Stockholm County GHG Emissions in the Year 2003

Introduction

In this report, we present a GHG emissions inventory for the region: Stockholm County for the year 2003. This inventory has been produced using the newly adapted "GRIP for Europe methodology". In this report we provide an overview of the region's characteristics, together with the emission sources and the methods used to estimate them. This is the first application of this methodology to the region. The results from this inventory form the platform for the "energy scenarios" developed in a further report.

Background

The inventory for Stockholm County (SC) covers estimates of emissions occurring in the year 2003, 2003 was chosen as it was the year for which most data was available. This inventory includes the six main[1] greenhouse gas emissions that emanate from the energy, industrial processes, waste and agricultural sectors[2]. The emissions estimates provide a platform on which subsequent analysis can be based, over the near-, medium- and long-term. Such work is important, as it can provide an insight into the potential effects that differing policies, taken at central or regional government level, may have on regional scale emissions. Funding to develop a further software model, that links to the new "GRIP for Europe" (GfE) methodology, to assist with this, is currently being applied for.

The inventory is based on a mix of data sets that are either measured or based upon an inferred value. These data sets include: Localised Energy Statistics (DUKES), the national inventory for Stockholm, together with a variety of locally held data sets. This data, together with a range of emissions factors taken from GfE[3], are used to form this emissions inventory that covers the six GHGs included in the Kyoto protocol. For comparison and clarity in this report, greenhouse gas emissions are presented across the four pilot regions..

For a true grounding to an inventory, the history, population and character of a region need to be understood. The latter includes its geographical location, transport links and economy, among other issues. The following sections therefore include a description of the Stockholm County region.

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[1] Carbon dioxide (CO_2); Methane (CH_4); Nitrous Oxide (N_2O); HFCs; PFCs; Sulphur Hexaflouride (SF_6)

[2] These figures are displayed in line with the GRIP approach. Within the energy sector, therefore, energy consumption and emissions are considered in terms of the domestic sector, the various sub-sectors of industrial and commerce together with emissions from transport and the various emissions associated with the transformation and distribution of energy.

[3] Sourced from international standards

The Stockholm County region in the year 2003: Geographical features

The Region covers an area of 6,519sq km^2 [4] and is divided into 26 municipalities. There are 0.88m households within the region. The population of the region in the year 2003 was approximately 1.89m, which when considering its land size, made the region the most densely-populated in Sweden. Stockholm itself is the capital of Sweden and is located on the east coast, the City of Stockholm (rather than the region) consists of fourteen islands. Home to both Sweden's Royal family and the national parliament.

The Stockholm County region in the year 2003: The economy

The Gross Domestic Product (GDP) of the region in the year 2003 accounted for approximately 29.1% of the Swedish economy. Employment figures for the region show that approximately 33,949 people were unemployed in the year 2003, accounting for 5.1% of the total working population. This level of unemployment placed SC above the Swedish average of 5.6%. The levels of economically active individuals fluctuated between the different municipalities The level of employment across Sweden has been relatively stable despite slow economic growth, this is due in part to the growth in public sector employment. In Stockholm however a higher level of growth has been experienced. In addition there has been a growing trend in the level of employment amongst the young (particularly females) However there are also a number of young that are economically inactive i.e. they are neither working, applying for jobs or studying. On the other end of the scale around 36% of the currently active employment force is expected to retire by 2015. The higher level of productivity experienced within the region means that GDP per capita within the SC region is higher then the rest of Sweden.

Stockholm is one of the most successful metropolitan regions within the OECD. It experienced large levels of growth during the 1990's particularly within the service sector. Its high educational attainment, low poverty levels and strong public health performance mean that it ranks highly in terms of quality of life. There are currently very few new high-growth companies within SC and wider Sweden, this presents a problem for the integration of immigrants, whilst growth is not aided by a transportation system that has not grown in line with the population. Understanding the relative size of different parts of the economy is important as it provides an insight to the potential levels of fossil fuel consumption and associated emissions. The service sector, for example, is important within a GHG inventory, as by its nature it is less energy intensive[5] than its industrial counterparts. The lower the consumption of fossil fuels, directly or indirectly by a sector – the lower the emissions in that sector (energy intensity and carbon intensity are generally heavily linked). These links must be understood when considering year-on-year comparisons of emissions change.

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[4] approximately 1.6% of Sweden's land mass

[5] Energy consumed per unit of GVA output. However note that this is only a direct consumption basis. The level of discrepancy between energy consumption and GVA is substantial between industry and services

The Stockholm County Region in the year 2003: Industry and services

The level of economic activity of SC is centrated on the Stockholm area. Stockholm has an established R&D strength, advanced business, logistical and financial services. The SC region is the major location for multinational companies within Sweden, the larger part of the national R&D expenditure is located within the region. The SC region is one of the highest ranked within the OECD regions in terms of high-tech patent activity. Sweden overall ranks highest for the level of R&D expenditure to GDP and investment in knowledge, and ranks second in terms of the number of researchers per unit of GDP.

Sodertalje is the third largest municipality within SC, it has developed from an industrial town into a diversified market. The municipality contains the head offices of two of the most successful companies in Sweden; Astra Zeneca and Scania. Sodertalje has a large amount of small companies (about 3,800), who employ less then five people. With the largest percentage of those employed being in the retail and catering field.

The Stockholm County Region in the year 2003: Transport

Good transport networks are associated with prosperous countries (Freeman and Soete 1997). The prosperity and development achieved in Western Europe during the Industrial Revolution, and the harmonising of other countries since that time, has been at least in part dependent on a superior transport infrastructure, reliance on transportation – and new modes of transferring data continue to remain key to regional development. The region contains a variety of seaports and a large international airport – this makes it an important commercial centre in Northern Europe and the Baltic Sea Region.

The international airport is the largest and busiest airport in Sweden accounting for more than half of all Swedish flights and passenger numbers it handled 16m in the year 2003. These passenger numbers have nearly doubled in the time since 1990.

The region has a diversified transportation system that includes; buses, commuter trains, light rail and boats. The rail based transport is primarily electric which because of the fuel mix presents much fewer emissions then fossil fuels would.

The region's population is distributed around the transportation system to permit easier access to work. The region is far more densely populated then Sweden as a whole, there are 285 people per sq km, against the national average of just 22. In 2003, there were approximately 760,000 cars registered in the region.

The Stockholm County region in the year 2003: Agriculture

The region holds a comparatively[6] small agricultural industry. The dairy sector accounts for the larger economic part of the agricultural sector in the region[7] and emissions.

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[6] In comparison to other regions
[7] In terms of wealth creation.

The Stockholm County region in the year 2003: Waste

How waste is handled and disposed of is a key issue for policy makers in Stockholm. Waste can be land filled, incinerated, recycled or treated and be classified in different ways, including sewage and municipal solid waste. It may be categorised as inert, hazardous, non-hazardous or biodegradable. The type of waste and how it is treated has a direct impact on emission levels. Waste is also of great importance to policy makers in terms of resource limitations and EU measures such as the Landfill Directive.

Waste is included in an inventory because of the high levels of associated methane gas releases. These emissions differ according to the waste disposal and waste management techniques employed. Land filling waste results in much higher levels of methane emissions than combustion or recycling. In landfills, emissions can be minimised by methane recovery - the lower the level of methane recovery the higher the emissions release. Regions, that have a greater propensity to landfill, have higher levels of emissions associated with waste.

The inventory is divided into four sectors in accordance with GRIP and "GRIP for Europe". This allows for direct comparisons to be drawn between the regional and national inventories. These sectors are: energy; industrial processes; agriculture; and waste. The results of which we will now present in turn.

Energy: The inventory and its results

The first sector addressed in the Stockholm County inventory is the energy sector. The "GRIP for Europe" methodology sub-divides the energy sector into the following categories: domestic energy use; services, and agricultural sector energy use; industrial energy use (five separate sectors); energy use in the energy industry; transport (all modes); and fugitive emissions

Energy Emissions in Stockholm County 2003: An overall view

The energy sector, including transport and fugitive emissions, accounts for 99.9% of regional CO_2 emissions (6,848kt[8] CO_2), with CH_4 and N_2O emissions adding an additional 140kt CO_2 Eqv, making a total of 6,987kt CO_2 Eqv for the year 2003. Chart 1, below, shows the breakdown of SC GHG emissions, from the energy sector in the year 2003.

[8] kt = thousand tonnes

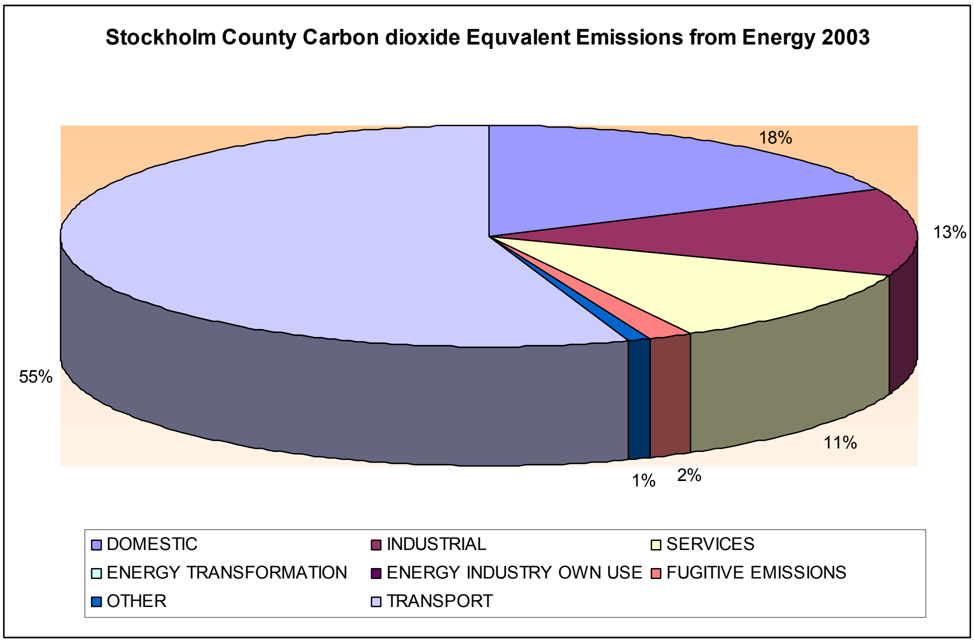

Chart 1: Stockholm County Energy Based Emissions 2003 (total 6,987kt)

We will now discuss these sectors in turn, beginning with the domestic sector.

Domestic energy emissions

Direct domestic emissions occur through the combustion of solid, liquid and gaseous fuels, burned in households across the region and indirectly through the consumption of electricity. A home in the region may be heated by gas- or liquid-fired central heating, electric heating, district heating or indeed a combination of these. The figures show that the region's households consume a slightly higher than average amount of fuel due, possibly, to the weather and the level of insulation in homes among other factors.

Using the GRIP methodology, total CO_2 emissions from the domestic sector in the region for the year 2003 were estimated to be 1,198kt CO_2. Table 1 below shows how these emissions are comprised in terms of fuel type regionally together with the CO_2 equivalent values. Chart 4.2 shows how the CO_2 emissions are split regionally in graphical format.

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Table 1: Domestic Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt $_{CO2}$	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity& District Heat	4,060	1,896	7,287	512	1,185	443	5,175	1,937
Gas	12,766	2,397	77	4.6	7,667	1,537	39,533	7,927
Solid	377	106	0	0	2	0.7	8	3
Liquid	990	267	2,558	682	515	284	2,855	727
Total	18,193	4,666	9,922	1,198	9,369	2,265	47,571	10,594
Households	786,768		880		455.1		1,852.9	
Per Household	23	5.93	11.275	1.36	20.6	4.9	25.6	5.7
Population	1747.040		1899.9		915.2		4,699.95	
Per Capita	10.4	2.67	5.22	0.63	10.23	2.47	10.12	2.3

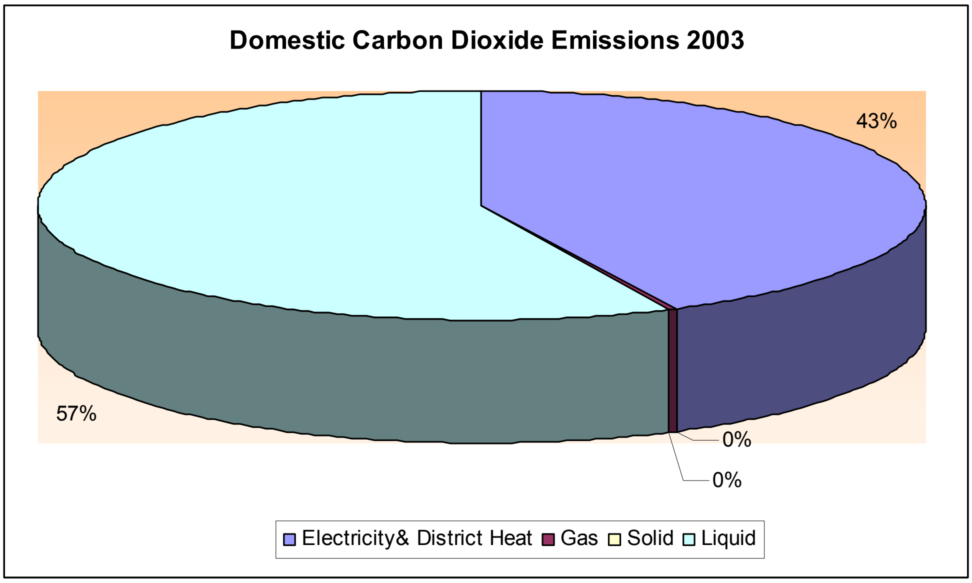

Chart 2: Stockholm County domestic fuel carbon dioxide emissions 2003 (total 1,899kt)

When coupled with the Global Warming Potentials (GWP_{100}) of CH_4 and N_2O from the domestic consumption section, total emissions are 1,261kt CO_2 Eqv.

Interpreting the findings of the GRIP inventory: Domestic

Greenhouse gas emissions from the domestic sector are presented within the region are contained in Table 1 above. The figures show the energy-related emissions generated by household, but do not include emissions that occur outside of the home (for example from transport). These emissions figures are dealt with separately.

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SC is the most densely-populated region of Sweden and also has a high level of ageing housing stock. Some households, particularly those in rural areas, are dependent on deliveries of liquid or solid fuels to provide their heating, as natural gas is not available. Whereas many new builds use electricity as their sole source of fuel for all their energy needs: heating, lighting, cooking and power. The figures show that emissions per household are the lowest of the four regions at 1.36t $CO_{2,}$ compared to Veneto's 5.7t, and that domestic emissions per person are 0.63t CO_2 regionally compared to the Glasgow region emissions of 2.63t per person.

The GRIP methodology assigns emissions associated with electricity generation to the end-user. This approach offers benefits to the region as it helps to better understand one of the key drivers of emissions, and consequently provides a comprehensive inventory. As part of this data is necessarily scaled from aggregated data sets, such figures act as a guide to emissions within the region. It is not possible to make definitive statements as to what this may mean for the other fuels, but using this data, policy makers can make informed decisions on where energy policy and associated GHG emission reduction policies can be targeted to greatest effect.

The data presented here, although the best available for the year 2003, does have some associated uncertainties. The data contained here is based upon a variety of data sets taken from regional and national stats relating to regional energy consumption, they are therefore the best available. However there are uncertainties associated with them due to the mechanisms used to collate and otherwise distil the data.

Service sector and Agricultural energy emissions

Emissions from these sub-sectors in "GRIP for Europe", as with the domestic sector, arise directly through the combustion of coal, fuel oil and gas and, indirectly, from the consumption of electricity and heat.

Total emissions from the commercial, public administration and agricultural sectors in Stockholm County region for the year 2003 were estimated to be 862CO_2. The tables 2-3 below show the breakdown per fuel type per sub-sector.

Table 2: Services Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity& Heat	2,230	1,042	7,843	551	1,663	622	6,826	2,555
Gas	1,412	265	412	87	3,495	701	14,648	2,937
Solid	1	0.5	0	0	0.14	0.3	0.6	0.2
Liquid	71	19	1,472	108	243	18	242.5	18
Total	3,720	1,331	9,727	746	5,401	1,341	21,717	5,510
GVA Services €m	32,416		55,671		18,109		74,896	
Per Unit GVA	0.11	0.04	0.17	0.01	0.298	0.07	0.289	0.07

Table 3: Agricultural Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity&Heat	126	59	117	6.5	105	39	526	197
Gas	82	17	9.4	1.97	42	9	170	36
Solid	1	0.5			0	0	0	0
Liquid	218	58.5	1,472	108	669	176	2,724	715
Total	444	148	1,598	116	816	224	3,420	948
GVA Agriculture €m	87		92		420		2,754	
Per Unit GVA	5.1	1.7	17.4	1.26	1.94	5.33	1.24	0.34

Interpreting the findings of the GRIP inventory

Tables 2-3, show the relative contribution that service and agricultural sectors make on energy-based GHG emissions between the four pilot regions. The data underpinning these calculations includes estimations of the quantity of energy consumed by these sub-sectors. The table shows CO_2 emissions (per unit of GVA) from the service sector is lowest in Stockholm and highest in Bologna/Veneto.

This data, when analysed in conjunction with the next section relating to industry, highlights the disparity between the service sector (low-carbon intensity) and industry (high-carbon intensity). In particular, the data clearly illustrates how much more the industrial sector emits than the service industry per unit of GVA. These findings, however, should not be seen as a justification for reducing emissions by pushing out industry in favour of the service sector. GHG emissions are a global problem and if the products are manufactured elsewhere, their production will still consume energy and there may well be additional energy required for their subsequent transportation, which may cause further increases in overall world emissions. Thus it is important to see regional emissions inventories within their wider context.

The agricultural element discussed in this section relates only to emissions from energy consumption associated with agricultural activities. We look at the non-combustion activities of the agricultural industry that may give rise to GHGs under the section Agriculture. These two areas are presented separately to maintain consistency with other inventory approaches. Interestingly these are highest in Bologna and Lowest in Veneto.

The data used to tabulate these emissions are not purely bottom-up and, therefore, entail a higher degree of uncertainty than measured data would. The figures displayed above use the apportioning methods within "GRIP for Europe" to allocate energy consumption to the respective sectors. It is not possible to provide a definitive guide to uncertainty of these figures-however we estimate these to be between 0-10% for the SC.

Industrial energy emissions

In the tables 4-10 below, the emissions resulting through the combustion of solid, liquid and gaseous fuels and indirectly from the use of electricity and heat within industry are presented. Total emissions from the industrial sector in the SC region for the year 2003 and were estimated to be 875kt CO_2. Note that these emissions they do not include emissions from industrial processes. These emissions are also represented graphically in chart 4-10 below. The latter process emissions are considered in section (of which there is very few in the SC region)

Table 4: Iron and Steel Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity&Heat	96	45	249	17.5	245	92	1,895	710
Gas	178	33	22	4.6	329	66	1,788	359
Solid	220	10	0	0	1,085	264	4,416	1,076
Liquid	8	0.6	264	66	3	1	32	8.4
Total	525	104.6	535	88.1	1,662	423	8,131	2,153

Table 5: Non-Ferrous Metals Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity & Heat	90	42	68	5	50	19	387	145
Gas	58	11	6	1.25	67	14	1,788	73
Solid	23	8			7	2.5	4,416	2.5
Liquid	7	0.5	14	4	2	0.5	32	5
Total	210	84.5	88	10.25	126	36	6,623	225.5

Table 6: Chemicals Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity & Heat	277	129	782	55	387	145	2,991	1,120
Gas	675	127	69	14	520	104	2,822	566
Solid	9	5			1.3	0.5	5	2
Liquid	26	2	313	72	33	8.7	324	86
Total	1,104	348	1,164	141	941	258	6,142	1,774

Table 7: Paper, Pulp and Print Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity & Heat	70	33	429	30	213	80	1,648	617
Gas	83	16	38	8	286	57	1,555	312
Solid	3	2						
Liquid	2	0.2	538	146	5	1.4	52	14
Total	174	63	1,005	184	504	138	3,255	943

Table 8: Food Processing, Beverages and Tobacco Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity & Heat	361	169	1,006	71	242	91	1,874	701
Gas	811	152	88	19	326	65	1,768	354
Solid	4	2						
Liquid	104	8	138	35	19.6	5.3	194	53
Total	1,306	350	1,232	125	588	161	3,836	1,108

Table 9: Other Industry Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity & Heat	1,733	809	976	69	1,076	403	8,320	3,114
Gas	1,367	257	85	18	1,446	290	7,850	1,574
Solid	172	82			152	51	618	209
Liquid	1,674	122	507	136	152	48	1,504	474
Total	4,981	1,296	1,568	223	2,826	792	18,292	5,371

Table 10: Total Industrial Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2	Consumption (GWh)	Kt CO2
Electricity	2,628	1,227	3510	247	2,213	829	17,117	6,407
Electricity CHP	250	181						
Gas	3,172	596	307	65	2,975	597	16,149	3,238
Solid	433	109	0	0	1,245	319	5,046	1,290
Liquid	1,821	134	2,174	563	215	65	2,125	641
Total	8,304	2,247	5,991	875	6,648	1,810	40,437	11,576
GVA Industry €m	10,450		10,779		8,669		41,165	
Per Unit GVA	0.79	0.22	0.56	0.08	0.77	0.21	0.98	0.28

Chart 2: Stockholm County Industrial Energy Emissions by Fuel Type

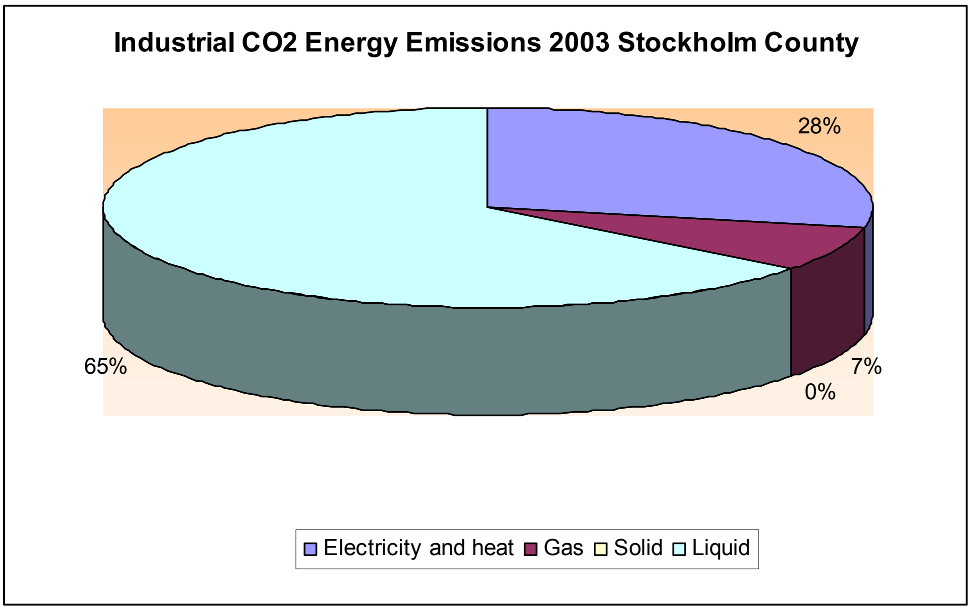
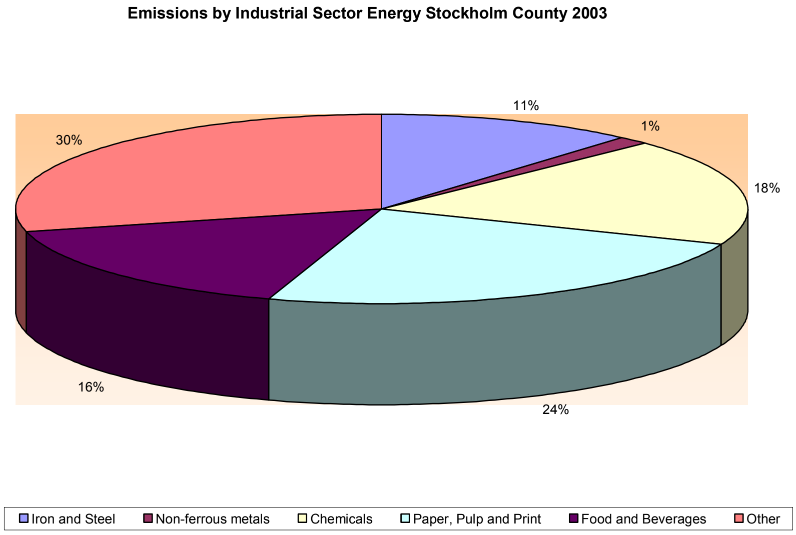


Chart 3: Stockholm County Emissions by Sector 2003



Interpreting the findings of the GRIP inventory

The results for industrial energy emissions offer some surprises as, in advance of this study, a lower rate of energy consumption and emissions was expected for the region. The SC region emits the lowest amount of emissions from industry per unit of GVA of the four regions, this is determined by the nature and type of industry and the fuels consumed. Some industries for example the chemical industry consume a lot of energy – however they are also fairly economically productive. This distorts overall figures. The level of data in the different regions and the country in which they reside is such that a basic set of industry sub-sectors were chosen. There are additional emissions associated with particular types of industry, these arise from chemical reactions. There are however no such emissions occurring within the region, emissions associated with the use and maintenance of certain products, and these are considered under the section "industrial processes".

These figures have been estimated using a combination of top-down and bottom up data. This falls under GRIP level 2 and, although they are deemed to be the most accurate data available currently, the results carry a degree of uncertainty. Nevertheless, by using this data, policy makers are given a real insight into the emission levels associated with industrial activity located in the SC area. With this level of information, a more targeted approach to mitigation becomes possible.

Energy industry emissions

The energy industry emission figures presented below include those from the following sub-sectors:

- petroleum refining;

- coal extraction;
- coke manufacture;
- blast furnaces;
- and oil and gas extraction.

Emissions from the sub-sectors under GRIP are assigned to the region according to where the level of activity is-based. There are no petroleum refineries, coke manufacture, blast furnaces or oil and gas extraction taking place in the any of the four pilot regions.

Table 11: Energy Industry Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	486	227	0	0	0	0	0	0
Gas	25	5	0	0	0	0	0	0
Solid	16	3	0	0	0	0	0	0
Total	527	235	0	0	0	0	0	0

Interpreting the findings of the GRIP inventory

The fact that there are no emissions from the energy industry are indicative of the absence of the sites within the region. The GRIP approach separates the emissions by fuel type and activity, so that the results enable a more informed and targeted understanding of emissions within the region. The uncertainty surrounding the results for this sub-sector in this inventory run is quite low as they have all been calculated using GRIP level 1.

Fugitive emissions from the energy sector

Fugitive greenhouse gas emissions occur unintentionally as a result of particular activities. Under GRIP, the fugitive emissions that are considered are those resulting from venting and flaring of natural gas and oil, and leakages from the gas transport network, electricity losses and methane released during coal extraction. The GCV region is the only one of the four regions that has any coal mining activity, as already identified this accounts for 15% of the UK's coal extraction.

Fugitive losses of natural gas, CH_4, (this is gas lost during its transmission) is estimated on the basis of throughput of gas within the region, the level of leakage is different within each country and this is reflected in the table below.

Emissions in the SC region from this category were estimated from data sets that were gathered from the Swedish national inventory. (all for the year 2003)

Fugitive emissions using GRIP

Using the methodology above, in conjunction with the listed data sources, total emissions from other energy sources in the SC region for 2003 were estimated to be 108kt CO_2 Eqv[9]. (please note the figures below are the CO_2 equivalent) The table below shows the breakdown per fuel type.

Table 12: Fugitive Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_{2e}	Consumption (GWh)	Kt CO_{2e}	Consumption (GWh)	Kt CO_{2e}	Consumption (GWh)	Kt CO_{2e}
Electricity	865	404	1,544	109	420	157	2,401	899
Methane	38.4	883	1	23	5	115	25	575
Total	903	1,287	1,545	132	425	272	2,426	1,474

Transport

Emissions from transport are divided into two categories under GRIP: firstly, emissions from the direct combustion of petroleum-based liquid fuels (motor spirit[10], DERV, natural gas, marine fuel, aviation spirit and aviation turbine fuels); and secondly, electricity consumption in the railway network.

The inventory shows that within the transport sector, road transport accounts for the largest proportion of emissions in the SC with 3,251kt CO_2 in 2003 (table 13-16). Under the GRIP approach, road transport includes: cars (private and business); buses; light goods vehicles (LGVs); heavy goods vehicles (HGVs); motorcycles; and airside support vehicles.

The road and rail data for the SC is based upon data sets taken from the email correspondence with representatives in Stockholm– the figures are the best and most consistent available, however the data does present uncertainties – which effects the emissions calculations. The data for marine and aviation is based upon regional and national activity data relating to number of regional flights and ship movements.

Under international standards, emissions from aviation are estimated on the basis of a combination of fuel consumed by domestic flights and international take-off and

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[9] Calculated using GWP_{100} values
[10] A generic name that covers unleaded petrol, lead replacement petrol (LRP) and Four Star), liquid petroleum gas (LPG) and DERV.

landings under altitudes of 3000 feet. This approach is mirrored in GRIP, the figures do not include international aviation cruise emissions and are therefore far lower then may be expected. Without international emissions, which are not included in the IPCC guidelines, a true picture of transport emissions is not be drawn. However, when conducting an emissions inventory on this scale the mechanism via which to allocate these emissions to a given area becomes contentious. For example, allocating all emissions of a planes flight to a set region ignores the fact that some or all of the passengers, and freight may originate from an entirely different region. A mechanism of how to do this is currently being established in the Tyndall Centre, and can be incorporated into the methodology at a later stage.

Marine-based emissions in the national inventory include all transport that takes place on inland waterways and within 12 miles of shore. These emissions are those that are associated with harbour operations and inland waterways. International marine emissions may also be significant but are not included. Bunker fuels are stated nationally but these are not included in emissions totals, and are expected to under represent emissions figures due to tankering[11]. Under GRIP only the former emissions are presented.

In national inventories only liquid fuel-based emissions from rail-based sources are included. This is because the emissions associated with electricity usage on railways (light and mainline) are captured within the power production section. The GRIP methodology however includes these emissions associated with rail-based electricity consumption. This requires a general understanding of the rail network within a given region. In the case of this inventory, the SC railway network is predominantly electrified, with a few diesel trains still running.

Transport emissions

Table 13: Road Transport Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Petrol&Diesel	12,204	3,178	12,544	3,251	7,841	2,041	39,883	10,356
Natural Gas			32	6	79	16	79	16
Total	12,204	3,178	12,576	3,257	7,920	2,057	39,962	10,372

[11] A process where both marine vessels and aviation fleet take economic advantage of the differing costs of fuels within originating and destination countries and "fill up" wherever the transportation costs will be minimised. Therefore the bunker fuels, may over or indeed underestimate a countries apportionment of energy consumption from these modes, and therefore emissions.

Table 14: Rail Transport Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	122	57	1,093	77	90	34	368	138
Diesel	184	49	109	29	30	9.5	122	39
Total	306	106	1,202	106	120	43.5	490	177

Table 15: Marine Transport Fuel Consumption and Emissions the Four Regions

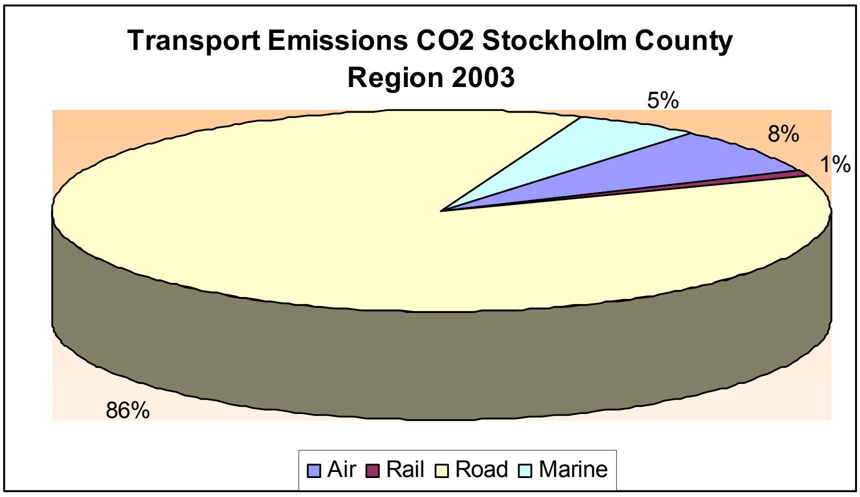
	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Diesel/Marine Diesel	101	26.47	767	202	0	0	2,085	559
Total	101	26.47	767	202	0	0	2,085	559

Table 16: Aviation Transport Fuel Consumption and Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Kerosene	326	84	1,086	286	231	59	940	239
Total	326	84	1,086	286	231	59	940	239

Chart 4 below and the tables 13-16 above show the overwhelming contribution of road transport as a percentage of GHG emissions within the SC region. It appears from these that aircraft emissions are of little significance. This can be seen in chart 4 below. This is to reiterate because they do not include the emissions associated with the cruise phase of an aircraft's journey. While this means that an accurate representation of the division of transport emissions is not provided the approach is taken to be in keeping with GRIP and IPCC standards. The percentage share of aviation emissions are actually higher in the SC inventory then that shown nationally because of the presence of the main national airport, this is reflected in Bologna Region and GCV region.

Chart 4: Emissions from road transport by source.



Interpreting the findings of the GRIP inventory

The transportation results are based on both measured and aggregated data sets relating to energy consumption by vehicles. The SC has a relatively lower level of car ownership per household within Sweden. This may be affected by the nature and type of journeys undertaken by the population, the types of vehicles that are driven and the way in which the inhabitants and those that drive through the region drive. The emissions are also higher due to the cars that are driven.

Summary: Emissions from the energy sector

In this section, we have presented the emissions associated with the energy sector in the SC region in the year 2003. The energy sector is broad and diverse, encapsulating activities from the domestic, commercial and industrial arenas, as well as those that arise from transport. The emissions presented here account for the significant majority of carbon dioxide emissions in the region – 99.9% of the total. This is a higher percentage then the national share, due mostly to the lack of large CO_2 emitting process sites such as cement manufacturers.

The kind of fuel that we use in the future and the way in which it is sourced has a direct effect on carbon dioxide levels. This essentially comes down to what fuels we use to heat and light our homes and businesses, as well as how we propel our vehicles. Understanding our current fuel choices and future fuel options, both primary and secondary, is key to producing a GHG sensitive energy policy. This is the reason for presenting emissions together with the energy that underpins them as we do above.

Table 17 below presents all the emissions by fuel type associated with energy in each of the four regions.

Table 17: Total Energy Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	10,516	4,912	21,512	1,501	5,677	2,125	32,413	12,133
Electricity CHP	273	359						
Heat CHP								
Gas	18,520	3,496	861	169	14,275	2,859	70,617	14,154
Solid	879	240			1,246	540	5,055	2,188
Liquid (all)	15,928	3,820	21,146	5,177	9,743	2,652	50,977	13,341
Total	46,116	12,827	43,519	6,847	30,941	8,176	159,062	41,816

Industrial Processes

As discussed above industrial process emissions result from either the GHG release from industrial chemical reactions and from the consumption of GHGs directly. They do not include those emissions that occur as the result of the combustion of fossil fuels: these are dealt with under the energy sector. Estimates of emissions from industrial processes within GRIP are made in relation to individual sites or groups of activities. This is to be in-keeping with international standards. Within each of the countries studied in the pilot phase, the operators of IPPC Part A (large emitting sites) regulated plants are required to supply emissions estimates to the relevant national and/or regional regulatory bodies on an annual basis. These estimates may be-based on fuel use, mass balances, direct measurement or other methodological approaches. These emissions include all six GHGs considered here as well as many other local air emissions not discussed here.

GHG emissions attributed to the industrial processes sector include emissions from the following process groups:

- mineral production;
- the chemical industry;
- metal production;
- and the production and consumption of halocarbons.

Data sources

Emissions estimates of large industrial sites are available in Sweden from the national regulatory body. The figures shown on this database are not always clear however. For example, CO_2 process emissions are combined with CO_2 emissions from energy use.

Methodology

The methodology used here comes in two forms, those associated with the mineral, chemical, metal and halocarbon production; and those associated with halocarbon consumption. The emissions for the SC region have been estimated using the GRIP level 1 approach.

Industrial processes emissions

The results for industrial process emissions contained can be viewed in summary format in table 19 Within the SC, there are no process emissions being released that are covered under international standards, as a consequence there are none contained in GRIP and therefore none are reported here. The only pilot region with such emissions is Veneto – this region contains two cement manufacturing plants. This is generally the largest contributor of industrial process CO_2 emissions in an emissions inventory.

A full description of all such sites is included in the soon to be released report on "how to produce the GRIP inventory using the web tool".

Table 18: Process Emissions Glasgow

	Glasgow					
Fuel	Kt $_{CO2}$	Kt CH_4	Kt N_2O	Kt PFC (GWP)	Kt HFC (GWP)	Kt SF_6
Mineral Industry	N/A	N/A	N/A	N/A	N/A	N/A
Chemical Production	N/A	N/A	N/A	N/A	N/A	N/A
Metal Production	N/A	N/A	N/A	N/A	N/A	N/A
Production of Halocarbons and SF_6	N/A	N/A	N/A	N/A	N/A	N/A
Consumption of Halocarbons and SF_6	N/A	N/A	N/A	243	2.65	N/A

Table 19: Process Emissions Stockholm

	Stockholm					
Fuel	Kt $_{CO2}$	Kt CH_4	Kt N_2O	Kt HFC	Kt PFC	Kt SF_6
Mineral Industry	N/O	N/O	N/O	N/O	N/O	N/O
Chemical Production	N/O	N/O	N/O	N/O	N/O	N/O
Metal Production	N/O	N/O	N/O	N/O	N/O	N/O
Production of Halocarbons and SF_6	N/O	N/O	N/O	N/O	N/O	N/O
Consumption of Halocarbons and SF_6	N/O	N/O	N/O	289	0.4	0.001

Table 20: Process Emissions Bologna

	Bologna					
Fuel	Kt CO_2	Kt CH_4	Kt N_2O	Kt HFC	Kt PFC	Kt SF_6
Mineral Industry	N/O	N/O	N/O	N/O	N/O	N/O
Chemical Production	N/O	N/O	N/O	N/O	N/O	N/O
Metal Production	N/O	N/O	N/O	N/O	N/O	N/O
Production of Halocarbons and SF_6	N/O	N/O	N/O	N/O	N/O	N/O
Consumption of Halocarbons and SF_6				70	3	0.002

Table 21: Process Emissions Veneto

	Bologna					
Fuel	Kt CO_2	Kt CH_4	Kt N_2O	Kt PFC	Kt HFC	Kt SF_6
Mineral Industry	2,000	N/O	N/O	N/O	N/O	N/O
Chemical Production	N/O	N/O	N/O	N/O	N/O	N/O
Metal Production	N/O	N/O	N/O	N/O	N/O	N/O
Production of Halocarbons and SF_6	N/O	N/O	N/O	N/O	N/O	N/O
Consumption of Halocarbons and SF_6	N/O	N/O	N/O	362	15.5	0.01

Interpreting the findings of the GRIP Inventory

The results from this section show that the SC region emits a relatively small amount of process emissions. However, these emissions are emitted elsewhere to produce such products as fertilisers which are subsequently used in the region. So whilst the region does not emit the gases with its boundaries its activities cause these emissions to be released elsewhere.

Summary: Emissions from the industrial processes sector

When considering emissions from the industrial processes sector, as with all sectors, they need to be considered in terms of their national and worldwide context. If we require cement, windows, metals or chemicals products, then the emissions associated with them will occur somewhere regardless the locations at which the products are used. Therefore, any emissions mitigation strategy needs to be considered in terms of what is practical. This will be determined by the cost and availability of mitigation technologies as well as alternative products. Removing the sites from a region may decrease regional and, potentially, national emissions, but their relocation elsewhere will have no effect on worldwide emissions and indeed it may even increase them particularly if they are situated in countries with a lower level of environmental regulation[12]. In addition, if these products are produced elsewhere, they may need to be transported back to the given region, which may further increase overall worldwide GHG emissions.

[12] This is regardless of the carbon implications associated with the construction of a new industrial plant

Agriculture

Emissions from agricultural soils and animal wastes are very important due to their contribution to overall GHG levels and, subsequently, calculation of emissions has been considerably extended. Generally speaking emissions of N_2O are most significant in this sector.

The largest source of agricultural methane emissions arise from enteric fermentation with emissions from animal wastes coming second. The levels of emissions in a given year are dependent on the number and type of farm animals, with dairy cattle being the most significant. The following paragraphs describe how the agricultural emissions have been estimated.

Enteric fermentation: methane is emitted directly from the animals themselves. These emissions have been estimated using GRIP level 1.

Manure management: methane emissions from manure management are considered separately to emissions from enteric fermentation, as the method by which the excreted waste is treated directly affects the emission level. Where the animal waste is deposited, it is directly related to the emissions levels. Separating the sources in this way also gives a more detailed picture of the agricultural sector. Emissions are calculated in much the same way as emissions from enteric fertilization. Here, there are two emissions factors, one relating to the animal (and the nitrogen and methane component of their waste), and one relating to the method of waste disposal. For the SC region the GRIP level 1 approach is used.

Agricultural soils: emissions from agricultural soils are considered in terms of the level of nitrogen applied to the soils through fertilizers. Fertilizer application rates are based on a study by the British Survey of Fertilizer Practice, and deemed to be similar across the pilot regions. This nitrogen is then considered in terms of where it is released including: direct emissions from soils; indirect emissions associated with atmospheric deposition; and nitrogen leaching and run-off.

Table 22: Agriculture Emissions the Four Regions

	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Kt CH_4	Kt N_2O	Kt CH_4	Kt N_2O	Kt CH_4	Kt N_2O	Kt $_{CH4}$	Kt N_2O
Enteric Fermentation	12.48		3.1		12.9		88	
Manure Management	1.76		0.43		2.7		15.11	
Animal Waste Management		0.07		0.3		0.2		1.21
Agricultural Soils		1.3		0.47		1.2		7.95
Total	14.24	1.37	3.53	0.77	15.6	1.4	103.11	9.16
Total GWP	733		309		773		5,083	

Interpreting the findings of the GRIP inventory

SC and other regional emissions from agriculture are displayed in Table 22 above. The results reflect both the region's economic share and past agricultural events: The emissions that do occur reflect the make up of the agricultural industry and the climate. The emissions in the SC region amount to 309kt CO_2 Eqv.

The results for the SC region have been estimated on the basis of provided agricultural census data and are bottom-up in nature. The calculations follow use GRIP level 1, and are therefore very accurate. However, as emissions factors have been used there is an inherent degree of uncertainty surrounding the accuracy of the values presented here. The emission factors assume an average animal weight and diet. or averaged fertilizer application rates per crop. Realistically, this is the only feasible method by which to calculate emissions on this scale, as measuring each animal's emission separately would be a costly process. The issue of uncertainty is addressed further in the final section.

Summary: Emissions from the agricultural sector

Agricultural emissions occur as the result of the activities that provide our sustenance and are an unavoidable aspect of our lives. We can, however, take steps to minimise them as well as emissions associated with them. However, wider understanding of agriculture is required, one that encapsulates regional, national and worldwide issues.

Being a series of regions within affluent westernised countries, we have become used to a year-round supply of agricultural produce that is out of synchronisation with our own production abilities. We have grown used to our trips to the supermarket yielding a plentiful supply of apples or bananas, no matter whether it is the middle of winter or at the height of summer. The origin of these products is normally portrayed in a positive light, and their availability a good thing even if they have been shipped or flown in from the other side of the world. This transportation would not occur if it were not for the demand for these products.

The levels of emissions from agriculture are climate-related, with particular crops, such as rice, only being produced in particular environments. Different levels of heat create different levels of emissions. Combating emissions from agriculture requires thought of both supply *and* demand. By creating a fixed year-round demand for agricultural produce, most particularly for perishable and air freighted goods e.g. exotic fruits, we are increasing worldwide carbon emissions from transport. The desire for such products is a fairly recent one that has developed as a result of cheaper transport[13] and has led to concern over 'foodmiles' (DEFRA 2005)

In principle future technologies may make it possible to grow products usually found in foreign climates in the Sweden and other technologies or agricultural systems may also eradicate the need for synthetic fertilizer use. But plans for mitigation should not rely on

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[13] The issue of transport becomes significantly less important if a non fossil fuel source is used.

technologies that have not yet been invented or verified as safe or feasible on a large scale. The approach to mitigation of emissions from agriculture probably requires a change in the demands of consumers and or a change in the way in which crops are grown. This inventory provides a baseline from which such futures may be considered.

Waste

The waste sector in the GRIP inventory covers emissions from landfill operations, as well as GHG releases from other waste treatment and disposal activities, such as waste incineration without energy recovery and sewerage treatment.

Under the GRIP methods, if any waste imported into the region for treatment or disposal gives rise to GHG releases, the emissions are assigned back to their original locality. And conversely, if any waste is exported by the region to other regions for treatment and disposal, the associated emissions are assigned to the focus region. In other words, the emissions are assigned to the region that produces the waste and not the region that treats it or disposes of it.

Landfill

Methane emissions from landfill sites occur as a result of the degradation of biodegradable waste, although some of this methane is recovered and put to other uses. Emissions are calculated on the basis of total waste deposited to landfill sites in a given year, in line with national and international standards. The SC region deposited emissions are calculated using emissions factors that assume a given level of methane recovery at the sites. This is based on GRIP level 3.

Waste incineration

In the GRIP inventory, GHG emissions associated with waste incineration are only considered if energy recovery does not take place. In particular, activities such as hospital waste incineration and crematoria (both human and animal) are the chief contributors to emissions as they have no energy recovery. Emissions from waste incineration without energy recovery are very small (due to EU directives), as table 23-24 show, accounting for just 16kt of CO_2 regionally.

Table 23: Waste Emissions Glasgow and Stockholm

	Glasgow			Stockholm		
Fuel	Kt CO_2	Kt CH_4	Kt N_2O	Kt CO_2	Kt CH_4	Kt N_2O
Solid Waste Disposal on Land		18.9			21	
Wastewater Handling		4.26	0.4			0.05
Waste Incineration	12.5			16		
Total	12.5	487	8.4	16	441	1.05

Table 24: Waste Emissions Bologna and Veneto

	Bologna			Veneto		
Fuel	Kt CO_2	Kt CH_4	Kt N_2O	Kt CO_2	Kt CH_4	Kt N_2O
Solid Waste Disposal on Land		9			28.1	
Wastewater Handling		1.7	0.05		8.84	0.3
Waste Incineration	3.1	0	0	16.02	0.01	0.04
Total	3.1	224.7	1.05	16.02	775	6.3

Waste incineration emissions (without energy recovery)

These emissions represent a very small proportion of overall emissions. By using quite a coarse scaling indicator such as population in a top-down approach, the results are rather uncertain. Grip level 3 method for this source was used.

Domestic and commercial waste water treatment

Emissions in this category emanate from the treatment of sewerage. They are dependant on the levels of nitrogen that are prevalent within the wastewater. This level of nitrogen is considered on the basis of the diets of individuals, even though it is emitted at the sewage treatment plants during the cleaning of water. The emissions associated with the energy component of this treatment are included under the services component of the energy section, although not explicitly stated. Table 22 shows that the SC region was responsible for 1.1kt of CO_2 Eqv in 2003.

Summary: Emissions from waste

Table 23 above outlines the level of waste emissions from each of the four pilot regions. The data shows that in terms of total GWP, the SC region emits a proportional amount of emissions to its population but this is due to the methodology used. This is due to its considerably larger propensity to landfill its waste. The region needs to take better account of its waste streams, not only because as a resource landfill sites are scarce and regulation is beginning to bite, but because emissions are far higher then they may otherwise be. With a greater propensity to incinerate, rather then landfill, emissions will be reduced. Not only will the more potent CH_4 emissions be considerably reduced, but the waste combusted will also displace the fossil fuel that would otherwise be combusted to produce the electricity.

The treatment of municipal solid waste needs to be considered in a wider context that includes the use of Life Cycle Analysis (LCA) to ascertain the best approach for waste treatment. There are many studies that have already been performed in this area that can be used in conjunction with the regional inventory by policy makers to judge the best approach. (eg. DEFRA) In terms of emissions reduction, incineration for energy recovery appears the best way forward.(ibid)

With respect to emissions emanating from wastewater, a change in N_2O and CH_4 emissions would require either a change in human diet or a change in the way in which the wastewater is treated.

There are two ways to minimise emissions from waste treatment: by changing the disposal method chosen; and by changing the packaging and composition of products. The former is the responsibility of regional, local and national government; the latter is the responsibility of national governance and international bodies, such as the EU.

Inventory Summary

The inventory presented here represents the most detailed ever carried out for an on this scale. The methods allow direct comparability with each region, the validity of such comparisons will increase over time and as more regions partake. The results here are based on calculations that use the best data currently available. The results show the relative contributions of the energy sector, industrial processes sector, agriculture and waste sector to emissions within the four regions.

The SC inventory is based on a large number of variables from a wide variety of sources. The base data has been chosen to fall in line with the GRIP standards. The GRIP standards, are formed on the basis of a detailed understanding of the four pilot regions national inventory's, international standards for inventory calculation as well as various previously applied local and regional approaches to GHG inventory formation.

While the inventory is end user focused it encompasses all areas of the energy system in SC and each part's contribution to emissions. Other sectors related to emissions, such as waste, agriculture and industrial processes, are dealt with in detail, delivering a comprehensive inventory that provides stakeholders with emissions estimates.

Below table 25 provides an overview of emissions from the SC Region in the year 2003 across all sectors. The table is divided into the six greenhouse gases studied.

Table 225: Total Emissions Stockholm County

	Stockholm County							
Source		Kt $_{CO2}$	Kt $_{CH4}$	Kt N_2O	Kt HFC	Kt PFC	Kt Sf_6	GWP_{100}
Energy	Total	6,847	1.5	0.36				6,987
Domestic		1,211	0.55	0.13				1,261
Industrial		874	0.26	0.06				898
Services		746	0.58	0.14				800
Energy Transformation								0
Energy Industry Own Use								0
Fugitive Emissions		108						108
Other		64	0.01	0.00				65
Transport		3,767	0.1	0.03				3,854
Industrial Processes	Total	0	0	0	289	0.39	0	322
Waste	Total	16.15	20.99	0.05				750
Agriculture	Total		3.1	0.5				606
Total		6,786	25.59	0.91	289	0.39	0	8,664
Population (thous)		1,889						
Per Capita (tonnes)		3.6	0.01	0.00048	0.15	0.000	0	4.6
GVA €m		10,779						
Per Unit GVA		0.63	0.002	0.00	0.03	0.000	0	0.8

The table 25 shows that the consumption, extraction and transformation of energy within the region in 2003 produced 6,987kt CO_2 Eqv, comprising: 1,261kt CO_2 Eqv from domestic energy consumed; 898kt CO_2 Eqv from industry energy consumed; 800kt CO_2 Eqv from services energy consumed; 108kt CO_2 Eqv from energy consumed in the energy industry and emissions from fugitive sources; and 3,854kt CO_2 Eqv from transport. Table 25 shows that the SC is responsible for a low level of industrial process emissions. Emissions from waste on a per capita basis are in line with the national average. This is due to the region's assumed commonalities in waste disposal methods. Better data sets will uncover how accurate this is. The high proportion of dairy farming that takes place in the SC is the main contributor to regional agricultural emissions, which is reflected in the proportion of the emissions emanating from animals in the region against those occurring from agricultural soils. Overall emissions from the region work out at 4.6t per person, this is inline with the national average and reflects the regions economic make up. The region is be far the lowest emitting, this is primarily driven by its higher propensity to combust biomass rather than fossil fuels.