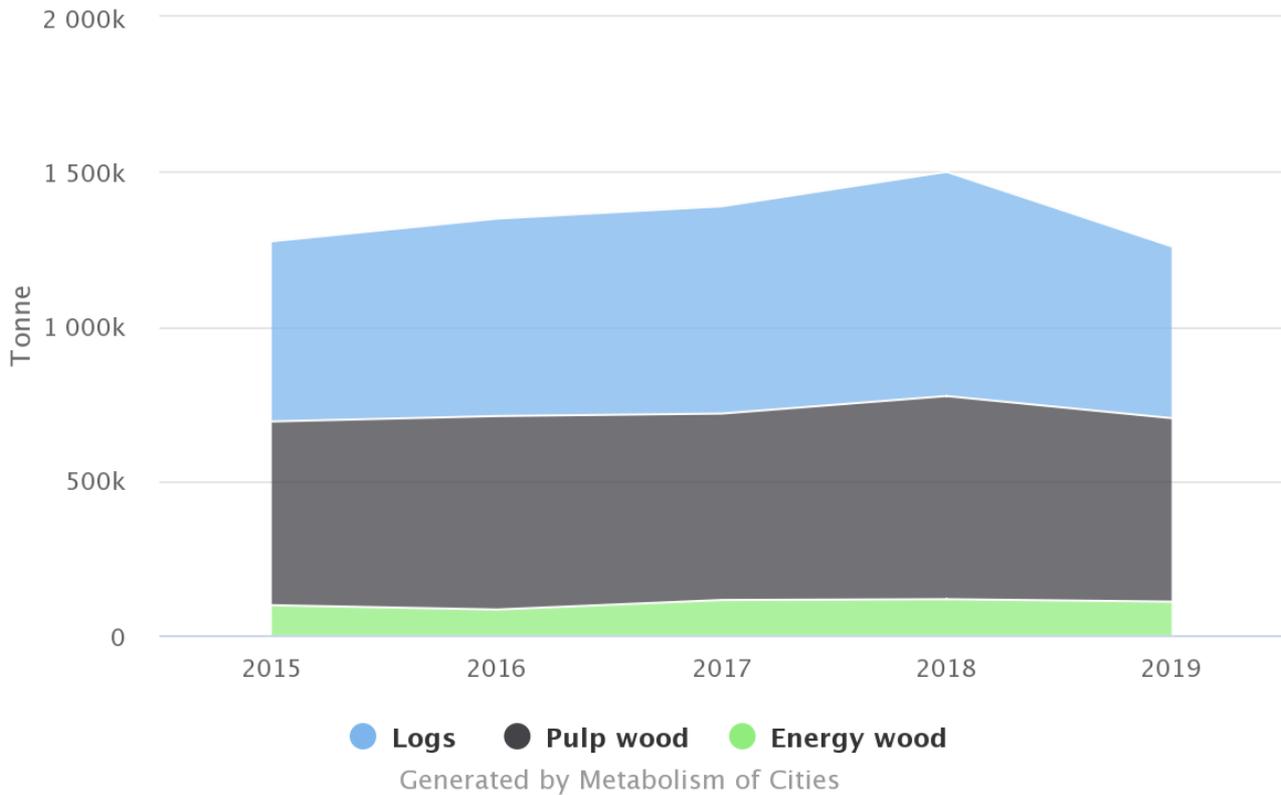
The actors of construction sector were listed by using data of Statistics Finland, where the total number of actors, employees as well as economical information are given by NACE-codes (EU classification of economic activities): ([Industries and employees in Mikkeli 2013-2018](#)).

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](#)).

Amount of harvested wood in Mikkeli



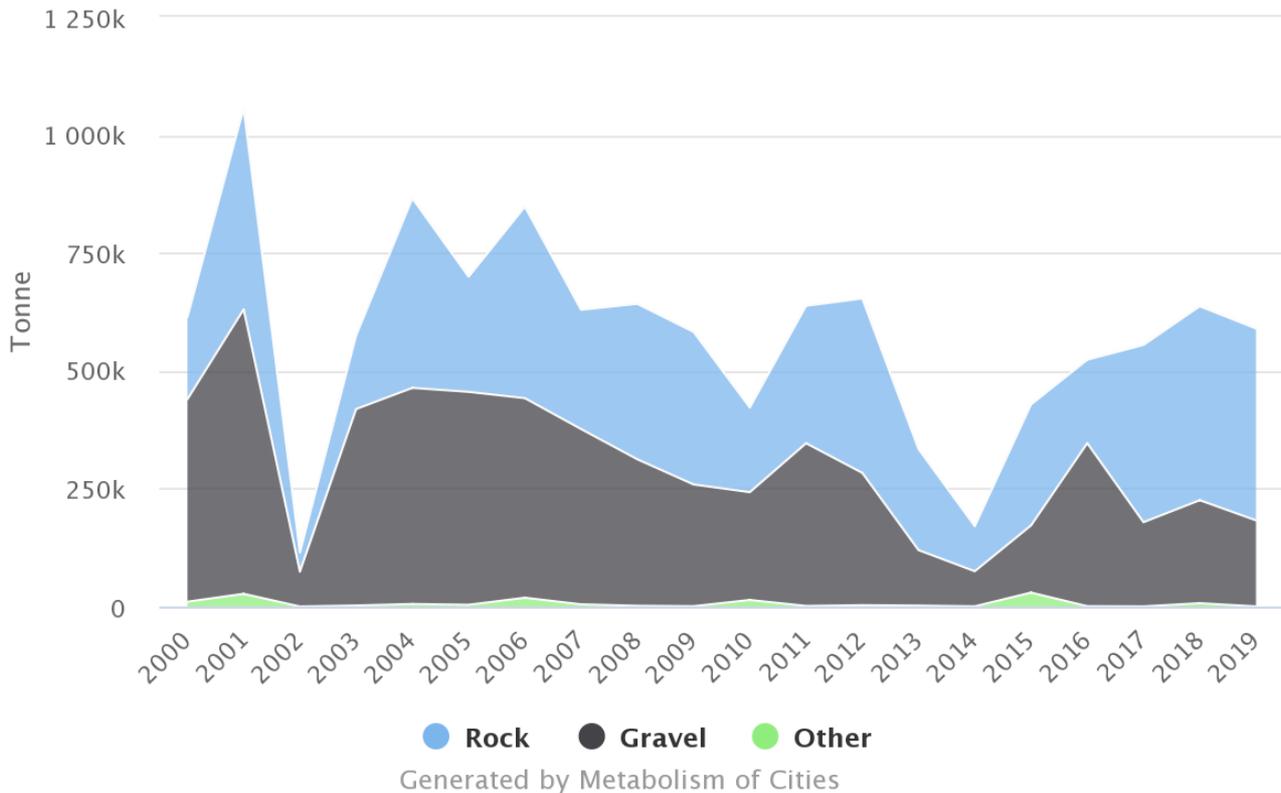
[Data source](#)

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 permits and amount of extracted rock and gravel in Mikkeli](#))



[Data source](#)

Amount of extracted rock and gravel in Mikkeli



[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](#)).

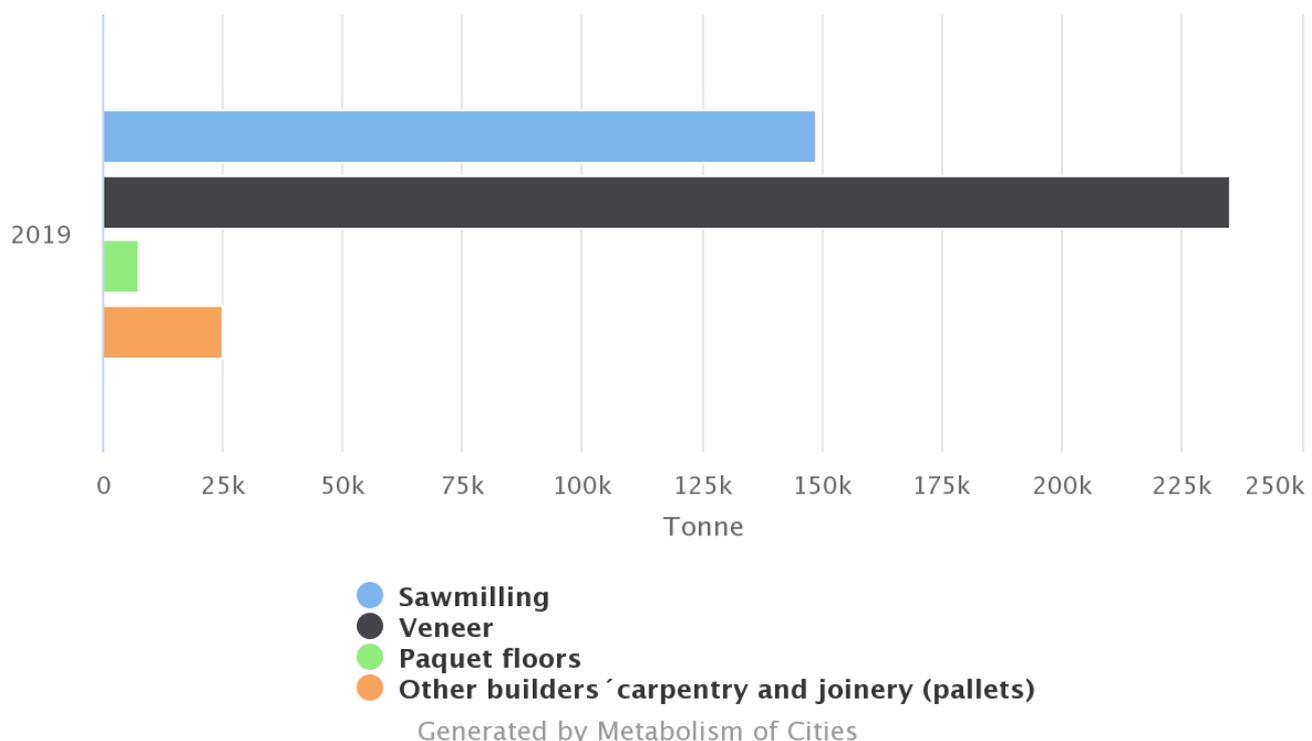
There were also 6 actors in Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials, 4 actors in Manufacture of kitchen furniture and 3 actors in Manufacture of other furniture. However, the role of these actors to the total material flows is assumed to be 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 m³ 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.

Manufacture of timber (sawmilling, plywood, parquet, pallets) in Mikkeli

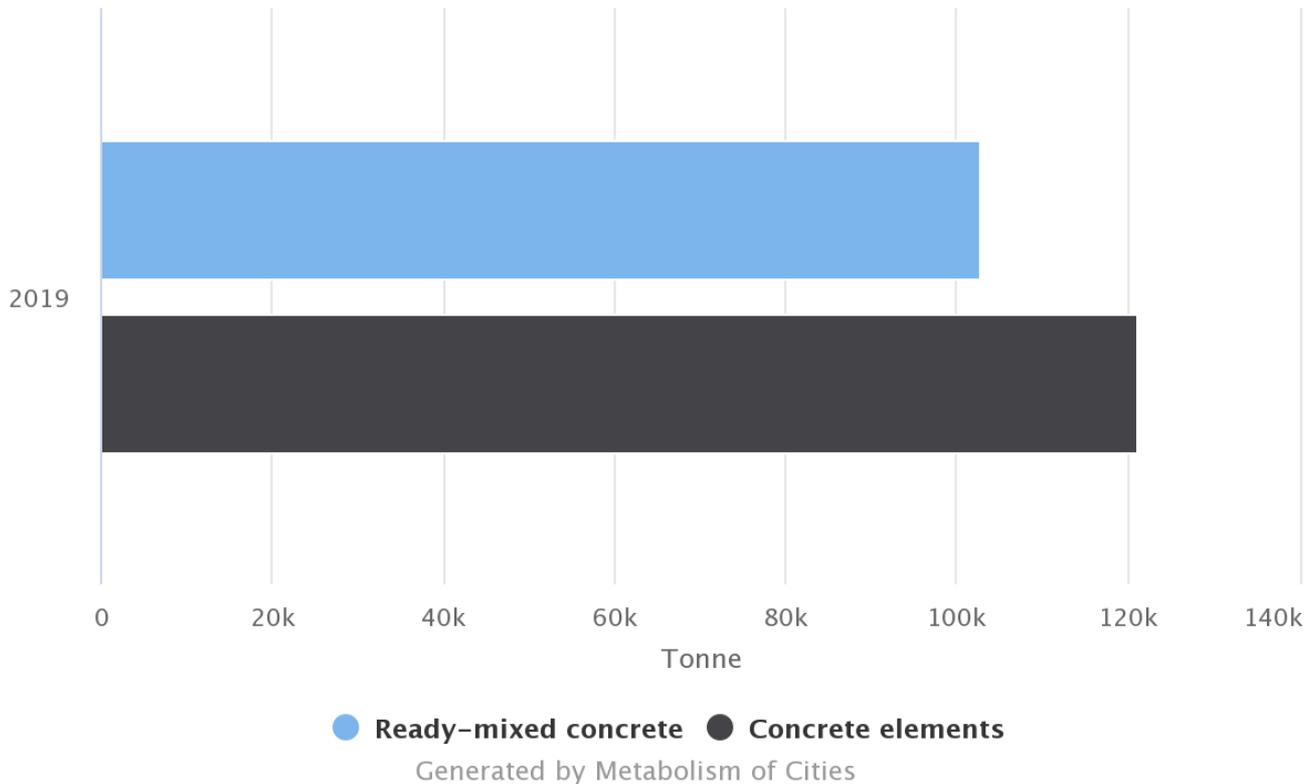


[Data source](#)

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.

Manufacture of concrete in Mikkeli



[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

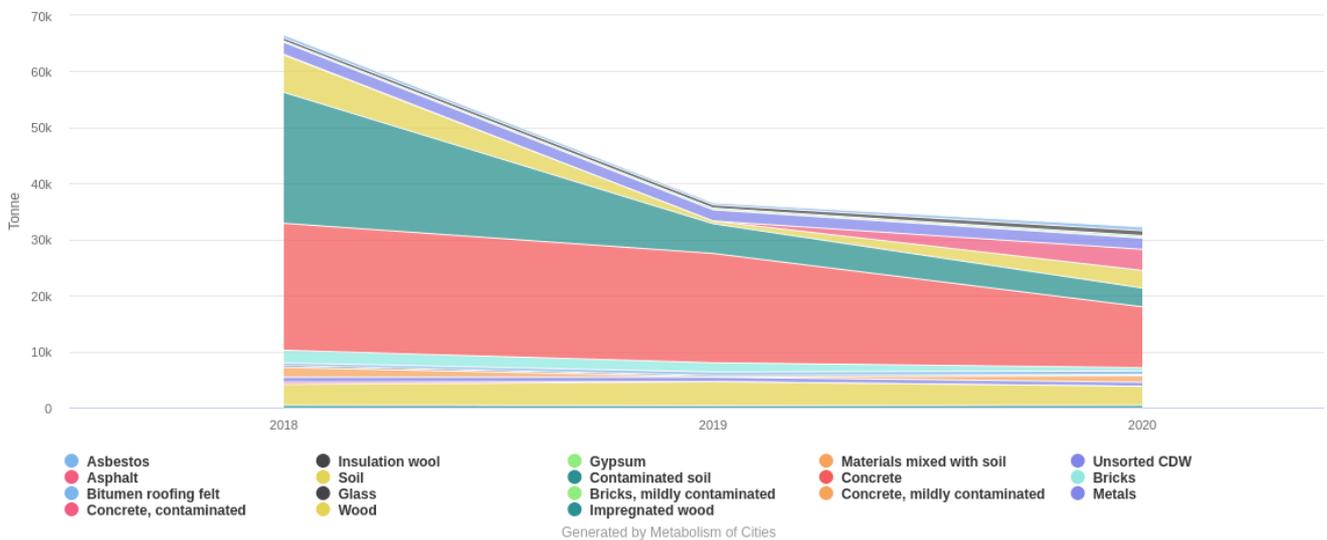
There were 425 actors in the construction sector in Mikkeli in 2018 ([Industries and employees in Mikkeli 2013-2018](#)). Most of these are small companies. The largest construction projects are often managed by national companies such as YIT, Skanska and Destia.

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 Metallit Ltd](#)

and [Mikkelin Romu Ltd](#) receive scrap metal in Mikkelin. 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 sell small quantities of materials from e.g. renovation and demolition sites to reuse.

CDW waste flows, Metsäsairila Ltd. 2018-2020



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: $DMC = \text{Domestic extraction used (DEI)} + \text{Imports (IMP)} - \text{Exports (EXP)}$.

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: $(\text{domestic recovery} - \text{imported waste for recycling} - \text{exported waste for recycling}) / ((\text{domestic material consumption} + (\text{domestic recovery} - \text{imported waste for recycling} - \text{exported waste for recycling})))$.

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: $\text{Import Reliance (IR)} = \text{Net import} / \text{Apparent consumption} = (1 - (\text{Import} - \text{Export})) / (\text{Domestic production} + \text{Import} - \text{Export})$.

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: $EOL\ RR = EOL\ Mass\ recycled / EOL\ Mass\ collected \times 100$.

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.

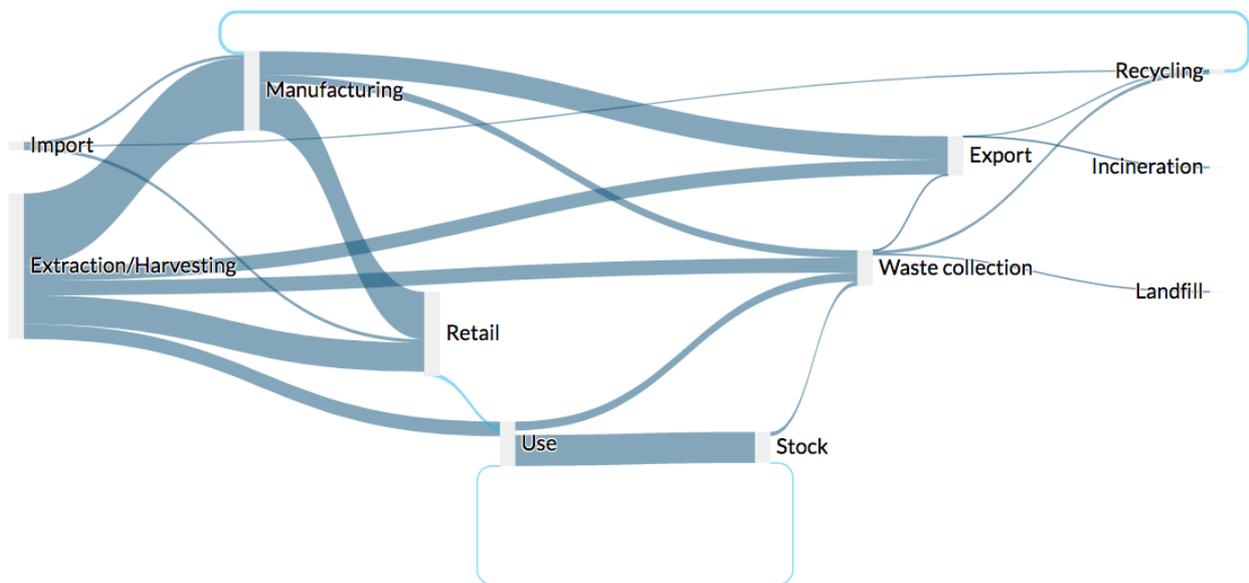
The Sankey diagram describes well that the main flows of construction materials in Mikkeli are in extraction and harvesting and in manufacturing. The amounts of extraction and harvesting as well as manufacturing are also the most reliable and complete datasets, which were collected. These lifecycle stages 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 diagram 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 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 activities	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				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			
Waste collection		Only Metsäsairila Ltd data		
Landfill				

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
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

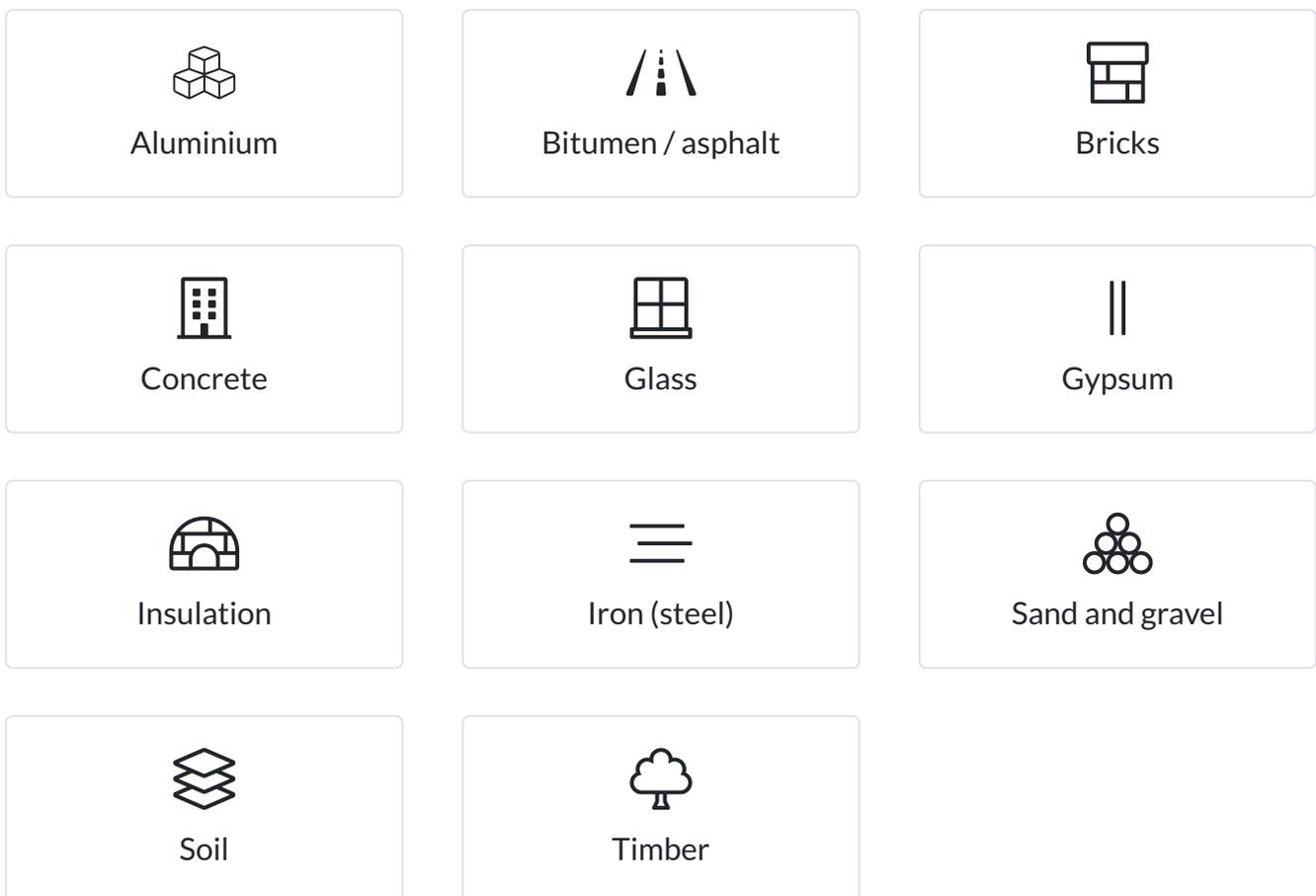
ROSKILDE



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.



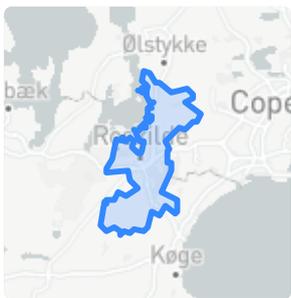
The assessment was carried out by the cities themselves after receiving extensive training in the form of courses on data collection ([construction](#) and [biomass](#)) and [data processing](#). Numerous additional insights can be found in the individual [Data Hubs](#) of each city.

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

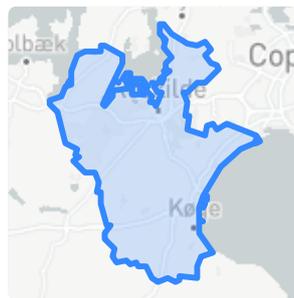
To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were 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 km²



Østsjælland

👤 253,321

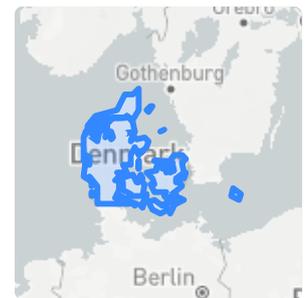
📏 808 km²



Sjælland

👤 2,659,634

📏 9,789 km²



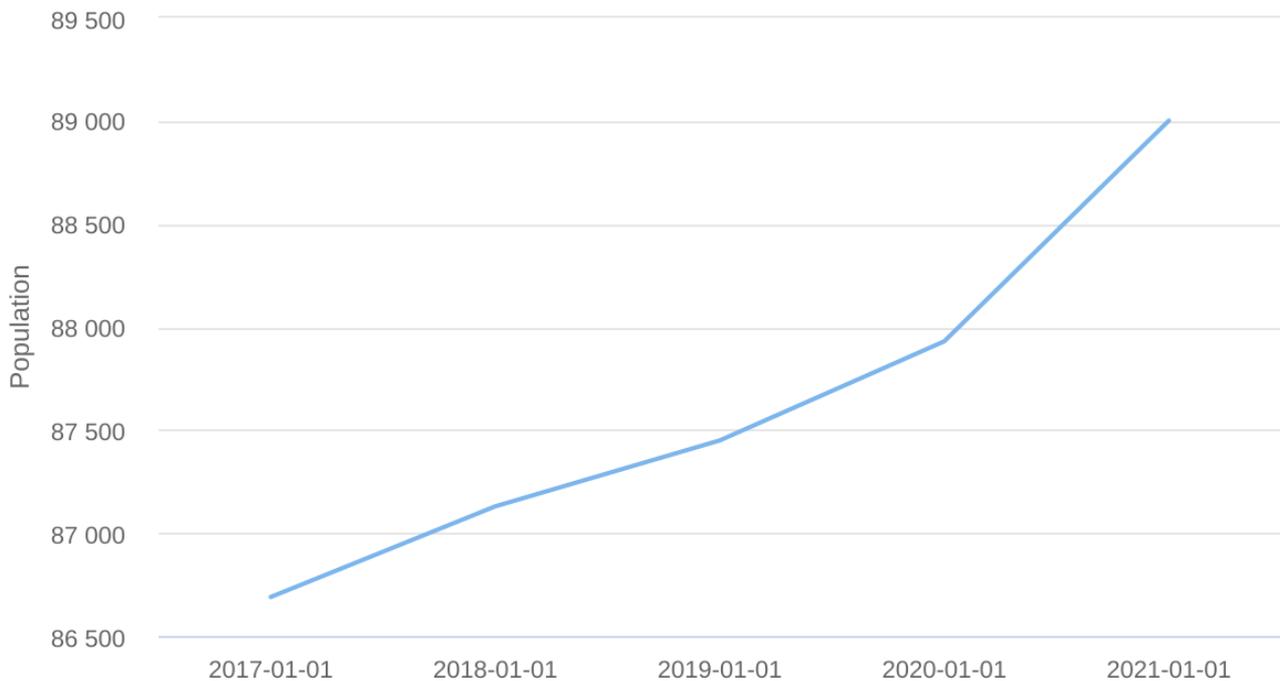
Denmark

👤 5,850,189

📏 42,933 km²

Population of Roskilde

City population in Roskilde, 2017-2021



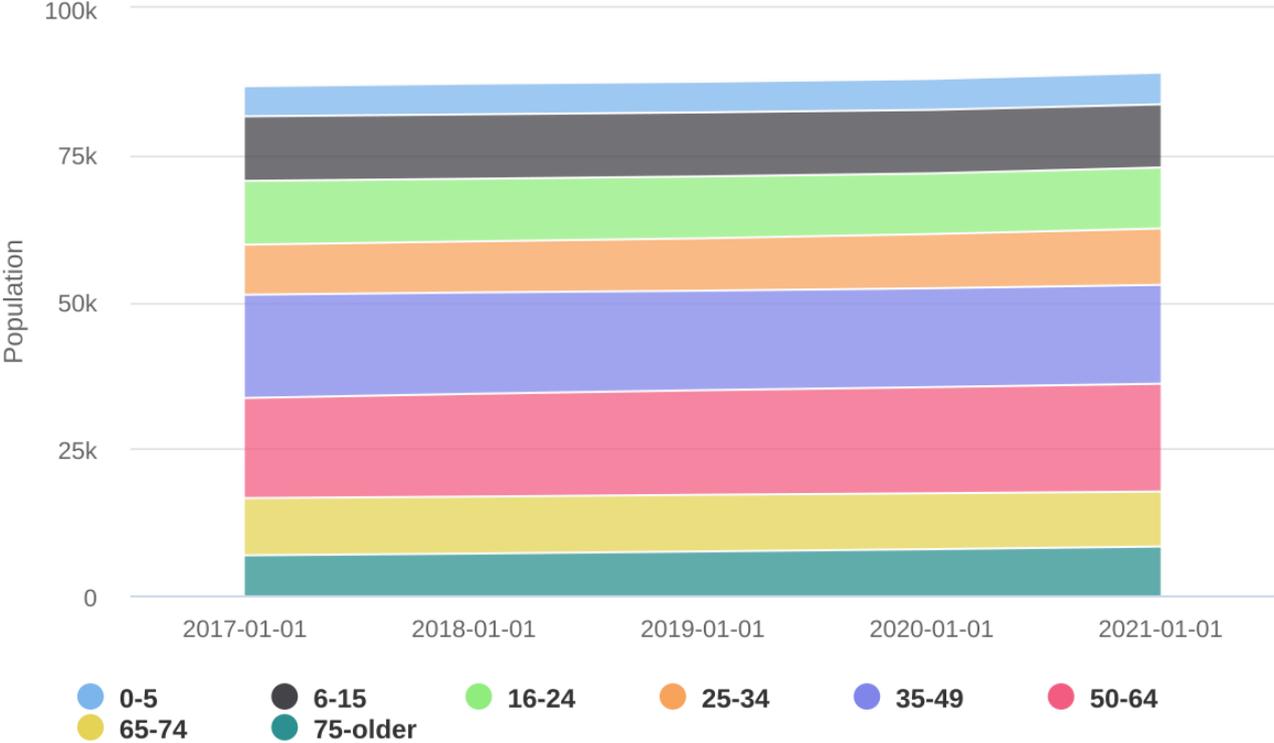
Generated by Metabolism of Cities

[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.

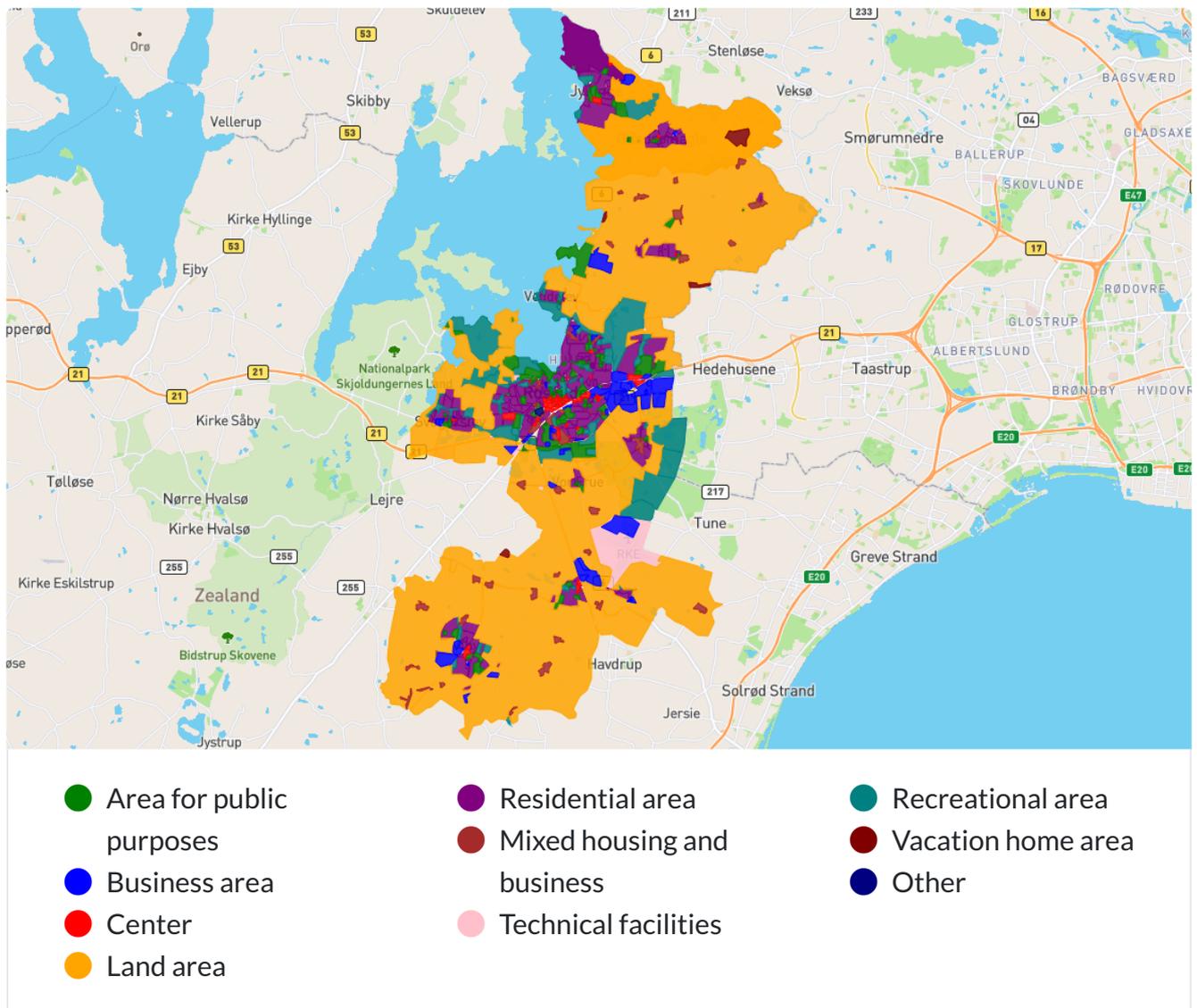
City Population in Roskilde, 2017-2021, by age group



Generated by Metabolism of Cities

[Data source](#)

Land use



[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

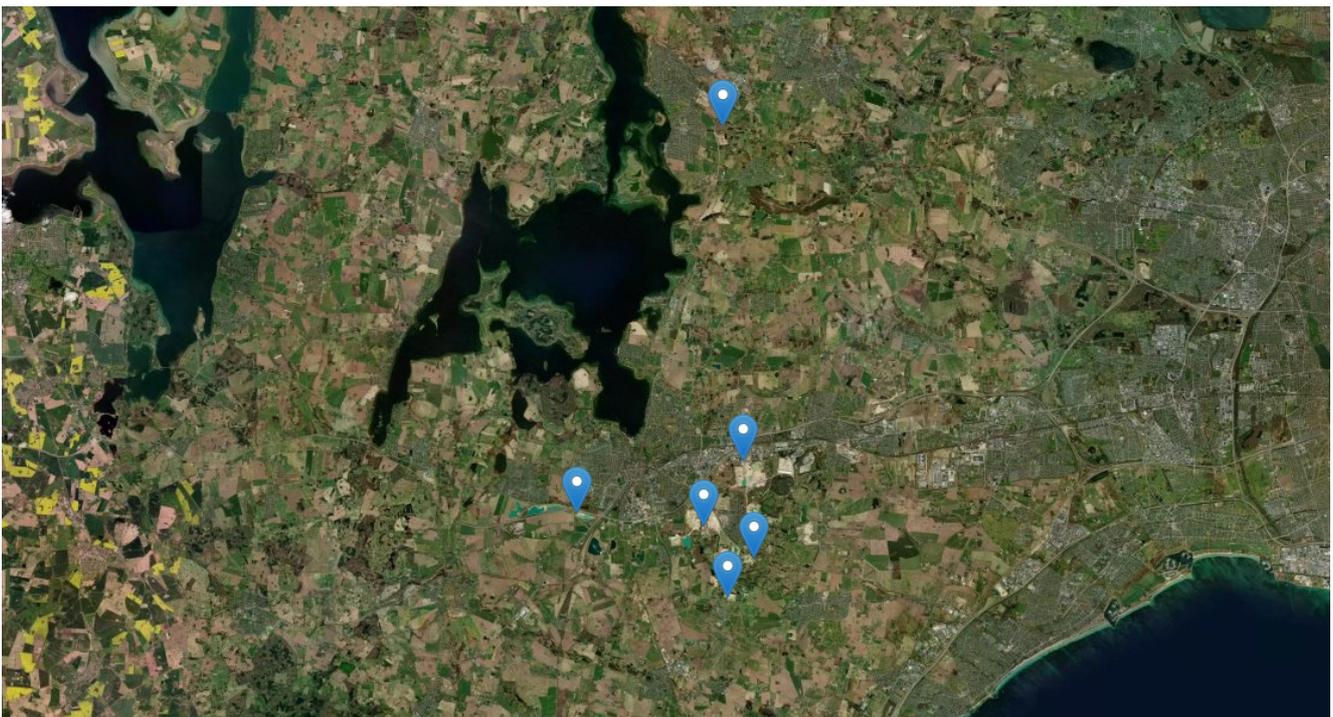
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	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 craftsmen.

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 Asphalt, 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.

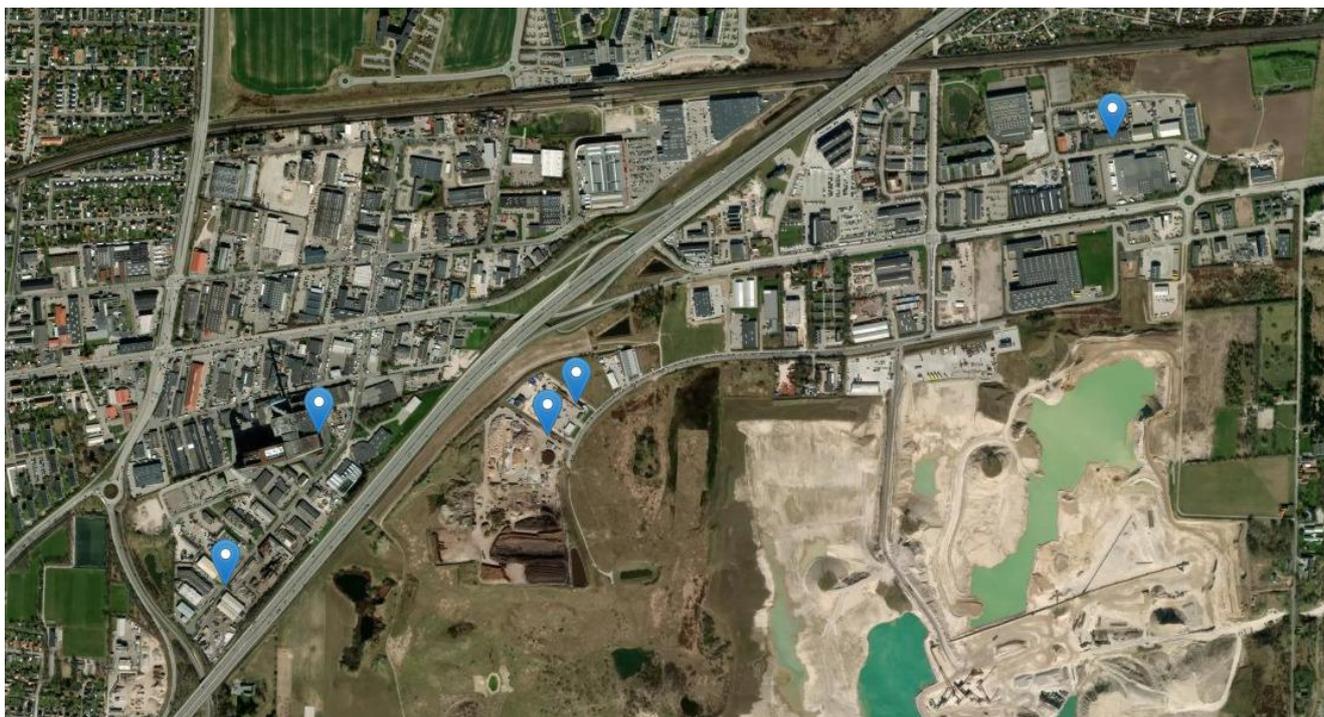
Use

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.

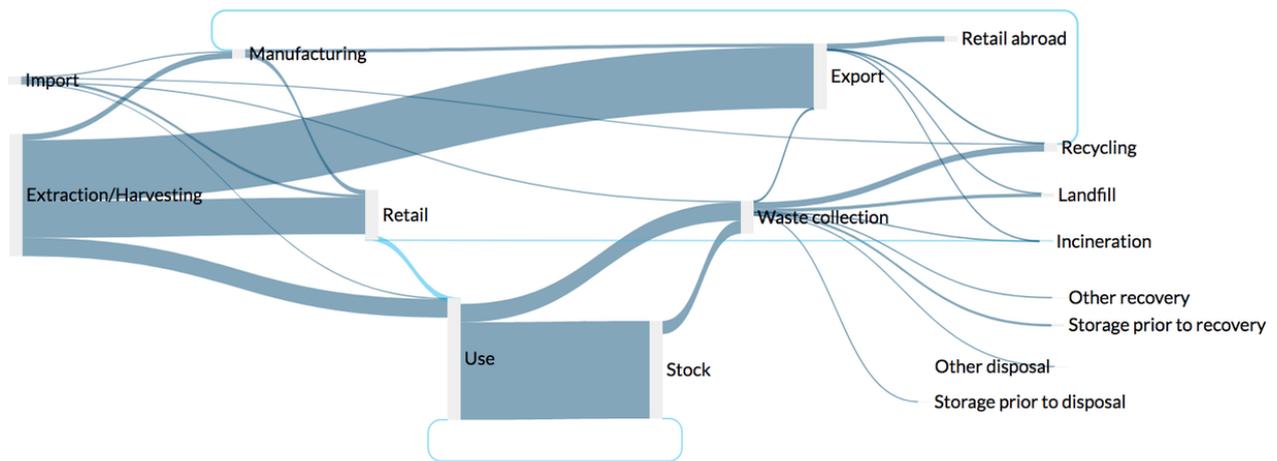
The EOL recycling and processing rates are still considerably low with about 14% and 30%, respectively. While 27% of materials are still subjected to disposal and 73% to recovery, the efficiency of recovery could still be improved. There is however uncertainty in those values, as the amounts derived 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 originate 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 activities	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	<i>Estimated data</i>	<i>Data exists for most single materials and most economic activities</i>	<i>Data less than 6 years difference to the time period of the data set</i>	<i>Regional-level data (NUTS 3)</i>
low	<i>Provisional data</i>	<i>Data exists for the sector only for the Life Cycle Stages</i>	<i>Data less than 10 years difference to the time period of the data set</i>	<i>NUTS 2 and country-level data</i>

Data quality matrix

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

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

_(Missing for now. Will be added in the final version of February 2022.) _

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.

References

- [Denmark](#)
- [Sjælland](#)
- [Østsjælland](#)
- [Population of Roskilde, 2017-2021 line graph](#)
- [Municipal planning framework 2019](#)
- [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

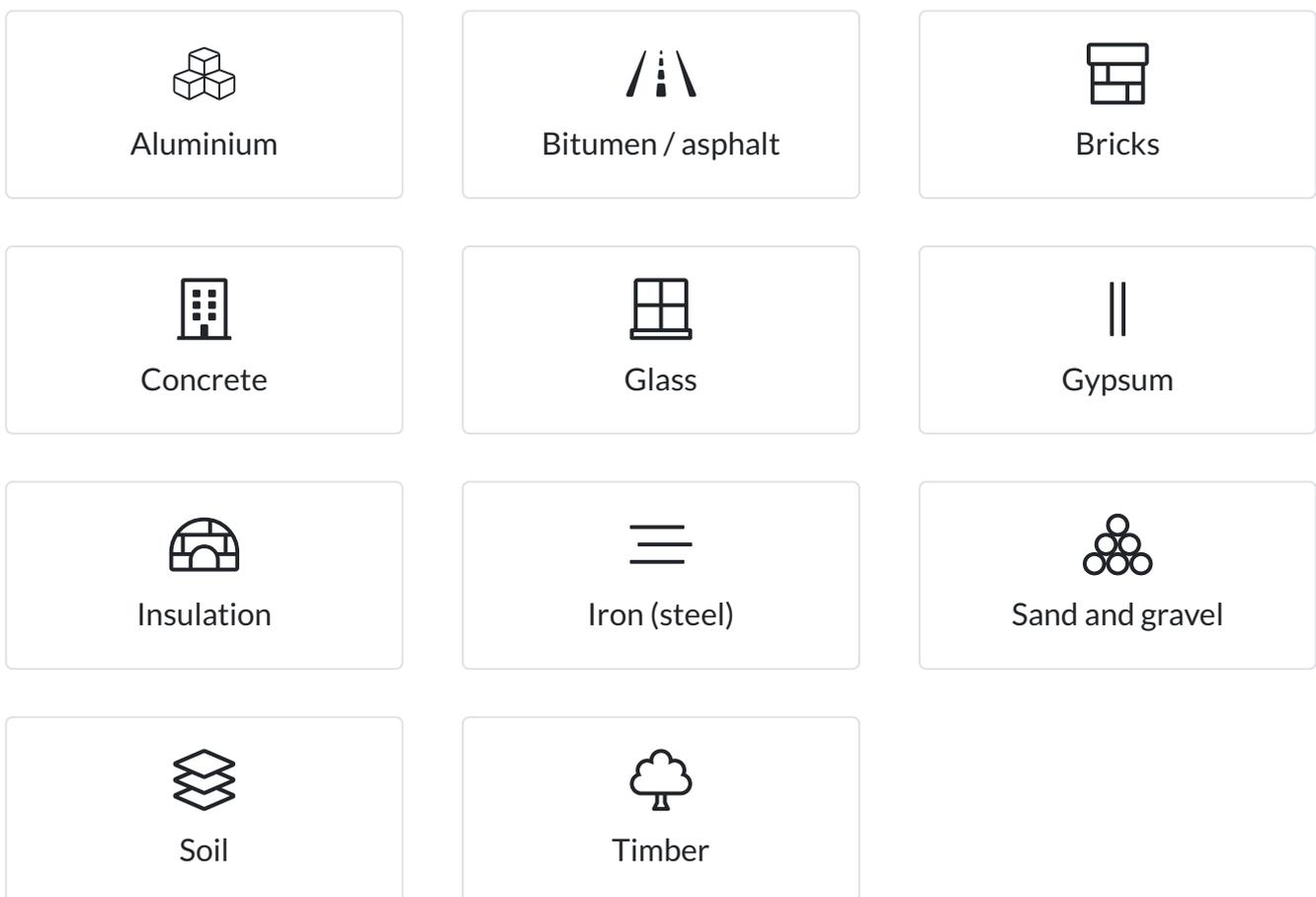
SEVILLA



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.



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 km²



Sevilla

👤 1,942,389

📏 14,036 km²



Andalucía

👤 8,414,240

📏 87,600 km²



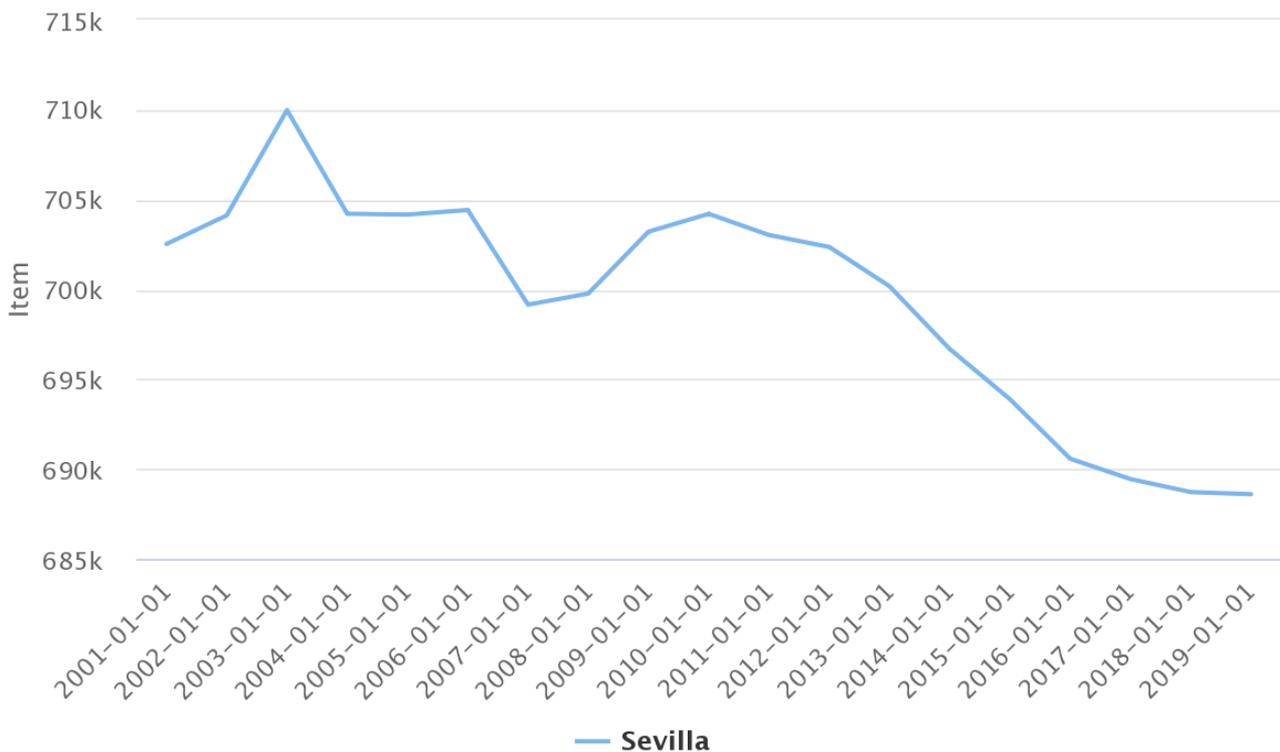
Spain

👤 47,026,208

📏 505,990 km²

Population of Sevilla

Population evolution of Sevilla

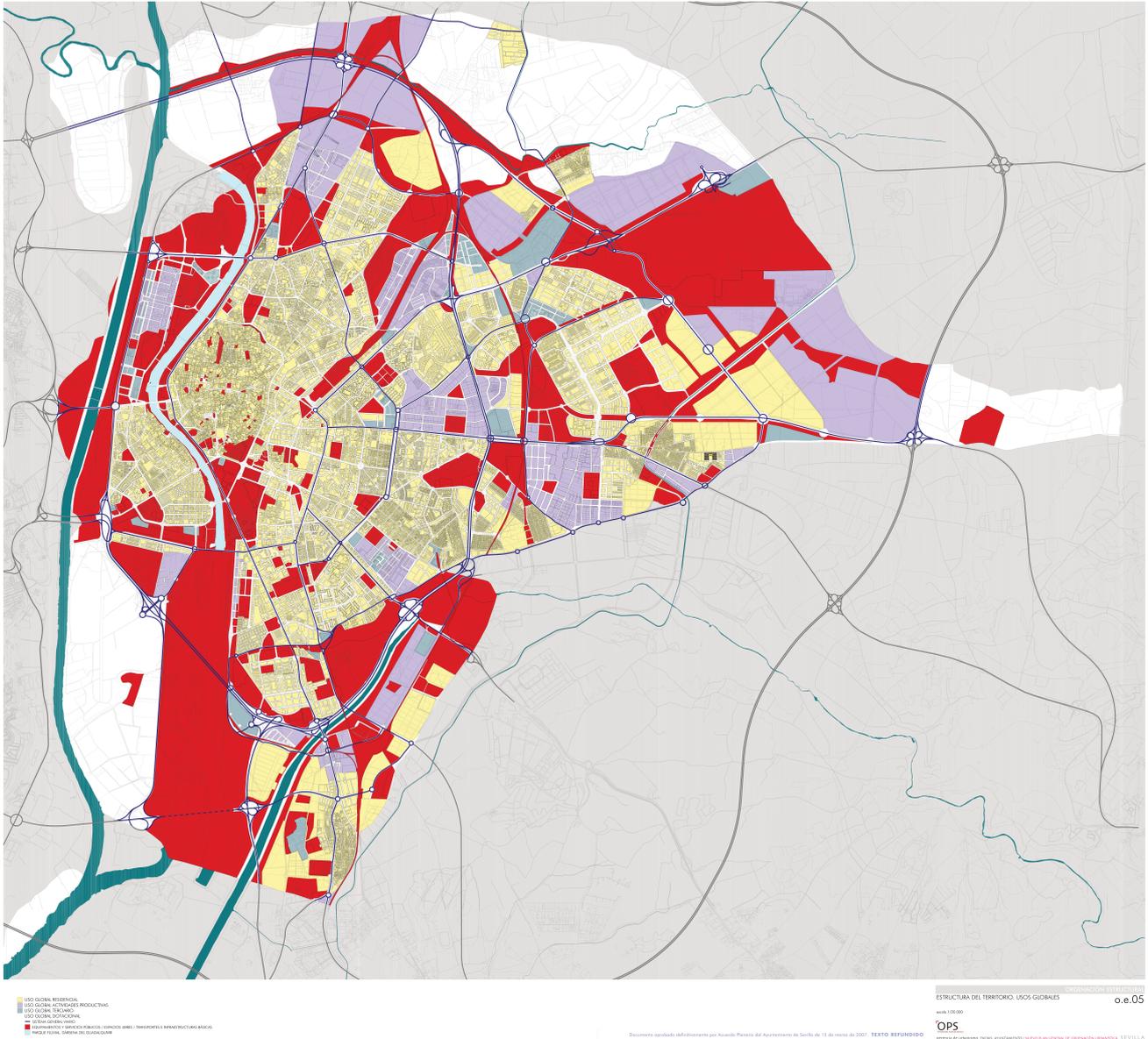


Generated by Metabolism of Cities

[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

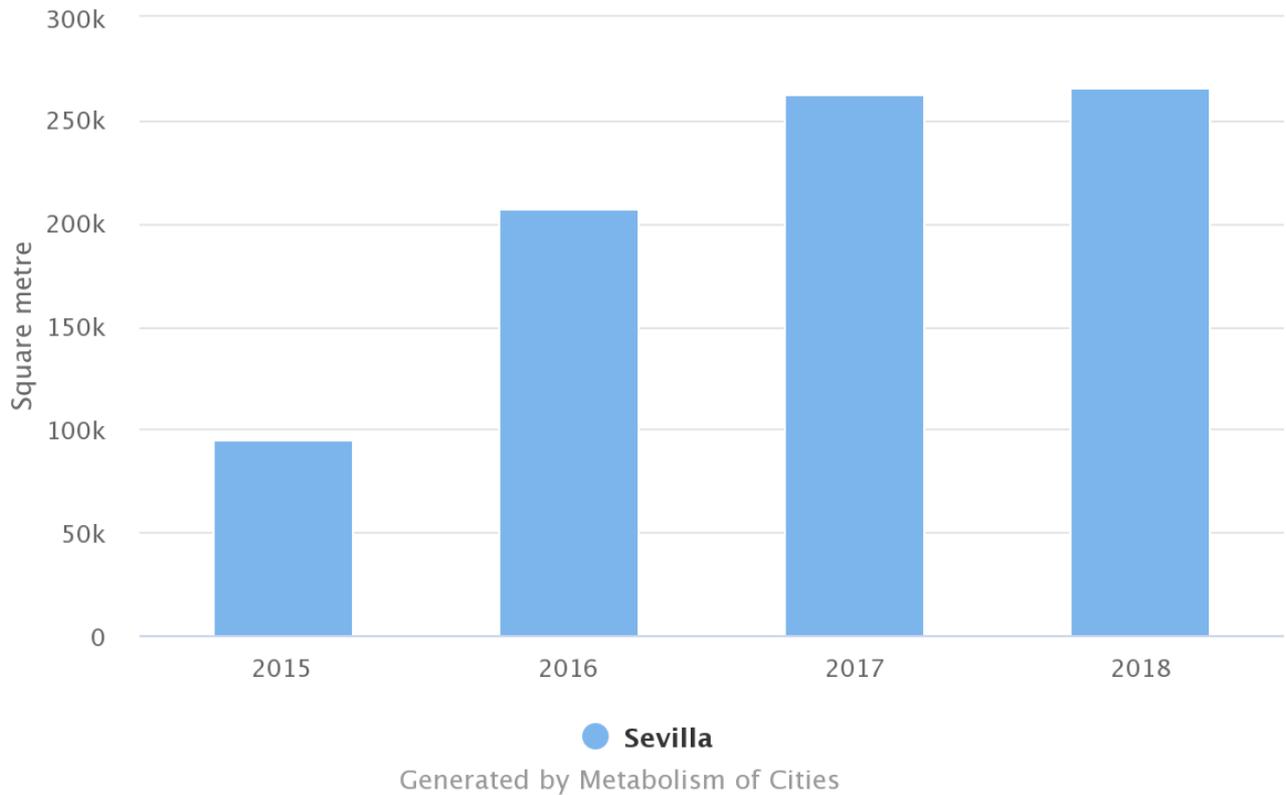
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

	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

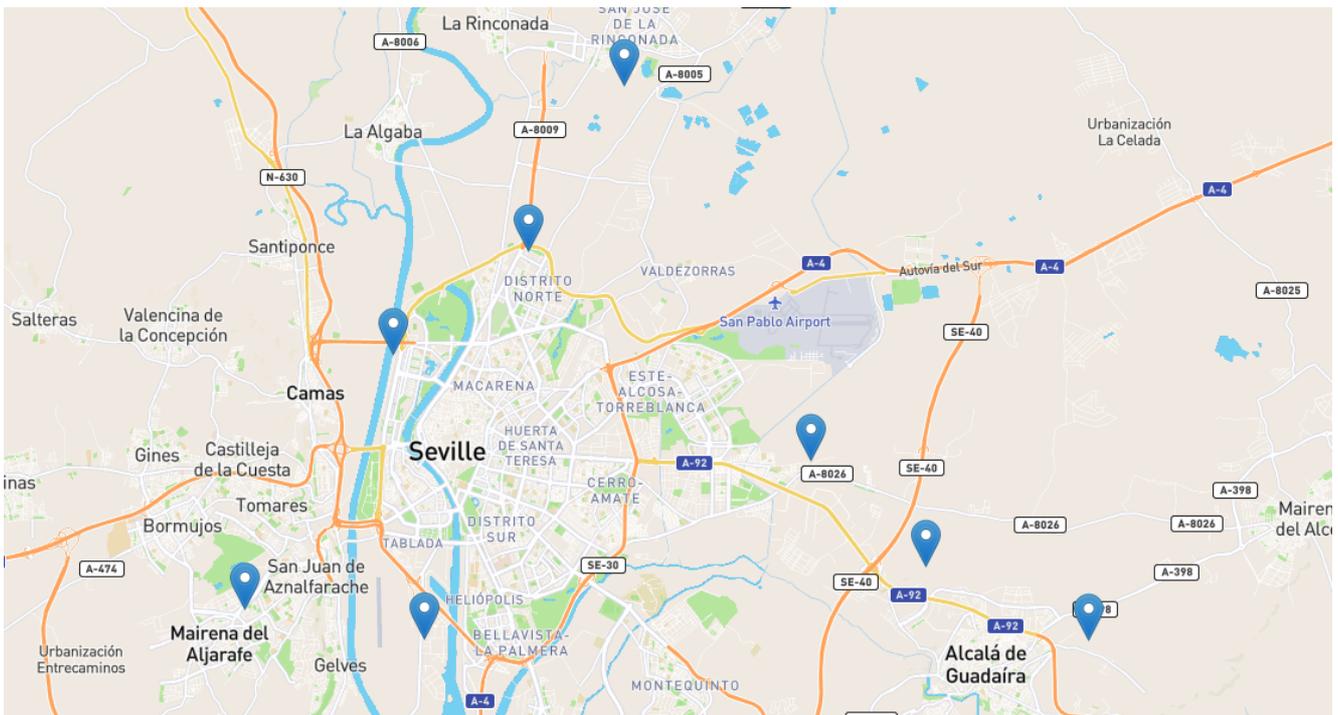
The construction sector employs 5.4% of employees in Seville. The corresponding percentage for the whole country of Spain is 6.4%. The most significant employment sectors in Seville are the Service sector (78.6%). Construction accounts for about 5.6% of Seville's GDP. Based on turnover, the most significant industries in Seville are wholesale and retail trade (11%) and the manufacturing industry (9.75%). (Data of Statistics Andalusia 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 m².

Number and square area of new buildings in Sevilla



[Data source](#)

The actors of the construction sector



[Data source](#)

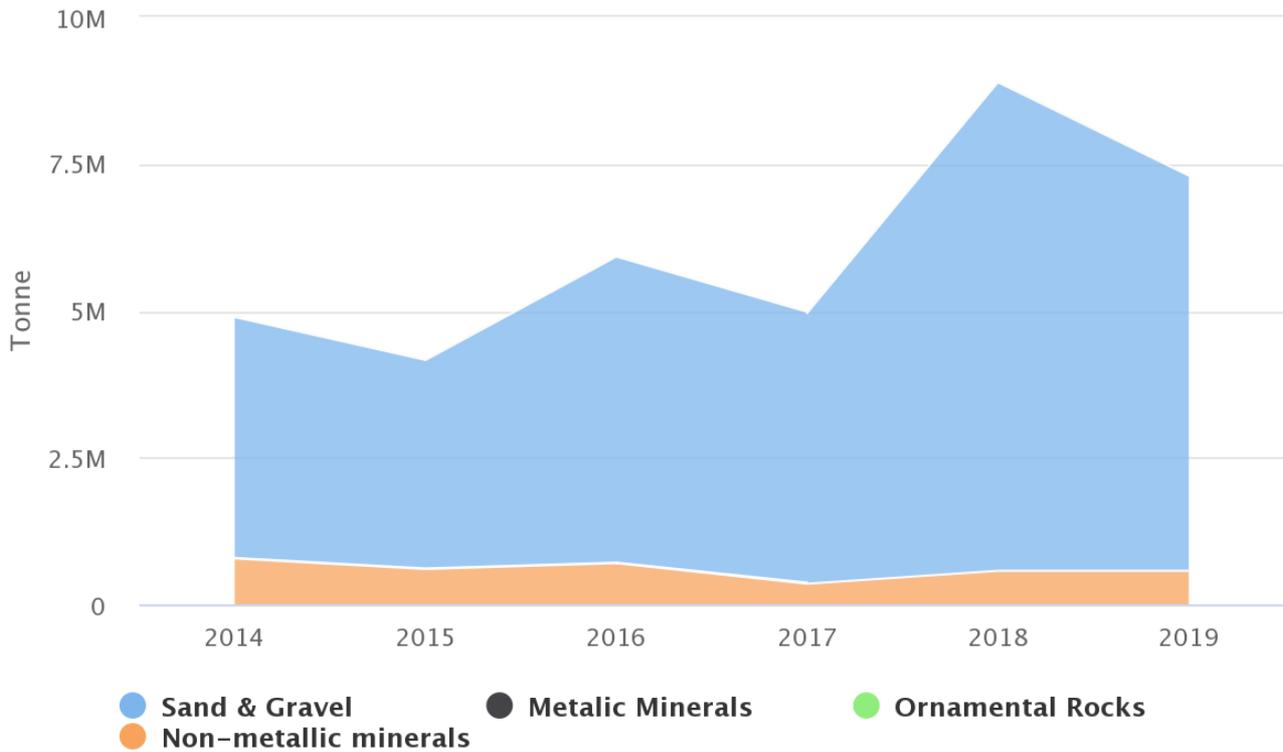
Seville shows 3,032 facilities focused on the construction sector, the corresponding percentage regarding the whole facilities (all economic sectors) located in Seville municipality is 6.5%. The construction facilities are mainly located in the metropolitan area of Seville and there are representatives 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



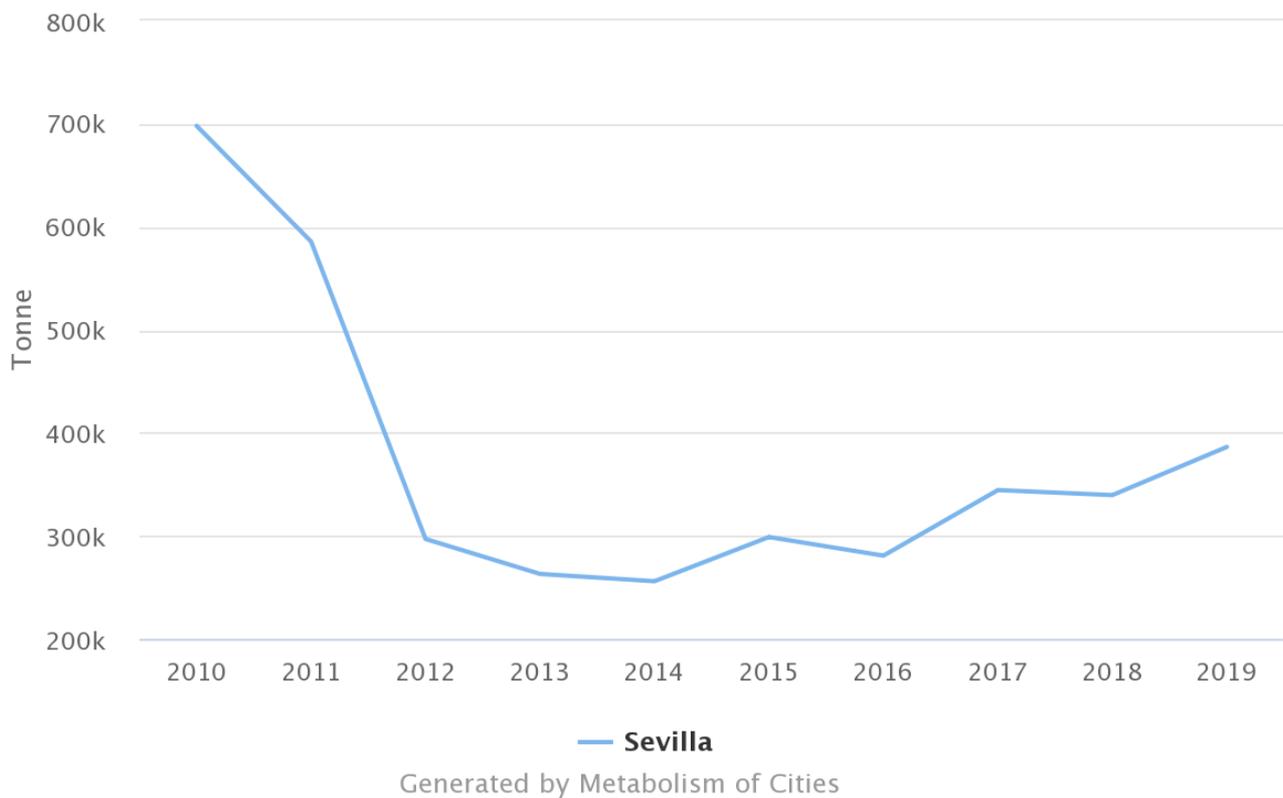
[Data source](#)

Amount of extracted products Sevilla



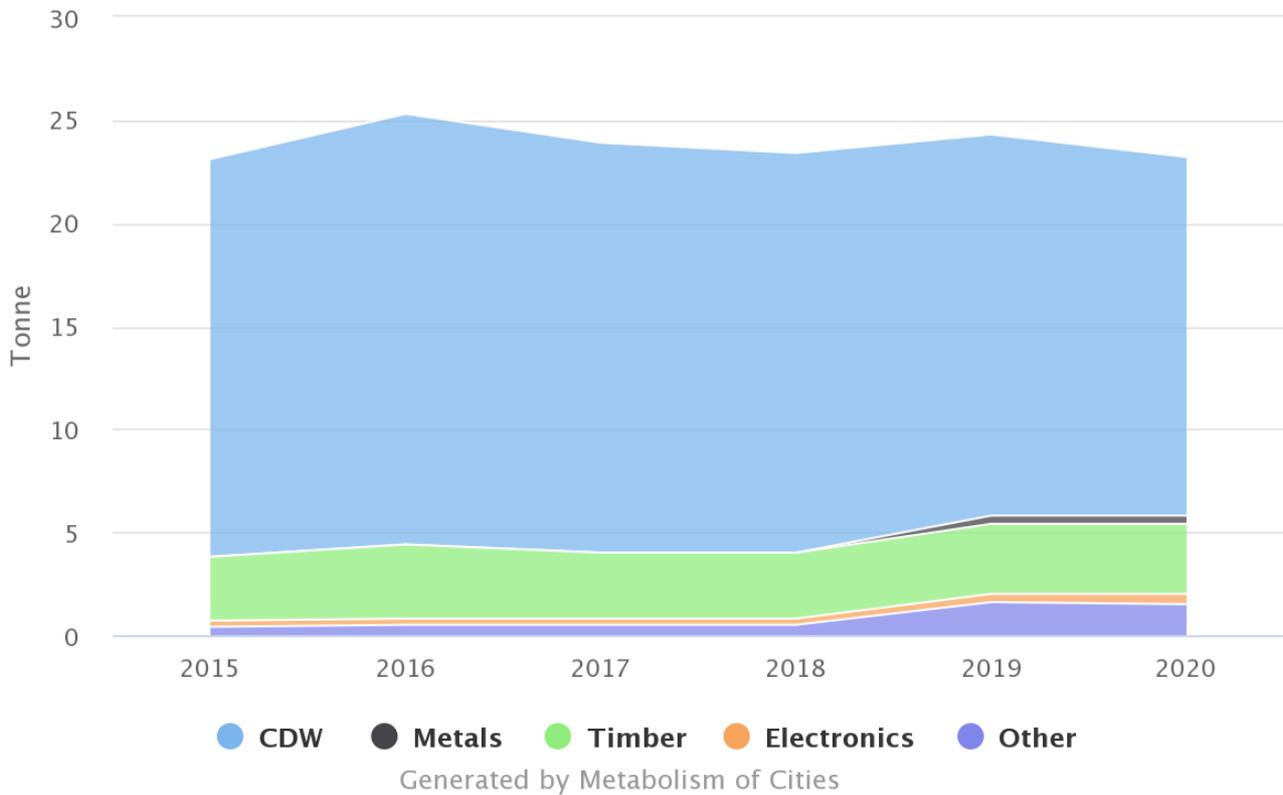
[Data source](#)

Manufacture of concrete in Sevilla



[Data source](#)

CDW waste flows managed by Lipasam



[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: $DMC = \text{Domestic extraction used (DEI)} + \text{Imports (IMP)} - \text{Exports (EXP)}$.

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: $\text{Import Reliance (IR)} = \frac{\text{Net import}}{\text{Apparent consumption}} = \frac{1 - (\text{Import} - \text{Export})}{(\text{Domestic production} + \text{Import} - \text{Export})}$.

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: $EOL\ RR = \frac{EOL\ Mass\ recycled}{EOL\ Mass\ collected} \times 100$.

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 $End-of-Life\ Processing\ Rate = \frac{End-of-Life\ mass\ recycled}{End-of-Life\ mass\ collected\ for\ recycling} \times 100$. 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.

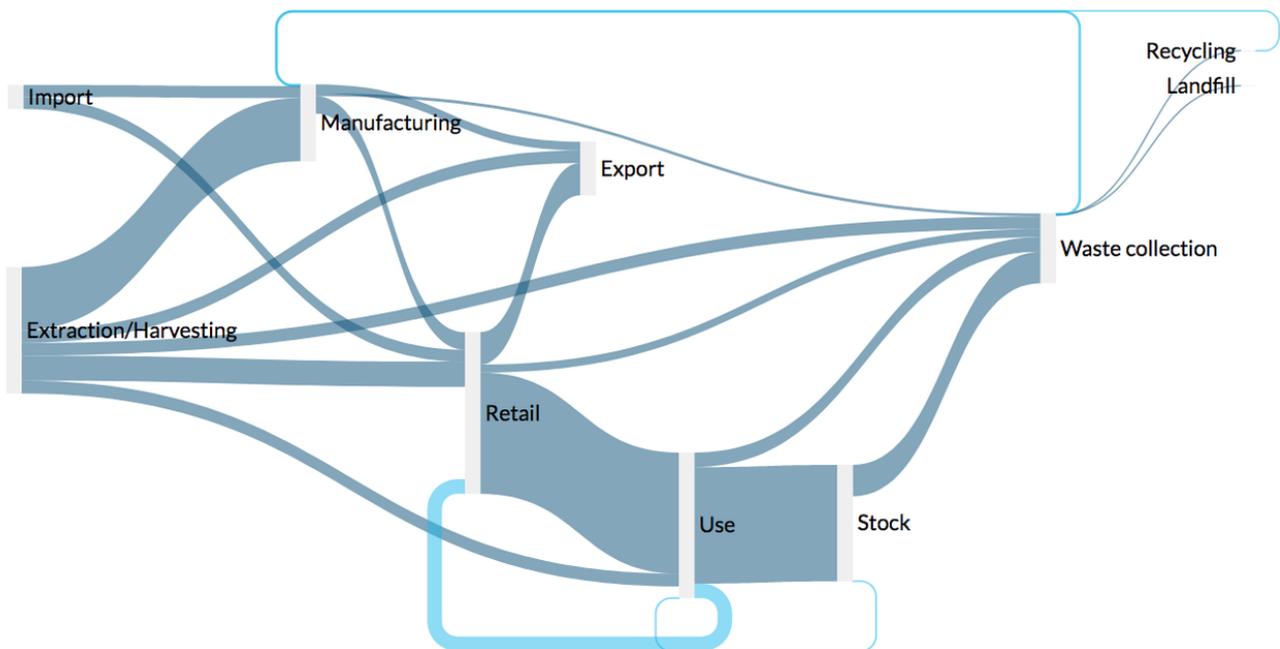
Incineration rate is the mass percentage of waste that is incinerated. The formula used in SCA is $\text{Incineration Rate} = \frac{\text{Incinerated waste}}{\text{Total waste} + \text{imported waste} - \text{exported waste}} \times 100$. The indicator shows the local incineration only. In the case of 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 $\text{Landfilling rate} = \frac{\text{Landfilled waste}}{\text{Total waste} + \text{imported waste} - \text{exported waste}}$. 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.

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 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 activities	Data less than 3 years difference to the time period of the data set	City-level data

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

Data quality matrix

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

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](#)

FOR MORE INFORMATION, VISIT:

<https://cityloops.metabolismofcities.org>



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

Disclaimer: The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

CITYLOOPS



**METABOLISM
OF CITIES**