

Metabolism of Östersund – a first draft

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Preface

As part of her studies at Mid Sweden University, Nathalie Burdová wrote the first draft for this report during the spring semester 2021. The outcome was of such a good quality as a first draft of the newly initiated project “Metabolism of Östersund”, the largest city in the Swedish mountain region, and is therefore published in this series. It will work as a basis for a Master by Research project starting during autumn 2021.

Erik Grönlund
Östersund, 21 November 2021.

1 Introduction

The urban population has been significantly increasing in the past decades. Urban settlements in general are a concentration of people, industries and services (Niza, 2009). This high concentration of human activity is resulting in most of the available resources to be used within the urban areas followed by considerable effects on the environment (Shahrokni, 2015).

Urban systems are usually compared to ecosystems, or even to single organisms. As Zhang (2013) described, "Nutrients must be imported by the city to sustain its metabolism, and the consumption of these nutrients generates metabolites." The city requires inputs such as fuels, electricity, materials, water, food and goods. These inputs are later transformed into services, products and wastes (Huang, 2020). However, cities, compared to organisms in nature, use resources less effectively. In nature, circular metabolic systems are prevailing which means that the outputs of the systems are later re-used as inputs again. Cities, on the other hand, tend to have linear metabolic systems. This results in either stocks of materials within the city borders or unmanaged wastes and emissions. This has crucial impact on the surrounding environment and the cities themselves (Zhang, 2013).

The study of urban metabolism focuses on the resources and its consumption, the cycling of materials and substances within the urban area, and the production of emissions, wastes and its treatment (Zhang, 2013). The first study was introduced already in 1965 when Wolman (1965) calculated basic metabolism for an imaginary American city with a population of one million people. Even though this study was not as complex it addressed the issue of the city's impacts on the environment. His study could be also recognised as fundamental for the later developed of Material Flow Analysis type of urban metabolism studies (Kennedy, 2011).

Since the 1970s many studies were conducted. With further development, the study of urban metabolism has separated into two main approaches, the analysis of material flows and the analysis of energy flows. Later, the studies started to be more detailed and specified. The focus was directed to specific flows (Bergbäck, 2001), to the hidden flows and cyclical processes, and to the transformations within the city borders (Kennedy, 2011).

The methodology for urban metabolism is very broad and multidisciplinary as it connects the field of environmental science, economics and sociology all together (Zhang, 2013).

There are many aspects affecting the methodology used. Every city differs in function, size, population, geographical position etc. These characteristics influences the analysis itself but also the availability of study materials. That is why each urban system needs "its own" methodology (Niza, 2009). The most followed type is however the Material Flow Analysis (Huang, 2020). This method uses as a background The Law of Conservation of Mass and Energy. It first classifies the different material flows by using reliable data, it looks at the connections of the flows and later it produces any type of a balance sheet with all accountings of these flows. If sufficient data is available, the whole life cycle of a specific type of material within the cities system can be tracked (Zhang, 2013).

The evaluation of urban metabolism serves as a key indicator of the current "sustainability state" of the chosen area. It also describes the city's functions, the citizen's habits and standard of living (Niza, 2009). After evaluating the city's metabolism, unsustainable processes and activities within the city can be pointed out which can contribute to policy and planning implications that promote sustainable development and improve the city's management in accomplishing the sustainable development goals (Huang, 2020).

With an increasing interest in this type of studies, the metabolism of Östersund was evaluated. This study first represents the methodology used that was adapted to the case area. Further it uses the available data sources and presents the results from these sources. As this is to be the first estimation of

a metabolism for this urban area, the focus is on the actual data collection and evaluation of the most important flows.

2 Methods

2.1 Material flow analysis

In this study, the Material Flow Analysis (MFA) model was followed. Within the model, the most significant flows were considered, specifically the flows of water, electricity and certain materials and goods, wastes and emissions. If more detailed data were found they were included in the analysis as well.

Depending on the amount of data available, two different approaches of the MFA were used for this case study.

The first approach used the “top-down” method. This type of method first uses broader data, usually on the national or regional level, and later allocates this data on the smaller scale.

To apply this specific type of methodology it is necessary to evaluate whether the data found is applicable for the case city and to use the right type of allocation. This was done by collecting and sorting information about the population dynamics, geographical position within the country and general information about the city’s characteristics from various sources.

At first, the national and regional data were collected. In majority of the chosen categories, the allocation for Östersund was done by using the population number: The national/regional data was divided by the population of Sweden for the specified year when the data was collected. This result was later multiplied by the population of Östersund.

Table 1 Population numbers used for the study

Sweden	
2015	9 747 000
2016	9 851 000
2019	10 230 000
Östersund	
2015	61 066
2016	61 745
2019	63 779
Jämtland county	
2015	127 376

Source: Statistics Sweden, 2015

The second approach used data already existing for the study area. This presented more detailed and precise results for the analysis.

As this was the first estimation of the metabolism of Östersund, the results were presented as combination of both of previously mentioned approaches. It also combines data from various years, as the availability of data sources is limited. The results were presented in separated categorised tables.

2.2 Balance sheet and Domestic material consumption

To conclude the results, a balance sheet and domestic material consumption (DMC) were calculated. This was done by using following equations:

$$\begin{aligned} \text{Inputs} &= \text{Import} + \text{Extraction} + \text{Water withdrawal} \\ \text{Outputs} &= \text{Export} + \text{Waste} + \text{Air emissions} + \text{Waste water outcome} \\ \text{Consumption} &= \text{Consumption} - \text{Water use} \\ \text{Stocks} &= \text{Inputs} - (\text{Outputs} + \text{Consumption}) \\ \text{Domestic material consumption} &= \frac{(\text{Inputs} - \text{Outputs} - \text{Stocks})}{\text{Population Östersund}} \end{aligned}$$

2.3 Östersund - Urban area description

Östersund is located in Jämtland county. Östersund, with its approximately 60 000 citizens, is the biggest and capital urban area in the county. The total land area within its boundaries in 2015 was 3499 ha (Table 2). Östersund could be recognised as an average Swedish urban area in both size, population and the turnover of the city (Statistics Sweden, 2020).

Table 2 Land use in Östersund in 2015

Type of land use	Hectares
Green space	2 074
Arable land	276
Total non-impervious surface	2 350
Impervious land	1 120
Other (unclassified) land	29
Water	8
Total	3 499

Source: Statistics Sweden, 2015

Östersund can be viewed from several perspectives. We can look at Östersund as the city itself or it can include both the city and its suburbs, or it can cover the whole municipality. The Östersund city represents majority of the municipality, as it has the highest concentration of people, businesses, consumption and industries. This is also resulting from the fact that many residents from the surroundings are commuting to the city of Östersund (Statistics Sweden, 2020). For the purpose of the study, Östersund was reviewed as the whole municipality, as most of the data available contains values for the whole municipality and as most of the categories covered are connected within this urban area.



Figure 1 A map of Östersund municipality,
<https://kartor.ostersund.se/spatialmap?>

3 Results

3.1 Data origin

Most of the data was taken from Statistics Sweden (Statistics Sweden, 2020). This website produces official statistics for general information, investigation and research (Statistics Sweden, 2020). Depending on the category, the data can differ from national databases to a municipality level. As this is the official Swedish source that undergoes certain quality policies it could be recognised as a reliable data source.

Another data source used in this study was Kolada (Kolada, 2020). Kolada contains databases for municipalities and regions that are concluded from Statistics Sweden. It could be described as a tool for easier comparison of different municipalities and regions. This source is however limited to less categories than Statistics Sweden.

The sources for the last group of data were either reports of Östersunds kommun, previous studies on that area, or a personal communication with the Östersund kommun. These data sources however represent a minority of the cases in this study as those datasets and information are usually hardly accessible.

In this case, the reliability of the data could be questionable as the source of information is in most cases unknown.

3.2 Extraction and production, import, export and consumption

Östersund is mostly dependent on import because of its geographical position. There are no sources of fossil fuels, metals or other essential materials in the surrounding of the city that could be accounted in the extraction category. The only large extraction in the area is represented by biomass. The extraction of biomass in 2015 was approximately 416 thousand tonnes. More than a half is covered by forestry

(Table 3). To compare, the extraction of the biomass within the area was higher than the consumption. The most consumed material in 2015 was non-metallic minerals followed by biomass as the second highest consumed (Table 4).

Table 3 Extraction of biomass, national data source, 2015 (tonnes)

Biomass total	415 840
Agriculture	119 118
Forestry	295 137

Source: Statistics Sweden, 2020

Table 4 Material consumption by category of material, national data source 2015

Category of material	Tonnes
Biomass	364 364
Metals	326 851
Non-metallic minerals	592 047
Fossil fuels	109 938
Other products	19 969

Source: Statistics Sweden, 2020

The import of food and agricultural products in 2015 was 40 666 tonnes. This was more than the actual consumption of these product which presented about 37 400 tonnes (Table 5). The import of these products covers approximately 10% of the total import of Östersund. This number is considered as part in the category import of finished products. In 2015 the total import of products (Raw products, semi-manufactured products, finished products) was almost 500 thousand tonnes (Table 6). The export was prevailing. The difference between import and export was approximately 50 000 tones (Table 6).

Table 5 Import and total consumption of food and agricultural products, national data source, 2015 (tonnes)

Import	Consumption
40 666	37 397

Source: Statistics Sweden, 2020

Table 6 Import and export of products, national data source 2015 (tonnes)

IMPORTS		EXPORTS	
Raw products	225 544	Raw products	175 423
Semi-manufactured products	87 712	Semi-manufactured products	125 302
Finished products	181 688	Finished products	244 339
Total	494 944	Total	545 064

Source: Statistics Sweden, 2020

The electricity production comes mainly from renewable sources. The production is however considerably smaller than the consumption, so that most of the electricity must be imported. The total energy consumption in 2019 was 286 440 000 MWh, equally shared by transport, heating and electricity (Table 7).

Table 7 Energy and electricity production and consumption, local data source (MWh)

Total electricity production (2018)	239 869
Renewable energy sources share	94%
Total end use of energy (2019)	286 440 000
Transport share	34%
Heating share	33%
Electricity share	33%

Source: Kolada 2020, Miljödovisning 2018

The main source of water for Östersund is the lake Storsjön. The surface water source is prevailing the ground water source (Statistics Sweden, 2020). The total freshwater withdrawal in 2015 was calculated to be about 8 400 000 m³ (Table 8). More than a half of the withdrawal is used in households. The rest is utilised in agriculture, industries or it has other use (Table 8).

Table 8 Fresh water use, regional data source, 2015 (1000 cubic meters)

Households	4 860
Agriculture	259,84
Industry	543,7
Other use	2 748,5
Total withdrawal	8 414

Source: Statistics Sweden, 2020

3.3 Waste and emissions

The wastewater is treated in a treatment plant in Reningsverk Göviken. This wastewater treatment plant receives water from Östersund, Brunflo and parts of Frösön, Lugnvik and Ås, which should correspond to approximately 50 000 people and some industries representing about 10 000 people (Östersund kommun, 2020). The daily water flow through WWTP was in 2020 about 19 400 m³. It was reported that the total flow in 2020 was more than 6 800 000 m³ (Table 9).

Table 9 Water flow in WWTP in Göviken, local data source, 2020 (cubic meters)

	Week	Day
Mean	130 862	19 407
Max	215 117	32 224
Min	92 614	13 690
Total flow in 2020	6 874 101	

Source: Personal correspondence with Östersund kommun

Östersund has three recycling centres (Odenskog, Brunflo, Lit) and one waste facility (Gräfsåsen) (Östersund kommun, 2020). Yearly, the city produces about 195 thousand tonnes of solid waste. The biggest contributors to the waste production are constructions and household (Table 10). The physical composition of the household waste was described in the previous decade by Sharma (2012). From the results of the study, most of the household waste could be classified as combustible waste (Table 11).

Table 10 Solid waste, national data source, 2015 (tonnes)

Households	27 340
Construction	60 820
Service activities	13 510
Total solid waste	195 400

Source: Statistics Sweden, 2020

Table 11 Physical composition of household solid waste, local data source (tonnes)

Type of waste	2006	2007	2008	2009	2010
To landfill	10 444	2 441	1 897	1 576	996
Combustible waste	4 679	11 813	11 902	11 336	11 730
Organic waste	4 097	4 165	3 3972	4 093	4 034
Total	19 220	18 419	17 771	17 005	16 760

Source: Sharma, S. 2012

Östersund produced 175 098 tonnes of air emissions in 2015, including emissions of CO₂, SO₂, NO_x and particulates. The greenhouse gasses were covered as one value of 225 000t CO₂e (Table 12).

Table 12 Air emissions, local data source, 2015 (tonnes)

CO ₂	174 000
SO ₂	47
Nox	708
Particulates	343
Greenhouse gases	225 000t CO ₂ e

Source: Statistics Sweden, 2020

3.4 Balance sheet and DMC

Table13 Balance sheet of material flows in Östersund

Inputs	Outputs	Consumption*	Stocks
9 365 450	7 676 436	1 450 566	238 448

*Excluding water use as water flow is included in outputs

The total input of materials to Östersund was 9 365 450 tonnes. In contrast, the output in connection with material consumption represented 9 127 002 which creates stocks of about 200 000 tonnes of material (Table 13). The domestic material consumption was calculated to be 23.75 tonnes per capita.

4 Discussion and Conclusion

The previous section offered results from the Material Flow Analysis for Östersund. The results show that the inputs and outputs, in combination with the consumption, of the area were rather in balance. Further, the domestic material consumption was 23.75 tonnes per capita.

Eurostat annually publishes reports about material flow accounts and resource productivity. In 2019, it was presented that the average domestic material consumption in Sweden was approximately 25 tonnes per capita (Eurostat, 2019), the numbers then show a high similarity. Another study that presented results from DMC Those numbers are however resulting from different methodology thus it is controversial whether they can be compared.

As this was the first estimation for this urban area, the results presented rather describe the most significant flows and exclude the hidden and detailed flows. This is mainly due to the lack of accessible data for Östersund.

Related studies showed similar difficulties with data collection. Study from Lisbon performed for its purposes comparable data collection. It included data sources on various scales; urban scale, a regional scale (Lisbon region), and a national scale (Portugal), and it covered different years (Niza, 2009). Barles (2009) pointed out that the analysis is highly dependent on the administrative status of the urban area. She mentioned that the administrative status of Paris was beneficial for the study which would not be the case for smaller urban areas in France. Even though there was a high amount of data sources on a smaller scale, the hidden flows were not conducted because of the limitations of those data. The overall difficulty in this type of analysis is that in many cases the data found are not compatible with the analysis. (Barles, 2009). The limits of the analysis that are brought by size of the urban area and its borders was also introduced by Niza (2009).

The results combine two methodology approaches together. The first approach brings a high probability of errors, as the accountings are made from sources that are concluded for the whole area and population of Sweden.

As an example, the number of exported materials was estimated to be higher than the one imported. For a city like Östersund, this could possibly be a recognisable error from the methodology used. The base number used for the allocation covers all the areas in Sweden. In areas with high extraction of materials, industries and bigger businesses the export might be prevailing as the accountings show. However, a geographically located city as Östersund, with smaller local businesses and no larger resources is dependent on import. To make this estimation more accurate, a deeper knowledge of the study place and detailed data from different sectors needs to be included.

On the other hand, this type of methodology relies on the fact, that the “top-down” approach represents an average Swedish person and average Swedish city which is seen to be applicable for this studied area.

In some cases, the results from general allocation were compared to a detailed source (if data available). There was a high similarity in a case of wastewater flow. The first estimated number was calculated from approximate amount of water that flows through WWTPs in whole Sweden. This was later compared with reports send by the municipality which showed a difference of just 1000 cubic meters per day. This proves that even this type of general and broad methodology can present reliable results.

Further, the results were not classified according to the years from which the data was taken as the dynamics of the area's population, as well as the characteristics in general, do not significantly change within the time period from 2015 till 2020. However, this is just an assumption which can bring possible inaccuracies as well.

Those errors and inaccuracies however can be considered as minor, as this was the first estimation made for Östersund. Overall, the study serves as a good base for a further general research on the material flows within this city and as a possible background for another urban metabolism study in Sweden.

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