Case Study Report

Comparing the demonstration cities

IVL Swedish Environmental Research Institute

IVL China

IIASA

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List of Abbreviations

CO2	Carbon Dioxide
CPI	Consumer Price Index
GDP	Gross Domestic Product
GRP	Gross Regional Product
ICT	Information, Communication and Technology
KPI	Key Performance Indicators
NUTS	Nomenclature of Territorial Units for Statistics
PPP	Purchasing Power Parity
R&D	Research and Development
SCE	Standard Coal Equivalent
TOE	Tons of Oil Equivalent

1 Introduction

The RECREATE project (Resource nexus for transformation to circular, resilient, and liveable cities in the context of climate change) aims to create sustainable, resilient, and liveable cities through the perspective of urban metabolism analysis.

The project will identify roles, opportunities, and pathways for cities to foster circular economy to significantly reduce energy, water and material resource use, and related environmental impacts, to build resilience to ever-increasing uncertainties from globalization and climate changes, and to become more liveable for growing populations in different urbanization contexts in China and Europe.

The RECREATE project focuses on four cities: Malmö, Vienna, Beijing, and Shanghai. This report compiles the baseline data for the four study cities and represents a review of the current status of each city. It is an initial assessment based on the key performance indicators of five dimensions: 1) resource management, 2) climate control, 3) city health, 4) community, and 5) economy (see the Key Performance Indicators chapter).

This report analyses the findings of the city's status in these dimensions. The findings of this report will be complemented by subsequent analyses of the policies, strategies and projects of the four cities to identify how current priorities align with the areas of improvement identified in the data. This report provides quantitative data on the four cities, that helps to understand the current trajectories of the cities across sustainability indicators, which will provide a foundation for modelling future scenarios of possible pathways and impacts for the cities.

2 Background of the study cities

2.1 Malmö

This section provides a brief overview of Malmö and its surrounding area.

2.1.1 The Area

Malmö is situated in Skåne in the South-west of Sweden. It is the third largest city in Sweden with 345 000 inhabitants as of the first quarter of 2020 (SCB, 2020a). The old city centre at the heart of the Municipality of Malmö lies bare the history of the city. Between its founding in the 13th century and now, Malmö was an important trading post for the Hanseatic League, a fishing centre, and a geographic stronghold. Up until the 17th century, Malmö was an important Danish city, but it became Swedish as a result of the Treaty of Roskilde in 1658 and has been ever since (OECD, 2013). Its connection with Copenhagen, and Denmark as a result, has always stayed, and the Capital Region of Denmark, Zealand, and Skåne now form the Øresund Region. The Øresund Region currently houses over four million people , and it is a flagship of cross-border European integration.

Malmö itself has a coastline north-west of the city centre, with the harbour to the north of the centre. The areas in Skåne surrounding Malmö are among the most fertile in the world, and agriculture is a main industry as a result (Visit Sweden, 2020). Public transport connections

between surrounding cities Lund and Copenhagen as well as other towns are abundant. Figure 1 shows an overview of the geographic location of Malmö.

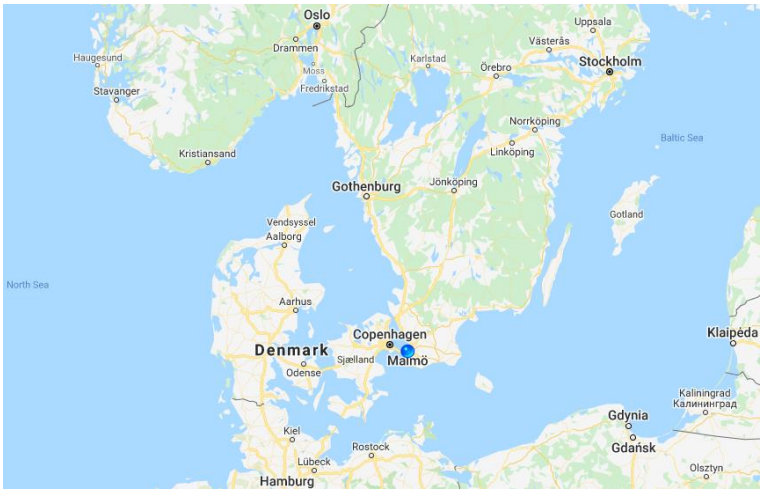


Figure 1 - Geographical Position of Malmö

2.1.2 Population

The population of Malmö is relatively young compared to other municipalities in Sweden since almost 49% of the population is below 35. The total pool includes inhabitants from 184 countries and around 70% of the households in Malmö are with two people or less. The city is growing at a fast pace, faster than the country average.

2.1.3 Economy

Following an industrial collapse in the 1980's, Malmö shifted its emphasis on conventional industries and now focuses more on the health industry, mobile media, and ICT and logistics among others (EU, 2014; Malmö Stad, 2020a). Since 2006, the GDP per capita moved from 369,000 SEK to 538,000 SEK in 2017, which is consistently above the Swedish average, 17% above the average in 2017 (Regionfakta, 2020). Disposable income, however, is consistently lower than the other two largest cities in Sweden (Gothenburg and Stockholm), and Sweden as a whole (Malmö Stad, 2019a). The four largest sectors in terms of workforce are business support services, human health, and social work activities, wholesale and retail trade, and education. Together these groups make up 55.2% of the paid employees (Ibid.).

2.2 Summary of Vienna

This section provides a brief overview of Vienna to provide context for this case study.

2.2.1 The Area

The Austrian capital city of Vienna is currently the home of almost 1.9 million people (City of Vienna, 2019b). As Vienna is not only the Austrian capital but also a statutory town and one of nine federal states, the city is by far more powerful than other cities in Austria (City of Vienna, 2019l). Currently, Vienna's Mayor and Governor, is Dr. Michael Ludwig, a member of the Austrian Social Democratic Party SPÖ (City of Vienna, 2019a). The SPÖ by itself or in coalition with the Greens has been the governing power in Vienna for the past decades and therefore strongly influenced the face of the city over time (Vienna.at, 2020).

Vienna can look back at a vivid history and smart decisions, which still influence the city today in many dimensions. Vienna evolved from being an early Roman settlement, to a medieval city, to becoming an important Baroque city, and in 1556 the capital of the Austro-Hungarian monarchy. Vienna has a reputation of being the European 'music capital', and hosted many outstanding personalities from the music scene, especially during the 16th to 20th centuries (UNESCO World Heritage Centre, 2019a).

In the year 1900, Vienna already had more than 2 million inhabitants. Back then, Vienna was the centre of the Austro-Hungarian monarchy, and many inhabitants of its affiliated countries immigrated to Vienna, leading to a housing shortage. In 1919, the first social housing construct was built, and since then, Vienna has continuously invested in municipal housing (City of Vienna, 2018a). Today, about one in four Viennese inhabitants live in apartments owned by the city of Vienna and managed through Wiener Wohnen. This leads to an overall sufficient housing stock, considerably low rent prices, a small number of homeless people and contributes to a high quality of life (City of Vienna, 2019b; Verlag and Bogacs, 2019).

"Vienna's social housing programme [*sic.*] remains a successful model that enjoys international recognition" (Verlag and Bogacs, 2019, p.3). Besides its outstanding performance in terms of municipal housing, Vienna also performs very well in international comparison in terms of its green areas. Despite Vienna being a very dense city, about 50% of the city is green areas, which not only offer space for leisure activities but also cool the city and provide protection in case of floods (City of Vienna, 2019c, 2019d). In 2020, Vienna was ranked 1st place in the city ranking of the "greenest" metropolises.

2.2.2 Population

Vienna has a tradition of being international and diverse, and today, people from 181 different nationalities live in Vienna (City of Vienna, 2018b). "Instead of a peripheral location close to the Iron Curtain, it now occupies a prime Central European spot in the vicinity of the rapidly emerging Eastern European markets" (Magistratsabteilung 18 - Stadtentwicklung und Stadtplanung, 2014). Moreover, Vienna is closely connected to the UN, as one of the four UN headquarters is located in the Vienna International Center (United Nations Information Service, 2019).

2.2.3 Economy

The economy of Vienna is comprised mainly by services, namely administration, research and science, and knowledge-intensive business services. The industrial sector is relatively small given that while most of the headquarters are located in the city, their respective industrial activities are located in other parts of Austria (DG Growth, n.d.).

Vienna furthermore has meager criminality rates, which were at their lowest point since the start of the tracking in 2018, and its public transport offerings are remarkable (Bundesministerium Inneres, 2018; Wiener Linien, 2019). Overall, 98% of public transport customers are satisfied with the current offer, according to market research of the Wiener Linien, the Viennese public transport company (Wiener Linien, 2019). Moreover, Vienna was the first city in the German-speaking area, to publish open data such as traffic data, environmental data, or budgetary data, and was in the European context among the leading cities to offer open government services (City of Vienna, 2014).

Vienna is internationally recognized for its cultural offerings and is well known for its two UNESCO world heritage sites, namely the city center and the palace and gardens of Schönbrunn. (UNESCO World Heritage Centre, 2019a, 2019b). Furthermore, the city has 261 museums, 99 theaters, and offers many free events, such as the Donauinselfest or the Sommernachtskonzert in Schönbrunn, and many discounts for students or inhabitants with lower income (City of Vienna, 2019e, 2019f, 2019g).

Vienna's efforts for being the most liveable city in the world pay off, as Vienna has a remarkable record of winning awards for being the most liveable city in the world. Examples include the *Mercer's Quality of Living Ranking*, or the Global Liveability Index (Mercer, 2019; The Economist Intelligence Unit, 2018) (Häupl et al., n.d.).

2.3 Summary of Beijing

This section provides a brief overview of Beijing and its surrounding area to provide context for this case study.

2.3.1 The Area

Beijing, with a history of more than 3,000 years, is situated in the North of China, and mostly surrounded by the Hebei Province with the exception of Tianjin, neighbouring to the southeast (seeFigure 2). As the capital of the China, it is the national political, educational, and cultural centre in China and governed as a municipality under the direct administration of the Central government. It is home to the headquarters of most of China's largest state-owned companies and houses the largest number of Fortune Global 500 companies in the world, as well as the world's four biggest financial institutions. It is also a major hub for the national highway, expressway, railway, and high-speed rail networks. In 2008, Beijing hosted the Summer Olympic Games, and will host the 2022 Winter Olympic Games as the first and the only city to host both of these events.

Figure 3 - Administrative divisions of Beijing (Beijing Municipality, n.d.)

Beijing, together with Tianjin and Hebei Province, form the Jingjinji Metropolitan Region or Jing-Jin-Ji (JJJ) as the Capital Economic Zone[1] in 2014.

[1] It is the biggest urbanized megalopolis region in North China. This emerging region is rising as a northern metropolitan region rivaling the Pearl River Delta in the south and the Yangtze River Delta in the east.

Figure 2 - Map of China with Beijing marked in red[2]

Beijing is marked by its flatness and arid climate. It is located in North China at the northern tip of the North China Plain, near the meeting point of the Xishan and Yanshan mountain ranges. The city itself lies on flat land (elevation 20 to 60 m (66 to 200 ft)) that opens to the east and south. The municipality's outlying districts and counties extend into the mountains that surround the city from the southwest to the northeast. The highest peaks are over 2,000 m (6,600 ft).

Beijing covers an administrative area of 16,410.5 km with 16 urban, suburban, and rural districts. There are five major waterways from west to east flowing through the municipality.

2.3.2 Population

Beijing has approximately 21.5 million residents in 2018 (of which 86.5% are urban and 13.5% are rural residents), making it the second largest city by population in China after Shanghai. During the investigated period, the population kept increasing between 2003-2016. The population gains are driven largely by migration. Since 2017, the population shows a declining trend largely due to 2017 Chinese government population controls for Beijing and Shanghai to fight with the so-called "big city disease[3]". And, because of this policy, Beijing's population declined by 20,000 from 2016 to 2017. Besides, some low-income people are being

[2] Source: https://en.wikipedia.org/wiki/China#/media/File:China_administrative.svg

[3] It includes congestion, pollution, and shortages of education and health care services.

forcibly removed from the city as both legal and illegal housing is being demolished in some high-density residential neighbourhoods. The population is being redistributed to Jing-Jin-Ji and Xiong'an New Area, the transfer to the latter expected to include 300,000-500,000 people working in government research, universities, and corporate headquarters.

In 2018, the population's birth rate and the natural population growth rate were positive (8.24‰ and 2.66‰, respectively (National Bureau of Statistics of China, n.d.)). The gender balance was 50.9% males and 49.1% females.

Figure 3 - Population of Beijing

Around 42% of the population in Beijing is under 35 (2018). A survey from 2018 showed 22.9% of households consist of a single person, 30.1% consist of two persons and 26.4% consist of 3 persons. Moreover, only 48.3% of the population has Beijing Hukou (similar a to Green card), of which around 0.8% live in Hongkong, Macao, Taiwan, or abroad.

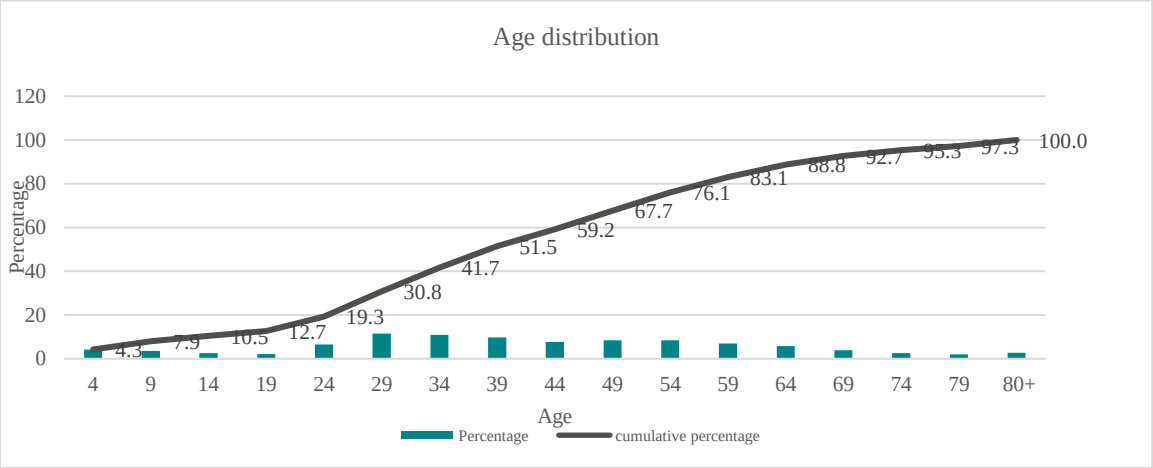


Figure 4 - Age distribution in Beijing in 2018

Beijing is marked by its flatness and arid climate. It is located in North China at the northern tip of the North China Plain, near the meeting point of the Xishan and Yanshan mountain ranges. The city itself lies on flat land (elevation 20 to 60 m (66 to 200 ft)) that opens to the east and south. The municipality's outlying districts and counties extend into the mountains that

surround the city from the southwest to the northeast. The highest peaks are over 2,000 m (6,600 ft).

2.3.3 Economy

Beijing's gross regional product (GRP) amounted to 3032.6 billion RMB (equivalent to 400 billion Euro) in 2018 which increased by 7 times compared with the GRP in 2003 and the total GDP of China in 2018 was 91928.1 billion RMB (12070 billion Euro). It is mainly the service production (account for 81% of the total GRP) that has increased during the investigated period. GPR per capita was 140,211 RMB (equivalent to 18,410 Euro) and disposable income per capita was 62,321RMB (equivalent to 8,183 Euro). Specifically, the service industry comprises the financial, research and development, cultural and education sectors, as well as government administration (Zhang, 2019). The consumer price index was 102.5% compared with the index in 2017(Beijing Municipal Bureau of Statistics, 2019). More information can be seen in Figure 5.

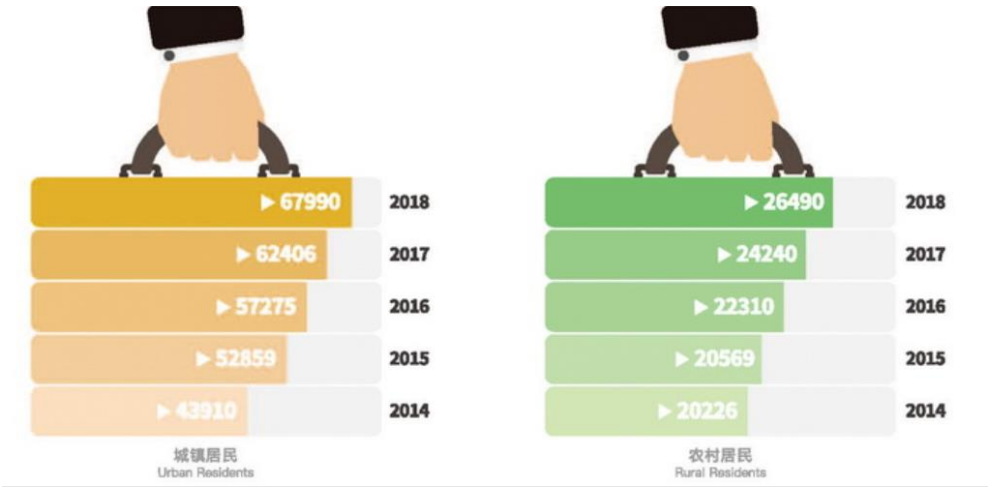


Figure 5 - Disposal income per capita (RMB)

2.4 Summary of Shanghai

This section provides a brief overview of Shanghai and its surrounding area to provide context for this case study.

2.4.1 The Area

Shanghai is bordered by Jiangsu and Zhejiang provinces to the west, the East China Sea to the east and Hangzhou Bay to the south. North of the city, the Yangtze River runs into the East China Sea. Shanghai covers across an area of over 6,340.5 square kilometres with a population of 24.2 million as of 2018.

In 1267, Shanghai Town was set up on the west bank of the Huangpu River. In 1292, the central government of the Yuan Dynasty approved the establishment of Shanghai County, which has widely been deemed as the official beginning of Shanghai as we know it today.

Figure 6 -Map of China with Shanghai marked in red[4]

Shanghai consists of three islands — Chongming, Changxing, and Hengsha — under its jurisdiction. Chongming Island is the third-largest island in China. In 1949, Shanghai was divided into 20 urban districts and 10 suburban districts.

After several adjustments, Shanghai now has 16 districts, 105 sub-district committees, 107 towns, two townships, 4,416 neighbourhood committees and 1,572 villagers' committees by the end of 2018.

[4] Source: https://en.wikipedia.org/wiki/China#/media/File:China_administrative.svg

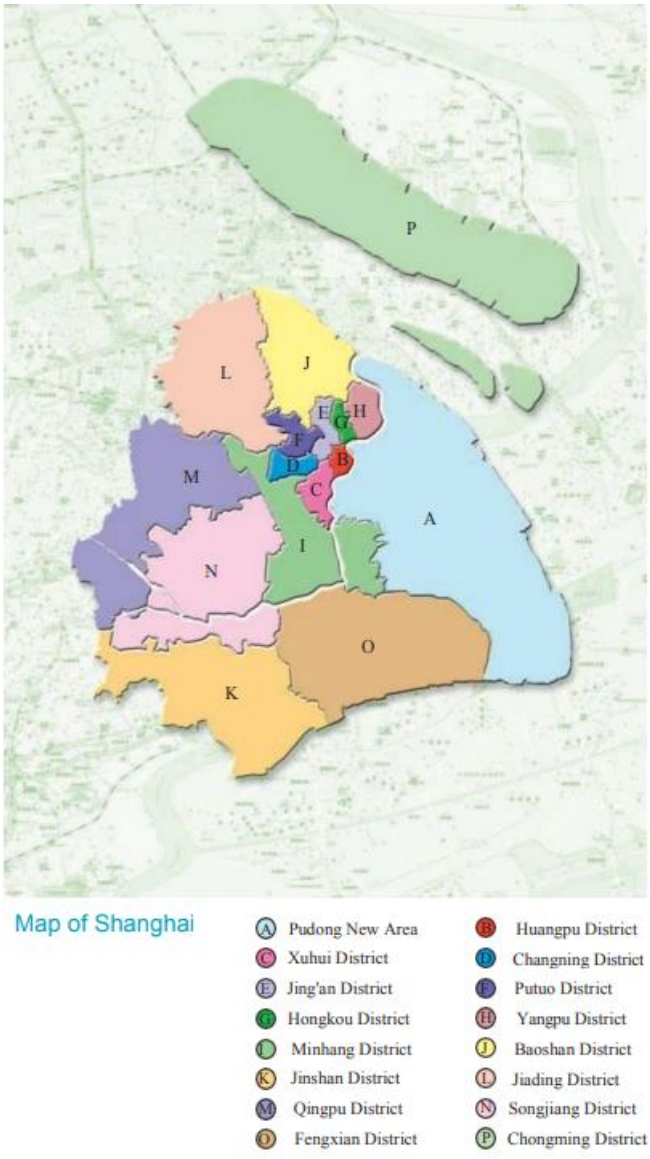


Figure 7 - Administrative divisions of Shanghai (Shanghai Municipal Government, 2009)

Except for a few hills lying in the southwest corner, most parts of Shanghai belong to the alluvial plain of the Yangtze River Delta region. The average sea-level elevation is about 2.19 meters. The land slopes slightly downward from east to west. The highest point within Shanghai is Dajin Hill Island, with a sea-level elevation of 103.7 meters.

2.4.2 Population

Shanghai is the largest city by population in China. Due to the constant inflow of people from other parts of the country, the population in Shanghai keeps growing. When Pend it had a population of less than 100,000. By the end of 1949, the figure had risen to 5.2 million. At the end of 2018 the number of permanent residents reached 24.23 million, including a household register population of 14.4757 million and an external population of 9.7621 million.

The city's population of permanent residents saw a birth rate of 6.6‰, a mortality rate of 8.4‰ and a natural growth rate of -1.8‰ in 2018. Migration played a role in the population change in 2018, however the high birth rate in Shanghai also plays a role in population change in the city.

In 2018, the average life expectancy of local permanent residents stood at 83.63 years – 81.25 for males and 86.08 for females – which is about the same as developed countries.

2.4.3 Economy

In 2018, Shanghai continued to improve its capacity and competitiveness to achieve high-quality development. The city's GDP reached 3.26 trillion yuan, up 6.6% over the previous year in terms of comparable prices.

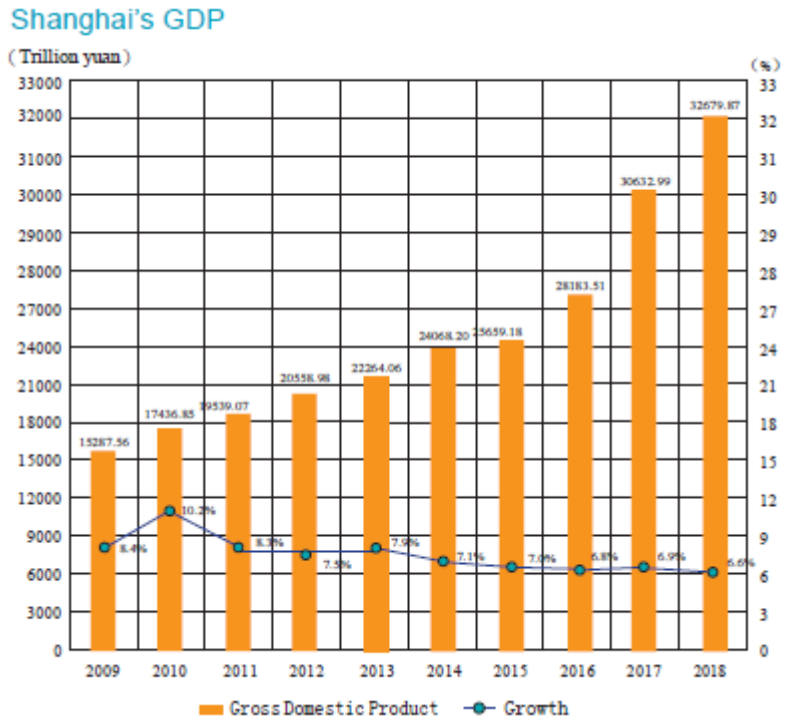


Figure 8 - GDP of Shanghai 2009-2018

The city's GDP per capita, calculated by the long-term resident population and the then exchange rate, jumped over the US$5,000 mark in 2004, and surged above the US$10,000 mark in 2009. In 2018, it exceeded US$20,000 for the first time to reach US$20,398, up 8.6% compared with the level the previous year.

Service Economy

The service economy plays a crucial role in Shanghai's economic development. In 2018, led by information services, business services and technology services, the added value of the service industry gained 8.7% compared to the previous year. A major propeller of the economy, the service industry contributed 92.0% to Shanghai's economic growth, driving overall economic growth up by 6.1 percentage points.

Emerging service industries such as information transfer, software and information technology posted a high-speed growth rate. Revenue of enterprises above the designated scale jumped 12.7% year on year. Revenue of leasing and business service rose 9.8% annually. Development of science research and technology service gained momentum with revenue from major enterprises soaring 16%. Traditional service industry seeks new opportunities as revenue from transportation, storage and post service increased 13% year on year.

Industrial Economy

Shanghai's industrial enterprises realized added value of 869.495 billion yuan in 2018, up an annual 1.9% based on comparable prices. Industrial output from enterprises above the designated size (i.e. enterprises with an annual income of 20 million RMB or above – this a threshold that was established in 2011) reached 3.484184 trillion yuan, up 1.4% from the previous year.

The six pillar industries in Shanghai refer to manufacturing of electronic and information-technology products, auto making, petrochemical and fine chemical processing, fine steel products manufacturing, the production of complete equipment, and biomedicine. In 2018, the combined output of the six industries hit 2.387077 trillion yuan, up 1.4% from the level a year earlier, accounting for 68.5% of the city's total industrial output from enterprises above the designated size.

Agricultural Economy

In 2018, Shanghai's agricultural sector recorded added value of 10.437 billion yuan, down an annual 6.9% calculated using comparable prices. The main reason for this is the re-structuring of industries in Shanghai to reduce the share of agriculture in the total economy and encourage the growth of others such as the information industry. In this process, modern agricultural approaches and the branding of agricultural products from Shanghai was promoted, while the source of basic agricultural products for consumption in Shanghai shifted to surrounding provinces.

The city's total agricultural output value reached 28.248 billion yuan in the year, an annual drop of 4.4%, including 14.754 billion yuan from the crop farming sector, down 2.1%, 1.526 billion yuan from forestry, down 3.6%, 3.634 billion yuan from the animal husbandry sector, down 17.9%, and 5.59 billion yuan from the fisheries sector, down 4.5%.

Employment

Shanghai created 581,700 new jobs in 2018. By the end of 2018, the city registered 194,100 unemployed people: an urban unemployment rate of 3.57%. Meanwhile, more high-end talent settled in Shanghai. By the end of 2018, Shanghai successfully helped 11,583 people, 7,029 of whom were college students, to start their own businesses. A total of 8,777 unemployed youth found jobs or started up their own businesses. The city also offered vocational training for 1.0583 million people, including 462,600 migrant workers. Highly skilled workers accounted for 33.03% of the labour force.

3 Methodology

This section describes the methodology applied for the initial assessment.

3.1 Key Performance Indicators

The four case study cities of Malmö, Vienna, Shanghai and Beijing are very diverse and present different local circumstances. A set of core dimensions and subdimensions were developed to categorise a set of 21 Key Performance Indicators (KPIs) designed to assess the sustainability of the cities (i.e. environmental, economic and social aspects). This provides the foundation to model potential future pathways and scenarios by describing the current status of the cities and the current trajectory in relation to the indicators. The five dimensions are 1) resource management, 2) climate control, 3) city health, 4) community and 5) economy. Each dimension is further divided into subdimensions and the KPIs Data on the individual KPIs was collected for the period 2000-2018, which enables a comparison of the relative performance of the cities.

The quantitative data on the four cities provides a foundation for modelling future scenarios of possible pathways and impacts for the cities. They will be used to develop ambitious scenarios in subsequent stages of the project for the cities to become even more sustainable, resilient and liveable. Urban metabolism analysis will then be conducted for these scenarios.

The data derives mostly from national databases, as further discussed in the data collection section below. To ensure comparability, the report uses Euros for economic indicators, and Tonnes of Oil Equivalent (ToE) for energy indicators unless stated otherwise

Table 1 below presents an overview of the different dimensions as well as the KPIs that the dimensions embody.

Table 1 - KPIs per Dimension

Dimension	Sub-dimension	KPI	Unit
Resource Management	Energy	Energy Intensity	Toe/Energy GDP
		Energy Consumption	Toe
		Carbon Intensity	Ton CO_2/Energy GDP
		Carbon Emissions per Sector	Ton CO_2
	Waste	Urban Waste Generation	Kg/person
	Water	Water Use Per Capita	M^3/Person
Climate Control	Ecosystem	Ecosystem Areas	Percentage

	Emissions Reduction System	Yes/No Description
City Health	Air Quality	Nº
	Green Spaces	Percentage
	Sustainable Transportation	Percentage
	City Density	Persons/km^2
Community	Age Distribution	Age Distribution over time
	Gender Distribution	Gender Distribution over time
Economy	Cost of Living	CPI or PPP
	Wealth Variation Rate	PPP/Person
	Employment Per Sector	Percentage
	Budget Deficit	Percentage of City's GDP
	Unemployment	Percentage
	GDP Variation per Sector	Percentage
	R&D Intensity	Percentage

3.2 Data Collection

For all KPIs, data that originated from national or local statistical databases or databases hosted by governmental, scientific, or non-profit organisations were given priority. Alternatives were used if none of these sources were available. Some of the data used and shown in this report originates from local authorities and are not available publicly. For all data used, the sources indicate its origin. If data for the defined geographical scope are not available, then the NUTS III or NUTS II level data are used instead. This is stated for every KPI where an alternative region is used, and only used if considered representative.

4 City Assessment

This section discusses all KPIs in order of appearance as shown in Table 1. For some KPIs, information on one of more cities is missing. Table 1 shows an overview of the initial KPIs and whether they are included.

4.1 Resource Management

This section focuses on how efficient the different cities handle their resources. The section handles three main topics: energy, waste, and water. The energy subsection focuses on total energy use, as well as per capita use and carbon intensity. The waste subsection handles industrial solid waste, urban solid waste, and waste recovery. The water subsection only handles water use per capita since the other KPIs were deemed untraceable.

4.1.1 Energy Intensity

Defined as "Total energy use per amount of expenditure", this KPI explores the ratio of gross energy consumption and GDP. Cities with more energy intensity per GDP consume more energy to produce the same amount of goods measured in GDP. It must be noted that differences in this KPI are not only the result of greater efficiency, but many other reasons such as labour laws, level of development, and type of industrial activities in the region.

Data are not available for Vienna and limited for Malmö due to a limited access to Regional GDP (Malmö Stad, 2019b; Regionfakta, 2020). Data for Beijing and Shanghai originate from their respective statistical books in table 3-1 (Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019). Figure 9 below shows an overview of the data available.

Beijing and Shanghai show to be close together, while Malmö shows to have a significantly higher energy intensity. However, the energy intensity of Malmö dropped 48.3% from the first available datapoint in 2003 to the last available data from 2017.

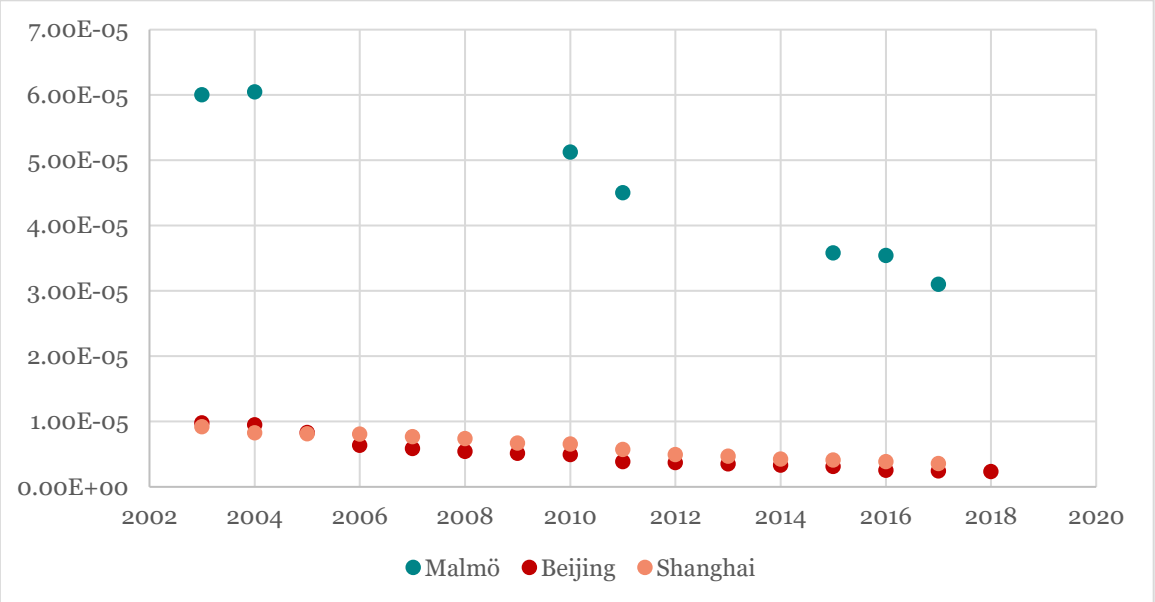


Figure 9 - Energy Intensity in ToE per € of GDP produced per city

4.1.2 Energy Consumption per Sector

Defined as "A measure for the sum of primary energy consumption in industry, agriculture, services, transports, residential and others; this indicator allows for the identification of sectors that are more energy intense and therefore need more action towards being more efficient". This indicator shows what sector consumes the most energy over time. There are no data available for Vienna, and a limited set of years for Malmö.

Table 2 - Overview of data available per city (data)

City	Years Available	Source
Malmö	2003, 2004, 2010, 2011, 2015, 2016, 2017	(Malmö Stad, 2019b)
Vienna	2003–2010, 2015, 2016	N/A
Beijing	2003-2017	(Beijing Municipal Bureau of Statistics, 2019)
Shanghai	2003-2017	(Shanghai Bureau of Statistics, 2019)

Figure 10 shows an overview of the normalised energy use for each city. For Vienna, the years 2011-2014 are excluded; the excluded years divide the service sector up between other sectors and are therefore not representable. Data for Beijing and Shanghai are more aggregated.

The changes in energy consumption per sector in Malmö are only minor, and the fluctuations from sector to sector are less than 4% for all sectors throughout the data available. These minor fluctuations also show in the absolute data. Energy consumption reaches a peak in 2010 but moves back towards early 2000's numbers as time progresses.

Figure 10 and Figure 11 below show an overview of the Energy consumption per sector in normalised and absolute numbers respectively. For the years available, the change over time is relatively small, with the agriculture sector ranging between 79.6–80.1% throughout the time series. The most volatile of the sectors is the Public and private services sector, which ranged between 5.4–4.4%. While the ratio between sectoral consumption is stable, absolute consumption is more volatile, as is shown in Figure 11 below.

Data for Beijing and Shanghai are more aggregated, but data for Beijing are available from 2003 to 2017. Figure 10 below shows a normalised overview of the energy consumption per sector in Beijing (Beijing Municipal Bureau of Statistics, 2019). As time progresses, the industry sector shows lowering relative consumption, while the service sector relatively grows and the other sectors being relatively stable. However, Figure 11 shows that total energy consumption grows in absolute terms. The relative shrinkage of the industry sector for Beijing in Figure 10 is merely due to a stark growth of the service industry, shrinking the relative share of the industry.

The trend shown in Figure 10 and Figure 11 is in line with the Chinese plans for Beijing as described in the thirteenth Chinese five-year plan, stating that Beijing is to be relieved of its nonessential functions, one of which is industry (Central Committee of the Communist Party of China, 2016) (Chapter 38, section 1). Therefore, the stable energy consumption for industry, while other sectors continue to grow, can be attributed to policy against allowing more industry to settle in the area.

Data for Shanghai were only available for the years 2006–2011, of which Figure 10 shows the data normalised and Figure 11 shows the absolute data(Shanghai Bureau of Statistics, 2019).

The relative energy consumption shrinks for all sectors in the five-year time period, with the greatest drop occurring in the agriculture sector.

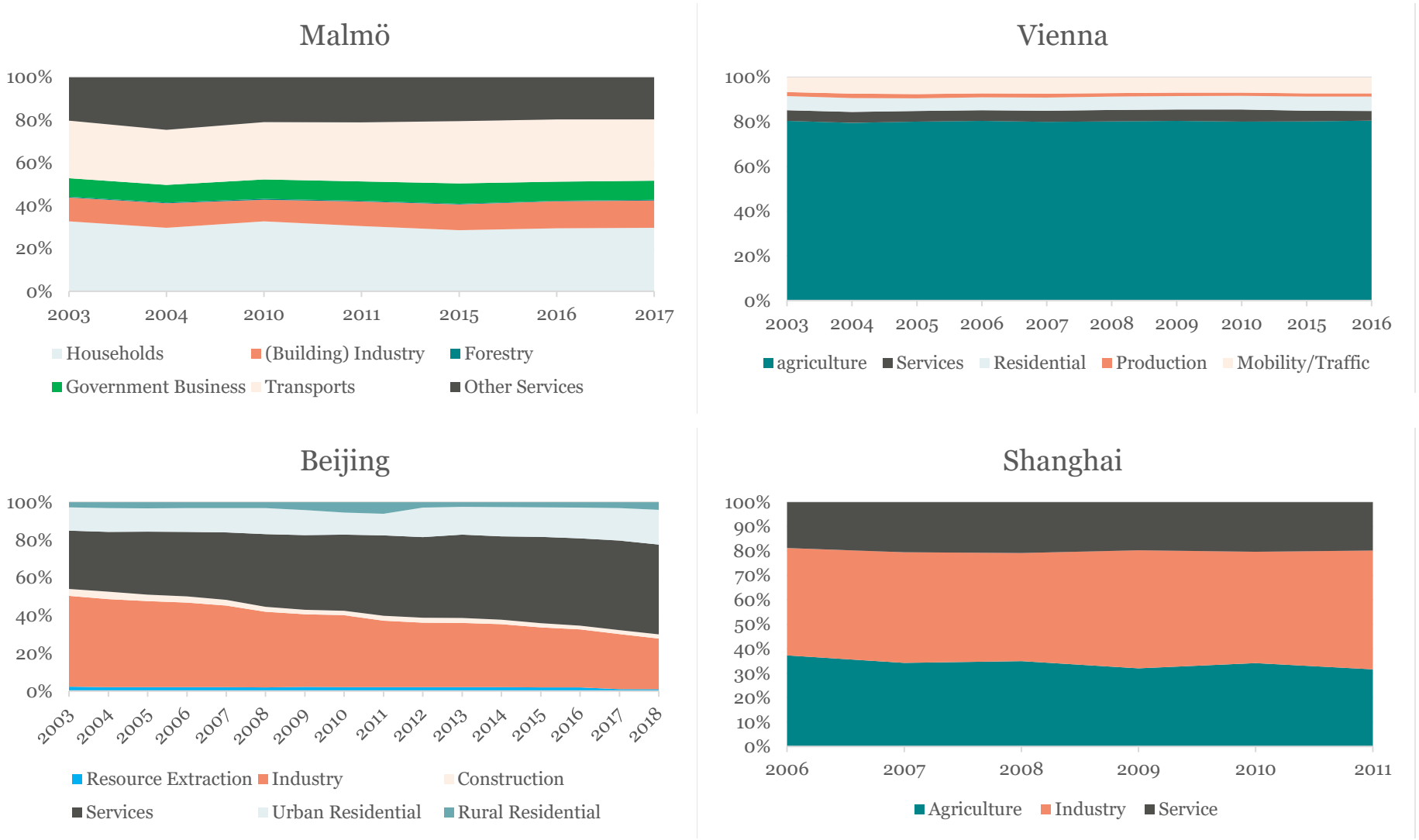


Figure 10 - Energy consumption per sector by percentage

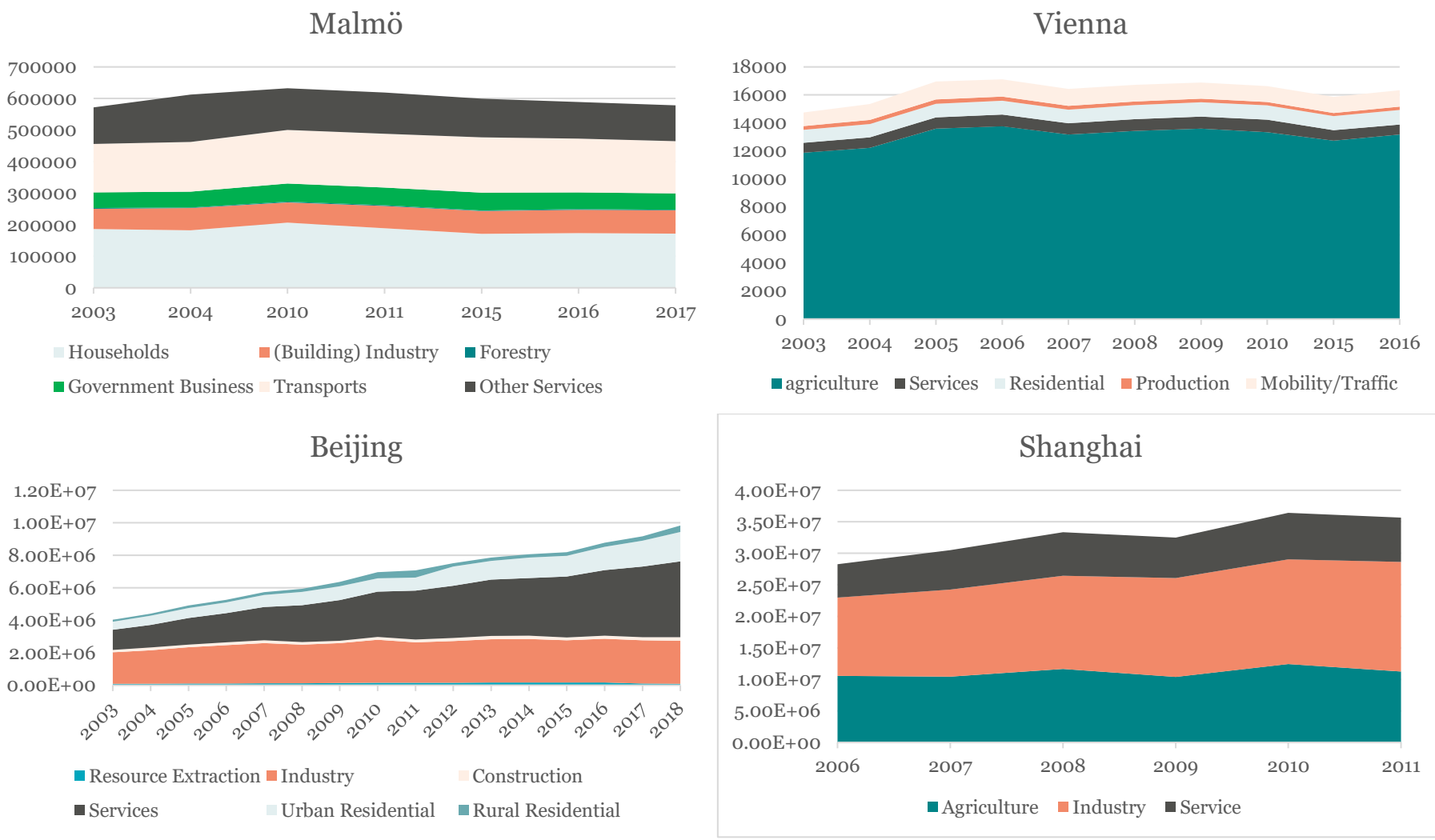


Figure 11 - Absolute Energy Consumption per sector

4.1.3 Carbon Intensity

The definition of this indicator is "Carbon emissions due to energy consumption. It is the ratio between CO2 emissions and GDP, showing energy efficiency", and is measured in Ton of CO_2 per € of GDP. Due to limited data availability, Malmö data were only available for three points (Malmö Stad, 2020b). Data for Beijing and Shanghai are for 2003–2017 (Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019). The data for Vienna covers 2002 to 2017 (Austria, Gross Domestic Product and Main Aggregates - Annual Data, 2020; Austria, Air Emissions Accounts, 2019). Figure 12 - Carbon Intensity for Malmö, Beijing, and Shanghai (Ton of CO_2 per € of GDP) below shows an overview of the carbon intensity over time. While there are only three points available for Malmö, it shows a stark decrease in CO_2 per € spent. However, in the last year available, it is still more than four times higher than either Beijing or Shanghai.

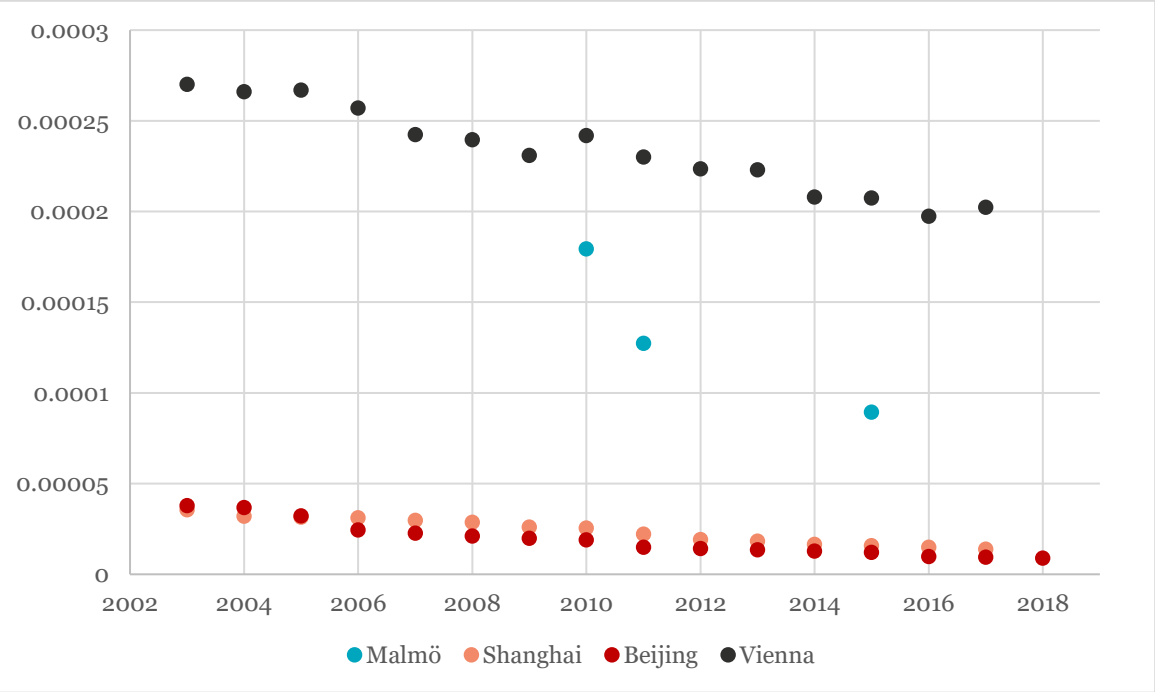
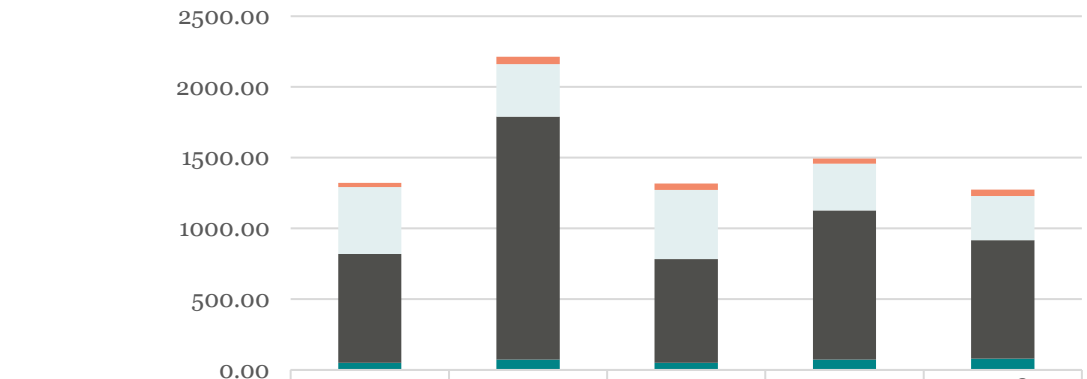


Figure 12 - Carbon Intensity for Malmö, Beijing, and Shanghai (Ton of CO_2 per € of GDP)

4.1.4 Carbon Emissions per Sector

The definition of this indicator is a "KPI that assesses the measurement of CO2 emissions per sector and shows the carbon dependency per sector". The data is not available for Vienna and only sporadically available for Malmö (Malmö Stad, 2020b) and Shanghai (Shanghai Bureau of Statistics, 2019). It is available for Beijing from 2003 to 2017. Figure 13 below shows an overview of the data for Malmö. The large peak for 2010 stands out and is the sole result of a swift increase and decrease of the Industry & Energy sector.



	2005	2010	2012	2015	2018
Other Transport	30.00	52.00	45.6	38.00	44.00
Road Transport	472.00	370.00	489	330.00	313.00
Industry & Energy	771.00	1717.19	734	1053.00	838.00
Work Machines & Tools	50.00	74.00	50	74.00	79.00

Figure 13 - Carbon emissions per sector for Malmö (in Ton CO_2)

4.1.5 Waste Production

As waste production for industries was difficult to find for the given areas, this indicator only focuses on the Urban solid waste production, defined as "The amount of city urban solid waste generated per capita in kilogram. This indicator gives an insight in the way products are consumed. Figure 14 below gives an overview of the amount of urban solid waste production in kilogram per capita per year. Household data for Malmö including the waste streams are shown in Figure 15 (Malmö stad, 2019). Which waste streams are included in the data of Shanghai and Beijing is unclear, however it should theoretically include the most common municipal waste streams such as paper, plastic, glass, metals, textiles, and organic waste (Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019). For Vienna, the figures represent national waste generation per year per capita (OECD, 2020).

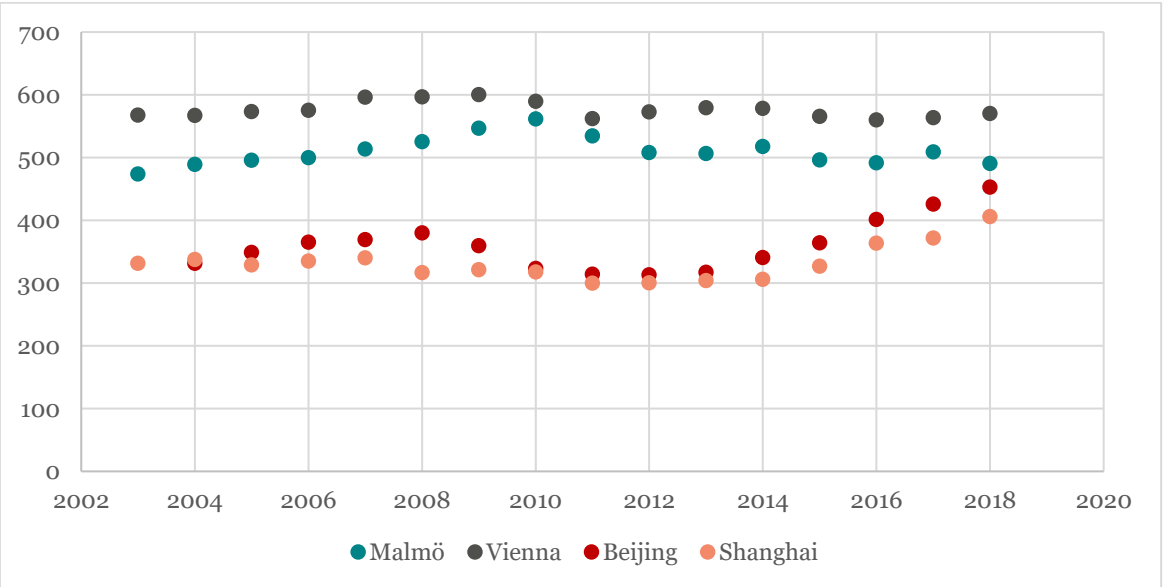


Figure 14 – Urban solid waste production in kilogram per capita per year

While waste production for Malmö goes up towards 2010, it moves back down towards 2018. Beijing sees a high-point in 2008, which dies down later but climbs starker towards the second half of the 2010's. Meanwhile, Shanghai sees a somewhat similar pattern, and both cities move towards Malmö's numbers over time. This is especially interesting given the stark difference in GDP for Malmö and these Chinese cities, which implies that, per GDP, Chinese cities produce far more waste in total than Malmö does.

Figure 15 below shows an overview of the different types of waste for Malmö (Malmö Stad, 2020). This disaggregation is not available for any other city.

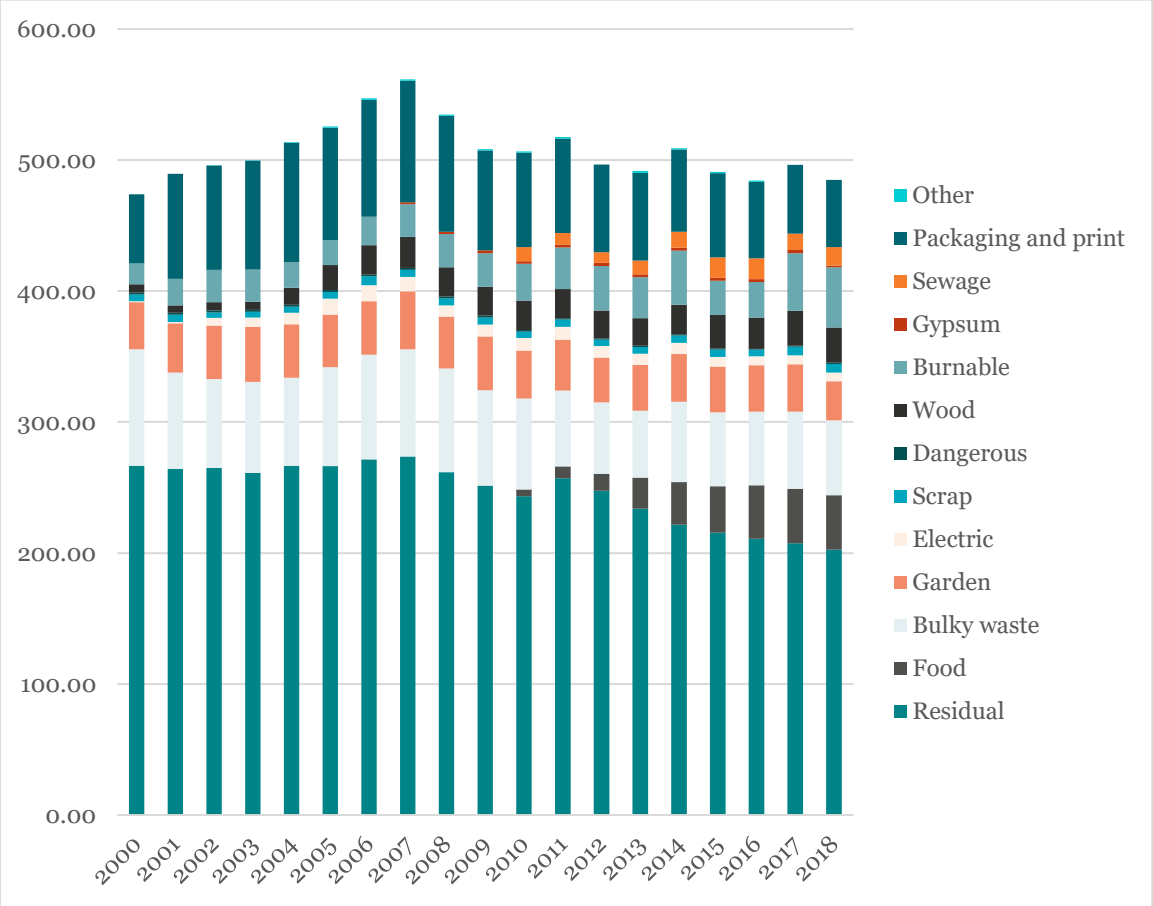


Figure 15 – Household waste production by type in Malmö (kg per capita)

4.1.6 Water Use Per Capita

This indicator focuses on urban water use, excluding industrial water use. The definition of this indicator is "Non-Industrial water use per capita; Water used by citizens in their private life". Figure 16 below shows an overview of the water use in m^3 per capita for the years 2003 to 2018 (Beijing Municipal Bureau of Statistics, 2019; Malmö Stad, 2019c; Shanghai Bureau of Statistics, 2019).

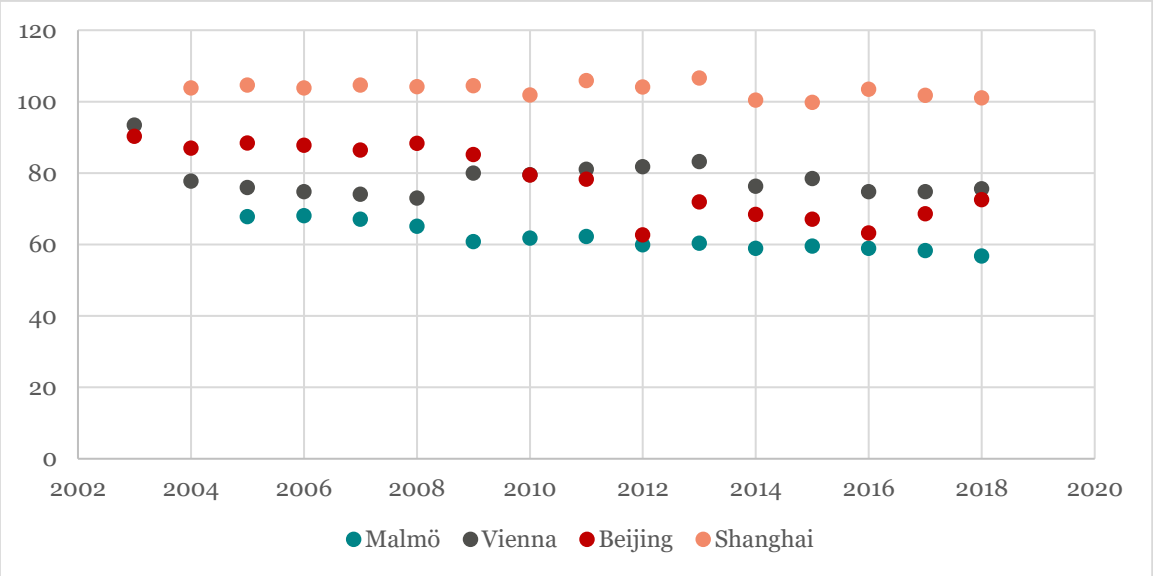


Figure 16 – Water use per capita in cubic meters

Figure 16 shows that Shanghai water use is consistently higher than the other cities. The other three cities also show an average decline of water use per capita, where this is less so the case for Shanghai.

4.2 Climate

4.2.1 Ecosystem Areas

Figure 17 below shows the percentage of municipal surface area covered by registered protected areas including both marine and terrestrial surface area (Beijing Municipal and Environment Bureau, 2019; SCB, 2010; Shanghai Bureau of Statistics, 2019; City of Vienna, 2007). The figures for Shanghai decreased quite drastically from 2008 to 2009 but it is unclear whether this is due to changes in calculation methodology, ecosystem area definition or other reasons.

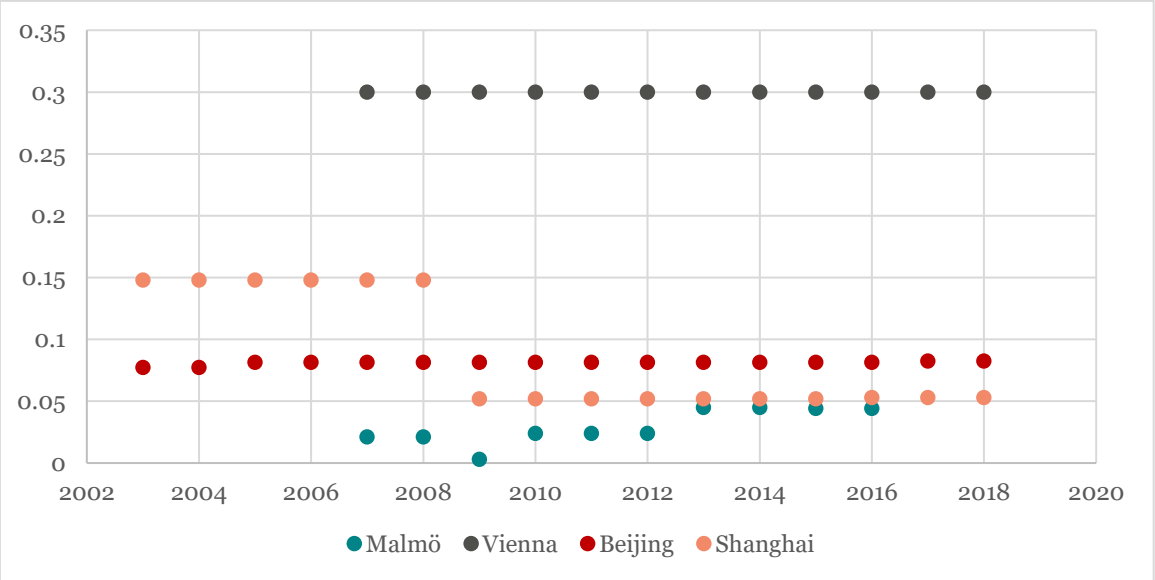


Figure 17 - The annual percentage of municipal surface area covered by registered protected areas during the year 2003-2018

4.2.2 Emissions Reduction System

The indicator checks the existence of a monitoring system for emissions reductions to compute the rate of accomplishment of the city's emission target relating to CO2 emissions. In Malmö and Vienna, a monitoring system for CO2 emissions reduction has been available for the whole studied time period, 2003-2018. While in Beijing and Shanghai, it has existed from 2013 to 2018.

4.3 City Health

4.3.1 Air Quality

Figure 18 below shows the air quality in the cities that is based on how many days per year the limits on the emission of O_3, SO_2, PM_{10}, and $PM_{2.5}$ were exceeded. Days where multiple limits were exceeded counted as multiple times (Beijing Municipal Bureau of Statistics, 2019; IVL, 2020; Shanghai Bureau of Statistics, 2019). For Vienna, specific data on the number of days exceeding set limits were not available.

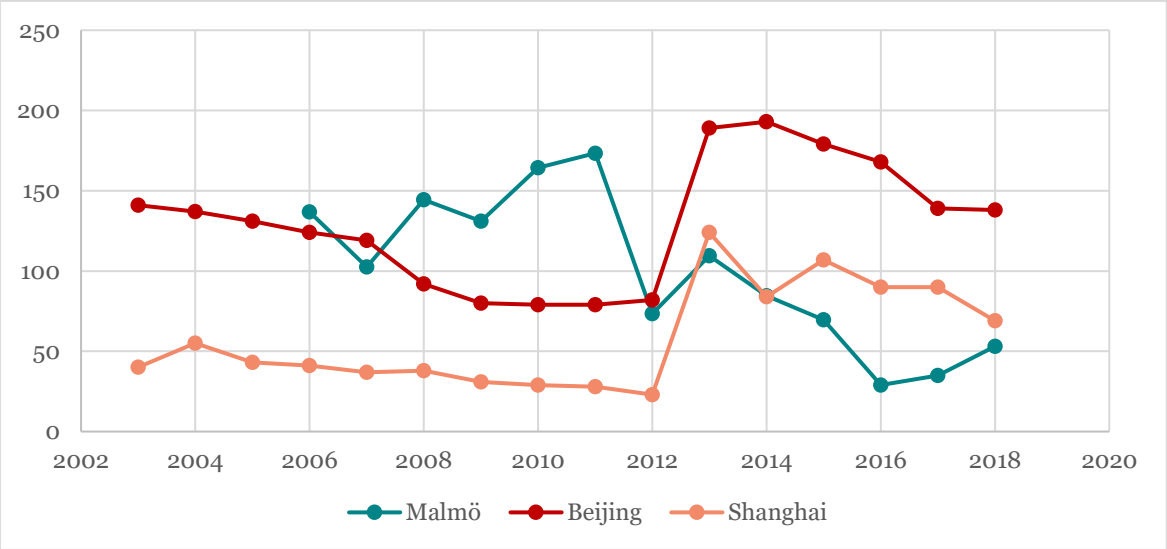


Figure 18 – Number of days exceeding limit values during the years 2003-2018.

The air quality in Malmö has been relatively fluctuating but overall a positive trend appears showing fewer days where the emission limits were exceeded. As for Beijing and Shanghai, the air quality has an approximate pattern to each other with a steep slope between the year 2012 and 2013.

4.3.2 Green Spaces

Figure 19 below shows the annual percentage of the municipal surface area of public green spaces, including urban forests, parks, and other green spaces that are not protected (Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019). Note data on Malmö was only available for the years 2005, 2010 and 2015 (Jerker, 2019; Malmö Stad, n.d.; SCB, 2010).

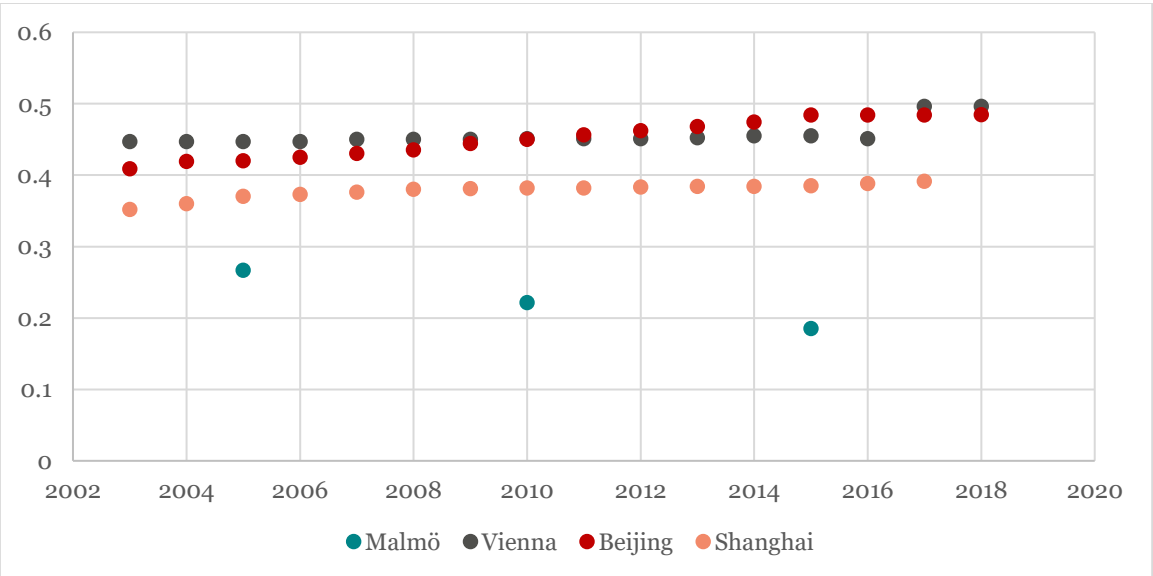


Figure 19 - Percentage of the municipal surface area of public green spaces during the years 2003 to 2018.

For Beijing and Shanghai, the trend is relatively stable with a slight increase of green spaces each year. The change in green spaces in Vienna has been mostly constant but took a relatively big leap between the years 2016 and 2017. The biggest difference in the annual variation of green space between the cities is seen in Malmö which has a decrease of around 31% from the year 2005 to 2015.

4.3.3 Sustainable Transportation

Figure 20 below shows the modal share of sustainable transportation and the results are expressed as a percentage of people per transportation mode. The sustainable transportation modes are the following: walking, bicycle, collective transportation (company, school, etc), public transport. All other modes of transport are considered unsustainable. Data from Beijing and Shanghai originate from their respective statistical yearbooks (Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019). Note data on Malmö were only available for the years 2003, 2007, 2008, 2013 and 2018 (Morin et al., 2018; Skåne.se, 2020).

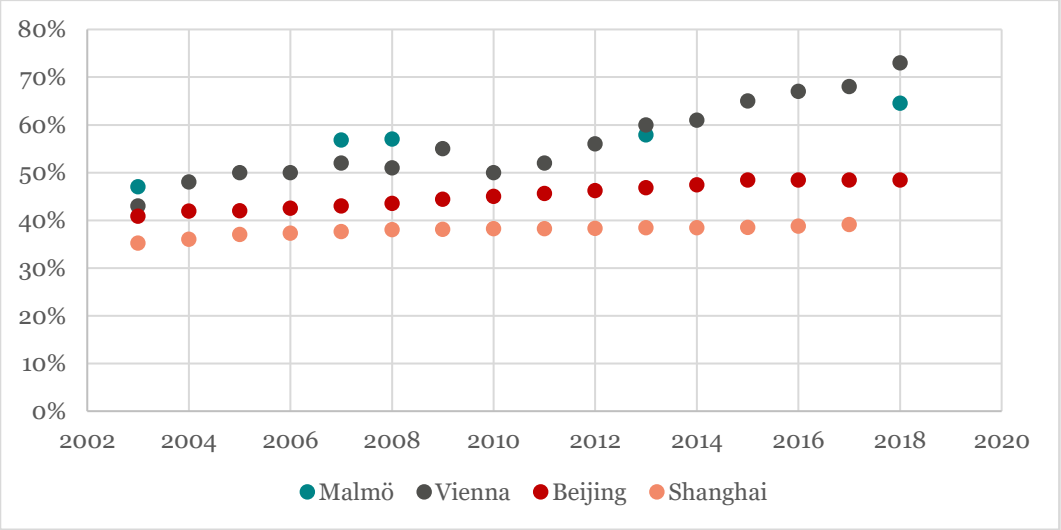


Figure 20 - Percentage of people using sustainable transportation.

4.3.4 City Density

Figure 21 below shows the city density per year measured in persons per km^2. For all cities, the city density has increased where the highest rate of increase is seen in Shanghai, approximately 37% (Beijing Municipal Bureau of Statistics, 2019; SCB, 2019a; Shanghai Bureau of Statistics, 2019), while the overall density is highest in Vienna. The data for Vienna was calculated based on change in population over the current city size as of 2018 (City of Vienna, n.d.).

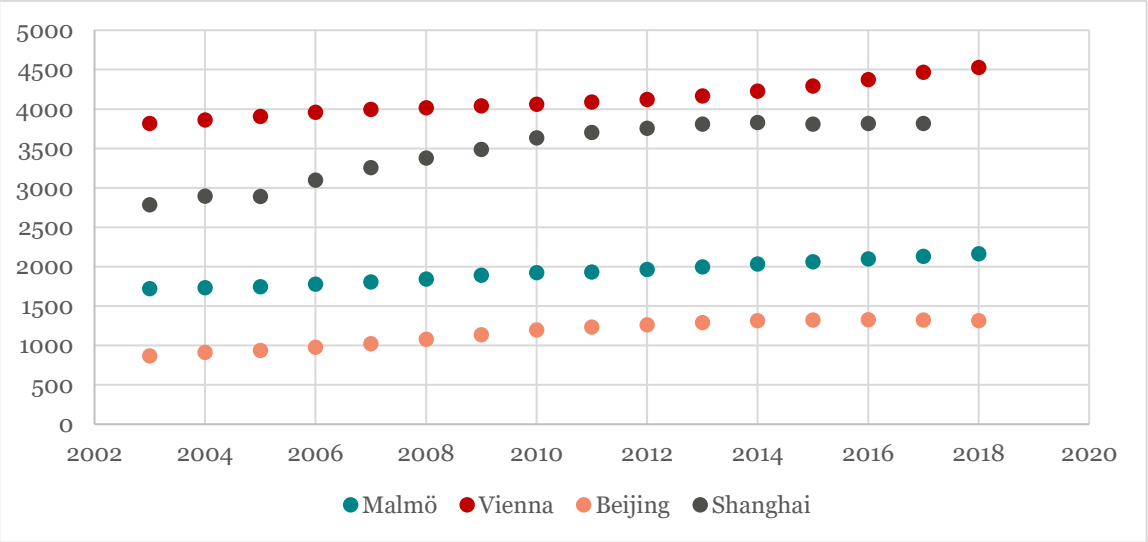


Figure 21 - City density (persons/km²) during the years 2003-2018

4.4 Community

4.4.1 Age Distribution

Figure 22 - Normalised ratio of age groups per city shows the age distribution per year. Note that the age distribution and time period between the cities varies (Beijing Municipal Bureau of Statistics, 2019; SCB, 2019b; Shanghai Bureau of Statistics, 2019).

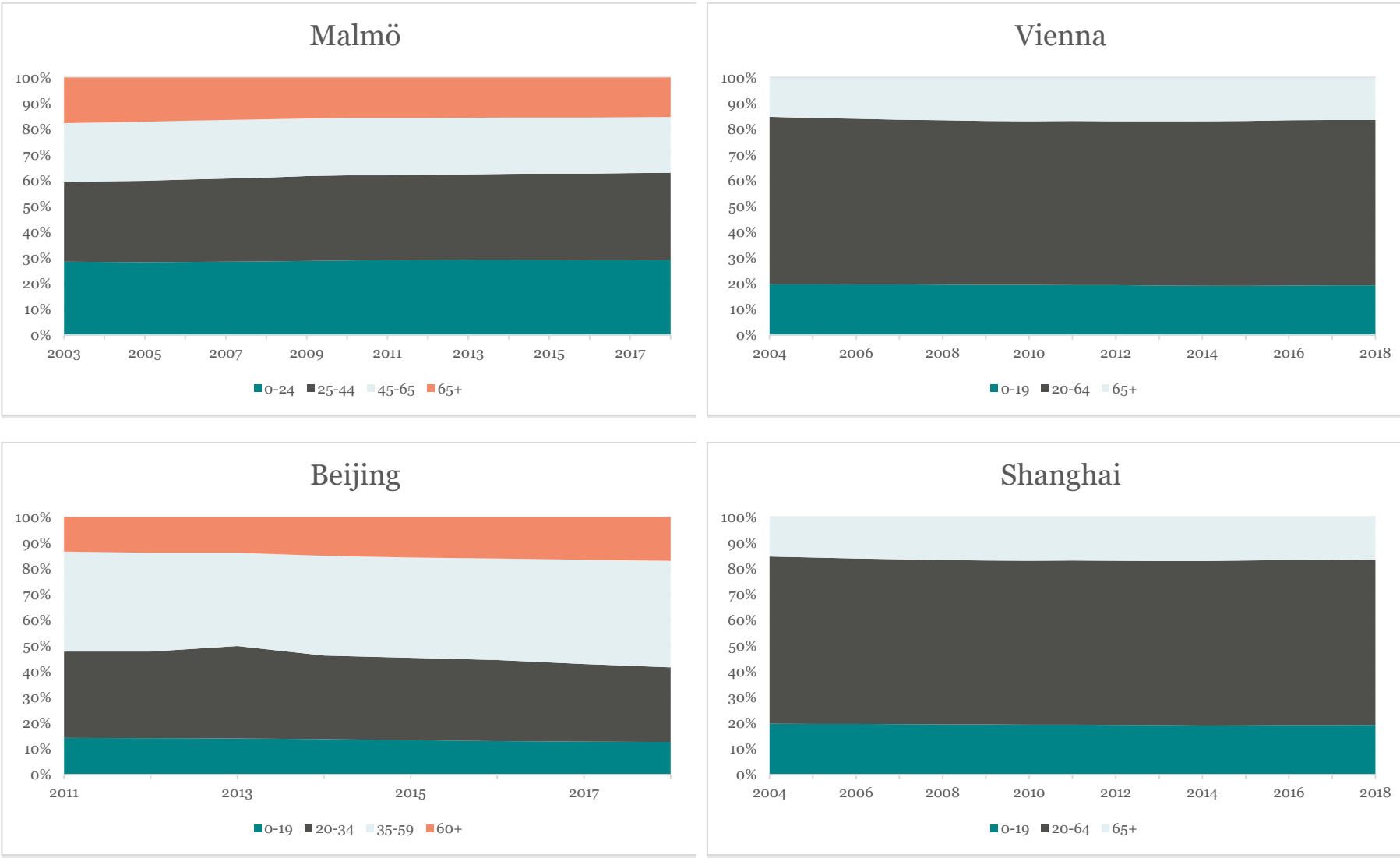


Figure 22 - Normalised ratio of age groups per city

According to Figure 22 - Normalised ratio of age groups per city , the age distributions are relatively stable during the sample period, except in Shanghai, where it is a noticeable increase and decrease in the age distribution 60+ and 35-59, respectively.

4.4.2 Gender Distribution

Figure 23 below shows the gender distribution per year. In Malmö, Vienna, and Beijing, the proportions of females are constantly higher than males during the studied time period (Beijing Municipal Bureau of Statistics, 2019; SCB, 2019b; Shanghai Bureau of Statistics, 2019).

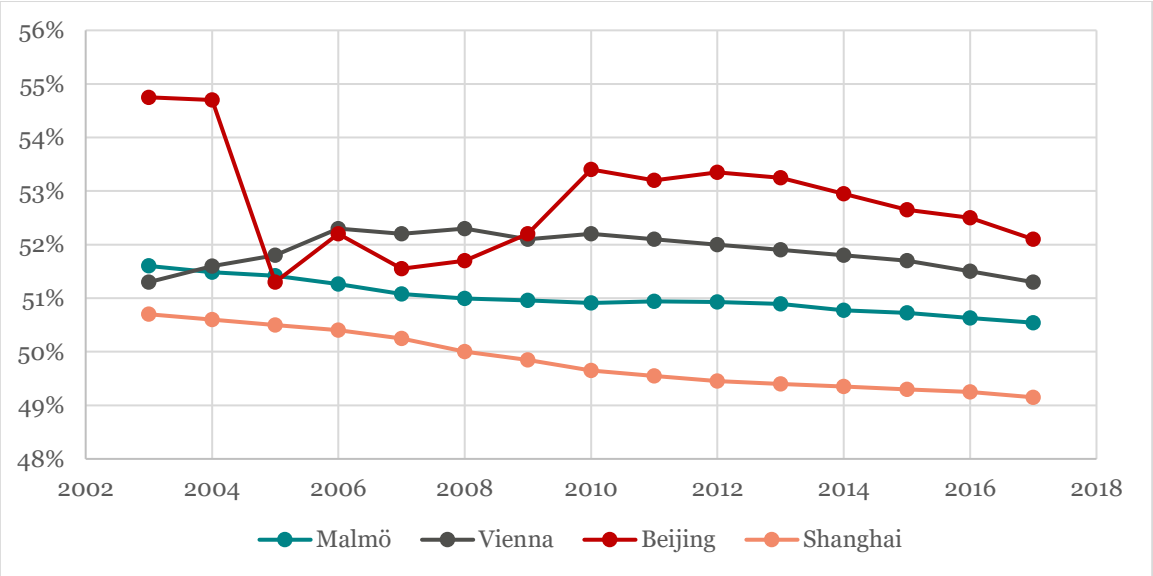


Figure 23 - Gender distribution of females during the years 2003-2017

The trends are relatively stable except for Beijing which has steep slopes between the years 2004 and 2010 with a maximum at around 55% and a minimum at around 51%.

4.5 Economy

4.5.1 Cost of Living

The indicator is defined as "Percentage of income that is spent on housing, food, taxes, and healthcare." Figure 24 below shows an overview of cost of living for the years 2003 to 2017(Beijing Municipal Bureau of Statistics, 2019; Shanghai Bureau of Statistics, 2019).

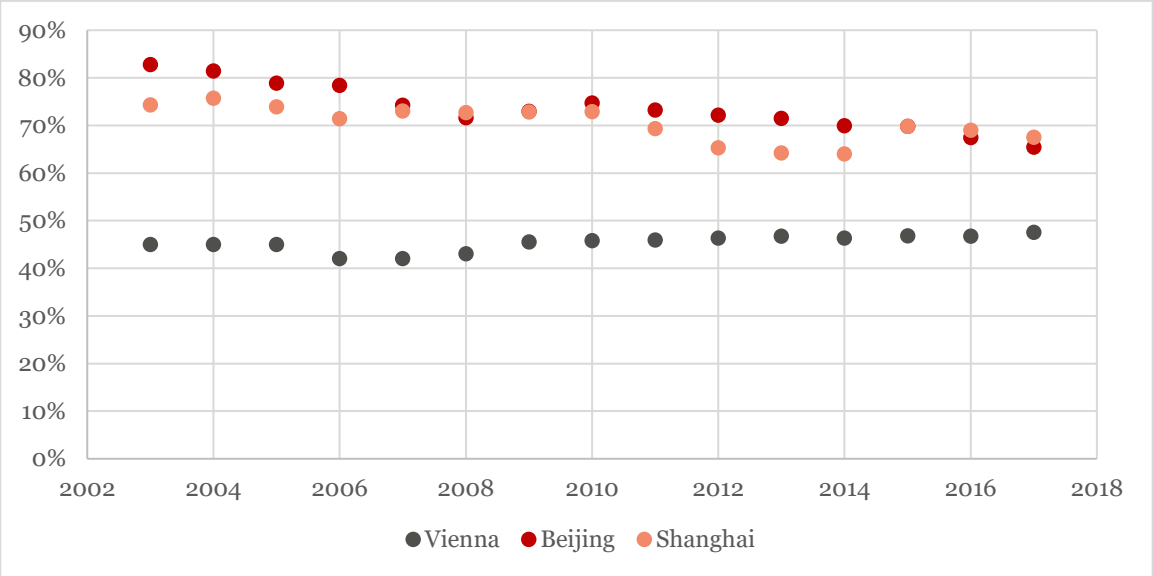


Figure 24 - Cost of living during the years 2003-2017

For Beijing and Shanghai, the cost of living has decreased by approximately 21% and 9%, respectively, while in Vienna, the cost of living has increased by around 6%. No data was found for Malmö.

4.5.2 Wealth Variation Rate

The indicator is defined as "Change of Total GDP over total population" Figure 25 below shows an overview of the GDP in euro per capita for the years 2003 to 2018 (Beijing Municipal Bureau of Statistics, 2019; European Central Bank, 2020; Regionfakta, 2020; Shanghai Bureau of Statistics, 2019).

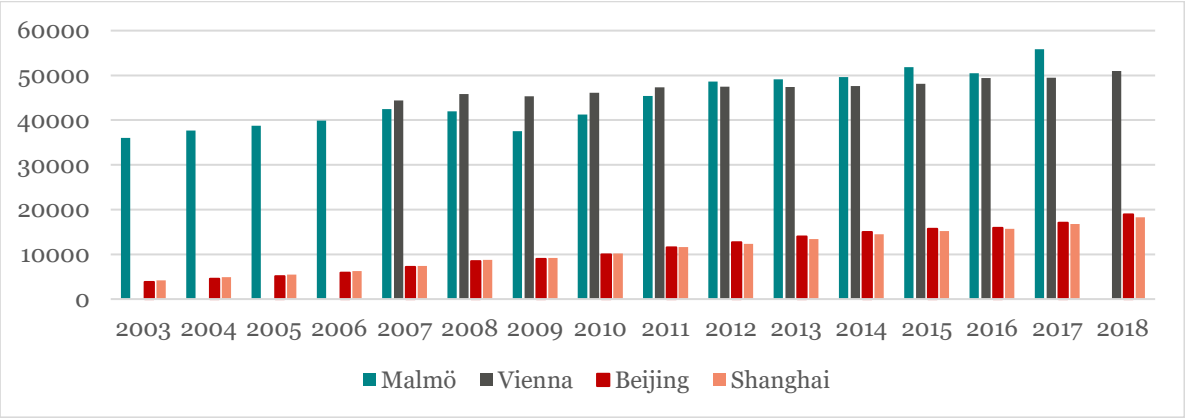


Figure 25 - Change of Total GDP over total population during the years 2003-2018

Figure 25 shows that euro per capita has increased significantly in Beijing (395%) and Shanghai (335%) during the years 2003 and 2018. Malmö has compared to the other cities (no data found for Vienna), the highest euro per capita but the increase is smaller (55%). The trend of the wealth variation in Shanghai and Beijing is roughly linear while Malmö is more fluctuated.

4.5.3 Employment Per Sector

The indicator is defined as "Employment ratio by economic activity sectors (NACE Rev. 2: Agriculture -section A, industry -sections B to F, services -sections G to U)" According to Table 3 - The median value on employment per economic sector during the years 2003-2017 showing the median value of GDP per sector, the service sector accounts for the largest share, followed by the industrial and agricultural sectors.

Table 3 - The median value on employment per economic sector during the years 2003-2017 (Note: data for Vienna is for whole of Austria for 2009-2017 only)

	Malmö	Vienna	Beijing	Shanghai
Agriculture	3%	5%	6%	4%
Industry	20%	26%	20%	38%
Service	77%	70%	74%	56%

According to Figure 26 showing the Employment per sector between the years 2003 to 2017, the share of the service sector is increasing for all three cities: Beijing ~38%, Shanghai ~26% and Malmö ~6% (Beijing Municipal Bureau of Statistics, 2019; SCB, n.d.; Shanghai Bureau of Statistics, 2019; Statista, 2020). Data for Vienna was not available.

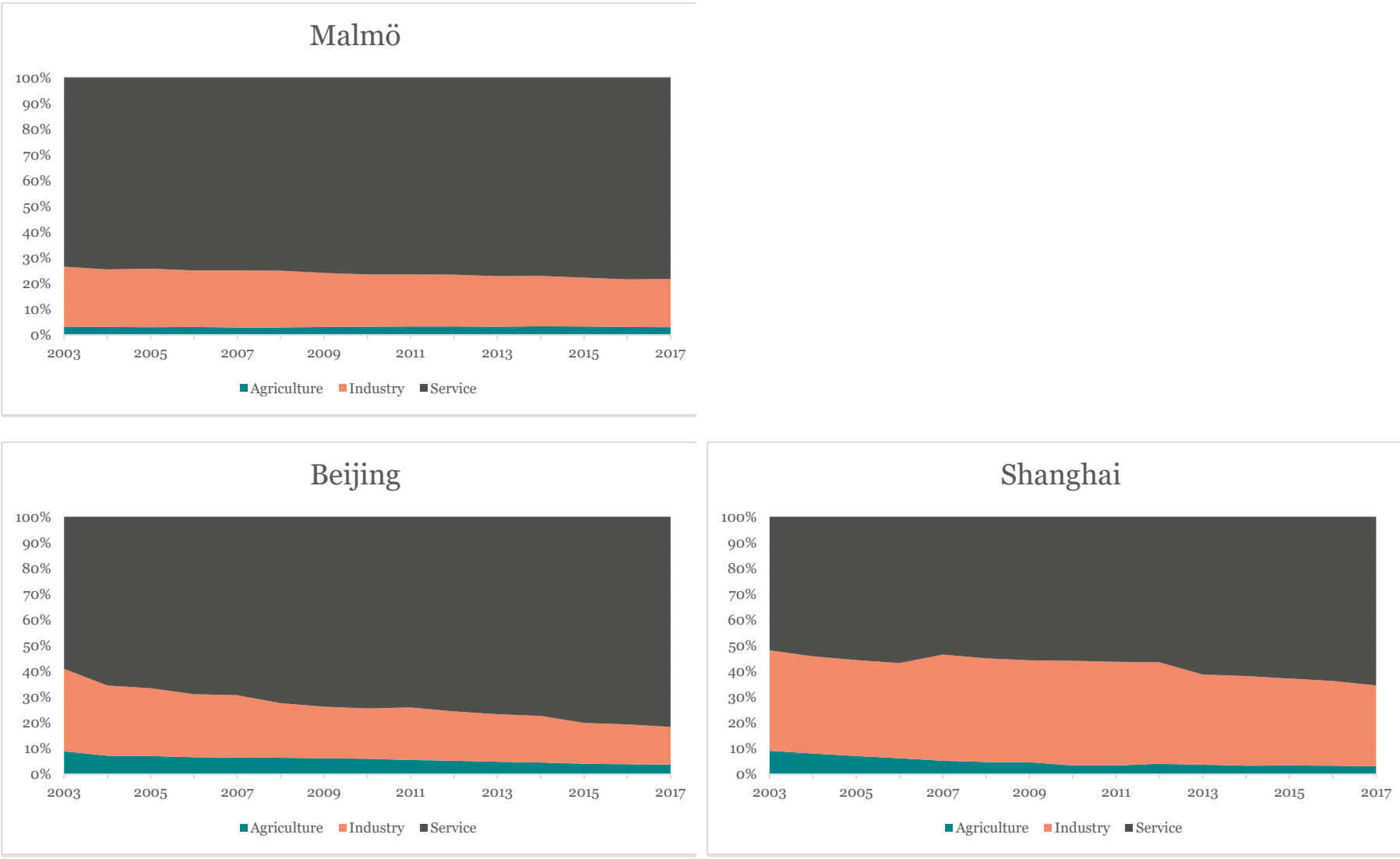


Figure 26 - Normalised employment per sector during 2003-2017 (data for Vienna was not available).

4.5.4 Budget Deficit

The indicator is defined as "Annual deficit as a percentage of GDP". According to Figure 27, Malmö and Vienna both have a budget deficit. The trend is relative stable and median value is 2.5%. In Beijing and Shanghai, the budget deficit is negative which means that the revenue exceeded the expenditures in the given years. Unlike Malmö, the trends are relative fluctuating with a similar pattern (Beijing Municipal Bureau of Statistics, 2019; SCB, 2020b; Shanghai Bureau of Statistics, 2019, Trading Economics, 2020). The data for Vienna was calculated by taking the national budget deficit to GDP ratio of Austria and scaling it to Vienna based on the gross regional product of Vienna over the years (Statistics Austria, 2019).

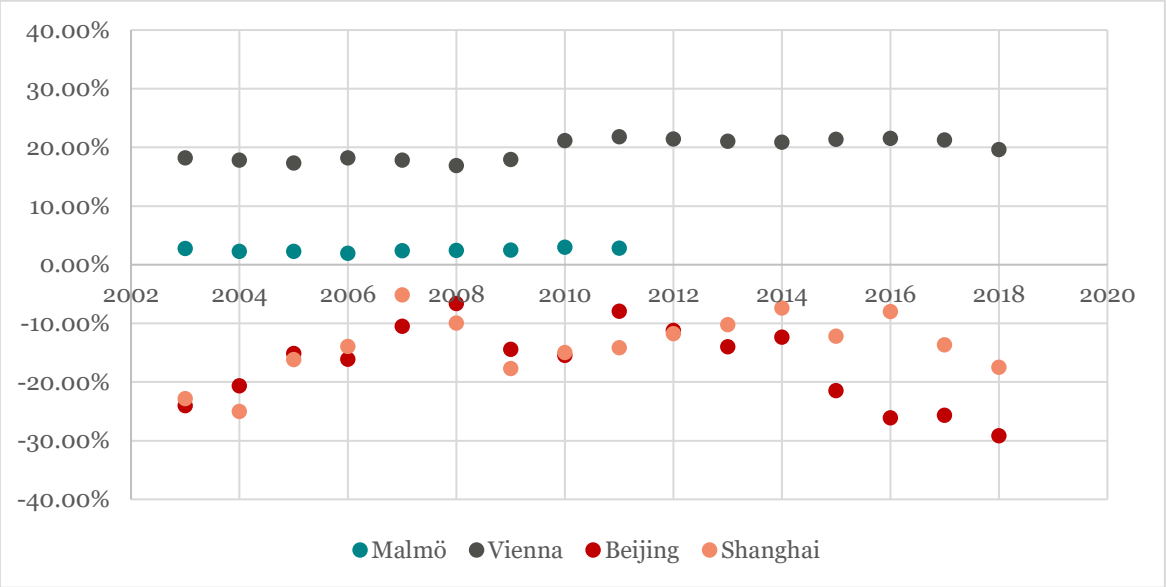


Figure 27 - Annual deficit as a percentage of GDP during the years 2003-2016

4.5.5 Unemployment

The indicator is defined as "Harmonised unemployment rate as an evolution" and is expressed as the share in a percentage of the population that is unemployed. According to Figure 28, the highest unemployment of the four cities is found in Vienna, which, together with Malmö, fluctuates more than Beijing or Shanghai. Between the years 2006 and 2014, the unemployment in Vienna and Malmö has a similar trend. In Beijing and Shanghai, the trends are relatively stable and unique (Beijing Municipal Bureau of Statistics, 2019; SCB, 2020c; Shanghai Bureau of Statistics, 2019).

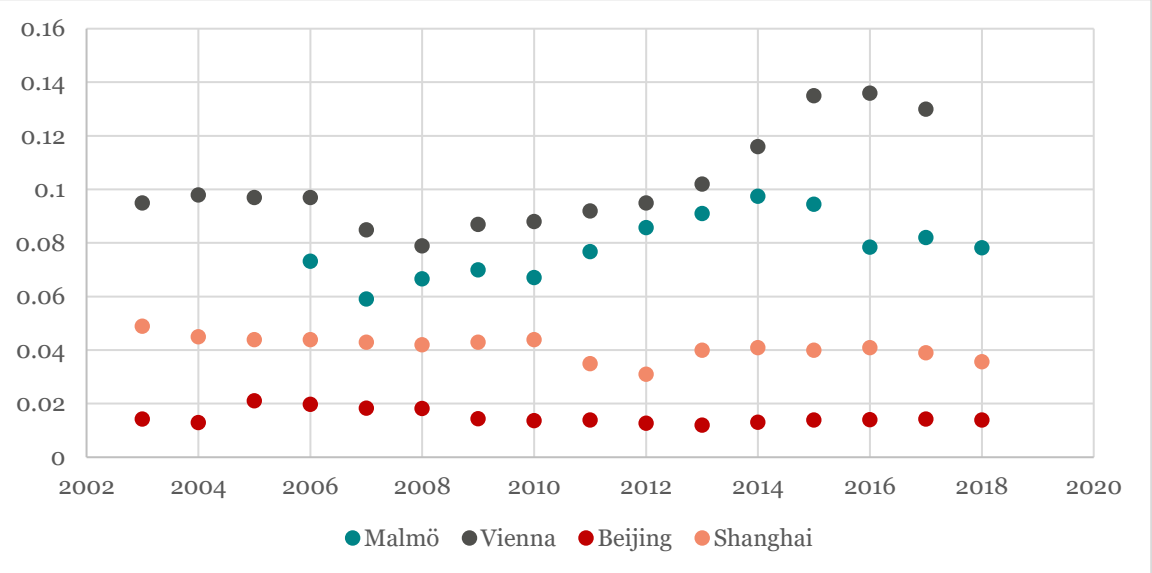


Figure 28 - Percentage of unemployment during the years 2003-2016

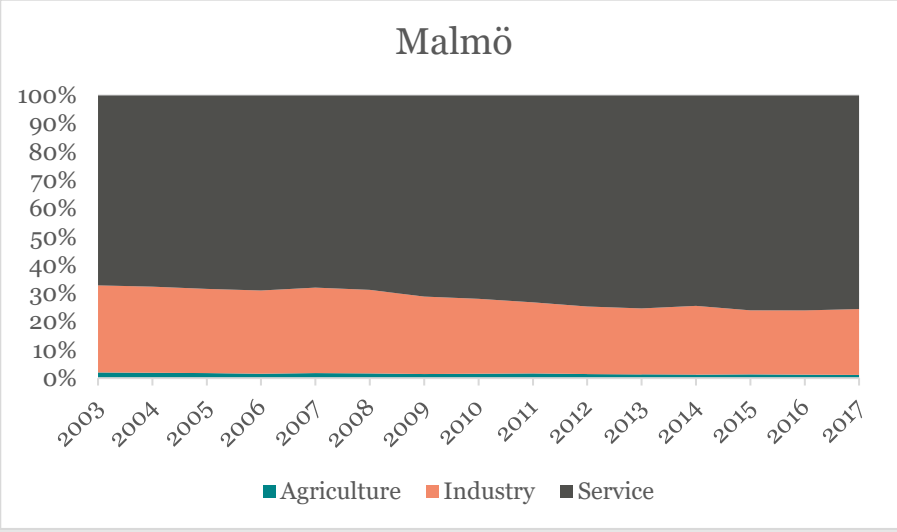
4.5.6 GDP Variation per Sector

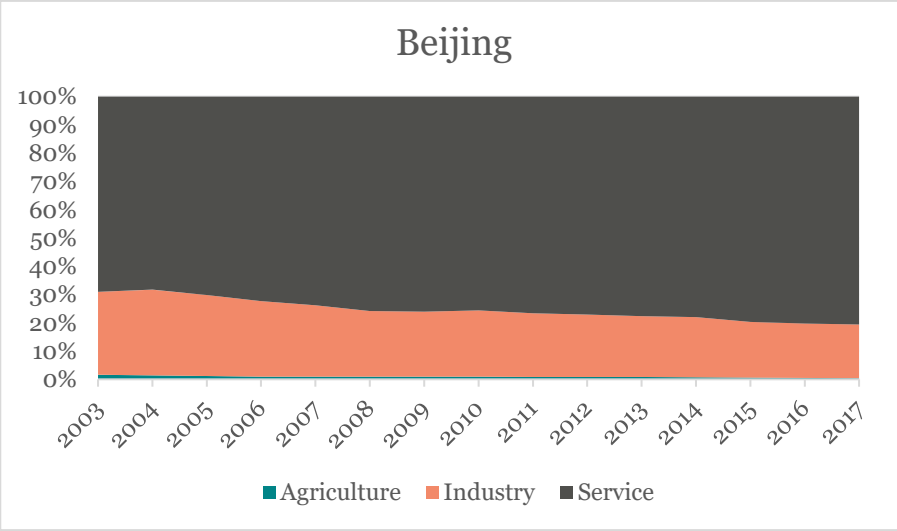
The indicator focuses on the economic activities in different sectors with consideration of the total GDP, defined as "The contributions of the different economic activity sectors (NACE Rev. 2: Agriculture -section A, industry-sections B to F, services -sections G to U) for the GDP." According to Table 4 - The median value on GDP variation per economic during the years 2003-2017. showing the median value of GDP per sector, the service sector accounts for the largest share, followed by the industrial and agricultural sectors. In the comparison between the three cities (no data found for Vienna), Shanghai has a more even distribution between the industrial and the service sector, while the service sector for Malmö and Beijing is more dominant.

Table 4 - The median value on GDP variation per economic during the years 2003-2017.

	Malmö	Beijing	Shanghai
Agriculture	2%	1%	1%
Industry	26%	23%	42%
Service	72%	76%	58%

According to Figure 29 showing the GDP variation per sector between the years 2003 to 2017, the share of the service sector is increasing for all three cities. For Shanghai, the total increase is approximately 36% which relatively high compared to the other two cities: Malmö 13% and Beijing 17%.





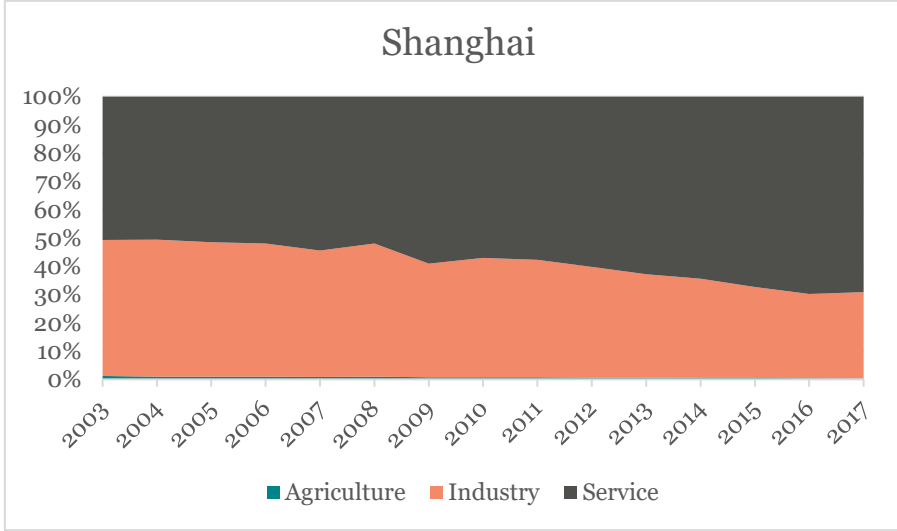


Figure 29 - Normalized GDP per sector for the three cities during the years 2003-2017 (Consistent data was not available for Vienna)

4.5.7 R&D Intensity

The indicator focuses on investments on Research and Development (R&D) in consideration of the total GDP, defined as "Total R&D expenditure as a percentage of GDP". According to Figure 30, all four cities have a relatively stable trend, whereas Beijing has the highest share on R&D (5-6%) based on the total GDP. Note: the data for R&D investment Malmö represents the percentage for Sydsverige or national investment since local data were not available.

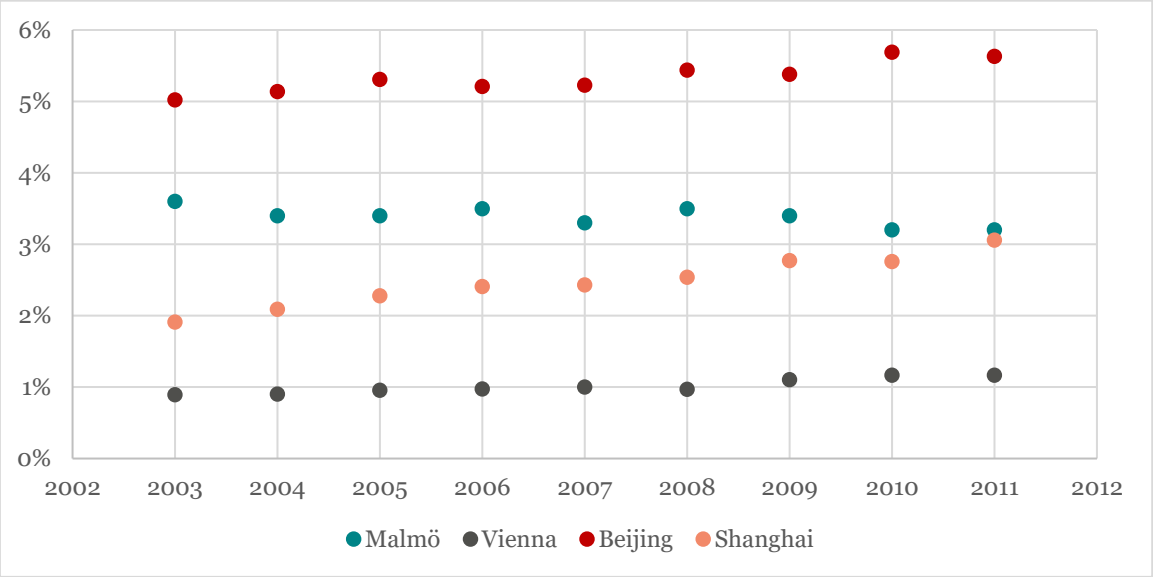


Figure 30 - R&D intensity for the four cities during the years 2003-2011

5 Conclusions

This report collected data on key indicators under six categories: resource management, climate control, city health, community, public safety and economy. To the extent feasible, the data collected covered the period 2000 to 2018 (or as many years as possible depending on data availability). The trends in the data were summarized and compared across the four study cities of Malmö, Vienna, Shanghai and Beijing. Some analysis was given to interpret the trends and offer potential reasoning for the patterns as well as initial conclusions on where apparent sustainability gaps can be filled.

The findings of this report will be complemented by subsequent analyses of the policies, strategies and projects of the four cities to identify how current priorities align with the areas of improvement identified in the data. The findings will also be analysed in terms of how the four cities can transition to be even more liveable, resilient and sustainable in the later stages of the RECREATE project of conducting scenario development and urban metabolism analysis.

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