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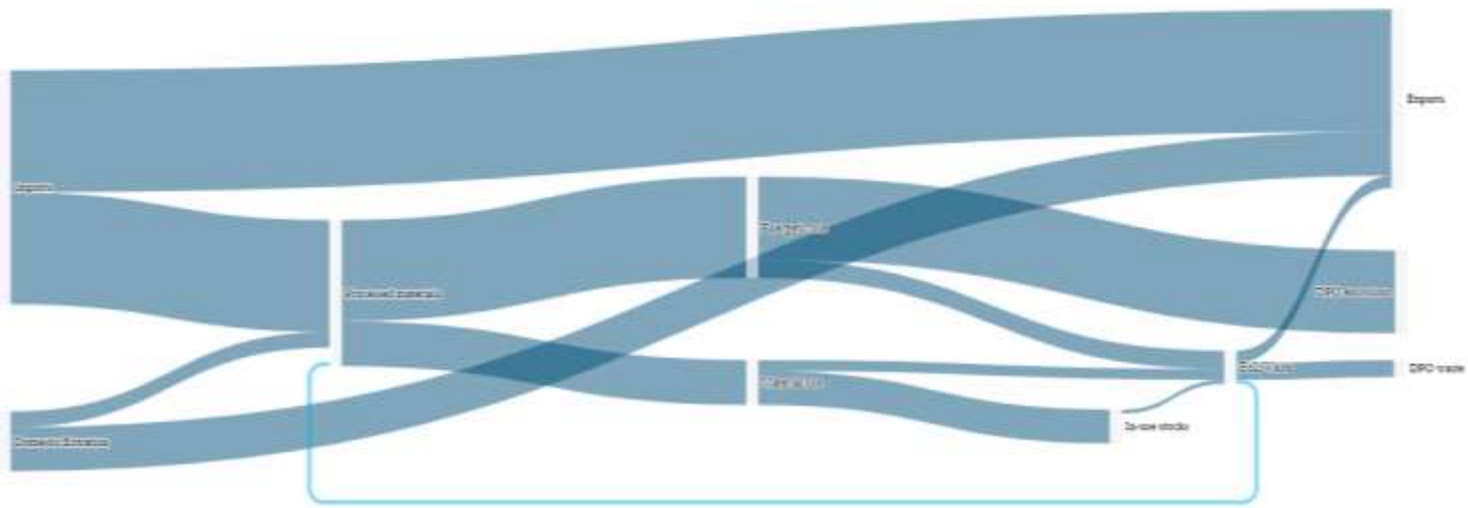
CITYLOOPS

URBAN CIRCULARITY ASSESSMENT SEVILLA

Deliverable 7.9

Metabolism of Cities



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Abstract	This Sevilla's Urban Circularity Assessment report presents gathered information and main findings on the local economy material flows for 2016 and 2020, as well as the building stock accounting. It provides city contextual information and local economy under study and then illustrates the quantities of flows in single parts of the supply chain, summarised by a Sankey diagram, followed by a material stock map. Both of accounted materials are evaluated as circularity indicators and their data quality. Finally, results are analysed and interpreted to determine a status quo, taking into account data limitations in order to offer recommendations for achieving greater material circularity in the municipality of Sevilla.
Keywords	Urban circularity assessment; Material flow accounting; Building stock; Circularity indicators; Urban metabolism; Circular city;
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Contents

Summary

Sevilla is a Spanish municipality located in the province of the same name (Sevilla). It has, according to the continuous census of inhabitants (National Institute of Statistics -INE-) as of January 1, 2022, a population of 681,998 inhabitants spread over an area of 141.28 km^2. Its local economy, in terms of number of companies (Directory of Establishments and Companies with economic activity in Andalusia), is mainly based on the economic activities of the service sector.

According to the application of the UCA methodology, Sevilla needs annually some 3,259 kt of raw materials and other materials. The main entry point is imports, since local production is quite limited (607 kt). In the internal urban circuit, it processes 1,750 kt in materials, of which 375 kt are added to the stock of buildings and urban equipment and the rest are destined for domestic consumption. It manages to reinject 174 kt of secondary materials recovered from waste into the economic circuit.

The main conclusion drawn from this initial UCA assessment is that Sevilla is basically a resource-consuming city. This conclusion is a logical result if we take into account that, of the land uses of the municipality of Sevilla, only 8.23% is covered with vegetation and only 33.7% is agricultural land, so that most of the municipal surface is occupied by urban infrastructures (residential, industrial and commercial) and other urban facilities, which require many materials for domestic consumption. The "weight" of the city of Sevilla can be illustrated through its building stock, which amounts to 70,960 kt (or 103.7 t per capita), which requires continuous flows of materials, both for its operation and for its construction.

Besides, a total of 1,282 kt of imports, to which a further 440 kt of local production must be added, go directly to outlets in the materials cycle. Therefore, Sevilla is also an exporting city. Not of processed materials, since it does not have a large goods and equipment industry, but of the imported materials themselves, which are directly destined for export. In recent years, Sevilla has become a logistics hub of some national importance in the transportation of goods, either for Spanish domestic trade or for international trade, as shown by the import and export data.

From these figures, the effort needed to improve circularity becomes evident, especially when the limited availability of agricultural land offers few opportunities to develop a circular bioeconomy, making Sevilla a city highly dependent on the exterior, forced to import a large part of its materials, especially fuels for energy and non-energy uses and construction materials, but also agricultural raw materials and processed food products.

Numerous data sets were collected and processed for the UCA, which are nested in several linked spreadsheets. Those interested in understanding the data or replicating the process can contact Metabolism of Cities (info@metabolismofcities.org). The Urban Circularity Assessment (UCA) of the municipality of Sevilla 2020 and its comparison with 2016 has been prepared between 2022 and 2023. The assessment has been completed in July 2023.

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 Sevilla are (planning to) implement demonstration actions to kickstart their circularity journey. To better understand what the current circularity status quo is, as well as the impact of these actions, and the efforts needed to transform their 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 gathered information in seven sections:

- *Urban Context*
- *Economic Context of Sevilla*
- *Material Flows in Sevilla*
- *Material Stock in Sevilla*
- *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 Sevilla.

(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 Sevilla. 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 Sevilla 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 Sevilla

The municipality of Sevilla is made up of 11 districts, which are administratively subdivided into 108 neighborhoods and these, in turn, into 542 census sections. The population of Sevilla has decreased by a total of 2,236 people in relation to the year 2021. The decrease is much more pronounced among women (-1.199) than among men (-1.037) and district 7 is the one that has lost most population, corresponding to Sevilla Norte, with a total of 871 inhabitants (436 women and 435 men), equivalent to a variation rate of -1.21% in relation to the previous year.

The most populated district in Sevilla is District 9, corresponding to Sevilla Este-Alcosa-Torreblanca, with a total of 104.629 people, representing 15.34% of the total population of Sevilla. The least populated district is District 11, corresponding to Los Remedios, one of the city's financial and economic districts, which only concentrates 3.67% of the population.

The loss of population in Sevilla has been a general trend in recent decades. The population has gone from 704.154 inhabitants on January, 1, 2005 to just under 682.000 on January, 1, 2022, a reduction of -3.1% in about 15 years (SIMA-IECA 2022). However, the loss of the largest population recorded in Sevilla (709.975 inhabitants on January,1, 2003) in a longer series of analyses since 1996, has come to represent a decline of 3.6% of Sevilla population.

Between 2016 and 2020, the two reference years of this circularity study, the number of inhabitants of the municipality of Sevilla has decreased by 5.200 people, from 689.434 in 2016 to 684.234 in 2020 (SIMA-IECA 2022).

The situation has been similar with sex disaggregated data. In both cases, the population has decreased over the last 15 years. In the case of men, the reduction has been 3.8%, while in women it has meant a smaller loss of 2.6%. In the reference years of this study, the male population has gone from 327.162 men in 2016 to 324.312 in 2020 (-2.850 men), while women have gone from 362.272 to 359.922 (-2.350 women).

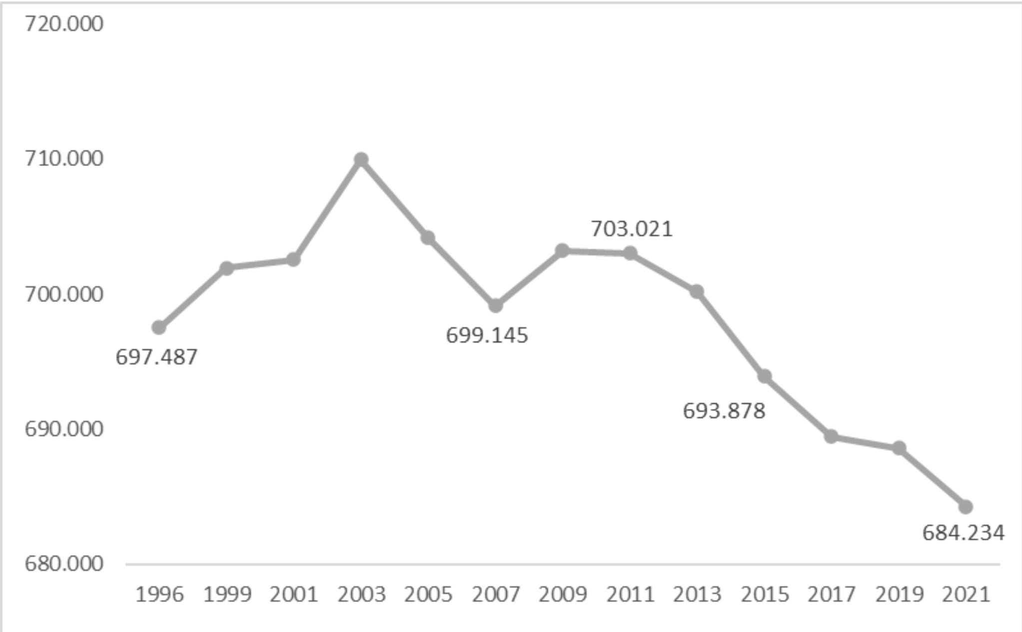

Figure 1 - Population of Sevilla.

Currently, according to age distribution, around 14.3% of Sevilla population is in between 0 and 14 years old, while 19.9% is over 65 years old. The majority of the population is between 45 and 64 years old (29.4%), while the bulk of the total population, 65.9%, is between 15 and 64 years old (SIMA-IECA, 2022).

2.2. Land Use

Total Sevilla municipality area covers 141.28 km^2. Of these, 135.10 km^2 (95.1%) are land areas, while the rest is covered by inland waters (7.03 km^2) (SIMA-IECA 2016), highlighting the Guadalquivir River that divides Sevilla city in two. This land is mainly dominated by urban areas (58.8%) and agricultural land uses (28%), while only 4.9% of the entire municipal area is covered by forest vegetation.

Sevilla's land use is urban and mostly classified as residential, but it has public facilities, services, free spaces, transport and basic infrastructures. The historic area is composed of 3.9 km^2. Green spaces occupy only 1.8 km^2 of territory.

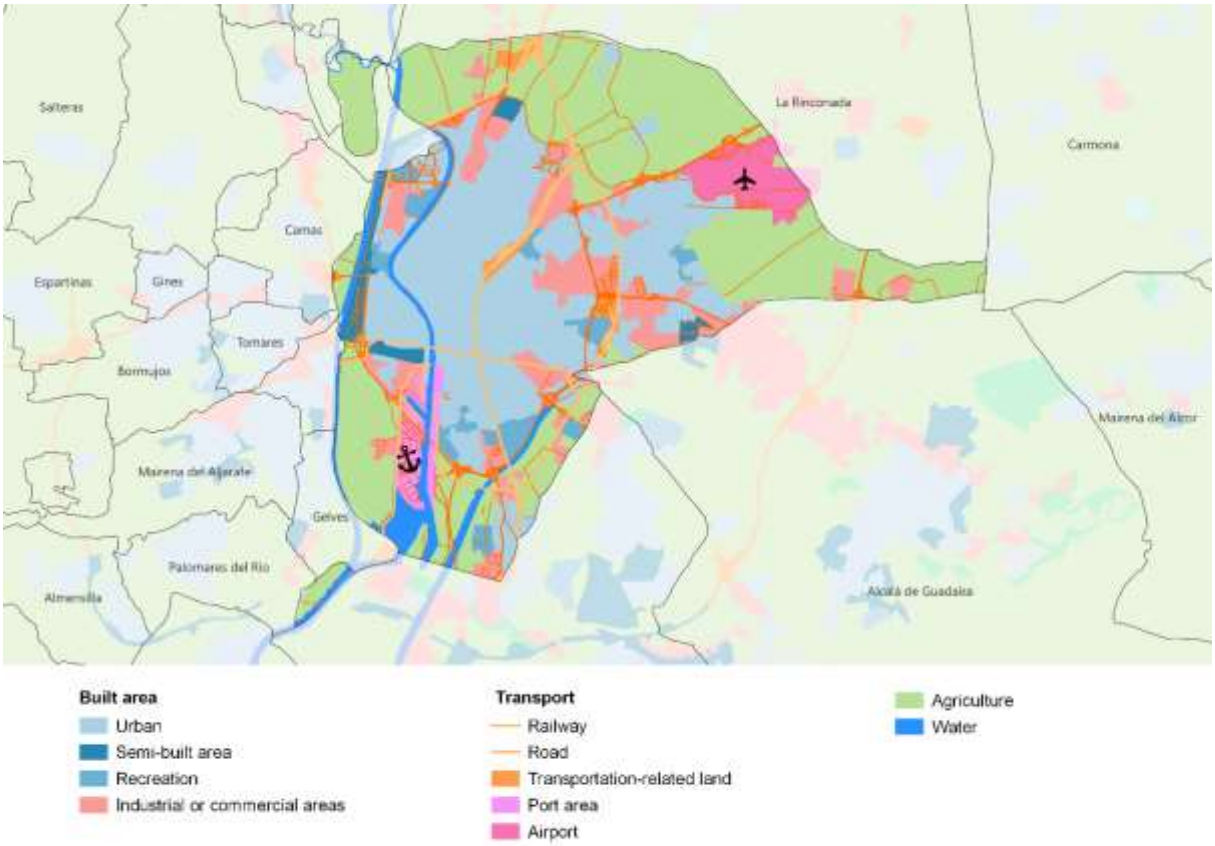

Figure 2 - Land use map.

According to the IECA's Urbanization Degree classification, Sevilla can be characterized under the typology “densely populated areas” (those municipalities in which at least 50% of the population resides in cells typified as urban centres), which corresponds to 95, 6% of the population living in densely populated urban areas and only 2% in rural areas (SIMA-IECA 2022); and the city itself has a marked urban character, as is made up mainly of neighborhoods, 63.1% of the surface area is mixed urban, business parks (12.2%) and transport infrastructure (22.7%) (SIMA-IECA 2016).

Rural area is basically made up of agricultural lands and transport infrastructures, as well as linear river systems, centered on the Guadalquivir River that runs through the municipality in the north. The Sevilla airport stands out in this rural context, located less than 7 km away from city center.

3. Economic Context of Sevilla

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 2020 (MONETARY VALUE, IN THOUSANDS OF €)	EMPLOYEES (2020)
Sevilla	-	265.900
Sevilla (NUTS 3)	41.972.710[1]	718.900
Andalusia	165.581.000	3.083.000
Spain	1.245.513.000	19.344.300

Sevilla has a highly outsourced economic structure, consistent with Andalusian and Spanish economic activity, which is highly dependent on the service sector. According to the Labour Force Survey (INE 2020), city of Sevilla has a total of 265,900 employees (2020). The economic sectors with the highest number of employed people in Sevilla are "Services", with more than two thirds of total employed people (76.7%) and "Industry" with 11.5%. The "Agriculture" and "Construction" sectors account for 5.9% of the employees.

As for the economic activities with the highest number of employees (provincial level -NUTS 2-) are "Public administration and defence; compulsory social security; education; health and social work activities; artistic, recreational and entertainment activities; repair of household goods and other services" (34.3%), "Wholesale and retail trade, repair of motor vehicles and motorcycles; repair of motor vehicles and motorbikes; transport and storage; accommodation and food service activities; information and communication" (29.2%) and "financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities" (16.7%). The lowest occupational occupation rate is devoted to "Agriculture, livestock, forestry and fishing" with only 4.6% (Spanish Regional Accounts, INE 2019[2]).

In 2021, a total of 50,376 companies were registered in Sevilla, which implies 2,695 more than in 2020, as the economic activity sections "Agriculture, livestock, forestry and fishing" and "Public administration, defence and compulsory social security", previously not included in the Directory of Establishments and Companies with economic activity in Andalucía (IECA, 2021), were included for the first time in the statistics. Taking into account this incorporation, it is estimated that, in 2020, a total of 50,232 companies existed in Sevilla, with companies dedicated to "Real estate, professional, auxiliary, auxiliary, artistic and other services

[1] Estimate based on the average GDP growth of Sevilla (NUTS2) in the historical series of the last 8 years (2011-2019) Estimate based on the average GDP growth of Sevilla (NUTS2) in the historical series of the last 8 years (2011-2019).

[2] Provisional data

activities" and "Trade" standing out, with 37.0% and 22.6% of the total, respectively, followed by other economic activities such as "Public administration, education and health" (10.5%), "Hotels and restaurants" (8.4%) and "Construction" (7.1%). Industrial activity is quite a minority in terms of the number of companies, only 1,810, 3.8% of the total, but it stands out as the third activity with the highest number of large companies (250 or more employees), only behind public administration and real estate, professional, auxiliary, artistic and other service activities.

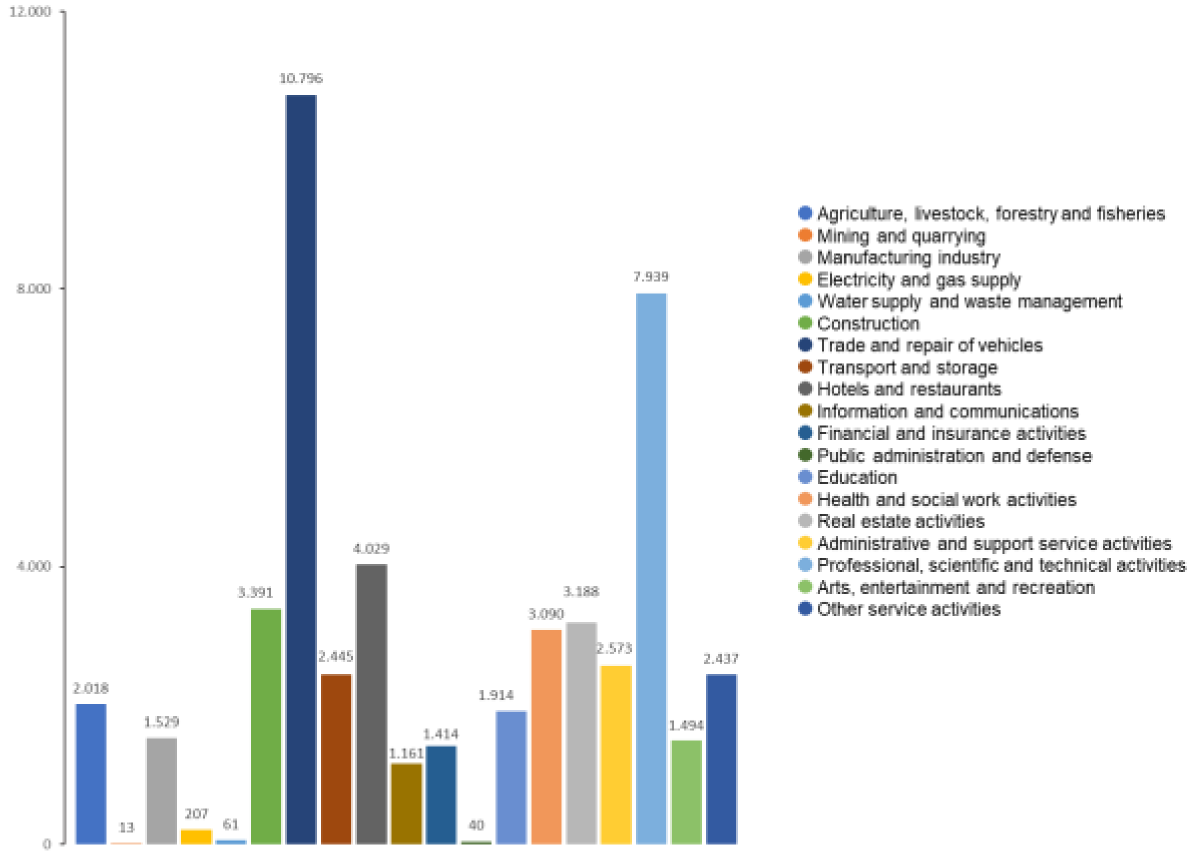

Figure 3 - Number of companies in Sevilla.

In total, most enterprises are engaged in "retail and wholesale trade" (9,923), "food and beverage service activities" (3,480), "real estate activities" (3,188) and "legal and accounting activities" (3,098). A very small number of enterprises are engaged in "agriculture, forestry and fishing" (IECA 2020) and only 11 enterprises are engaged in mining, quarrying or other extractive industries.

As Sevilla is a city for small businesses (14%), business activity is widely spread throughout the urban fabric. However, several local shopping areas stand out. “Casco Antiguo” and “Los Remedios” are the main districts with open commercial areas, while other neighbourhoods stand out for the presence of large shopping centres; Torre Triana, Los Arcos or the more recent Lagoh Sevilla are examples. Industrial activity is concentrated in the industrial estates on the city outskirts, mainly in the north-east. To the east of the city, on the railway A-92 exit towards Malaga-Granada, is the “Mercados Centrales de Abastecimiento de Sevilla”

(MERCASEVILLA), the main wholesale market for fruit and vegetables, fish and meat in Sevilla and the province; and to the south is the ZAL Sevilla (Logistics Activities Zone), within the port area, designed specifically for logistics; on SE-30 ring road, the Campus Abengoa Palmas Altas, one of the most important companies in Sevilla dedicated to infrastructure, energy and water sectors. Logistics and transport are an emerging economic sector that can be attributed to the accessibility and availability of the business parks.

In monetary terms, the province of Sevilla (NUTS 3) generated approximately 38,220.87 million euros of Gross Domestic Product in 2020, equivalent to approximately 24.6% and 3.3% of the Andalucía (NUTS 2) and Spain (NUTS 1) GDP, respectively. The economic activities that contribute most to this provincial GDP are mainly from the service sector (68.65%) and, at a great distance, the manufacturing industry (8.38%).

Within the framework of services sector, public administrations, including defence and social security, education and health activities and social services activities are the main contributors to GDP with 8,024.27 million euros, 28.43% of total GDP, while trade, repair of motor vehicles and motorbikes, transport and storage and hotels and restaurants contribute a further 16.29% (6,226.27 million euros), with real estate activities and commercial activities and vehicle repair shops being the main economic activities in the province of Sevilla with 12.14% and 10.47% of the total, respectively. The industrial, construction and agriculture sectors together, accounted for 21.53% of provincial GDP (Spanish Regional Accounts, Statistical Review 2019, IECA).

Manufacturing industry

The manufacturing industry has a token presence in the city of Sevilla considering the total number of existing companies (3.2%), with most of their activities accounting individually for less than 0.5% of total. Of the 1,529 existing industries (Directory of Establishments and Companies with economic activity in Andalusia, IECA 2020), the one with the greatest presence in the municipality in relation to the use of raw material domestic extraction with agricultural origin is the food industry (202 companies), given that the annual municipal production is a minimal part of the annual raw material needs of these companies, so that the import of materials related to biomass is the fundamental basis of this industrial activity. Moreover, it is an activity that has suffered a decline in the last year, with 31 companies falling in 2021.

As for other biomass manufacturing industries, the paper, furniture or beverage manufacturing industry has an even smaller presence in Sevilla with only 88 companies out of the total, of which 60 are furniture manufacturing companies, which require a complete import of their raw materials provided the wood production lack at a local level.

Waste sector in Sevilla

Given that waste is an essential component of Urban Circularity Assessment, what follows is a very close estimate of waste management companies actual situation, to underline Sevilla output flows and set up to deal with them, based on the information available in the

Andalusian Environmental Information Network (REDIAM, Indicadores del Informe de Medio Ambiente de Andalucía, 2022).

In Sevilla there are a total number of 35 non-hazardous waste management facilities and 27 hazardous waste management facilities. What concerns to hazardous waste facilities, we can basically find 4 different typologies, among which temporary storage facilities stand out (40.7% of the total). The rest of the hazardous waste facilities are for soil decontamination (2) or end-of-life vehicles (8) and materials recovery (6).

Typologies are more differentiated for municipal waste facilities. Main waste treatment plant, Montemarta Cónica Integral Urban Waste Treatment Centre, final destination of most Sevilla's municipal waste, is located in the neighbor municipality of Alcalá de Guadaíra (province of Sevilla). Managed by Abonos Orgánicos Sevilla (ABOGARSE). This facility covers more than one and a half million inhabitants of Sevilla and its metropolitan area and has managed a total of 668,000 tonnes of waste in 2020 (Sustainability Report, Abogarse 2020), 57.3% belonging to Sevilla city.

The rest of facilities are mainly used for intermediate operations prior to the waste final recovery, either prior conditioning or other intermediate operations with a final destination for recovery or disposal. They account for 68.6% of all treatment installations, followed by those for soil treatment (17.1%) and, at a considerable distance, recovery of organic substances not used as solvents or metals and metallic compounds (2+2 installations in total).

4. Material Flows in Sevilla

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 Sevilla 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.

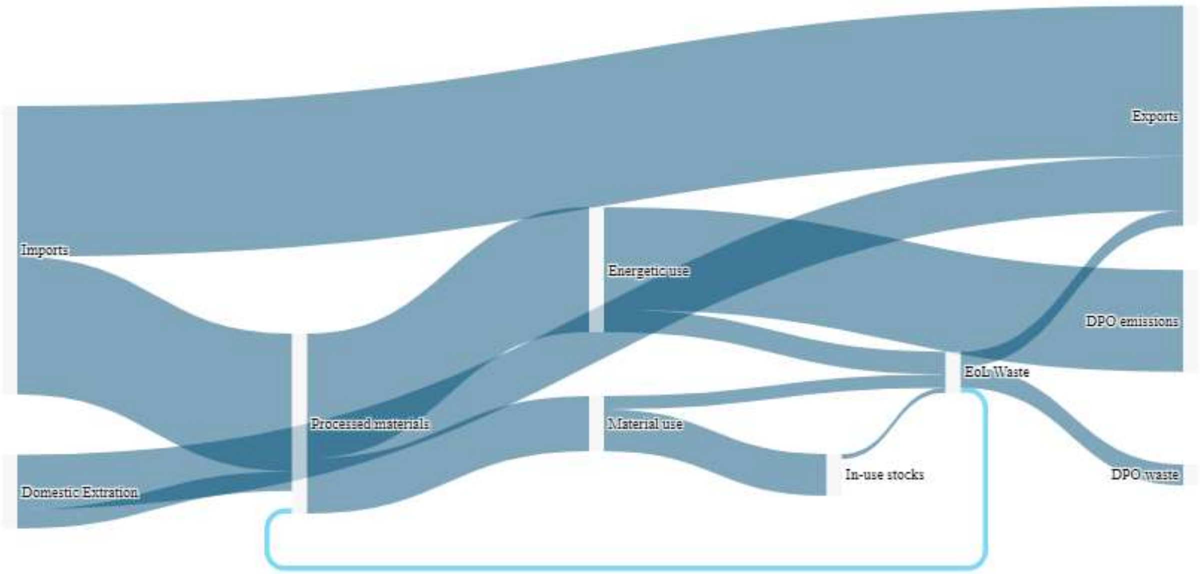

Figure 4 - Sevilla *Sankey diagram*

4.1. Domestic Extraction

Most of Sevilla municipal area is occupied by urban uses (residential housing, public buildings, commercial and industrial spaces and the rest of the urban infrastructures). The area destined for agricultural uses is very small. Only one third of the municipal area has agricultural uses (4,763 hectares). It is evident that, with this space available for production, domestic extraction (DE) of biomass, minerals as well as fossil fuels plays a very residual role in Sevilla, as can be seen in the Sankey diagram. Basically, local extraction is limited to biomass materials, as well as occasional extraction of non-metallic minerals (sands and gravels).

Given that Spain is not a country with fossil energy sources (oil or gas), apart from the natural gas deposits in offshore areas in the south of the country, no extraction of these energy materials was expected for Sevilla.

The total biomass locally extracted was 607,015.18 tonnes in 2020 and 1,117,219.22 tonnes in 2016, representing a decrease of almost half of local production (-45.67%) between the two years.

The total biomass locally extracted was 607,015.18 tonnes in 2020 and 1,117,219.22 tonnes in 2016, representing a decrease of almost half of local production (-45.67%) between the two years.

Basically, this domestic extraction is marked by the production of gravel and sand for construction associated with the two mining rights licences for the extraction of these materials (Mining Cadaster of Spain, MITECO), which, although in 2020 has seen its contribution to total local production fall to 89.10%, in 2016 it accounted for 96.82% of total domestic extraction. Thus, in 2020, the extraction of sand and gravel accounted for 540,851.37 tonnes, while in 2016, it almost doubled this amount (1,081,702.75 tonnes).

The rest of materials locally generated accounted for only 3.18% in 2016, increasing its presence to 10.90% in 2020.

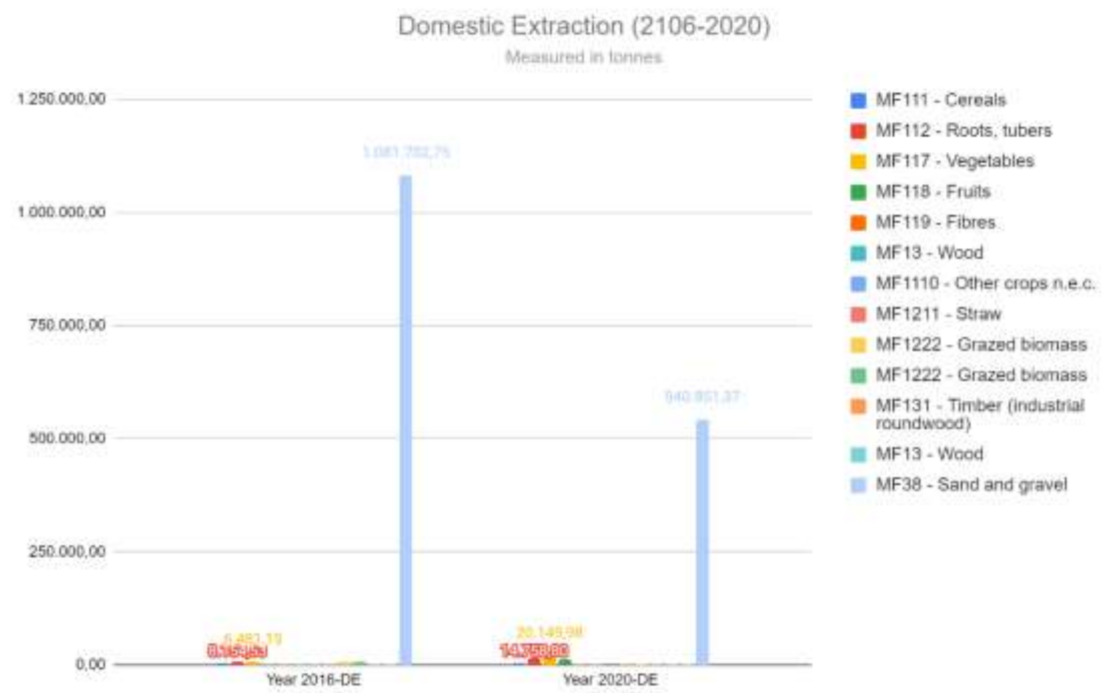

Figure 5 - Domestic Extraction in Sevilla.

As for Biomass (MF1), as can be seen in the following graph, 2020 production is dominated by crops (MF11), excluding fodder crops, which account for 91.72% of the total and

60,684.24 tonnes per year. Within these crops, vegetables stand out with 20,149.98 tonnes (30.45%), tuber crops with 14,758.80 tonnes (22.31%) and fruit trees, crops that have been gaining ground in Sevilla's production, so much so that they have gone from being a minority crop in 2016 (1,693.1 tonnes) to being the 3rd most important crop in local production, placing production at over 11,900 tonnes in 2020 (18.00%). These woody crops are accompanied by the cultivation of olive groves for oil, the main oil crop in the city of Sevilla, which has also seen a considerable increase in recent years to reach 8,500.91 tonnes.

Finally, associated with the presence of some livestock near the city, a total of 4,377.47 tonnes of fodder crops and pasture for different types of livestock have been harvested.

The rest of the biomass extracted is marginal and accounted for a total of 293.20 tonnes in 2016 for other crops n.e.c., while only 188.25 tonnes were harvested in 2020. Likewise, the crop areas from which straw is harvested, 520.29 tonnes in 2016, have seen their production increase to 1,480.65 tonnes in 2020.

For the rest of the crops, it has been necessary to resort to provincial (NUTS 3), Andalusian and even national extractions, bearing in mind the potential existence of these productions in those areas of mixed or undefined agricultural uses in the statistical or cartographic bases. To do this, an extraction had to be made with a proxy of local surface area to which, in addition, an approximation factor of the existing agricultural surface area in Sevilla has been applied.

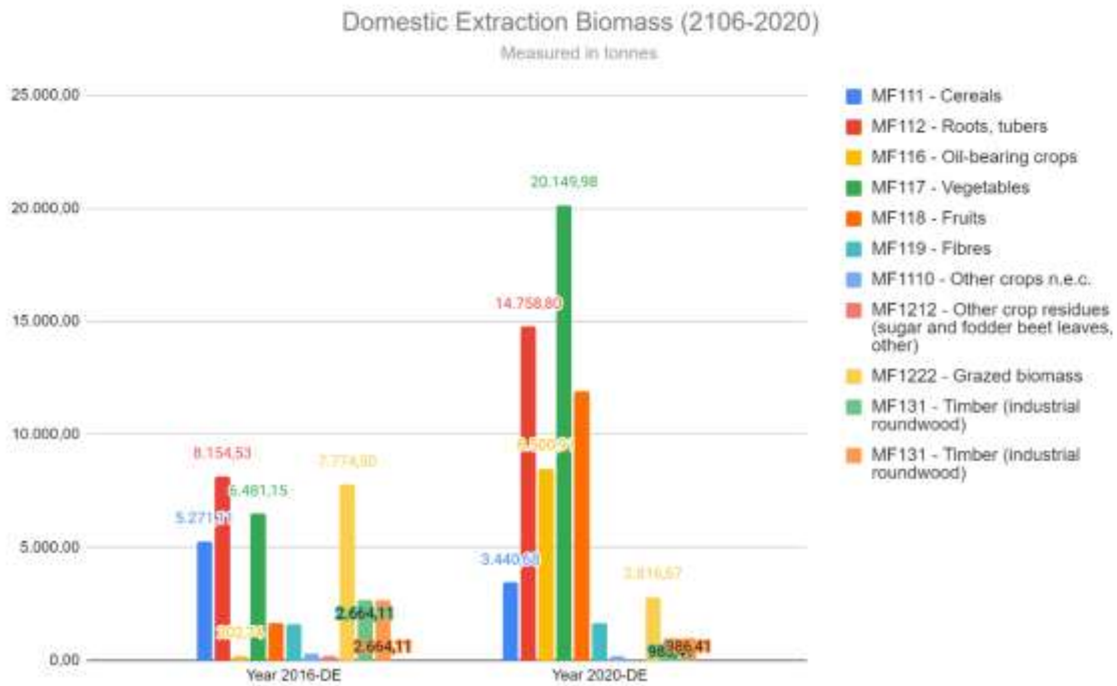

Figure 6 - Domestic Extraction Biomass in Sevilla.

Among the crops for which approximation has had to be used are the extraction of wood for industry, given that Sevilla has, according to SIMA-IECA data, more than 67 hectares of timber forest, which has allowed us to estimate a production of wood for industrial uses of 1,102.09 tonnes in 2020.

4.2. Imports & Exports

Sevilla is eminently a consumer city as it does not have sufficient domestic production of materials and products for self-sufficiency. Hence, imports and exports represent a very large part of the Sevilla's economy flows inputs and outputs (much larger than domestic extraction), as can be seen in the Sankey diagram.

On the other hand, the difficulty in obtaining import and export data at the city level makes these values considerably less reliable than those of Domestic Extraction (as will be discussed in the part on data quality).

In the case of the city of Sevilla, no (measured) data were found for import and export flows. The most reliable data found for the analysis were the provincial (NUTS 3) data on imports and exports, which, in turn, were reduced with a proxy based on the number of employees per sector (NACE code) based on the CPA codes of imported/exported products.

In this sense, we have chosen a detailed analysis of goods into Sevilla inputs and based on transport, using the same methodology as other cities in the Cityloops project (i.e. Apeldoorm). There are four possible inputs and outputs of goods: road, ship, airport, and rail transport. As can be seen in the figure below, between 2016 and 2020, road traffic is responsible for 93~95% of city imports and exports.

Imports

Total import amount from Sevilla goes from 4.349.376,89 tonnes during 2016 to 2.995.161,98 tonnes for 2020. These significant reductions in annual imports have been partially offset by some materials, for which annual imports have seen significant increases. Among the materials with the largest increases are all biomass materials (MF1) and non-metallic mining (MF3). Thus, among agricultural crops, the increases in pulses imports (+92.3%) or fibre (52.5%) stand out, while in absolute values (tonnes), the 26,766.57 tonnes of cereals, the 12,571.11 tonnes of oil-bearing crops or the 11,078.61 tonnes of timber (industrial roundwood) stand out.

By materials, the group of liquid and gaseous energy materials/carriers (MF42) stands out above the rest, with a decrease of 976.2 thousand tonnes (-45.13%). Within this group, the fall in imports of crude oil, condensate and natural gas liquids (NGL) is particularly striking, by over 751.4 thousand tonnes (-42.73%). Coal and other solid energy materials/carriers, such as lignite (brown coal) or hard coal have seen their imports reduced almost entirely. Natural gas has also reduced its imports in 2020 compared to 2016 by 67.9%, as well as the import of waste for final treatment and disposal, that has fallen in 2020 by 92.05%.

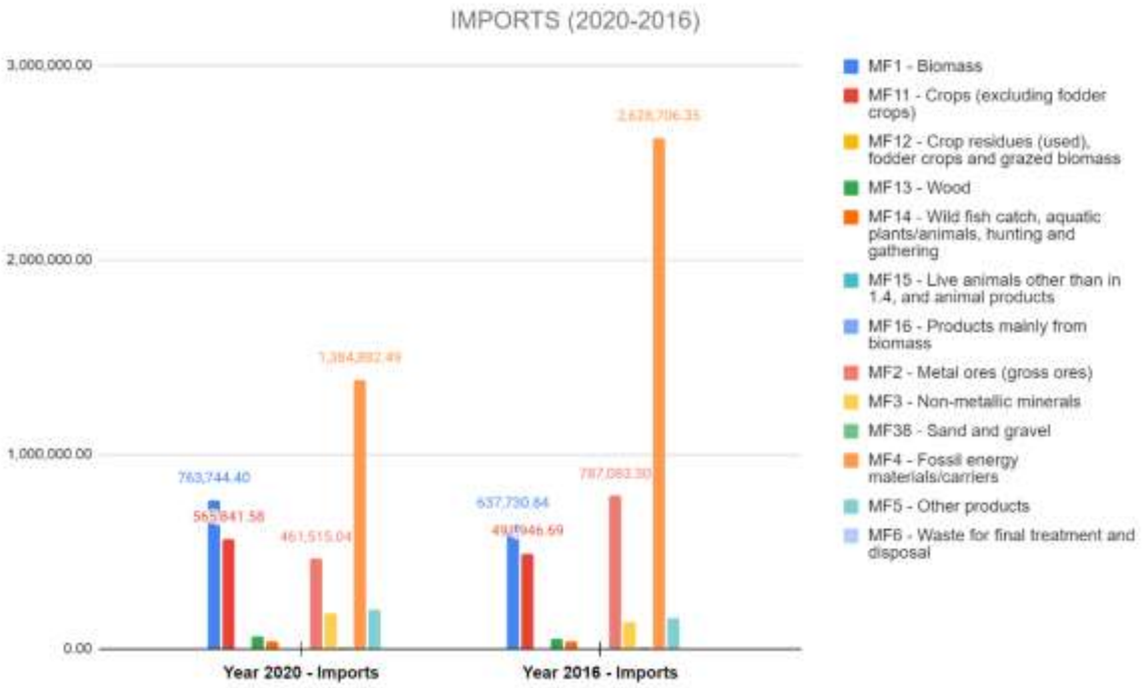

Figure 7 - Imports to Sevilla 2016 and 2020.

By groups of materials, fossil energy materials/carriers imports make up the largest part of annual imports, with values of 46.2% in 2020 and 60.44% in 2016. Within this main group, the most important imports are liquid and gaseous energy materials/carriers which, despite suffering a significant drop between 2020 and 2016, remain the most imported products in Sevilla with values close to 40%, especially the import of crude oil, condensate and natural gas liquids (NGL), which in 2020 continues to lead Sevilla's imports with 33.62% of total.

On the other hand, biomass-related materials (MF1) occupy the second place in imports in 2020 with 25.5% of the total, followed by Metal ores (gross ores -MF2-), especially iron and non-ferrous metals, and other products (MF5) with values of 15.41% and 6.75%, respectively. Among the biomass materials, imports of crops (excluding fodder crops) stand out, accounting for 18.89% of the total, especially cereals, which account for 10.6% of the city's total imports.

This is clearly in line with the city's energy-intensive consumption and residual manufacturing industry, which requires imports of finished products, mainly for human consumption. On the other hand, the high imports of raw materials for processing in a city that does not have the necessary industries gives an idea of the importance the city is acquiring as an import-export logistics centre.

Exports

Total annual exports in Sevilla are in the same order of magnitude as imports, which corroborates an idea of the city, in addition to being fundamentally a consumer, as a logistical hub in the transport of materials and products.

The total quantities exported from Sevilla were 2,691,898.71 tonnes in 2016 and 2,259,536.32 tonnes in 2020. As in imports, exports have also suffered a decline in recent years, although with less intensity, only 16.1% less than in 2016, supported by the good results of exports of biomass and non-metallic minerals. These data on the decline in imports and exports are the result of the paralysis of economic activity, not only in Sevilla, but also worldwide due to the COVID-19 pandemic.

By groups of materials stand out the decreases in exports of fossil fuels, which have fallen by 509.22 thousand tonnes in these 4 years, 52.1% less, and of metallic minerals, which have fallen by 279.34 thousand tonnes, almost 48.8% less than in 2016. By materials, the decreases in exports of nickel (64.22%) and iron (43.89%) or particular cases such as uranium and thorium which have almost ceased to be exported (-90.94%) are remarkable. In relation to fossil fuels, crude oil, condensate and natural gas liquids (NGL), MF421, with a fall in exports of around 58.9%, or natural gas (43.52%), as well as other materials, such as oil shale and tar sands (87.47%), have lost very significant amounts of their exports.

On the other hand, biomass materials and products and non-metallic mining have seen their exports increase significantly. Thus, within the biomass group (MF1), crops (excluding fodder crops) have increased their exports by 86.14 thousand tonnes (+24.69%), especially vegetables (33.8 thousand tonnes), fruits (33.5 thousand tonnes) and cereals (17.29 thousand tonnes). As for non-metallic minerals, the considerable increase in exports of limestone and gypsum (MF36) stands out, with a growth of 80.72% compared to 2016.

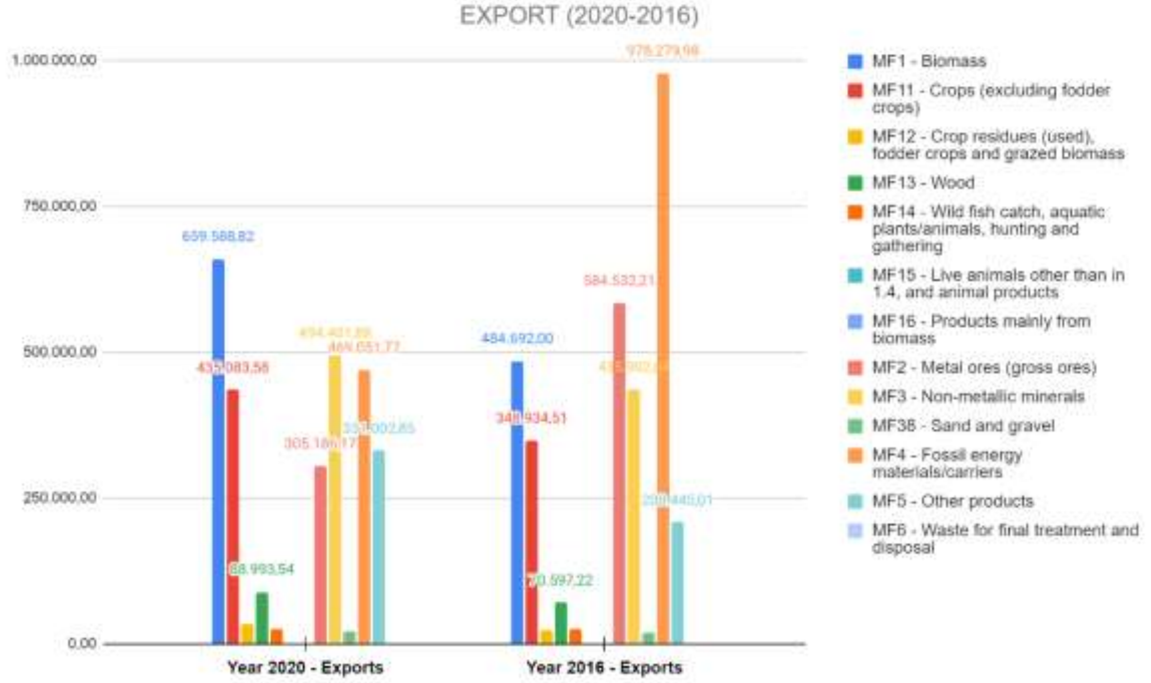

Figure 8 - Exports from Sevilla in 2016 and 2020.

By groups of materials, as in imports, and as could not be otherwise in a city in which logistics activities are becoming increasingly important, the city has become an important logistics centre for the entry and exit of goods and products, either for final consumption in the city itself, or for domestic and foreign markets. According to data from the Statistical Yearbook of the City of Sevilla, in 2020 the main destinations of products sold in the city's markets accounted for 48% on average for local consumption, between 42-46% for the rest of the municipalities in the province and the remaining 6-10% for other localities.

Thus, products derived from biomass account for 29.19% of exports in 2020, non-metallic minerals 21.88%, followed by fossil fuel materials (20.76%) and, finally, metallic minerals (13.51%).

4.3. Domestic Material Consumption

Domestic material consumption (DMC) is calculated by adding domestic extraction to imports and subtracting exports (DE+IMPORT-EXPORT). It represents the total amount of material consumed in the municipality. In 2020, the city of Sevilla consumed a total of 1,572.69 kt. This quantity, added to the 62.4 kt of secondary materials recovered from waste, constitutes the input flow to the processed materials (1,746.87 kt), destined basically for energetic uses, mostly (1,233.11 kt) and, to a lesser extent, for used materials (513.76 kt), representing 70% and 30%, respectively.

It is clear that a city like Sevilla, which is a particularly consuming city, needs a lot of energy for its maintenance and to boost the local economy, but this energy consumption translates into high emissions to the atmosphere, which reached 1,024.17 kt in 2020 (DPO emissions) and a significant generation of solid and liquid waste with a final destination to landfill (EoL Waste 208.91 kt), with the consequent environmental impacts.

On the other hand, part of the material use (513.75 kt) remains in the city in the form of equipment and infrastructures or is disposed of as construction and demolition waste. Thus, 73% of the materials use (375.43 kt) is destined for the overall stock in the form of buildings, infrastructures and goods that remain in the city for more than one year, while the remaining 27% is construction material waste that is not reused and has its final destination as landfill (138.33 kt).

4.4. Waste

The last component of UCA material flow accounting, which is on the right-hand side of the Sankey diagram, is Sevillas's waste production. In this case, quality data was available from the competent environmental body for waste of Junta de Andalucía, the Waste and Land Quality Service of the Regional Ministry of Sustainability, Environment and Blue Economy, as well as from the annual data of the body responsible for municipal waste management in the city of Sevilla, LIPASAM.

Data were obtained on the management and treatment of, on the one hand, the mainly hazardous waste generated and the final destination operations for its treatment and, on the other hand, the non-hazardous waste under municipal jurisdiction, the vast majority of which is sent to the Montemarta Cónica Integrated MSW Treatment Centre (Alcalá de Guadaíra), where it is treated together with the rest of the waste from 44 other municipalities in Sevilla province.

The centre has different waste treatment facilities: a recycling and composting plant for the remaining fraction (mixed household waste) that can treat 400,000 tons/year, a light packaging waste sorting plant with a treatment capacity of 12,000 tons/year; and a controlled landfill with a useful life until 2052 and 15 million tons of waste already accumulated. It also has other complementary facilities; 10 MW electric power generation plant that generated in 2017 more than 66,000 MWh, a bio-sanitary waste plant, a construction and demolition waste plant and a bio-waste and vegetable remains plant.

In the absence of information on municipal waste management operations, an approximation has been made to the final treatment of the waste data provided by LIPASAM based on the waste destination in Spain, according to Eurostat's Municipal waste by waste management operations data for years 2020 and 2016.

In addition, it is important to note that most waste operators (waste managers) in Sevilla act as intermediaries in the treatment, sending this waste to other places in the province of Sevilla, Andalusia, Spain and even, through cross-border shipments, to the rest of the world for final treatment, so its destination could not be established with complete certainty.

Likewise, the final waste managers in Sevilla themselves import waste from elsewhere for final treatment at their facilities.

In total, waste generated in 2020 reached 326,894.7 tonnes, a decrease of 7.32% compared to 2016 (353,302.4 tonnes). The largest share corresponds to mixed and undifferentiated materials, with 76.1% in 2016 (268,880 t) and with 72.4% in 2020 (237,067 tonnes). Next, the dominant waste fraction in a much smaller proportion is mineral waste from construction and demolition with 11.87% in 2020 (38,862 tonnes), which has increased by 18.77% compared to 2016. Thereafter, the most significant fractions are paper and cardboard waste, which represents 4.01% in 2020 (13,140.88 tonnes), glass waste with 3.32% and plastic waste with 2.69%.

Comparing the two reference years, the fraction that has increased significantly by 749% is household and similar waste, from 211.19 tonnes in 2016 to 1,792 tonnes in 2020. These figures could be justified by the landfill situation resulting from COVID-19. Other wastes that have also increased significantly between the two reference years are batteries and accumulators waste with 152.88%, industrial effluent sludge with 83.78%, discarded equipment (except discarded vehicles and batteries and accumulators waste) with 54.57%, wastepaper and cardboard with 52.40% and plastic waste with 43.13%.

On the other hand, mixed and undifferentiated material waste, which represents the largest percentage of municipal waste (72.40% in 2020), has decreased by approximately 11.83%, one of the main reasons for the total reduction in waste production between 2020 and 2016. Some wastes have completely disappeared from the annual production in 2020, such as combustion waste or metal waste, ferrous, although their annual production in 2016 was already very residual.

On the other hand, waste such as other mineral waste or health care and biological wastes, which are important in the characterisation of waste, have seen very significant decreases. While other mineral wastes have decreased by up to 85.50%, health care and biological wastes has decreased by more than 68%. Almost all waste containing PCBs, which are highly hazardous, has decreased almost completely (98.75%).

Figure 9 - Household waste composition in Sevilla in 2016 and 2020.

As already mentioned in the introduction to this chapter, with respect to waste management operations, most of Sevilla's municipal waste is sent to a treatment plant where it is mixed with waste from the province for final treatment, mainly the recovery of by-products, ferrous materials, plastics, glass, etc., with a total of 11,601 tonnes recovered in 2020, the non-energy recovery of organic material (818 tonnes of compost) and the energy recovery of the biogas generated in the controlled landfill, 60,777 MWh of electrical energy with 6.9% self-consumption.

In relation to industrial waste, it has also been mentioned that most of it is sent to intermediate waste management operations, either to storage prior to its final treatment, or to waste operations prior to its landfill disposal, as in the case of the stabilisation of some hazardous waste, or to its final recovery. In these cases, there are also problems of traceability of the final waste management operations, as operators are only obliged to report the final treatment when the intermediate steps are significantly reduced.

In this respect, most of the operations reported in the waste shipment, the basis for the management reports used to extract data from the competent authority's databases, only report intermediate operations, which does not make it possible to know exactly the management operations of Sevilla's waste.

The final treatment of most of the waste generated in Sevilla is the non-energy-recovery (53.20%), mainly the recovery of materials through recycling or reuse, although the latter still has very little presence, as shown by public data at regional (NUTS2) or national (NUTS1) level. Thus, the overall recycling rate in Sevilla is around 53% in relation to the total waste generated.

At NUTS2 level, according to the [Andalusia Environment Report 2022](), both paper and cardboard waste (64.4%) and light packaging waste (66.9%) meet the recycling targets established in current legislation, both in Andalusia, which are 60% and 55% respectively, and in Spain, although it is true that these will become more demanding when the modifications to the European directives approved in recent years will be transposed into national legislation. Only glass waste does not meet these targets, which are set at 60% for packaging from households and hotels, restaurants and cafés.

In any case, the city of Sevilla has experienced a very significant growth in waste recycling compared to 2016, when the rate was around 30% of the total generated, growing in these 4 years by over 67.7%.

Another treatment that has seen exponential growth in this period has been waste incineration/disposal (D10) which practically did not exist in 2016 and currently stands at around 520 tonnes per year, but which, in the case of energy recovery (R1) has suffered a considerable drop of 28.1%, from 45,381.4 tonnes in 2016 to 32,630.8 tonnes in 2020.

This is obviously a bad environmental figure for Sevilla which has been counterbalanced by the excellent results of waste disposal/landfill which has suffered a decrease of 40.5% in relation to 2016, getting closer and closer to the national and European targets.

In any case, waste recovery, whether energetic or non-energetic (recovery of materials and products, recycling or reuse) continues to be a pending issue in waste management in Spain.

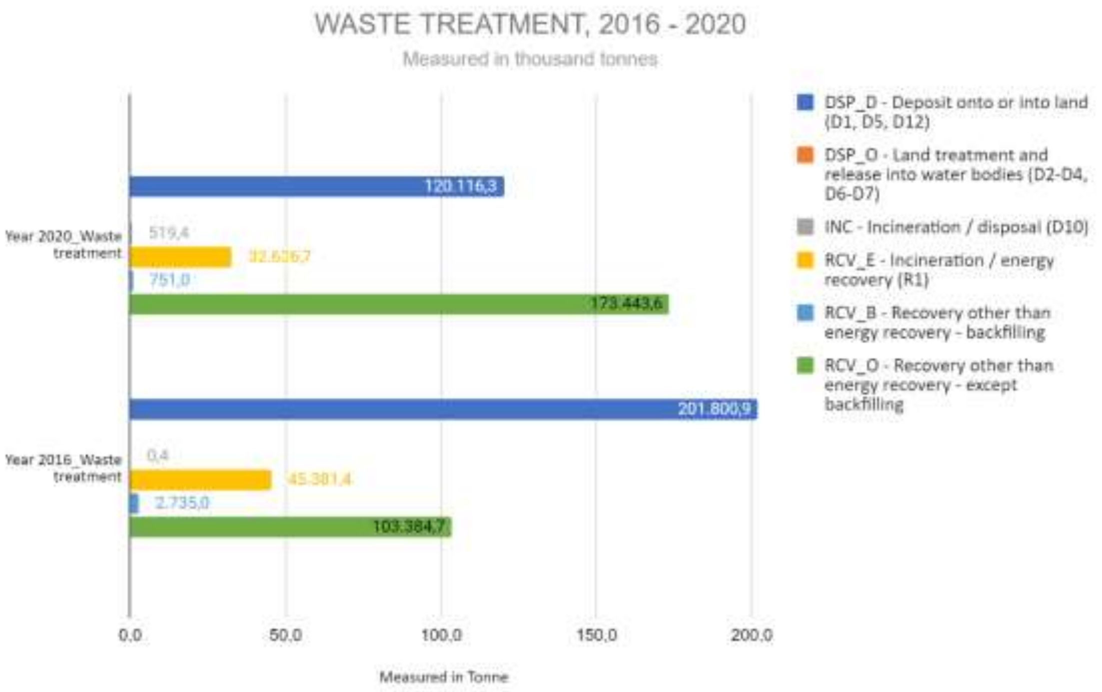

Figure 10 - Waste treatment distribution.

5. Material stock in Sevilla

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.

The embedded map allows to explore the building stock of Sevilla 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.

The embedded map (Figure 9) makes visible the real estate in Sevilla where the different weight ranges calculated during the study can be identified.

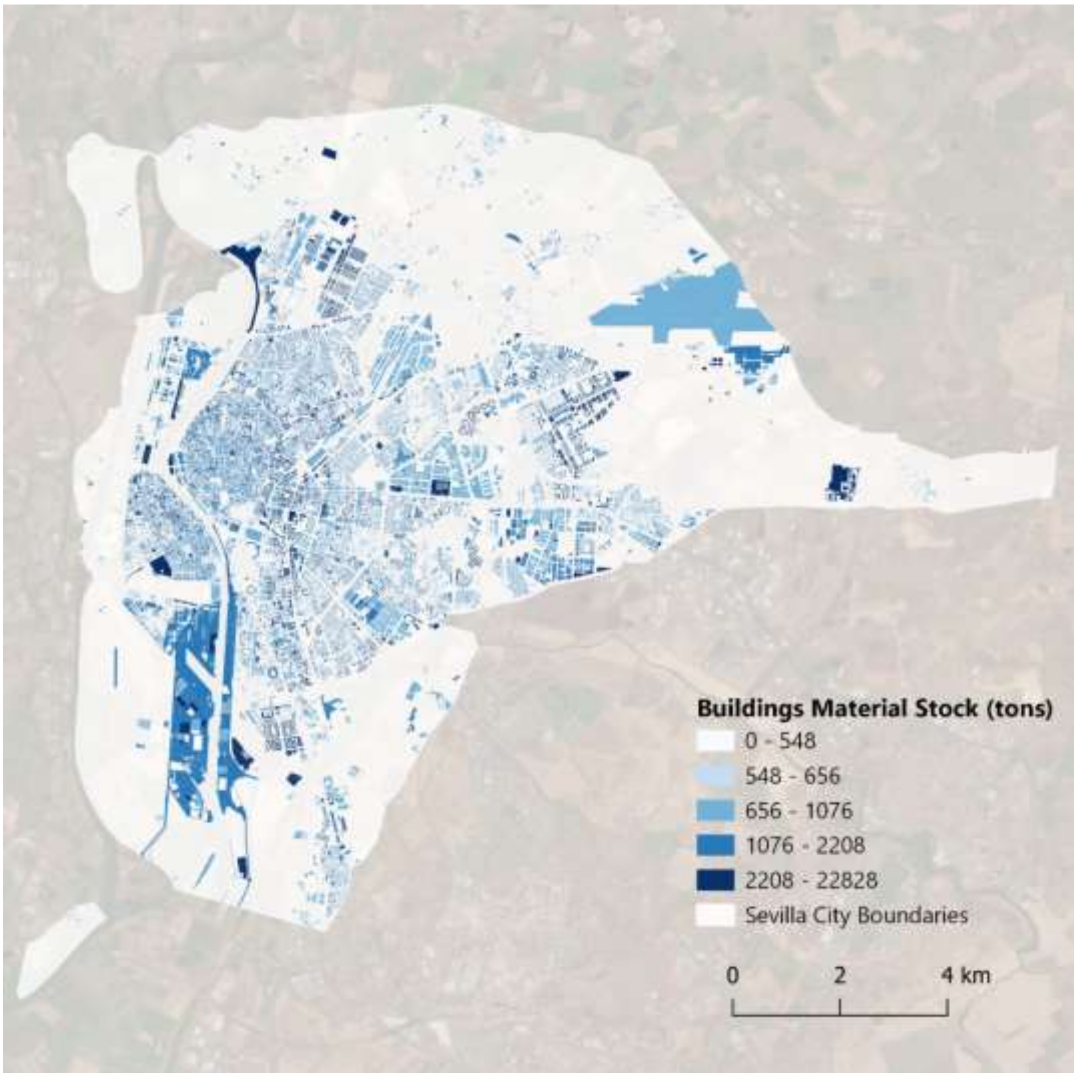

Figure 11- Map of Building Material Stock in Sevilla expressed in tonnes and with an overlaid heatmap to facilitate its compression. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

5.1. Building typologies in Sevilla

An essential component for the analysis of the real estate stock of Sevilla are the typologies of buildings. Although typologies are traditionally defined directly through this data set and then material intensities are measured, in Sevilla's case these have been determined by the different reference studies that have been taken into account. To date, no reference study of material intensities has been found in Spain, despite the numerous studies available regarding building typologies and energy demands. Given that in Sevilla and Spain a study has not been found in which an approximation of material intensities according to typologies and by band of years is sufficiently broken down, it has been decided to take as reference the Study of Padua Alessio Miatto et al. (2019), among the references found. In this way, the different typologies analysed have been identified, according to the use data and number of floors obtained from cadaster and establishing a classification following the criteria of Miatto et al. (2019), in the Padua Study.

In this way, the property park of Sevilla has been identified and classified in the following typologies taking into account the similarities of uses and height of the buildings of Padua, multiplying the number of floors by an average height of three meters:

- Residential one and two floors.

- Residential with three floors

- Residential of more than four floors

- Non-residential, taking into account in this typology the following uses according to cadaster; industrial, offices, agriculture and utilities

- Other buildings

In the following map (Fugure 10) it is represented how the different typologies are distributed in the city. As it can be observed, the different typologies of residential are distributed throughout the city, with a high concentration in the historic quarter and non-residential are concentrated in different bags away from the centre. Apart of that you can see that in the historic centre there is a great mixture of residential uses of different heights with non-residential of small surfaces, with a concentration of residential of less than three floors to the north of the historic centre. Although there are residential buildings of more than 3 floors in the centre, the large extensions of buildings of more than 3 floors (being able to reach 16 and 21 floors in some cases), are located outside the historic centre. On the other hand, the large extensions of non-residential uses are located outside the historic centre concentrated in different bags surrounding the city.

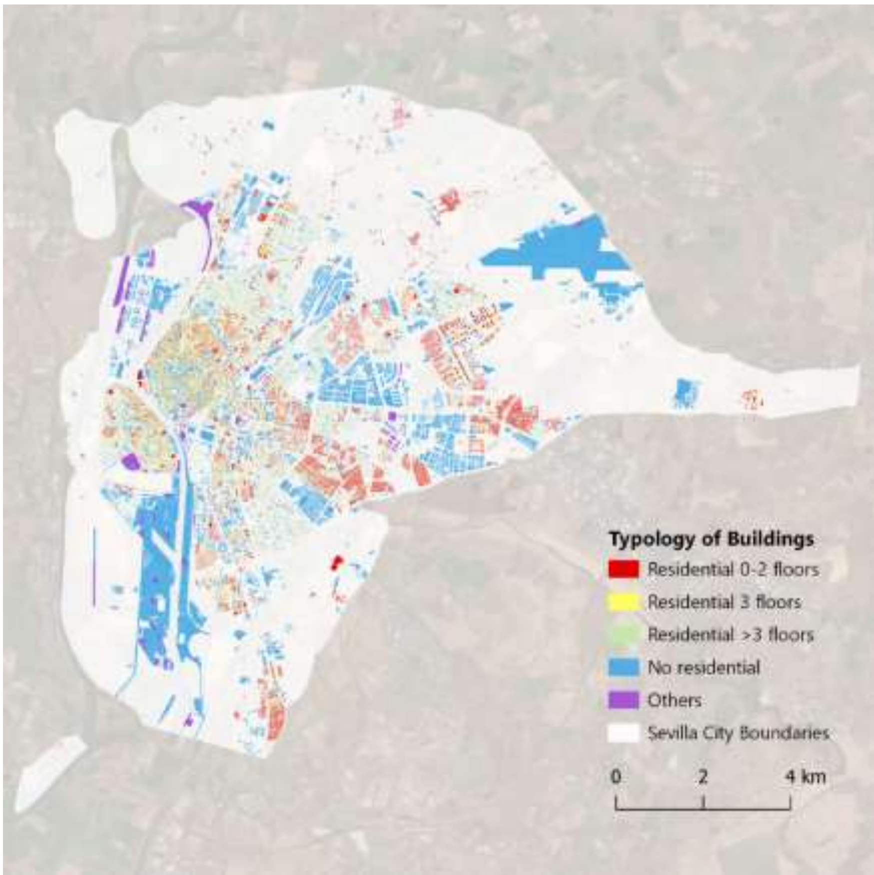

Figure 12- Map of the distribution by typologies of building in Sevilla. Own elaboration from Sevilla´s Cadaster

In total, there are 58,588 buildings in the municipality of Sevilla. The graph (figure 10) illustrates the proportion of each typology in the total housing stock. It can be seen that most of the buildings (59.5%) are more than four floors residential, which is a typical typology of buildings in Sevilla. It is followed by residential buildings up to 2 floors (15.2%) and non-residential (14.4%). The three-storey residential category accounts for 9.9% and that of others for 1% of the total.

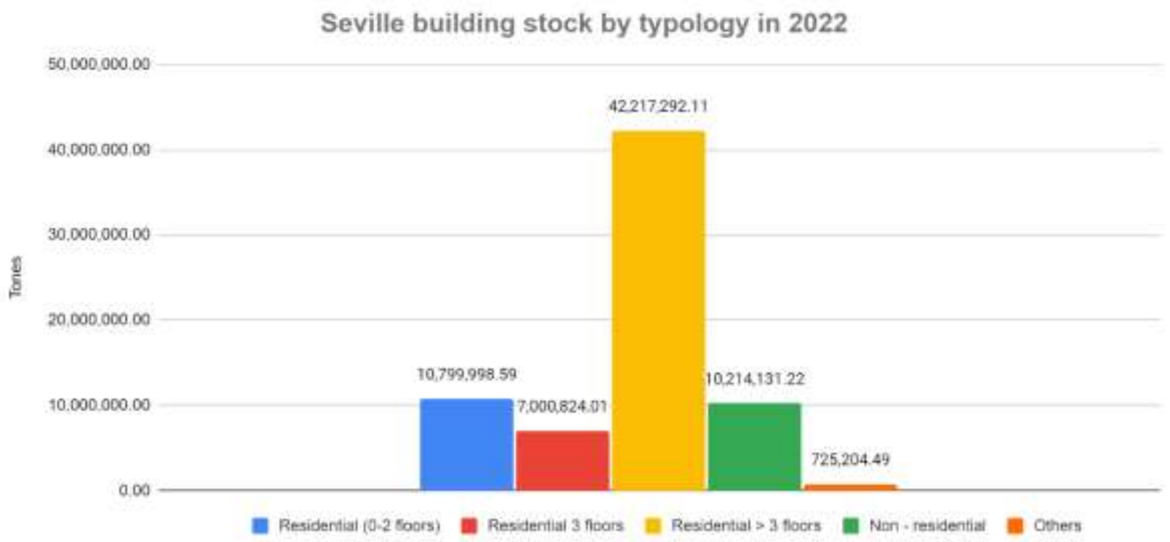

Figure 13 – Sevilla building stock by type of building. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

In terms of age distribution, we observe in figure 12 that until 1902, only 1.8% of the city's real estate had been built, with a large expansion between 1903 and 1954, where it reached 11% of the total in 2022. It can be observed that the buildings from 1970 - 1981 period have the highest proportion with 26% followed by 1982 - 1996 period (21.6%) probably due to the concentration of constructions for the 1992 Universal Exhibition, which represented a great milestone in the reconfiguration of the city and the period before 1955 to 1939 (17.2%). Since 1981 there has been a progressive decrease in construction, with 14% in the period between 1997 and 2007 and 8% between 2007 and 2022.

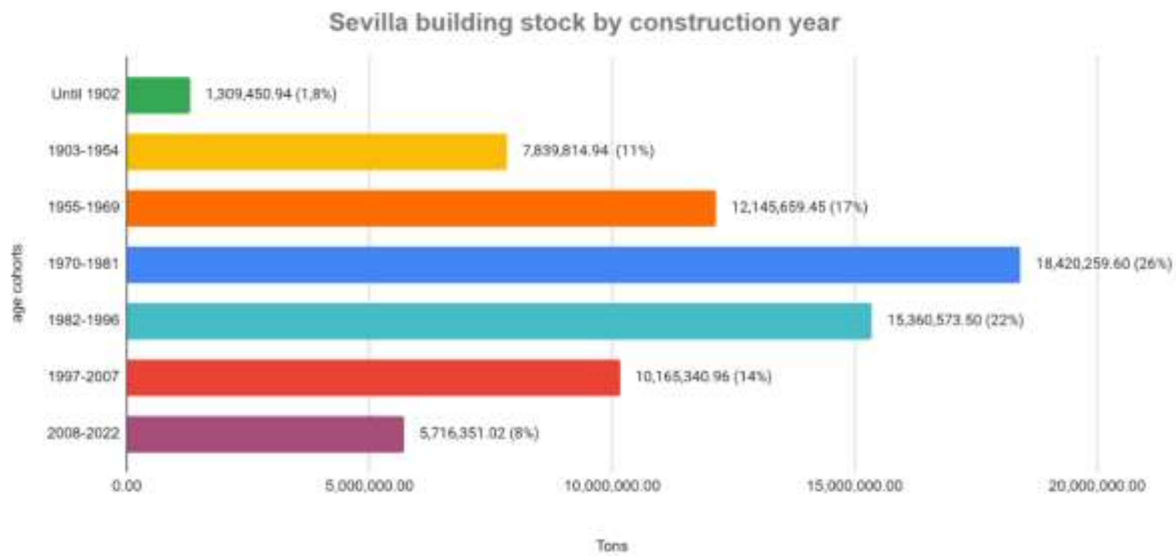

Figure 14 – Sevilla building stock by construction year. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

On the spatial distribution map by age (figure 13), we can see that buildings until 1954 are concentrated in historic quarter, and mainly to the river Guadalquivir east side, except for the Port area built, and the expansion that generated the Universal Exhibition of 1929 towards the south. From 1955 it is seen how the city begins to expand throughout the municipal area. We can differentiate in yellow the arc that was generated until 1969 around the historic centre and from which the city continues to expand in later years.

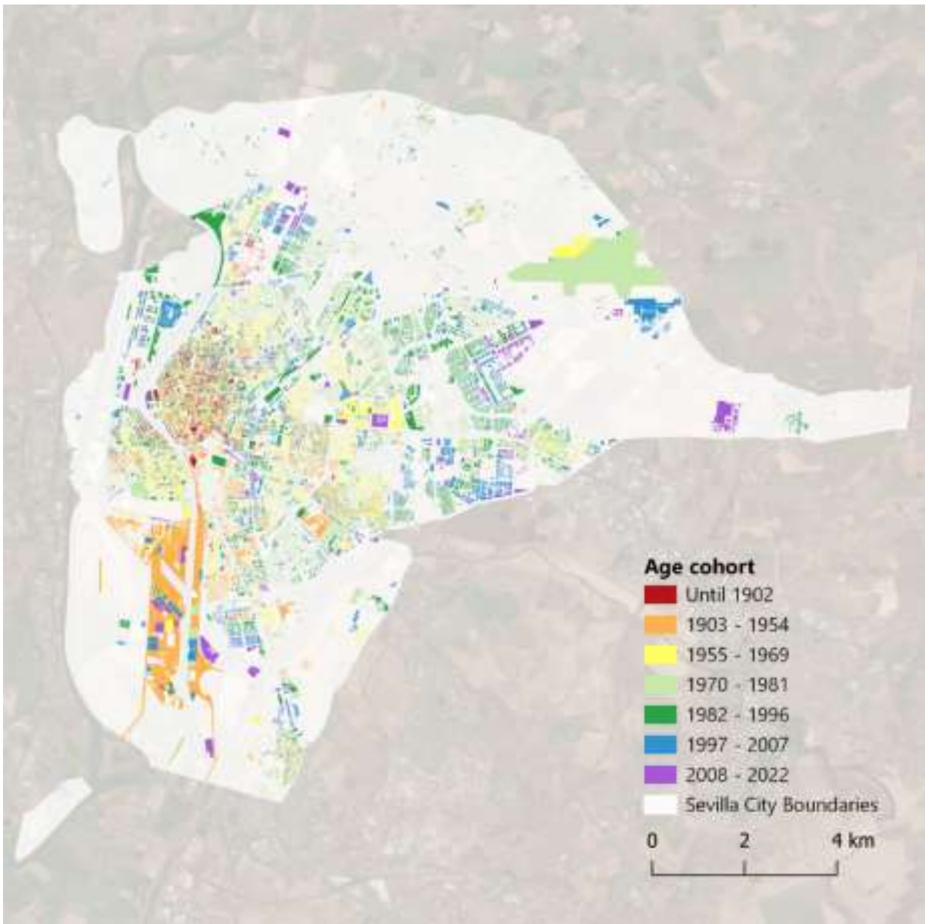

Figure 15. Map of the distribution by age of building in Sevilla. Own elaboration from Sevilla´s Cadaster

5.2. Analysis of Material Stock

Using the construction typologies developed in the previous part and the material intensities of Miatto et al. (2019), it was possible to make a first approximation to measure the material of the real estate in Sevilla. First, we obtained the cubic meters of the different typologies in the different periods, multiplying the gross surface of each building by its height, based on the number of plants and an average height of three meters per plant. The tons of each material were then calculated for each period, multiplying the cubic meters by the different material intensities of Miatto et al. (2019).

Thus, it is estimated that the housing stock of Sevilla weighs approximately 70.96 million tons.

Analysing the composition and total materials used in the buildings built up to 1981, it can be seen that material storage has increased considerably, totalling 39.72 million tonnes (which represents the peak of addition of material, reaching 56 % of the existing population in 2022). Another period in which there was a large contribution is 1982 to 1996 with 15.36 million tonnes.

Looking at the map in figure 9, it can be seen that the Sevilla city has a denser urban fabric in the historic quarter, concentrating a great intensity of materials in its 4.23 km^2, which represents 12% of the buildings built and 0.03% of its total surface (140.8 km2 in 2022). You can see how the density and intensity of materials is decreasing as we move away from it, with the exception of some recent buildings that concentrate a lot of materials. The intensity of materials of the large areas represents the port built in 1953 and the airport built in 1992, that stands out.

Since 30% of the materials (21,294,9925 tonnes) are built until 1970, much of these existing materials distributed both in the historic centre of the city, as in the first extension area of the city (represented in yellow) could soon be available and used to meet future resource use demands, starting with future renovation, assuming that the useful life of buildings is 50 years (minimum useful life period established in the Spanish structural regulations, such as the EH, EHE, Technical Building Code and the Structural Code) and the new European directives that require the energy rehabilitation of the same. We could highlight the intensity of existing materials in the port built in 1953. In this way, the results of this analysis allow quantifying and mapping the mine of materials available in the real estate of Sevilla.

Apart from that, for the detailed analysis of the stock, the following typologies of materials collected in the studio of Miatto et al. (2019) have been taken into account: concrete, steel, bricks, sawn wood, glass, synthetic insulation materials, mineral mortar materials, other insulation materials, bituminous waterproofing materials, coating materials, and other materials.

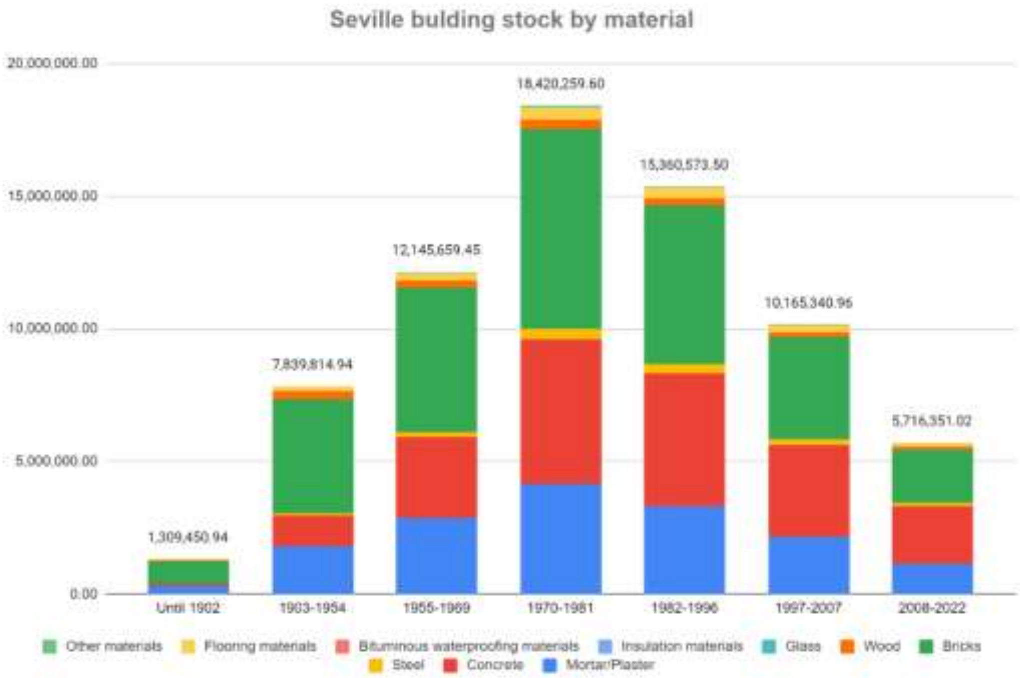

Figure 16- Building stock by age cohort and materials. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

As can be seen in graphics, bricks represent most of the material approaching 42.2% of the total mass, followed by concrete with 28,7% and plaster mortar with 22.11%, which represent the most representative materials in terms of mass. While in significantly smaller proportions, flooring materials (2.33%), steel (2.08%) and wood (2.04%) are the following materials in terms of quantity.

Type of buildings that generate most of the mass

As can be seen in the graph 15 about typologies and construction materials, the residential sector is responsible for the largest proportion of available material (residential buildings of more than 3 floors being the type with the greatest impact). Another important part of the material reserve can be found under the 1 and 2-floors residential typology and non-residential ones, where industrial uses, offices, agriculture and public services are mixed.

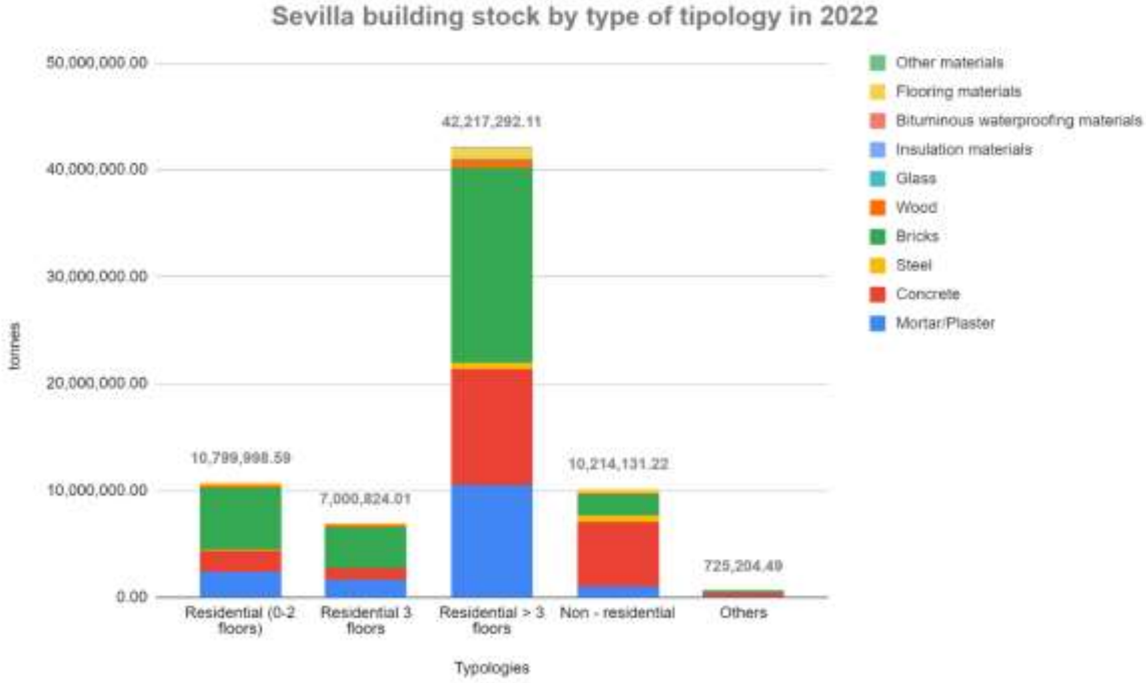

Figure 17 - Building stock by building typologies and materials. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

From the point of view of material, bricks appear as the predominant material in Sevilla with 42,17%, followed by concrete with 28,7%.

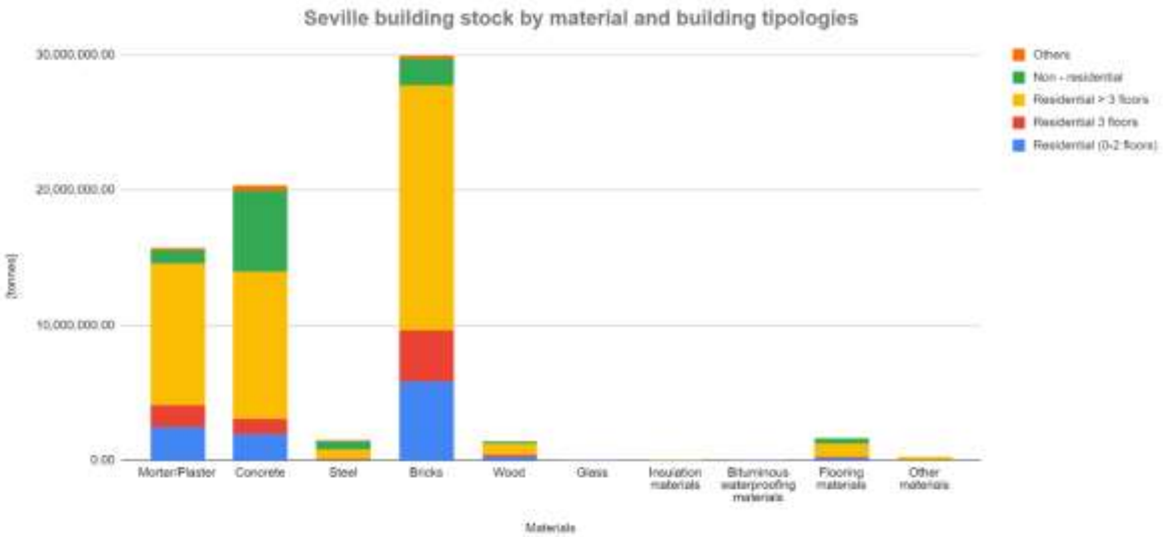

Figure 18 - Building stock by materials and building typologies. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

Relating stock with flows entering and exiting

Another useful aspect within the analysis is the relationship of material stocks with flows related to the entry and exit of construction materials.

If we compare the total materials used in buildings built in 2016 and 2020 according to the cadaster, it can be seen that there has been a considerable increase, adding 73,722 tonnes in 2016 and 280,217 tonnes in 2020 to stocks respectively. However, according to the data obtained in the material flow analysis, the use of materials for stock in general has decreased significantly, with 948,490 tonnes in 2016 and 375,430 tonnes in 2020, which coincides with the decreasing trend of material storage of the real estate stock.

	2016	2020
Stock – buildings (cadaster)	73.722 tonnes	280.217 tonnes
In- use in stocks (Sankey)	948.490 tonnes	375.430 tonnes

Chart 2. Comparison of the tons of material used for stock obtained from the UCA Sevilla and the calculation of the stock of real estate, obtained for the years 2016 and 2020. Own elaboration from Sevilla´s Cadaster and UCA Sevilla.

This difference is due to the fact that stock calculation data obtained from the cadaster only analyse the material storage of the real estate stock and those of Sankey refers to the overall use of the materials, where infrastructure constructions could also be included, as well as the rehabilitation of buildings and infrastructure, which would not be comparing the same data. Despite the increase in the use of stock between 2016 and 2020 for the housing stock, it could be due to the situation of the exit from the crisis of the construction sector in Spain, which has allowed the recent years increase.

On the other hand, analyzing the material flows, the volume of the use of materials for the stock of the city in 2020 (375,430 tonnes) represents 73% of the total materials in use in the city (514 tonnes), coming from the material processing. In turn, of the total materials processed in Sevilla (1,746.86 thousand tonnes) which is overwhelmingly imported materials), only 29% are put into use in Sevilla, with the other 71% destined for energy uses. Similarly, 28% of the materials extracted in Sevilla are destined for processing in Sevilla. Most of the materials extracted in Sevilla (97% in 2016 and 89% in 2020) are sand and gravel, and the volume of extraction has decreased by 54%.

In summary we could highlight on the one hand that, although the trend of storage volume of building materials has decreased significantly since 1981 by approximately 70%, within the period between 2016 and 2020 there has been an increase due to the crisis exit. On the other hand, analyzing the calculations obtained from material flows between 2016 and 2020, the use of materials for stock in general has been reduced by about 60% and the extraction of materials, which has also reduced by 54%, which 90% is used for stock, so that both data coincide with the overall trend of decreasing stock of real estate. Finally, it should be noted that in the city of Sevilla it is already observed in 2020 that 6% of the material in use for stock (22,3 thousand tonnes) is added to demolition and disposal waste (EoL Waste), and in turn, of the total demolition waste (369 Kt), 16% are reused for material processing, so you can already sense the beginning of a circular dynamic in the flow of construction materials.

Comparison with other case studies

Figure 17 compares the material stock per capita of Sevilla obtained from this study, with those of several global cities (Athanassiadis et al. 2017) and Apeldoorn (Metabolism of cities). Compared to other cities, Sevilla is on the lower stretch. Its material stock represents approximately 103.7 Tn/cap and 501.679 t/km². This result shows that the results of the material stock of Sevilla are within a correct range and order of magnitude, although the results of 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 mean that the accumulated population or density of Sevilla is high compared to its mass, or that it uses "heavy" materials (e.g. concrete and bricks) with a medium population.

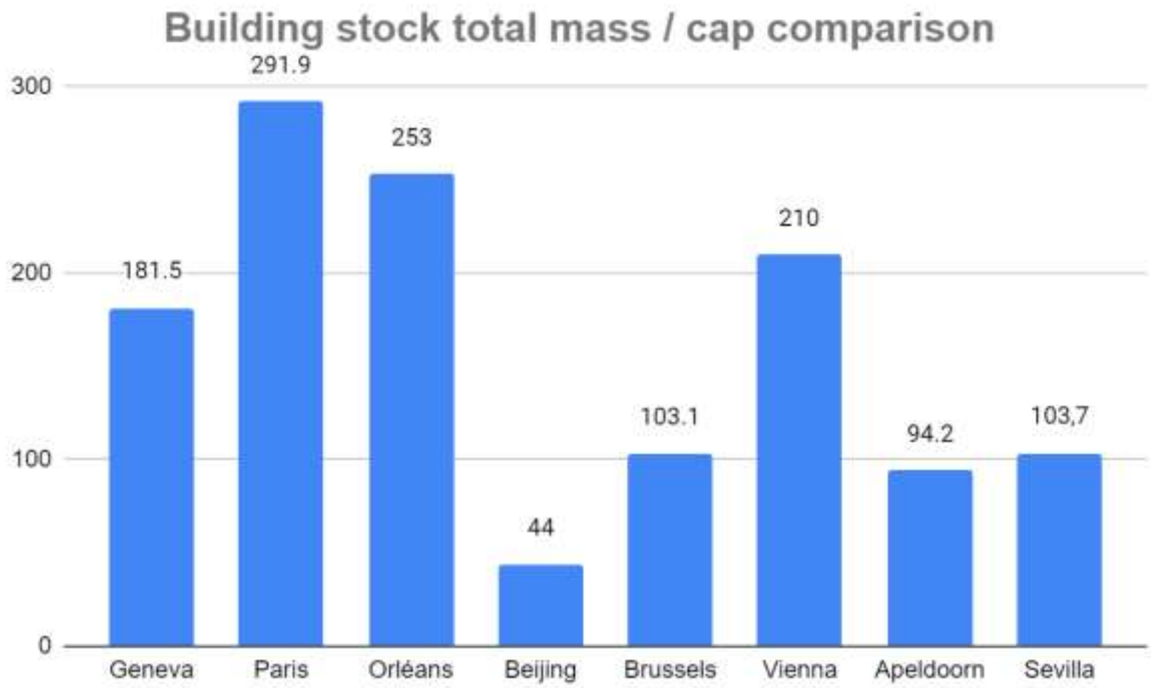

Figure 19 - Material stock in total mass per capita for major cities and Sevilla. Own elaboration from UCA Apeldoorn and UCA Sevilla.

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	2016	2020	Unit	Change from 2016 to 2020 (%)
Input Socioeconomic Cycling Rates (ISCr)	3.8%	10.0%	%	161.1%
Output Socioeconomic Cycling Rate (OSCr)	5.6%	12.5%	%	123.0%
Input Ecological Cycling Rate Potential (IECrp)	4.7%	19.6%	%	314.2%
Output Ecological Cycling Rate Potential	6.1%	19.2%	%	215.0%
Input Non-circularity Rate (INCr)	57.0%	51.2%	%	-10.3%
Output Non-circularity Rate (ONCr)	83.7%	64.1%	%	-23.4%
Remaining non-renewable primary resources	34.4%	19.3%	%	-44.0%
Remaining interim outputs	4.6%	4.2%	%	-9.9%
Material recovery	28.9%	47.1%	%	63.1%
Direct Material Input (DMI)	5,411,497.3	3,258,935.8	tonnes / year	-39.8%
Domestic Processed Output (DPO)	1,830,288.7	1,219,589.3	tonnes / year	-33.4%
Domestic Material Consumption (DMC)	2,736,650.0	1,572,688.5	tonnes / year	-42.5%
Domestic Material Consumption Corrected (DMCcorr)	2,718,586.6	999,620.1	tonnes / year	-63.2%
Local and Exported Processed Output (LEPO)	1,830,336.2	1,219,894.1	tonnes / year	-33.4%
Processed Material (PM)	2,845,295.5	1,746,864.3	tonnes / year	-38.6%
Interim Outputs (IntOut)	1,938,934.2	1,393,765.1	tonnes / year	-28.1%
Secondary Material (SM)	108,645.5	174,175.8	tonnes / year	60.3%

Net Addition to Stock (NAS)	906,361.3	353,099.2	tonnes / year	-61.0%
Physical Trade Balance (PTB)	1,657,478.2	735,625.7	tonnes / year	-55.6%
Material Productivity (MP)	0.0	0.0	national currency / tonnes	70.3%
Material Intensity (MI)	163.6	96.1	tonnes / national currency	-41.3%

Indicators that were chosen and their development over time

In 2020, 79.78% (1,393,765 tons) of Processed Material (PM) became Interim Outputs (IntOut), decreasing by 28.1% compared to 2016. The remaining 20.22% were added to stock (Net Addition to Stock), such as buildings, infrastructure, and durable goods, which in 2020 were 353,099.2 tons (NAS).

Almost 16.86% of the total end-of-life waste (EoL Waste) was recovered in 2020 and re-injected into material processing.

The Output Socioeconomic Cycling Rate (OSCr) expressing the contribution of secondary materials (SM) to intermediate products (IntOut) has remained low in 2020, with values of 12.5%, but experienced a high increase (123%), more than doubling its contribution, compared to 2016, reflecting a positive trend towards raw material substitution.

The Input Socioeconomic Cycling Rates (ISCr), which measures recycled materials reprocessed as secondary material (SM) inputs into the household economy, was also higher in 2020 than in 2016, with a 10% contribution and an increase of 161% between the two years.

The high importance of fossil energy sources in primary energy supply, flows that cannot be recycled or reused, led to an Input Non-circularity Rate (INCr) of 51.2% and decreased by 10.3% compared to 2016. In addition, it resulted in an Output Non-circularity Rate (ONCr) of 64.1%, which decreased considerably by 23.4% in the analysis period.

A notable decrease in Domestic Material Consumption (DMC) of 1,163,961.15 tons was found between 2016 and 2020, as well as an increase in the flow of secondary materials, which resulted in a notable increase of 61% in the Input Ecological Cycling Rate (ISCr) between 2016 and 2020.

The Input Ecological Cycling Rate Potential (IECrp), which indicates the maximum proportion of processed materials (PM), was 19.6% in 2020 and increased significantly by 314% compared to 2016. The Output Ecological Cycling Rate Potential (OECrp), which measures the contribution of domestically processed output (Domestic Processed Output-DPO) of biomass in intermediate outputs (IntOut), was about the same at 19.2% and increased significantly from 2016 (215%).

The internal consumption of materials has decreased significantly, as has the consumption of fossil or non-circular resources. Nevertheless, their values are still very high. If Sevilla's high dependence on fossil fuel imports is added to this, this may lead to an unsustainable trend. Thus, the indicators of Input Non-circularity Rate (INCr), Output Non-circularity Rate (ONCr) and remaining non-renewable primary resources indicate a clear field of action in Sevilla: dependence on fossil fuels and imports for energy use.

Sevilla should reverse this situation by developing strategies to obtain energy from renewable sources through distributed generation and the purchase of green energy, among other alternatives to reduce the demand for fossil fuels (mostly imported and domestically extracted), as well as a strategy of energy rehabilitation of existing buildings and the construction of new buildings with near-zero consumption criteria to reduce energy demand and the energy incorporated in the production processes of materials that allow the municipality and its citizens to move towards more circular strategies and a reduction of external dependence on materials and energy.

On the other hand, given that practically half of the imported materials are exported, because Sevilla is becoming a logistic hub, and that, in turn, most of the transport is carried out by road, implying an increasing trend in fuel consumption, the study and reconsideration of the entry and exit routes is recommended, as well as the transition to clean fuels. Finally, it is noted that there is great potential in improving the management and recovery of waste from construction and demolition, which will be increasingly necessary, because about 30% of the material storage of the building stock is more than 50 years old and will require rehabilitation, with the consequent demand for materials. All this without considering the rehabilitation and construction of new infrastructures for the development of the city's logistics centre, and the necessary implementation of renewables, as above mentioned.

7. Data Quality Assessment

En la Evaluación de la Circularidad Urbana se recopilaron y tuvieron en cuenta numerosos conjuntos de datos, y en esta sección se evalúa cualitativamente la fiabilidad de los datos utilizados. En algunos casos, no se disponía de conjuntos de datos para algunos materiales o para algunas fases del ciclo de vida de la ciudad. Por lo tanto, fue necesario realizar estimaciones examinando los datos a escalas espaciales superiores (región o país) y reduciéndolos con aproximaciones, descritas en la parte sobre lagunas de datos e hipótesis.

Numerous datasets were collected and considered in the Urban Circularity Assessment and this section qualitatively assesses how reliable the data used are. 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 for 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	Reviewed or measured data	Data were found for all materials that are extracted locally.	For the 2016-2018 series, cultivated area data were obtained from SIMA-IECA	Cultivated area data at city level.
Imports & Exports	Estimated data	Data exists for most of sible sub-material groups and/or materials	Data available in the series 2016-2020 for all estimated data	NUTS2 and NUTS1 level data
MF1 - Biomass	Estimated data	Estimated data are not fully reliable		
MF2 - Metal ores (gross ores)				

Lifecycle stage	Reliability	Completeness	Temporal correlation	Spatial correlation
MF3 - Non-metallic minerals				
MF4 - Fossil energy materials/carriers				
MF5 - Other products				
MF6 - Waste for final treatment and disposal				
Waste	Reviewed or measured data	Municipal waste (LIPASAM) and other waste collection data (SIRA)	Data available in the series 2016-2020 for all estimated data	City-level data
Material stock	Data measured from the cadaster	Data exists for all the single sub-material groups and/or materials material but material intensity data are taken from another similar city as a reference.	Data available in cadaster from 1023 to 2022.	City - level cadaster data

7.1. Data Quality

It is necessary to establish the premise that, although there are different sources of public and private statistical information, it is not possible to extract the necessary information for this circularity report at the required level of detail, as the data provided by the different sources are often not homogeneous and there are considerable information gaps at the lowest scales (municipality).

Data collected for this report are a combination of public data, either requested directly from the sources (Waste and Land Quality Service of the Junta de Andalucía and LIPASAM) or extracted from official sources at European (Eurostat), national (INE, Spanish Mining Yearbook, Foreign Trade Database, etc.), regional, provincial and local (SIMA-IECA, MAPA Statistical Yearbook and Statistical Yearbook of the City of Sevilla) levels. Most of data have been modelled and/or rescaled from larger spatial scales and, therefore, their accuracy is somewhat compromised.

As can be seen in the data quality matrix above, the overall quality of the data is average for most life cycle stages (LCA) and material groups:

- The reliability of the data is quite acceptable. For most LCAs, data have been measured (domestic extraction and material stocks), while only imports and exports have had to be estimated.
- Data completeness is average for imports and exports, while domestic extraction, material stocks and waste are very complete.

- Temporal correlation is very good for all life cycle stages, as the data were almost always from the reference years (2016 and 2020), although in some cases longer series were available, even with values to 2021 and provisional values to 2022. As the time correlation was more uniform at 2020, this year was chosen for the circularity analysis. For example, data on employees at city level went up to 2021, but disaggregated by economic activities were only available up to 2020 and with higher territorial levels (NUTS3).
- In general, spatial correlation are the more problematic data as in domestic extraction it was necessary to use provincial (NUTS3) data on area and annual production and to approximate them at city level by applying an improved area proxy (agricultural area relative to total) and imports and exports were obtained from regional data. Data on stocks of building materials are much better (although it was necessary to use papers for material intensity). Waste data are excellent.

7.2. Data Gaps and Assumptions

Domestic Extraction

To obtain the domestic extraction of cultivated biomass in Sevilla, the most updated land use mapping (SIG PAC 2018) was initially used to define areas occupied by crops (levels and sublevels from MF11 to MF13) and yield application (STRUCPRO - yield data NUTS2, Andalucía 2016-2020). The information collected was very limited, only applicable to a minimum of crops, leaving other materials for which there was certain evidence of existence without extraction data, thus limiting the reliability of the final data.

The use of SIMA-IECA statistical data on general land distribution provided information with time series 2010-2020 for different arable and woody crops in rainfed and irrigated areas, but, although they could be associated with a certain degree of consistency and reliability to biomass crops (MF), some cultivated areas could not be related or there were problems for the application of yields.

Finally, it was decided to turn to the agricultural statistics of the 2017-2021 Statistical Yearbooks of the Spanish Ministry of Agriculture, Livestock, Fisheries and Food (MAPA, *from its Spanish acronym*) which has area and yield data at provincial level (NUTS3) for all crops differentiated by levels, sub-levels, and crops, allowing easy associations for all biomass crops up to level 4 MF. Statistical data on areas, yields and annual productions were obtained for most of the biomass crops.

With the data at NUTS level, yields have been applied to the crop area data obtained in SIMA-IECA at Sevilla city level to obtain local biomass extraction data (MF11-MF13) for most of the crops. The information gaps have been filled by approximations of the national values obtained from Eurostat (Material Flow Account) to which an approximation factor of the agricultural area of Sevilla was applied (area proxy improved on the area proxy factor of Sevilla in relation to the province -NUTS3-).

In order to determine whether other materials were extracted in the city of Sevilla during the years analysed, the Mining Exploitation Rights, which can be consulted in the Mining Register of Andalusia (Andalusian Mining Portal, dependent on the Regional Ministry of Industrial Policy and Energy), were consulted.

The Mining Exploitation Rights do not include information on the surface area in exploitation of the different mining licences; they only indicate the validity of these licences. To obtain the data on the surface area in operation, it is necessary to consult the Mining Cadaster (dependent on the Ministry for Ecological Transition and the Demographic Challenge).

In addition to the surface area, the data from the Mining Cadaster provides information on the current surface area of exploitation and the type of materials extracted by each operation, but not the total yield in tonnes.

This data had to be consulted in the Statistics on mining production in Andalusia (Industrial Policy and Energy of the Andalusian Regional Government), which shows the total tonnes produced in the reference years for the whole province. Given the total production of the province (NUTS3), and the total surface area of existing exploitations both in the province and in the city of Sevilla, it was possible to estimate the single typology (sands and gravels) and the volume of mining production in the city of Sevilla.

Given that Spain is not a country with fossil energy sources (oil or gas), apart from the natural gas deposits in marine areas in the south of the country, there is no extraction of these energy materials for Sevilla.

Imports & Exports

For imports and exports the situation is even more complex as statistical data at city level are not available. Eurostat provides national import and export data as a starting point, which can be rescaled by using a proxy of employees by industry and matching the classes with the relevant material codes. This method of reducing imports and exports from the national level using economic activities is standard practice in similar assessments (Lavers Westin et al. 2020).

For the analysis of Sevilla City imports and exports, we initially used data on foreign trade at provincial level obtained from the Foreign Trade Database of the State Tax Administration Agency (AEAT), but as we did not have data on domestic trade, which represents approximately 88.76% of the total inputs and outputs of materials and products in the city of Sevilla, it was not possible to consider these as significant data on the city's imports and exports.

In this sense, we have chosen a detailed analysis of Sevilla inputs and outputs of goods based on transport, using the same methodology as other cities in the Cityloops project (e.g., Apeldoorm). There are four possible inputs and outputs of goods: road, ship, airport and rail transport. Between 2016 and 2020, road traffic is responsible for 93~95% of the city's imports and exports.

Once this assumption was taken into account, the values of imports and exports were estimated following the calculation methodology used in other cities, as in the case of Apledoorm, by reducing imports and exports from the entry and exit data of *National annual road freight transport by regions of loading (NUTS 3) and by group of goods (1 000 t), from 2008 onwards* and using information on employees according to the NACE classification for Sevilla, from the exploitation of statistical data from the Labour Force Survey (EPA) at the different territorial levels; city (Sevilla Economic Yearbook), province and region (SIMA-IECA) and national (INE), to calculate the approximate ratio to be used for specific MF codes.

To do this, first the NACE codes were matched with the CPA, and the CPA with the MF, since there is no correspondence between the NACE and the MF. Once the MF values were matched by summing the respective NACE classes related to the MF classification, the final approximation coefficients to be used to reduce the provincial values (NUTS3) were calculated.

At this point there was a problem in defining in detail the employees at city level as the LFS exploitation data only provided total employed persons without distinction for the NACE classification. As these data were available disaggregated by level 1 categories (2-digit NACE codes) at provincial, regional and national level and total employees at city level, by means of a regression analysis the employees in the city were estimated for the economic sectors; NACE A (agriculture sector), NACE B-E (industrial sector) and NACE F (construction sector) in such a way that they could be applied to the NUTS3 import and export data to calculate the final values at city level.

This methodology implies that 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, resulting in some employees being counted several times in some cases. Although undesirable, it was necessary to do so in order to match the Mayer et al. framework which requires more detail than information at the 1-digit MF level.

A final way to estimate imports and exports would have been to estimate the consumption and production levels of Sevilla 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 provided 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

Spanish and Andalusian legislation on access to environmental information obliges administrations to publish relevant information on waste. However, this detailed information only reaches the provincial territorial level (NUTS3) and most of the information retrieved referred to domestic waste, with very little information on industrial waste, limited to companies that have to declare their annual production.

However, the city's waste management company, LIPASAM, is part of the Cityloops project within the municipality of Sevilla, which made it possible to access annually measured data on the waste collected. This municipal waste is sent for final treatment mainly to the waste treatment and recovery plant of Cónica Monte Marta (ABOGARSE).

On the other hand, the drafting team is specialized in waste management and has been able to access the waste data at city level available in the Integrated Waste System of Andalucia (SIRA) by request to the competent regional public administration, the Waste and Land Quality Service of the Junta de Andalucía.

In this way it has been possible to complete all the information at local level on waste production in 2016-2020 from the collection data of the different waste fractions of LIPASAM and the data on shipments of waste subject to the prior notification procedure recorded in SIRA, mainly commercial and industrial waste.

The information in the SIRA is catalogued by the European Waste List coding (LER codes), so it was necessary, beforehand, to relate them to the W codes for waste categories (Eurostat), grouping the LER waste for each W category (Eurostat code). These wastes also had the final treatment for their treatment since prior notifications of shipments are obliged to inform about the origin and destination of the waste moved by producers and operators. However, it is very common in waste shipments that the destination of these wastes are intermediate operations (D13-D15 or R12-R14) prior to their final destination, operations not contemplated in the categorization of waste-by-waste management operations, so that partial information on the treatment was available.

In the case of LIPASAM there is no direct information available on the coding of waste or the final treatment, since, basically, waste generation data is collected from municipal waste collection. Therefore, it was necessary to relate each of the collection fractions with Eurostat W-codes relating waste fraction to a waste category.

Lacking direct information on the destination of waste and its treatment, mainly from municipal waste (LIPASAM) and part of those obtained from the SIRA application, it was decided to estimate the values of the final destination of all waste, in terms of waste treatment, using as a correspondence the final destination of waste in Spain in 2016-2020 (Treatment of waste by waste category, hazardousness and waste management operations). The analysis has been carried out for each waste stream, together with the corresponding treatment.

Material Stock

For the analysis of the construction material, data from the Sevilla cadaster were used, thus obtaining the following information on the buildings: geometries, year of construction, typology, gross surface of the plots and number of heights.

On the other hand, given that no studies have been found for Sevilla and Spain in which an approximation of material intensities according to typologies and by band of years is sufficiently broken down, it has been decided to take as reference the Study of Padua by Alessio Miatto et al. (2019).

Taking into account an average height of 3 meters per plant, it has been possible to calculate the m^3 built, grouping the data according to typologies and periods of years provided in the studio of Miatto in al. 2019, to apply the corresponding material intensities according to typology and year.

One of the main limitations of the study, when taking into account the material intensities of Miatto et al. (2019), is the difference in heights of the building in general, since the maximum height of the buildings in Padua is four floors, in front of the 17 floors that can be found in Sevilla in residential and non-residential (existing a building of 20 floors in residential and 21 floors in non-residential).

Another limitation is the difference in the use of materials according to typologies of the two cities, despite the similarities between the construction systems given their geographical proximity and similarity of climatic conditions.

In this way, the cadaster data used are of high quality; however, they have had to assume the variations that surely would existed if the study of material intensity of Sevilla could have been carried out.

On the other hand, the material intensities of Miaato et al. 2019, were only disaggregated until 2007, which has assumed the same material intensities for the period between 2008 and 2022, assuming that the construction systems have not changed too much from that year to the present.

Finally, it should be pointed out that the analysis of the stock is focused only on stored materials by the building stock, so materials stored in the construction of the infrastructure and the rehabilitation were not taken into account. This difficulty arises when comparing the storage of materials in the housing stock with the flows of materials (extracted, imported and exported). However, the data obtained are in the same order of magnitude.

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 Sevilla. 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 Sevilla.

8.1. Insights on Status Quo of Sevilla

As previously stated, the city of Sevilla is highly dependent on the exterior in terms of circularity. Like most European cities, import flows (2,650 kt) far exceed local production (607 kt), a fact that is particularly evident in Sevilla, where a small quantity of materials is produced that in no case covers local needs. In addition, there is little reuse of the waste generated.

As an eminently consuming city, the external dependence is demonstrated by the need to import materials for energy uses to supply domestic consumption (1,230 kt in 2020). Of the rest of the materials imported and produced locally, only a small part is destined for material uses (514 kt), of which just over half are used in construction and renovation of buildings.

A large part of the extraction and local production is exported directly to supply consumption in other territories. A total of 1,282 kt of imports, plus another 440 kt of local production, go directly to outlets in the materials cycle. This situation has been increasing considerably in recent years, associated with the implementation of transport logistics services in the city, due to its strategic location which have made it a logistics hub of great importance in Andalusia and Spain.

The consumption of energy materials is responsible for the vast majority of local emissions (1,200 kt), while import and export flows have much less "weight", but have an important responsibility in other related challenges, such as climate change.

It is also evident that a very small amount of the waste generated follows a circular economy practice (reuse, recycling, etc.) This amount represents an even smaller part (3.44%) of the materials processed.

Sevilla needs some 3,259 kt of raw materials and other materials annually. The main entry point are imports, as local production is quite limited (607 kt). At internal urban circuit, it processes 1,750 kt in materials, of which 375 kt are added to the stock of buildings and urban equipment and the rest are destined for domestic consumption in the city. It manages to reinject 174 kt of secondary materials recovered from waste into its economic circuit.

The study of Sevilla's stock of materials provides valuable insights on how to reduce the extraction of virgin materials and waste streams going to landfills; and increase the reuse and recycling of building materials. Knowing where and when materials entered Sevilla's urban mine allows us to predict outflows and where they will exit. The "weight" of the built-up city of Sevilla, defined on the basis of its building stock, amounts to 70,960 kt (or 103.7 t per capita), which requires continuous flows for both operation and construction.

Furthermore, the information obtained from measuring material stocks could not only propose circular strategies in the construction sector, but also where to locate reuse centres, develop a materials market and calculate job creation (in materials handling, logistics, etc.)

The results provide a first unique insight into the materiality of Sevilla's economy. However, it also highlights how scarce knowledge and data on these topics are. In collaborating with the city of Sevilla, it is very clear how information and datasets are isolated, poorly accessible or confidential. Those that are available in public sources of information at different territorial levels are neither homogeneous nor sufficiently disaggregated, and sometimes do not even exist. This new type of systemic exercise required gathering information at national, local and corporate levels. It highlights the difficulty of understanding how cities function in physical, economic and employment terms and, therefore, how difficult it is to develop systemic policies.

From this first exercise, numerous data sources were examined, analyzed and processed to carry out the analyses presented. It is true that the data needed to carry out this analysis were often missing at the scale of Sevilla, although they existed at higher spatial levels. This made necessary numerous assumptions and calculations to reduce data to the city scale. This fact compromised the quality of the results, but still provides a solid basis for understanding, using an accounting method that has been validated and employed in a national and European context. In the future, further validations could be carried out by comparing the values with other cities and the Andalusian and Spanish economies.

The following section provides recommendations on how to use the results of this study and how to improve it.

8.2. Recommendations for Making Sevilla More Circular

Through the UCA, several opportunities arose to make Sevilla a more circular city:

- If the elaboration of this study has demonstrated anything, it is the **lack of background information** to be able to address it in depth. Although it is considered that a considerable effort has been made in the search for reliable and exhaustive information, both in more or less long time series and in their territorial correlation, it is not less true that the results suffer, as stated in the data quality matrix, from its maximum reliability, as it is necessary to make estimates for the final data of the city based on superior territorial information.

Therefore, these recommendations should first of all include an effort to make **data available** to improve not only the analysis of the situation, but also the monitoring and evolution of Sevilla circularity. Although the city council already offers relevant information in its Statistical Yearbook of the City of Sevilla, as well as other sources of information, whether local, regional, national or European, it is necessary to make an effort to collect better data to monitor the situation, and this should be a task to be assumed by the city's local administration.

It is difficult to propose circularity actions when some data are not as reliable as may be expected. Quality data is the basis for decision-making.

Actual report provides starting information on how to make the city more circular. This exercise shows where future efforts should be focused to make the analysis more relevant, as well as to develop internal capacity.

More specifically, here are some proposals for improving the quality of the assessment in future iterations.

- For domestic extraction, the information on economic activity in the city can be extended by enhancing the information on consumption and markets with local production data following the reporting patterns of agricultural statistics from other public agencies.

- For imports and exports, it is essential to obtain more granular and qualitative information on flows, focusing on city data, by examining production flows (a local survey of production activities could be a good start) and consumption flows (a local survey of consumption households' patterns and other population segments).

- With regard to waste, more detailed information is needed on the final treatment of municipal waste (landfill, incineration, energy recovery, recycling and landfilling). It is not enough to know that most of waste is destined for treatment and recovery plants; it is necessary, under the principle of co-responsibility in management, to look more closely at the final treatment of the waste delivered to the waste managers and what percentage of it is recovered, defined by differentiated fractions.

  It is also important to homogenise the information collected annually according to criteria of habitual or standardised use in other institutions and public bodies, so that the information reported can be comparable with different spatial correlations.

Finally, it would be necessary to deepen in the knowledge of some waste categories (chemical and medical waste, recyclable waste, equipment, biomass, mixed waste, minerals and metallic waste) in order to get an idea of circularity practices and how to improve them.

- As for the analysis of stock it is recommended to carry out the study of the intensity of materials of the different typologies adapted to the city of Sevilla. From the University of Sevilla and the Valencian Institute of Building (IVE). Much progress has been made and resources should be allocated for a calculation more adapted to the city, taking into account also the materials stored in the rehabilitation, in road infrastructure and others generally in a disaggregated manner. In addition, this study should set up a monitoring and evaluation system to monitor the evolution of the consumption and storage of materials for construction and rehabilitation.

- This data collection effort would be meaningless without accompanying **research and development**. There are still gaps in information about urban metabolism. The current analysis provides a first reference of the circular evaluation for Sevilla, but it is necessary to go deeper into material flows and how these flows are reflected in the city, not only in materials used in construction or the waste and emissions generated in these uses, but also in the knowledge of the intensity of the materials used in construction in order to know in detail the existing stock in the city of Sevilla, both in buildings and in infrastructures and equipment.

  Part of the future task of the city of Sevilla should be to rely in this effort on research centers about flow of materials and energy, as well as on those research and development teams that can contribute information of interest to the in-depth analysis of local circularity.

- Ideally, circularity is improved by **increasing self-sufficiency**. Increasing the city of Sevilla own resources clashes with the handicap of the territorial model. Sevilla does not have a large amount of land covered by vegetation, only 33% of the territory has agricultural and forestry uses, which are difficult to expand. On the contrary, urban uses are more likely to reduce the availability of agricultural and forestry land. Therefore, it would be advisable to protect the available vegetation-covered space, not expanding urban space into areas with high agrological potential.

  Reducing domestic extraction destined directly for exports, and even increasing the part of imports stored in logistics centres and destined directly for exports, would make it possible to cover part of Sevilla biomass demand, which could be satisfied by local food production, and part of this biomass could even be used for energy purposes, reducing the demand for imports and, in part, GHG emissions.

  This self-sufficiency can be supported by the Andalusian Circular Bioeconomy Strategy which focuses its efforts on agriculture, forestry, fisheries, food and paper production, as well as part of the chemical, biotechnology and energy industries, considered key sectors and which could support the economy of Sevilla to increase, on the one hand, the availability of sustainable biomass for its use through innovative treatments and, on the other hand, the markets and consumption of bioproducts and bioenergy, as well as increasing the number of bioindustries and biorefineries.

Within the strategies of self-sufficiency is proposed both the development of strategies for obtaining renewable energies, through distributed generation, energy communities, purchase of green energy, as well as the promotion of the storage of renewable energies that allow the increase of self-consumption, which will also reduce the consumption of fossil fuels.

- Increasing the **re-injection of secondary materials** from waste should be a municipal priority. Exploiting the reuse and recycling of materials that are currently landfilled would not only improve local self-sufficiency in materials, but also reduce the problems of pollution and environmental degradation from waste.

  In the context of waste treatment, recycling, especially of light packaging, is reaching the targets set at regional, national, and European level. However, there are still fractions that need to improve their annual results, such as glass waste or bio-waste, as well as construction and demolition waste. Sevilla does not have sufficient waste treatment and recovery facilities, but the province does, which could allow for an increase in the presence of recycled and recyclable materials in the construction and renovation of buildings.

  Finally, the municipality of Sevilla should also better regulate new construction by filling existing empty buildings instead of building new ones. Empty buildings could also house new productive activities that use small waste streams (coffee waste, bread waste, composting, etc.) and transform them locally for their inhabitants).

  Finally, it is proposed to improve the construction and demolition management and recovery waste, which will be increasingly needed, because about 30% of the physical storage of the property is more than 50 years old and its rehabilitation will be necessary, with the consequent demand for materials. All this without taking into account the operations of rehabilitation and construction of new infrastructures for the development of the city logistic pole, and the necessary implementation of renewables.

- **Implementation and deployment of renewable energies** for the reduction of import demand (for the most part) and domestic extraction (for a smaller proportion) of fossil fuels for energy use.

- **Promote the storage of renewable energies** that allow the increase of self-consumption, which will also reduce the consumption of fossil fuels.

- **Strategy of energy rehabilitation of existing buildings and construction of new plant with almost zero consumption criteria and reuse and recyclability of the**

used materials, to reduce energy demand and the energy incorporated in the materials production processes.

- **Reordering operations and urban planning** focused on the superblocks model in which the equipment and mobility infrastructure would be reorganized, so as to reduce the flow of displacements, promoting that most of them are made inside the superbloks of approximately one hectare. These operations are based on reducing or eliminating indoor road traffic, reversing this surface as a public space for residents of the superblock, leaving in the perimeter the connecting roads.
- **Improve the sustainable mobility of the city**, promoting public transport for reduction of fossil fuels.
- **Review of communication routes and means of transport to and from imported and exported materials, as well as the promotion of clean fuels**, given that most transport takes place by road, with the aim of reducing the import and consumption of fossil materials.
- Collaboration between public and private bodies forms part of another recommendation of interest for circularity, the **creation of networks for the exchange and transfer of information and experiences**. Sevilla as the regional capital and logistics and communications hub of southern Spain could play an active role in all these new actions by developing a circularity roadmap. This could be done by further elaborating the actions presented and identifying the stakeholders responsible for implementing these actions, as well as budgeting the necessary efforts and money. In this sense, this circularity report should serve as the start of a roadmap that incorporates urban metabolism and circularity, not only into the rest of the activities of the city of Sevilla, but extends as a network to the rest of the large and medium-sized cities in Andalusia, and from there, to the rest of Spain, by improving inter-administrative collaboration, research and development and the implementation of measures that reduce the need for natural resources.

  By working more closely with waste extraction, production, and management companies, it would also be possible to refine the data needed to assess and monitor Sevilla circularity. Another fundamental line of collaboration is cooperation with other municipalities in the metropolitan area, both for the promotion of renewable energy, since Sevilla does not have the land for its development, as well as for the promotion of metropolitan public transport, which significantly influences the city, given the high volume of traffic coming from the adjacent municipalities. It should also be noted the necessary collaboration with the University of Sevilla and the Valencian Institute of building for the study of material intensities adapted to the city of Sevilla.

  To this end, thematic working tables could be organized by bringing together groups of experts and public participation actions. The results of the strategies to be established could be recorded in online tools, which facilitate management of the circularity roadmap listing the circularity actions to be developed and track their progress, a forum as well as a map showing where they take place. Another tool that could be used is a material/space/equipment matching tool such as PlatformU.

- **Awareness and education of citizens** towards more sustainable habits. For the adoption of all the measures, it will be necessary actions of information, awareness and education of citizens that allow them to understand and assimilate the necessary changes for Sevilla to be oriented to a model of circular economy more sustainable. These actions will be aimed at raising awareness about the relevance of measures towards a Circular Economy and what it implies, in information of the Roadmap for Ownership in order to facilitate the implementation of measures.
- **Professional training and knowledge management.** Similarly, a professional training plan will be needed for the implementation of the different measures.

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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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