Bologna Province GHG Emissions in the Year 2004

Introduction

In this report, we present a GHG emissions inventory for the region: Bologna for the year 2004. 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 most detailed account of GHG emissions on this performed thus far for the region.

Background

The inventory for Bologna covers estimates of emissions occurring in the year 2004, the most recent year for which data was available. This inventory includes the six main greenhouse gas emissions that emanate from the energy, industrial processes, waste and agricultural sectors[1]. 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 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 have been sourced locally by the partner region. This data, together with a range of emissions factors taken from GRIP[2], are used to form this emissions inventory that covers the six GHGs included in the Kyoto protocol. For

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[1] 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.

[2] Sourced from international standards

comparison and clarity in this chapter, greenhouse gas emissions are presented across the four participating 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 Bologna region.

The Bologna Province in the year 2004: Geographical features

The Region covers an area of 140 sq km [3] and sits within the region of Emilio-Romagna. There are 0.46m households within the region. The population of the region in the year 2004 stood at 0.9m

Bologna Province in the year 2004: The economy

The Gross Domestic Product (GDP) of the region in the year 2004 was valued at €29.4Bn. This relatively low level of economic activity equated to GDP per capita of €32,142, above the Italian average of €22,678. Employment figures for the region show that approximately 3,900 people were unemployed in the year 2004, accounting for 0.8% of the total working population and that there had been an downward trend in this value. The levels of economically active individuals fluctuated between the province and Emilia-Romagna.

Statistics from the eurostat show that there was an upward trend in regional Industrial and Service related employment between 1995 and 2004. Whilst the numbers employed in the agricultural sector declined in the same period. The relative size of these sectors is important within a GHG inventory, the service sector for example is by its nature less

[3] approximately 0.5% of the Italian land mass.

energy intensive[4] than its industrial counterparts. The lower the consumption of fossil fuels, directly or indirectly by a sector – the lower the emissions (energy intensity and carbon intensity are generally heavily linked). These links must be understood when making year-on-year comparisons of emissions change.

The Bologna Province in the year 2004: Industry and services

There is limited data available regarding Bologna Province and we therefore focus on Emillia Romagna as a whole. The level of economic activity within the region is 25% above the Italian average and this partly due to the Bologna Province. The economy within Emillia Romagna has changed greatly, from one that was agriculturally dominated to one that is dominated by the service industry (62% of GDP). The region continues to house a large amount of heavy and polluting industrial activity (34% GDP).

In the year 2004, the region accounted for just under 10% of Italy's manufacturing output. Different industrial sectors and activities have differing levels and types of emissions associated with them. Some industries are prominent as highly carbon- and energy-intensive (iron and steel, for example) due to the fuels that they consume. Other industrial groups (such as minerals and chemicals, for example) are also associated with high levels of "process emissions". Process emissions occur as a result of the nature and rate of a given activity and may result from, among other possibilities, chemical reactions or as a direct consequence of product use. In order to compile a representative emissions inventory for the region that is comparable to national inventory reporting standards, process emissions and emissions produced as a direct result of fuel use are considered separately.

[4] 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 Bologna Province in the year 2004: 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 has two main airports serving it. These are Bologna, and Bologna Forli. The main railway line departing from the region is electrified, which presents less direct emissions than a non-electrified route. The Bologna province holds both the most important motorway and rail interchanges in Italy. These carry the majority of traffic passing between north and south Italy. In fact of the 1,080 industrial areas within the region 85% of them are within 8km of the principal road network.

The Bologna Province in the year 2004: Agriculture

The region has an agricultural industry which in 2004, held approximately 4% of the regions GDP. Changes to farming practices have had a subsequent effect on releases of methane (CH_4) and nitrous oxide (N_2O) from the agricultural sector. The dairy sector accounts for the larger economic part of the agricultural sector in the region[5] and emissions.

The Bologna Province in the year 2004: Waste

How waste is handled and disposed of is a key issue for policy makers in the across the EU[6]. 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

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[5] In terms of wealth creation.

[6] These concerns operate beyond the climate change field.

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 Bologna Province (BoP) 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 Bologna Province 2004: An overall view

The energy sector, including transport and fugitive emissions, accounts for 99.9% of regional CO_2 emissions (8,175kt[7] CO_2), with CH_4 and N_2O emissions adding an

[7] kt = thousand tonnes

additional 226kt CO_2 Eqv, making a total of 8,401kt CO_2 Eqv for the year 2004. Chart 1, below, shows the breakdown of Bologna GHG emissions, from the energy sector in the year 2004.

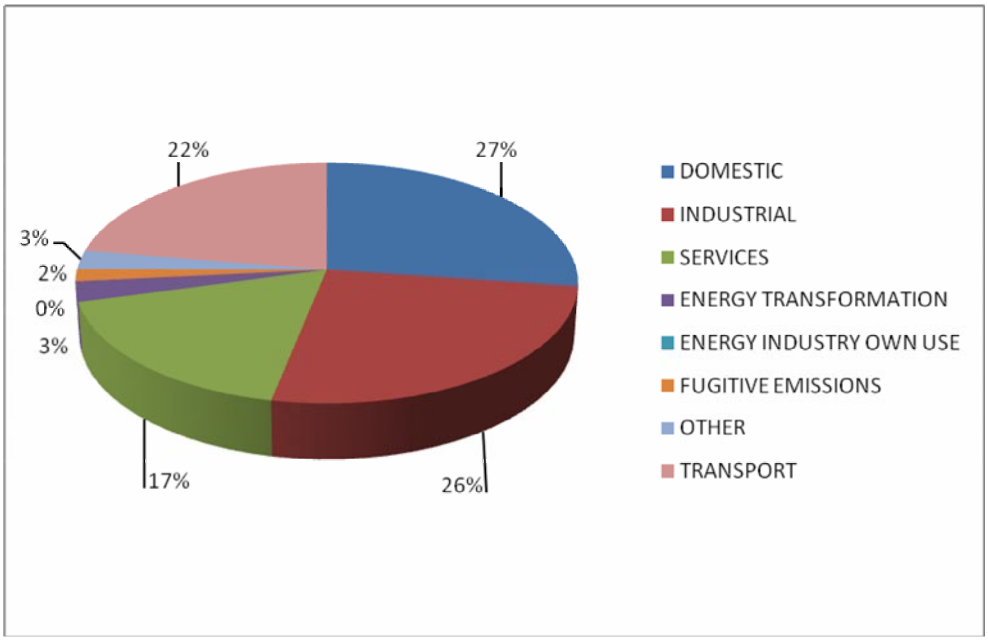

Chart 1: Bologna Province Carbon Dioxide Emissions 2004 (total 8,401kt)

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 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 2004 were estimated to be 2,265kt CO_2. Table 1 below shows how these emissions are comprised in terms of fuel type regionally together with the CO_2

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equivalent values. Chart 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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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

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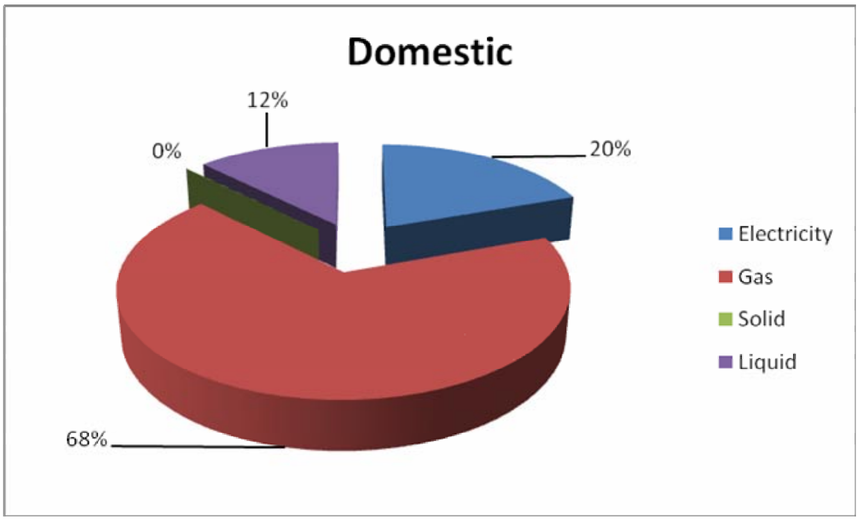


Chart 2: Bologna Province domestic fuel carbon dioxide emissions 2004 (total 2,265kt)

When coupled with the Global Warming Potentials (GWP_{100}) of CH_4 and N_2O from the domestic consumption section, total emissions are 2,310kt 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.

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. The figures show that emissions per household are the second lowest of the four regions at 4.9t CO_2, compared to Stockholm's 1.36t, and that domestic emissions per person are 2.47t CO_2 regionally compared to the Veneto region emissions of 2.3t per household.

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. The data presented here, although the best available for the year 2004, does have some associated uncertainties. The data contained here is based upon consistent data sets taken from the partner region relating to regional energy consumption, they are therefore the best available. However there may be 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.

Total emissions from the commercial, public administration and agricultural sectors in BoP for the year 2004 were estimated to be 1,565kt CO_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	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	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-energy intensity) and industry (high-energy intensity). In particular, the data clearly illustrates how much more the industrial sector emits than the service industry. 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, in terms of carbon intensity, 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. This is because the data is not always at the same level of detail. Some of the figures displayed above use the apportionting 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 Bologna.

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 within industry are presented. Total emissions from the industrial sector in the BoP for the year 2004 were estimated to be 1,808kt CO_2. Note that these emissions they do not include emissions from industrial processes. These emissions are also represented graphically in chart 2-4 below. The latter process emissions are considered in section (of which there is very few in the BoP region)

Table 4: Iron and Steel 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	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Electricity	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 CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
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	4,981	1,296	1,568	223	2,826	792	18,292	5,371
GVA Industry €m	10,450		10,779		8,669		41,165	
Per Unit GVA	0.476	0.124	0.145	0.021	0.33	0.1	0.44	0.13

Chart 2: Glasgow Industrial Energy Emissions by Fuel Type

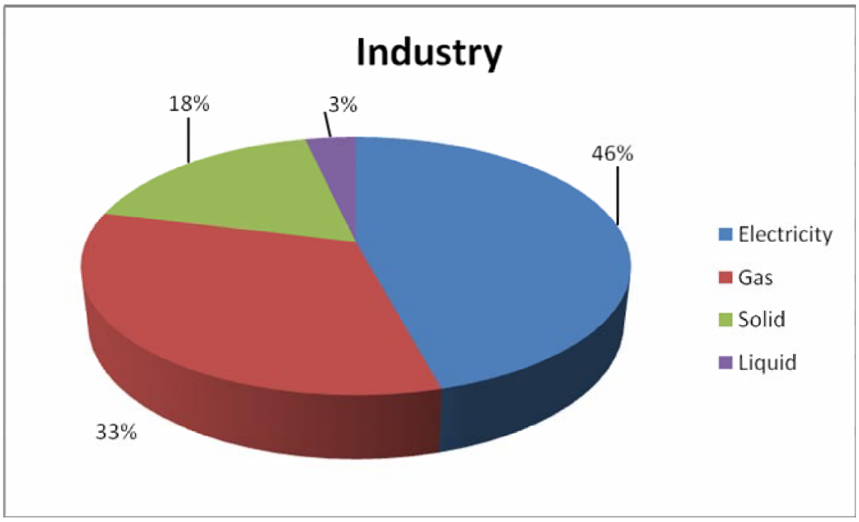
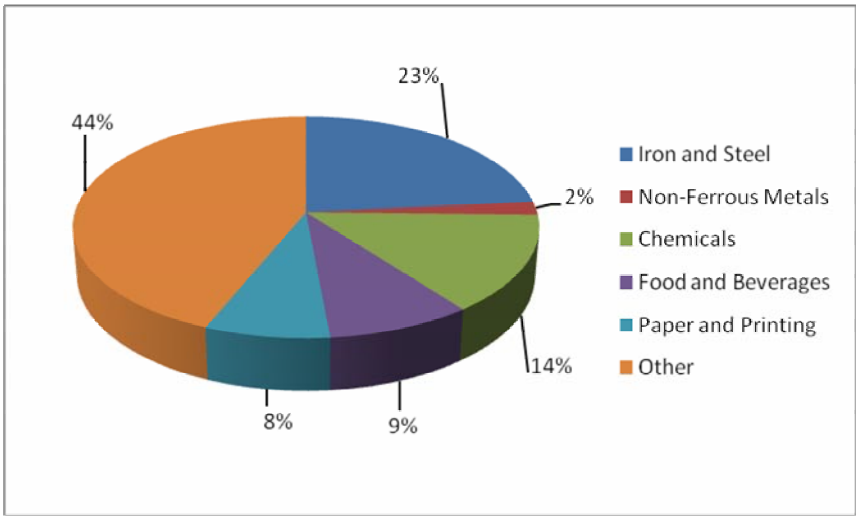


Chart 3: Bologna Province Split Industrial Emissions by sector 2004



Interpreting the findings of the GRIP inventory

The results for industrial energy emissions offer some surprises as, in advance of this study, a higher rate of energy consumption and emissions was expected for the region. The BoP region emits the second lowest amount of emissions from industry per unit of GVA of the four regions, this is determined by the nature and type of industry. 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 1&2 methods 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 BoP 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; and Electricity consumption at power stations

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. There is however coal extraction taking place in the GCV region, in fact 15% of the UK's coal extraction comes from this region. There is also some electricity consumed at the pumped storage station within the region, as this site consumes electricity – the emissions associated with that consumption are allocated to the region.

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 data shows that the BoP is at the lower end of the industrial emissions scale of the four regions. This does not mean the region is "better" as the impacts of the consumer choices in the region may lead to emissions elsewhere – which are not accounted for here. 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 varies as they have all been estimated using a mixture of GRIP level 1 & 2. However, because of the nature of this sector uncertainties can fluctuate each year.

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.

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.

Fugitive emissions using GRIP

Using the methodology above, in conjunction with the listed data sources, total emissions from other energy sources in the BoP region for 2004 were estimated to be 272kt CO_2 Eqv[8]. (please note the figures below are the CO_2 equivalent) The table below shows the breakdown per fuel type.

[8] Calculated using GWP_{100} values

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[9], 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 second largest proportion of emissions in BoP with 2,159kt CO_2 in 2004 (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 BoP is based upon data sets taken from the partner region, the figures are the best and most consistent available, however the data may 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.

[9] A generic name that covers unleaded petrol, lead replacement petrol (LRP) and Four Star), liquid petroleum gas (LPG) and DERV.

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 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 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[10]. 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 BoP railway network is predominantly electrified, with a few diesel trains still running.

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[10] 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.

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

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

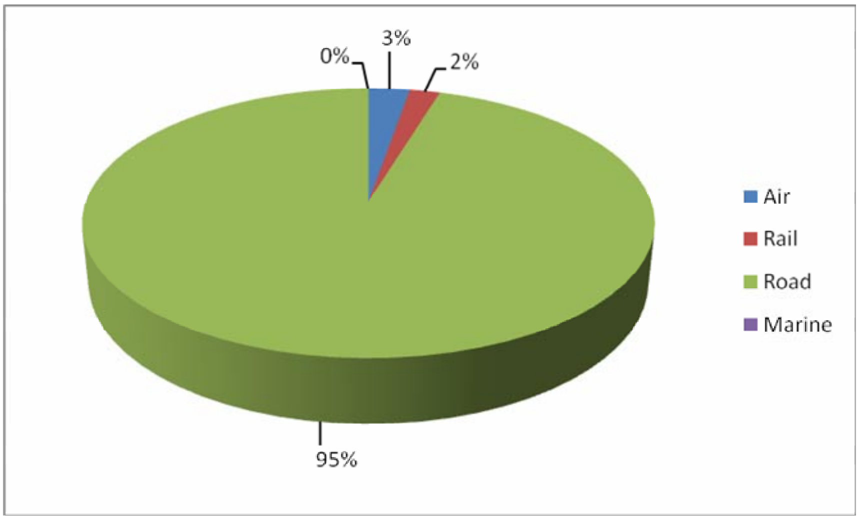
	Glasgow		Stockholm		Bologna		Veneto	
Fuel	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2	Consumption (GWh)	Kt CO_2
Diesel/Marine Diesel	101	26.47	767	202	0	0	2,085	559
Total	101	26.47	767	202	0	0	2,085	559

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 BoP 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 BoP inventory due to the relationship between inhabitants and airports.

Chart 4: Emissions from 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 value for Bologna may be higher then expected as it is a transportation hub. This is higher then its population would indicate. 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.

Summary: Emissions from the energy sector

In this section, we have presented the emissions associated with the energy sector in the BoP region in the year 2004. 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
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.

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 GCV 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 17. According to communication within the BoP, 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 CO_2	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 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	N/O	N/O	N/O	289	0.4	0.001

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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

	Veneto					
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 GCV 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[11]. 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.

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, for example N_2O emissions from agricultural soils currently account for around 65% of total UK emissions of N_2O, which mostly result from fertilizer application.

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

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

one relating to the method of waste disposal. For the BoP 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 CH_4	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

Interpreting the findings of the GRIP inventory

The BoP and other regional emissions from agriculture are displayed in Table 22 above. The results reflect the region's agricultural shares: the region's agricultural sector has been shaped by governmental legislation, international competition and more recently events such as Foot and Mouth and BSE. The emissions that do occur reflect the make up of the agricultural industry and the climate. The emissions in BoP amount to 705kt CO_2 Eqv.

The results for the BoP region have been estimated on the basis of agricultural data provided by the partner region 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 difficult 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[12] 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 Italy, and other technologies or agricultural systems may also eradicate the need for synthetic fertilizer use. But plans for mitigation should not rely on 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.

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

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 BoP 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 3kt 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 BoP region was responsible for 246kt of CO_2 Eqv in 2004.

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 BoP 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. This category is relatively small nationally.

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 BoP 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 the BoP 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 that are the most accurate to date in any regional inventory.

Below table 25 provides an overview of emissions from BoP in the year 2004 across all sectors. The table is divided into the six greenhouse gases studied.

Table 225: Total Emissions Bologna

	Bologna							
Source		Kt CO_2	Kt CH_4	Kt N_2O	Kt HFC	Kt PFC	Kt Sf_6	GWP_{100}
Energy	Total	8,175	5.83	2				8,928
Domestic		2,265	0.1	0.55				2,438
Industrial		1,809	0.12	0.3				1,904
Services		1,341	0.08	0.4				1,467
Energy Transformation		220	0.02	0.15				267
Energy Industry Own Use			0.00	0.01				
Fugitive Emissions		157	5	0.09				274
Other		224	0.01	0.5				250
Transport		2,159	0.51	0.03				2,326
Industrial Processes	Total	0	0	0	69	3	0	72
Waste	Total	3	11	0.06				273
Agriculture	Total		13	1.43				726
Total		8,178	29.84	3.52	69	3	0	9,997
Population		915,225						
Per Capita (tonnes)		8.9	0.03	0.004	0.08	0.003	0	10.9
GVA €m		29,428						
Per Unit GVA		0.28	0.001	0.0001	0.002	0.0001	0	0.34

The table 25 shows that the consumption, extraction and transformation of energy within the region in 2004 produced 9,997kt CO_2 Eqv, comprising: 2,438kt CO_2 Eqv from domestic energy consumed; 1,904kt CO_2 Eqv from industry energy consumed; 1,467kt CO_2 Eqv from services energy consumed; 530kt CO_2 Eqv from energy consumed in the energy industry and emissions from fugitive sources; and 2,326kt CO_2 Eqv from transport. The figures show that, at a disaggregated level the BoP is just under national trends. However, domestic emissions regionally are higher relative to the rest of the UK.

Table 25 shows that the BoP 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 dairy farming that takes place in the BoP 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 10.9t CO_2 eqv per person.