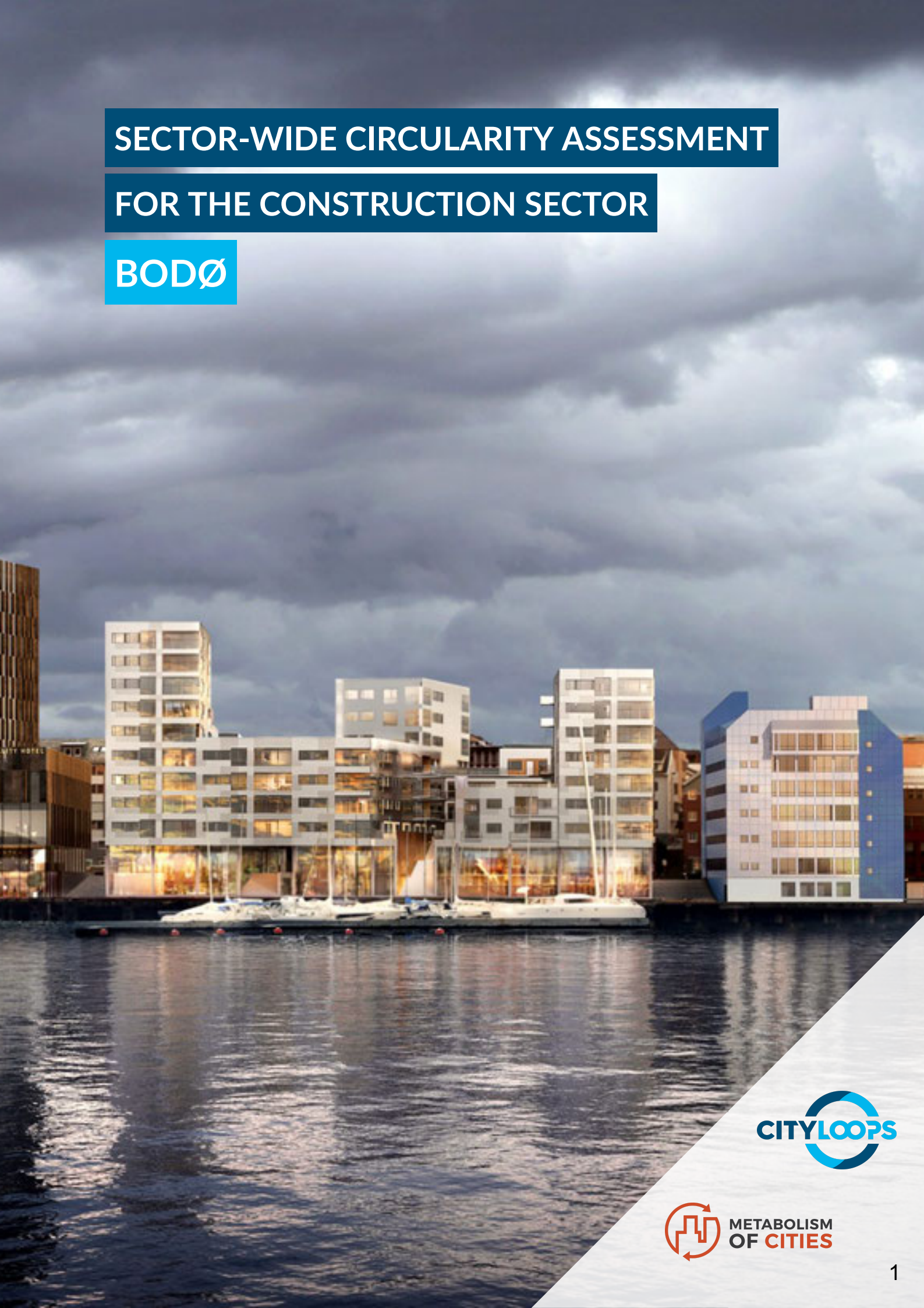
SECTOR-WIDE CIRCULARITY ASSESSMENT FOR THE CONSTRUCTION SECTOR

BODØ



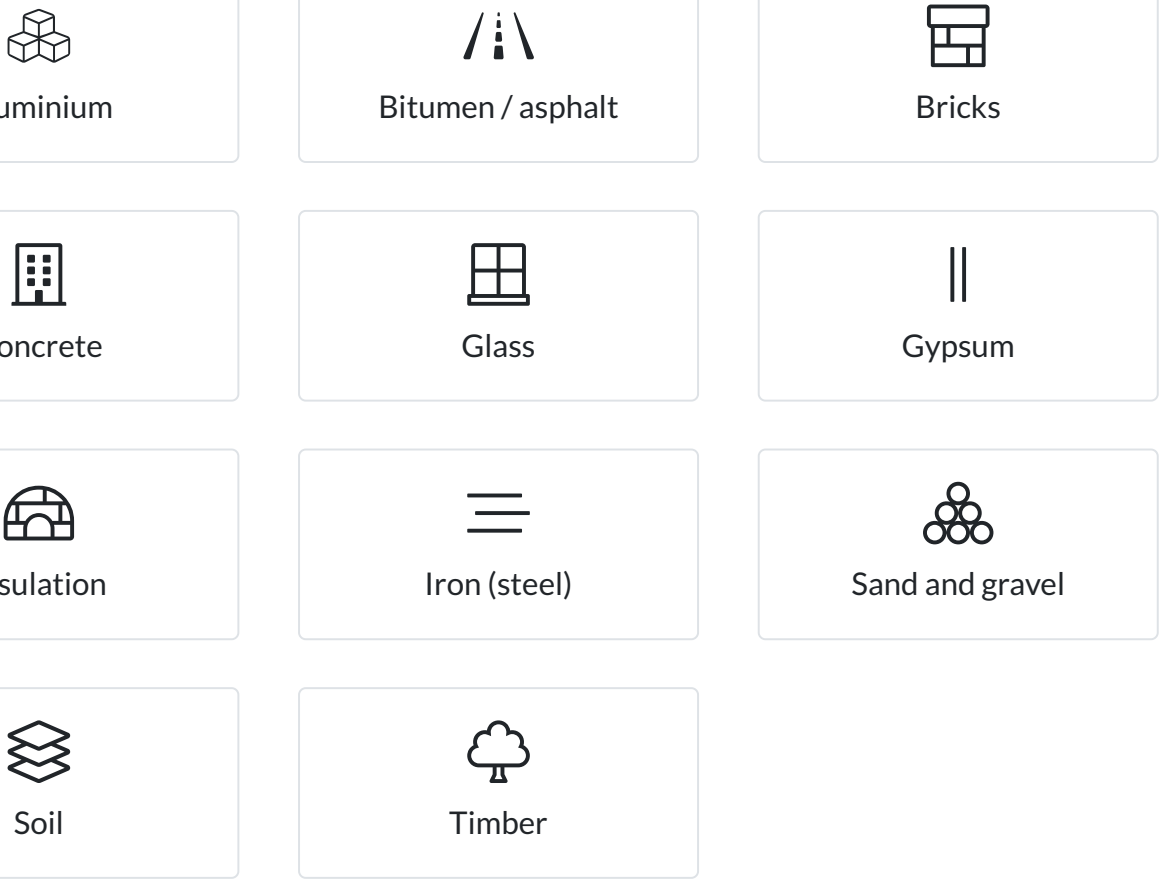
CITYLOOPS

METABOLISM OF CITIES

Introduction

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

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



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

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

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

Urban context

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

Bodø

52,560

1,395 km^2

Nordland

240,559

38,155 km^2

Nord-Norge

482,839

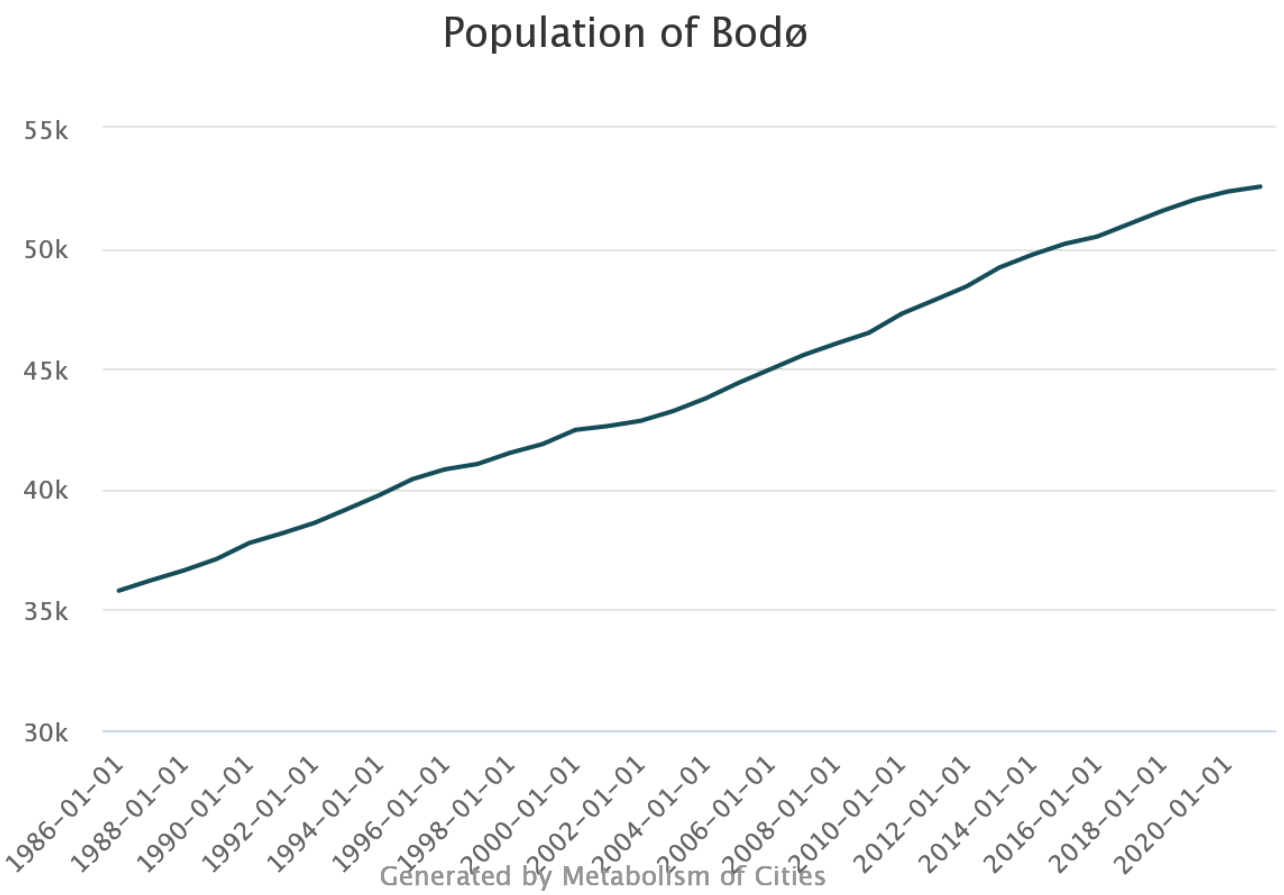
112,975 km^2

Norway

5,398,804

385,207 km^2

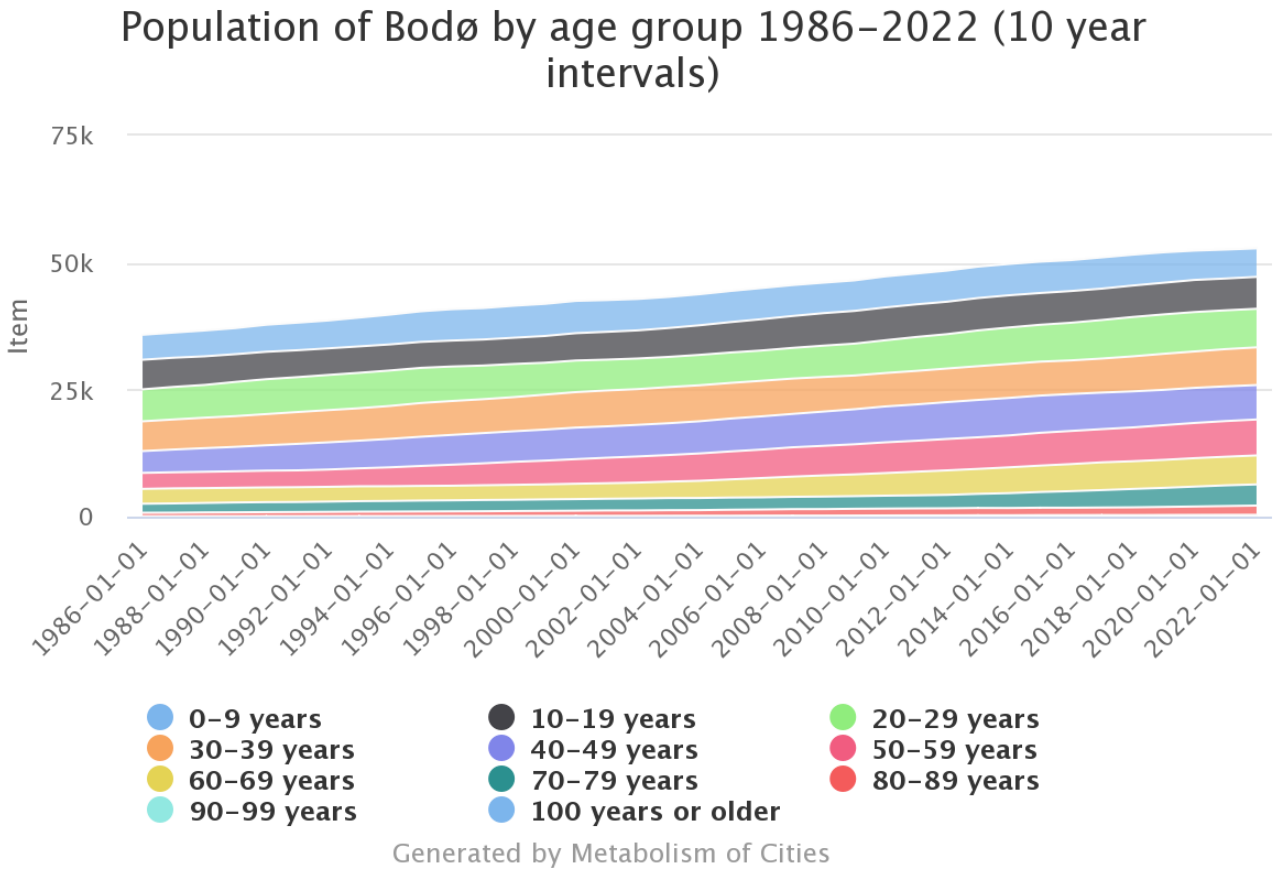
Population of Bodø



Data source

The population of Bodø was 52,560 in 2021. Over the last 35 years, it has been increasing significantly, namely by 46.8%, where there were only 35,792 inhabitants in 1986. On average, the municipality grew by 471 people each year over the last 10 years. The population density is quite low with 40 inhabitants per km² of land area in 2020.

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



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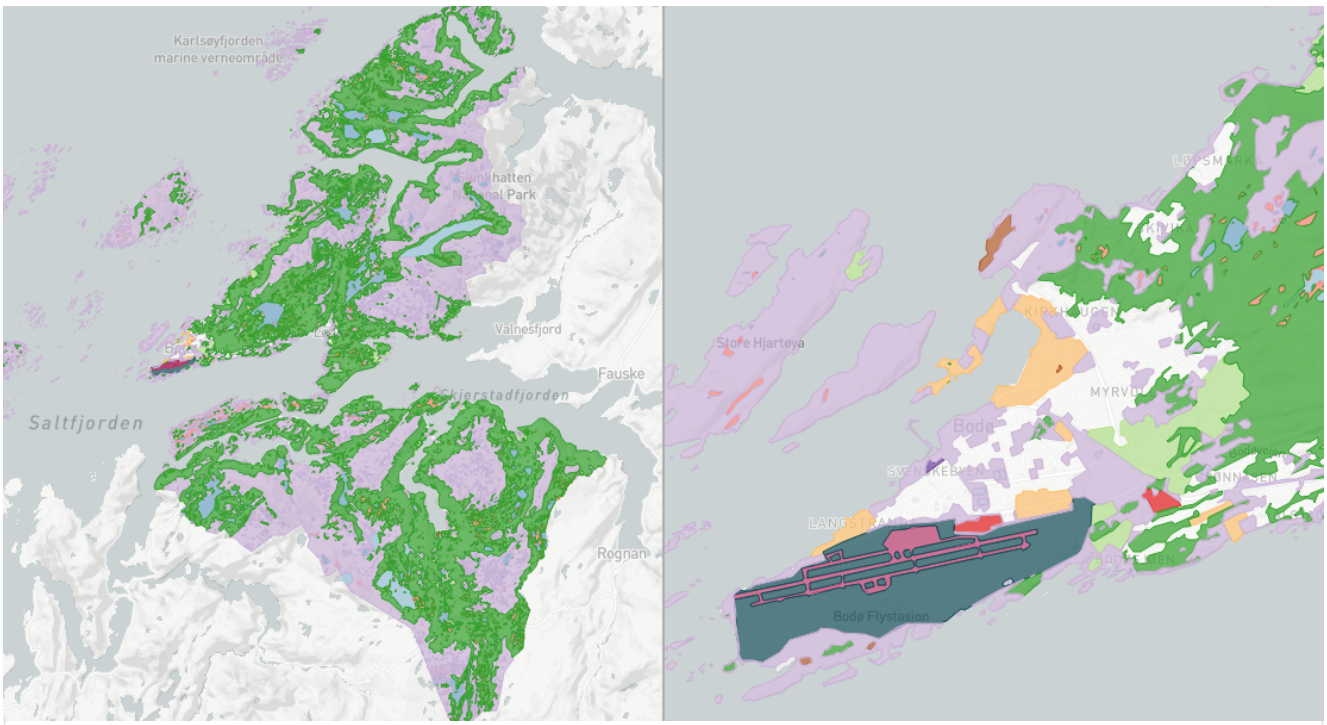
Land use



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

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

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

Economic context of construction sector

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

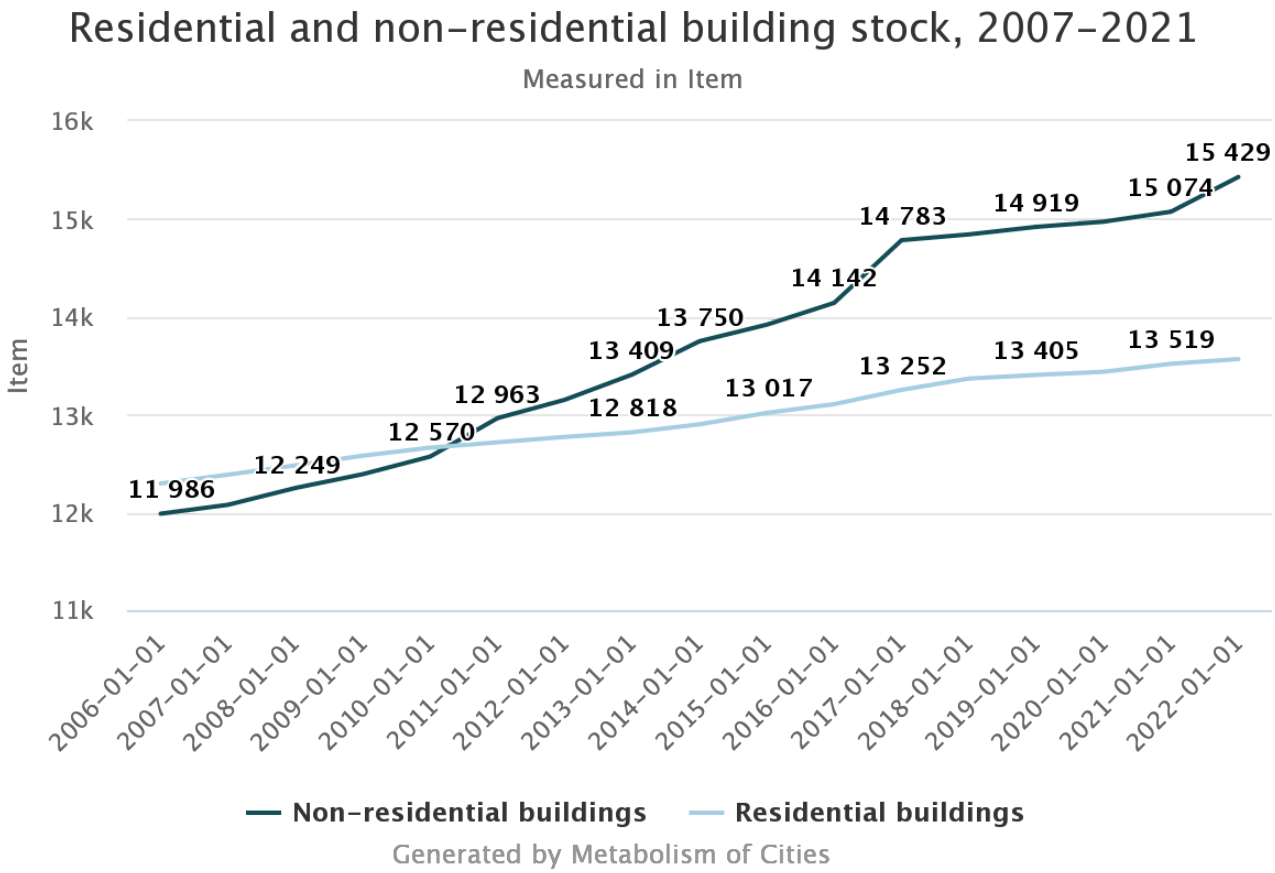
	Turnover (monetary value, in kr)	Employees
Bodø	8,154,000	2,249
Nordland	161,592,100,000	10,508
Nord-Norge	327,060,000,000	104,918
Norway	626,851,800,000	260,560

The construction sector in Bodø

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

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

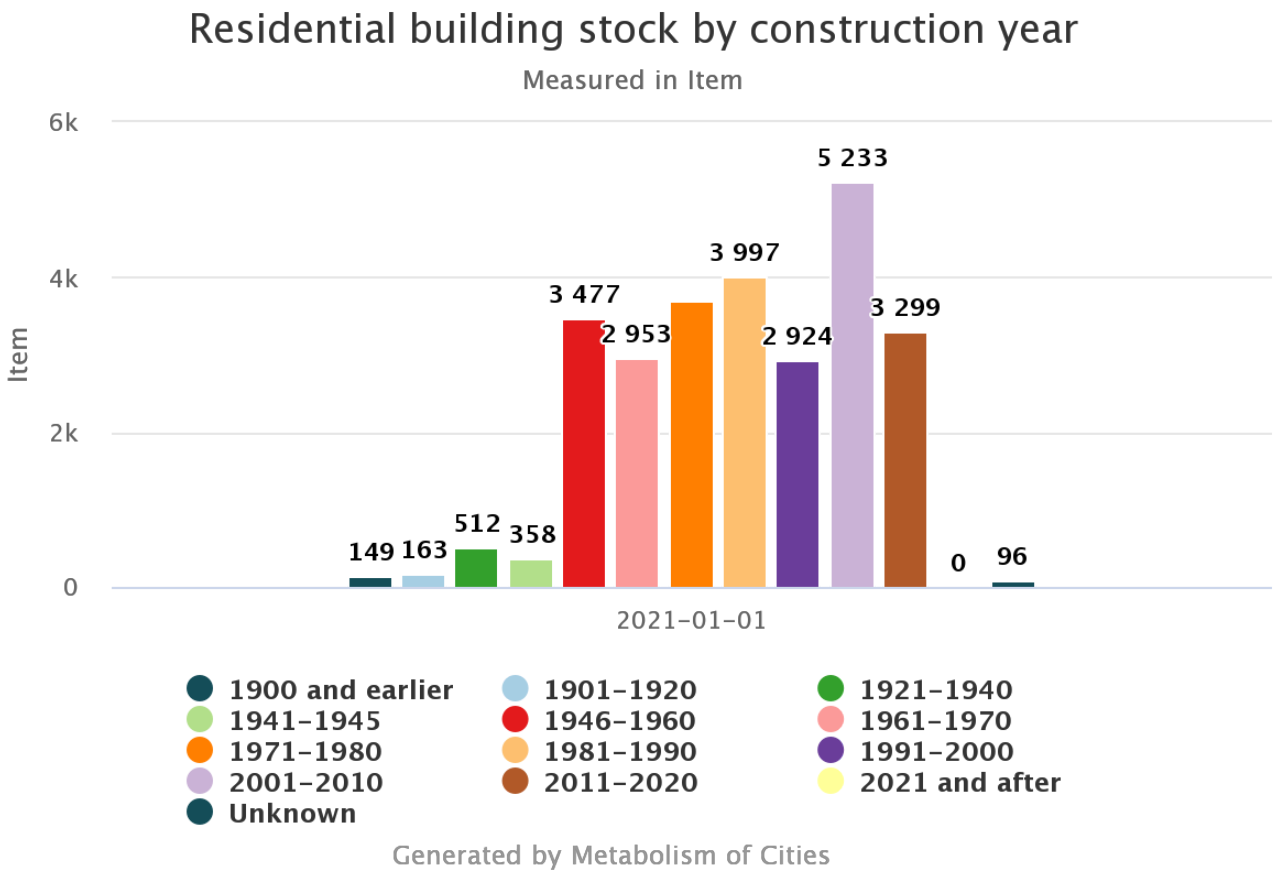
In Bodø, the building stock is fairly equally distributed between residential and non-residential buildings. 47% of the buildings are residential (source), of which 4% are municipally managed housing (source) and remaining 43% are private housing. 53% of buildings are non-residential (source). As is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



Data source

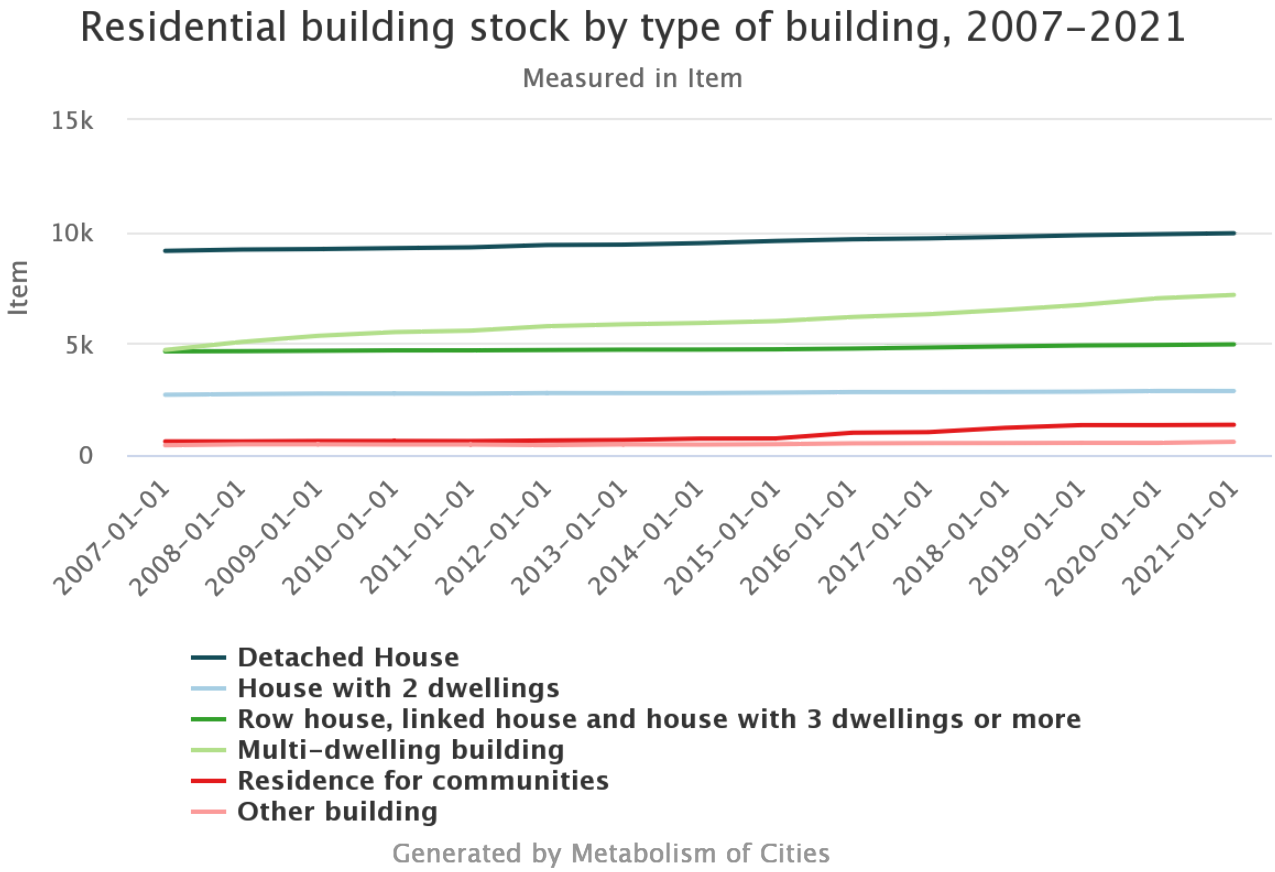
The 13,519 residential buildings comprise 26,861 dwellings. These dwellings can be further categorised by the year of construction and into six different housing typologies. The graphic here shows the number of buildings that were built in different groups of years, counting in decades from 1961 onwards.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

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



Data source

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



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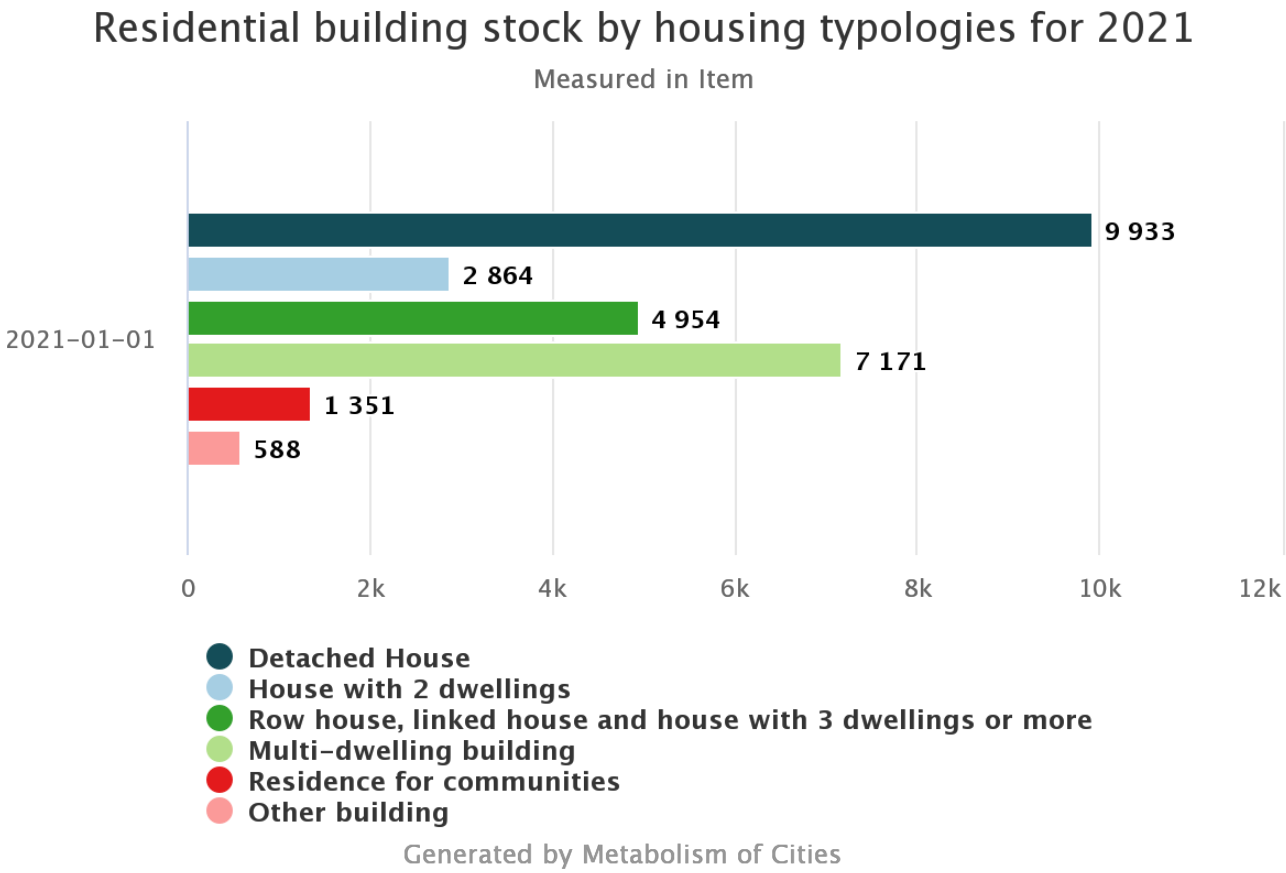
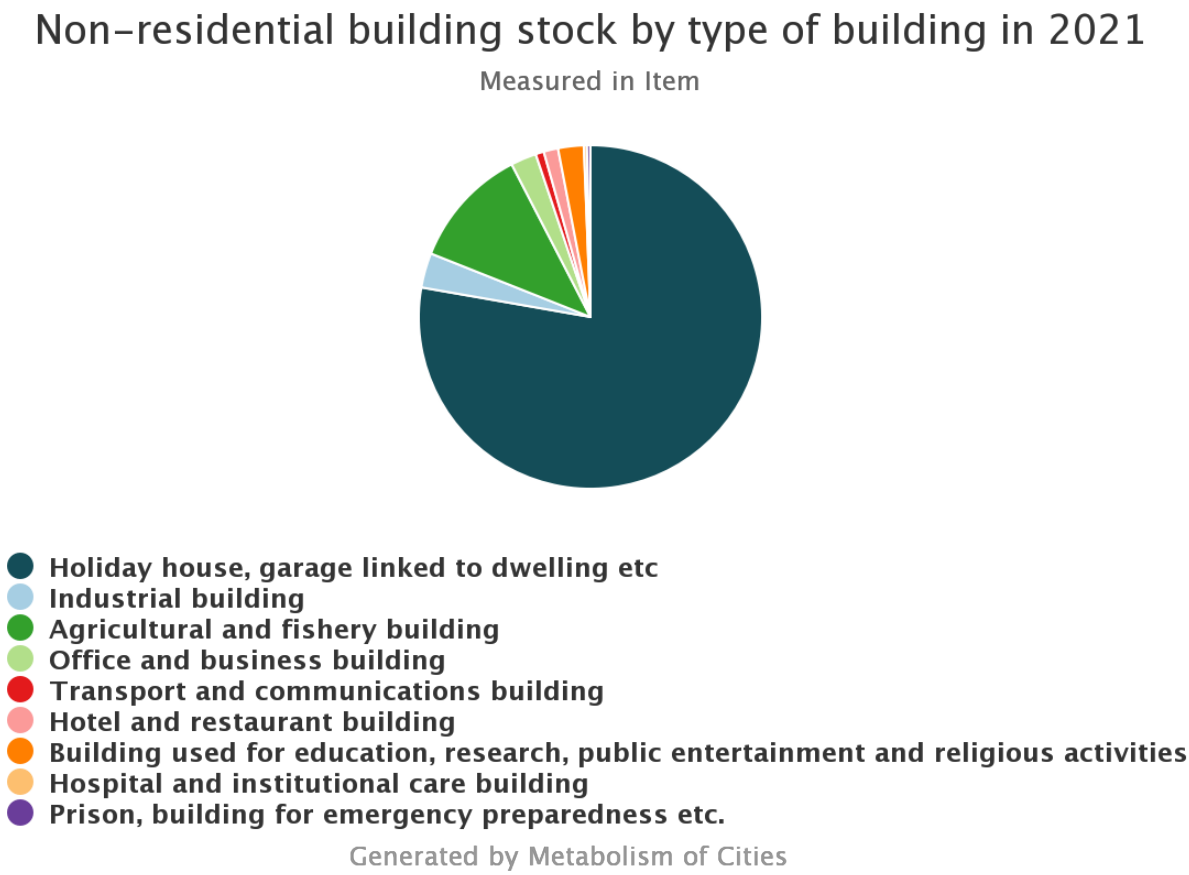


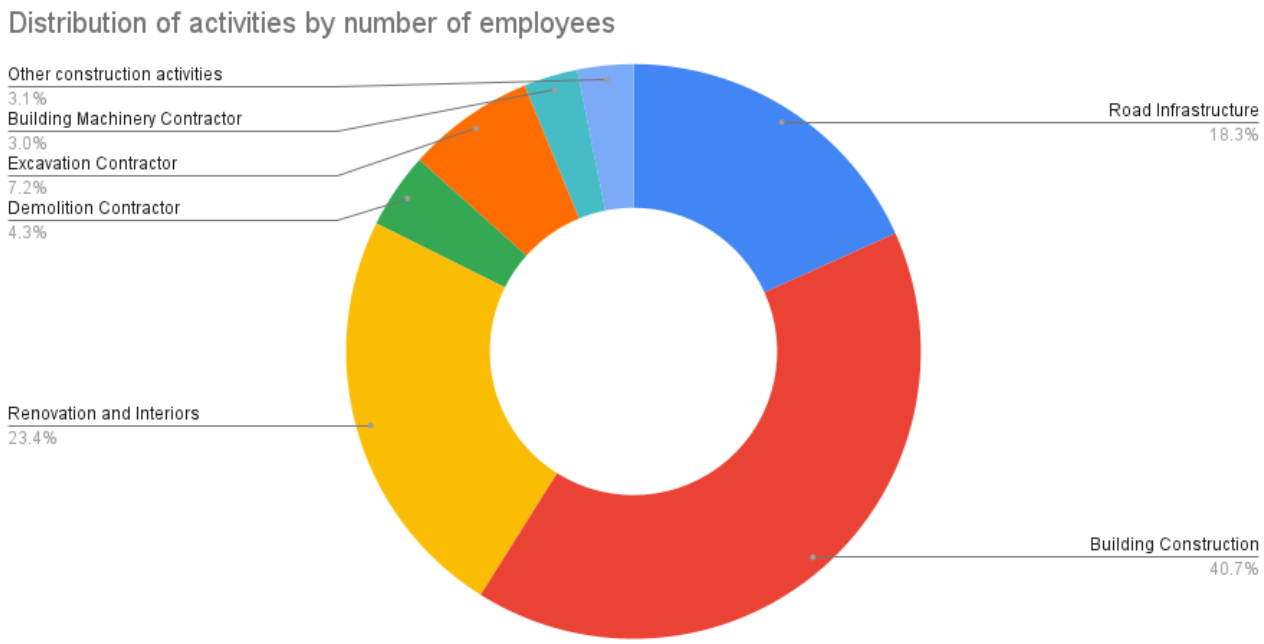
Data source

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



Data source

The actors of the construction sector



Data source

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

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

Extraction

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

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

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

Data source

Manufacturing

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

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

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

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

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

Retail

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

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

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

Use

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

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

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

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

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

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

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

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

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

Waste collection and treatment

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

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

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

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

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

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

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

Data source

Indicators

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

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

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

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

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

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

EU self-sufficiency for raw materials measures how independent a city is from importing raw materials from the rest of the world. Bodø's self-sufficiency indicator is very low with 0.91%. Unfortunately, there is no national value to compare it to. And since the data completeness was

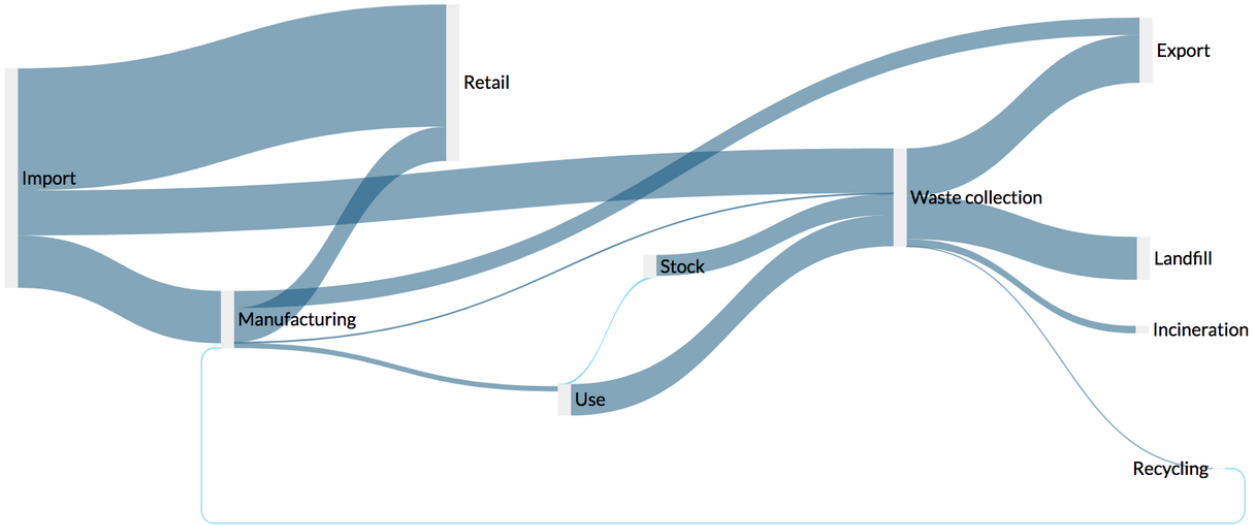
lacking in terms of differentiation of the single materials, this indicator couldn't be calculated for them individually to determine the various self-sufficiency levels.

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

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

Visualisations

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



Data source

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

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

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

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

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

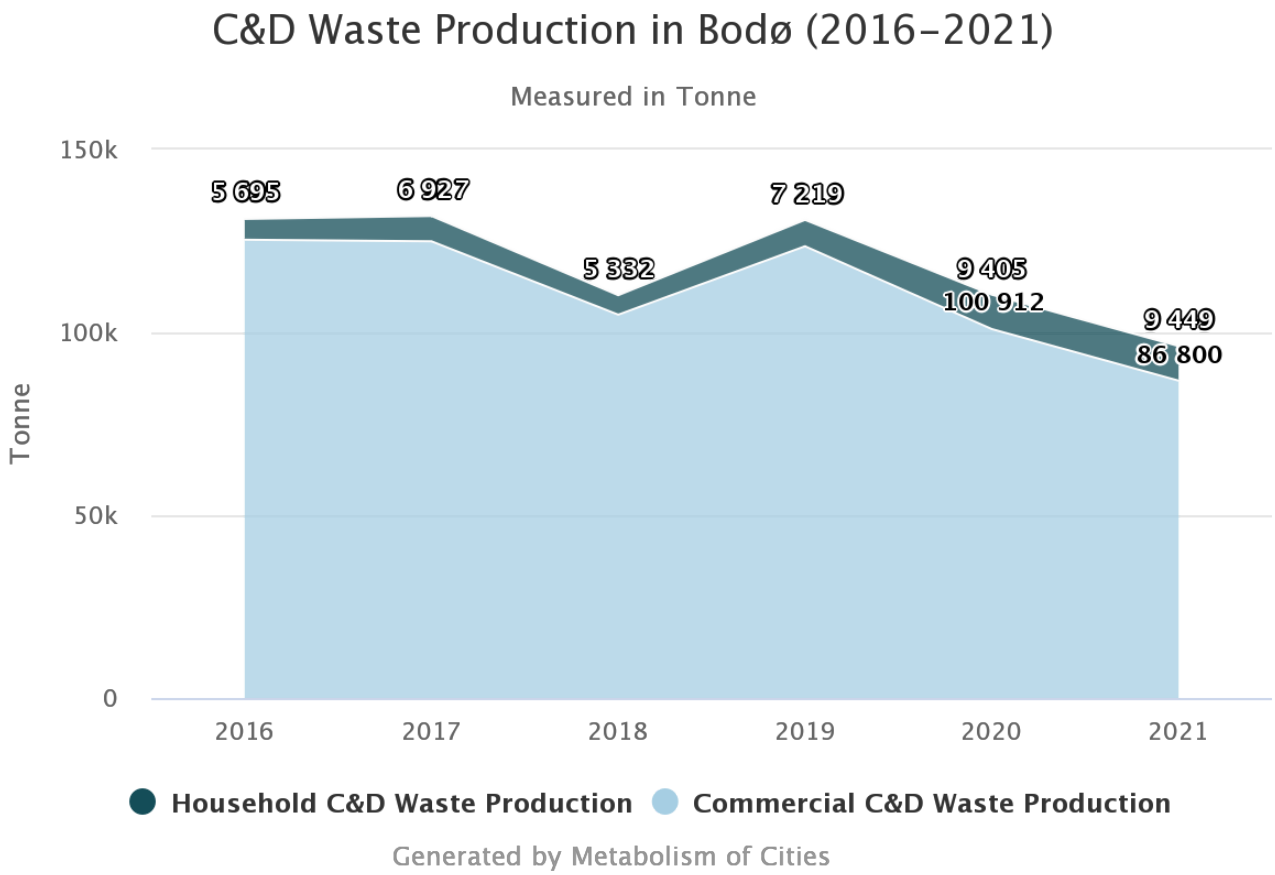
With regards to **retail** in Bodø, it was estimated that 22% of the materials came from local manufacturing, while the remaining 78% were imported from outside of the municipality.

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

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

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

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



Data source

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

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

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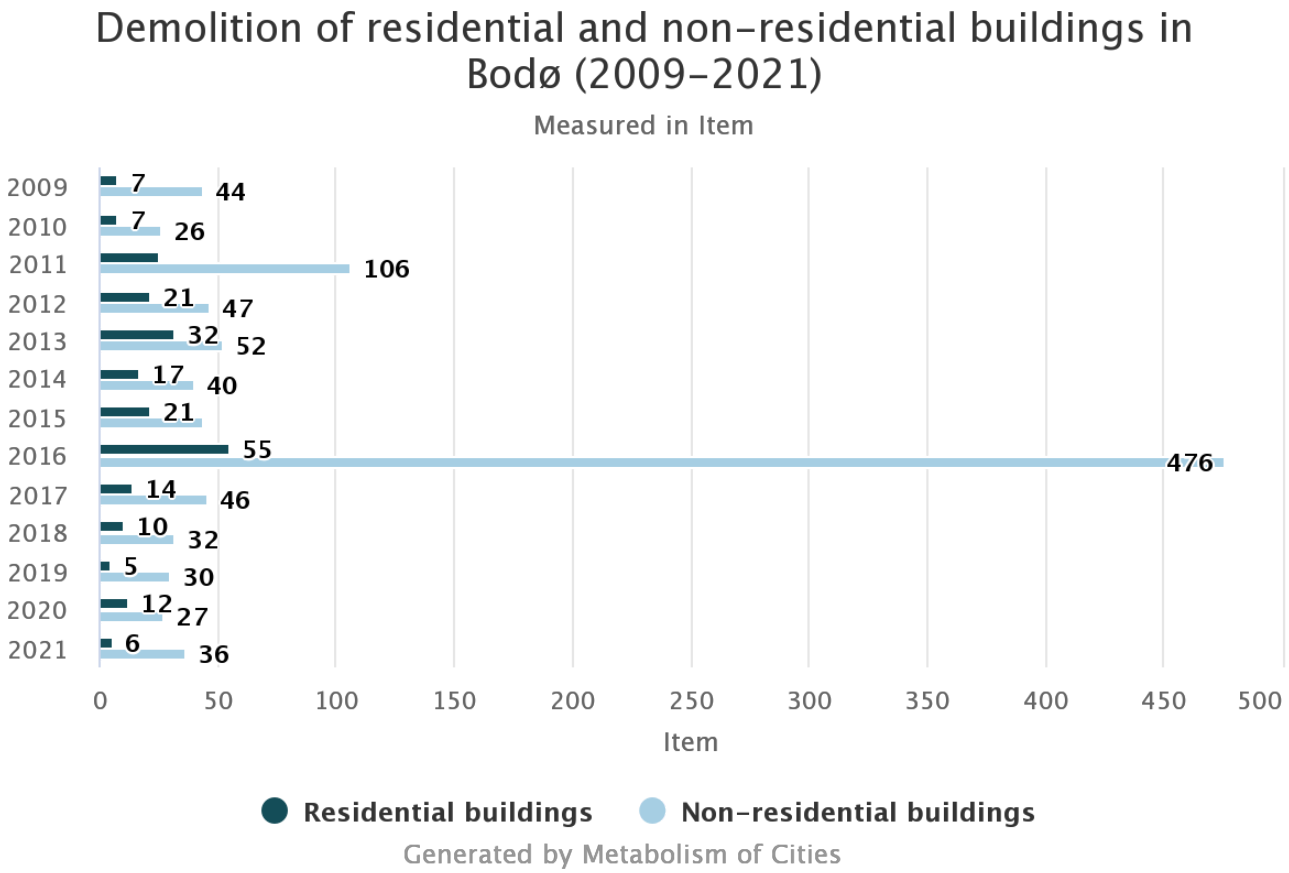
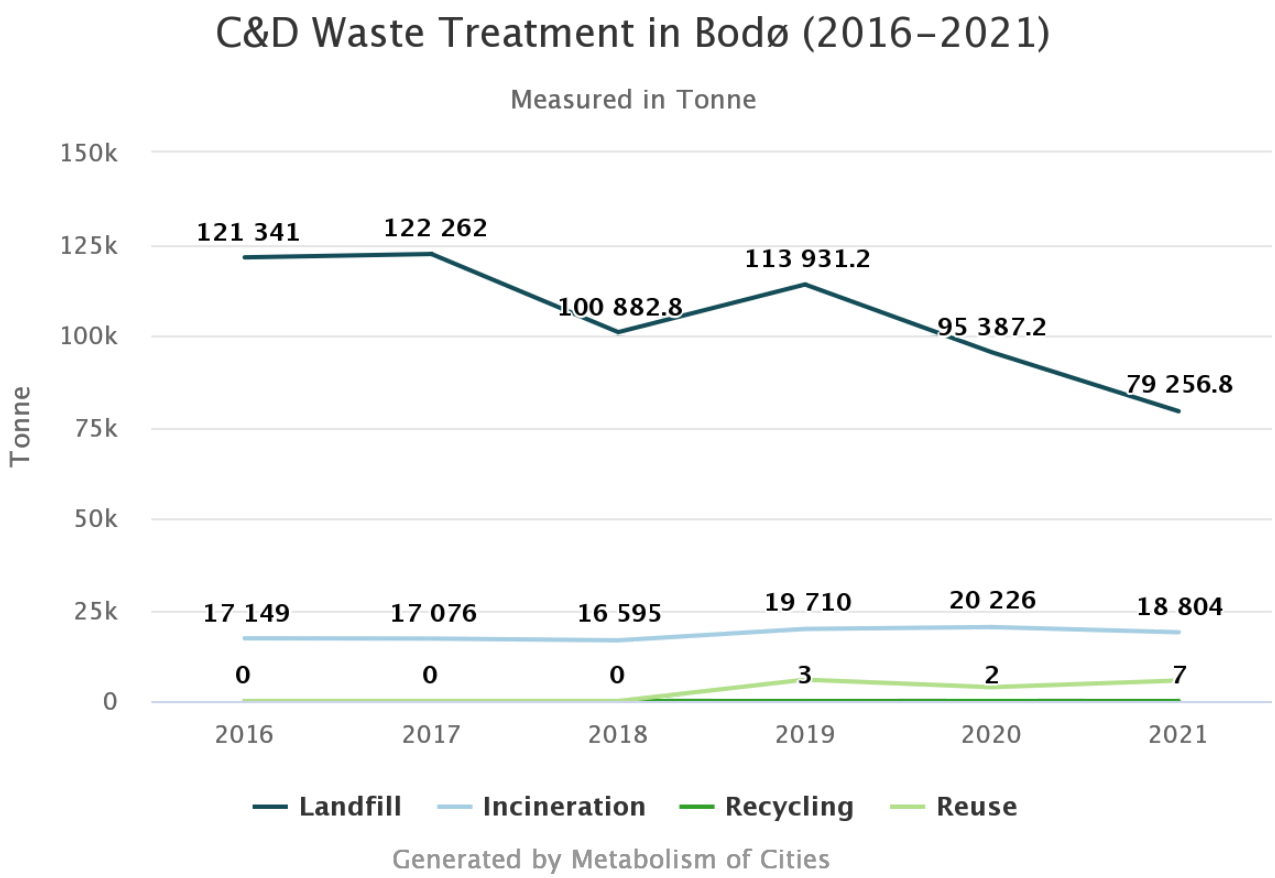


Data source

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

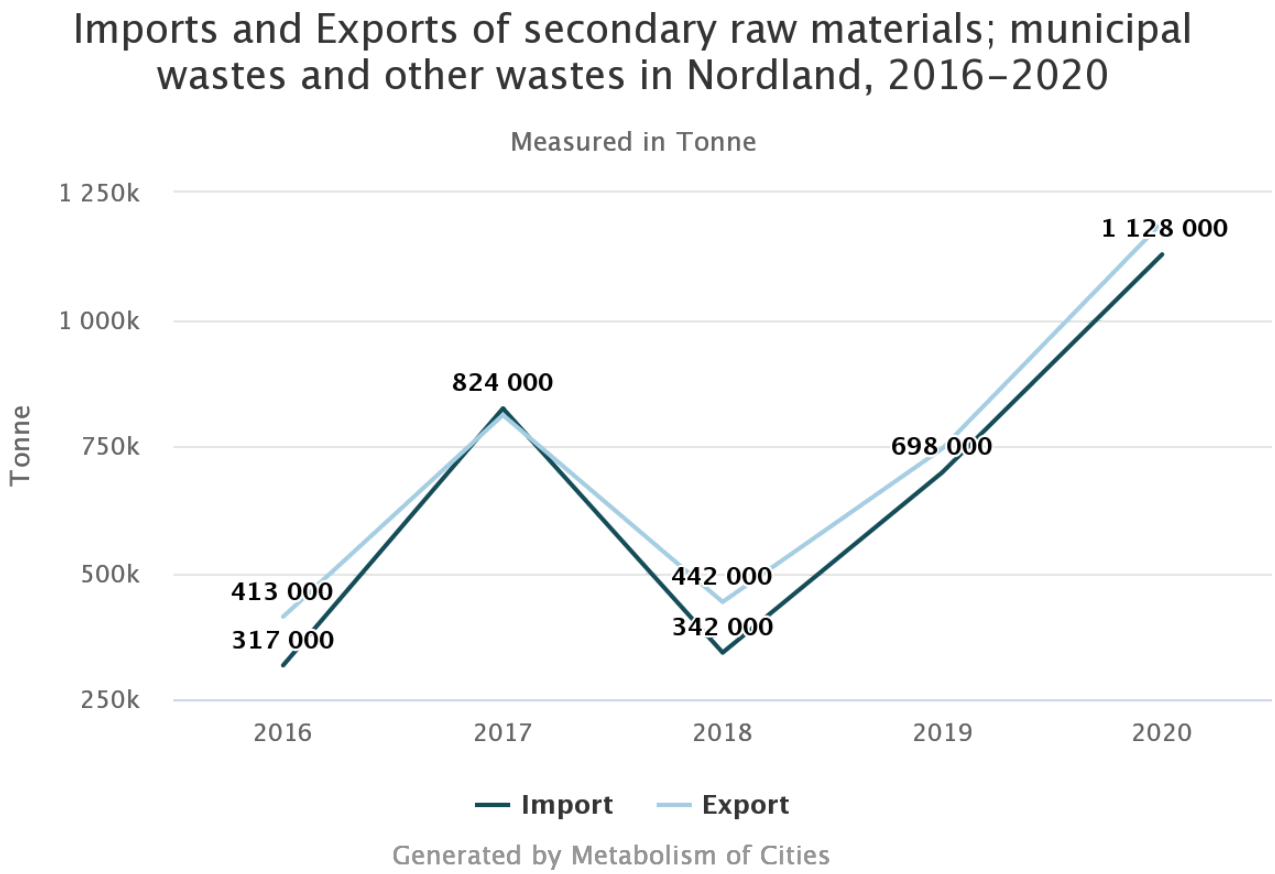


Data source

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

regarding the CDW treatment of concrete, there are three pathways. If the concrete is lightly contaminated, it is crushed, sorted, and resold and if the concrete is uncontaminated, it is resold for reuse directly to other construction sites. In the case that the concrete is heavily contaminated, it is also sent to landfill.

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



Data source

Data quality assessment

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

Data quality

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

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

Data quality matrix

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

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

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

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

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

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

Data gaps and assumptions

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

Extraction

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

Manufacturing

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

Retail

In the case of retail, the data gap could not be closed. While the value could be derived by subtracting exports from production, the data quality of both of those parts is already quite poor overall that deriving a number through calculation of them would not have produced any valuable

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

Use

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

Stock

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

Data

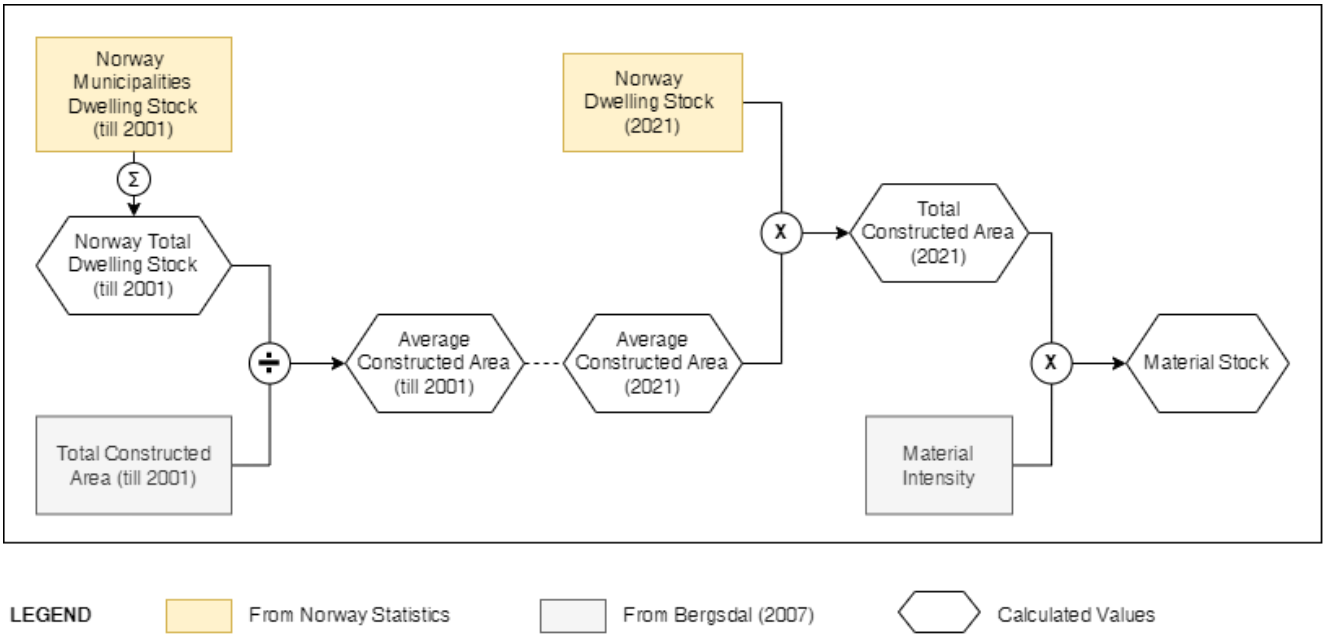
For the calculation of the building stock, two data sources were mainly used, namely, the StatBank data from Statistics Norway and a research paper by Bergsdal et al. (2007) titled 'Dynamic material flow analysis for Norway's dwelling stock'.

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

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

Methodology

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



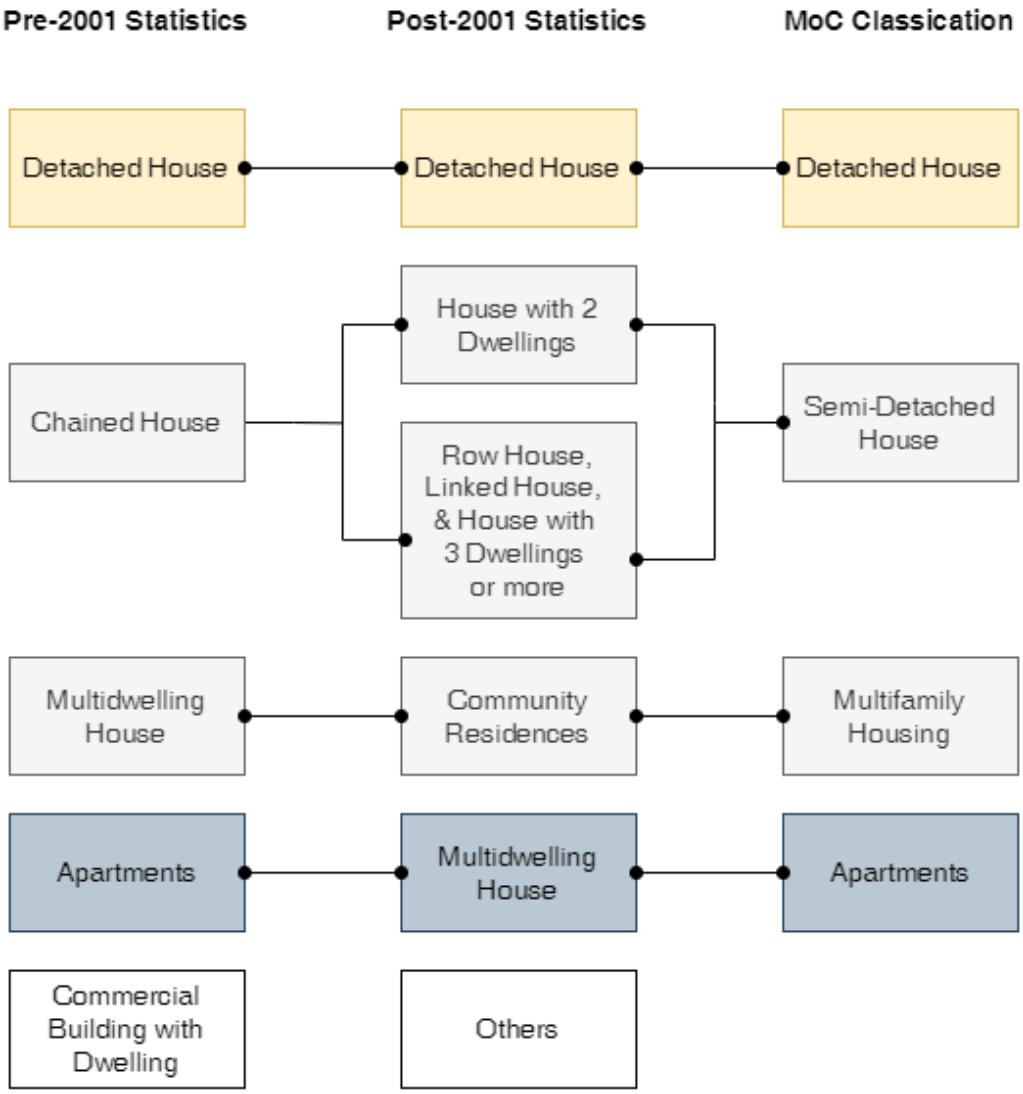
Data Source

Step 1: Cleaning up the data

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

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

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



Data Source

Step 2: Calculating the Multiplier

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

Step 3: Adjusting the Tables

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

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

Step 5: Calculating Material Stocks

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

Waste collection and treatment

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

Imports and Exports

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

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

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

Data analysis

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

Insights on status quo of the construction sector

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

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

Connection to and upscaling of demonstration actions

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

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

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

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

- **DA 3**: DA 3 is the final stage of embedding **circular strategies into the planning** of the new city district.

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

Recommendations for making the construction sector more circular

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

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

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

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

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

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

References

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