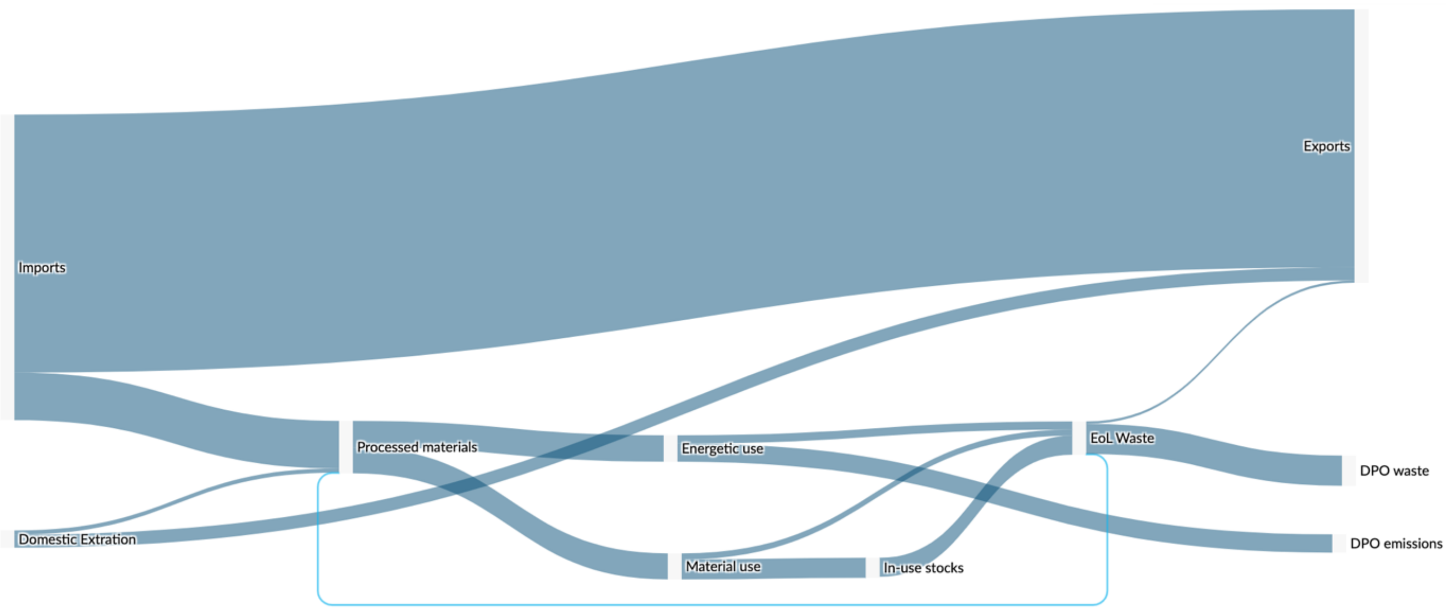
URBAN CIRCULARITY ASSESSMENT APELDOORN

Deliverable 7.5

Metabolism of Cities



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Abstract	This report on the Urban Circularity Assessment for Apeldoorn presents the gathered information and main findings on the material flows of the local economy for 2014 and 2018, as well as the building stock accounting. It provides contextual information of the city and the local economy under study and then illustrates the quantities of flows in the single parts of the supply chain, summarised by a Sankey diagram, followed by a map of the material stock. Both of the accounted materials are evaluated in the form of circularity indicators and their data quality. Finally, the results are analysed and interpreted to determine a status quo, taking into account limitations of the data used, before recommendations are offered on how to achieve greater material circularity in the municipality of Apeldoorn.
Keywords	Urban circularity assessment; Material flow accounting; Building stock; Circularity indicators; Urban metabolism; Circular city;
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Summary

The Urban Circularity Assessment (UCA) was carried out for the municipality of Apeldoorn in 2022 for the years 2014 and 2018. The Dutch municipality, located in the province of Gelderland has a population of 166,306 people that are spread over an area of 341.15 km2. Its local economy is mainly based on “Health and Welfare care” (17.8%), “Trade” (14.5%) and “Public Administration, and Government services” (12.7%) economic activities in terms of employees.

By applying the developed method, it is possible to illustrate that Apeldoorn is a linear and carbon-rich city (90-95% linear), processing yearly approximately 650 kt of materials, adding 13 kt in the building stock and reinjecting just 4 kt of secondary materials in their economy. From these numbers, the magnitude of the efforts becomes visible. In addition, the “weight” of Apeldoorn can be illustrated through its building stock which amounts to 15,000 kt (or 95 t per capita), which requires continuous flows for both its operation and construction.

Given the land use of Apeldoorn (78% covered by vegetation), this provides a considerable opportunity to develop a circular bioeconomy. For instance, a significant share of biomass demands of Apeldoorn could be covered by local production of food. In addition, a part of this biomass could be used for energetic use, reducing the demand of imports and partly GHG emissions.

Numerous datasets were collected and processed for the UCA, which are nested in several spreadsheets that are connected with each other. People with an interest in understanding the data or replicating the process are encouraged to reach out to Metabolism of Cities (info@metabolismofcities.org). It is also suggested to browse the online version of the UCA report where charts, Sankey diagram and the material stock map can be interacted with: https://cityloops.metabolismofcities.org/city/apeldoorn/uca-report/

1. Introduction

The EU Horizon 2020 funded CityLoops project focuses on closing the material loops of cities in terms of material flows, societal needs and employment. Cities, depending on their magnitude and types of economic activities, possess considerable opportunities and various levers to transform their metabolism and economy towards a more environmentally sustainable and circular state.

Within this project, seven European cities, amongst those also the city of Apeldoorn are (planning to) implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their cities, an Urban Circularity Assessment (UCA) method was developed. The method consists of urban material flow and stock accounting that paired with system-wide indicators assesses the material circularity of a city.

The material flows are accounted economy-wide for two separate years, applying a city-level adjusted Mayer et al. (2019) framework, which in itself builds on the EW-MFA method, including a wide material scope (specified below), while optimised for a circular economy assessment. The material stock accounting is limited to the buildings of the municipality, with the exact material scope depending on data availability in each city. Finally, the mass-based, “circularity” indicators cover the entire system and enable the assessment of a city’s circularity. As such, a balance between comprehensiveness and scientific rigour on the one hand, and operability by urban policy makers and practitioners on the other is sought by the UCA method.

The material scope of the flow accounting aims to cover the entire local economy and is divided into a total of six material groups. These material groups are depicted as icons here and were studied each with more specific materials in sub-categories and along the supply chain of domestic extraction, imports & exports, domestic material consumption and waste. When studying these materials and the entire supply chain, together, these elements help to set a solid knowledge and analytical foundation to develop future circularity roadmaps and action plans.

Within the CityLoops project, the Urban Circularity Assessment was carried out by three of the seven cities (Mikkeli, Porto and Sevilla) themselves after having previously successfully completed their Sector-wide Circularity Assessments and Reports. They could build on extensive training that they had received in the form of courses on data collection for the *construction and biomass sectors and data processing. The cities were accompanied and supported in their work by the Metabolism of Cities team, who conducted the UCA for two further cities (Apeldoorn and Bodø). Numerous additional insights can be found in the individual Data Hubs of each city.*

This current Urban Circularity Assessment report presents the gathered information in seven sections:

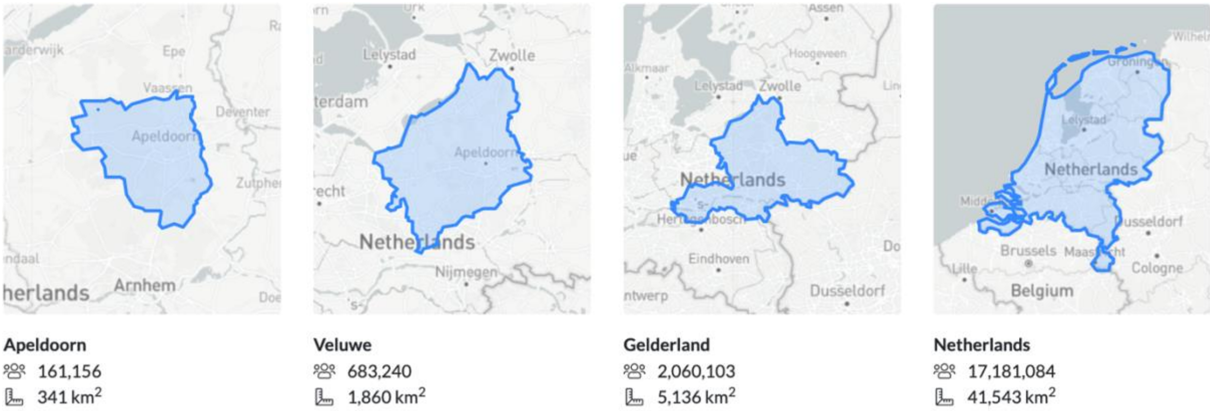
- *Urban Context*
- *Economic Context of Apeldoorn*
- *Material Flows in Apeldoorn*
- *Material Stock in Apeldoorn*
- *Analysis of Flows and Stocks: Measuring Indicators*
- *Data Quality Assessment*
- *Analysis of Data and Indicators: Assessing Circularity*

It provides contextual information of the city and the local economy under study. It then illustrates the quantities of flows in the single parts of the supply chain, summarised by a Sankey diagram, followed by a map of the material stock. Both of the accounted materials are evaluated in the form of circularity indicators and their data quality. Finally, the results are analysed and interpreted to determine a status quo, taking into account limitations of the data used, before recommendations are offered on how to achieve greater material circularity in the municipality of Apeldoorn.

(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.)*

2. Urban Context

To contextualise the results of the Urban Circularity Assessment, this section provides population and land use information data for Apeldoorn. In addition, population numbers and area size of the city under study, as well as its corresponding NUTS3, NUTS2 and country were included, as can be seen to the right of the Apeldoorn map. Data for these scales were added to better understand how relevant and important the approximations are when downscaling data from these scales to the city level.



2.1. Population of Apeldoorn

The population of Apeldoorn has been increasing significantly over the past decades. The population grew from 149,869 inhabitants in 1990 to well over 166,306 in 2022, a growth of 9.88% in about 30 years (CBS 2022c). Between 2014 and 2018, the two reference years of this study, the number of inhabitants in the municipality of Apeldoorn has increased by 3,611 persons from 157,545 in 2014 to 161,156 in 2018 (CBS 2022b).

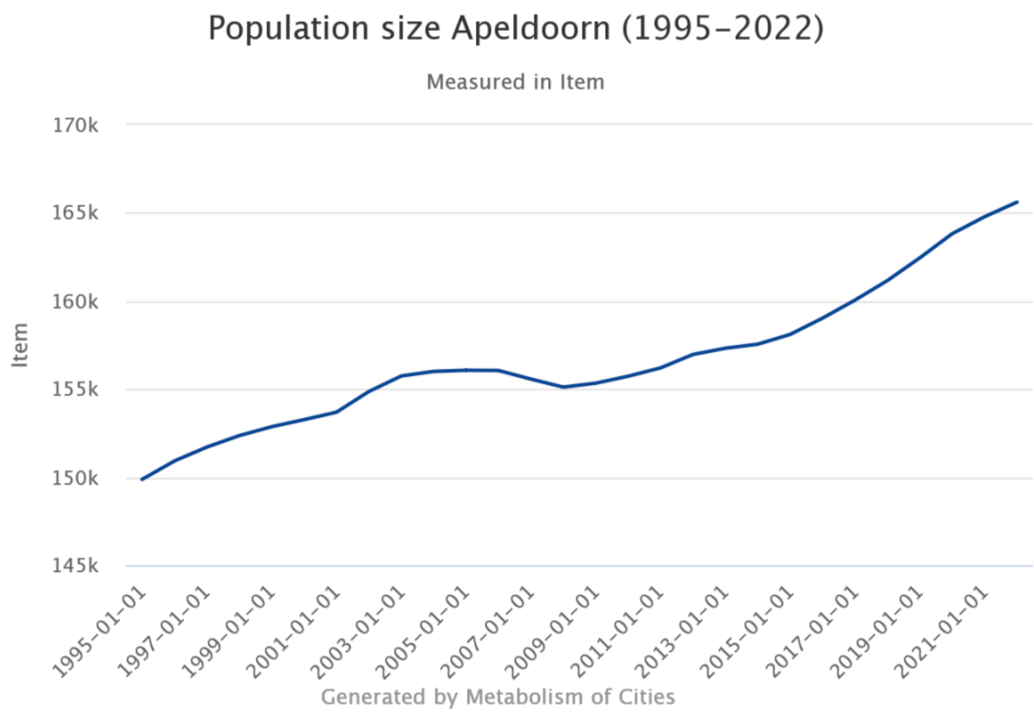


Figure 1 - Population of Apeldoorn (interactive graphic)

Currently, according to the age distribution, around 19% of Apeldoorn's population is between the ages of 0 and 18, while 20% is above the age of 65. The majority of the population is between the ages of 18 and 65, accounting for 60% of the total population (Municipality of Apeldoorn 2022).

2.2. Land Use

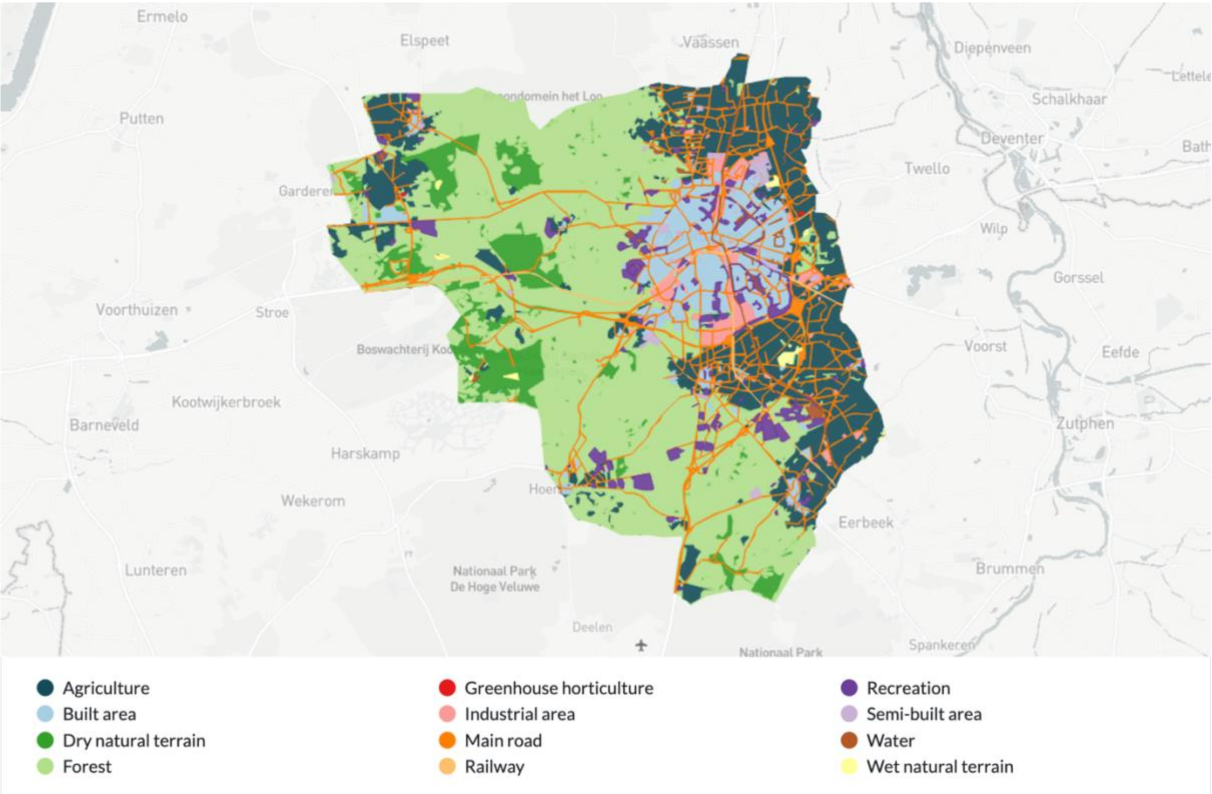


Figure 2 - Land use map (interactive graphic)

The total area of the municipality of Apeldoorn encompasses 341.15 km2. Of these, 339.86 km2 (99.6%) are land area, while the rest is covered by inland water (1.29 km2) (CBS 2022d). Forests, agricultural land use, and urban areas predominate this land, while 78% of the entire municipal land area is covered by vegetation (Cleaver 2021). Still, according to the CBS degree of urbanity classification, Apeldoorn is **highly urban**[1] corresponding to 2,500 addresses/km^2 (CBS 2022d) and the city itself has a strong urban character and primarily consists of neighbourhoods and business parks (PDOK 2017)

The rural region consists of both agricultural and forested areas, as well as numerous smaller towns that are all part of the municipality (Omgevingsdienst Veluwe IJssel and Apeldoorn Gemente 2013a). Early in the days, the fertile soil conditions attracted agriculture, which today occupies much of the flat land between the city of Apeldoorn and the IJssel valley (Cleaver 2021).

[1] A municipality's neighborhood address density (OAD) is the average number of addresses per square kilometer inside a circle with a radius of one kilometer. The goal of the OAD is to represent the level of concentration of human activities (living, working, going to school, shopping, going out, etc.). The OAD is used by Statistics Netherlands (CBS) to measure the urbanity of a certain region.

3. Economic Context of Apeldoorn

This section puts into perspective the economic context of the city under study. It describes its significance in terms of GDP or GVA and provides information on the number of people employed, as well as the main economic activities. Main actors that play a significant importance may also be highlighted.

	GDP (MONETARY VALUE, IN €)	EMPLOYEES (2018)
Apeldoorn	7,772,000,000	94,400
Veluwe	27,587,800,000	332,800
Gelderland	78,192,990,000	953,100
Netherlands	773,987,000,000	8,422,000

Apeldoorn has a diverse economic structure with a total of **94,400 employees** (2018). The economic activities with the highest number of employees in Apeldoorn were “Health and Welfare care” (17.8%), “Trade” (14.5%) and “Public Administration, and Government services” (12.7%) (CBS 2022a). This distribution is consistent with the one of the Netherlands, which has a significant number of employees in health, trade industries.

In 2018, a total of **12,955 companies** were registered in Apeldoorn, excluding those related with the government, education and care activities. These were distributed mostly over a handful of neighbourhoods: Most of the companies are located in the West, Noord, Noordoost, Zuid, Oost, Zuidoost, Zuidwest, and Centrum districts, each one with at least over 1,000 companies. In total, most of the companies deal with “business services” (3,615) and “trade and hospitality” (3,210). A very small number of companies are working on ‘agriculture, forestry, and fisheries’ (CBS 2021) and none in mineral extraction. Logistics and transportation are an emerging economic sector which can be attributed to the business parks’ accessibility and availability (Omgevingsdienst Veluwe IJssel and Apeldoorn Gemente 2013b).

In monetary terms, Apeldoorn generated approximately **7,772 mio Euro in Gross Domestic Product** in 2017, making up about 1% of the Dutch economy’s output. At a regional level, the sectors that stand out the most in Veluwe are trade (20,027 mio. Euro), industry (14,911 mio. Euro) and construction (5,365 mio. Euro), which together totalled 40,303 million Euro in 2017. The Netherlands has a similar distribution, where trade and industry were the sectors that showed the highest values, with 600,119 million Euros, and 319,789 million Euro, respectively (‘Bedrijfsleven; Arbeids- En Financiële Gegevens, per Branche, SBI 2008’ 2022).

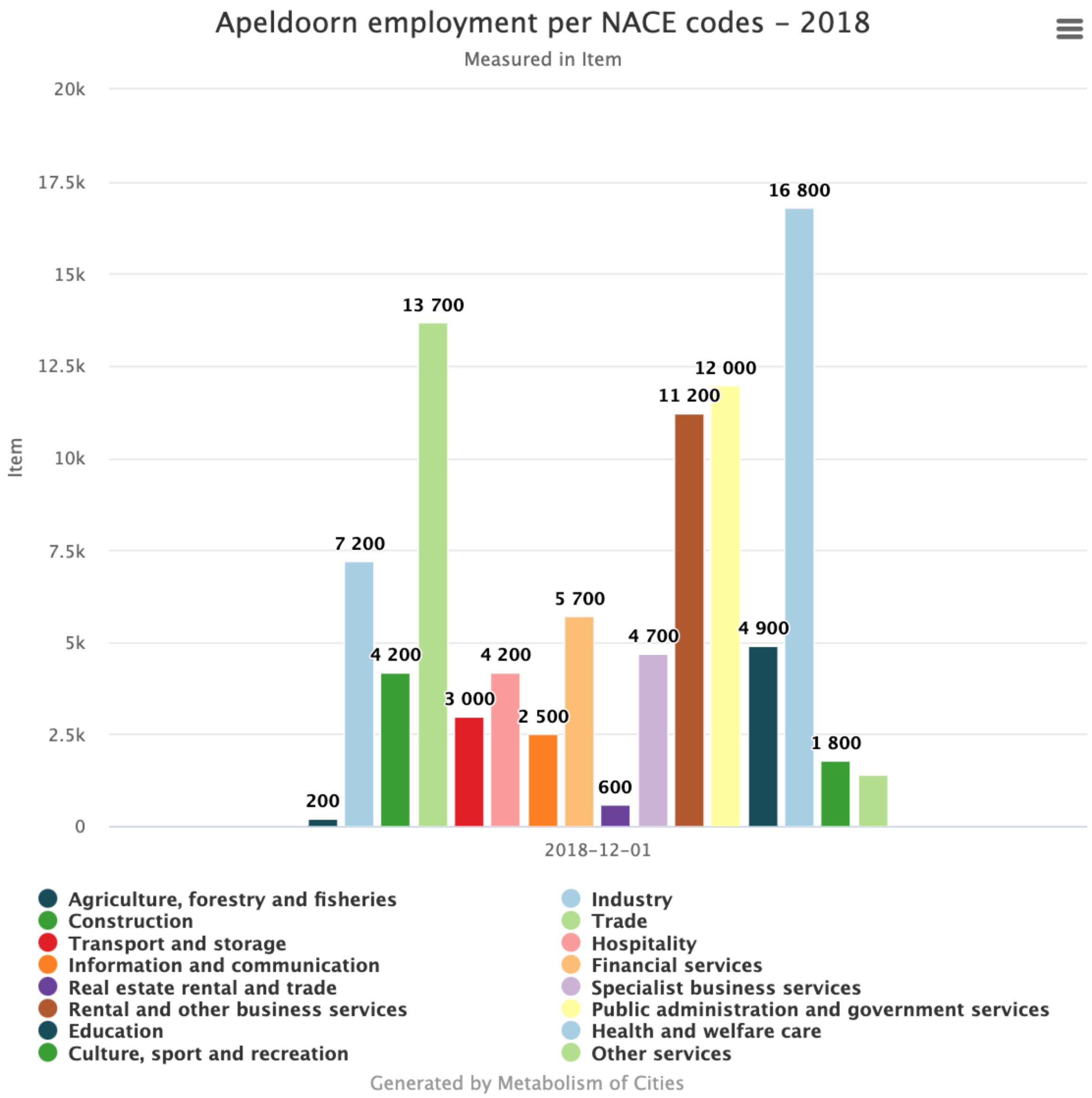


Figure 3 - Apeldoorn employment numbers (interactive graphic)

Paper production industry

The availability of clean groundwater together with the presence of extensive forests, has attracted the papermaking business to the surroundings of the Apeldoorn region. It has also become a significant industry for the rest of the Gelderland province. Historically, water has played an important role in Apeldoorn and more significantly so from the second half of the last century, when it was used for other industrial activities, such as textiles, laundries, graphics, and metallurgic activities (Omgevingsdienst Veluwe IJssel and Apeldoorn Gemente 2013b).. While in 1740, there were 168 paper mills on the Veluwe, today only the 400-year-old “De

Middelste Molen" in Loenen remains. Most papermakers went bankrupt or converted their mills into laundries in the second half of the 19th century, but De Middelste Molen, in operation since 1622, remains as the only authentic water-powered producing paper mill in the Netherlands (Mill n.d.). As it only follows the traditional paper making and not industrial production, it was neglected from further analysis.

Meat processing industry

The meat processing industry plays a significant role in Apeldoorn. Annually, it slaughters and processes 1.8 million pigs, calves and dairy cows in local production and storage facilities. The following companies operate in Apeldoorn:

- Vion Apeldoorn BV: a slaughterhouse and industrial butcher for pork meat that slaughters 25,000 pigs of Dutch origin (born and bred) per week (1.3 million per year), making up the majority of pigs in Gelderland and almost 10% of the pigs in the Netherlands (BRGS Food Safety and LRQA 2022)
- Van Drie Group (Esa), (Ekro): the largest veal producer in the world, which slaughters 400,000 calves per year (Partij Voor de Dieren 2018).
- Grolleman Groep: which operates in cold storing (total capacity of 1,500 tonnes per day for Apeldoorn for freezing and 650 tonnes in cooling), packaging, transport and meat processing.
- Amsterdam Meat Company: a company that slaughters and processes 1,900 dairy cows weekly.

From the number of animals that these companies operate with, it can be easily assumed that a lot of associated transport activities are involved to facilitate the operations of this industry. In the material flows section, the impact of this industry and the rest of the local economy will be further elaborated.

Waste sector

While not visible in the employee graphic, there were 290 employees working in the waste sector in 2014 versus 750 in 2018. As waste is an essential component of the Urban Circularity Assessment, waste companies are presented in more detail, to highlight the situation around and readiness to deal with outflows in Apeldoorn.

- Circulus-Berkel: Collects all household waste in the municipality of Apeldoorn. It is owned by Apeldoorn and eight other municipalities. The company implements municipal policy, collects residential waste, and contracts waste treatment centres and recycling stations in the Netherlands (Smart Waste 2021).
- PreZero, previously known as Sita Recycling: The company focuses on collecting, processing and recycling waste into raw materials for new products. The waste streams that they engage with are LDPE, glass, wood, coffee grounds, plastic, residual waste, e-waste, hazardous waste, paper and cardboard, and styrofoam.

- WEEE Apeldoorn: WEEE Apeldoorn focuses on chain optimisation for processing electrical appliances so that raw materials can be reused.
- Atterro: Operates a landfill, recovers and reuses the energy and raw materials from waste.
- Hoogeboom: collects rubble, construction waste, bulky household waste, sand and green waste.
- G. Schrijver B.V.: purchases and sales of waste paper, scrap iron, metals and plastic films.
- Van Gerrevink B.V.: Sorts, processes, destructs, and (temporary) stores paper, scrap iron, metal, wood, plastic and electronic waste.
- Jakiro Metaal Recycling - Oud ijzer en Metalen: is a junk yard, collecting iron and metals.
- Rumi Recycling B.V.: is a recycling and trading company focusing on plastic recycling; collection and reuse of copper, aluminium, and special steel alloys residues; production of wood pellets and briquettes, and tire recycling.
- Clear Polymers B.V.: is a recycling centre that recycles agricultural plastic films and produces granules by extruding the film into granules (LDPE granulate) "- Greenferm B.V.: focuses on the processing of animal slurry (cattle, calves, pigs and sow slurry). Greenferm is carrying out large-scale manure processing in Apeldoorn. At the “Ecofactorij” in Apeldoorn, the company is developing its first manure processing factory with a processing capacity of 350,000 tons.

4. Material Flows in Apeldoorn

Measuring material flows and circularity is a data heavy exercise. Numerous datasets were collected and visualised throughout the Urban Circularity Assessment process. To synthesise these findings, a Sankey diagram illustrates how material flows of the local economy of Apeldoorn 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 economy 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 a materials' circularity.

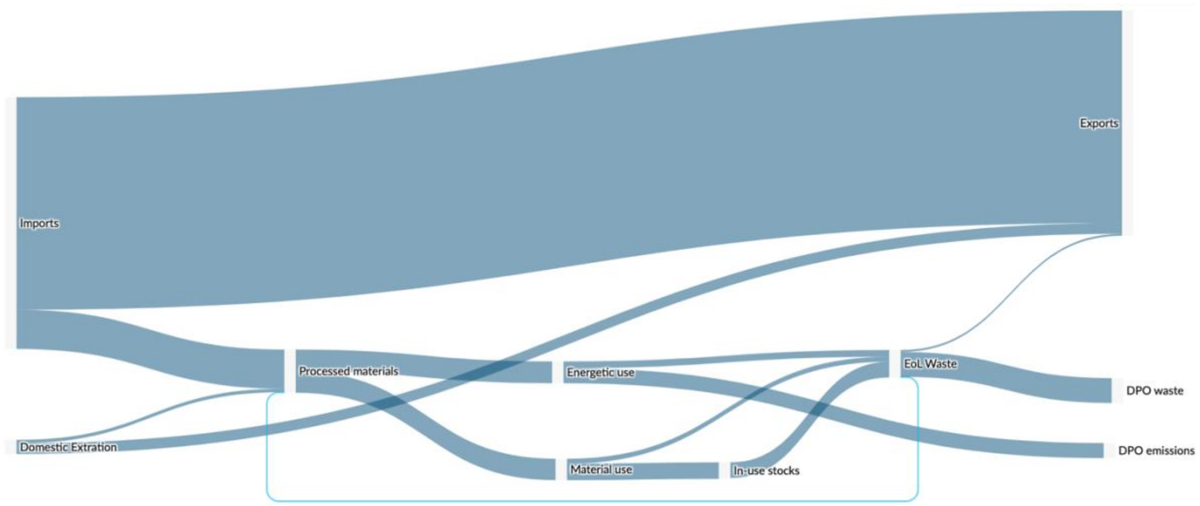


Figure 4 - Apeldoorn Sankey diagram (interactive diagram in online report)

4.1. Domestic Extraction

Domestic Extraction (DE) of biomass, minerals (metallic and non-metallic), as well as fossil fuels plays a minor role in Apeldoorn as can be observed in the Sankey diagram. Local extraction is limited to biomass materials.

As metal ores and fossil fuel extraction is minimal or non-existent for the Netherlands, no extraction was expected for Apeldoorn. In terms of non-metallic minerals, salt, limestone and gypsum, clays and kaolin, sand and gravel were extracted in the Netherlands for at least 10 years, although none of those were extracted in Apeldoorn.

The biomass extracted locally were 225,833.6 tonnes in 2018 and 248,821.8 tonnes in 2014, which represents a decrease of 9%. Overall, fodder crops and grazed biomass dominated this material group by far (see chart). Grazed biomass (184,568.5 tonnes in 2018) is the material that the 42,513 grazing animals, cattle (95% of animals), sheep, goats, and horses were consuming in Apeldoorn (2018). They ate about 80% of the total biomass in both years and consumed an additional 14-19% of the rest in the form of fodder crops.

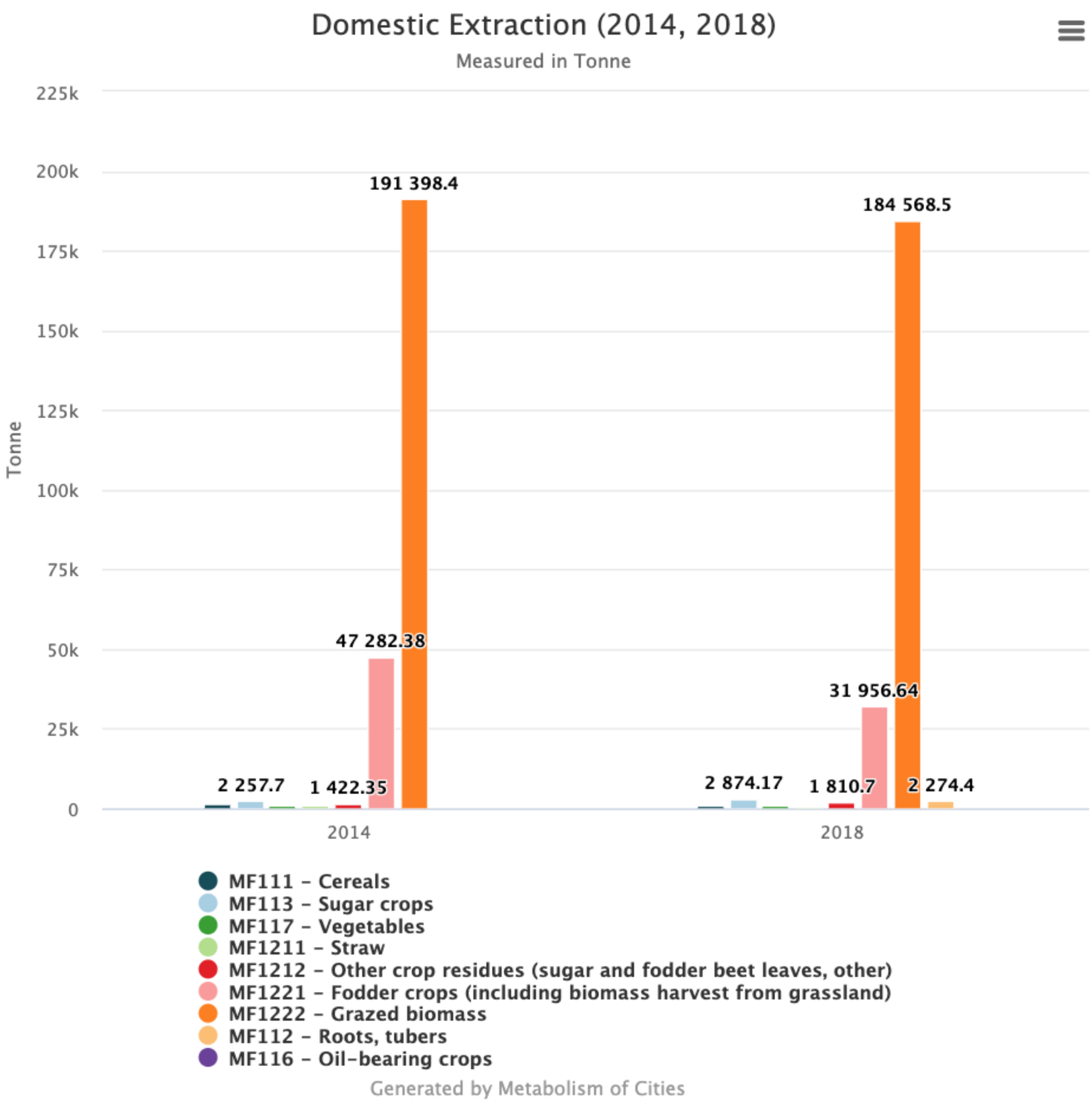


Figure 5 - Domestic Extraction in Apeldoorn (source)

The rest of the biomass extracted is marginal and represented a total of 9,308 tonnes or 4% in 2018. Potatoes and sugar beets made up more than half of it. This comes as little surprise considering that only 167 ha, 3.41% of the cultural land was used for arable farming and horticulture. An "honourable mention" should be made of the Stadsakker, an initiative that owns and cultivates a 2.5 ha field to bring fruits, vegetables and education around local food production to Apeldoorn. Since their annual production was unknown and the land very small, they were not included in the analysis.

Lastly, it was reported from the municipality that there are several timber companies in the city as well. Upon further investigation, most of them seem to be wholesalers or retailers and the Nederlandse Rondhout Combinatie B.V., a large local roundwood company, does not harvest timber in the municipality.

4.2. Imports & Exports

Imports & exports account for a very large share of the flows entering and exiting Apeldoorn's economy (much larger than the domestic extraction), as visible in the Sankey diagram. However, these values are considerably less reliable than the DE ones (as will be discussed in the data quality part) as they can be very difficult to obtain at a city level. In the case of Apeldoorn, no (measured) data was found for imports and exports flows.

The most reliable data found for the analysis were national data on imports & exports which were in turn downscaled with employee numbers.

Imports

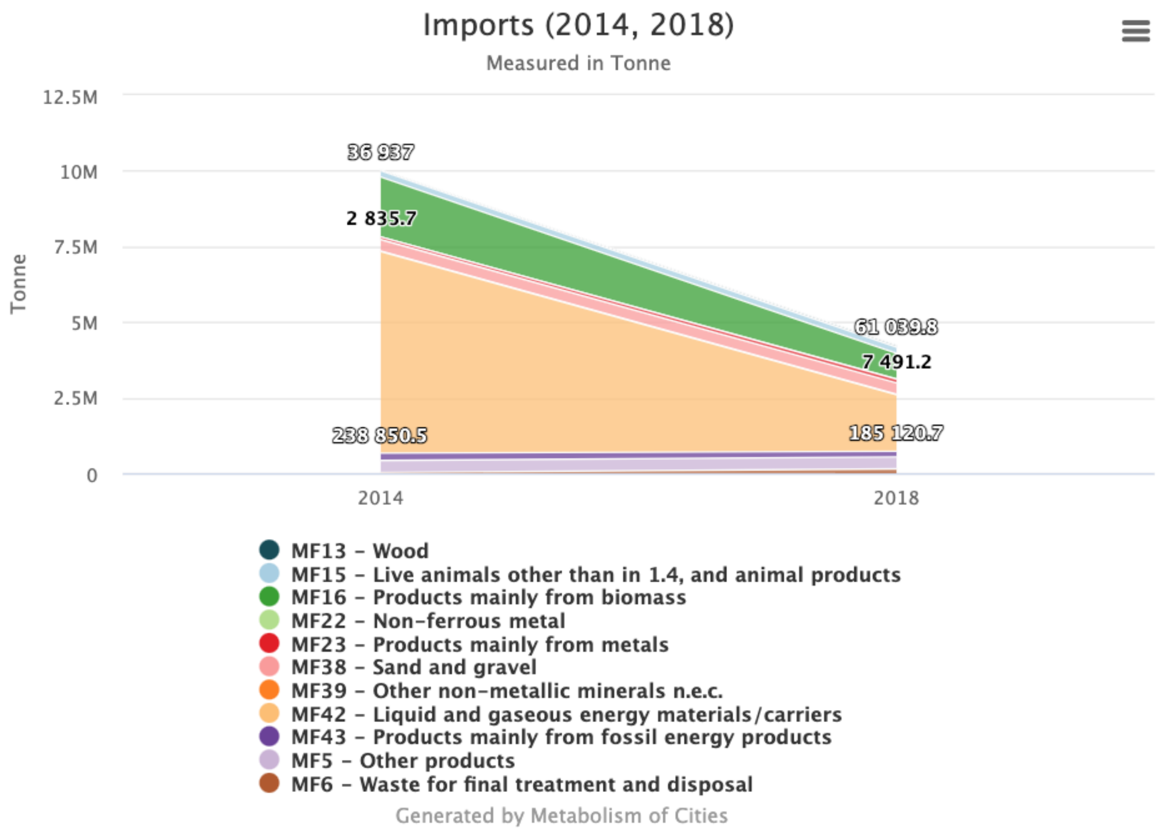


Figure 6 - Imports to Apeldoorn 2014 and 2018 (interactive graphic)

The total amount of materials imported to Apeldoorn were 10,031,909 tonnes in 2014 and 4,234,552 tonnes in 2018. This considerable decrease of 58% between these two years may possibly be explained by the economic downturn in 2018, which on the one hand is supported by the reduced import of biomass and fossil fuels. On the other hand, the import of waste increased by 572% and metals as well by 46%. However, the absolute numbers on a national level tell a different story for 2018, as the imports actually increased by 9%. Therefore, it could be deduced that the employee proxy may not adequately represent the actual changes in imports and exports (more information is available in the data quality part).

The distribution of the imported material groups found in the graphs show that fossil fuels make up the main share of imports with 69% and 49%, with biomass following at 22-27%, metals, non-metallic minerals, other products and waste together made up 9% in 2014 and 25% in 2018.

Exports

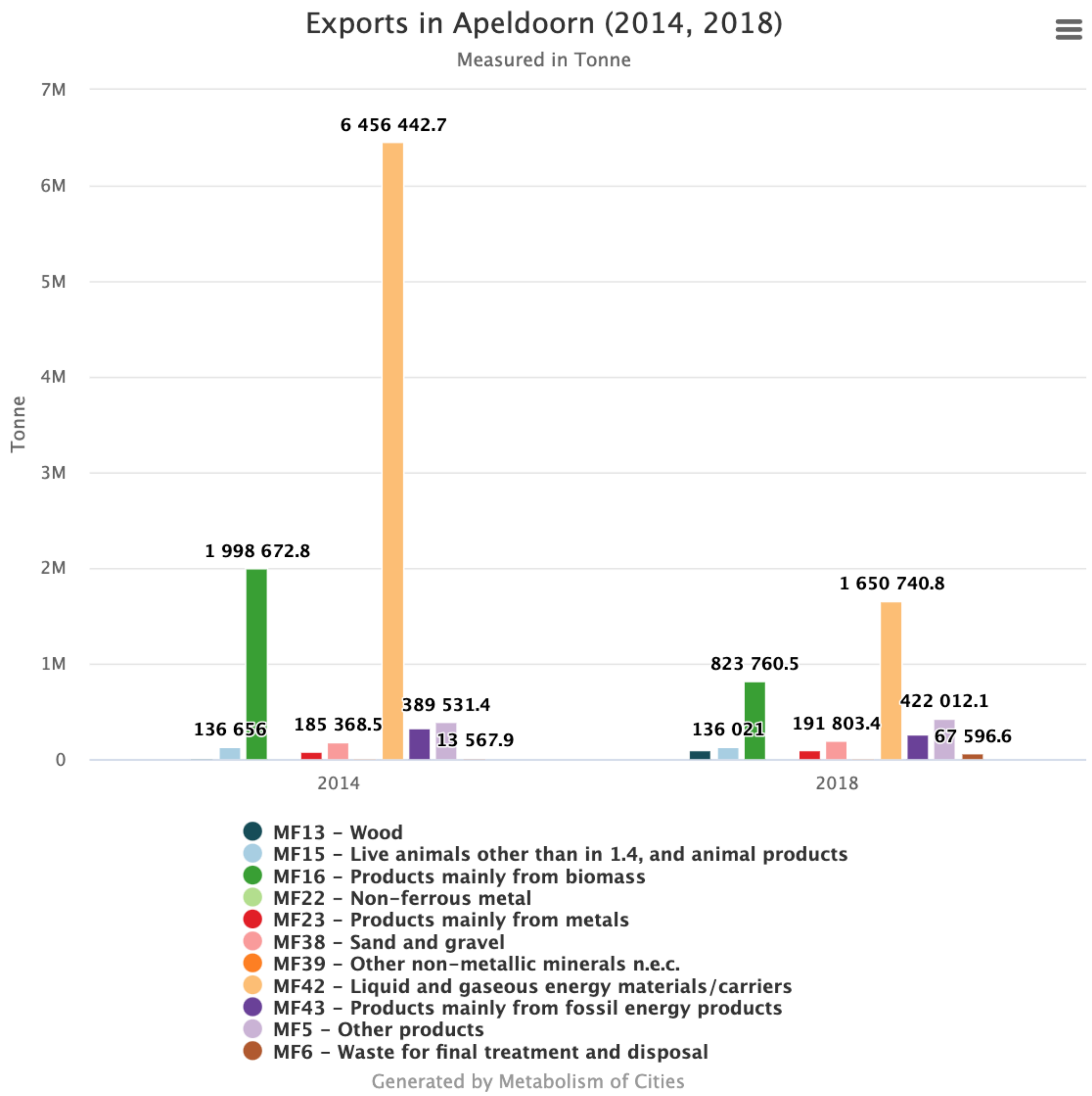


Figure 7 - Exports from Apeldoorn (interactive chart)

The total amounts exported from Apeldoorn were 9,631,182 tonnes in 2014 and 3,767,297 tonnes in 2018. Similarly to imports, a sharp decrease of 61%, can be observed and similar justifications could be given. More specifically, the import of waste increased by 398% and metals by 32%. Again, the national trend does not follow this development. On the contrary, exports were 6% higher in 2018 compared to 2014.

As for the single years, the distribution of the exported material groups are reflected in the graphs. It can be seen that fossil fuels make up the main share of imports with 70% and 51%, followed by biomass with 22-28%. Metals, non-metallic minerals, other products and waste together made up 7% in 2014 and 21% in 2018. These figures can be quite surprising as they would imply that either there is a transformation phase in Apeldoorn (importing, transforming and exporting), or that materials are transiting through Apeldoorn for a final destination elsewhere in the Netherlands.

To reflect the imports and exports from the meat processing industry that was mentioned earlier, the values that were not downscaled, but could be deducted from the amounts of animals needed to be imported for slaughtering and the meat and other animal products exported from these processes. A total of 1,798,800 animals need to be imported to Apeldoorn annually, because the livestock that exists locally does not suffice to satisfy the demand from slaughterhouses. Accounting for the different weights of pigs, calves and dairy cows, this sums up to 186,658 tonnes (imported biomass). Using carcass yields, a total of 110,709.7 tonnes of meat and meat preparations are produced and exported outside of Apeldoorn (it is assumed that all meat production is exported.).

4.3. Domestic Material Consumption

The domestic material consumption (DMC) is calculated by adding the domestic extraction with imports and subtracting exports. It represents the quantities that are consumed in the municipality and totalled 647,024 tonnes in 2018. This amount, added up with 41,683 tonnes of secondary materials forms the input flow to the processed materials (688,707 tonnes in 2018), which was split up evenly (50% each) in energetic and material use, 346,789 tonnes and 341,918 tonnes, respectively.

The energetic use powers the local economy and results in emissions to air (DPOemissions with 239,486 tonnes), as well as to land, in the form of solid & liquid wastes - 107,303 tonnes that ended up at the end-of-life (EoL) waste.

A part of the material use, with 262,183 tonnes, found its permanent destination as gross additions to stock at the “societal in-use stocks”, such as infrastructure and goods that stay in the city for more than one year. Throughput materials are the second stream that leave the material use and were 79,736 tonnes of used materials that ended up at EoL waste.

4.4. Waste

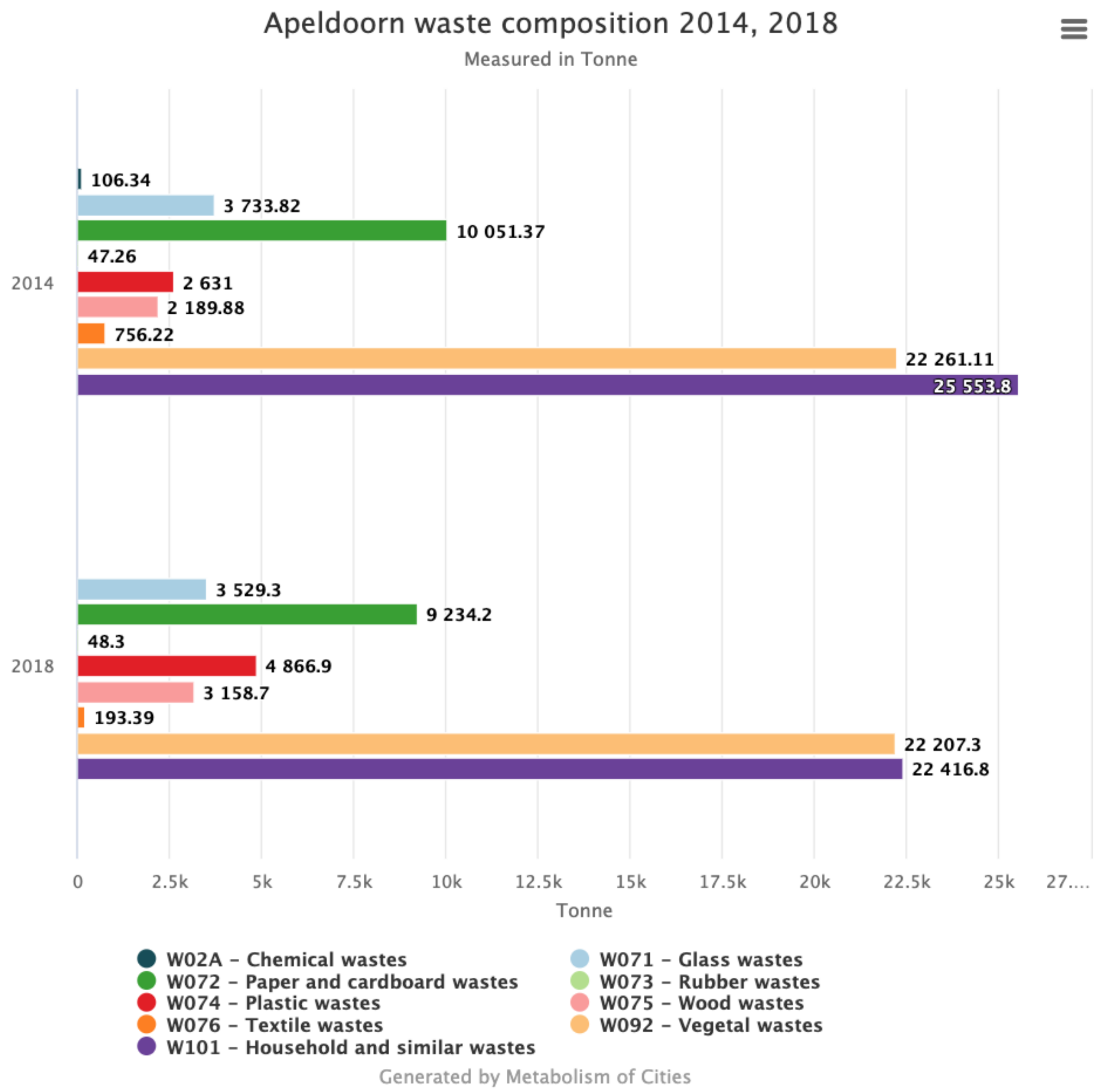


Figure 8 - Household waste composition (interactive chart)

The last component of the material flow accounting for the UCA, found on the right side of the Sankey diagram, is the waste output of Apeldoorn. As it will be explained in the data quality part, only household waste and manure could be included in the accounting, as no information was available from industrial and commercial waste. These totalled at 398,800 tonnes in 2018, an increase of 2% from 2014 (391,331 tonnes). The largest fraction was manure with about 83% in both years. Since manure is the only non-household waste included, drastically altering the picture of the waste composition, it was excluded from the waste composition graph. Thereafter, the dominating waste fractions are “household waste and similar waste” (22,416.8 tonnes in 2018), which is the residual waste that is not separated, and vegetal waste (22,207.3

tonnes). The recycled waste, namely glass, paper & cardboard, rubber, plastic, wood and textile, totals at 21,030.9 tonnes (2018) with paper & cardboard and plastic waste as two largest fractions.

The total end-of-life waste in 2018, however, was 436,471 tonnes. This encompasses the total waste (reported), both energetic and material use, as well as the total waste (non-reported). In the Sankey diagram, EoL waste splits up as DPO waste, the material left after recycling or not subjected to it in the first place, which was 394,788 tonnes in 2018, as well as secondary materials. The latter equalled 41,683 tonnes in 2018 and consists of materials from recycling and for backfilling, where 24% (9,853 tonnes) made it back to processed materials and 76% were exported.

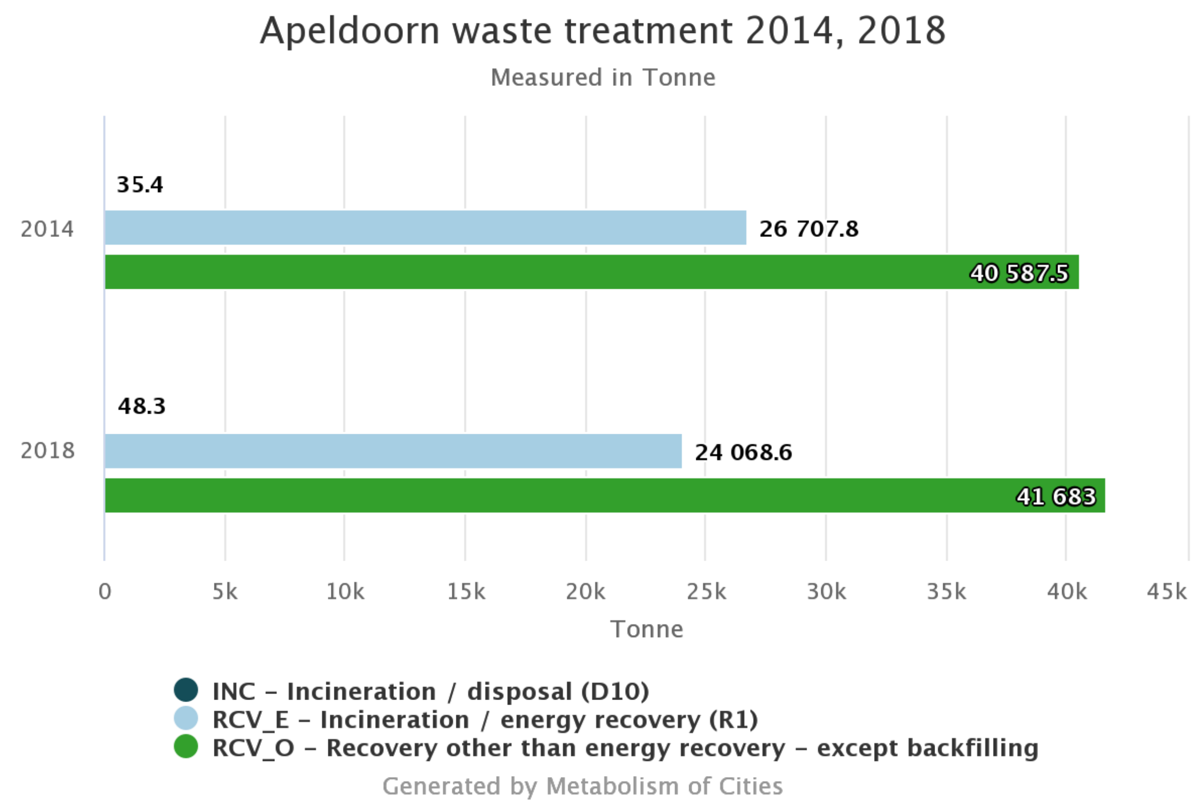


Figure 9 - Waste treatment distribution (interactive chart)

With regards to waste treatment, household waste from Apeldoorn is subjected to recycling, incineration and landfilling. It is unknown what happens to the industrial and commercial waste i.e. whether and how it is treated locally or exported for treatment. Recycling in the UCA method bundles into one group various operations that take place within Apeldoorn such as fermentation (anaerobic digestion), chemical or physical separation, composting (aerobic), sorting or separation, transhipment / bulking. Therefore, it cannot be further distinguished what exactly happens to the various waste fractions. Taking this into account, it still is relevant to mention that recycling predominates waste treatment operations in 2014 (60%) and 2018 (63%). 40% of the remaining waste were incinerated in 2014, while in 2018 it had decreased to 37%.

5. Material stock in Apeldoorn

Determining and analysing the material stock of a city can, similarly to the material flow accounting, also be a data intensive endeavour. The intensity depends on the scope and the data availability. For the Urban Circularity Assessment, the scope includes all residential and non-residential buildings in the municipality. Unlike for the material flow quantification, the analysis is not done for one or several specific reference years, but considers all buildings that have been constructed and still exist, up until and including 2022 (year of study). The aim is to quantify the materials that every single building contains and represent them spatially on a map. Depending on the data availability around building typologies, age cohorts, building height and material intensities, different, specific quantifications and investigations can be made.

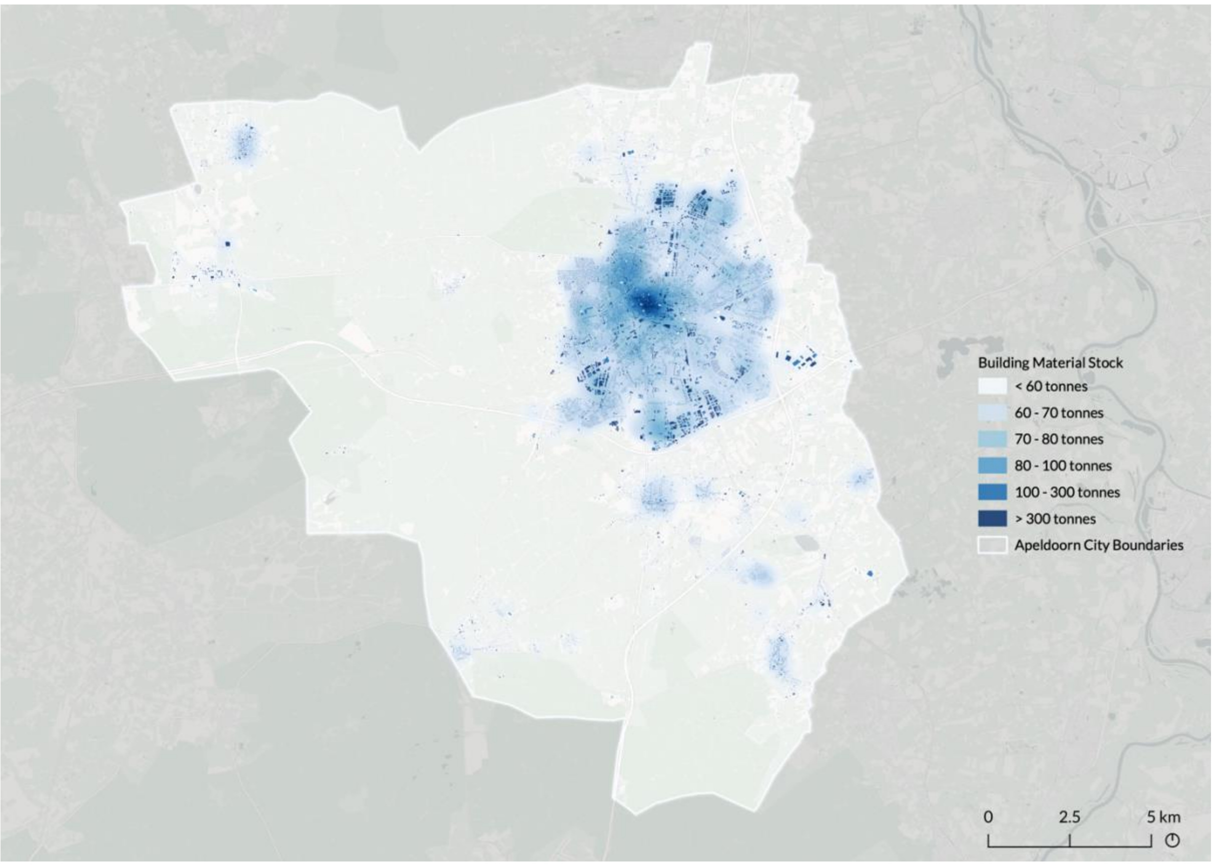


Figure 10 - Map of Building Material Stock in Apeldoorn expressed in tonnes and with an overlaid heatmap to facilitate its compression. (interactive map – explore it!)

The embedded map allows to explore the building stock of Apeldoorn and interact with the different scales and buildings by zooming in and out, and clicking on the buildings to discover more about typologies and quantity of building materials. The widgets on the right can be used to account for certain information, e.g. the number of buildings in an area, or to filter for specific construction years, which in combination with the average useful life of buildings can be used *to calculate the potential urban mine. Furthermore, an analysis can also be performed by using the lasso tool and drawing an area (a block, a neighbourhood or an urban area) to be analysed.*

5.1. Building typologies in Apeldoorn

An essential component for material stock of buildings in Apeldoorn is building typologies (more detail is provided in the next section). To define them the following pieces of information are needed: building footprints of all buildings (ideally geo-spatialised) as well as their land use, age, height and gross floor area. These pieces of information were provided by the Dutch Kadaster.

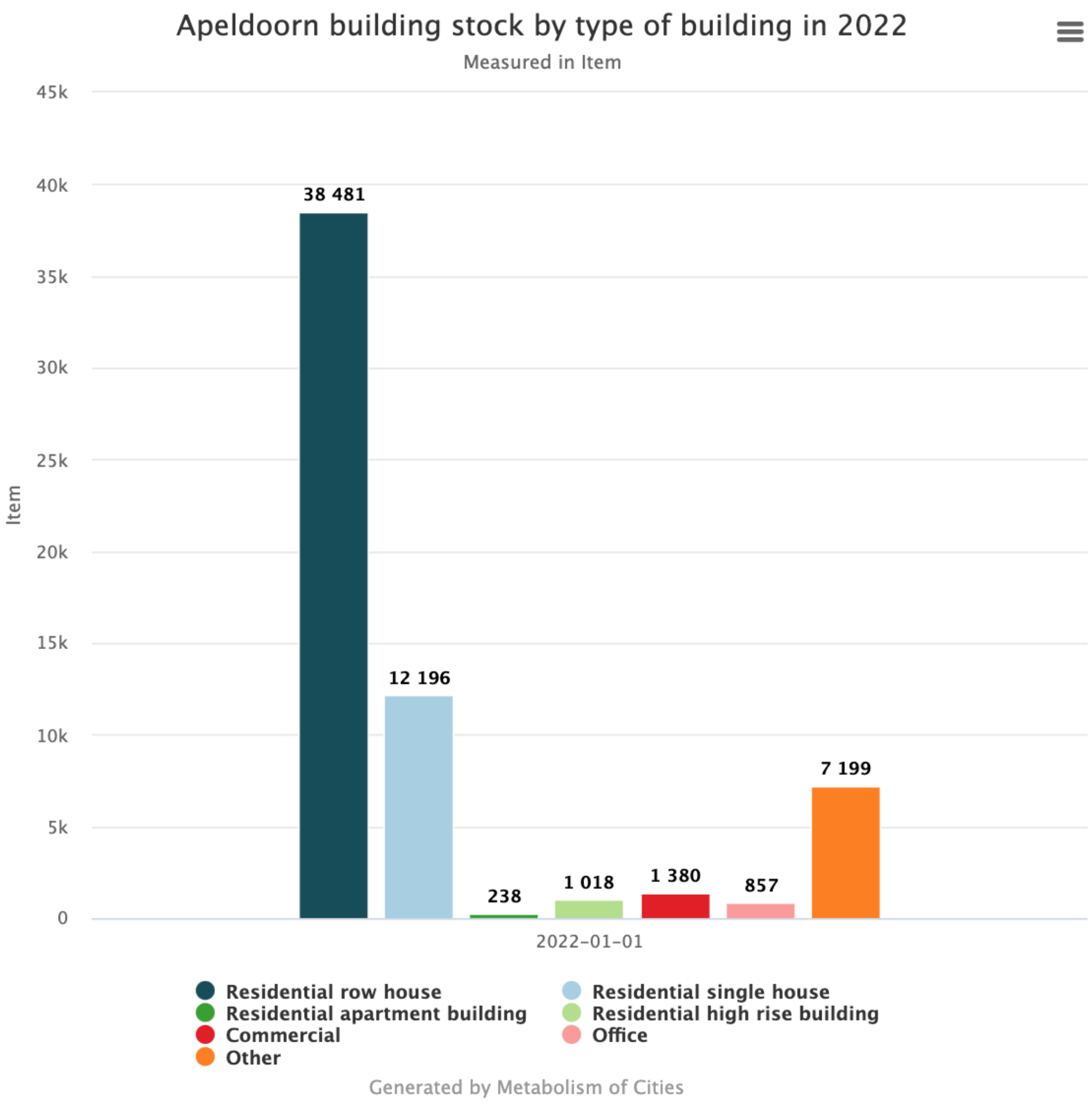


Figure 11 - Apeldoorn building stock by type of building (interactive chart)

While traditionally the typologies are defined directly through this dataset and then material intensities are measured, in the case of The Netherlands, a very relevant database on Dutch material intensities was already available (Sprecher et al. 2022). As such, in this specific case, the building typologies were developed to fit the ones already available in the material intensity database. **Seven main building typologies** were defined:

- Residential row house (when the function of the cadaster is 'Woonfunctie', the building ‘touches’ another one; and is below 3 storeys)
- Residential single house (when the function of the cadaster is 'Woonfunctie', the building ‘does not touch’ another one; and is below 3 storeys)
- Residential apartment building (when the function of the cadaster is 'Woonfunctie', the building ‘does not touch’ another one; and is below 3 storeys)
- Residential high-rise building (when the function of the cadaster is 'Woonfunctie', the building ‘does not touch’ another one; and is above 3 storeys)
- Commercial (when the function of the cadaster is 'Winkelfunctie')
- Office (when the function of the cadaster is 'Kantoorfunctie')
- Other (when the function of the cadaster is 'Overige Gebruiksfunctie', 'Gezondheidszorgfunctie', 'Industriefunctie', 'Sportfunctie', 'Onderwijsfunctie', 'Logiesfunctie')

In total, there are **61,369 buildings in the municipality of Apeldoorn.** The chart here illustrates the share of each typology in the total building stock. It can be seen that the majority of the buildings (62.7%) are residential row houses, which is a typical building typology in the Netherlands. This is followed by residential single houses (19.9%) and a group of others (11.7%), followed by commercial (2.2%), high rise (1.7%) and offices (1.4%).

As for the age distribution, it can be seen that the buildings constructed in the cohort of 1945-1970 have the largest share (39.3%), while the ones of before 1945 and after the year 2000 are similarly low with 19% and 16.8% respectively.

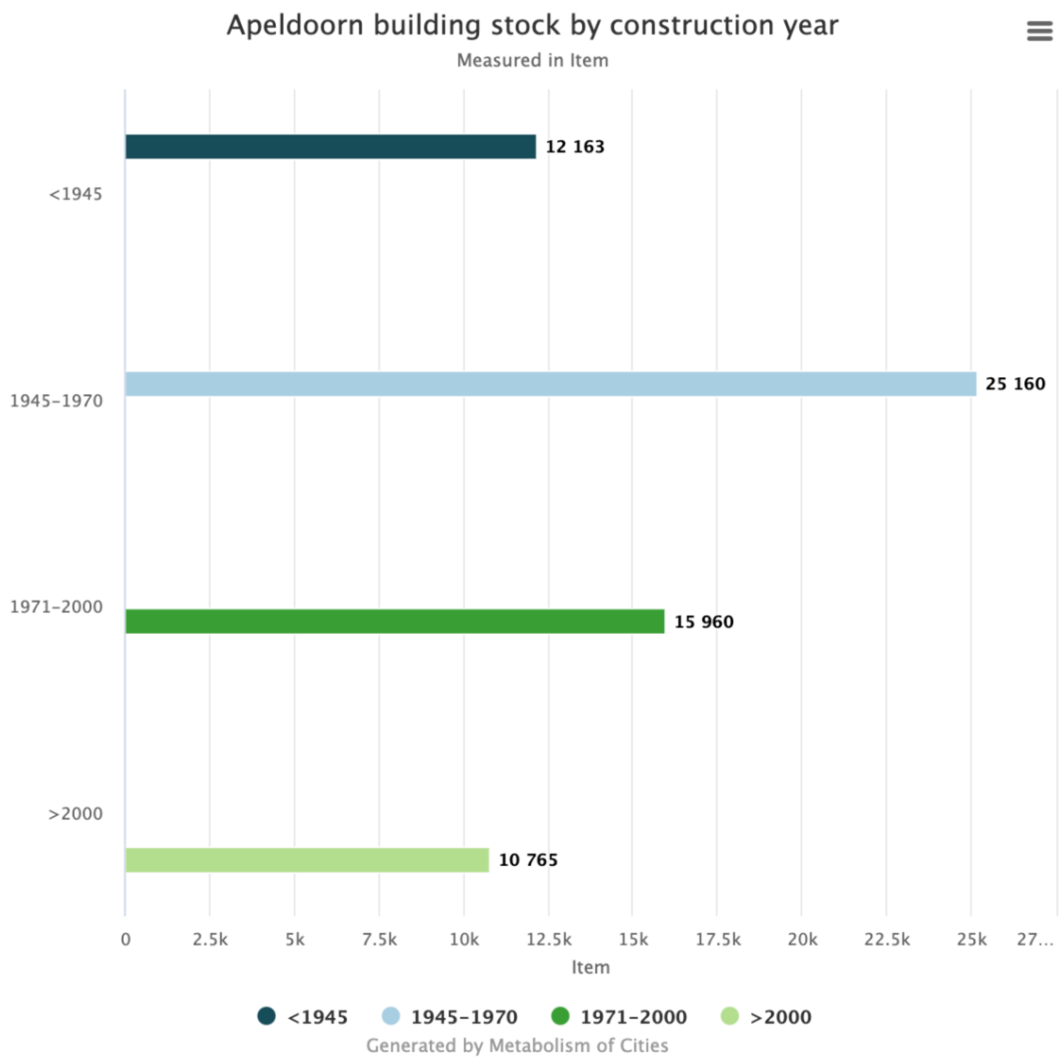


Figure 12 - Apeldoorn building stock by construction year (interactive chart)

5.2. Analysis of Material Stock

Using the building typologies developed in the previous part and the material intensities from Sprecher et al. (2022), it was possible to measure the material stock of Apeldoorn's building stock. To obtain it, the gross floor area for each building was multiplied by its associated material intensity, which depends on the typology of that building.

Thanks to the spatial explicitness of the material stock, it is possible to map the material stored within the city and identify some zones with higher material intensity (higher density of buildings or high-rise buildings). Overall, it is estimated that Apeldoorn's **building stock weighs approximately 15 million tonnes**.

Looking at the map in the beginning of this section (Figure 10), it can be seen that the city of Apeldoorn has a denser urban fabric in the city centre with a mix of newly built, large-scale, mono-functional (predominantly retail) buildings. In contrast, surrounding the city centre, residential areas expand along road networks with smaller and older buildings and a clear presence of single and row house buildings.

The greater floor area and material intensity of buildings located in the city centre, coincide with a greater material building stock per building. However, given the recent date of construction of these buildings, these materials will not become available until their renovation or demolition in the future. Besides those buildings, 15.6% of the total building stock in Apeldoorn was built before 1945 and 7.3% was built between 1945 and 1970. Assuming the lifespan of buildings constructed in the post-war period is about 50 years (Thomsen and Straub 2008), the materials embedded in these buildings could soon become available and used to satisfy future resource use demands. Thus, the results from this analysis enable to quantify and map Apeldoorn's urban mine.

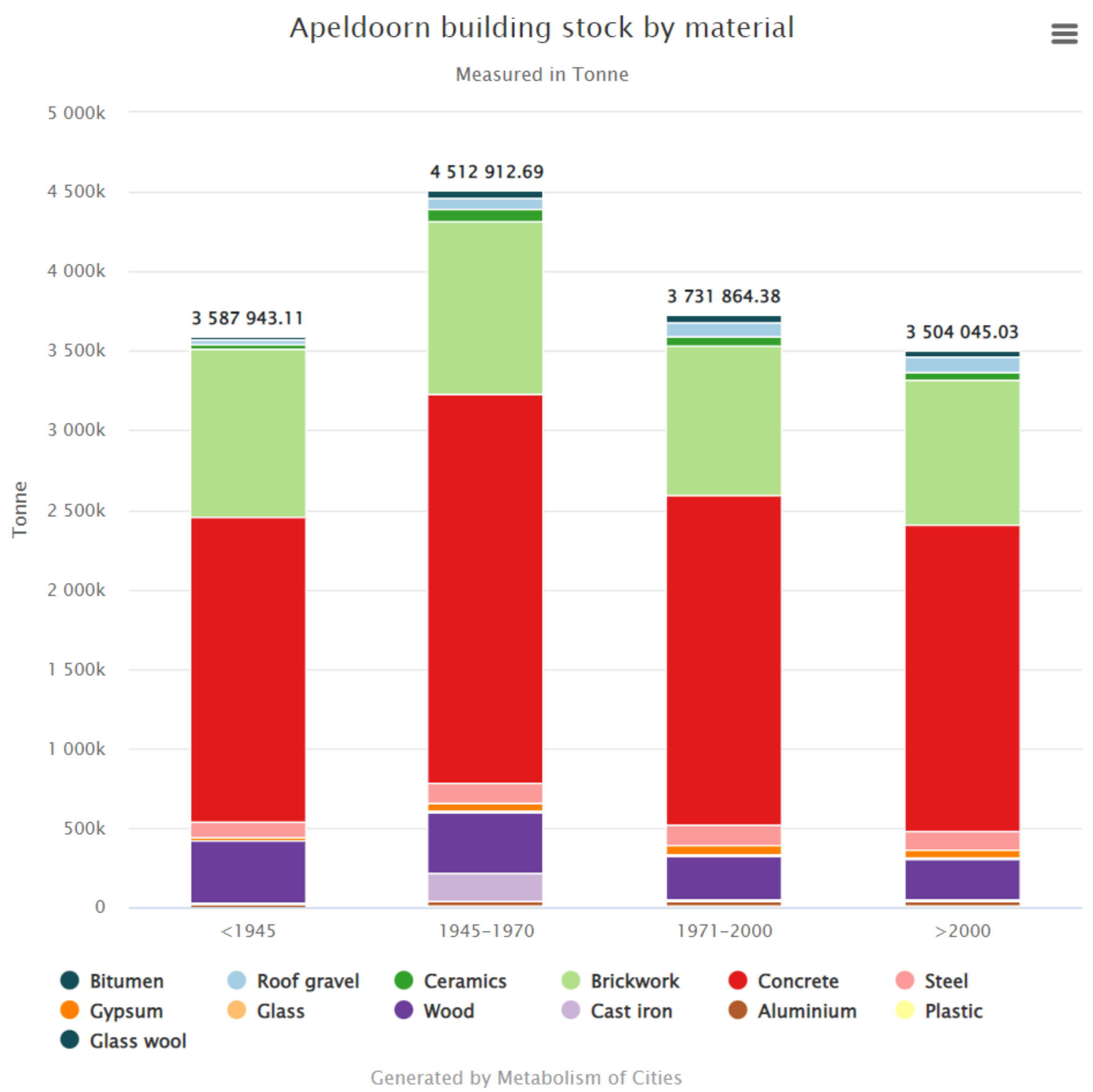


Figure 13 - Building stock by age cohort and materials (interactive chart)

As can be seen from the remaining charts, concrete represents the vast majority of the material stock approximating 75% of the total mass. Together with brick, they represent the most representative materials in terms of mass. While in significantly smaller shares, wood and steel are the two next materials in terms of quantity.

From a circular economy perspective, it appears that perhaps the most important strategy would be to maintain the building stock. When this is not possible the reuse (slab or columns) or recycling of concrete (using it as aggregates in new concrete structures) and reuse of bricks, wood and steel would be most desirable.

Type of buildings that generate most of the mass

As is visible from the chart on building typologies and materials, the residential sector is responsible for the highest share of the material stock (with single houses being the typology with the highest impact). Another important share of the material stock can be found under the row house typology and "other" mixing many different sub-typologies.

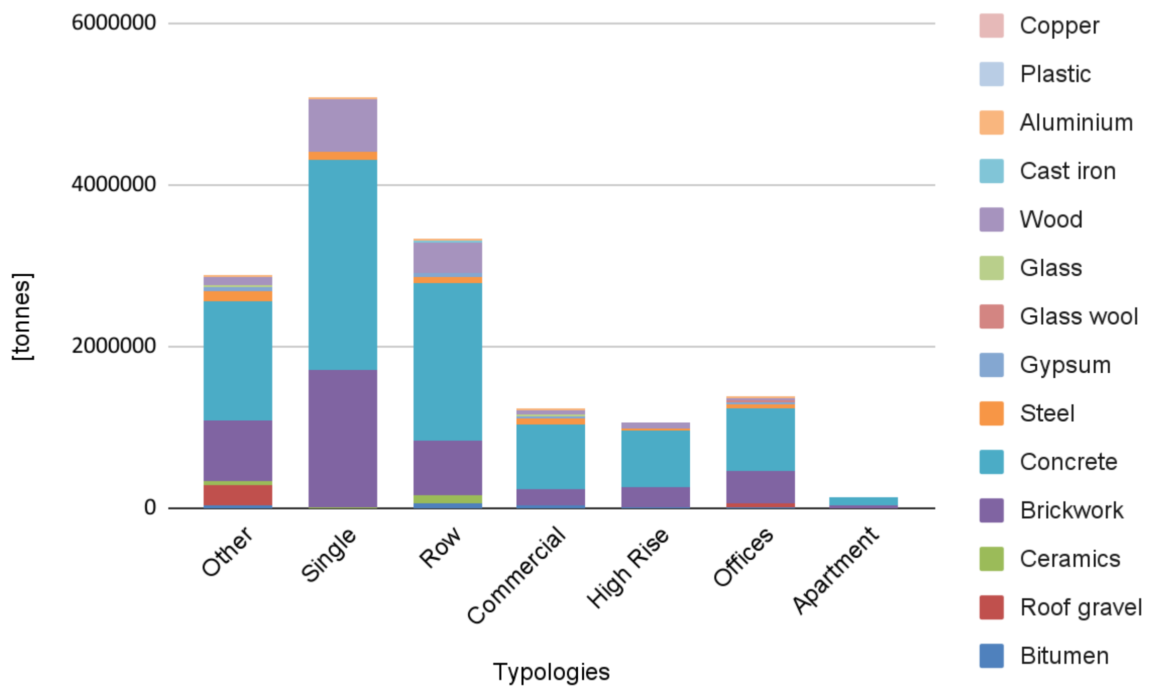


Figure 14 - Building stock by building typologies and materials

From a material perspective, concrete is the predominant material in Apeldoorn with 55%, followed by brickwork with 26% and wood with 8.4% of all materials.

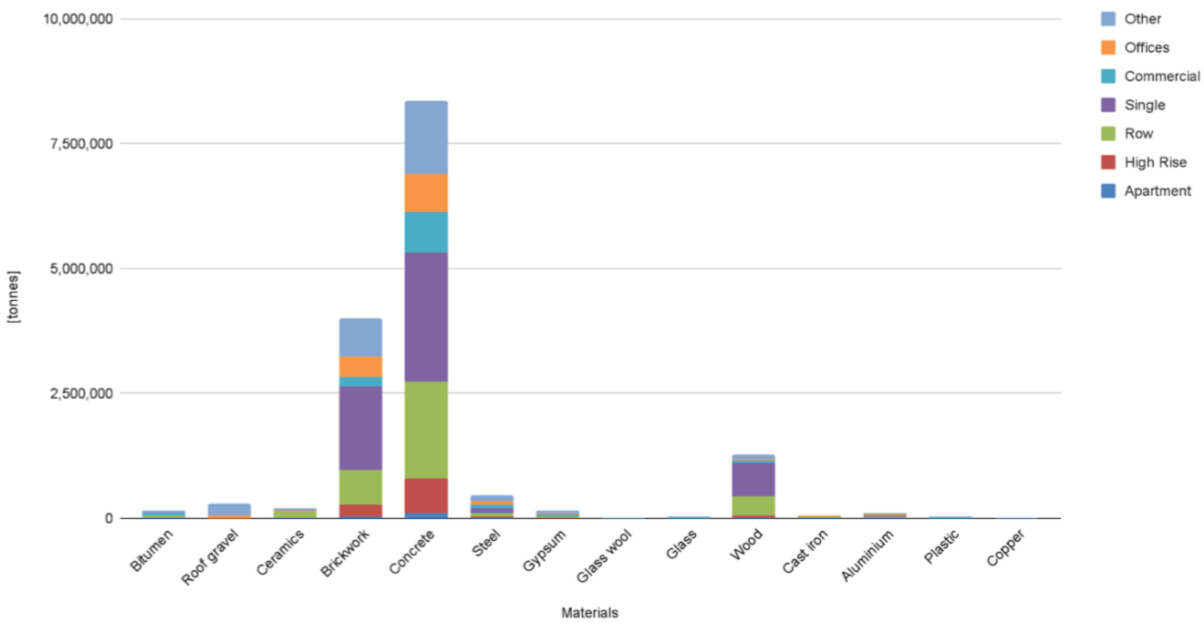


Figure 15 - Building stock by materials and building typologies

Relating stock with flows entering and exiting

Relating the material stock to construction material related flows, entering and exiting, is another useful part of the material stock analysis. Analysing the composition and total materials used in the buildings constructed in 2014 and 2018, it can be seen that comparing these two years the addition to the material stock has increased considerably, adding 56,044 tonnes in 2014 and 121,944 tonnes in 2018 to the stock respectively. However, the difficulty here, for the comparison and to create context, is that for entering flows there are no domestically extracted materials in Apeldoorn and the imported fraction is very small. On the output side, there was no data on construction and demolition waste and a small quantity of exported materials. Consequently, this comparison would not be insightful.

Comparison with other case studies

Figure 16 compares the material stock per capita of a number of global cities (Athanassiadis et al. 2017) to the one of Apeldoorn. Compared with other cities, Apeldoorn is situated at the lower end. Its material stock accounts for approximately 94 t/cap and 44 000 t/km². This result showcases that the results of the material stock of Apeldoorn are within a correct range and in the order of magnitude, although the results from different studies also have a number of assumptions and were not carried out during the same year (2008, 2011 Beijing; 2022 Apeldoorn; 2015 Melbourne; 2012, 2015 Brussels; 2003 Geneva; 2013 Paris; 2013 Vienna; 2006 Orléans). The results obtained could signify that the population or built-up density of Apeldoorn is relatively high compared to its mass, or that it uses "heavy" materials (i.e. concrete and bricks) with a low population.

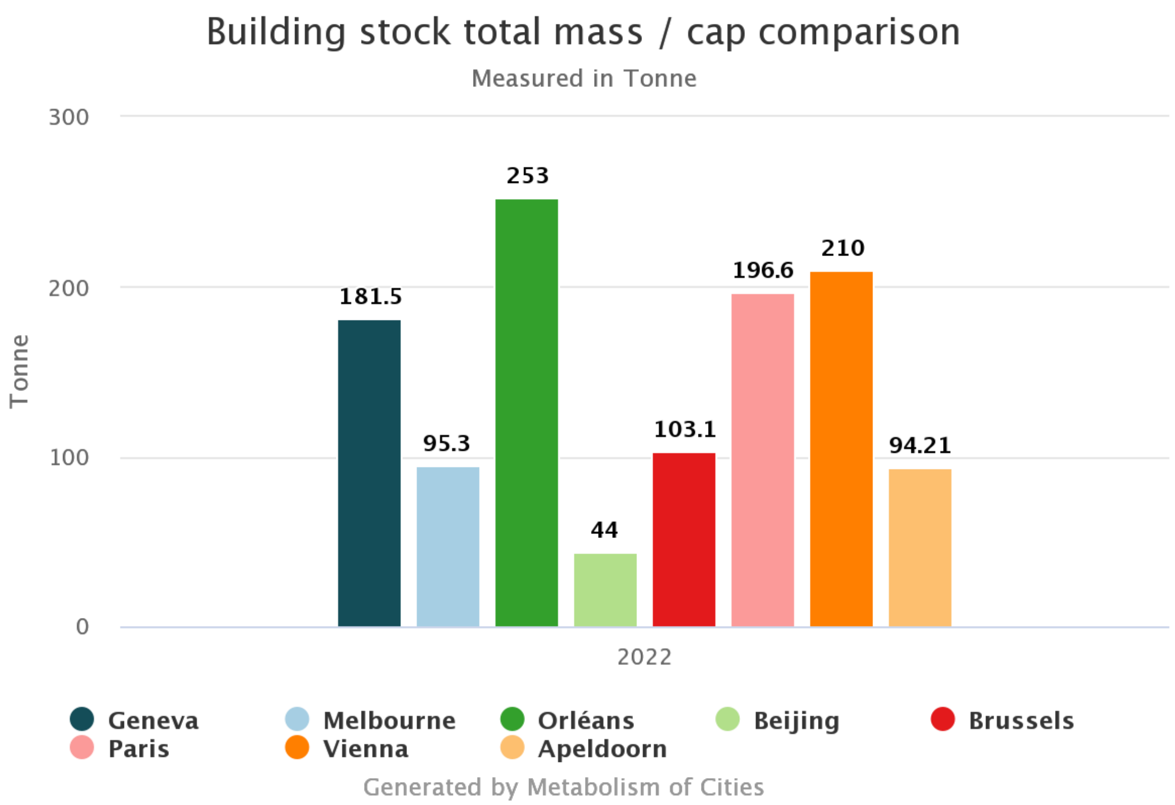


Figure 16 - Material stock in total mass per capita for major cities and Apeldoorn ([interactive graphic](#))

6. Analysis of Flows and Stocks: Measuring Indicators

To monitor the progress of the local economy 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 city's progress towards circularity. The below table provides the value for two reference years, where possible, and the percentage change between the two.

Indicator table

Indicator	2014	2018	Unit	Change from 2014 to 2018 (%)
Input Socioeconomic Cycling Rates (ISCr)	6.1%	6.1%	%	-0.9%
Output Socioeconomic Cycling Rate (OSCr)	6.3%	6.2%	%	-1.8%
Input Ecological Cycling Rate Potential (IECrp)	44.7%	45.4%	%	1.7%
Output Ecological Cycling Rate Potential	81.9%	81.3%	%	-0.7%
Input Non-circularity Rate (INCr)	10.3%	11.2%	%	9.2%
Output Non-circularity Rate (ONCr)	10.5%	11.4%	%	8.2%
Remaining non-renewable primary resources	39.0%	37.3%	%	-4.2%
Remaining interim outputs	1.3%	1.1%	%	-15.7%
Material recovery	9.5%	9.6%	%	0.6%
Direct Material Input (DMI)	10,129,488.5	4,239,929.8	tonnes / year	-58.1%
Domestic Processed Output (DPO)	605,942.6	634,273.2	tonnes / year	4.7%
Domestic Material Consumption (DMC)	623,841.5	647,024.3	tonnes / year	3.7%
Domestic Material Consumption Corrected (DMCcorr)	491,375.5	402,533.6	tonnes / year	-18.1%
Local and Exported Processed Output (LEPO)	619,510.5	701,869.8	tonnes / year	13.3%
Processed Material (PM)	664,429.2	688,707.4	tonnes / year	3.7%

Interim Outputs (IntOut)	646,530.2	675,956.3	tonnes / year	4.6%
Secondary Material (SM)	40,587.6	41,683.1	tonnes / year	2.7%
Net Addition to Stock (NAS)	17,899.0	12,751.1	tonnes / year	-28.8%
Physical Trade Balance (PTB)	400,726.7	467,255.0	tonnes / year	16.6%
Material Productivity (MP)	11.7	12.0	Euro / tonnes	2.8%
Material Intensity (MI)	0.1	0.1	tonnes / Euro	-2.7%

Indicators that were chosen and their development over time

In 2018, 98.15% (646,530.2 tonnes) of processed materials (PM) were converted into interim outputs (IntOut), increasing by 0.84% from 2014. The remaining 1.85% were added to in-use stocks of buildings, infrastructure, and durable goods, which in 2018 were 12,751 tonnes (NAS). Nearly 9.55% of the total End-of-Life (EoL) waste was recovered in 2018 and used as secondary resources, while in 2014, it was slightly lower at 9.5%. The Output Socioeconomic Cycling Rate (OSCr) which expresses the contribution of secondary materials to IntOut remained low, at only 6.2% and decreasing by 1.8% from 2014, reflecting a move away from replacing virgin materials. The input socioeconomic cycling rate, measuring the recycled and downcycled materials reprocessed as secondary material inputs into the domestic economy, was also lower in 2018, at 6.1% and decreased by 0.9% from 2014.

The high significance of fossil energy carriers in the (Apeldoorn) primary energy supply, flows that cannot be recycled or reused, led to an Input Non-Circularity rate (INCr) of 11.2% and increased by 9.2% from 2014. Moreover, it resulted in an Output Non-circularity rate (ONCr) of 11.4% that grew considerably by 8.2% from 2014.

A slight decrease in DMC of 23,182 tonnes between 2014 and 2018 was found, and a relatively stable flow of secondary materials, which resulted in a slight decrease of 1.8% in Input Socioeconomic Cycling Rates (ISCr) between 2014 and 2018.

Ecological cycling, although indicated only as theoretical potential, was comparatively high: the Input Ecological Cycling Rate Potential (IECrp), indicating the maximum share of Processed Materials (PM) that qualifies for ecological cycling, was 45.4% in 2018 and increased by 1.7% from 2014; the Output Ecological Cycling Rate Potential (OECrp) which measures the contribution of Domestic Processed Output (DPO) from biomass in IntOut was even higher, at 81.3%, but decreasing slightly from 2014 (-0.7%).

While domestic material consumption has decreased slightly, consumption of fossil or non-circular resources has not. If to this, Apeldoorn's high dependence on imports is added, this may lead to an unsustainable situation. However, both indicators of ecological cycling rate (Input and Output Ecological Cycling Rate Potential, IECrp and OECrp), indicate a clear field of action in Apeldoorn: biomass. Apeldoorn could take advantage of this situation and develop a circular bioeconomy that will enable the municipality and its citizens to move towards more circular strategies and a reduction of external dependence on materials and energy.

7. Data Quality Assessment

Numerous datasets were collected and considered in the Urban Circularity Assessment and this section qualitatively assesses how reliable the data used is. In some cases, datasets were not available for some materials or for some lifecycle stages for the city. Therefore, estimations needed to be done by looking at data at higher spatial scales (region or country) and downscaling it with proxies, described in the part on data gaps and assumptions.

The overall data quality is considered as well and depicted in the data quality matrix below. It is expressed through four data quality dimensions: 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 here. There may 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 sub-material groups and/or materials*	*1 data less than 3 years difference to the time period of the data set*	*City-level data*
medium	*Estimated data*	*Data exists for most of the single sub-material groups and/or materials*	*2 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 main material group only*	*3 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
Domestic extraction - MF1 Biomass		Data was found for all materials that are extracted locally.	2018 for satellite data. For non-satellite captured other crops and year 2014, data for those exact years were used. Crop yield were also employed for the respective years.	Local satellite data and CBS data for the municipality.
Imports & Exports	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
MF1 - Biomass	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
MF2 - Metal ores (gross ores)	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
MF3 - Non-metallic minerals	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
MF4 - Fossil energy materials/carriers	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
MF5 - Other products	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.

MF6 - Waste for final treatment and disposal	Proxy calculation makes it unreliable.		Data from 2018 and 2014.	National data.
Waste		Other waste origins are missing and matching is not adequate.	Data from 2018 and 2014.	Data on Apeldoorn municipality.
Material stock	Good material intensities and cadaster data.	Detailed attributes for each building.	Data from 1600 - 2022.	Building level data.

7.1. Data Quality

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 medium for most lifecycle stages (LCS) and material groups:

- The reliability of the data is fairly acceptable. For half of the LCS, the data were measured (domestic extraction and material stock), while the other half (imports & exports and waste) was estimated or provisional.
- The completeness of data scores medium for imports & exports and waste, while again, domestic extraction and material stock score high and are as complete as possible.
- The temporal correlation is very good for all lifecycle stages, as the data was almost always from the reference years (2014 and 2018). The Apeldoorn GDP data was used for 2017, while the stock data included up until 2022.
- The spatial correlation overall is medium at best. The material stock data on building is excellent (although national material intensity data are used), as is the satellite data for domestic extraction. However, it does suffer for imports & exports where national data was employed.

7.2. Data Gaps and Assumptions

Domestic Extraction

To measure biomass domestic extraction of crops in Apeldoorn, 2018 Eurocrops (D'andrimont et al. 2018) satellite imagery with cultivated land area and yield information were used. Statistical data from CBS also had cereals arable land area information at city level for the last 10 years. Finally, Eurostat has information on crops yield data at a NUTS 2 level, which were used to calculate the weight of extracted crops by multiplying yield with arable land area values. The weight of extracted crops was calculated using CBS arable land area data for 2014.

To determine whether other materials were extracted, several sources were considered. The Economy-Wide Material Flow Analysis data from Eurostat for the Netherlands over the last 10 years were essential to determine whether the extraction of some materials exists at all in the country (if they don't, then they can't be extracted in Apeldoorn). The SCA sources, mining websites and local employee numbers for extraction were used.

While it became clear that no metallic and fossil fuels were extracted, it is unclear whether non-metallic minerals were extracted in Apeldoorn as no mining information was found and no mining employees were registered locally. Therefore, non-metallic mineral extraction was considered as non-existent.

Imports & Exports

To the report authors' knowledge, imports and exports data at the city level does not exist. Eurostat provides national data for Imports & Exports, which were downscaled using employment by Industries and matching classes with relevant material codes. This method of downscaling imports and exports from national level using economic activities is a normal practice in similar assessments (Lavers Westin et al. 2020). However, in this case, downscaling with this method was not reliable overall, because the national level told a different story. From 2014 to 2018, the absolute imports and exports increased nationally, 9% and 6% respectively, while the overall workforce decreased nationally by 6% and 1% in Apeldoorn. In some economic activities, there were drastic changes. For example, in the "MF42 - Liquid and gaseous energy materials/carriers industry", there was an increase of 409% in the persons employed in the Netherlands, but in Apeldoorn it only grew by 17%. Although the imports of liquid and gaseous energy materials/carriers increased by 22% nationally, because of the reduced employee proxy, it appears that there is a decreased import of those materials of 72%. This shows that data from local production companies on imports and exports are necessary to obtain results accurately at the city level. The results of this downscaling still provide some surprising results, as it implies that a very small quantity of MF3 are imported and none are extracted. This is highly unrealistic as construction flows often account for 1/4 to 1/3 of the flows entering an economy) and a more detailed analysis on the construction sector should be carried out separately.

In this case, values were estimated from provisional data by downscaling imports and exports using employee information with detailed NACE classification from Apeldoorn municipality and from CBS at national level to calculate the proxy ratio to be used for specific MF codes. To do so, first NACE codes were matched to CPA, and CPA to MF since the correspondence from NACE to MF does not exist. After matching MF values by adding up the respective NACE classes that related with MF classification, the final proxy ratios to be used to downscale national values were calculated. Although there were four-digit NACE codes available, some employees could belong to different MF classes at the same time. Consequently, this method includes double counting in the matching process between NACE, CPA, and MF, leading to some employees being counted multiple times in some instances. While not desirable, it was necessary to do so in order to match with the Mayer et al. framework that requires more detail than the MF 1-digit level information. The results were driven using this methodology.

It is important to mention that Eurostat also provides national road freight information loading (export) / unloading (unloading) by group of goods in NUTS 3 level, in this case “Veluwe”. However, this dataset only includes road freight information and excludes maritime, rail and aviation transport modes. Additionally, only main groups of material information (MF codes with 1 digit) can be matched with groups of goods using conversion table NST07 to MF codes. Since this data is on NUTS 3 level, not on the city level, it would also need downscaling. Furthermore, the NUTS3 level road freight dataset contains information on national road transport by a vehicle registered in a given country, here only in the Netherlands, between two places, which may result in some information being missed, i.e. all the road freight from vehicles outside of the Netherlands. Nevertheless, this data was used to cross check whether the values from the two sources (road freight vs. downscaled national values) are comparable. It was found that road freight values were close to 10 times bigger than downscaled national values, for all the available proxies of land area, population, employment and GDP. Therefore, using road freight was found to be inadequate and economic activities were used as a downscaling proxy.

A final way to estimate imports and exports would have been to estimate the consumption and production levels of Apeldoorn and their associated imports and exports flows. However, while this would have probably been the most accurate way, production and consumption patterns would have been very time consuming to be measured, which was unfeasible in the amount of time available.

Domestic Material Consumption

As DMC is a measured indicator (DMC = DE + IMP - EXP) no extra assumptions were made, neither data collected to calculate this indicator. However, it inherits all assumptions and uncertainties from the two previous sections.

Waste

After reviewing the main possible sources, Eurostat, CBS, Apeldoorn (municipality) annual reports, and the websites of the leading companies dealing with waste at a city level and seeking to understand how waste management works in Apeldoorn, most of the information retrieved was about household waste.

The CBS household data were available in kg/inhabitant. It was, therefore, necessary to multiply the quantities by the population in each reference year and convert these results to tonnes.

In order to estimate values for the final destination of waste, in terms of waste treatment, a *correspondence table of EWC with treatment operations* was used, since there was a lack of direct information on the fate of wastes and their treatment. The analysis was done for each waste stream, along with the treatment that corresponds to it. In the waste categories where there is more than one treatment available (there were three), the treatments were divided up into equal shares.

The data on the exact amounts of waste and their treatment is accessible to the city of Apeldoorn, but could unfortunately not be obtained at this stage. The same is true for the remaining industrial and commercial wastes, albeit data could not be retrieved for a different reason: waste from these types of origins are not collected by the city of Apeldoorn or covered in its policies. Instead, every company has a private contract with a waste company, which results in several waste companies collecting waste from the industry or other organisations. They do have to report to AMICE, the national waste register, however, this data is highly confidential and not disclosed.

Material Stock

For the analysis of the building stock material, data from the Dutch cadastre (pdok) were used, in particular through the Key Register Addresses and Buildings (BAG). The following information on the buildings was obtained: geometries, year of construction, gross floor area and typology.

For the correct calculation and matching of typologies, this dataset was enriched with 3DBAG heights using the elevation above sea level at roof level, calculated as the 70th percentile of all elevation points on the corresponding roof parts and corrected with Amsterdam Ordnance Datum at the ground level of the building, calculated as the 5th percentile of the ground points found within a 4-metre radius of the building.

In addition, for the calculation of the material stock, the material intensities of the Dutch Building Stock, analysed by Sprecher et al. (2022), were used. Their research paper analyses the MI by studying 61 large-scale demolition projects with a total of 781 data points, representing more than 306,000 square metres of built floor space. The dataset is representative of the types of buildings being demolished in the Netherlands.

The material intensities provided by Sprecher et al. have been linked to the dataset of this study matching the typologies with spatial methods described above, using the typology, height and spatial configuration.

The data used are of high quality; however, during their pre-processing, some of the information was lost. Initially, 122,555 buildings were available, of which 63,492 had a gross floor area and of which 61,138 had heights, leaving the latter to be included in the analysis, due to insufficient data (either missing gross floor area or heights) of the rest. Therefore, it was possible to analyse 49.8% of the building stock. A spatial examination of these data, which could be carried out thereafter, shows that the previously excluded units (that do not have a gross floor area) correspond to annexes to the dwelling, such as garages.

8. Analysis of Data and Indicators: Assessing Circularity

This last section of the UCA report analyses the status quo in terms of material circularity in Apeldoorn. It takes into account the findings visualised in the (Sankey) diagrams and the conclusions from the indicators. The overall results of the Urban Circularity Assessment are discussed and interpreted here, before providing recommendations to accelerate the transition towards a more circular Apeldoorn.

8.1. Insights on Status Quo of Apeldoorn

After assessing the circularity of Apeldoorn, it becomes clear that the city is an open system that throughputs materials, but does not cover its needs, nor reuses sufficiently the materials that it outputs. As most European cities, the import flows far exceed the domestic extraction. In addition, most of the local extraction and production are exported to satisfy consumption from other territories.

Almost half of the materials processed locally are used for energetic uses whereas the other half is for material uses (most of them employed for the construction and renovation of buildings). Energetic use is responsible for the vast majority of emissions, which in comparison to imports and exports flows "weigh" less, but are responsible for other related challenges such as climate change.

It is also clear that a very small quantity of waste generated is following a circular economy practice (reuse, recycling, etc.). This quantity represents an even smaller share (6%) of the processed materials.

As such Apeldoorn is clearly a linear and carbon-rich city (90-95% linear) processing yearly approximately 650 kt, adding 13 kt in the building stock and reinjecting just 4 kt of materials in their economy. From these numbers the magnitude of the efforts becomes visible. In addition, the "weight" of Apeldoorn can be illustrated through its building stock which amounts to 15,000 kt (or 95 t per capita) which requires continuous flows for both its operation and construction. The study of Apeldoorn's material stock provides valuable insights about how to reduce the extraction of virgin materials, reduce waste flows going to landfill and increase the reuse and recycling of construction materials. Knowing where and when materials entered Apeldoorn's urban mine, enables to forecast output flows and where they will emerge. In addition, the insights from measuring the material stock could not only propose circular strategies in the construction sector, but propose where to locate reuse hubs, develop a materials marketplace and estimate jobs creation (in material handling, logistics, etc.).

The results provide a unique first insight about the materiality of Apeldoorn's economy. Nevertheless, it also highlights how scarce the knowledge and data about such topics are. When collaborating with the city of Apeldoorn, it becomes very clear how information and datasets are siloed, confidential and sometimes absent. This new type of systemic exercise required to pull together information from national, local and company level. It showcases the difficulty of understanding how cities function in physical, economic and employment terms and therefore how difficult it is to produce systemic policies.

From this first exercise, numerous data sources were scrutinised, analysed and processed to carry out the presented analyses. Admittedly, the data required to carry out this analysis were frequently missing at Apeldoorn's scale, although they existed at higher spatial levels. This implied that numerous assumptions and calculations were needed to be carried out, in order to downscale data at a city level. This compromised the quality of the results, but still provides a solid basis for understanding, using an accounting method that has been validated and used at a national and European context. In the future, further validations by comparing values with other Dutch cities and the Dutch economy could be carried out. Further recommendation about how to use the results of this study and how to improve it can be found in the next section.

8.2. Recommendations for Making Apeldoorn More Circular

Several opportunities to make Apeldoorn more circular appeared through the UCA:

- **Develop a bioeconomy**: Given the land use of Apeldoorn (78% covered by vegetation), this provides a considerable opportunity to develop a circular bioeconomy. For instance, a significant share of biomass demands of Apeldoorn could be covered by local production of food. In addition, a part of this biomass could be used for energetic use reducing the demand of imports and partly GHG emissions.

- **Create reuse opportunities**: Given the space available in Apeldoorn, local hubs for storing materials for reuse from the construction sector could significantly reduce the use of virgin materials as well as reduce construction and demolition waste generation. Ideally, Apeldoorn should also better regulate new constructions by filling existing vacant buildings instead of constructing new ones. Vacant buildings could also host new productive activities which could use small waste flows (coffee waste, bread waste, composting, etc.) and transform them locally for its inhabitants.

- **Support collaboration**: Apeldoorn could play an active role in all these new actions by developing a circularity roadmap. This could be carried out by elaborating further the actions presented and identifying the stakeholders responsible for implementing these actions as well as budgeting the efforts and money required. By collaborating more closely with extraction, production and waste management companies, it would be possible to also refine the data necessary to assess and monitor the circularity of Apeldoorn. To do so, a number of online tools could be used (or developed). For instance, a circularity roadmap manager which lists the circularity actions to be developed and tracks their progress, a forum and a map showcasing where they take place. Another tool which could be used is a material/space/equipment matchmaking tool such as *PlatformU.*

- **Collect better data to monitor the situation**: The current analysis provides a first baseline of Apeldoorn's circular assessment. It provides insights about how to make the city more circular. However, it also highlights how important data collection of material flows is essential to propose actions. This exercise showcases where future efforts should be placed to make the analysis more relevant as well as develop internal capacity. More specifically, here are some proposals to enhance the quality of the assessment for future iterations.
  - For imports & exports, it is essential to get more granular and qualitative information of the flows by looking at production flows (a local survey with the productive activities could be a good start) and consumption flows (a local survey with consumption patterns of households and other segments of the population).
  - For waste, more detailed information on their treatment (landfill, incineration, energy recovery, recycling, and backfilling) and waste categories (chemical and medical wastes, recyclable wastes, equipment, biomass, mixed, mineral, and metallic wastes) would be needed to get a sense of the circularity practices and how to improve them. As mentioned in the data quality part, only household waste and manure could be included. This significantly underestimates the total amounts, misrepresents the situation and fails to unravel opportunities for circular economy activities, since the potential of waste streams remains unknown. A better characterisation of commercial and industrial waste should be done using confidential data internally.

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- Netherlands
- Gelderland
- Veluwe

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

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

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

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

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