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Urban Economies Resource Productivity and Decoupling: Metabolism Trends of 1996−2011 in Sweden, Stockholm, and Gothenburg

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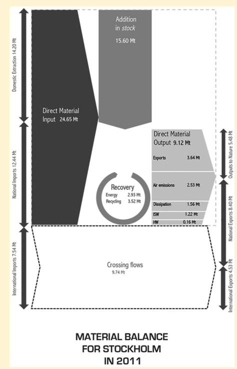
Supporting Information

ABSTRACT: Resource productivity and evidence of economic decoupling were investigated on the basis of the time series in 1996−2011 of material flow analysis for Sweden, Stockholm, and Gothenburg. In the three cases, absolute reductions in CO_2 emissions by about 20% were observed, energy consumption per capita decreased, while gross domestic product (GDP) per capita grew. The energy consumption of the residential and public sectors decreased drastically, while the transport energy consumption is still growing steadily. Decoupling of the economy as a whole (i.e., including materials) is not yet happening at any scale. The domestic material consumption (DMC) continues to increase, in parallel with the GDP. The rate of increase for DMC is slower than that for GDP in both Stockholm and Sweden as a whole (i.e., relative decoupling). The metabolism of the cities does not replicate the national metabolism, and the two cities each have their own distinct metabolism profiles. As a consequence, policy implications for each of the case studies were suggested. In general, because of the necessarily different roles of the two cities in the national economy, generic resource productivity benchmarks, such as CO_2 per capita, should be avoided in favor of sectorial benchmarks, such as industry, transport, or residential CO_2 per capita. In addition, the share of the city impacts caused by the provision of a service for the rest of the country, such as a port, could be allocated to the national economy.



■ INTRODUCTION

Rapid urbanization makes attention to cities imperative. The majority of resources are extracted and transformed for final consumption in cities.[1] These material flows represent potential ecosystem impacts on scales ranging from local through regional to global[2] because of the existence of global supply chains. Moreover, it is not possible to achieve existing climate goals without a substantial reduction of the resource consumption in cities, because they are responsible for 75% of the global resource and energy consumption and 80% of the global CO_2 emissions.[3] On the other hand, regional and city scales are important levels for planning and implementation, including sustainable development (SD), and are, therefore, also relevant scales for analyzing sustainability (see the study by Ravetz[4] for a review on SD assessment in cities and regions).

Resource productivity and decoupling [disconnection of the economic growth, e.g., as measured by the gross domestic product (GDP) growth, from material and energy throughput] can be used as guidance to sustainable development of cities. The state of the art in resource productivity assessment at the national scale currently includes impacts of global trade, such as material footprint,[5,6] energy use,[7] carbon footprint,[8] and emissions transfer.[9,10] In this study, resource productivity is assessed on the basis of direct resource use and emissions, such as the GDP/domestic material consumption (DMC) indicator used by Eurostat.[11,12]

The study of resource productivity of cities is in its infancy because of challenges in obtaining data at the city scale. Although the use of energy and CO_2 emissions accounting in cities has been studied in some detail, with several case studies covering different aspects, very few studies have looked at material flows in detail. Urban metabolism is a field of research that addresses the resource consumption of cities in a systematic way (see the studies by Kennedy and colleagues for a review).[13,14] Most studies are performed for a single city and year, with data estimations from the national level frequently used, while some material flows are omitted, including some of considerable size, such as construction materials and industrial waste.[15,16] To date, the most advanced and comprehensive urban metabolism model, the urban metabolism analyst (UMAn) has been recently applied to the Lisbon metropolitan area for the years of 2003−2009.[17] Resource productivity was not, however, the focus of the study. Relative economy decoupling from physical resources has been observed for Limerick (1992−2002)[18] and Toronto (1987−1999).[16]

A number of studies have looked at the drivers of energy use and the resulting carbon footprints across cities[7] and identified different typologies according to GDP, population density, gasoline price, and heating degree days. Others have focused on studying the differences between cities and hinterlands as well as the role of production activities that contribute to the carbon footprint.[8] In this study, it is argued that there is a high degree of variability between cities with different production activities and that a better understanding of this effect needs to be achieved if we are to understand the drivers of consumption in cities.

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Other challenges include the generalization of patterns and trends in urban resource use and identification of those components of the material and energy systems, which are specific to the urban scale as opposed to rural or national scales.[19]

In this paper, we contribute to the understanding of the metabolism of cities by providing further details on the characteristics of cities, with focus on the differences between the country as a whole and cities with different production activities in a highly affluent context. The metabolism of cities is studied over time, to assess the importance of variability to the results. In particular, we suggest and demonstrate techniques for resource productivity assessments for cities, discuss urban metabolism compared to national metabolism, and identify metabolism trends and their consequences for policy development.

The research questions (RQs) are as follows: (1) Can an increase in resource productivity and decoupling be observed? (2) To what extent does urban metabolism reflect the national metabolism? (3) In what ways do the urban metabolisms of cities differ? (4) What are the policy implications of the differences in the metabolism of the country as a whole and the studied cities?

■ METHODS

Study Area. Sweden is a country of 9.5 million people in the northwest of Europe. Stockholm is the capital of Sweden and its largest metropolitan area, covering 26 municipalities, with a total population of 2.1 million. The Stockholm metropolitan area (hereinafter "Stockholm") is a NUTS III region, and a Eurostat metro region. Statistics are reported for both the region as a whole and each of the municipalities. Stockholm generates 27% of the GDP of Sweden, and its GDP per capita grew by on average 3.1% per year in 1995−2008, placing it among the strongest performing European metro regions.[20] On the basis of the distribution of employment between different industry sectors and the historical changes in employment patterns, the Organisation for Economic Co-operation and Development (OECD) defined Stockholm as being in "an advanced stage of structural transformation towards a service-based and knowledge-intensive economy". In particular, Stockholm has the highest number of workers in knowledge-intensive services of all of the OECD metro regions (2008), with 85% of employment in service sectors compared to only 9 and 6% in the industrial and construction sectors, respectively.[19] There are several ports in the metropolitan area; the Port of Stockholm is the biggest passenger port in Sweden, with over 9 million passengers per year. The port also handles 4.5 and 0.6 million tonnes of freight and oil, respectively.

Gothenburg is the second largest metropolitan area in Sweden, covering 13 municipalities, with a total population of 0.95 million. In Swedish statistics, the Gothenburg metropolitan area (hereinafter "Gothenburg") corresponds to a NUTS III region (Västra Götaland) plus one municipality (Kungsbacka) from the Halland NUTS III region. The Eurostat metro region Gothenburg corresponds to the NUTS III region (Västra Götaland). Statistics are reported for each of the municipalities, although some data instead relate to the metropolitan area as a whole. In 2008, the service sector employed 77% of the workforce, whereas the industrial and construction sectors employed 16 and 7%, respectively. Gothenburg had one of the highest growth rates in Europe between 2002 and 2007.[21] The largest port in Scandinavia is located in Gothenburg; almost 30% of the Swedish foreign trade passes through this port (42 and 22.2 million tonnes of freight and oil, respectively). The passenger traffic amounts to 1.7 million passengers per year.

Material Flow Analysis (MFA). The material flows and MFA indicators were accounted using the UMAn method at the country and city scale.[17] The UMAn method is based on the Eurostat economy-wide MFA method and provides a standard protocol for assembling statistically reported data.[22] For the detailed method description, see ref 17.

In particular, the inputs and outputs are accounted for by collecting: (1) the transport data for all imports and exports of goods, national and international, by means of transport (water, road, rail, and air), (2) the domestic extraction of materials, such as crop production, bulk material, and metallic mineral extraction, and (3) outputs to nature, i.e., emissions to air, urban waste, and economic activity waste. Water, air, and passive energy flows (solar radiation and heat loss) are not studied here, because they tend to obscure the importance of other material flows when measured on a mass basis, because of their much larger magnitude. Whenever possible, data for the MFA relating to the cities were collected at the municipal level or the metropolitan area level (i.e., municipalities combined).[23] Where this was not possible, data for the NUTS III regions were used. When no data existed for the previously mentioned spatial scales, an estimation was made based on the national data. The data sources and the estimations used in this paper have been described in great detail, and the uncertainty of the results has been accounted for in the study by Patricio et al.[24] This study is the first to define and account the crossing flows (CF), part of the domestic material input (DMI) that is aimed for re-export, rather than own consumption, i.e., merely transported but not transformed in the study area.

The following MFA indicators are used in this study: DE, domestic extraction; direct material input, DMI = DE + imports; domestic material consumption, DMC = DMI − exports; CF (Crossing Flows), materials aimed for re-export; DMI excluding CF; exports excluding CF; direct material output to air, land and water, DPO = emissions + waste; net additions to stock, NAS = DMI- DPO − exports.

Indicators and Trend Analysis. DMC in absolute and per capita terms was used as an indicator of the resource consumption. The following resource productivity indicators were used: ratio of final energy consumption (MWh), DMC (tonnes), and CO_2 emissions (tonnes of carbon) to GDP (million SEK in constant 2011 prices). The impact = population × affluence × technology (IPAT) identity was used to decompose factors responsible for changes in the material consumption. The environmental pressure, expressed as DMC, is used as the environmental impact; GDP/population is used as a measure of affluence; and DMC/GDP (i.e., material intensity) is used as a measure of technology.[4] The IPAT form is DMC = population × (GDP/population) × (DMC/GDP).

■ RESULTS

Metabolism Characteristics on Country and City Scales. The economies of Sweden and the two cities could be referred to as service economies because of the considerably higher proportion of service-generated GDP than industry-generated GDP (Figure 1). However, the metabolism of the two cities does not have the same characteristics as the metabolism for the country (RQ 2). As expected, the national DE per capita is much higher than in the cities, which in this case reflects the importance of the primary industries of northern Sweden, such as mining and forestry, and means that both the national DMC and the final energy consumption (FEC) per capita are much higher

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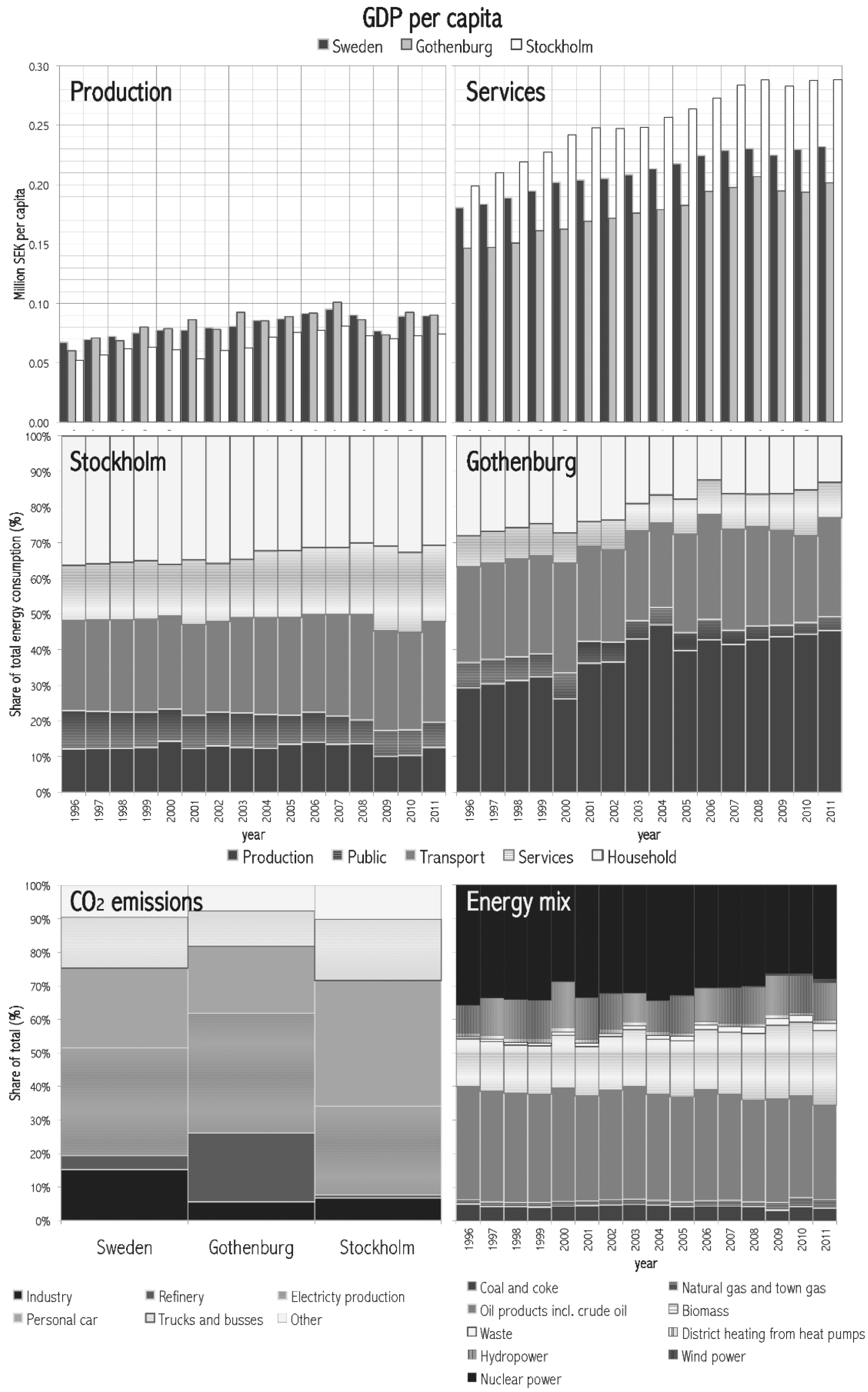

Figure 1. Energy consumption, GDP, and CO_2 emission distribution over different economy sectors.

(Table 1 and Figure 3). On the national scale, the transport and energy supply sectors contribute equally to the fossil CO_2 emissions, at 40% each, while the importance of the transport sector differs between the two cities (Figure 1), with a larger proportion in Stockholm of about 60% and a smaller proportion in Gothenburg of about 30%.

Most of the DMC is made up of NAS, i.e. the growth of the material stock of a city. In particular, the NAS contributes 75% of the DMC of Stockholm, 65% of the DMC of Gothenburg, and around 55% of the DMC of the country.

A distinctive feature of both cities is the importance of CF. While CF are small at the country scale (about 3% of the DMI), a

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Table 1. Metabolism Benchmarks for Sweden, Stockholm, and Gothenburg[a]

indicator (unit)	per capita in 2011		
	Sweden	Stockholm	Gothenburg
DMC (tonnes)	17.8	10.1	11.7
DE (tonnes)	16.0	6.8	9.4
DMI (excluding CF) (tonnes)	7.3 (26.4)	16.3 (11.7)	46.8 (26.4)
export (excluding CF) (tonnes)	9.4 (8.5)	6.2 (1.6)	35.1 (14.7)
FEC (MWh)	61	24	39
total waste (household) (tonnes)	4.27 (0.55)	3.81 (0.63)	4.22 (0.59)
population density (capita/km^2)	21	320	254

[a]See Supplementary Tables 1−3 of the Supporting Information for the time series data.

quarter of the DMI of Stockholm is a CF and almost half of the DMI of Gothenburg is a CF. For Gothenburg, this is a result of the role of the city as the main port in Scandinavia (Figure 2). See the Discussion for possible implications of CF on urban metabolism analysis and policy.

The direct material output (DMO), excluding CF, is constituted mostly (60%) of the outputs to nature (air emissions, dissipation, and waste) in Stockholm, while in Gothenburg, 80% of the DMO is constituted by the export (Figure 2). This difference between the economies is one of a number of contributing factors potentially responsible for the distinct metabolism profiles of the two cities (RQ 3) (see Figure 2 and the complete time series data set in Supplementary Tables 1−3 of the Supporting Information). Of the two cities, Stockholm deviates most from the national metabolism profile and is benchmarked as less resource-intensive. In particular, its FEC per capita is a third of the national consumption per capita, and the CO_2 emissions per capita are half of the emissions at a country level. The main energy-consuming (residential and transport) and CO_2-generating (transport) sectors are different from those for Sweden and Gothenburg (where industry is the main contributor to energy consumption and electricity production is the main contributor to CO_2 emissions) (Table 1 and Figure 1). In Gothenburg, both the energy consumption and fossil CO_2 emissions by sector follow the national patterns. On the other hand, the role of Gothenburg as a transport hub means that import and export per capita are several times larger than for the country as a whole and for Stockholm.

Metabolism Trends. *Energy Consumption and CO_2 Emissions.* In general, the energy productivity, i.e., GDP/FEC, has improved equally (50%) in Stockholm and Sweden but less (30%) in Gothenburg (RQ 1) (Figure 3). An absolute reduction

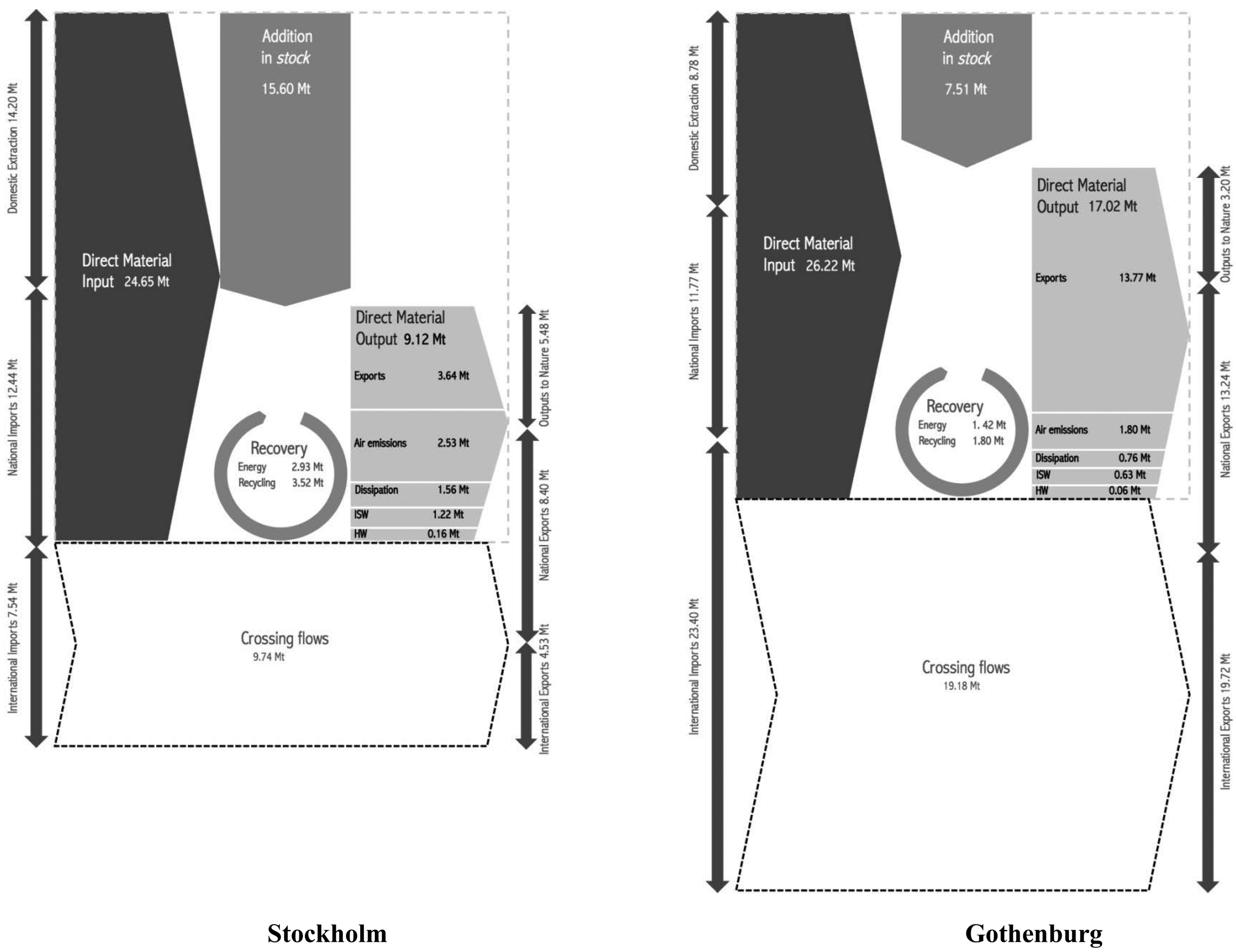

Figure 2. Material balances for Stockholm and Gothenburg in 2011.

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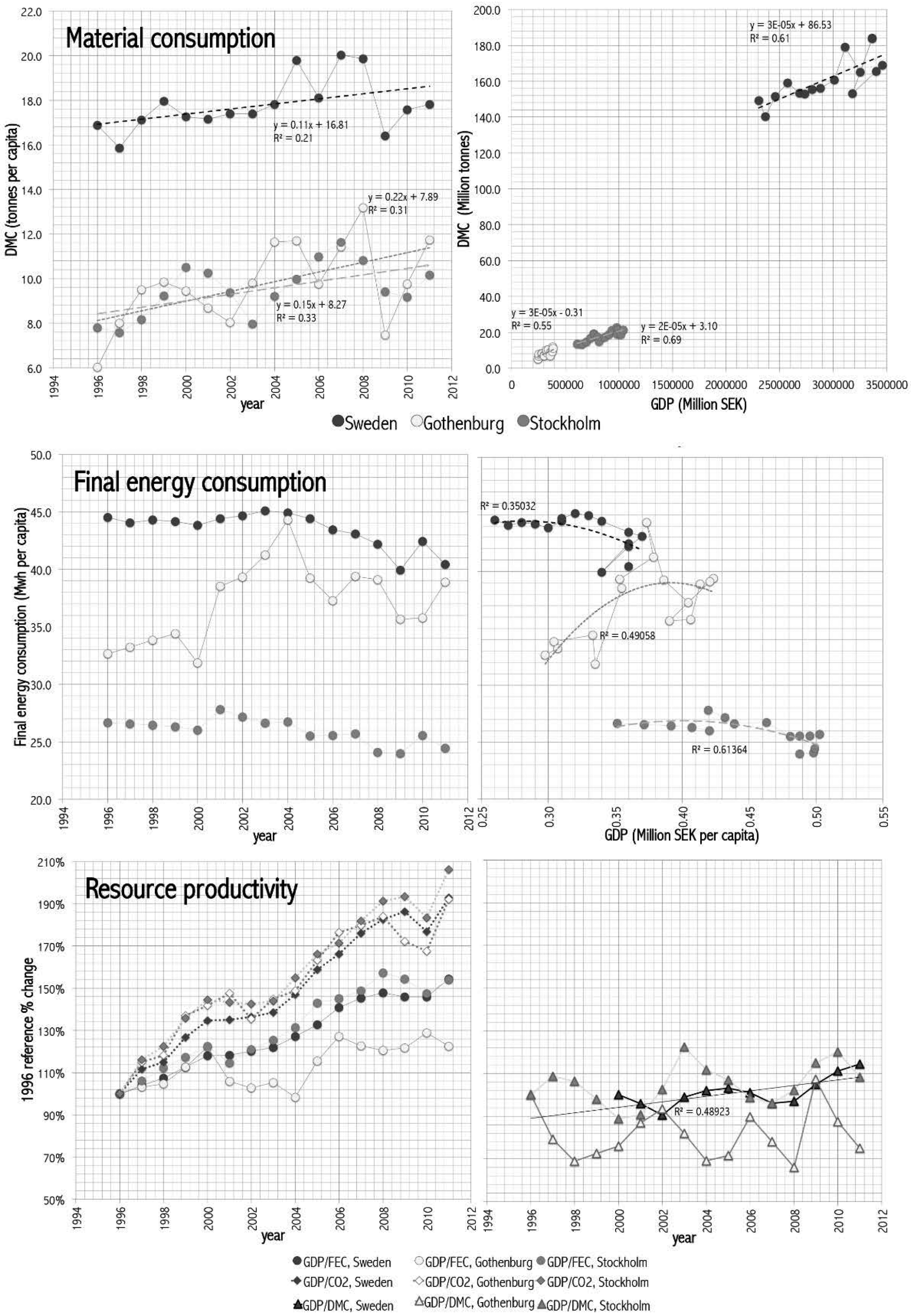

Figure 3. Trends in energy and material consumption and productivity indicators in 1996–2011.

in fossil CO_2 emissions of 20% has been achieved in Sweden and Stockholm over the last 16 years. The equivalent reduction in Gothenburg is about 13%. The emission intensity of the economy (GDP/CO_2) has halved. This is true for all of the studied areas (Figure 3).

The FEC per capita has decreased in Stockholm and Sweden and increased in Gothenburg (mostly because of industrial energy use). A behavior similar to the inverted Kuznets curve is observed for the FEC per capita versus GDP per capita (Figure 3). The underlying cause of reductions in energy

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Table 2. Percentage Change of DMC and GDP (Constant 2011 Prices) and the IPAT Identity

	I	*P*	*A*	*T*	
1996−2011	DMC	population	GDP/population	DMC/GDP	GDP
Sweden	1.3	1.07	1.39	0.76	1.49
Stockholm	1.56	1.20	1.42	0.92	1.70
Gothenburg	2.22	1.14	1.39	1.40	1.59

consumption is likely to be improved energy efficiency, notably in the residential and public sectors. In particular, the residential energy consumption per capita decreased by 20% in Stockholm and Sweden over the last 16 years and by 45% in Gothenburg. The public sector energy consumption also decreased by 35−40% per capita for all of the studied areas. These savings in energy are the results of a range of policies relating to building energy efficiency as well as changes in heating fuels and technology implemented since 1977.[25] Moreover, despite the residential sector being one of the largest energy-consuming sectors in Swedish cities, it contributes only about 2% of the fossil CO_2 emissions for all of the studied areas, down from about 15% in 1996. Such a remarkable reduction has been achieved because of a shift in the sources of heating energy, from heating oil to renewable energy. The results support the study by Kennedy et al.,[26] which found that Sweden was the most successful of the OECD countries when it comes to decoupling of emissions from the energy consumption in the residential sector. They defined a period of "green growth" in the sector during 1995−2007 and showed that the rate of reduction of emissions depends linearly upon the rate of investment.

In reverse of this, the energy consumption of transport is increasing, in both the cities and the country as a whole, and transport may soon be the main energy-consuming sector. Transport is already the sector mainly responsible for CO_2 emissions, contributing between 30% (in Gothenburg) and 60% (in Stockholm) (Figure 1). The greater challenge of reducing emissions in the transport sector compared to the building sector was also acknowledged in the International Energy Agency (IEA)[27] review.

Material Consumption. DMC (Figure 3) and waste generation (see Supplementary Tables 1−3 of the Supporting Information) increased during the study period, on both country and city scale (RQ 1). This result is in contrast to the reported absolute dematerialization for Sweden in 1980−2000.[11] Large productivity and efficiency improvements were implemented in industry during 1980−2000, while less powerful changes were made in the last 2 decades, despite the availability of appropriate technology.[28] For a more detailed discussion on the impact of policy, economy, and lifestyle on the material flows in Sweden during the last 2 decades, see ref 25.

As shown in Table 2, relative dematerialization is occurring in Sweden and Stockholm, while the opposite trend, increased material intensity of the economy (rematerialization), is observed in Gothenburg. There is a positive correlation between the consumption of materials and GDP generation, where the increase in DMC explains 60% of the increase in national GDP. The corresponding figures for Stockholm and Gothenburg are 70 and 55%, respectively (Figure 3). This result is in contrast to the energy consumption, which has decreased with increasing GDP per capita. The rate of DMC increase in Gothenburg is twice that of the rate of increase in Stockholm.

As mentioned previously, a major part of the DMC of the cities relates to the NAS. In particular, as shown elsewhere, construction materials are the largest material flow in the studied cities. This flow has also increased exponentially over the last 2 decades.[25]

The waste generation of the cities has been growing at a constant pace and faster than in the country as a whole. Household waste generation has increased by about 15% in Sweden. In Gothenburg and Stockholm, the increase is 40 and 60%, respectively. The generation of industrial waste has decreased in Sweden, by about 25%, but increased in the cities, by 40 and 50% for Gothenburg and Stockholm, respectively.

Most of the industrial waste in cities is composed of demolition waste. The increase in industrial waste may be explained by the ongoing renewal of existing building stock and new construction. Recycling of industrial waste is particularly important because of the considerable quantities involved: about 20% of the DMC for Sweden and 40% of the DMC of the cities (as a comparison, household waste only amounts to 2−3% of the DMC). Currently, half of the industrial waste is landfilled. In comparison, about half of the household waste is material-recycled, and the rest is incinerated for energy production.

The IPAT identity, in the form DMC = population × (GDP/population) × (DMC/GDP), was used to investigate the contribution of population, affluence, and technology to resource use. The proportional changes in the indicators over the study period demonstrate the relationship between the factors (Table 2). For example, in Stockholm, the 56% increase in DMC over the study period can be accounted for by a 20% population increase, a 42% increase in affluence, and 8% material intensity reduction. During the same period, the total GDP of Stockholm increased by 70%. The economy of Stockholm appears to be in a state of relative dematerialization, with GDP growing faster than DMC during 1996−2011. In contrast, the material consumption in Gothenburg more than doubled, and the GDP grew by 60%. Increasing affluence is potentially the main driver of resource consumption in Stockholm, while the DMC of Gothenburg has grown because of the increase in both affluence (39%), and material intensity (40%).

■ DISCUSSION

As our results show, resource efficiency and climate targets should not be based on the national-level consumption levels and targets but instead on data specific to a certain city or type of city.

The two studied cities, separated by only 400 km, displayed a range of different characteristics and trends, which were also different from the national-scale patterns. In particular, energy consumption trends varied, from increasing for Gothenburg to decreasing in Stockholm and at the national level. The main energy-consuming sectors are also different and changing. The CO_2 emissions decline at different paces and in different sectors. The material consumption trends also vary, from relative dematerialization in Sweden and Stockholm to rematerialization in Gothenburg. These observations underline the importance of studying resource consumption and socioeconomic trends on regional and city scales, to (i) monitor sustainability progress, (ii) develop site-specific targets for resource use and emissions, which take into account the differences in metabolism and,

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therefore, the needs of individual cities, (iii) develop portfolios of solutions for cities of different metabolism type, taking into account their different opportunities and potential for improvements, and (iv) evaluate the effects of national-, regional-, and city-scale policies.

Policy Implications Common to Sweden and the Cities. The increasing energy consumption of the transport sector and the declining share of public transport is a common trend in the reported studies.[29,30] This was also true for Sweden as a whole, where public transport use fell from 49% of all journeys in 1950 to 18% in 2009.[31]

Reforming the transport sector toward non-fossil vehicles is imperative; this is also a governmental target for an oil-free economy by 2020. In particular, large reductions in fossil fuel consumption can be achieved by replacing truck transports, which is currently the dominating mode of transportation for goods, by railway.

Because of the policy focus on energy consumption and CO_2 emissions in the past decade, the achievements within resource productivity are restricted to these areas. The material consumption continues to increase as does the waste generation. Sophisticated city planning, efficient use of the existing stock, and improved recycling of stock outflows should play a significant role in a future city-level material management strategy.

Site-Specific Policy Implications for Stockholm. Because it is a service economy, Stockholm could achieve a relative dematerialization development. Further decoupling of the economy from material consumption and emissions will require reforms in the transport and construction sectors. Reducing the car dependence of cities could reduce their overall material and energy flows.[19] Congestion charge systems, as introduced in Stockholm in 2007 and in Gothenburg in 2013, lead to a decrease in transport emissions.[25] In addition, incentives to use public transport should be developed and implemented. Another significant factor in transportation energy requirements is the urban form, density, in particular.[19] The range of policies implemented to address the urban form of the city of Gothenburg, aimed at promoting densification and deterring car transport, is the most relevant example to explore for the other Swedish cities.[25]

As shown earlier,[25] the construction material consumption is growing continuously and dominates (75% of the total) the DMC of Stockholm. No reduction in the demand for construction materials is anticipated in either city over the next decade, because of large ongoing infrastructure projects and a shortage of housing in both. Therefore, a reduction in the consumption of construction materials can only be achieved through better city planning, urban design, and form, in combination with other strategies. In particular, further densification of cities could result in a decrease of the residential space per capita, which is currently higher than the European Union (EU) median.[25] Policies for more efficient and multi-purpose use of the existing building stock should be developed. In addition, the input of construction materials could be reduced using lighter and more resource-efficient structures and recycling of construction materials.

The transport sector is responsible for 60% of the CO_2 emissions in Stockholm. The effect of the congestion charge on car travel is limited and may abate with time. To curb emissions, a shift to renewable fuels for trucks, buses, and private vehicles will be required.

Site-Specific Policy Implications for Gothenburg. Gothenburg has a different economy from Stockholm and a different role in the country. Its considerable industrial sector and major Scandinavian port induce significant material flows and emissions. The nationally homogeneous CO_2 per capita reduction targets could undermine the economy of Gothenburg while, at the same time, be understimulating for Stockholm. Differentiated targets, which appreciate both the needs of the industry in Gothenburg and the opportunities for exceptionally low metabolism in cities such as Stockholm, are preferable to promote further decoupling of the national economy. The policies suggested for the transport and construction sectors in Stockholm should also be implemented in Gothenburg. In addition, industrial symbiosis should be implemented to reduce the material and energy consumption and waste generation of industry.

There are several factors that must be considered when applying MFA and studying resource productivity at the city scale: (1) Time series of MFA should be studied instead of single years because of the high volatility of the annual DMC. In particular, a 25% year-on-year variability in DMC has been observed for Gothenburg, and 10% year-on-year variability in DMC has been observed for Stockholm (Figure 3, DMC per capita and year). (2) The IPAT analysis should be accompanied by a visual inspection of the DMC versus GDP trends. One consequence of the high DMC volatility is that contradicting conclusions on decoupling can be drawn for Gothenburg, depending upon the years being analyzed. For example, if the years 2000−2010 were chosen for the IPAT identity analysis, a relative decoupling for Gothenburg would have been found. The annual variability in the DMC for Stockholm was shown to be acceptable and to lead to consistent conclusions, irrespective of the length of the time series studied. (3) When possible, decoupling and resource efficiency claims should be supported by sectorial analysis (i.e., resource use and waste production per sector). This is due to the following factors that affect the GDP accounting: (1) registration of economic agents and (2) differences in the value development for the production and service sectors. With regard to the first factor, the production facilities (i.e., resource consumption) and headquarters of economic agents may be physically separated in such a way that headquarters are concentrated to certain areas, for example, a capital city. The produced economic value will be reported for the headquarters and result in a skewed GDP to physical resource use ratio in favor of decoupling. For the second factor, GDP growth resulting from a faster increase in service value than in production value does not indicate efficiency in physical resource use. Again, the GDP per sector can be compared to the resource consumption of the sectors. (4) National scale consumption benchmarks should not be used as a basis for urban metabolism analysis or policy development. Development of urban metabolism typologies will enable use of national data when no city-scale data is available. Because of the lack of data on the resource and energy consumption and emissions at the region and city scales, national MFA indicators are often adjusted to these scales.[13] Our results suggest that rules for allocation may vary depending upon the type of city. It is therefore necessary to develop a typology for cities, including a set of indicators that may inform the allocation rules. (5) When estimation of CF is unavailable, DMI should be used with care for the urban metabolism analysis and policy development. DMI data are often used in the evaluation of MFA results, because of their ready availability and good precision. However, as shown in this paper, to distinguish the CF is crucial for a correct understanding of the metabolism of cities that are trading places. For instance, almost half of the DMI of Gothenburg is CF, because the city is home to

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the busiest port in Scandinavia. This flow of materials and the corresponding transport emissions add to the account of Gothenburg, even though the city is providing a service to the rest of the country.

■ ASSOCIATED CONTENT

Supporting Information

Information on the material balance as well as the MFA indicators, for Stockholm, Gothenburg, and Sweden, respectively (Supplementary Tables 1−3), including annual data from 1996 to 2011 in tonnes, with material balance encompassing the following data: imports, DE, exports, industrial production, CF, air emissions from fossil fuels (divided into appliances, energy supply, industrial process, transport, international aviation, maritime, and other), air emissions from biomass, household waste, wastewater solid part, and economic activity waste, and MFA indicators including the following: DMI, DMO, DPO, DMC, NAS, and physical trade balance (PTB); FEC in MWh per capita for Gothenburg, Stockholm, and Sweden (Supplementary Table 4), with the FEC divided into different categories, including residential, transport, public sector, services, and industry and agriculture, for data shown in 1996, 2000, 2004, 2008, and 2011; data also presented in three graphs for 2011 (Supplementary Graphs 1−3); carbon weight of the CO_2 emissions from fossil fuel origin (per capita) (Supplementary Table 5), with data presented in tonnes per capita, for Stockholm, Gothenburg, and Sweden for 1996 and 2011 (PDF). The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.est.5b01431.

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Notes

The authors declare no competing financial interest.

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