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Greenhouse gas emissions from public consumption in Gothenburg

Master of Science Thesis in the Master Degree Programme, Industrial ecology

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Göteborg, Sweden, 2013
Report No. 2013:7

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Cover: The statue of Gustav II Adolf, the founder of Gothenburg, photographed by the author.

The thesis is a part of the Mistra Urban Futures project "Well-being in Sustainable cities".

Technical report No. 2013:7
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Göteborg, Sweden 2013

Acknowledgements

First I would like to thank my supervisor Jörgen Larsson for his support and all the interesting discussions we had during the project. I also would like to thank all involved from Miljöförvaltningen, Västra Götalandsregionen, Physical Resource Theory and SP (Sveriges Tekniska Forskningsinstitut) in the Mistra Urban Futures project about consumption in Gothenburg. Thanks to people at the municipality of Gothenburg and VGR for answering many of my questions and handing over data. Furthermore I also would like to thank my family and friends for support and shown interest in my work. Last but not least I thank my examiner Professor John Holmberg for taking his time.

Abstract

The purpose of this thesis is to explore and estimate greenhouse gas emissions from the public consumption in Gothenburg. By doing so it should be possible to see where the emissions are originating from and how large they are. Potentials for lowering emissions from public food consumption and the public transportation system in the year of 2030 are also investigated.

This thesis is part of a Mistra Urban Futures project which is done in collaboration between Chalmers University of Technology, the Environment department of the municipality of Gothenburg and Västra Götalandsregionen (VGR). The entire project's goal is to estimate greenhouse gas emissions for typical citizens in Gothenburg according to a consumption perspective.

The consumption perspective differs from the (usually reported) production perspective where the latter only includes emissions emitted within a geographical area whereas the consumption perspective includes all the up-stream emissions the consumption of a product or service is responsible for.

A top-down method using greenhouse gas emission intensities for different activities, per million SEK, from Swedish Input-Output data was used to estimate the total greenhouse gas emissions from public consumption. A bottom-up method (combining LCA data with consumption quantities) was also used to estimate emissions from public food consumption and from the public transportation system, this to get another perspective and to be able to estimate potentials for lowering emissions from these two activities. The definition of the public consumption was set to involve expenditures from all public activities, even those partly paid from private funds e.g. hospital costs including patient fee.

The emissions carried out by the municipality of Gothenburg, VGR and the state were estimated to about 1,8 ton CO_2-eq per citizen in Gothenburg and year. Large contributors were the four categories (based on SNI); Authorities, The educational system, Construction, Healthcare and care. State subsidies to the agricultural sector are also generating large amount of emissions.

By using the bottom-up perspective the public food consumption in the municipality of Gothenburg was estimated to 0,053 ton CO_2-eq per person and year with a potential of decreasing emissions between 31 % and 88 % per person. This was estimated by changing type of food, increasing energy efficiency and use non fossil fuels in the food production. The public transportation consumption was estimated to 0,072 ton CO_2-eq per person and year of which half was allocated to public consumption. By changing technologies and fuels the potential for reducing greenhouse gas emissions was estimated up to 87 % per person and year.

The goal, set by the municipality of Gothenburg, is to reach below a total (including public and private consumption) of 1,9 tons CO_2-eq per person in 2050. It is thus of high relevance to also treat emissions from public consumption to a larger extent than what is done today. This since emissions from public consumption itself is close to the limit.

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1 Introduction

This chapter will introduce the reader to the master thesis. First the background is described followed by the purpose of the study. Further the research questions are presented and finally the limitations of the project are stated.

1.1 Background

This chapter provides background information about the municipality of Gothenburg, the county council Västra Götalandsregionen (VGR), global warming, and a definition and description of the consumption perspective together with some information regarding Swedish consumption. Data and statistics are for the year of 2011 if nothing else is stated. Most of the information regarding organizations included in the project is gathered from contacts and publications from the specific organizations. The text or data is referring to the municipality of Gothenburg's territorial area and its inhabitants when the name Gothenburg is used. The municipality of Gothenburg refers to the municipal organization only.

This thesis is part of a Mistra Urban Futures project which is carried out in collaboration between Chalmers University of Technology, the Environment department of the municipality of Gothenburg and VGR. The entire project's goal is to estimate greenhouse gas emissions for typical citizens in Gothenburg from a consumption perspective, whereas this thesis covers emissions from public activity.

1.1.1 The municipality of Gothenburg

The municipality of Gothenburg, also called the City of Gothenburg, is the second largest city in Sweden with its 520 374 inhabitants. There are about 300 thousand jobs in Gothenburg, of which about 48 thousand are in the municipal public sector. Gothenburg is a popular university city and has about 38 thousaand students (Göteborgs Stad, 2013). Two large universities are Chalmers University of Technology and University of Gothenburg.

The municipality of Gothenburg mainly gets its income from municipal tax which is contributing to 63 % of the total income (Göteborgs Stad, 2012). State subsidies, financial incomes, rents and charges are other important income sources. The municipality of Gothenburg owns and partly owns companies, which are providing everything from apartments to cultural activities. Examples of companies are Göteborg & Co, Göteborgs Hamn AB, Renova AB, Gryaab, Göteborgs Energi AB, Göteborgs Stadsteater AB, Liseberg AB, Got Event, Boplats Göteborg AB and Göteborgs Spårvägar AB (Göteborgs Stad, 2012).

In the municipality of Gothenburg there is an environment department with a mission to create a good living environment for the inhabitants and to minimize the negative impact, from the society, on health and the environment. There are about 150 employees at the department, a department which is divided into three operation departments (food inspection, environmental inspections and urban environment) and one business support (administration, communication, law and personnel) (Göteborgs Stad, 2013).

1.1.1.1 The environment and the municipality of Gothenburg

The local emissions are estimated to 5.6 tons CO_2 per person and year (notice that only CO_2 emissions are considered here) (Miljöförvaltningen, 2012). These emissions are from a production/territorial perspective. By using a consumption perspective (for a definition see chapter 1.1.3 Consumption and production perspective and Swedish consumption in general) and including other greenhouse gases as well, there will be higher emissions (Miljöförvaltningen, 2012).

From a production perspective the CO_2 emissions in Gothenburg have increased by eight percent from year 1990, this can partly be explained by the increased population (Miljöförvaltningen, 2012). If the emissions are divided upon the inhabitants the trend is showing slightly declining emissions during the years. Increasing energy usage along with not using energy efficient technology is believed to play an important role to prevent reductions of emissions. Other important factors affecting emissions are the need of heating, which is depending on the temperature, and the development of the economy since we tend to produce/consume less in bad times.

To lower the emissions further support to public transportation and other sustainable transport systems are needed (Miljöförvaltningen, 2012). But not only transportation is seen as a problem since energy efficiency regarding buildings but also placing the buildings and public transportation system close to each other are important factors as well. Further the private consumption and behavioral patterns must change along with phasing out fossil fuels.

The municipality of Gothenburg is monitoring the share of ecological food served within the organization. By increasing the share the municipality of Gothenburg is, according to them, supporting a production of food which is free from chemical pesticides. The share is close to 25 % (Miljöförvaltningen, 2012), however there is hard to say whether and to what extent this is a measure against climate issues.

1.1.2 Region Västra Götaland

Region Västra Götaland's mission is to support the health of the inhabitants in the region and is responsible for healthcare and public transportation. Their operation is mainly funded by county tax (VGR, 2013a). The region consists of 49 municipalities and has about 1.6 million inhabitants (VGR, 2012a).

VGR is a politically driven organization which can be divided into two parts, were one is the political part and the other is referred to as the officials organization (VGR, 2013). The political part consists of the regional council, boards and committees with about 1100 elected politicians deciding over the economy, alignment, goals and so on. The official's organization with 55 000 employees is headed by the regional director and works to realize the political decisions by is exercising all the activities, offices and secretariats. The offices and secretariats mission is to provide support to the political organization, such as investigations, calculations, analyzes and impact assessments.

1.1.2.1 The environment and VGR

According to VGR the organization should support a good environment and is acting together with municipalities, county administration and other authorities to contribute to a sustainable development in the region of Västra Götaland.

VGR has set a goal of having no dependence on fossil energy in the year of 2020 and environmental projects for energy, transport and food are now being conducted (VGR, 2012a). Today the dependence according to them is mainly because of the (increasing) public transport system which has a share of about one fourth of total local person transportation. A milestone is to reach a kilometer production of 35% renewables or corresponding increase in energy efficiency in 2013 (for busses and non electric trains), in 2011 it was at 30 % and in 2010 it was 16 %, were increasing use of biodiesel and biogas are mainly the reasons for the renewable share increase.

The increase of the public transport is partly being achieved by the congestion tax which recently was introduced in Gothenburg. The tax is being used to partly finance the Västsvenska paketet which is a package of infrastructure (Trafikverket, 2013). The idea is to make the public transport more attractive and also to make the business sector transportation more reliable. Further it will hopefully contribute to a better environment and enhance commuting by public transportation in the region.

VGR is implementing methods to reduce travelling within the organization, an organization which is located widely dispersed in the region (VGR, 2012a). New technologies are suggested to play an important role where for instance meetings can be achieved by using Internet or phones instead of travelling to a physical meeting room. However the share of fossil independent vehicles has decreased compared to 2010, this since the number of ethanol vehicles has decreased whereas the number of diesel vehicles has increased. VGR have decided that biogas should be of high priority as a fuel for their vehicles and they are an active part in a program to develop biogas in the region. The region has about 25 % of the biogas vehicles in Sweden (VGR, 2012a), worth noticing is that the region includes about 17 % of Sweden's inhabitants.

The biogas production is linked to food waste in Västra Götaland and to expand the biogas production VGR supports municipalities in the collection of food waste. The goal for 2020 is to increase the biogas production with 25 times compared to the production in 2010 (VGR 2012a). Also 50 % of the food budget should be used for ecological food of which the share now reaches 25 % (VGR 2012a). VGR states that they are prioritizing locally produced food since it together with ecological food is considered to be important for a sustainable development (VGR, 2013a).

While the energy consumption from buildings are declining, because of higher energy efficiency in new and renovated buildings along with optimizing control systems and ventilation in old ones, an increase in electricity demand is due to the increased use of lighting, computers and medical equipment. It is seen as a great challenge to buy new energy efficient equipments. VGR states that they are only purchasing environmentally friendly electricity from renewable sources and the district heating provided is from about 80 % renewables (VGR, 2012a). Whether this can be seen as a true picture of the reality is open for debate since it’s hard to actually get electricity with only renewable origin from the relatively complex electricity grid. The heat and electricity consumption during 2011 was 163 and 161 MWh respectively[1].

VGR has estimated their CO_2-eq emissions (carbon dioxide equivalents is a way of describing all the greenhouse gas emissions as if they all were carbon dioxide) to be 140 000 tons[2] during 2011, which divided upon the inhabitants end up at 0.09 tons per person (VGR, 2012a). During healthcare activities VGR emitted about 31 tons of nitrous oxide (N_2O) per year (or 9,6 Kton if expressed in CO_2-eq) which stands for 7 % of VGR's reported greenhouse gas emissions (VGR 2012a). However the nitrous oxide emissions are declining; in 2009 it was 38 ton; in 2010 it was 35 ton. The goal is to reduce the emissions to 9.5 tons in the year of 2020.

VGR is acting to reduce the impacts from the consumption of pharmaceuticals by increasing awareness of the logistics of their stocks and encouraging non pharmaceutical treatments, further the organization has set environmental requirements for the antibiotic producers (VGR, 2012a).

1.1.3 Consumption and production perspective and Swedish consumption in general

In this thesis the consumption perspective is used to estimate greenhouse gas emissions from public consumption. This means that the final users/consumers of goods and services are responsible for the emissions no matter where, in the life cycle or geographically, the emissions have taken place. The emissions can be from raw material extraction, production, distribution, usage and waste handling, which not always take place in the same country (Naturvårdsverket, 2008). The consumption can be divided into private and public consumption where the first is the consumption made by individuals, inhabitants in a country, funded by private funds whereas the public consumption is funded mainly by taxes. Using consumption to estimate greenhouse gas emissions visualizes the climate impact of the citizen's living standard and their lifestyles (Naturvårdsverket, 2008). Naturvårdsverket further states that one must still understand that not all responsibility should be placed upon the consumers. Policy makers and producers must also take action and create possibilities for consumers to make good choices in order to minimize emissions.

Another perspective than the consumption perspective is the production perspective which is based on all emissions within a geographic area, usually a country. Thus the emissions from an industry in the area are included no matter for whom and where the products are being used. This perspective is the basis for accounting emissions in most of the international negotiations (Holmberg, 2011). It is for instance this type of emissions which the municipality of Gothenburg is reporting in their environmental report, or being reported for the Kyoto protocol. Both perspectives have their pros and cons.

The Swedish EPA (Naturvårdsverket) has estimated the consumption related greenhouse gas emissions Sweden is responsible for with data from 2003 (gases included are carbon dioxide, methane and nitrous oxide, i.e. same as in this thesis). The estimated amount was 95 Mton

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[1] Sara Eriksson (Environment Secretariat, VGR) from a mail conversation from 23 of April

[2] Estimated from energy and fuel usage; notice the inclusion of life cycle emissions renewables are responsible for and the low used emission factor for electricity production used in their report.

CO_2-eq per year excluding emissions from exports and including emissions from imports. Divided upon the Swedish population they ended up at about 10 tons CO_2-eq per person and year. Approximately eight tons originated from private consumption, thus the other two tons came from public consumption. The private consumption was divided into four categories, eating, housing, traveling and shopping with the corresponding emissions (in percent) of 25, 30, 30 and 15 (Naturvårdsverket, 2008). Five activities have been identified to contribute to about half of the emissions, it is thus easy to say that emissions from these activities should be lowered. The important activities are: how much and what kind of car we drive, how we heat our houses, how much electricity we use in our houses, how much and which kind of meat we eat, how long and how often we travel by airplane (Naturvårdsverket, 2008).

Whereas emissions from the private consumption are organized into specific activities the total emissions from public consumption are by the Swedish EPA seen as more uncertain (Naturvårdsverket, 2008). This since the estimated value for public consumption of about two tons CO_2-eq is actually calculated by subtracting the emissions from private consumption from the total estimated emissions, thus there is no clear picture about specific emission amounts for different activities or sectors within the public sector.

During the years between 2000 and 2008 the total emissions from Swedish consumption (both private and public) increased, by 9 %, from 90 million tons CO_2-eq to 98 million tons CO_2-eq of which 58 million tons was emitted abroad (Naturvårdsverket, 2012a). Emissions within Sweden, resulting from Swedish consumption, have decreased with 13 % whereas foreign emissions, resulting from Swedish consumption, have increased with 30 %. This is a result from the increasing imports. For the total emission increase the increasing population were responsible for about half, another reason might be because of changes in consumption patterns. Emissions per person increased with about a total of 5 % during the period (Naturvårdsverket, 2012a).

The public consumption is rather stable and has been so since the eighties and is only expected to grow because of demographic changes (Naturvårdsverket, 2012c). This might be one of the reasons why not that many studies have been made on emissions from public consumption in Sweden. Other reasons might be since the emissions are less the than private ones and the public sector being more service oriented than the private sector.

The municipality of Gothenburg’s local climate goal is to have a "sustainable and fair level of carbon dioxide emissions" (own translation of; “hållbar och rättvis utsläppsnivå för koldioxid”) in 2050 and this has been quantified as less than 1.9 tons CO_2 per person and year (Miljöförvaltningen, 2012). Further it is stated that fair includes a global perspective, it is thus relevant to also include emissions regarding the consumption, no matter where these emissions have occurred. Therefore the consumption perspective seems relevant for this goal. However the municipality of Gothenburg is not expecting that the global two-degree target will be met and the city is actually starting to adapt itself to rising sea levels by building the ground level in new buildings higher compared to earlier (Miljöförvaltningen, 2012).

Another way of expressing our living standard is that of the ecological footprint. This is an indicator which in short terms is showing the amount of land needed to supply the anthropogenic extracted natural resources. Research has shown that the ecological footprint would be equal to 3,25 earths if all the people living on the planet were having the same standard as the Swedish citizens, whereas the entire earth’s population were using resources equal to 1,5 earths (Axelsson, 2012).

The greenhouse gas emissions from public consumption should not be neglected. Since the goal is to get under a total of 1.9 tons of greenhouse gas emissions reductions must take place in all areas. An important part of this can be done within public consumption and this is one of the reasons for making this thesis.

1.1.4 Global warming

Jean-Baptiste Joseph Fourier is famous because of his work in mathematics, but he is also seen as one of the founders to the theory of the greenhouse gas effect (Azar, 2009). Fourier published a report in the year of 1824 (it was republished slightly different in 1827) where he stated that the atmosphere has an important role for our climate since it has the ability to capture long wave radiation (heat) leaving the earth's surface, thus heating the earth (Fourier, 1827). Fourier did not mention any greenhouse gas effect, nor did he mention anything about carbon dioxide's role. It was John Tyndall who by his experiments discovered the ability for water and carbon dioxide to capture the earth's heat radiation in the middle of the 19^{th} century (Azar, 2009).

While the greenhouse effect mostly is associated with negative effects the natural greenhouse gas effect is actually good for us. Without it the temperature at the earth's surface would have been less than zero degrees Celsius, however today the carbon dioxide concentration is more than 35 % above the concentration before the industrial revolution (Azar, 2009). Why increasing concentration of greenhouse gases can be seen as one of the biggest challenges today can be explained by the following; the emissions are contributing to rising temperatures in our climate. This will contribute to more extreme weathers, raising sea levels and other often disastrous events (IPCC, 2007) which all are related to each other in the complex system called earth.

One way to measure the performance in terms of greenhouse gas emissions is to estimate our emissions from consumption activities or the concentration of such gases in the atmosphere and to compare it to previous years or set goals. Measuring emissions is of course not an easy task since emissions might be emitted by diffuse or point sources and they can be direct or indirect which demands clear boundaries, sophisticated calculations and measures to give an exact picture as possible. When this is done in a sophisticated way it is easier for the consumers to make environmental informed choices. This is not eased by the fact that the climate sensitivity is rather uncertain (IPCC, 2007), thus making goals of emission targets harder to set.

The Swedish government has set a goal of reducing greenhouse gas emissions in 2020 by 40 % compared to the emissions in the year 1990 (Sveriges regering, 2010). This however only covers the activities not included in the European Union Emissions Trading System and is from a production perspective thus not affecting emissions from imports or international flights. Today the Swedish national energy supply has a 47 % share of renewables, which is the highest share in the entire EU (Lönnqvist, 2013).

1.2 Purpose and research questions

The purpose of this thesis is to explore and estimate greenhouse gas emissions from the public consumption in Gothenburg. The following questions have been used for fulfilling the purpose:

1. How large are the emissions from public consumption within Gothenburg?
2. Which amount of emissions are the consumption of food and public transportation in the public sector responsible for?
3. Are there other important public activities generating emissions?
4. What are the potentials to reduce climate impact from public food consumption and public transportation consumption until 2030?

1.3 Limitations

Here are the most important limitations of the study presented

- The state's share to the public consumption in Gothenburg will be allocated by dividing their emissions upon all the citizens in Sweden, thus equal allocation and no consideration regarding differences in consumption is included.
- VGR's emissions will be divided by the number of citizens in the region, thus equal allocation and no consideration regarding differences in consumption is included.
- Included Greenhouse gas emissions are carbon dioxide, methane and nitrous oxide. The emissions will be presented in the aggregated number carbon dioxide equivalents (CO_2-eq).
- Emission factors from Swedish Input-Output (see description of Input-output in chapter: 2.1 Input-Output analysis) data was used, thus activities abroad was calculated as if they were performed with Swedish standard.
- The emission intensities (see description about emission intensities in chapter: 2.1 Input-Output analysis) are the mean values for Sweden and no consideration about differences between Gothenburg compared to the rest of Sweden was made.
- Emissions from land use change are not included in the emission intensities from the Input-Output data and will thus not be included in the estimations.
- Welfare and subsidy expenditures to citizens are not included.
- Not all activities will be covered while using the bottom-up strategy (see description of the bottom-up strategy in chapter: 3 Method)

2 Theory and literature review

This chapter will go through the theory behind the method being used, information about consumption of food and public transportation in Sweden will also be presented. Some of the information is specific or detailed but is included to support transparency for the calculations.

2.1 Input-Output analysis

Gathering of data is often time consuming and since time and budget often are limited resources easily accessible data can be handy. Input-Output data with environmental information regarding products and sectors can often be seen as easily accessible and can be used in different environmental systems analysis tools (Finnveden, 2007). Following is a short presentation of the Input-Output methodology which is a basis for the emission estimations done in this thesis.

Input-Output analysis (IOA) was developed in the 1930s and is an economical method where matrixes are used to describe how different branches are trading with each other, it is common to express it in economical values instead of weight or volume of considered goods (Finnveden, 2007). With IOA one can estimate how much inputs are needed in the process of producing a product or service. This type of analysis has been combined with environmental and energy data and this method has increased in terms of usage in the last couple of years (SCB, 2013). One example is to include emission factors for estimating emissions for different inputs into products, services or sectors (Finnveden, 2007). This is referred to as Environmentally extended Input-Output analysis and the emission factors can be in terms of carbon dioxide per SEK of input. By aggregating all the emissions for the production of a product the total emissions the product is responsible for is estimated (Finnveden, 2007).

In Sweden the Input-Output matrixes are created by using Use and Supply matrixes, which are in line with the international system of Accounts (Finnveden, 2007). These matrixes are yearly updated, where both the Use and Supply matrixes are consisting of product * branch, that is products on the lines and branches on the columns. In the Use matrix the columns describes how the total value for a branch is divided between input's values and final added value. The lines describes how a product is being used as either input divided in the different branches or final usage in private or public consumption, investments or exports. The Supply matrix shows which products are being produced by a branch on the columns and which branches are producing a product on the lines (Finnveden, 2007).

This can be summarized as being a method quantifying the total production of different input products for producing a product, reaching a consumer. The following formula is describing IOA (Finnveden, 2007):

$$x = (I - A)^{-1} \cdot y \qquad (1)$$

Where x is the needed production, y is the final usage during one year, I is the identity matrix and A represents the production required to meet various operational inputs between producers (or different input shares of each producer's total production).

Formula (1) can be modified with emission factors, thus presenting the amount of emissions the production of products are responsible for:

$$CO_2 = Ef_{co_2}(I - A)^{-1} \cdot y \quad (2)$$

Where Ef_{co_2} is expressed in mass CO_2-eq per monetary value.

One problem appears since the production not only occurs in one country, in this case Sweden, and one usual way to get around this is to calculate foreign production as if it occurred in Sweden, thus with Swedish Input-Output data. However this is usually an underestimation since Sweden usually emits less emission per unit of production compared to other countries (SCB, 2013). Another disadvantage is that emissions from land use are not included yet since there are no used methods to link land use to consumption (Naturvårdsverket, 2012a).

The Input-Output analysis is a rough tool which makes it hard to draw conclusions from specific details (Naturvårdsverket, 2008). There are only relatively few branches and products included in the Input-Output analysis which the entire consumption should be represented through. In reality there are many ways to produce one product and not all products of one type are exactly the same when it comes to function and attributes. However, this analysis usually matches with national reported total emissions (Naturvårdsverket, 2008) and is thus good for this broad perspective since the included products can be seen as a mean.

When the total greenhouse gas emissions for a product or branch is estimated, including emissions from other industries which the specific product is responsible for, an emission intensity can be calculated by dividing the emissions by the product’s value (base price) (Finnveden, 2007), thus an emission intensity consisting of CO_2-eq. per monetary value is obtained. It is this type of emission intensities which are being used in the top-down (see chapter: 3 Method) approach in this study. If the value of a product is known it can be multiplied with the corresponding emission intensity, thus the emissions before final use is calculated.

SNI (Svensk Näringsgrensindelning i.e. Swedish Standard Industrial Classification) which primarily can be described as an industry/business activity classification (SCB, 2013) is used in this thesis in the form of SNI 2002 for classifying branches or as often referred to, activities. This is done since there are available emission intensities reported according to SNI (see SCB (2007and 2013) for further details).

2.2 Food consumption

Food is responsible for a large share of the total greenhouse gas emissions in private consumption and is also believed to do so in the public consumption (SIK, 2011), where food is served in schools, hospitals, homes for the elderly and so on. The different types of food have been shown to greatly affect the amount of emissions a meal is responsible for (SIK, 2011). Further can also the same type of food differ greatly in terms of emissions because of different production methods and geographical locations.

2.2.1 The agricultural sector in general

Different types of food have different impact on the environment. Usually animal products have larger impacts compared to vegetable ones, with about 2-30 kg CO_2-eq per kg of food higher than for vegetables (SIK, 2011), but sometimes even vegetables are responsible for large amount of emissions. A high emitting vegetable type of food is rice with large amounts of methane emissions from the rice fields. Vegetables grown in greenhouses heated by fossil fuels are also responsible for relatively large quantities of emissions. Low emitting types of vegetable food are root-crops, fruits and vegetables being grown on fields (SIK, 2011).

The agricultural sector is contributing to climate change and land degradation. The sector is responsible for about a third of the total emissions resulting from human activity (FAO, 2012). Of the total anthropogenic greenhouse gas emissions agriculture is responsible for 25 % of carbon dioxide, 50 % of methane and more than 75 % of nitrous oxide. Large quantities of the carbon dioxide comes from deforestation, whereas large quantities of the methane comes from rice production and cattle and lastly nitrous oxide mostly comes from fertilizers (FAO, 2012).The sector is also responsible for a huge share of the land usage and the same goes for water usage (FAO, 2012); the sector uses about 75 % of the fresh water resources withdrawn by human activity from aquifers, lakes and rivers. Further about 100 million tons of the important nutrient nitrogen is used in agriculture. Expectations are that the global demand for food will double until 2050 because of population growth and economic growth (FAO, 2012).

Meat production alone has been reported for 18 % of the total greenhouse gas emissions (FAO, 2006). The emission intensity for producing one kilo of beef where the animals comes from milk production is at about 14-19 kg CO_2-eq, whereas producing one kilo of beef directly from specialized beef production has the emission intensity of 22-40 kg CO_2-eq (Jordbruksverket, 2013:1). This difference is due to the emission allocations between different products in the milk and meat production. New estimation to include deforestation suggests using 700 kg CO_2-eq per kilo of meat if deforestation occurred as a result from the meat production (Jordbruksverket, 2013:1). Chicken and free living fish usually are low emitters; values around 2 kg CO_2-eq per kg of food have been reported. However, important to have in mind is that chicken which is given soybean as feed can have higher emission intensity if land use changes are included resulting from the expansion of soybean production (SIK, 2011). The choice of boundaries and assumptions while estimating emissions from food plays a vital role.

2.2.2 Meat consumption in Sweden

The importance of meat when talking about climate issues cannot be underestimated since it generally, as described above, is more emission intensive than vegetable food. Therefore some information about the Swedish meat consumption is included.

The total consumption of meat in the year of 2011 was 87 kg per person (Jordbruksverket, 2013:2). The consumption was divided between the following types of meat; pork, 37 kg; beef, 26 kg; poultry, 19 kg; other, 4,5 kg. Other can further be divided into; wild, 2 kg; sheep, 1,5 kg; guts, 0,6 kg; horse, 0,2 kg; reindeer, 0,2 kg. The total consumption has increased by about 40 % during the period 1990-2012 of which poultry stands for the largest increase (Jordbruksverket, 2013:2). Jordbruksverket has also noticed another trend which is that of the decreasing consumption share of meat produced in Sweden. For instance the share of Swedish produced beef has decreased from 89 % to 53 % and stated reasons for this are the increased milk production efficiency together with decreased milk consumption. Another reason is because of the competeition with the imported and usuaually cheaper meat (Jordbruksverket, 2013:2). Data regarding public consumption of food is rather limited.

The trend of increasing meat consumption can be seen in the entire world and not only in Sweden, it is not only negative from a climate perspective; studies shows that people in the western world are eating too much red meat, which is unhealthy; it would be easier to feed more people if the meat consumption was changed into a more vegetable consumption (Jordbruksverket, 2013:1). Changes in meat consumption are stronger linked to economics compared to changes in staple food consumption. Meat stands for a relatively large share of the food expentidures, thus changes in price and income are relevant parameters that changes the trends for meat consumption (Jordbruksverket, 2013:2). Jordbruksverket has discussed a meat tax (Jordbruksverket, 2013:1). The meat tax can be dependent on the amount of greenhouse gas emissions the specific meat is responsible for to help the decline in consumption of meat, since it’s believed that information alone is not enough. This policy would probably also reduce losses of edible meat, now being thrown away. Other factors that also can play a role in the change of meat consumption can be the attitude towards nutritional recommendations, food trends and advertising. One example is the high protein diets such as LCHF and GI which have been introduced (Jordbruksverket, 2013:2). Trends of high protein diets have been claimed to be a result from lobbying by the meat producing industry (SR, 2011).

Jordbruksverket claims that there are reasons to still have a meat production in Sweden (Jordbruksverket, 2013:1) since natural pastures are contributing to a higher biodiversity along with preserving the landscape, the opportunity for employment at the countryside and animals living in a more natural environment are usually healthier resulting in less antibiotics being used. However one can always question about the alternative to using the land as pasture and whereas the landscape argument is of high importance.

2.2.3 Food consumption in the future

The possibilities to lower the emissions from food consumption are in some cases rather limited in terms of technical solutions. Take the example of cattle; no matter how good problem solvers people are the ability to reduce methane production in a cow’s stomach can be seen as low. On the other hand a study regarding methane emissions from cattle has shown that it might be possible to reduce methane emissions by up to 20 % by adding fat to the fodder (Grainger, 2011). The possibility to add fat on pasture land is rather limited and locking in all cattle and thus only providing them with fodder can be argued as being partly environmental friendly (but generating losses in biodiversity), there can also be reasons to consider ethical aspects when locking in all cattle.

Possibilities to reduce emissions by environmentally better manure handling are an area where technical fixes can be seen as more relevant. Manure can for instance be used as a raw material for producing biogas (see chapter 2.3.2 Public transportation data for future) thus preventing emissions of both methane and nitrous oxide from conventional manure storage (Börjesson, 2010). Further the digestion residues from biogas production can replace fertilizers. Other technical solutions are to use renewable energy and to increase the energy efficiency in the food production. By only changing into non fossil fuels a 31 % decrease of greenhouse gas emissions in a typical person's diet in 2050 can be achived, taking into account continued trends (e.g. more meat and less milk) (Bryngelsson, 2013). By also assuming some technical, yet quite expensive, fixes (e.g. those described above) reductions of a total of 47 % have been estimated. Of great relevance for lower emissions are dietary changes in food consumption. By taking into account for such changes together with using non fossil fuels and implementing technical solutions the following reductions of greenhouse gas emissions have been estimated (Bryngelsson, 2013); changing type of meat into eating less beef and more poultry and pork (67%); eating less meat and increase eating of quorn, tofu and legums (78%); eating a totally vegan diet (88%).

2.3 The transportation sector in general

The (domestic) transportation sector uses approximately one fourth of the total energy consumption in Sweden (Energimyndigheten, 2011) and in the European Union the sector stands for about 20 % of the total greenhouse gas emissions (UITP, 2006). About 40 % of the transport related emissions are emitted from European cities (UITP, 2006). Therefore there is a rather large possibility to reduce those emissions by increasing the public transportation share of the market.

According to EU's energy targets the sector must increase its share of renewable fuels to a total of ten percent in year 2020 (The European parliament and the council, 2009). During 2011 the renewable share in the transportation sector in Sweden stood for about 9,8 %, thus being close to EU's target (Energimyndigheten, 2012). Biogas and biodiesel are the renewables believed to be the major fuels to reach EU's goal (Energimyndigheten, 2011), of which the biogas demand is expected to be 1,1 TWh (Lönnqvist, 2013) which was the amount of produced biogas in Sweden during 2008 (53 % of the produced biogas was used in the transport sector) (Energimyndigheten, 2010).

2.3.1 Public transportation consumption

Västtrafik is the company providing the public transportation service in Gothenburg and in the entire region of Västra Götaland. About half of the cost is financed by tax and the other half is financed by ticket fares (VGR, 2013a). In the year of 2011 VGR together with the municipalities owned Västtrafik, however this is not the case today. Now VGR owns the company itself but gets funds from the municipalities (Västtrafik, 2012).

The advantages of using public transportation are many and Västtrafik has developed cost models for estimating the worth of the services (Västtrafik, 2012). It has shown that less people get hurt or killed by using public transportation instead of travel by the car, bicycle or by walking and the public transportation system prevented about 1800 injuries and deaths during 2011. The environmental benefits are also important; the greenhouse gas emissions would have been higher if people didn't use the public transportation system since the alternative is often to travel by car. Union Internationale des Transports Publics (UITP) have shown that the mean transportation has 25% occupancy, for both car and public transportation, which makes public transportation three times as effective as cars in terms of greenhouse gas emissions. During peak hours the efficiency for public transportation reaches ten times as high as for the car and fuel savings up to 400-500 kg of fuel per person and year can be made (UITP, 2006). However it has been seen that the passenger fares for public transportation increases faster than the cost for using private car (UITP, 2006).

The decreased wear on the roads (which prevented costs reaching 19 million SEK), since less cars are traveling on them, is another positive effect by using public transportation. The shareholder contributions of just over 2,5 billion SEK have been estimated to give a public benefit of about 4,5 billion SEK (Västtrafik, 2012). The worth of public transportation have been estimated higher than the expenditures in other studies as well with multipliers between 2-4,6 describing the local and regional economical benefits compared to the investments (UITP, 2006).

What can be seen as a successful example of increasing public transportation in a city is London where a congestion tax was implemented and used for financing improvements in the bus system (UITP, 2006). CO_2 emissions from transportation in the area were reduced by 19% during 2002-2006 of which the decrease of 16 % occurred during 2002-2003 (TfL, 2008). It is too early to say anything about the new congestion tax in Gothenburg though.

VGR estimated the emissions from the consumption of fuels in the public transportation system to be 88 200 ton CO_2 (VGR, 2012a), allocated for the population share in Gothenburg the amount reaches 28 855 ton or 0,055 ton CO_2 per citizen. This only includes life cycle emissions the fuels, consumed by the vehicles, are responsible for and not emissions from all consumption (e.g. from production of vehicles). The electricity used by trams and trains is specified as renewable (Ecoplan, 2012) and is estimated with low emission factors (VGR, 2012a).

2.3.2 Public transportation data for future

There are many different alternatives for improvements in the future and some of them will be presented here. The text is containing a lot of details which are included to provide transparency for the calculations.

VGR has set goals for the future public transportation and some of them will be presented here. One goal is to increase the share of the renewable energy used in their public transportation to 95 % in the year of 2025 together with an energy efficiency increase of 25 % compared to year 2010 (VGR, 2013b). There are also goals regarding increasing their share on the market and the goal is to double the number of travels which was done in the year of 2006 (201 million travels then) until 2025 (VGR, 2013c).

Biogas

As previously stated (chapter 1.1.2.1 The environment and VGR) VGR is focusing on biogas as a more sustainable alternative compared to fossil fuels. Work is being done in VGR's project "Biogas Väst" which is a programme for developing production (172 GWh was produced in the region during 2010) and usage of biogas within the region (Biogas Väst, 2013).

A study of a Swedish biogas plant (Lantz, 2009) showed that the emission intensity in the production and distribution steps for biogas was 16 g CO_2-eq/kWh, which is about 95% better than the life cycle emissions from gasoline. The emissions mostly came from methane leakage from the plant. Cost neutral or even beneficial suggestions for improvement would lower the emission intensity with about 3 grams. Included in the biogas intensity are also the benefits of avoiding conventional manure handling, the replacement of mineral fertilizers and some land effects. SEA (Swedish Energy Agency, Energimyndigheten) states on their website that biogas reduces fossil CO_2 emissions with a mean of about 80 % compared to gasoline (Energimyndigheten, 2013). According to the Swedish Consumer Agency the usage of pure biogas emits almost nothing, however some leakage occur during the production (Konsumentverket, 2013). VGR uses an emission intensity of 0,51 kg CO_2-eq/Nm^3 (or 52 g CO_2-eq/kWh by assuming 9,77 kWh/Nm^3 for biogas) in their estimations (VGR, 2012a). Even negative emissions have been reported with production methods utilizing manure, industrial food waste and biological household waste, with reductions of greenhouse gas emissions of up to 148 %, 119 % and 103 % respectively compared to fossil fuels (Börjesson, 2010). Indirect effects such as increased utilization of nutrients decreases the use of mineral fertilizers is the explanation of negative emissions.

It is believed that 70 % of the buses in the year of 2020 within the entire region of Västra Götaland can be of biogas type with the limiting factors of the investment costs for biogas refueling places and the lacking of biogas models for double-deckers (fuel limitation not considered) (Ecoplan, 2012).

VGR's goal is to produce 2400 GWh biogas in the year of 2020 whereas the now planned production is about 1215 GWh (Ecoplan, 2012). One should have in mind that it is not only the public transportation sector which is interested in using biogas but rather the transportation sector as a whole. It is thus important to look at the production potential for the future. A rather conservative estimation for a practical total biogas production in Sweden ended at 8,86 TWh, which is equal to about 9 % of 2010's domestic transport energy consumption (Lönnqvist, 2013). Thus it is today hard to see that biogas can be used by all vehicles in the future, however using it in public transportation might be very relevant.

What is seen as an obstacle for the biogas engine is the relatively low energy efficiency whereas a combined heat and power production is more favorable for biogas (Ecoplan, 2012). Biogas buses today uses the typical petrol engine which is less energy efficient compared to the typical diesel engine (which is used in the diesel buses) (Ecoplan, 2012). Today a biogas bus consumes about 30 % more energy than a biodiesel bus and 90 % more energy than a biodiesel electrical hybrid bus (VGR, 2013b). Projects for combining the positive characteristics of biogas and the diesel engine are being conducted (Ecoplan, 2012). Compared to conventional diesel busses the additional cost of using biogas is about 2,5-5 SEK per km (VGR, 2013b).

There are also other already commercialized renewable fuel alternatives available for public transportation, some of them are; biodiesel (FAME), hydrotreated vegetable oil (HVO) and electrical power (which is not directly a fuel) (VGR, 2013b). They will be presented shortly.

Biodiesel (FAME)

Biodiesel or FAME (fatty acid methyl ester) can be made out of rapeseed oil and is today added to the fossil diesel (about 5 % biodiesel) which can be compared to the way ethanol is added to gasoline. Vehicles using only biodiesel are strictly limited because of few available vehicles (Energimyndigheten, 2011) and the expectations of the increasing use of pure biodiesel is low, in 2014 biodiesel engines must be certified. The increased use of biodiesel is believed to come from the increased use of fossil diesel (Ecoplan, 2012). Compared to conventional diesel busses the additional cost of using biodiesel is about 0,5-1 SEK per km (VGR, 2013b). Emission reduction of up to 68 % compared to fossil fuels has been reported (Börjesson, 2010). Västtrafik are testing eleven buses with an engine utilizing diesel technology combining the fuels of biogas and biodiesel, (Västtrafik, 2012).

Hydrotreated vegetable oil (HVO)

HVO is a bio based synthetic diesel which can be seen as a somewhat better fuel than biodiesel (i.e. FAME) since it can be utilized in conventional diesel engines, thus does not need any special certified engines. Limiting factors today are the supply of the fuel and the higher cost compared to conventional diesel (Ecoplan, 2012). HVO does not suffer from the same negative effects as biodiesel fuels, such as; increased emissions of NO_x; storage stability problems; a more rapid aging of engine oil; relatively poor cold properties (EBTP, 2013).

HVO is the only, by VGR suggested, non-fossil fuel which can be used in ferries, but since usage of fossil fuel in ferries is excluded from energy or CO_2 taxes HVO is further less competing (about 34 MSEK in higher fuel cost per year for Västtrafik's ferries) (VGR, 2013b). HVO can also be used in the few diesel trains which are used today. The petroleum company Preem is producing a diesel consisting of about 23 % HVO (made out of tall oil), 7 % FAME and 70 % fossil diesel (Preem, 2013). Life cycle studies for different HVO production methods abroad have shown that emissions from soil in the cultivation phase are the most significant ones, and the total greenhouse gas emissions are about half of the ones from conventional fossil diesel (HVO out of tall oil was not included in this study) (Arvidsson, 2010). Preem's crude tall diesel production, with an annual production of 1 TWh, using black liquor from the pulp industry as a feedstock, has been estimated to reduce emissions with 85-90 % compared to diesel (Åkerman, 2012).

Electricity

When it comes to electricity driven vehicles there are different types which can be considered; the plug in electric vehicle which is plugged into the grid to charge the battery; the hybrid which uses electricity (generated while driving) along with another fuel like diesel or biodiesel; the plug in hybrid which can be seen as a mixture of the previous two types (Ecoplan, 2012) (VGR, 2013b).

What differentiates electric power from the other fuels is that the production of electricity is the crucial part, and this can be done in renewable or in fossil ways. No additional running costs is estimated for using hybrid busses, compared to today's buses and in a couple of years it is believed that the costs for using both hybrid and plug in electric busses will decrease, thus making them cheaper than today's conventional busses (VGR, 2013b).

Of particular interest is the new plug in hybrid Volvo bus which is exclusively tested in Gothenburg where reduction in tailpipe greenhouse gas emissions of up to 75 % percent have been estimated (Business Region Göteborg, 2011). Whereas the now used hybrid bus reduces fuel consumption and greenhouse gas emissions with about 37 % each compared to conventional diesel, however the busses can use biodiesel instead of fossil diesel, thus reducing the emissions even further (Volvo Group, 2013). A new Volvo hybrid with emission reductions reaching 39 % has been developed (Volvo Busses, 2013).

The public transportation system also offers transportation with cars by the service "färdtjänst" and therefore it is also relevant to look at cars. There is a goal set by the European Union regarding new cars for the year of 2020, the goal is to emit no more than 95 g CO_2/km from tailpipe emissions whereas total emissions for a diesel car, probably reaches close to 180 g CO_2/km by including emissions from driving (tailpipe emission), production of car and fuel and maintenance (Åkerman, 2012). For a plug in hybrid (gasoline) and an electric car the emissions have been estimated to 110 and 80 g CO_2/km respectively with the assumption of a marginal electricity production in the year of 2020 emitting 160 g CO_2/kWh (Åkerman, 2012).

The EU limit of 95 g CO_2/km is not a strict number and should be seen as a mean, this since the number is differentiated depending on the size of the car. But even larger cars can be made efficient close to the limit and it seems to be practically possible to develop a car like a Volvo V70 to reach 90-100 g CO_2/km (Åkerman, 2012) and Volvo's plug in hybrid diesel V60 has reported tailpipe emissions of 48 g CO_2/km with a fuel consumption of 1,8l/100km (Volvo cars, 2013).

3 Method

Two different methods have been employed to estimate the emissions from public consumption within Gothenburg. The first method, top-down, is based on how public money are being used in different sectors. These numbers are then combined with emission intensities from SCB's Input-Output data for each specific sector. The other method, bottom-up, is to gather information regarding purchases (e.g. fuel and meat) and activities (e.g. construction of roads and buildings) and to combine this with studies such as life cycle assessments to estimate emissions from these purchases and activities. However because of the time limit of this study the bottom-up method is just covered to some extent.

3.1 Data collection

Economical and other data have been gathered from the central organizations VGR (including Västtrafik), the municipality of Gothenburg and the Swedish state. Meetings with representatives from the municipality of Gothenburg and VGR have been done on a regular basis. Publications such as economical and environmental reports, published on each organizations website, have been used. Running costs for the municipality of Gothenburg were received directly from Stadsledningskontoret. Further data for the literature review and calculations have been collected from literature.

3.2 General calculation assumptions and allocations

To allocate the consumption by state activities the expenditures were divided upon all the citizens in Sweden (and then multiplied with the citizens of Gothenburg to get total emissions). The same goes for VGR, but instead of dividing upon all Sweden's citizens VGR's expenditures were divided upon the region's citizens. This was done because of the complexity of estimating who is using what and to what extend in the concerned geographical areas. For instance, the Sahlgrenska Hospital in Gothenburg is used by the entire region, the same goes for infrastructural projects financed by the government and so on. Further the citizens in Gothenburg were treated as equal consumers in terms of public consumption, which means; consuming the same amount independent on how much one is paying in tax or is using public services and products.

Table 1: The following population figures for 2011 have been used.

	The municipality of Gothenburg	VGR	Sweden
Citizens	520374[3]	1 590 604[4]	9 482 855[5]

For allocating the greenhouse gas emissions from public transportation it is assumed that the public and private sector each are responsible for 50 % of the emissions. This is done since the public transportation is financed in this manner, 50 % from taxes and 50 % from ticket sales. For the sake of simplification, the public transportation share of emissions is allocated to VGR activity only, and not divided between the municipality of Gothenburg and VGR.

3 http://www4.goteborg.se/prod/G-info/statistik.nsf
4 VGR, Årsredovisning 2011 (VGR, 2012b)
5 http://www.scb.se/Pages/PressRelease____350650.aspx

One important aspect in this study is the definition of what is assumed to be private or public consumption. In Naturvårdsverket's previous study (Naturvårdsverket, 2010) the definition is in short terms that public consumption is the consumption financed by tax whereas private consumption is financed from the citizens' own wallets. This definition is not used in this study and the reasons will be explained here. However Naturvårdsverket's definition has also in been applied, in this thesis, for the municipality of Gothenburg, just to show the difference in the two methods.

The definition of public consumption in this report is to classify the entire running costs and investment costs for consumption provided by the municipality of Gothenburg, VGR and the state to be public consumption. For instance the cost of healthcare is both financed by taxes and the patient fees and in this report all of this is defined as public consumption. The same goes for preschool/kindergarten were the parents have to pay a fee for their children where this also is considered as public consumption. The only exception is the public transportation system which was described earlier.

The state consumption was handled in an aggregated form, not separated into running costs and investments costs, and state funds to municipal and regional activities was excluded from state consumption, to prevent double counting. Companies owned by the public sector, acting on the market just as private ones (e.g. Liseberg AB) without significant public founding is not included. These companies are not reported together with the municipality of Gothenburg nor VGR's running costs for their public activities, the same goes for waste handling and waste water treatment which are financed by fees.

The reasons for using another definition compared to Naturvårdsverket are the following; the activities are seen as public ones (not partly public because of a minor fee funding), tracing which activities and how large shares of them are financed by tax, fees or other income is rather complex, according to the time limit of this study and the situation where, for instance hospitals raises their patient fee, thus lowering "their" emissions is not optimal in any case. One can also debate about the limitations of choosing when to go to hospitals or using kindergartens whereas choosing between using your car and using public transportation is more of an active choice.

3.3 Calculating emissions with the top-down approach

To calculate the emissions from the public consumption expenditures was collected from the concerned actors; the municipality of Gothenburg, VGR and the Swedish state. The expenditures was divided and classified as activities within SNI 2002 and multiplied with the corresponding emission intensity (see Table 2) to estimate the greenhouse gas emissions. When all the expenditures had been turned into emissions and summarized, the total amount was divided upon the citizens (see Table 1) in Gothenburg. The calculations are presented further in Appendix 1.

Table 2: Emissions intensities[6] used in the top-down study.

SNI activity	Emission intensity (tons/MSEK)
75 Authorities	14
80 The educational system	8
85 Healthcare and care	7
92 Recreation, culture and sports	19
45 Construction	30
60 Land Transport	28
01 Agriculture	255
33 Medical and optical instruments	15
35 Manufacture of other transport equipment	21

One can always argue about if a specific expenditure is placed in the right SNI activity, i.e. if the right emission intensity is being used. For instance authority expenditures might end up being used for something which might fit in another activity. The money is being transferred from the top to the bottom in the hierarchy and tracing the end use of all the included expenditures would be too time consuming. The SNI 2002 description (SCB, 2007) is comprehensive and it has been used as a support to classify expenditures into SNI activities. Public transportation is associated with the SNI activity 60 Land transport, however in this study it is assumed that ferries also goes under this activity, which is not true according to SNI.

The emission factor for agriculture is around ten times higher than the other. It is thus of high importance to include only the right expenditures here and a rigorous check on the states's expenditures regarding the subject has been done. This resulted in the Swedish state budget post "UO 23 Areella näringar, landsbygd och livsmedel" as reported in (Sveriges regering, 2012) being split between Authorities and Agriculture. Similar approaches have been used for other posts in the states' expenditures and this is displayed in Appendix 1. Special attention regarding this subject was not relevant for the municipality of Gothenburg or for VGR since their expenditures were presented in a more transparent way.

The investments by the municipality of Gothenburg and VGR are presented separately from the running costs since they differ a lot from year to year. The investments by the state are however presented aggregated, see Table 5. This since they were not presented separately, no further investigation was done since there was no exclusive analysis for state expenditures in the scope and timeframe of this thesis.

3.4 Estimating potential emission savings in 2030 and bottom-up

Potentials were researched through existing data, literature and were also discussed during meetings with staff from Chalmers, municipality of Gothenburg (including the Environment department) and VGR. To get a better understanding about possible reductions bottom-up data was collected regarding food and public transportation. These two sectors were chosen because of being major emitters along with being illustrative examples of potentials through behavioral changes and technical solutions.

[6] Intensities taken from (SCB, 2013)

During the estimation of possible emission savings different type of methodologies was used. Generally accepted ideas were included, along with more theoretically or radical ones. As a rule of thumb the largest contributors, or what was believed to be the largest contributor (because of lack of data), was investigated more thoroughly (e.g. meat and busses) than those which was seen as a small contributors or technically or socially infeasible to implement. Potentials for lowering the total emissions but raising the public emissions were also analyzed and it should be stressed that the main goal is to reduce the total emissions. One obvious example is the expansion of public transportation which might raise the public emissions but lower the total ones.

Potentials for the entire public consumption are rather discussed than presented in total numbers, this since the top-down approach is relatively limited in going into details and there is not only one general solution or quick fix to each specific problem. The complexity of estimating the potentials is usually high, depending on many parameters in society.

3.4.1 Bottom-up data and estimations for public food consumption

It would have been optimal to have data for quantities of all the public food consumed in Gothenburg. However this type of data is not being recorded in a centralized and easy-to-use way. The procurement companies in the municipality and the region are signing contracts with suppliers and the different public actors within Gothenburg are using these contracts when purchasing food. The share of bought ecological food is however being reported, not saying much about the climate impact though.

Instead an alternative method was used for estimating the emissions from the food consumption. This was done by using numbers from a SIK report (2011) covering emissions from eight typical dishes being served in schools together with three more climate friendly vegetarian dishes. Further it is known that about 19 million meals are being served by the municipality of Gothenburg per year (Göteborgs Stad, 2013). The calculations regarding food emissions only cover the municipality of Gothenburg’s activities (e.g. not including meals served in hospitals).

The typical dishes were used to create a mean dish, see Table 3, which was used to estimate the emissions for the entire public food consumption in the municipality of Gothenburg. This mean dish also had to reflect the fact that a part of the consumed dishes were vegetarian ones. Many schools are serving one vegetarian alternative each day, and schools are also starting to have a vegetarian day once a week (Göteborgs Stad, 2013). However no statistics regarding the share of the vegetarian dishes is being recorded, thus an assumption was made of 1/7 of the served meals being vegetarian ones. Why not 1/5 was used (as the case in many schools) is because this is not done in all the retirement homes and preschools. Retirement homes are serving all day’s dishes, breakfast, lunch, dinner and so on, and yet no vegetarian day is implemented.

Table 3: Emission factors (SIK, 2011) for different type of food served in the public sector used for estimating emissions during 2011 and for the potentials for 2030. The values for the mean dishes are estimated from the SIK data.

Standard meals	**kg CO_2-eq per serving**
Spaghetti and minced meat sauce (beef)	2,35
Falukorv (pork) and pasta	0,8
Hamburger with bread and potato wedges (beef)	3
Kebab stew with rice (pork)	0,95
Chicken stew with rice	0,9
Saithe with mashed potatoes	0,6
Meat and vegetable soup (beef)	1,95
Moussaka (beef)	2,4
Mean standard meal	1,62
Vegetarian meals	
Lentil sause with spaghetti	0,4
Bean stew with rice	0,6
Carrot and lentil soup	0,55
Mean vegetarian meal	0,52
Mean dish used in calculations	1,46

Potentials have been calculated using previously described estimations (Bryngelsson, 2013) with a greenhouse gas emission reduction of; 31 % for using non fossil fuels; 47 % also including technical solutions (see chapter 2.2.3 Food consumption in the future). The effects from increased meat consumption and decreased milk consumption in Bryngelsson's scenarios are neglected, so are also the other differences in included food types between these two studies. Further emission reductions by combining non-fossil fuels and including technical fixes with behavioural changes resulted in the following reductions; 67 % by changing type of meat; 78 % by eating less meat; 88 % by having a completely vegan diet.

The consumption of food was assumed to increase together with the population increase, thus being constant per person. The municipality of Gothenburg have estimated the population to be 610 000 in the year of 2025 with an annual average increase of 6 400 (Göteborgs Stad, 2013). It is assumed for the calculation that the same annual increase occur until 2030, thus reaching 642 000 inhabitants. This can be expressed as a total increase of 23,4 % during 2011-2030 and by assuming the same increase of served food it becomes 23 440 833 meals.

See Appendix 2 for a detailed description of the calculations.

3.4.2 Bottom-up data and estimations for public transportation

Generally the calculations for the potentials in the public transportation systems can be described as; estimating the number of vehicles or travel distance in 2030, estimating the greenhouse gas emissions according to the increase, either by scaling up the emissions if the same technology as today is used, or use emission data for new technologies with emission per travel distance or a non conventional technology's capacity of reducing emissions. The needed data for these estimations have been collected from different sources, thus being presented in different ways, which is the reason for not using exactly the same calculation method throughout the process. Only greenhouse gas emission performance is included, no economical aspects have been taken into account during the estimations. The data in Table 4 is from Västtrafik for the year of 2012 and was used for estimating potentials in lowering the emissions for public transportation in the year of 2030.

Table 4: Reported CO_2 emissions (ton), including each fuel's life cycle, from the different vehicle types used in the public transportation system in Gothenburg. The data is for the year of 2012 and is provided by Västtrafik[7].

	Diesel	Gas	MDE	Ethanol	Gasoline	Electricity	Total	vehicles	Mkm driven
Bus	78397	3012	62				81471	1816	128,1
Ferry	11665						11665	32	
Car	3629	568		12	237		4446	1438	20,0
Tram						9	9	265	16,7
Train	3649					5	3654	94	11,3
Total	97340	3580	62	12	237	14	101245		

The emissions are larger than those reported in VGR's environmental report for the year of 2011. Explanations for this can be the later inclusion of emission data from "Car[7]", 4 446 ton carbon dioxide, which provides "färdtjänst" (a service for those having troubles, like elders, to travel with "usual" public transportation) and also the growth of the market share (from 25,1 % to 26,8 % of the motorized transportation market (Västtrafik, 2012)) and these are the reasons why the data for 2012 was chosen instead of the data from 2011.

The emissions from electricity production are by Västtrafik (in the table above) estimated as small since "green" electricity is being purchased. These numbers will not be used and instead a new estimation using a Nordic electricity mix emitting 100 g CO_2-eq/kWh (Svensk Energi, 2010) will be used. The same emission factor will be used for all calculations, including future potentials, since change in production is not directly connected to Gothenburg. It is mainly connected to Swedish, Nordic and even European actions. The choice of emission factor is very crucial for new, electricity using, technologies so special considerations must be taken when judging the results.

For estimating the potentials different fuels are assumed to entirely phase out the ones used today. VGR's goal to double the transportation during 2006-2025 can be expressed as an annual increase of 3,7 percent. A big share of that increase has already been seen and it is thus assumed an annual increase of 2 percent, which also is in line with the estimations in one of Biogas Väst's studies (Ecoplan, 2012). Thus an annual increase of 2 % assumed to go on between 2012 and 2030 for all the transportation types except for ferries which is assumed to be constant at 32 ferries. Further an energy efficiency increase of 0,9 % per year was used (Grübler, 1998). An expected population increase of 0,6 % per year (VGR, 2013) is assumed for estimating the per person emissions in the year of 2030.

Bus

For busses three potentials assuming 100 % use of biogas, 50 000 Nm^3 gas per bus and year (Ecoplan, 2012) was used. One with emissions of 0,51 kg CO_2-eq/Nm^3 and a "better case" of 16 g CO_2-eq/kWh (about 0,16 kg CO_2-eq/Nm^3), the latter was chosen since the standard most likely will get better than SEA's values for today (better values are already presented in the

[7] Hanna Björk (environmental strategist, Västtrafik) from mail conversation between 12 of March and 8 of April.

previous cited study of Lantz, (2009)). A scenario using biogas from biological household waste, with reduced emissions of 103 % compared to using fossil fuel was also estimated.

An optimistic 75 % emission reduction compared to Västtrafiks conventional diesel busses was assumed in a plug in (HVO) diesel scenario, using Swedish HVO with further emission reduction of 85 % and excluding emissions from electricity production because of lack of data. A scenario for a hybrid bus with a 39 % emission reduction compared to conventional diesel combined with utilizing Swedish HVO for a further 85 % emission reduction was also estimated.

Car

For the cars one potential was estimated by using EU's goal of 95 g CO_2/km tailpipe emissions, this is relatively optimistic since it means that all the cars used by Västtrafik in 2030 will have the standard from the goal for 2020, however 180 g CO_2/km is used for the estimations to include the life cycle of the fuel and car manufacturing and maintenance. Potentials with gasoline hybrid or electric cars with emissions of 99,8 and 69 g CO_2/km respectively was also estimated (estimated from Åkerman's data but assuming 100 g CO_2/kWh instead of Åkerman's assumption of 160 g CO_2/kWh) . Emissions from production and maintenance of the cars were included which differentiates from the rest of the used emission factors (only including LCA data for the fuel) in the transportation potential estimations. This is done because of the following reasons; data was available; there are reasons to believe that emissions from production and maintenance of the car are larger per person km than for other included transportation vehicles; to include the emission differences in production and maintenance of the conventional, hybrid and plug in car.

Train and Tram

For trains it is assumed that all diesel trains are changed into electricity trains until 2030. All trains and trams are facing the energy efficiency increase along with rising travel demand as the other transportation methods. No further alternatives are estimated since the emissions are depending on the electricity production. Västtrafik estimated the electricity and diesel consumption for trains to be 72 674 MWh during 2011[8], the number of diesel trains was constant, 11, and the electricity driven trains increased from 65 to 83, between 2011 and 2012. The electricity consumption for trains in 2012 was then estimated to 76 508 MWh. The company driving the trams have reported electricity consumption of 52 760 MWh for 248 trams during 2011 (Göteborgs Spårvägar, 2012), scaled to 265 trams in 2012 the electricity consumption was estimated to 56 377 MWh.

Ferry

For the ferries it is assumed that either HVO manufactured abroad or from Swedish production is utilized and the emissions are therefore reduced by 50 % and a best case scenario with 85 % reduction compared to the using the conventional fuel.

See Appendix 2 for a detailed description of the calculations.

[8] Hanna Björk (environmental strategist, Västtrafik) from mail conversation.

4 Result

In this chapter the results are presented. Numbers presented here are allocated to Gothenburg according to previous descriptions. First are the top-down results presented, followed by the bottom-up results.

4.1 Consumption related emissions in Gothenburg; top-down.

Below is the result for the consumption related emissions in Gothenburg presented.

Table 5: Presents the CO_2-eq emissions per actor and SNI activity, the share for each SNI activity and emissions per person in Gothenburg. A more extensive version is presented in Appendix 1.

From running costs	**Municipality of Gothenburg (kton)**	**VGR (kton)**	**The state (kton)**	**Total (kton)**	**Activity emission share (%)**	**Per citizen in Gothenburg (ton/person)**
75 Authorities	23,5	50,9	198	272	31	0,52
80 The educational system	92,4	0,48	23,6	116	13	0,22
85 Healthcare and care	87,3	89,0	13,1	189	22	0,36
92 Recreation, culture and sports	29,9	6,49	12,5	48,9	6	0,09
45 Construction	52,4		63,7	116	13	0,22
60 Land Transport		28,2		28,2	3	0,05
01 Agriculture			95,0	95,0	11	0,18
Total from running costs	286	175	406	866	100	1,67
From investments done by the municipality of Gothenburg and VGR	**Municipality of Gothenburg (kton)**	**VGR (kton)**		**Total (kton)**	**Activity emission share (%)**	**Per citizen in Gothenburg ton/person)**
45 Construction	46,3	14,0		60,3	91	0,12
33 Medical and optical instruments		4,24		4,24	6	0,01
35 Manufacture of other transport equipment		1,77		1,77	3	0,003
Total from investments	46,3	20,0		66,4	100	0,13
Total from running costs and investments	332	195	406	933		1,8
Actor share (%)	36	21	43	100		

Greenhouse gas emissions from public consumption in Gothenburg was estimated to about 1,8 ton CO_2-eq per person and year. The state is responsible for the largest share, 43 %, of the total emissions, next is the municipality of Gothenburg with 36 %, whereas VGR has about 21 % of the emissions[9]. This is further shown in emissions per person in Figure 1. Even though the state's expenditures are close to those of VGR the state's expenditures to a larger extent occur in emission intensive activities.

[9] The, to Gothenburg allocated, expenditures (in billion SEK) for the actors are; the state 22,1; the municipality of Gothenburg 30,2; VGR 18,5.

The “authorities” activity is the largest emitter, and it is also one of the broadest ones in this thesis including activities such as the military, police, judiciary, political activities, labour market measures and environmental protection.

The educational system and healthcare and care stands for significant amounts of emissions in terms of consumption since they are two large services provided to the citizens. However worth noticing is the large share for agriculture, which mainly stands for agriculture subsidies and livestock subsidies. This is mainly financed by funds which the state receives from the EU.

The construction activity in running costs emissions is also a large post and it is mainly due to the maintenance and construction of roads and tracks. If the municipality of Gothenburg’s emissions from construction running costs and investments are added together they become the largest post from the actor, reaching 99 kton.

Land transport is Västtrafik’s emissions (according to the described allocation). If the entire responsibility for the emissions is allocated to Västtrafik (instead of 50 %) the amount would be the double, 56 kton, which is close to 0,11 ton per person and is thus about the double amount compared to the one VGR reported during 2011 (0,055 ton CO_2 per person) of which the latter only is including emissions from fuels.

For the investments done by the municipality of Gothenburg (1,54 billion SEK) and VGR (0,75 billion SEK) the dominating activity in terms of emissions is construction standing for 91 % of the total investment emissions. Emissions from the municipality of Gothenburg's investments stand for 14 % of their total emissions whereas it for VGR stands for 10 %. The both actor’s investments stands for 7 % of the total emissions.

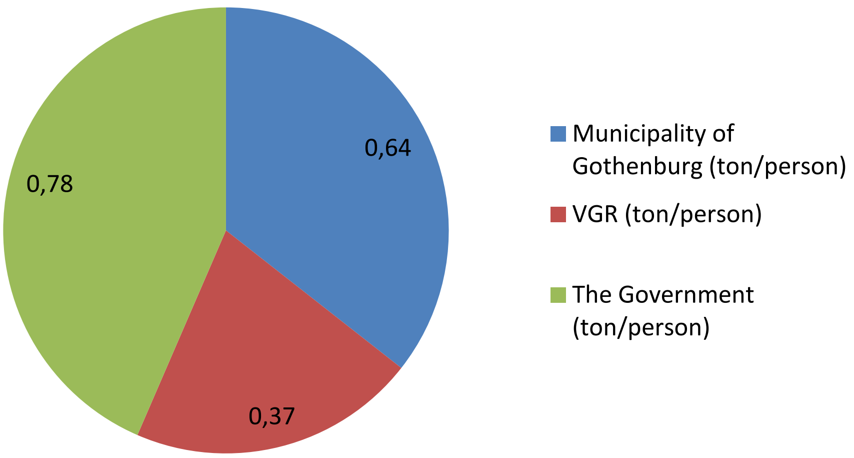

Figure 1: Shows emissions from running and investment costs divided by each actor.

The emissions from the municipality of Gothenburg if Naturvårdsverket’s definition (only including emissions from tax financed activities) is being used was estimated to a total of 208 kton or 0,4 ton per person, this is 37 % lower than the emissions when the definition in this thesis is used (total 332 kton including emissions from investments) or 27 % lower by excluding emissions from investments. This only includes activities paid with municipal tax and not possible subsidies from the state to the municipality of Gothenburg (see Appendix 1 for further details).

4.2 Consumption related emissions in Gothenburg; bottom-up and potentials.

Here are the results for the bottom-up data and potentials for public food consumption and public transportation presented.

4.2.1 Public food consumption and potentials

Here are the estimated food consumption emissions and future potentials for meals served by the municipality of Gothenburg presented.

Table 6: Estimated CO2-eq emissions from public food consumption and potentials for the year of 2030.

Scenarios	2030 (ton/person)
Business as usual (same per person as in 2011)	0,053
Non fossil fuels	0,037
Non fossil fuels & technical fixes	0,028
Non fossil fuels, technical fixes & changed meat	0,018
Non fossil fuels, technical fixes & eating less meat	0,012
Non fossil fuels, technical fixes & vegan	0,006

By implementing only renewable energy with or without technical solutions the emissions in 2030 are being lower than the emissions in business as usual (or in 2011). The emissions can be further reduced by changing type and amount of meat. Depending on chosen scenario the reductions reaches between 31 % and 88 % per person.

If the food consumption emissions in 2011 (with a total of 27,8 kton CO_2-eq) are expressed as a share of total emissions in the top-down estimation for the municipality of Gothenburg they stand for about 8 % (or 10 % if emissions from investments are excluded).

4.2.2 Public transportation and potentials

Presented below are Västtrafik's own presented data for 2012 together with new estimations for electricity consumption. Emissions for future potentials are presented together with a business as usual scenario. The distribution between transportation types are assumed to be the same when scaled up in the future potentials except for ferries which are assumed to be constant in absolute terms. It should be stressed, again, that the electricity emissions per kWh are assumed to be the same in 2012 and 2030.

Table 7: Estimated greenhouse gas emissions in kton for the public transportation system in 2012. The future potentials are presented and the lowest emitting technology for each vehicle type is underlined. Notice that emissions have not been allocated to Gothenburg and the 50 % to public and 50 % to private consumption in the table and is thus valid for the entire Västra Götlandsregionen.

	2012	2030					
Bus		**Business as usual**	**Biogas**	**Biogas better case**	**Biogas household waste**	**HVO hybrid**	**HVO plug in hybrid**
	81,47	99,03	56,29	17,66	<u>-2,97</u>	9,82	4,03
Ferry		**Business as usual**	**HVO**	**HVO Swedish production**			
	11,67	9,93	4,96	<u>1,49</u>			
Car		**Business as usual**	**EU's goal 2020**	**Plug in hybrid**	**Electric**		
	4,45	5,40	4,70	2,60	<u>1,75</u>		
Tram		**Business as usual**	**Electricity**				
	5,64	6,85	<u>6,85</u>				
Train		**Business as usual**	**Electricity**				
	11,30	13,74	<u>10,53</u>				
		Business as usual	**Best case**				
total	114,52	134,95	<u>17,65</u>				
Total (ton/person)	0,072	0,076	<u>0,010</u>				

If the per person emissions for public transportation in the year of 2012 are expressed as a share of the total estimated top-down emissions from VGR they stand for about 19 %[10].

The best case reduces the total public transportation emissions and the per person emissions with 87 % compared to the business as usual scenario or with 85 % compared to today. The business as usual scenario has higher per person emissions than 2012 since the public transportation share is assumed to increase faster than the expected population increase, thus most likely decreasing the share of car transportation and by that decreasing the total emission from transportation. The negative emissions for biogas from household waste as a fuel for busses are only due to if the indirect effects are still true (see chapter 2.3.2 Public transportation data for future).

By using another emission factor for electricity in this thesis compared to the one Västtrafik is using in their reported values the emissions in 2012 became 13 % higher than those reported by Västtrafik.

[10] If the emissions are allocated with 50 % to public consumption and 50 % to private consumption they end up at 0,036 ton CO_2-eq per person and thus 8,5 % of the VGR top-down emissions.

5 Discussion

This chapter contains a discussion regarding the results, possibilities and recommendations for future investigations and recommendations for actions.

5.1 Top-down results and methodology

The total result from public consumption of about 1,8 ton CO_2-eq/citizen in Gothenburg is in line with that of Naturvårdsverket, however since the definitions of the public consumption differs it is hard to compare those two values.

Since Naturvårdsverket's definition only includes activities financed by taxes the definition in this thesis should lead to include more expenditures, this since the entire running costs for public activities, together with parts paid by consumers (e.g. patient fee), also are included. This was seen in the difference between the estimation from this thesis' definition and the estimation by using Naturvårdsverket's definition for the municipality of Gothenburg where the latter resulted in 37 % lower emissions. If this is true it is quite interesting that emissions are lower according to the definition in this thesis compared to the two tons CO_2-eq/citizen reported by Naturvårdsverket, but by only looking at municipal tax financed activities within the municipality of Gothenburg the state subsidies are not included and this might be a reason for the 37 % lower emissions. Other reason might be the possibilities for a relatively large city to be more effective than small municipalities, or lower emissions per expenditure today compared to 2003, these two reasons are just guesses.

The strengths of using greenhouse gas emission intensities from input-output analysis are that the method is easy to use and can be seen as rather robust since the intensities are calculated from actual data within the country. By using economical expenditures to estimate emissions the public consumption trends gets a new dimension, that of linking together the consumption with greenhouse gas emissions. It thus gets rather understandable that by increasing expenditures the emissions will also increase from the relevant activity. It also gets relatively clear which activities can be seen as large emitters as a whole and per spent money. Further the input-output data is from actual activity and doesn't leave much out, whereas life cycle assessments can build upon assumptions not matching the reality. In a LCA the transportation of a good might be assumed from point A to B whereas in reality there might be congestion, an accident, another road was driven etc. while this in input-output analysis will be covered since all consumption is included. The method can be seen as relatively fast and easy to use while having easily accessible economical data.

Negative aspects by using the input-output method are also important to have in mind. The data is a mean of the national production and emissions, local differences in the way activities are conducted, e.g. using a less emission intensive method, will not be reflected in the result more than to what extent it actually alters the total national data. The method will not show the reality for the investigated region if it radically differs from the national mean. The uncertainty declines with increased covered activity, which means that using this method on a smaller scale, say a specific company's production is rather risky. There are however no indications for Gothenburg to be radically different than other parts in Sweden.

Representing the diversity of products, services or sectors by a relatively few ones is one of the reasons why the mean might differ from a specific studied activity. Further the complexity of taking into account emissions from imported goods is a problem which should not be neglected. Countries are not using the same methodology when reporting emissions or might use other production methods somewhere in the production chain and while assuming the production to be the same as in Sweden the result might not be reflecting the reality. But since public consumption to a large extent consists of services the problem is more limited compared to private consumption, which is more goods oriented. Another aspect to take into consideration is the emission intensities, which are from data for the year of 2008. That is three years earlier than the economical data used in this study and the trend is declining emission intensities during the reported years, thus possibly overestimating the emissions. Since running costs and investment costs were used instead of base prices (the value of the product/service) the estimations might be slightly overestimated, but since only the costs within the public sector are covered without any further income generating gain, the costs most likely ends up close to the base price. Public purchases from private business will however be higher than the base price since private business will sell goods/services generating gain, however the public sector usually negotiates lower prices compared to private consumers (thus resulting in a reduced overestimation).

One weakness that is of great importance is the lacking ability to use this method as a benchmarking tool from year to year (not true for the total consumption in Sweden), if major changes resulting in lower or higher emissions have been implemented, since only economical expenditures are considered. As previously pointed out a true change will only be visible in the result if the costs and the emissions follows the same pattern while implementing changes. One example is that of food; environmental benefits of changing into more vegetarian food will in this method only be visible if it also is cheaper (but that is not always true since ecological food tend to be more expensive). However the coincidence that the change in spent money is equal to changed emissions is rather low in a case like this, whereas increasing fuel efficiency will reduce the costs to more or less the same extent as the efficiency increase.

Since the goal according to the Gothenburg is to reach below a total of 1,9 tons CO_2-eq per person it is thus of high relevance to also start to decrease emissions from public consumption to a larger extent than what is done today. The estimated 1,8 ton CO_2-eq per person must be decreased substantially, about 80 %, depending on how ambitious the decrease of greenhouse gas emissions from private consumption will be.

5.2 Bottom-up results and methodology

As previously mentioned the optimal way of estimating the emissions from public food consumption would be by using exact amount of kilos of consumed food. But since the considered meals (being the base of this study) can be seen as typical meals served in school kitchens it is still considered that the results are in the right order of magnitude, thus visualizing patterns in today's food consumption regarding emissions. It would be good to gain better knowledge about food consumption within Gothenburg, crucial is the amount of food being consumed and it is relevant to start with emission intensive food like meat, rice and vegetables grown in fossil powered greenhouses. Further it could be interesting to see how large share of the served meals actually are vegetarian ones, thus getting to know the trends of the inhabitants and easier monitoring the changes in trends.

The potentials to lower the emission from food consumption are quite large. It is rather well known that reducing meat consumption reduces the emissions. However since the potentials are estimated with numbers from Bryngelsson’s study (2013) assuming higher meat consumption in the future than it is today, the potentials for changing the type of meat and reducing the meat consumption can be seen as rather overestimating the changes in emissions. There are reasons to assume that consumption of meat will not increase dramatically in the public kitchens because of awareness and also for economical reasons. There are also reasons to believe that the efficiency increase possibilities for meat and vegetarian food are different. Also the included food in these two studies differs in more aspects than meat and milk which further increases the uncertainty of utilizing the potentials in this thesis. These are just small uncertainties compared to what would happen if land use changes also were included while estimating emissions from food consumption, which most likely would point out meat as even worse. The latter uncertainty could be lowered by only consuming locally produced meat.

The fact that it from this thesis seems like the food consumption can be responsible for about 8,4 % of the estimated (top-down) total emissions from the municipality of Gothenburg's public emissions stresses the fact that this is an important area to consider.

When it comes to the public transportation system in Gothenburg the result is rather depending on the assumed increase in consumption of public transportation. If the change in reality will be different it will change the result of the emissions rather similar to the change in traffic. One can for instance question to what extent an increased consumption of biogas buses utilizing household waste decreases the total emissions and to what extent. In reality we might run out of waste before the negative emissions from consumption of the gas is getting enormous proportions. The negative emissions might turn positive in the future if the indirect effects cannot be accounted for in the same way because of structural changes, like not utilizing the nutrition value of the byproducts when manufacturing the biogas for some reason.

The potentials calculated in this thesis for decreasing the emissions are kind of extreme in the sense that they assume that one type of vehicle only uses one type of fuel; there are reasons to think about a division between fuel types, as can be seen in today’s different technologies being used or tested. Further the emission factors can be seen as relatively uncertain since the technologies are rather new compared to the conventional fossil fuels. There are reasons to think that unforeseen changes might occur while scaling up the technologies, some technologies might even turn up as bad ones in the big scale. Further it is very important for the future technologies to be independent on fossil fuels during the production chain if the emissions should be lowered, which is not the case today when manufacturing vehicles or renewable fuels. Therefore the results should not be seen as carved in stone but more as something hinting at new interesting technologies which should be tried. The best case scenario might turn out different in reality. Interesting is however the indications the potentials shows by rather massive reductions in emissions of which an 87 % reduction compared to business as usual shines positive light upon the matter.

It should also be stressed that emissions from construction and maintenance of the vehicles are only included for the cars, by including this for the other vehicles the result would have been slightly higher. The result would also be slightly higher if the ferries were not treated as land transportation in the calculations.

5.3 Actions to lower the emissions

The easiest way of reducing emissions from consumption is, surprisingly not, to consume less. It should however be stressed here that this can be seen as more relevant for private consumption since large parts of that type of consumption can be classified as luxury. Regarding public consumption the included activities, often services, can be seen, as used for satisfying basic human needs to a higher extent. We need hospitals, education, police, public transportation, and so on. To consume less by reducing the amount of healthcare provided is not a step towards sustainable development. Surely, measures towards making the citizens healthier, thus reducing the amount of healthcare needed, are an attractive alternative.

It is theoretically easy to see what can be done to lower the emissions from the four private consumption categories of eating, housing, traveling and shopping and some of them are true for public consumption as well; drive less with your fossil fuel consuming car and take the bus or bicycle instead; use excess heat from industry instead of burning oil or using CO_2 emitting electricity for heating houses etc.; use less electrical equipment and use energy efficient alternatives; exchange (some) meat with protein rich vegetarian alternatives; exchange the holiday or conference from one needing transport with airplane to one that doesn't. However it is obviously hard to implement changes reducing emissions from these activities without interfering with people's habits and expectations, and the suggestions above are just a tiny fraction of all the alternatives that does exist.

For public consumption the behavioral changes can be seen as highly relevant. Eating less meat and dairy products and reducing food waste can be seen as behavioral changes which can be implemented at public kitchens. By showing early the possibilities of cooking great tasting food which also is more sustainable, like vegetarian alternatives, in children's lives, it might be possible to change patterns in the citizens' food consumption in the long term.

The public transportation system is a crucial part in creating a sustainable, but also smoother and more effective, transportation as it looks now. It is of great importance to use the possibilities of public support for developing and testing new technologies, like the new plug in hybrid buses. It seems like the conditions are good in the municipality of Gothenburg to do significant changes. As stated in the literature review the positive effects of public transportation are many. Decreasing the use of the ineffective car transportation is one and another one is the decrease of road wear which lower the costs for the activity of construction, a rather high emitting activity. It is central that implemented changes are motivated clearly to the citizens so that failures, similar to the negative opinion towards the congestion tax can be avoided.

By showing that it is possible to base the public transportation on other fuels than fossil, Gothenburg can be a good example inspiring others. Being associated with the trademark of an innovative and yet environmental friendly city has many benefits, especially in times were it is seemed as something desired to be innovative and to be at the forefront.

The estimated potentials together with general technical fixes of higher energy efficiency, CO_2-neutral production of electricity and the usage of CO_2-neutral fuels, will all, if implemented correctly, lower the emissions for all public consumption. These actions needs research, further development, acceptance and final investment decisions in order to be implemented.

The possibilities that come with this need of change are large and should for no reason be forgotten. Industries have changed, improved and new have shown up throughout the history Being innovative and leading the development is crucial and can be profitable whereas being counteracting or reserved might lead to missing the window of opportunity. There are a lot of people who trusts the technology to solve all our issues and many new technologies are already developed or under development but yet not implemented in a larger scale. The reasons are many but the cost is a large factor, but the cost is always largest in the beginning until know-how, scaling up and commercializing plays it parts to lower the costs. One obstacle is the cheap fossil fuels holding back new technologies which today are more expensive and less proven (comparing the price of such an old technology with new ones being tested on small scales is irrational from a societal perspective).

Another aspect of this is the energy security. By producing energy and fuels locally an independence of other areas or countries can be established. Whereas we now are depending on fossil fuel extractors, the availability and changes in price are uncertain and very hard for Sweden or Gothenburg to influence. By increasing the local production the energy security raises, not to mention all the work opportunities by doing this. It also becomes easier to monitor if production processes are environmental and ethical just.

6 Conclusions

Here are the research questions briefly answered, in addition recommendations regarding future research are given.

6.1 Answers to the research questions

The purpose of this thesis is to explore and estimate greenhouse gas emissions from the public consumption in Gothenburg by answering the four research questions. Each of them will here be answered shortly.

1. How large are the emissions from public consumption within Gothenburg?

The emissions were estimated to 1,8 ton CO_2-eq per person and year and the emissions have been linked to the specific consumption activities and actors (shown in Table 5).

2. What amount of emissions are the consumption of food and public transportation in the public sector responsible for?

The food consumption in the municipality of Gothenburg was through bottom-up methodology estimated to 0,053 ton CO_2-eq per person and year which stands for about 8,4 % of the total estimated top-down emissions from the municipality of Gothenburg.

The public transportation emissions was through bottom-up methodology estimated to 0,072 ton CO_2-eq per person and year which stands for about 19 % of the total estimated top-down emissions from VGR, however according to the allocation in this thesis with 50 % to public and 50 % to private consumption the emissions will thus be the half (0,036 ton CO_2-eq per person). According to the top-down estimation the allocated emission amount was 0,05 ton CO_2-eq per person, thus higher than those 0,036 ton CO_2-eq per person from the bottom-up estimation.

3. Are there other important public activities generating emissions?

To reduce the total emissions to less than two tons per person and year all sectors must be involved in lowering emissions. It has in this thesis been shown that the SNI activities Authorities, The educational system, Construction, Healthcare and care are the four major ones. For a more details see Appendix 1.

4. What are the potentials to reduce climate impact from public food and public transportation consumption until 2030?

Potential greenhouse gas reductions between 31 % and 87 % per person from public food consumption were estimated. These were estimated by changing type of food and increasing energy efficiency in the food production. Reducing meat consumption and increasing consumption of vegetarian alternatives is a way to reach high emission reductions.

By changing technologies and fuels the potential for reducing public transportation greenhouse gas emissions was estimated up to an 87 % reduction per person compared to the business as usual scenario (which reached 0,076 ton CO_2-eq per person and year in 2030).

6.2 Future work recommendations

Here are some recommendations for future investigations and actions regarding greenhouse gas emissions from public consumption given.

- Try to cover emissions from all public consumption (e.g. cement) by using a bottom-up perspective.
- Start keeping records of relevant purchases, like meat, rice and other emission generating goods. Good would be to keep record of all purchased public food.
- Start to report emissions from a consumption perspective, as a complement to the production perspective, in the environmental reports. This is important to look at if the emissions are supposed to be fair according the goal of Gothenburg.
- Investigate about practical possibilities to invest in new technologies for the public transportation system.

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Appendix 1

Inventory calculations and data for top-down analysis

Here are the economical and emission data for each SNI activity presented in a more detailed version compared to Table 5 and Figure 1: Shows emissions from running and investment costs divided by each Figure 1. Economical data for the municipality of Gothenburg comes from (Göteborgs Stad, 2012), (SCB, 2012). Economical data for VGR comes from (VGR, 2012b). Economical data for the state comes from (Sveriges regering, 2012).

Calculating the emission was conducted as follows; Expenditures for a SNI activity was summed and multiplied with associated emission intensity.

Example of calculating "The municipality of Gothenburg's" emissions in the SNI activity Authorities:

$$1676{,}557\ mkr \cdot 14\,\frac{ton\ CO_2eq}{mkr} = 23471{,}8\ ton\ CO_2eq$$

The calculations are then repeated for VGR and state (emissions from VGR and the state were scaled to Gothenburg by dividing with the population in VGR and Sweden respectively then multiplied with the population in Gothenburg). The emissions are then divided upon all the citizens in Gothenburg.

The following changes have been done with the governmental expenditure to avoid double calculation and exclude subsidies to private persons. The titles of the expenditures are the same as in the state's financial report.

- UO7 Internationellt bistånd is excluded.
- U09 Hälsovård, sjukvård och social omsorg 1:5 Aid for läkemedelsförmånerna is excluded since they are included in VGR's data
- UO10 Ekonomisk trygghet vid sjukdom och handikapp edited witch exclusion of 1:2 Aktivitets och sjukersättningar.
- UO 11 Ekonomisk trygghet vid ålderdom is excluded.
- UO12 Ekonomisk trygghet för familjer och barn is excluded.
- UO14 Arbetsmarknad och arbetsliv 1:2 Bidrag till arbetslöshetsersättning och aktivitetsstöd is excluded.
- UO 15 Studiestöd is excluded.
- UO23 Areella näringar, landsbygd och livsmedel is divided upon SNI activities Authorities and Agriculture.
- UO 25 Allmänna bidrag till kommuner is excluded to avoid double calculation.
- UO 26 Statsskuldsräntor m.m. is excluded.

The SNI activity Banks was included in the activity for Authorities, this since Banks was relatively small. The SNI activity Property management was included in the activity for Authorities, this was done for practical reasons since it is rather small and it has almost the same emission intensity as Authorities (13 compared to 14 ton/MSEK).

An English (Table 8) and a Swedish (Table 9) extended version of Table 5 is presented since some translations from the Swedish posts into English ones are vague, names are not translated and some activities without a proper English counterpart is not translated.

Table 8 presents the economical expenditures for each SNI activity, all data is in MSEK if nothing else is stated. Emissions are presented at the bottom cells of each activity.

75 Authorities					
The municipality of Gothenburg		**VGR**		**The state**	
Committee and board activities	59,227	**Natural resources board**	317,2	**UO1 governance**	11188
Support for political parties	20,569	**The regional development committee**	550,3	**UO2 national economy & financial management**	12894
Revision	32,253	**The environmental committee**	56,5	**UO3 Tax, custom and enforcement organization**	9910
Other political activities	81,432	**The cultural committee**	739,8	**UO4 Judiciary**	37 164
refugee reception	156,57	**Västsvenska Turistrådet AB**	64,8	**UO5 International cooperation**	1892
Labour market measures	340,139	**Region service**	4045,5	**UO6 Defense and contingency measures**	44 153
Enterprise and Industry promotion activities	10	**Regionfullmäktige**	65,2	**UO8 Migration**	7572
Consumer and energy advice	21,692	**Regionstyrelsen**	3236,2	**UO10 Financial security for the ill and disabled**	37569
Environmental and health protection exercise	50,574	**Archive board**	25,9	**UO 13Integration and Equality**	4968
Environmental health and sustainable development	95,154	**Public health committee**	35,9	**UOUO14 Labor and employment**	32 283
Alcohol permit etc.	12,787	**Committee for rights issues**	26,1	**UO18 Planning, housing, construction and consumer policy**	1 110
tourism activity	92,9	**College of auditors**	19,9	**UO19 Regional growth**	3 222
Emergency services	351,616	**Patient boards**	15,4	**UO20 General environment and nature conservation**	5 069
Military and civil protection	11,505	**Kommunalförbundet Stretered**	0,4	**UO21 Energy**	2 918
Labour market measures	340,139	**ALMI Företagspartner Väst AB**	18,3	**UO23 Agricultural sciences, rural & food (part rest)**	9 580
		Group bank	103	**UO24 Enterprise**	5 368
		Västfastigheter	1789,9	**UO27 fee for the European union**	30 596
Total expenditure	1676,557		11110,3		257456
Total emissions (ton)	23471,8		155544,2		3604384
Gothenburg's share of emissions (ton)	23471,8		50887,06		197791,5
Per citizen in Gothenburg (ton/person)	0,045106		0,097789		0,380095
Total Authorities emissions per citizen in Gothenburg (ton/person)	0,477819				
80 The educational system					
The municipality of Gothenburg		**VGR**		**The state**	
Open preschool	15,856	**Göteborgs folk high school**	38,6	**UO16 Education and academic research**	53 685
Preschool	3314,755	**Grebbestads folk high school**	22,7		
Pedagogical care	58,605	**Billströmska folk high school**	28,6		
Oppen fritidsverksamhet	27,849	**Vara folk high school**	26,5		
Fritidshem	628,681	**Fristads folk high school**	31,8		
Pre-school (pre-primary)	236,097	**Dalslands folk high school**	24,4		

Primary School	4396,076	**Agnesbergs folk high school**	10,2		
Primary special school	254,667				
Upper secondary school	1828,179				
Upper secondary special school	141,017				
Basic adult education	59,112				
Adult upper secondary- and further education	222,868				
Särvux	13,929				
Swedish for Immigrants	210,376				
Commissioned education	140,02				
Total expenditure	11548,09		182,8		53 685
Total emissions (ton)	92384,7		1462,4		429480
Gothenburg's share of emissions (ton)	92384,7		478,4314		23567,82
Per citizen in Gothenburg (ton/person)	0,177535		0,000919		0,04529
Total The educational system emissions per citizen in Gothenburg (ton/person)	0,223745				
85 Healthcare and care					
The municipality of Gothenburg		**VGR**		**The state**	
Healthcare and care for elders	5667,099			**UO9 Health, care and social care**	33 981
Support to people with disabilities (no LSS/SFB)	1003,493	**Representatives**			
Support LSS/SFB	2867,403	**HSN 1 Norra Bohuslän**	354,5		
Färdtjänst/riksfärdtjänst	326,083	**HSN 2 Dalsland**	159,4		
Care for adults with addiction	688,288	**HSN 3 Trestad**	467,4		
Child and youth care	1339,27	**HSN 4 Mellersta Bohuslän**	461,5		
Other support to adults	394,258	**HSN 5 Göteborg, centrum-väster**	911,4		
Family law and family counseling	27,283	**HSN 6 Mittenälvsborg**	212		
Refugee reception	156,57	**HSN 7 Södra Bohuslän**	442,1		
		HSN 8 Sjuhärad	506,9		
		HSN 9 Västra Skaraborg	341,7		
		HSN 10 Östra Skaraborg	334,5		
		HSN 11 Göteborg, Hisingen	505,2		
		HSN 12 Nord-östra Göteborg	505,9		
		Sahlgrenska Universitetssjukhuset	12674,3		
		NU-sjukvården	4124,9		
		Södra Älvsborgs Hospital	3201,1		
		Skaraborgs Hospital	3500,7		
		Kungälvs Hospital	986,2		
		Alingsås Hospital	510,2		
		Frölunda Specialistsjukhus	202,1		
		Angereds Närsjukhus	136		
		Primärvården Skaraborg	1039,3		
		Primärvården södra Älvsborg	1155,1		

		Primärvården Göteborg	1660,7		
		Primärvården södra Bohuslän	705,5		
		Primärvården FyrBoDal	957,9		
		Folktandvården i VGR	1970,8		
		Habilitering & Hälsa	748		
		Sahlgrenska International Care AB	30,8		
		Hälsan & Arbetslivet	71,9		
Total expenditure	12469,75		38878		33 981
Total emissions (ton)	87288,23		272146		237867
Gothenburg's share of emissions (ton)	87288,23		89033,92		13053,01
Per citizen in Gothenburg (ton/person)	0,167741		0,171096		0,025084
Total Healthcare and care emissions per citizen in Gothenburg (ton/person)	0,363921				
92 Recreation, culture and sports					
The municipality of Gothenburg		**VGR**		**The state**	
General cultural activities, other	329,55	**Kultur i Väst**	91,7	**UO17 Culture, media, religious and recreational**	11 952
Library	223,658	**Västarvet**	190,2		
Music School / arts school	90,653	**Göteborgs botaniska trädgård**	38,6		
Public recreation activities	192,887	**GöteborgsOperan AB**	413,1		
Sports and leisure facilities	320,864	**Göteborgs Symfoniker AB**	177,1		
Parks	302,712	**Film i Väst AB**	99,9		
Fritidsgårdar	114,22	**Regionteater Väst AB**	33,7		
Total expenditure	1574,544		1044,3		11 952
Total emissions (ton)	29916,34		19841,7		227088
Gothenburg's share of emissions (ton)	29916,34		6491,311		12461,51
Per citizen in Gothenburg (ton/person)	0,05749		0,012474		0,023947
Total recreation, culture and sports emissions per citizen in Gothenburg (ton/person)	0,093912				
45 Construction					
The municipality of Gothenburg				**The state**	
Physical and technical planning, residence improvement	238,779			**UO22 communications (transport)**	38710
Streets, roads and parking	1508,988				
Total expenditure	1747,767				38710
Total emissions (ton)	52433,01				1161300
Gothenburg's share of emissions (ton)	52433,01				63726,62
Per citizen in Gothenburg (ton/person)	0,10076				0,122463
Total construction emissions per citizen in Gothenburg (ton/person)	0,223223				

60 Land transport					
		VGR			
		Västtrafik (obs total kostnad för hela västtrafik!)	6158		
Total expenditure			3079		
Total emissions (ton)			86212		
Gothenburg's share of emissions (ton)			28204,68		
		Per citizen in Gothenburg (ton/person)	0,054201		
Total land transport emissions per citizen in Gothenburg (ton/person)	0,054201				
01 Agriculture					
				The state	
				UO23 Agricultural sciences, rural & food (part agriculture)	6792
Total expenditure					6792
Total emissions (ton)					1731960
Gothenburg's share of emissions (ton)					95041,73
Per citizen in Gothenburg (ton/person)					0,182641
Total agriculture emissions per citizen in Gothenburg (ton/person)	0,182641				
Investments					
45 Construction					
The municipality of Gothenburg		**VGR**			
Room committe	949	**property investment**	1428		
Board of Gothenburg water	182				
Traffic committee	239				
Parks and Landscape Committee	73				
Property Management Committee	59				
Sports and Associations Committee	42				
Total expenditure	1544		1428		
Total emissions (ton)	46320		42840		
Gothenburg's share of emissions (ton)	46320		14015,32		
Per citizen in Gothenburg (ton/person)	0,089013		0,026933		
Total investment construction emissions per citizen in Gothenburg (ton/person)	0,115946				
33 Medical and optical instruments					
		VGR			
Equipment investment			864		
Total expenditure			864		
Total emissions (ton)			12960		
Gothenburg's emissions (ton)			4239,928		

		Per citizen in Gothenburg (ton/person)	0,008148		
Total investment medical and optical instruments emissions per citizen in Gothenburg (ton/person)	0,008148				
35 Manufacture of other transport equipment					
		VGR			
		Trains etc	258		
		Total expenditure	258		
		Total emissions (ton)	5418		
		Gothenburg's share emissions	1772,526		
		Per citizen in Gothenburg (ton/person)	0,003406		
Total investment manufacture and other transport equipment per citizen in Gothenburg (ton/person)	0,003406				

Table 9: Presents the economical expenditures for each SNI activity, all data is in MSEK if nothing else is stated. Emissions for each activity is always presented. (Same as Table 8 but with Swedish titles)

75 Myndigheter					
The municipality of Gothenburg		**VGR**		**The state**	
Nämnd- och styrelseverksamhet	59,227	**Naturbruksstyrelsen**	317,2	**UO1 Rikets styrelse**	11188
Stöd till politiska partier	20,569	**Regionutvecklingsnämnden**	550,3	**UO2 Samhällsekonomi och finansförvaltning**	12894
Revision	32,253	**Miljönämnden**	56,5	**UO3 Skatt, tull och exekution**	9910
Övrig politisk verksamhet	81,432	**Kulturnämnden**	739,8	**UO4 Rättsväsendet**	37 164
Flyktingmottagande	156,57	**Västsvenska Turistrådet AB**	64,8	**UO5 Internationell samverkan**	1892
Arbetsmarknadsåtgärder	340,139	**Regionservice**	4045,5	**UO6 Försvar och samhällets krisberedskap**	44153
Näringslivsfrämjande åtgärder	10	**Regionfullmäktige**	65,2	**UO8 Migration**	7572
Konsument- och energirådgivning	21,692	**Regionstyrelsen**	3236,2	**UO10 Ekonomisk trygghet vid sjukdom och handikapp**	37569
Miljö- och hälsoskydd, myndighetsutövning	50,574	**Arkivnämnd**	25,9	**UO 13 Integration och jämställdhet**	4968
Miljö- hälsa och hållbar utveckling	95,154	**Folkhälsokommittén**	35,9	**UOUO14 Arbetsmarknad och arbetsliv**	32 283
Alkoholtillstånd m.m.	12,787	**Kommittén för rättighetsfrågor**	26,1	**UO18 Samhällsplanering, bostadsförsörjning, byggande samt konsumentpolitik**	1 110
Turistverksamhet	92,9	**Revisorskollegiet**	19,9	**UO19 Regional tillväxt**	3 222
Räddningstjänst	351,616	**Patientnämnder**	15,4	**UO20 Allmän miljö- och naturvård**	5 069
Totalförsvar och samhällsskydd	11,505	**Kommunalförbundet Stretered**	0,4	**UO21 Energi**	2 918
Arbetsmarknadsåtgärder	340,139	**ALMI Företagspartner Väst AB**	18,3	**UO23 Areella näringar, landsbygd och livsmedel**	9 580
		Koncernbank	103	**UO24 Näringsliv**	5 368
		Västfastigheter	1789,9	**UO27 Avgiften till Europeiska unionen**	30 596
Total expenditure	1676,557		11110,3		257456
Total emissions (ton)	23471,8		155544,2		3176040
Gothenburg's share of emissions (ton)	23471,8		50887,06		174286
Per citizen in Gothenburg (ton/person)	0,045106		0,097789		0,334924

Total per citizen in Gothenburg (ton/person)	0,477819				
80 Utbildningsväsendet					
The municipality of Gothenburg		**VGR**		**The state**	
Öppen förskola	15,856	**Göteborgs folkhögskola**	38,6	**UO16 Utbildning och universitetsforskning**	53 685
Förskola	3314,755	**Grebbestads folkhögskola**	22,7		
Pedagogisk omsorg	58,605	**Billströmska folkhögskola**	28,6		
Öppen fritidsverksamhet	27,849	**Vara folkhögskola**	26,5		
Fritidshem	628,681	**Fristads folkhögskola**	31,8		
Förskoleklass (inför grundskola)	236,097	**Dalslands folkhögskola**	24,4		
Grundskola	4396,076	**Agnesbergs folkhögskola**	10,2		
Grundsärskola	254,667				
Gymnasieskola	1828,179				
Gymnasiesärskola	141,017				
Grundläggande vuxenutbildning	59,112				
Gymnasial vuxen- och påbyggnadsutbildning	222,868				
Särvux	13,929				
Svenska för invandrare	210,376				
Uppdragsutbildning	140,02				
Total expenditure	11548,09		182,8		53 685
Total emissions (ton)	92384,7		1462,4		429480
Gothenburg's share emissions (ton)	92384,7		478,4314		23567,82
Per citizen in Gothenburg (ton/person)	0,177535		0,000919		0,04529
Total per citizen in Gothenburg (ton/person)	0,223745				
85 Sjukvård och omsorg					
The municipality of Gothenburg		**VGR**		**The state**	
Vård och omsorg om äldre	5667,099	**85 Sjukvård och omsorg**		**UO9 Hälsovård, sjukvård och social omsorg care**	33 981
Insatser till personer med funktionsnedsättning (ej LSS/SFB)	1003,493	**Företrädare**			
Insatser enligt LSS/SFB	2867,403	**HSN 1 Norra Bohuslän**	354,5		
Färdtjänst/riksfärdtjänst	326,083	**HSN 2 Dalsland**	159,4		
Vård för vuxna med missbruksproblem	688,288	**HSN 3 Trestad**	467,4		
Barn och ungdomsvård	1339,27	**HSN 4 Mellersta Bohuslän**	461,5		
Övriga insatser till vuxna	394,258	**HSN 5 Göteborg, centrum-väster**	911,4		
Familjerätt och familjerådgivning	27,283	**HSN 6 Mittenälvsborg**	212		
Flyktingmottagande	156,57	**HSN 7 Södra Bohuslän**	442,1		
		HSN 8 Sjuhärad	506,9		
		HSN 9 Västra Skaraborg	341,7		
		HSN 10 Östra Skaraborg	334,5		
		HSN 11 Göteborg, Hisingen	505,2		

		HSN 12 Nord-östra Göteborg	505,9		
		Sahlgrenska Universitetssjukhuset	12674,3		
		NU-sjukvården	4124,9		
		Södra Älvsborgs Sjukhus	3201,1		
		Skaraborgs Sjukhus	3500,7		
		Kungälvs sjukhus	986,2		
		Alingsås lasarett	510,2		
		Frölunda Specialistsjukhus	202,1		
		Angereds Närsjukhus	136		
		Primärvården Skaraborg	1039,3		
		Primärvården södra Älvsborg	1155,1		
		Primärvården Göteborg	1660,7		
		Primärvården södra Bohuslän	705,5		
		Primärvården FyrBoDal	957,9		
		Folktandvården i VGR	1970,8		
		Habilitering & Hälsa	748		
		Sahlgrenska International Care AB	30,8		
		Hälsan & Arbetslivet	71,9		
Total expenditure	12469,75		38878		33 981
Total emissions (ton)	87288,23		272146		237867
Gothenburg's share of emissions (ton)	87288,23		89033,92		13053,01
Per citizen in Gothenburg (ton/person)	0,167741		0,171096		0,025084
Total per citizen in Gothenburg (ton/person)	0,363921				
92 Rekreation, kultur och sport					
The municipality of Gothenburg		**VGR**		**The state**	
Allmän kulturverksamhet, övrigt	329,55	**Kultur i Väst**	91,7	**UO17 Kultur, medier, trossamfund och fritid**	11 952
Bibliotek	223,658	**Västarvet**	190,2		
Musikskola / kulturskola	90,653	**Göteborgs botaniska trädgård**	38,6		
Allmän fritidsverksamhet	192,887	**GöteborgsOperan AB**	413,1		
Idrotts- och fritidsanläggningar	320,864	**Göteborgs Symfoniker AB**	177,1		
Parker	302,712	**Film i Väst AB**	99,9		
Fritidsgårdar	114,22	**Regionteater Väst AB**	33,7		
Total expenditure	1574,544		1044,3		11 952
Total emissions (ton)	29916,34		19841,7		227088
Gothenburg's share of emissions (ton)	29916,34		6491,311		12461,51
Per citizen in Gothenburg (ton/person)	0,05749		0,012474		0,023947
Total per citizen in Gothenburg (ton/person)	0,093912				

45 Byggindustri					
The municipality of Gothenburg				**The state**	
Fysisk o.teknisk planering, bostadsförbättr.	238,779			**UO22 Kommunikationer (transport)**	38710
Gator, vägar o parkering	1508,988				
Total expenditure	1747,767				38710
Total emissions (ton)	52433,01				1161300
Gothenburg's share of emissions (ton)	52433,01				63726,62
Per citizen in Gothenburg (ton/person)	0,10076				0,122463
Total per citizen in Gothenburg (ton/person)	0,223223				
60 Landtransportföretag					
		VGR			
		Västtrafik (obs total kostnad för hela västtrafik!)	6158		
Total expenditure			3079		
Total emissions (ton)			86212		
Gothenburg's share of emissions (ton)			28204,68		
Per citizen in Gothenburg (ton/person)			0,054201		
Total per citizen in Gothenburg (ton/person)	0,054201				
01 Jordbruk					
				The state	
				UO23 Areella näringar, landsbygd och livsmeden (jordbruksdel)	6792
Total expenditure					6792
Total emissions (ton)					1731960
Gothenburg's share of emissions (ton)					95041,73
Per citizen in Gothenburg (ton/person)					0,182641
Total per citizen in Gothenburg (ton/person)	0,182641				
Investments					
45 Byggindustri					
The municipality of Gothenburg		**VGR**			
Lokalnämnden	949	**fastighetsinvesteringar**	1428		
Nämnden för Göteborg vatten	182				
Trafiknämnden	239				
Park- och naturnämnden	73				
Fastighetsnämnden	59				
Idrotts och föreningsnämnden	42				
Total expenditure	1544		1428		
Total emissions (ton)	46320		42840		
Gothenburg's share of emissions (ton)	46320		14015,32		

Per citizen in Gothenburg (ton/person)	0,089013		0,026933		
Total per citizen in Gothenburg (ton/person)	0,115946				
33 Medicinska och optiska instrument					
		VGR			
		Utrustningsinvesteringar	864		
Total expenditure			864		
Total emissions (ton)			12 960		
Gothenburg's share of emissions (ton)			4 240		
Per citizen in Gothenburg (ton/person)			0,008148		
Total per citizen in Gothenburg (ton/person)	0,008148				
35 Tillverkning av andra transportmedel					
		VGR			
		Tåg med mera	258		
Total expenditure			258		
Total emissions (ton)			5418		
Gothenburg's share of emissions (ton)			1772,526		
Per citizen in Gothenburg (ton/person)			0,003406		
Total per citizen in Gothenburg (ton/person)	0,003406				

Here are calculations and data for estimating the emissions from the municipality of Gothenburg, using Naturvårdsverket’s definition of public consumption of financed by taxes presented. The calculations are based on the total amount of tax, 23967 MSEK, in the year of 2012 (including municipal financial equalization) and all economical data comes from (Göteborgs Stad, 2012).

The emissions were calculated as follows:

$$Share\ of\ tax \cdot 23967\ MSEK \cdot Emission\ intensity = emissions$$

Table 10: Data for estimating the emissions from tax by activities from the municipality of Gothenburg and calculated emissions.

SNI activity	Share of tax (Göteborgs Stad, 2012),	Emission intensity (ton/MSEK)	Emissions (ton)
80 The educational system	0,44	8	84363,84
85 Healthcare and care (excluding subsidies)	0,4	7	67107,6
45 Construction (streets, roads, parking lots)	0,05	30	35950,5
75 Authorities (civil protection)	0,02	14	6710,76
75 Authorities (business)	0,03	14	10066,14
75 Authorities (politics and audits)	0,01	14	3355,38
total			207554,2
Total per citizen			0,398856

Appendix 2

Bottom up data calculations for public food consumption

For estimating the emissions from public food consumption a mean dish was estimated by utilizing the numbers in Table 11.

Table 11: Emission factors (from (SIK, 2011)) for different type of food served in the public sector used for estimating emissions during 2011 and for the potentials for 2030, the values for the mean dishes are estimated out of the SIK data.

Standard meals	**kg CO_2-eq per serving**
Spaghetti and minced meat sauce (beef)	2,35
Falukorv (pork) and pasta	0,8
Hamburger with bread and potato wedges (beef)	3
Kebab stew with rice (pork)	0,95
Chicken stew with rice	0,9
Saithe with mashed potatoes	0,6
Meat and vegetable soup (beef)	1,95
Moussaka (beef)	2,4
Mean standard meal	1,62
Vegetarian meals	
Lentil sause with spaghetti	0,4
Bean stew with rice	0,6
Carrot and lentil soup	0,55
Mean vegetarian meal	0,52
Mean dish used in calculations	1,46

It was assumed that 1/7 of the meals were vegetarian ones thus the mean dish was estimated to the following emission per served meal:

$$\left(\frac{6}{7}1{,}62\right) + \left(\frac{1}{7}0{,}52\right) = 1{,}46 \text{ Kg } CO_2\text{eq/serving}$$

Then the emissions for 2011 were estimated as through multiplying 1,46 kg CO_2-eq/serving with 19 million servings, resulting in 27,8 kton CO_2-eq.

The potentials were estimated by scaling the number of 27,8 Kton CO_2-eq with the estimated increase of 23,4 % which is an proportional increase to the estimated population increase from 520374 to 642000 during 2011-2030, then further scaled with the changes in Table 12.

Example of estimating emissions by changing into non fossil fuels:

$$27{,}8 \text{ Kton } CO_2 - \text{eq} \cdot 23{,}4 \cdot (1 - 0{,}31) = 31 \text{ Kton } CO_2 - \text{eq}$$

Table 12: The used greenhouse gas emission decreases compared to business as usual.

Change	Reduction in emissions %
Non fossil fuels	31
Non fossil fuels & technical fixes	47
Non fossil fuels, technical fixes & changed meat	67
Non fossil fuels, technical fixes & eating less meat	78
Non fossil fuels, technical fixes & vegan	88

Bottom up data calculations for public transportation

Table 13: CO_2 emissions (ton) from the different vehicle types used in the public transportation system in Gothenburg. The data is for the year of 2012, provided by Västtrafik and each fuel's life cycle is included.

	Diesel	Gas	MDE	Ethanol	Gasoline	Electricity	Total	vehicles	Mkm driven
Bus	78397	3012	62				81471	1816	128,1
Ferry	11665						11665	32	
Car	3629	568		12	237		4446	1438	20,0
Tram						9	9	265	16,7
Train	3649					5	3654	94	11,3
Total	97340	3580	62	12	237	14	101245		

Table 14: Different emission factors used for estimating alternative transportation technologies in the potentials for public transportation. All are described in 3.4.2 Bottom-up data and estimations for public transportation.

Fuel technology	Emission factor
Electricity (ton CO_2/MWh)	0,1
Bus Biogas VGR intensity (kg CO2/Nm3)	0,51
Bus Biogas better (kg CO2/Nm3)	0,16
Bus Biogas household waste (CO2 from biogas/CO2 from fossil fuel)	-0,03
Bus diesel hybrid (CO2 from hybrid/CO2 from fossil fuel)	0,61
Bus Swedish HVO (CO2 from HVO/CO2 from Diesel)	0,15
Bus plug in diesel hybrid (CO2 from plug in hybrid/CO2 from fossil fuel)	0,25
Ferry HVO (CO2 from HVO/CO2 from Diesel)	0,5
Ferry Swedish HVO (CO2 from HVO/CO2 from Diesel)	0,15
Car EU's goal 2020 (g CO2/km)	180
Car plug in hybrid (g CO2/km)	99,8
Car electric (g CO2/km)	67

Table 15: Used data for estimating expansion of public transportation and energy efficiency.

Expansion	
Per year	1,02
Increase during 2012-2030	1,428246
Energy efficiency	
Per year	1,009
Increase during 2012-2030	1,175008
Increase during 2020-2030	1,093734

Table 16: CO_2 emission data used for the plug in hybrid car and the electric car where literature data is adjusted into data with 100g CO_2/kWh from electricity production.

plug in hybrid car	
tot emissions from literature (g/km)	107
from energy production (el. & gasoline)	35,84
from gasoline production	16,64
from electricity only (160 g/kWh)	19,2
from electricity only (100 g/kWh)	12
total emissions for hybrid potential	99,8
Electric car	
tot emissions from literature (g/km)	79
from energy production (el. 160g/kWh)	32
from energy production (el. 100g/kWh)	20
total emissions for electric car potential	67

To estimate the business as usual scenario the emissions in 2012 for each transportation method was multiplied with the estimated increase in public transportation during 2012-2030 (except for the ferries which were assumed to be constant at 32 ferries) which was about 1,428, then divided with the estimated energy efficiency increase during the same years of about 1,175. Example of the bus emissions:

$$\frac{81471\ ton\ CO_2 \cdot 1{,}428}{1{,}175} = 99\ 030\ ton\ CO_2$$

And for ferries:

$$\frac{11665\ ton\ CO_2}{1{,}175} = 9\ 928\ ton\ CO_2$$

Future Potentials for alternative technologies in 2030

In general the same methodology for estimating the business as usual was used for estimating the potentials for alternative technologies, but some further changes regarding changed emissions was also included.

Busses

All bus potentials were based on a total amount of 2594 busses in 2030, coming from an 1,428 increase compared to 2012. From Table 13 it was estimated that one buss emitted 48,6 ton CO_2 during 2012 and as stated in the text a biogas bus is assumed to consume 50 000 Nm^3 biogas per year.

$$1816\ busses * 1{,}428 = 2594\ busses$$

Biogas VGR intensity:

$$\frac{2594\ busses \cdot 50000 \frac{Nm^3 biogas}{year} \cdot 0{,}51\ kg\ CO_2/Nm^3 biogas}{1{,}175} = 56\ 288\ ton\ CO_2$$

Biogas better case:

$$\frac{2594\ busses \cdot 50000 \frac{Nm^3 biogas}{bus \cdot year} \cdot 0{,}16\ kg\ CO_2/Nm^3 biogas}{1{,}175} = 17659\ ton\ CO_2$$

Biogas household waste:

$$99\ 030\ ton\ CO_2 \cdot -0{,}03\ \frac{g\ CO_2 frombiogas}{g\ CO_2 from\ fossil\ fuel} = -2971 ton\ CO_2$$

HVO hybrid:

$$\frac{2594\ busses \cdot 48{,}6 \frac{ton\ CO_2}{bus \cdot year} \cdot 0{,}61\ \text{g CO2 from hybrid/g CO2 from fossil fuel}}{1{,}175} \cdot 0{,}15\ (\text{CO2 from HVO/CO2 from Diesel}) = 9823\ ton\ CO_2$$

HVO plug in hybrid:

$$\frac{2594\ busses \cdot 48{,}6 \frac{ton\ CO_2}{bus \cdot year} \cdot 0{,}25\ g\ \text{CO2 from plug in hybrid/g CO2 from fossil fuel}}{1{,}175} \cdot 0{,}15\ (\text{CO2 from HVO/CO2 from Diesel}) = 4026\ ton\ CO_2$$

Ferry

For ferries the business as usual scenario was multiplied with 0,5 for the first HVO potential and by 0,15 for the scenario with Swedish production of HVO.

Car

All alternative scenarios for the car have emission factors per km driven, therefore they have been multiplied with the estimated distance driven in the year of 2030. The estimated distance has been estimated in the same manner as the increased emissions in the business as usual scenario. However since the emission factors were estimates for 2020 only an increase of energy efficiency, total of 1,094, during 2020-2030 were used,

$$\frac{19975382\ km/year \cdot 1{,}428}{1{,}094} = 26084741\ km/year$$

EU's goal 2020

$$26084741 \frac{km}{year} \cdot 180\text{g} \frac{\text{CO}_2}{\text{km}} = 4695 \text{ ton } CO_2$$

Plug in hybrid

$$26084741 \frac{km}{year} \cdot 99{,}8\text{g} \frac{\text{CO}_2}{\text{km}} = 2603 \text{ ton } CO_2$$

Electric

$$26084741 \frac{km}{year} \cdot 67\text{g} \frac{\text{CO}_2}{\text{km}} = 1748 \text{ ton } CO_2$$

Tram

For the tram only the business as usual scenario was estimated. 2012’s emissions were estimated in a different fashion than the one used by Västtrafik by using another emission intensity, 100 g CO_2/kWh, for the electricity production. The electricity consumption from 2011, 52760 MWh, was used and scaled to 2012’s amount of trams.

2012

$$52760\ MWh \cdot \left(\frac{265\ trams\ in\ 2012}{248\ trams\ in\ 2011}\right) \cdot 0{,}1\text{ton} \frac{\text{CO}_2}{\text{MWh}} = 5638 \text{ ton } CO_2$$

Business as usual 2030

$$\frac{5638 \text{ ton } CO_2 \cdot 1{,}428}{1{,}175} = 6853 \text{ ton } CO_2$$

Train

The train emissions were estimated in the same manner as for the tram with the exception of the 11 diesel train’s emissions of 3649 ton CO2 and a fuel consumption of 1305845 l (mk 1) diesel with an assumption of 9,77 kWh/l diesel (Energimyndigheten, 2013). Thus ending up at 12758 MWh from diesel and total energy consumption 2011 was 72674 MWh. Thus 59916 MWh from electricity was provided.

2012

$$59916\ MWh \cdot \frac{83\ electric\ trains\ in\ 2012}{65\ electric\ trains\ in\ 2011} \cdot 0{,}1\text{ton} \frac{\text{CO}_2}{\text{MWh}} + 3649 \text{ ton CO}_2 = 11300 \text{ ton CO}_2$$

The scaled up electricity consumption in the formula above, for 83 trains, was 76508 MWh with an electricity consumption per train of 921,8 MWh.

Business as usual 2030

$$\frac{11300 \text{ ton } CO_2 \cdot 1{,}428}{1{,}175} = 13735 \text{ ton } CO_2$$

Only electrical trains 2030

$$\frac{921{,}8 \text{ MWh} \cdot 94\ trains \cdot 0{,}1\text{ton} \frac{\text{CO}_2}{\text{MWh}} \cdot 1{,}428}{1{,}175} = 10532 \text{ ton } CO_2$$