SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

HØJE-TAASTRUP

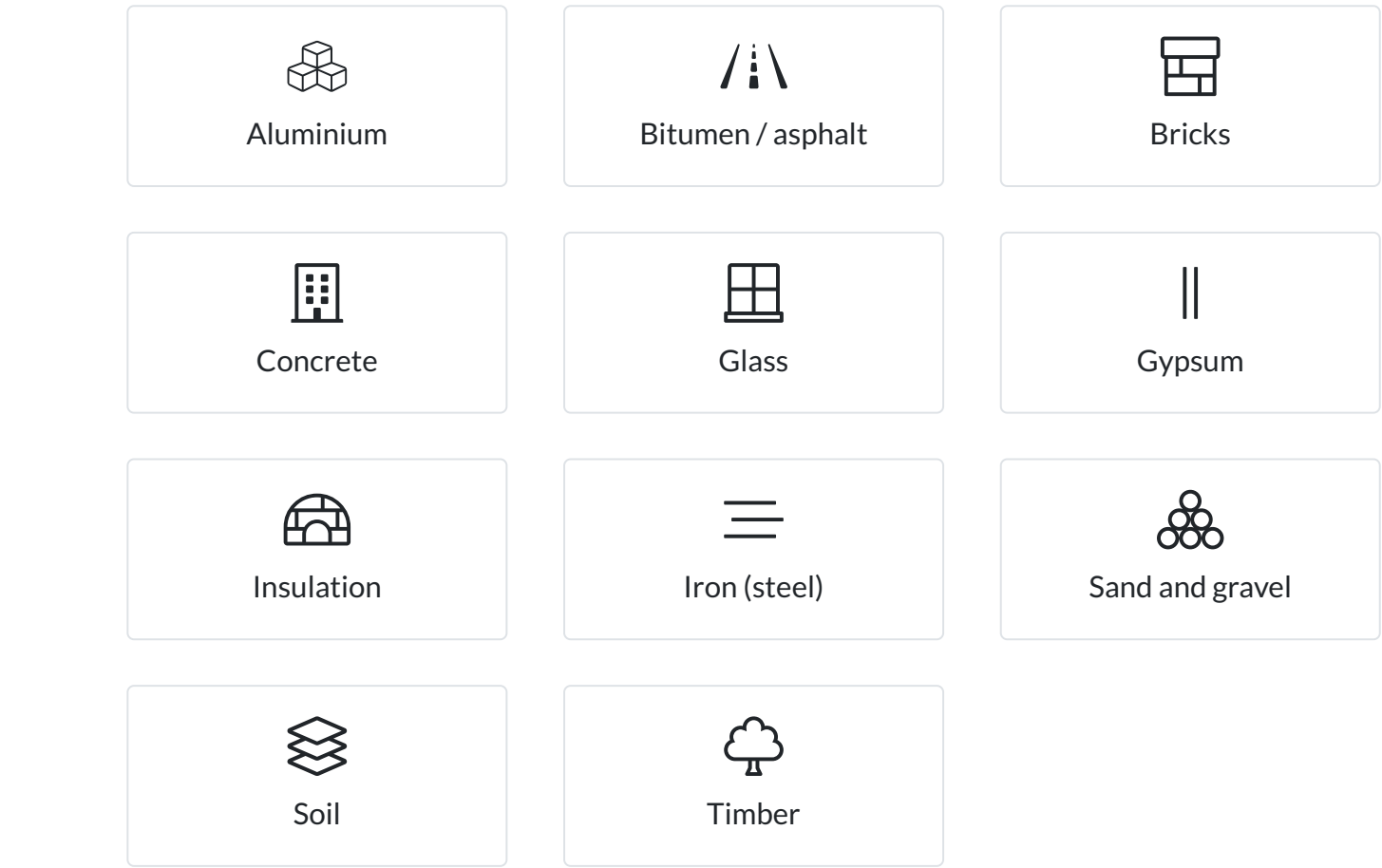
CITYLOOPS

METABOLISM OF CITIES

Introduction

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

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



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

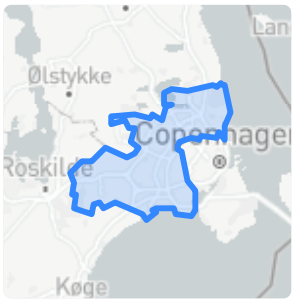
This current Sector-Wide Circularity Assessment report provides contextual information on the city and the economic sector under study. It then illustrates how circular these sectors are through circularity indicators and a Sankey diagram. Finally, it analyses and interprets the results, presents the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

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

Urban context

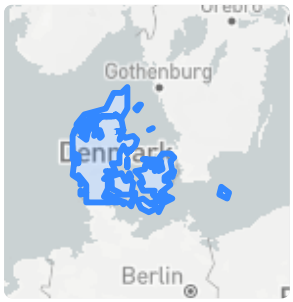
To contextualise the results of the sector-wide circularity assessment, this section provides population and land use information data of the city. In addition, population and area of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included. Data for these scales were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

Høje-Taastrup
50,759
78 km^2



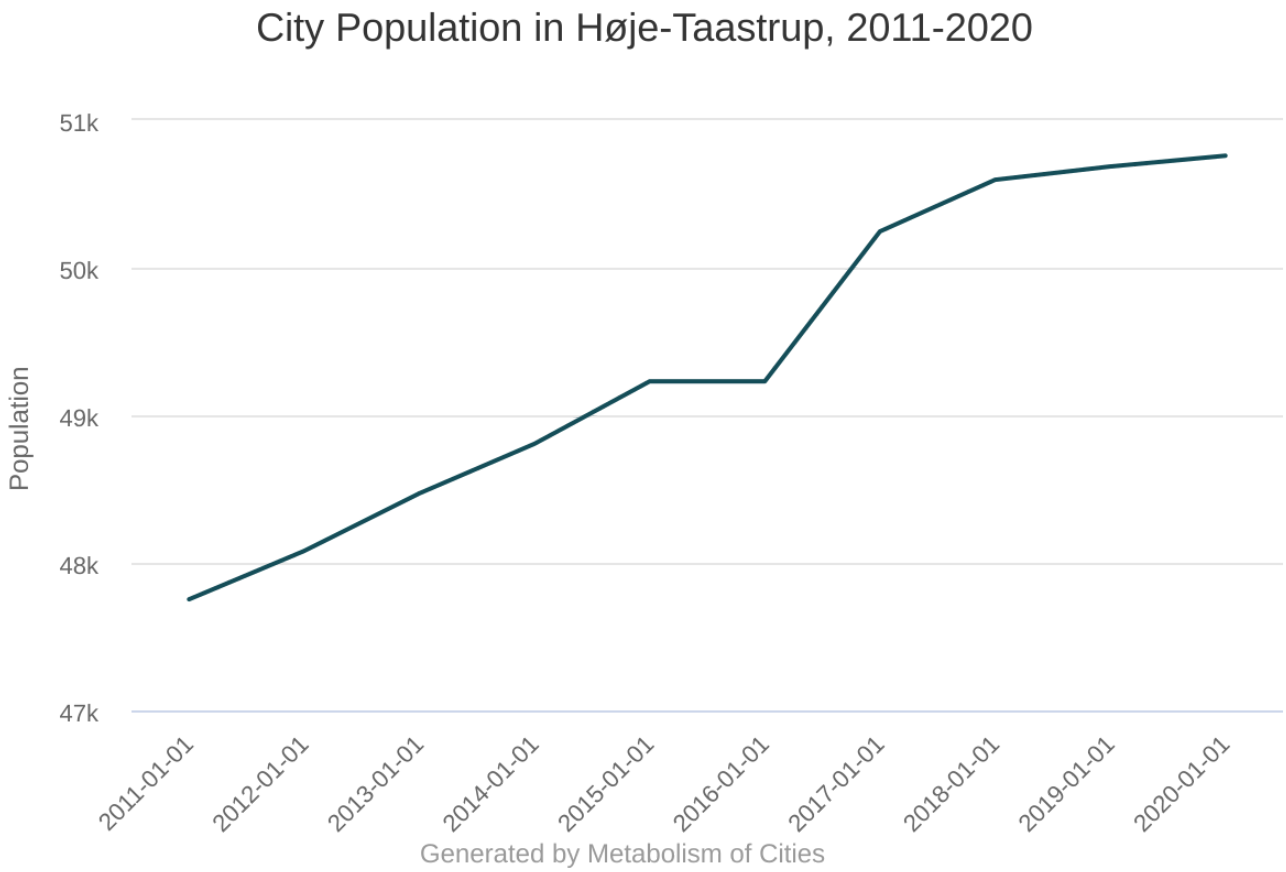
Københavns omegn
548,370
342 km^2

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



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

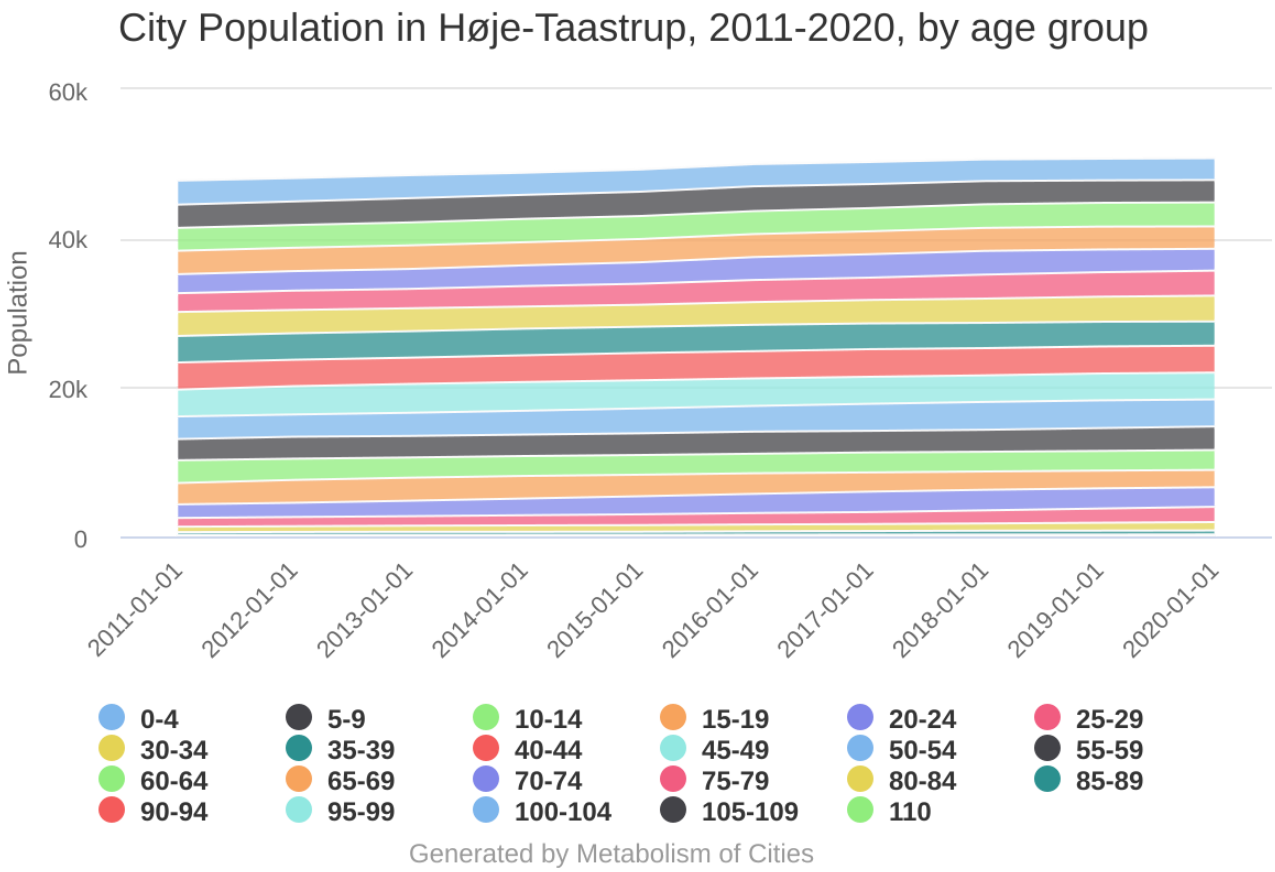
Population of Høje-Taastrup



Data source

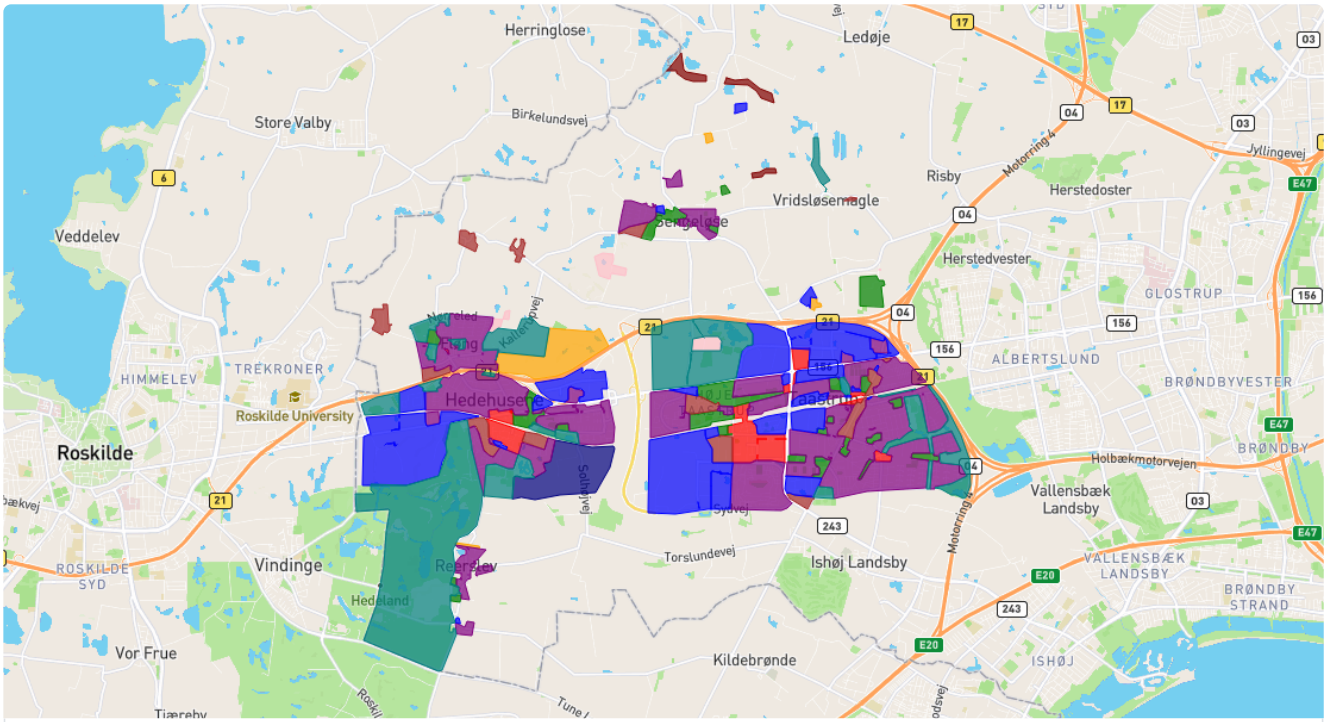
The population of Høje-Taastrup has been slightly increasing, namely by 6.3%, from 47,753 inhabitants in 2011 to 50,759 in 2020. There were a total of 21,645 households in 2020. Due to urban development measures, the population is expected to further increase to about 60,000 - 65,000 inhabitants in the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

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


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

Data source

Land use



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

Data source

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

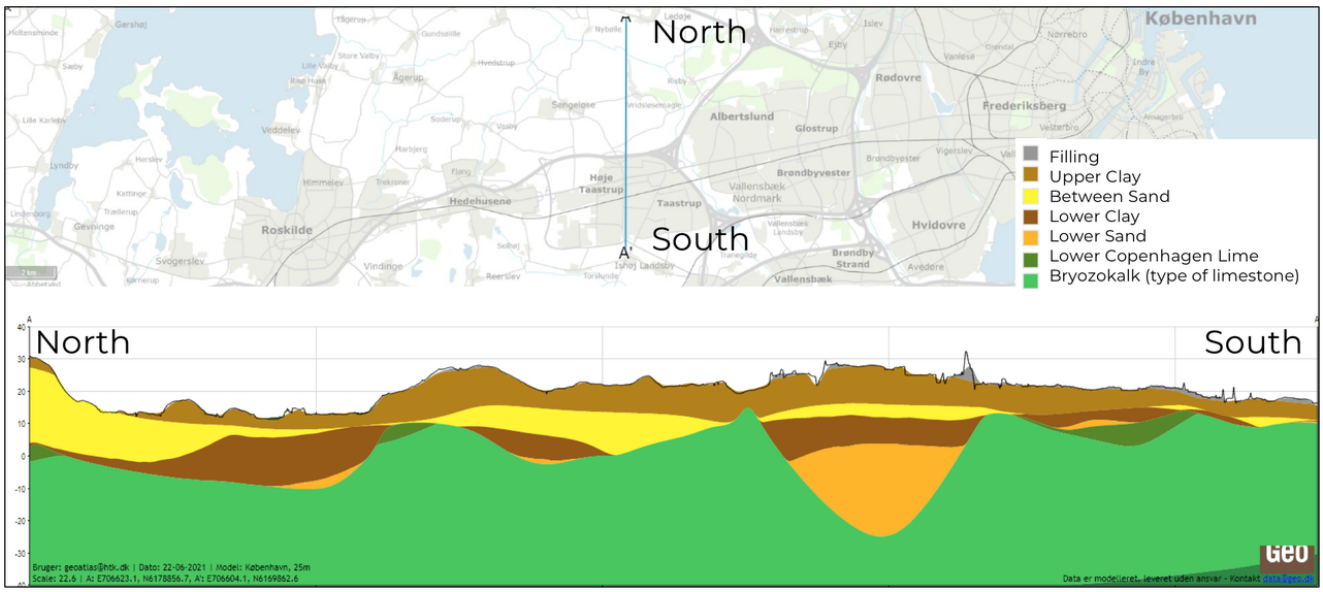
The land use map of Høje-Taastrup shows 10 different types of land use. It needs to be noted that those are the ones represented in the municipal planning framework of 2014, which do not account for the entire area of the municipality (78 km2), but for 45% of it (34.9 km2). These land uses include general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

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

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

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

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



Data source

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

Economic context of construction sector

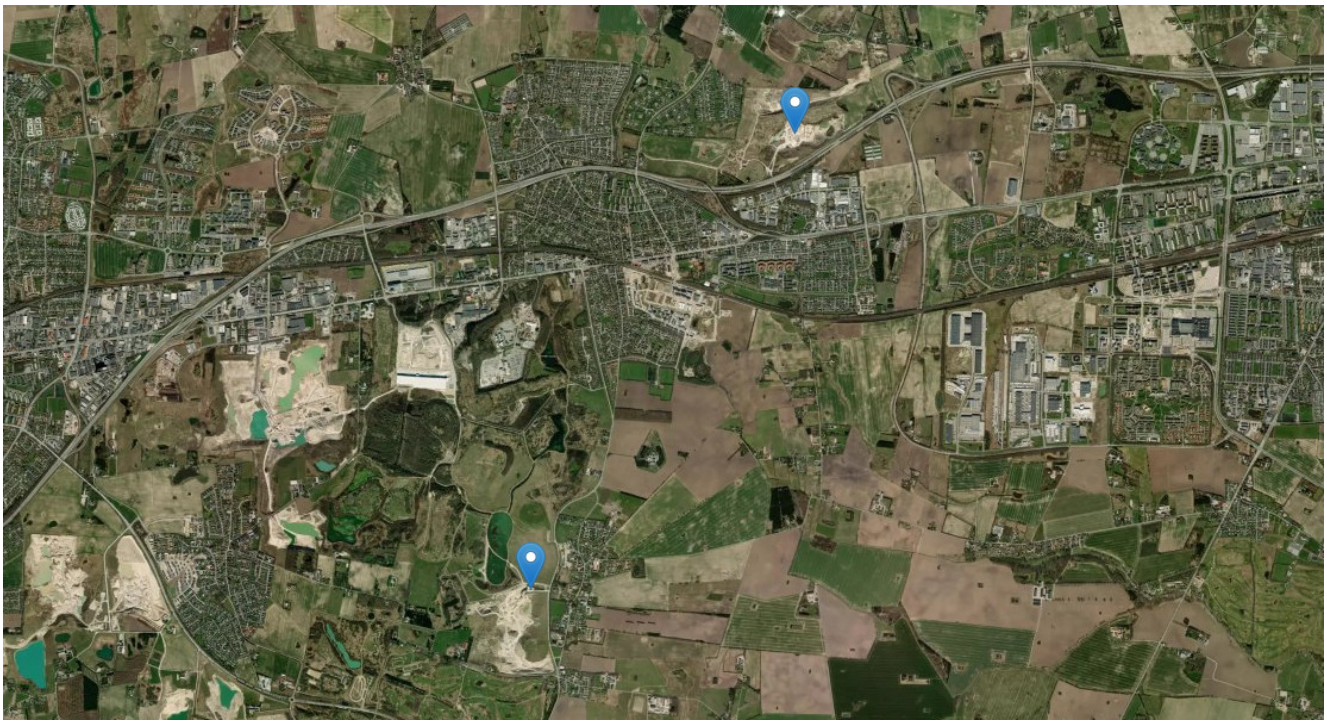
This section puts into perspective the economic context of the sector under study. It describes how many people are employed in this sector, as well as who the main actors involved (from all lifecycle stages for the sector's materials) are.

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

The construction sector in Høje-Taastrup

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

The actors of the construction sector



Data source

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

Extraction

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

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

Manufacturing

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

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

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

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

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

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

Retail

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

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

Use

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

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

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

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

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

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

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

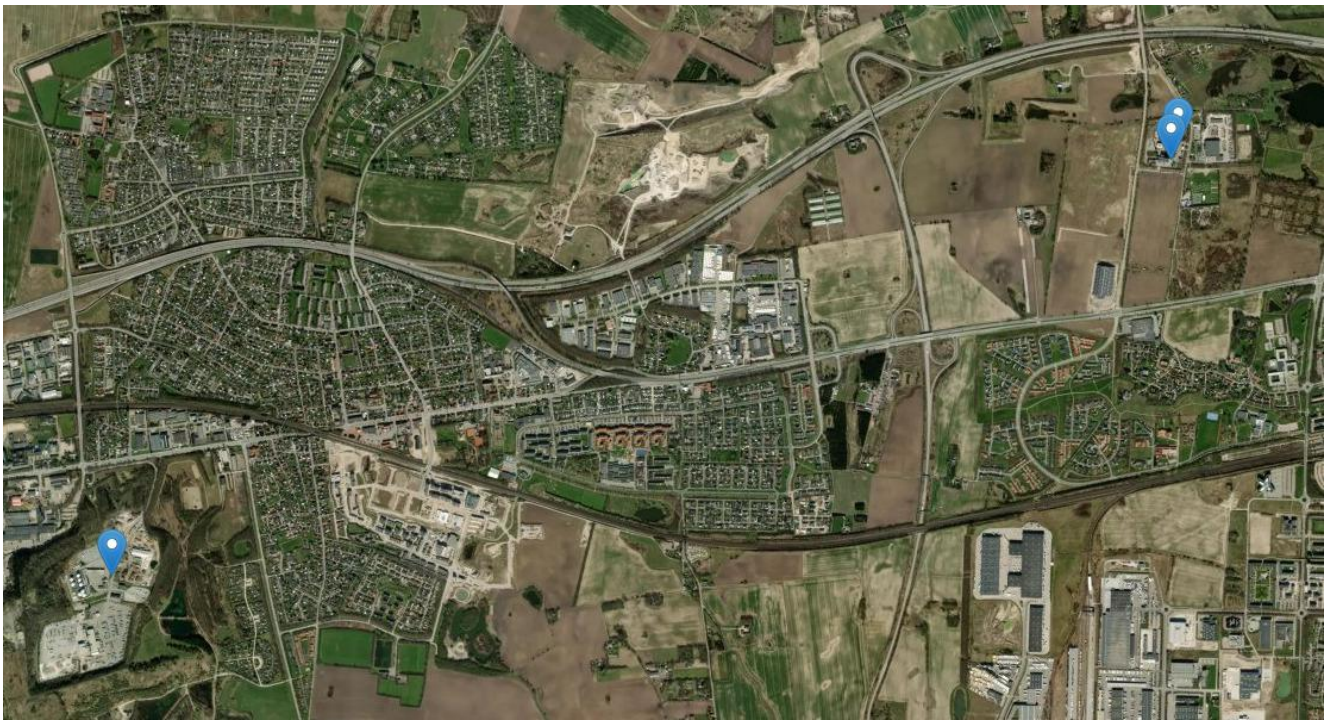
As for joinery installation, Deko P/S is a big employer with 214 employees. The company works on the design, production and installation of partitions of glass, wood, and aluminium. However, it seems that the production site is not actually in Taastrup, but that the location serves as office and storage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

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

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

Waste collection and treatment

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



Data source

As for the waste actors, two main ones with three facilities exist, as can be seen on the map just above. Dansk Miljøforbedring and Vestforbrænding are both waste collection facilities. Dansk Miljøforbedring primarily handles construction waste from large construction projects. The recycling station (Genbrugsstationen) is operated by Høje-Taastrup municipality in collaboration with I / S Vestforbrænding and is geared towards local inhabitants, businesses and smaller constructors doing minor renovations. (Companies can deliver a maximum of 200 kg per year.) At

the Vestforbrænding site, 30 different types of waste are collected for recycling and some waste also gets incinerated. Smaller amounts can more easily be collected there. For example, citizens can dispose of up to ten roofing sheets without declaring it at www.bygningsaffald.dk, the national notification form for construction waste. (It should be noted that this website is an optional portal for notification of construction and demolition waste, operated by a consultancy company. There are other systems for notifications of construction and demolition waste, but Høje-Taastrup employs that one.)

Indicators

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

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

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

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

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

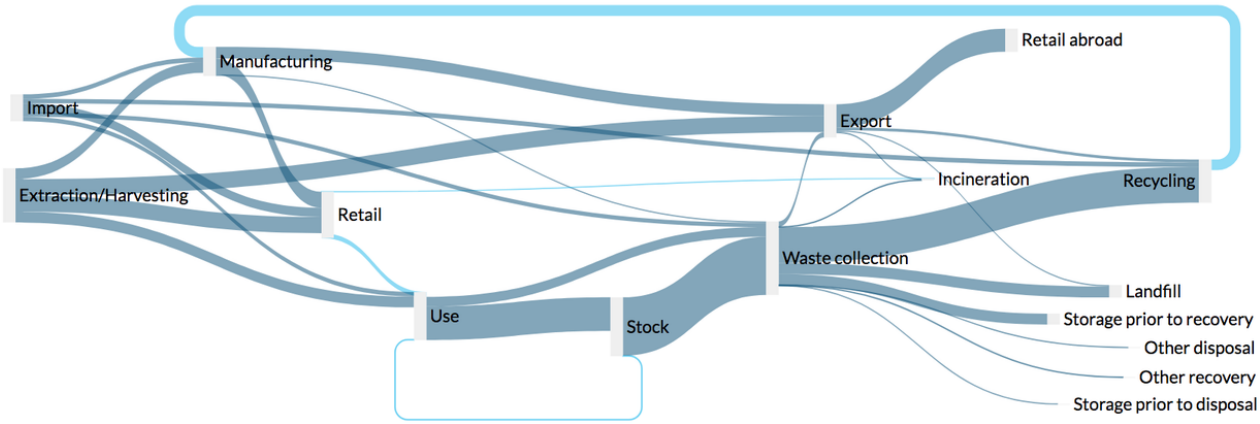
The EOL recycling and processing rates are still considerably low with about 15% and 23% respectively. While 19% of materials are still subjected to disposal and 81% to recovery, the efficiency of recovery could still be improved. There is however uncertainty in those values, as the amounts derived from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

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

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

Visualisations

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



Data source

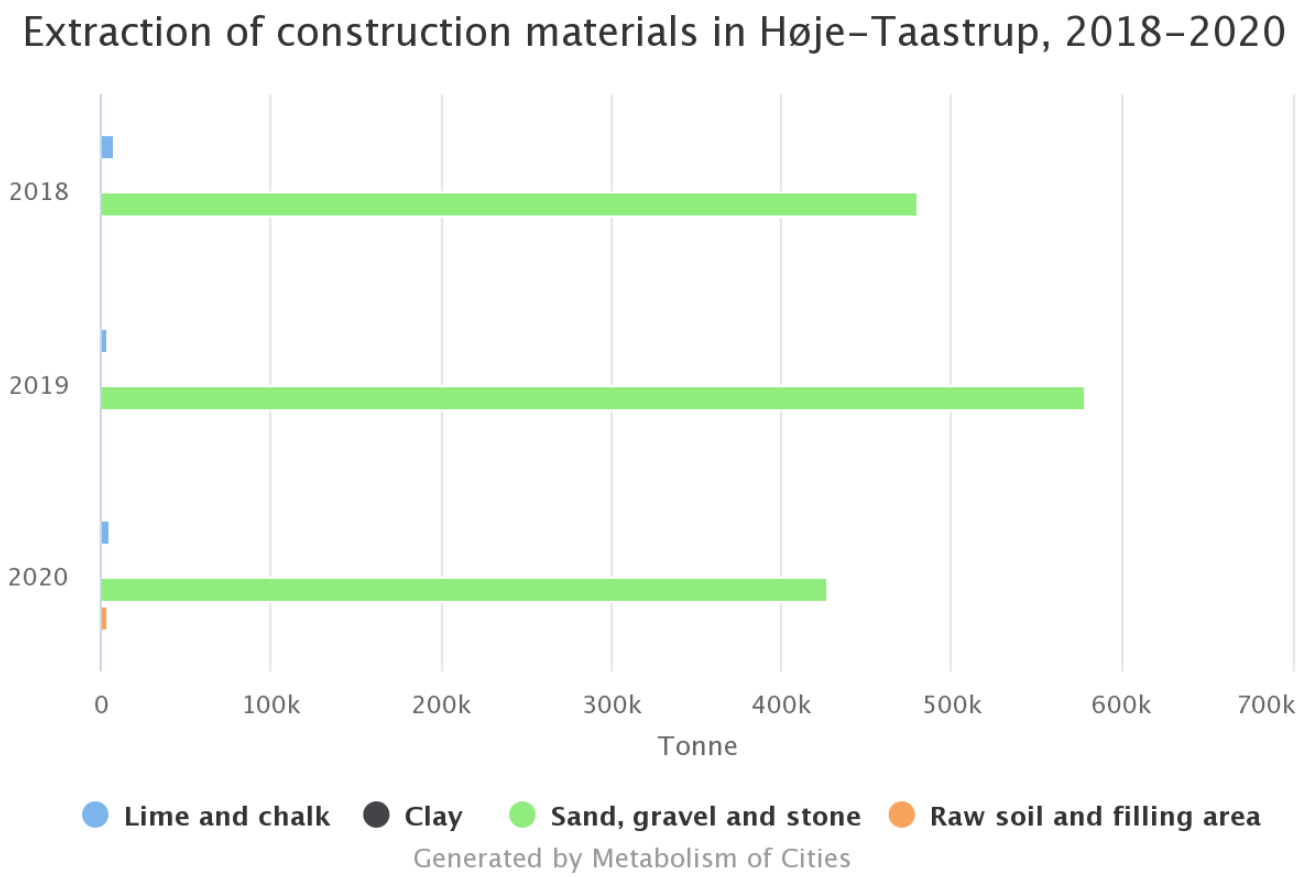
The Sankey diagram builds of course on the collected data that also the indicators have been derived from. Therefore, it needs to be taken into account that the previously discussed data quality influences also the quality and informative value of the Sankey diagram. In addition to the data quality,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

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

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

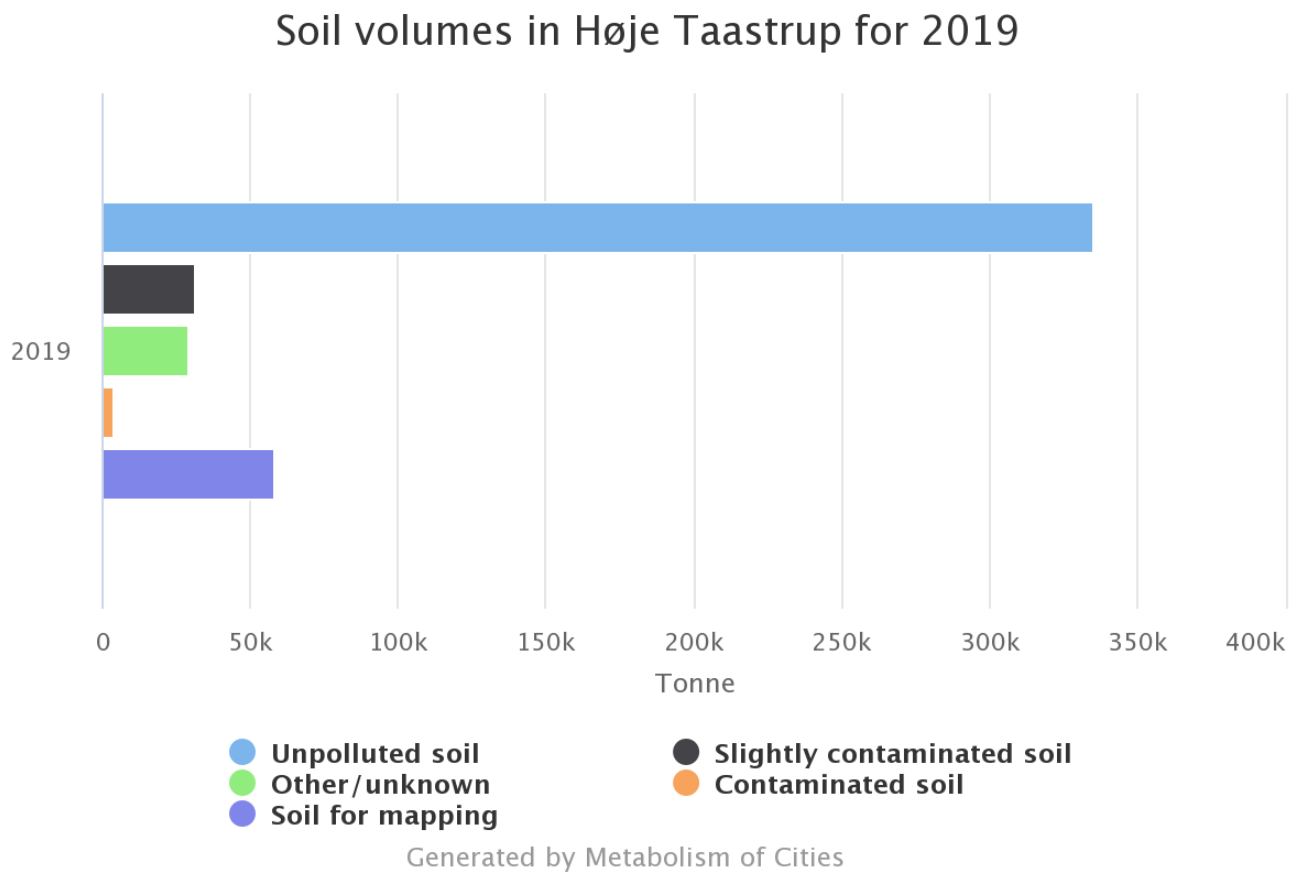
It can also be seen that a lot of the extracted materials get exported to retail outside of the municipality.

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



Data source

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



Data source

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

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

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

While the **waste collection** node does receive most materials from the stock, it also gets inflows from imports, manufacturing and use. The diagram shows that the main share of materials leaves to **recycling**, which is also fed by imports and which has a large outflow as return flow to

manufacturing. As for the other waste treatment options, **landfill** is quite high and very similar in size to **storage of materials for recycling**. Finally, a significant stream is from **export** to **retail abroad**.

Data quality assessment

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

Data quality

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

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

Data quality matrix

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

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

Data gaps and assumptions

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

Extraction

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

Manufacturing

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

Retail

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

Use

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

Stock

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

Waste collection and treatment

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

Imports and Exports

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

To summarise overall, the data gaps stemmed from:

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

These barriers gave valuable insights into the nature and availability of data surrounding the construction sector. It became clear to the municipality that they are not the correct actor to perform a SCA based on the skill-sets and data that are available to a municipality. It is clear that Høje-Taastrup is too small on a Danish scale to make a representative Sankey diagram, and that

examining things on a regional or national level would provide much more meaningful, accurate and rich information. Since the municipality is so relatively small, most flows are in and out of the municipality and very few are contained within municipal borders.

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

Data analysis

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

Insights on status quo of the construction sector

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References

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