Application of PAS 2070 – London, United Kingdom

An assessment of greenhouse gas emissions of a city

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1 PAS 2070

1.1 What is PAS 2070?

PAS 2070 [1)] is a specification that sets out requirements for the assessment of greenhouse gas (GHG) emissions of a city or urban area. PAS 2070 captures both direct GHG emissions – from sources within the city boundary – as well as indirect GHG emissions – from goods and services that are produced outside the city boundary for consumption and/or use within the city boundary – using two distinct methodologies. These recognize cities as both consumers and producers of goods and services, and provide a complementary insight of a city's GHG emissions. The GHG emissions assessment methodologies are:

a) a direct plus supply chain (DPSC) methodology;

b) a consumption-based (CB) methodology.

PAS 2070 is for use by organizations or people assessing GHG emissions of a city or an urban area, such as municipal or national governments, academic researchers, consultants, and others, and is intended for international application.

This guide explains how to apply the standard to measure city-wide GHG emissions, and account for both inboundary (direct) and out of boundary (indirect) GHG emissions, using London, United Kingdom as an example.

1.2 Why should I use PAS 2070?

Making cities more sustainable is among the most important challenges of the 21st century. Cities exert a significant impact on the natural environment and are particularly vulnerable to environmental change. When it comes to tackling climate change, therefore, cities play a key role. The ability of city leaders and other stakeholders to take effective action depends on access to good quality data on GHG emissions. Measurement enables cities to assess their risks and opportunities, create a strategy to reduce GHG emissions in a quantifiable and transparent way, and track their progress.

Many cities around the world have already developed GHG inventories and are disclosing these publicly [2), 3)]. However, existing GHG accounting methodologies used by cities are variable. They cover different scopes and have important methodological differences, making comparisons between cities difficult. To allow for credible reporting and meaningful benchmarking of climate data, greater consistency in GHG accounting is required.

PAS 2070 responds to this challenge by providing a robust and transparent method for consistent, comparable and relevant quantification, attribution and reporting of city-scale GHG emissions, following internationally recognized GHG accounting and reporting principles. It specifies requirements for identifying the assessment boundaries, the sources of GHG emissions to be included, the data requirements for carrying out the analysis, and the calculation of the results to develop a city-scale GHG inventory.

Using PAS 2070 allows cities to take a more holistic approach to measuring GHG emissions, assess the carbon dependence of the local economy, and help to realize opportunities for more efficient urban supply chains. And as more cities use PAS 2070, benchmarking will yield further insight into the sources and drivers of urban GHG emissions.

1) PAS 2070:2013+A1:2014, Specification for the measurement of greenhouse emissions of a city – Direct plus supply chain and consumption-based methodologies.

2) CDP. *Measurement for Management: CDP Cities 2012 Global Report*. New York and London: CDP, 2012. Web published at: www.cdproject.net/en-US/Programmes/Pages/CDP-Cities.aspx

3) Carbon*n* Cities Climate Registry: http://citiesclimateregistry.org

1.3 The methodologies

Direct plus supply chain (DPSC) methodology

The DPSC methodology captures territorial GHG emissions and those associated with the largest supply chains serving cities, many of which are associated with city infrastructures. It covers direct GHG emissions from activities within the city boundary and indirect GHG emissions from the consumption of grid-supplied electricity, district heating or cooling, transboundary travel and the supply chains from consumption of key goods and services produced outside the city boundary (e.g. water supply, food, building materials).

The DPSC methodology builds on the *Global protocol for community-scale greenhouse gas emissions* (GPC) [4] developed by the World Resources Institute (WRI), C40 Cities Climate Leadership Group and ICLEI Local Governments for Sustainability to include a wider range of indirect GHG emissions, and is consistent with emission sources covered by the GPC.

Consumption-based (CB) methodology

The CB methodology captures direct and life cycle GHG emissions for all goods and services consumed by residents of a city, i.e. GHG emissions are allocated to the final consumers of goods and services, rather than to the original producers of those GHG emissions. The CB methodology does not assess the impacts of the production of goods and services within a city that are exported for consumption outside the city boundary, visitor activities, or services provided to visitors.

A purely territorial accounting methodology, which focuses on all GHG sources within the city boundary, is not provided in PAS 2070, but these GHG emissions can be calculated as a subset of the DPSC methodology.

[4] World Resources Institute, C40 Climate Cities Leadership Group, and ICLEI Local Governments for Sustainability (2014). *Global protocol for community-scale GHG emissions* (GPC) version 2.0. Web published at: www.ghgprotocol.org/city-accounting

2 Introduction

2.1 Why this guide?

This guide provides a detailed case study of the application of PAS 2070 to London in order to assist users and provide clarity on specific technical aspects of PAS 2070 and how to use it in practice. It is intended to be used alongside PAS 2070, not replace it. It includes guidance on data collection, quantifying emissions, and provides a template for reporting.

This guide presents the assessment results for London of the DPSC and CB methodologies. Assessment results of the DPSC methodology are broken down by the categories listed in Table 1. Assessment results of the CB methodology are broken down by consumption expenditure categories.

Table 1 – PAS 2070 GHG emission sources categories

PAS 2070 category		IPCC sector	
A	Stationary sources of GHG emissions	1A, 1B	Energy
B	Mobile sources of GHG emissions		
C	Industrial processes and product use	2	IPPU
D	Agriculture, forestry and other land uses (AFOLU)	3	AFOLU
E	Waste and wastewater treatment	4	Waste
F	Goods and services – water provision, food and drink and construction materials	5	Other

2.2 Process

Each section of the DPSC methodology is set out according to the following series of sequential steps which demonstrate the process of conducting a GHG assessment as given in Table 2.

Table 2 – Process for determining GHG emissions

Process		Task
1	Define assessment boundary	• Agree system boundary • Draw process map
2	Data collection	• Collect primary and secondary data • Assess data quality
3	Emission factors	• Identify sources of emission factors • Check time and geographic relevance
4	Calculation	• Multiply activity data by emission factors to generate GHG assessment • Allocate emissions according to scope

The equation for estimating GHG emissions is: activity data multiplied by an emission factor.

Activity data is a quantitative measure of a level of activity that results in GHG emissions, such as the combustion of a given amount of coal at a power station, or the number of cows.

An **emission factor** is a measure of the mass of GHG emissions relative to a unit of activity.

For example, estimated GHG emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor (kgCO_2e/kWh) for electricity, which will depend on the type of fuel used to generate the electricity.

2.3 Data quality

Significant amounts of data need to be collected to conduct a GHG assessment. This data will vary in quality, format and completeness and, in many cases, will need to be adjusted for the purposes of the assessment. Particular challenges are associated with the attribution of transboundary emissions and reducing the spatial area of analysis to the city where national or regional data is used.

PAS 2070 recognizes these challenges. It sets out data quality rules that take a pragmatic approach to data collection and analysis (PAS 2070:2013+A1:2014, **6.1**), and allow for multiple sources of activity data and emission factors to be used (PAS 2070:2013+A1:2014, **6.1** and **6.3**).

2.4 Notation keys

To accommodate limitations in data availability and differences in emission sources between cities, PAS 2070 encourages the use of notation keys and accompanying explanation to justify exclusion or partial accounting [5)]. The notation keys are described in Table 3 (see also PAS 2070:2013+A1:2014, **9.6**). These have been used as appropriate in this assessment.

2.5 Scopes

GHG emissions of organizations are generally categorized as Scope 1, Scope 2 or Scope 3 emissions. These categorizations are based upon where the GHG emissions arise and their relationship with the inventorying body. Such definitions are important for the attribution of GHG emissions that occur outside the city, to activities within the city boundary. The DPSC methodology uses the definitions for Scope 1, Scope 2 and Scope 3 emissions adapted from the GHG Protocol and as adopted for community-scale use in the GPC [6)]. These are given in Table 4.

Figure 1 provides an overview of emission sources in relation to scope and illustrates the life cycle perspective taken for the assessment of goods, services and activities. The adapted scope definitions cannot be applied when calculating the consumption-based emissions using the CB methodology as the data are aggregated across scopes.

2.6 Double counting

The need to avoid double counting of GHG emissions is set out in PAS 2070:2013+A1:2014, **9.3**. In this case study, all emissions sources are calculated and reported by (sub) sector. Where GHG emissions are shown in brackets this indicates that they are included and counted elsewhere in the assessment.

[5)] Adapted from IPCC (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. Web published at: www.ipcc-nggip.iges.or.jp/public/2006gl/index/html

[6)] World Resources Institute, C40 Climate Cities Leadership Group, and ICLEI Local Governments for Sustainability (2014). *Global protocol for community-scale GHG emissions* (GPC) version 2.0. Web published at: www.ghgprotocol.org/city-accounting

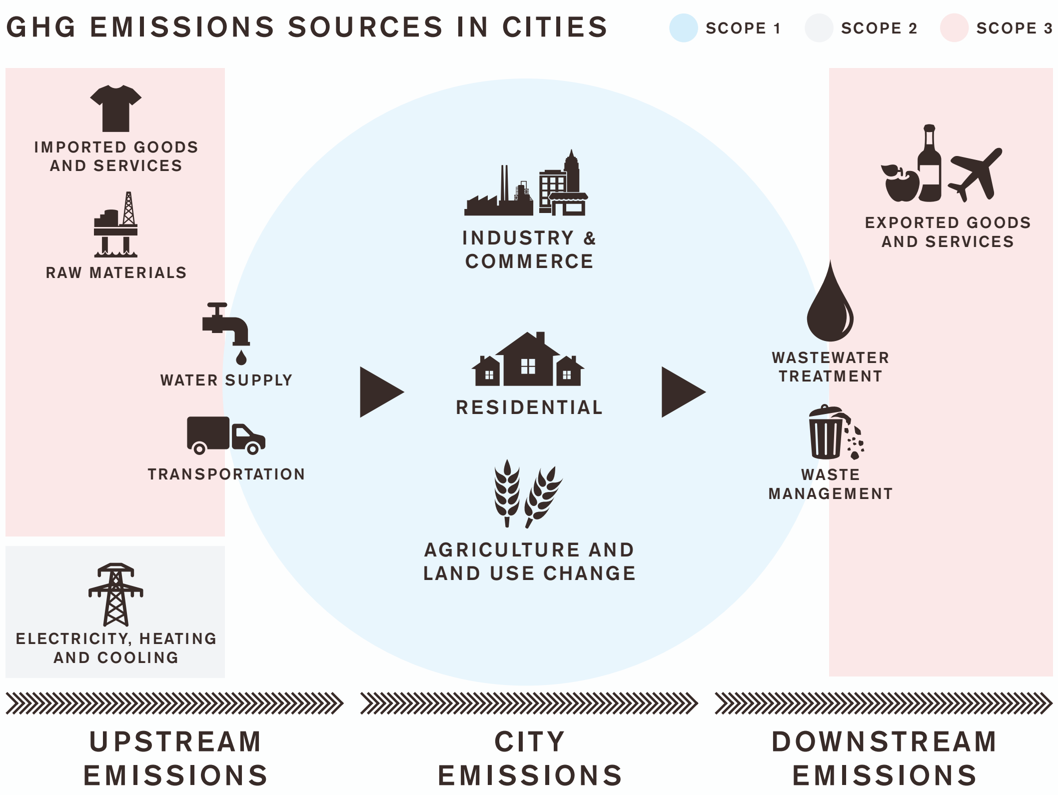
Table 3 – Use of notation keys

Notation key	Notation	Description
IE	Included elsewhere	GHG emissions for this activity are estimated and included in the inventory but not presented separately in the category. The category where these GHG emissions are included should be noted in the explanation.
NA	Not applicable	The activity exists but relevant GHG emissions are considered never to occur. Explanation should be provided as to why the category activity occurs, but GHG emissions do not.
NO	Not occurring	An activity or process does not exist within the community.
NE	Not estimated	GHG emissions occur but have not been estimated or reported. GHG emissions sources not estimated should note justification for exclusion.

Table 4 – City scope definitions

Emissions scope	Definition
Scope 1	All direct GHG emissions sources from activities taking place within the city boundary
Scope 2	Energy-related indirect GHG emissions that result as a consequence of use of grid-supplied electricity, district heating or cooling, within the city boundary
Scope 3	All other [i.e. other than Scopes 1 and 2] indirect GHG emissions that occur as a result of activities within the city boundary

Figure 1 – GHG emissions sources in cities in relation to Scope 1, 2 and 3



[SOURCE: PAS 2070:2013+A1:2014]

3 Case study: London

3.1 Background

Since 2004, London has produced an annual inventory of GHG emissions to support the Mayor of London's Climate Change Mitigation and Energy Strategy by providing an evidence base to measure impact, design interventions and track progress in a quantifiable and transparent way. Previously the inventory – the London Energy and Greenhouse Gas Inventory (LEGGI) – covered Scope 1 and Scope 2 carbon dioxide (CO_2) emissions only from the combustion of energy used within the city boundary: (a) for transport; and (b) to power and heat homes/workplaces.

However, the vitality of a city like London – and other large cities – inevitably gives rise to the production of GHG emissions beyond its boundaries. Research by the London Sustainable Development Commission and Bioregional in 2009[7] estimated London's consumption-based GHG emissions, and highlighted the need to include a wider range of emission sources in London's GHG inventory. In response the Mayor of London committed to conducting a more complete assessment of London's GHG emissions[8]. This case study shows the results of that assessment.

3.2 Assessment

The assessment of London's GHG emissions has been verified by Best Foot Forward (part of the Anthesis Consulting Group PLC), an independent third-party certification body, and found to be in compliance with the principles and requirements of PAS 2070.

Figure 2 – Location of London, United Kingdom

[7] *Capital Consumption*. London Sustainable Development Commission and Bioregional, 2009. Web published at: www.londonsdc.org/documents/research/Capital%20Consumption.pdf
[8] *Delivering London's Energy Future: The Mayor's Climate Change Mitigation and Energy Strategy* (Action 17.3). GLA, 2011. Web published at: www.london.gov.uk

For further detail on the verification, see:
Best Foot Forward *GLA80512: Third party verification of London's GHG assessment using PAS2070*, 2014.
Web published at: http://www.london.gov.uk

To ensure full transparency and reproducibility, all data sources and emission factors used in the London case study, as well as the assumptions and calculations made when compiling the estimates (PAS 2070:2013+A1:2014, **6.4**), are identified and referenced in the accompanying data spreadsheet *London GHG emissions using PAS 2070, 2010* available from the London Datastore [9].

Activity data used for this assessment have been selected from a variety of sources, based on availability of data, time- and geographical-specificity to the assessment boundary and credibility of the source. In general, preference is given to city-specific data published by official government sources.

Where the best available activity data do not align with the time period of the assessment, or the geographical boundary of the city, the data have been adapted to meet the assessment boundary by adjusting for changes in activity using a scaling factor, such as population. Calendar year data have been used whenever possible, however, where these are unavailable, other types of annual year data have been used, primarily non-calendar fiscal year data (April to March).

Most emission factors used in this case study come from the UK government's *GHG Conversion Factors for Company Reporting* (hereafter referred to as the *UK GHG Conversion Factors*), which represents the official set of UK government emissions factors. These are based on the default emission factors used in the UK GHG Inventory for 2010 [10], and use global warming potential factors from the IPCC's second assessment report.

For further information on the methodological approach, key data sources and the assumptions used to define the emission factors, see: *Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors*.
Defra, 2013. Web published at: www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-business

An indicative assessment of data quality for each emission source is included, which identifies data quality as high, medium or low according to the criteria set out in Table 5 (PAS 2070:2013+A1:2014, Note 2 to **6.1.2**).

Table 5 – Data quality assessment

Data quality	Definition
High	Detailed activity data and specific emission factors
Medium	Modelled activity data using robust assumptions and more general emission factors
Low	Highly-modelled or uncertain activity data using default emission factors

All GHG emissions data are reported as metric tonnes of CO_2 equivalent (CO_2e) [11], and include the six main gases under the Kyoto Protocol (PAS 2070:2013+A1:2014, **4.1**) where these gases are emitted and unless otherwise specified.

The assessment boundary (PAS 2070:2013+A1:2014, **5**) and supplementary data to provide context (PAS 2070:2013+A1:2014, **9.5**) are given in Table 6.

[9] http://data.london.gov.uk. In accordance with the requirements of PAS 2070:2013+A1:2014, **6.5** the data will be maintained for a minimum of three years.

[10] Upstream GHG emissions are based on the European JRC Well-To-Wheels study: Joint Research Council (2011). *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context* [EUR 24952 EN – 2011]. Web published at: http://ies.jrc.ec.europa.eu/uploads/media/WTT_Report_010307.pdf

[11] CO_2e is a universal unit of measurement that allows the global warming potential (GWP) of different GHGs to be compared. Individual GHGs are converted into CO_2e by multiplying by the 100-year GWP coefficients in the IPCC Guidelines.

Table 6 – Assessment boundaries and supplementary data

Assessment boundaries		Source
Name of city	London	N/A
Country	United Kingdom	N/A
City boundary	Greater London (hereafter referred to as London)	Local Government Commission for England (1998). *Final recommendations: electoral areas for the assembly of the Greater London Authority* [12)
Land area	1 573 km^2	The Times (2010). *Atlas of Britain*, Times Books, London
Time period of assessment	2010 (January – December)	

Supplementary data		Source
Resident population	8 061 500 (2010)	ONS (2013) mid-year population estimates [13)
Number of people working in the city who are not residents	796 333 (2010)	ONS (2013). *Annual Population Survey commuter flows, local authorities in Great Britain, 2010 and 2011* (Table 2) [13)
GDP	US$ 751.8 BN (2010)	McKinsey & Company (2012). *Urban world: Cities and the rise of the consuming class* [14)
Average annual temperature	9.41 °C (2010)	Met Office (2013). *Regional values – Annual 2010* [15)

12) www.lgbce.org.uk/__documents/lgbce/all-reviews/south-east/greater-london/greater-london-authority/gla-greater-london-authority-final-recs-nov1998.pdf
13) www.ons.gov.uk
14) www.mckinsey.com/insights/urbanization/urban_world_cities_and_the_rise_of_the_consuming_class
15) www.metoffice.gov.uk/climate/uk/summaries/2010/annual/regional-values. Note, data is for South East and Central South England.

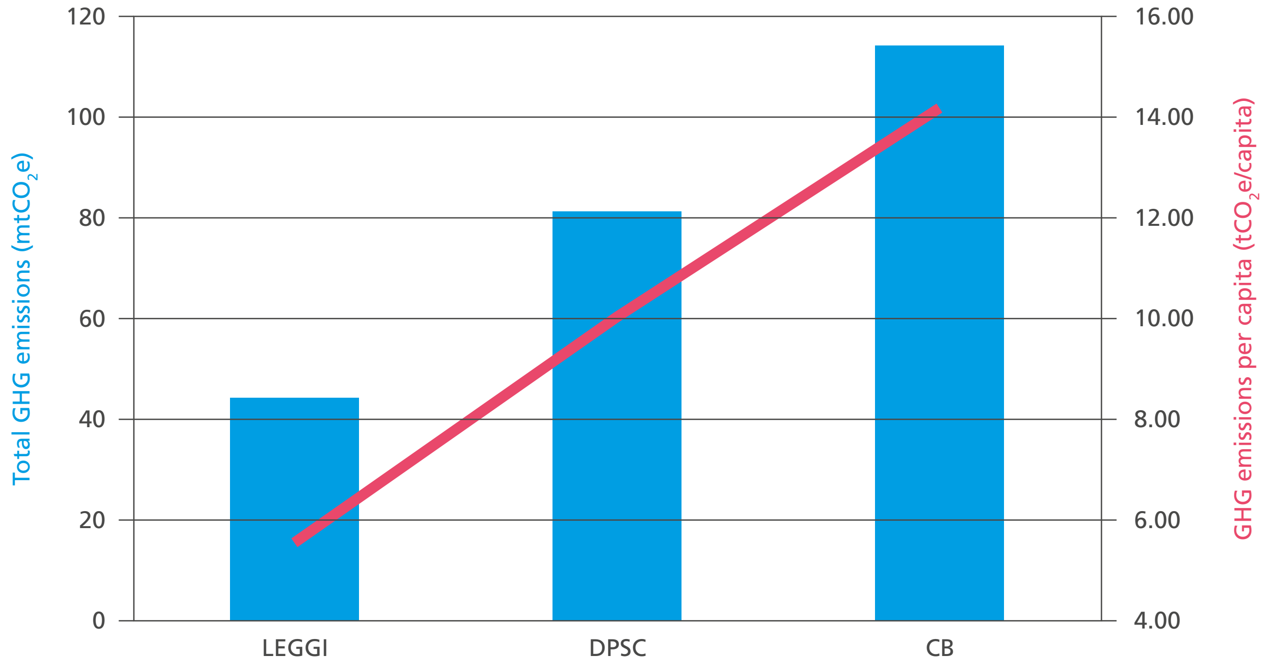
3.3 Summary of results

Table 7 shows the total GHG emissions of London using the DPSC and CB methodologies, and compares them to results calculated previously using LEGGI. The difference in GHG emissions is a reflection of the different emission sources, scopes and GHGs covered by the various methodologies.

Table 7 – High level comparison of total GHG by methodology

Methodology	LEGGI [16]	Direct plus supply chain (DPSC)	Consumption-based (CB)
Emission sources	Energy use in buildings, inboundary transport	Energy use in buildings, inboundary and transboundary transport, industrial processes and product use, land use, waste, water, food and construction materials	Supply emissions from consumption of goods and services
Scopes	1, 2	1, 2, 3	
GHG	CO_2	CO_2, CH_4, N_2O, HFCs, PFCs and SF_6	
Total	44.44 $mtCO_2e$	81.06 $mtCO_2e$	114.10 $mtCO_2e$
Per capita	5.51 tCO_2e/capita	10.05 tCO_2e/capita	14.15 tCO_2e/capita

Figure 3 – High level comparison of total GHG by methodology



[16] GLA (2012). *London Energy and Greenhouse Gas Inventory* (LEGGI). Web published at: http://data.london.gov.uk

3.4 Direct plus supply chain

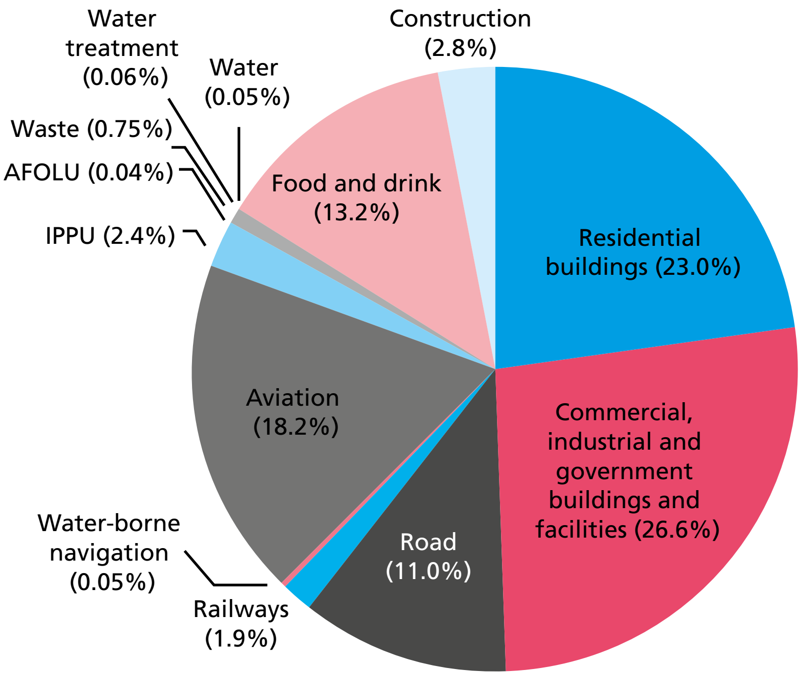
Table 8 shows the assessment results for London using the DPSC methodology. Activity data are not available for transboundary freight transport by road or water and the results therefore do not include GHG emissions from these sources. The notation key NE (not estimated) is used to indicate this. All other GHG emission sources are included or deemed to be not occurring (notation key NO)[17)]. Chapter 4 provides a detailed breakdown of the results and calculations using the DPSC methodology by emission source.

Table 8 – GHG emissions using the DPSC methodology

Sector		GHG emissions $mtCO_2e$			
		Scope 1	Scope 2	Scope 3	Total
Stationary	Residential buildings	9.34	6.79	2.52	18.64
	Commercial, industrial and government buildings and facilities	5.36	12.74	3.48	21.57
	Sub-total	14.69	19.53	5.99	40.21
Transport	Road	6.13	0.00	2.79	8.92
	Railways	0.13	1.10	0.31	1.53
	Water-borne navigation	0.02	0.00	0.02	0.04
	Aviation	0.98	0.00	13.74	14.72
	Sub-total	7.26	1.10	16.86	25.21
IPPU	Sub-total	1.91			1.91
AFOLU	Sub-total	0.03			0.03
Waste	Waste	0.18		0.42	0.60
	Wastewater treatment	0.02		0.03	0.05
	Sub-total	0.20		0.46	0.66
Goods and services	Water	0.00		0.04	0.04
	Food and drink	0.01		10.71	10.71
	Construction	0.00		2.27	2.27
	Sub-total	0.01		13.02	13.03
Total		**24.11**	**20.62**	**36.33**	**81.06**

[17)] Where activity data indicates that GHG emissions are deemed to be not occurring, they are reported as zero. Note, however, that for some of these sources, activity may be taking place at a level that is insignificant and where obtaining meaningful data is difficult. Any associated GHG emissions would thus be immaterial.

Figure 4 – Breakdown of GHG emissions using the DPSC methodology



- London emitted 81 million tonnes of CO_2e in 2010. On a per capita basis this equals 10.05 tonnes CO_2e per person.
- Energy use in buildings is the largest source of GHG emissions in London accounting for 50% of London's GHG emissions. The use of electricity in buildings released almost 20 million tonnes of CO_2e in 2010, whilst the combustion of primary fuels released almost 15 million tonnes of CO_2e in 2010. 54% of total GHG emissions come from commercial buildings and the remaining 46% from residential buildings.
- Transport is the second biggest source of GHG emissions, accounting for 31% of London's GHG emissions. Aviation contributes most (18%), followed by road (11%) and rail (2%).
- IPPU accounts for 2.4% of total GHG emissions – this is largely from the use of HFCs for refrigeration, air conditioning and aerosols.
- AFOLU emissions account for less than 0.1% of total GHG emissions.
- GHG emissions from waste and wastewater treatment released just over half a million tonnes of CO_2e, accounting for 0.8% of total GHG emissions in London.
- The consumption of food and drink accounts for 13% of GHG emissions. The use of concrete and steel in construction accounts for a further 3% of GHG emissions.

3.5 Consumption-based

Table 9 shows the assessment results for London using the CB methodology, which uses an environmentally-extended multi-region input-output model to calculate the GHG emissions that occur due to the consumption activities of London residents. Chapter 5 provides background and a more detailed breakdown of the results using COICOP categories.

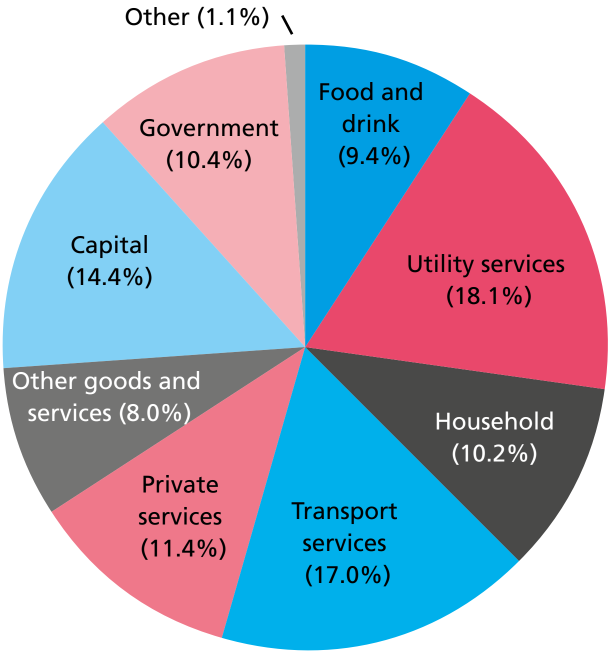
Table 9 – GHG emissions using the CB methodology

Sector	PAS 2070 category	GHG emissions $mtCO_2e$		
		CO_2	Non-CO_2	GHG
Households	Food and drink	3.68	7.03	10.71
	Utility services	19.51	1.16	20.67
	Household	8.40	3.23	11.63
	Transport services	17.96	1.49	19.44
	Private services	9.52	3.48	13.00
	Other goods and services	4.39	4.78	9.17
	Sub-total	63.45	21.17	84.62
Capital		11.62	4.76	16.38
Government		8.75	3.11	11.86
Other		0.93	0.31	1.25
Total		**84.75**	**29.35**	**114.10**

- London emitted 114 million tonnes of CO_2e in 2010. On a per capita basis this equals 14.15 tonnes CO_2e per person.
- Total GHG emissions calculated using the CB methodology are 40% higher than those calculated using the DPSC methodology.
- Utility services is the largest sources of GHG emissions for London (18.1%), followed by transport services (17.0%).
- 75% of the GHG emissions relate to household consumption, 14% relate to capital investment and 10% relate to government expenditure.

These assessment results demonstrate the importance of London continuing to target GHG emissions from energy use in buildings and road transport. They also show that aviation, food, and other goods and services consumed by Londoners, previously not captured in London's GHG assessment, are associated with significant GHG emissions.

Figure 5 – Breakdown of GHG emissions using the CB methodology



4 DPSC methodology

A. Stationary sources of GHG emissions

Stationary sources of GHG emissions		Cross reference
A1	Direct GHG emissions from fuel combustion	7.2.1.1
A2	Indirect GHG emissions from generation of grid-supplied electricity, district heating or cooling	7.2.1.2
A3	Direct GHG emissions from generation of grid-supplied electricity, district heating or cooling	7.2.1.3
A4	Indirect GHG emissions from upstream activities	7.2.1.4

1 Assessment boundary

All stationary sources of GHG emissions from combustion of fossil fuels, and generation of grid-supplied electricity, district heating or cooling, used in London. Includes GHG emissions from upstream activities.

2 Activity data

Type and quantity of fossil fuel, grid-supplied electricity, district heating or cooling consumed by building type: (a) residential buildings; and (b) commercial, industrial and government buildings and facilities.

3 Emission factor

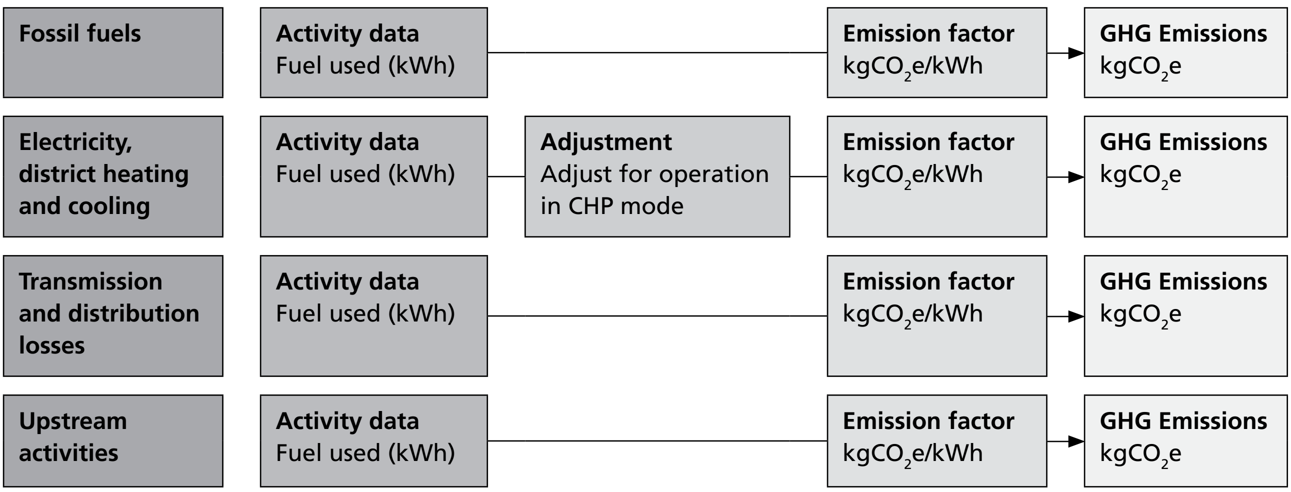
UK GHG Conversion factors

4 Calculation

$$GHG = \frac{\sum[Energy_{a,b} \times EF_a]}{1\,000}$$

GHG — GHG emissions (metric tonnes CO_2e)
Energy — Total fuel/energy used (kWh)
a — Type of fuel/energy
b — Building type
EF — Emission factor ($kgCO_2e/kWh$)

Figure 6 – Calculation flowcharts, stationary sources of GHG emission



Stationary sources refer to GHG emissions from energy use in buildings (and non-mobile equipment), either from the combustion of fossil fuels within the city boundary or through the use of grid-supplied electricity, district heating or cooling. To calculate GHG emissions from stationary sources in the city, it is necessary to identify all the types of energy used in the city's buildings: fossil fuels, grid-supplied electricity, district heating, and district cooling, and determine the quantity of each type of energy used by building type (residential or industrial and commercial). This is likely to be limited by the availability of activity data. For London, the identified sources are: gas, oil, coal, manufactured solid waste, other waste and renewables, grid-supplied electricity and district heating.

A1. Direct GHG emissions from fuel combustion

Activity data on the use of fuels by buildings in the UK is provided annually at sub-national level by the UK Department of Energy & Climate Change, including for London. The data is broken down by sector and fuel type, and excludes fuel used for generation of grid-supplied energy.

Gas use data is based on aggregated Meter Point Reference Number (MPRN) readings throughout London[18)] and is subject to a weather correction factor. To conform to the requirements of PAS 2070, however, this weather correction has been removed[19)]. Residential users are defined as those with an annual consumption of 73 200 kWh or lower, with the rest being classified as industrial and commercial users[20)]. This includes government buildings and facilities, but excludes large industrial customers which are identified as a separate category. Data for use of other fuels – oil, coal, manufactured solid fuel (MSF), waste and renewables – are estimated by spatially disaggregating national totals, from the Digest of UK Energy Statistics (DUKES), onto 1 km^2 grids according to population or employment data and other supporting data, such as the location of smoke control areas and access to the gas network. Known point sources are added to the 1 km^2 grids, which are then aggregated up to local authority level. National emission factors from the UK GHG Conversion Factors and Ricardo-AEA are used.

For further detail on the methodology, assumptions and data interpretation relating to gas, electricity and residual fuel use data, see: DECC (2013). *Sub-national consumption statistics: Methodology and guidance booklet.* 12D/473. Department of Energy & Climate Change, 2013. Web published at: www.gov.uk/government/publications/regional-energy-data-guidance-note

A2. Indirect GHG emissions from generation of grid-supplied electricity, district heating or cooling

Similarly, activity data on the use of grid-supplied electricity by buildings in the UK is provided annually at sub-national level by the Department of Energy & Climate Change, including for London. It is based on the aggregation of Meter Point Administration Number (MPAN) readings in London[21)], and is disaggregated by sector[22), 23)]. Unlike A1 above and due to the limited availability of data, the data excludes large industrial customers[24)]. Activity data on district heating is calculated in A3 below and is disaggregated by sector according to the gas split in A1. No district cooling is provided in London.

[18)] Readings cover the gas year from 1 October 2009 to 30 September 2010.

[19)] Gas consumption in the UK is predominantly used for heating purposes, and as a result is driven by external temperature and weather conditions. A weather correction factor enables comparisons of gas use over time by controlling for weather changes. The weather correction was removed by Ricardo-AEA, who lead the consortium that develops and maintains The UK National Atmospheric Emissions Inventory (NAEI): http://naei.defra.gov.uk

[20)] This means that some small and medium businesses with usage below the 73 200 kWh threshold are incorrectly categorized as residential users.

[21)] Readings cover two periods – from 31 January 2010 to 30 January 2011 for non-half hourly metered data (NHH), and from 1 January 2010 to 31 December 2010 for half hourly metered data (HH).

[22)] Industrial and commercial meter data is reported separately from residential data, and residential meters logging over 100 000 kWh are re-classified as industrial. Further, the addresses of those meters logging usage between 50 000 kWh to 100 000 kWh are manually checked, and if the address is indicative of industrial or commercial activity these records are also re-classified.

[23)] The activity data for the industrial and commercial sector includes electricity used by rail travel, which currently cannot be separated out from industrial and commercial electricity use. Therefore, activity data for indirect GHG emissions from inboundary rail travel (in B. Mobile sources of GHG emissions) is subtracted from the dataset.

[24)] Based on the proportion of employment in heavy industries in Greater London, large industrial customers would account for an additional 0.5% of electricity use. As the figure is low and the assumptions relatively uncertain, this data is not included.

PAS 2070 requires separate reporting of GHG emissions from the generation of grid-supplied electricity and district heating or cooling, and transmission and distribution losses of grid-supplied electricity and district heating or cooling, which occur between the power station and user. GHG emissions from generation are attributed to Scope 2 and GHG emissions from distribution and transmission losses are attributed to Scope 3.

Emission factors from the UK GHG Conversion Factors are used for both the generation of grid-supplied electricity and district heating, and the transmission and distribution losses associated with them [25)]. The same activity (kWh) data are used in both instances.

The emission factors used also need to correspond to the energy supply grid, and this requires an understanding of where the city receives its grid-supplied energy from. Electricity use in London is supplied through the National Grid, and so national emission factors for the generation, and transmission and distribution, of grid-supplied electricity are used [26)]. Due to the limited availability of local data, national average emission factors for district heating are used as well.

A3. Direct GHG emissions from generation of grid-supplied electricity, district heating or cooling

This is a separate reporting requirement to identify GHG emissions from the generation of grid-supplied electricity, district heating or cooling reported under A2 that are emitted within the city boundary. These GHG emissions are reported in Table 10, separately from the summary table to avoid double counting. This requirement does not apply to the combustion of fossil fuels which are used to generate electricity, heating or cooling, on-site and which is not supplied to a grid. These emissions are captured in A1.

Direct GHG emissions from the generation of grid-supplied electricity and district heating are estimated by identifying all large power stations and energy generating facilities in the city and determining their fuel type [including operation in CHP mode [27)]], installed capacity (MW), load factor (%) and the grid/network the energy output(s) connect(s) to. This is used to calculate the amount and type of energy generated (GWh) at each facility per annum. It is assumed that all electricity generated connects to the National Grid, but that generators above 50 MWe connect at high voltage, and those below at distribution voltages. In practice, however, this will depend on local network loadings and capacity. All district heating connects to a local network. Data for this exercise was obtained from multiple sources, including UK government reports on power stations in the UK and expert advice.

Sub-regional data on installed capacity of CHP and renewables (by fuel type, installed capacity and energy generated) is also available, and this is used to determine additional capacity not accounted for by the large power stations identified above. No breakdown, however, is provided of individual schemes and whether these connect to a grid or not. In the absence of this data, the conservative approach has been adopted and all facilities are assumed to connect to a grid [28)].

As in A3, national emission factors for the generation, and transmission and distribution, of grid-supplied electricity and district heating are obtained from the UK GHG Conversion Factors.

[25)] If the available emission factors include losses from transmission and distribution grids, the latter will need to be estimated and accounted for separately. This can be done by applying typical loss factors.

[26)] The emission factors for electricity generation represents the average GHG emissions from the UK national grid per kWh of electricity and factors in net imports of electricity via the interconnectors with Ireland and France.

[27)] Combined Heat and Power (CHP) simultaneously produces both heat and electricity. To determine the amount of fuel attributed to CHP heat or electricity, and therefore GHG emissions, it is necessary to apportion the total fuel used by the CHP scheme to the separate heat and electricity outputs. There are a number of conventions used to allocate emissions between these products. The UK GHG Conversion Factors uses the 1/3:2/3 method which assumes twice as many units of fuel are required to generate each unit of electricity than are required to generate each unit of heat. Emission factors are based on average CO_2e emission per kWh of supplied heat and steam from UK CHPQA scheme operators in the UK. For district heating systems, distribution losses of 5% are assumed to reflect average energy losses in the supplied heat distribution.

[28)] In practice, some of these will be building-level CHP. This is likely to lead to some double counting with emissions from fuel combustion in A1. The maximum error is estimated at 1% of all GHG emission from stationary sources.

A4. Indirect GHG emissions from upstream activities

In addition to GHG emissions that result from the combustion of fossil fuels and generation of grid-supplied energy, their use also creates indirect emissions which arise upstream from the point of use and result from the extraction, storage, processing, and transport of fossil fuels for direct use by end-users and in the generation of grid-supplied energy. They are classified as Scope 3 emissions. Activity data for A4 is provided in A1 and A2 above. Well-To-Tank (WTT) emission factors from the UK GHG Conversion Factors are used for all fuel types in A1 and A2. For grid-supplied electricity and district heating/cooling, both generation, and transmission and distribution losses, have separate WTT GHG emissions assigned to them.

Summary

Table 10 – GHG emissions from stationary sources

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Residential buildings	1	Direct, from fuel combustion	Natural gas	50 127	GWh	9.28			H
			Coal	1	GWh	0.00			M
			Gas oil	184	GWh	0.05			M
			Manufactured solid fuel	0	GWh	0.00			M
			Waste and renewables	0	GWh	0.00			M
		Sub-total				**9.34**			
	2	Direct and indirect, from generation of grid-supplied energy	Electricity	13 468	GWh	6.54			H
			Heating	1 114	GWh	0.25			M
			Cooling	0	GWh	0.00	NO	No district cooling identified	
		Sub-total				**6.79**			
	3	Indirect, from transmission and distribution losses	Electricity	AS ABOVE		0.53			H
			Heating	AS ABOVE		0.01			M
			Cooling	AS ABOVE		0.00	NO	No district cooling identified	
		Indirect, from upstream activities	Various	AS ABOVE		1.98			M
		Sub-total				**2.52**			
	Sub-total					**18.64**			

Table 10 – GHG emissions from stationary sources *(continued)*

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Commercial, industrial and government buildings and facilities	1	Direct, from fuel combustion	Natural gas	25 934	GWh	4.80			H
			Coal	12	GWh	0.00			M
			Fuel oil	2 007	GWh	0.54			M
			Manufactured solid fuel	19	GWh	0.00			M
			Waste and renewables	60	GWh	0.01			M
		Sub-total				**5.36**			
	2	Direct and indirect, from generation of grid-supplied energy	Electricity	25 986	GWh	12.61			H
			Heating	566	GWh	0.13			M
			Cooling	0	GWh	0.00	NO	No district cooling identified	
		Sub-total				**12.74**			
	3	Indirect, from transmission and distribution losses	Electricity	AS ABOVE		1.02			H
			Heating	AS ABOVE		0.01			M
			Cooling	AS ABOVE		0.00	NO	No district cooling identified	
		Indirect, from upstream activities	Various	AS ABOVE		2.45			M
		Sub-total				**3.48**			
	Sub-total					**21.57**			
Total						**40.21**			

Table 11 – GHG emissions from the combustion of fuels for generation of grid-supplied electricity, district heating or cooling in London

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Energy generation	1	Direct, from generation of grid-supplied energy	Electricity	3 794	GWh	(1.84)	IE	Information item (included in A2)	M
			Heating	1 680	GWh	(0.38)	IE	Information item (included in A2)	M
			Cooling	0	GWh	(0.00)	IE	Information item (included in A2)	
	Sub-total					**2.22**			

B. Mobile sources of GHG emissions

Mobile sources of GHG emissions		Cross reference
B1	Direct GHG emissions from inboundary transport of goods and people	7.3.1.1
B2	Indirect GHG emissions from inboundary transport of goods and people	7.3.1.2
B3	Indirect GHG emissions from transboundary transport of goods and people	7.3.1.3
B4	Indirect GHG emissions from upstream activities	7.3.1.4

GHG emissions from mobile sources are assessed separately by mode of travel: road, railways, water-borne navigation and aviation.

ROAD

1 Assessment boundary

All road travel within London and half of all transboundary return journeys made by road that begin or end within London. Includes GHG emissions from upstream activities.

2 Activity data

A transport model to estimate inboundary fuel consumption by vehicle type based on estimated distance travelled data, fuel type and fuel economy figures. Household expenditure data on fuels for personal transport to estimate transboundary passenger journeys.

3 Emission factor

UK GHG Conversion Factors

4 Calculation

Inboundary

$$GHG = \frac{\sum[Fuel_{a,b,c} \times EF_a]}{1\ 000}$$

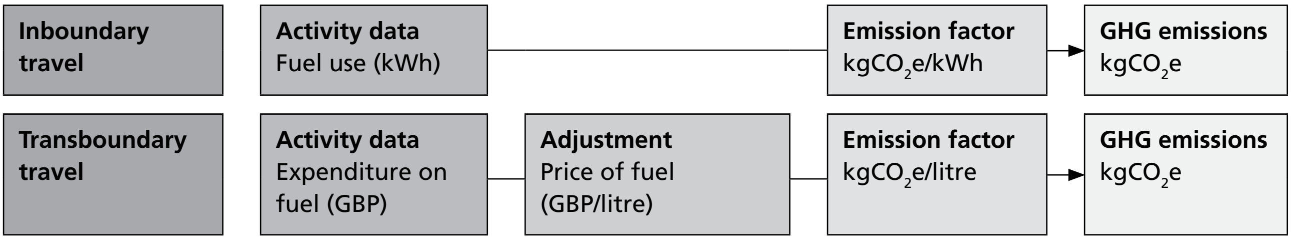
GHG	GHG emissions (metric tonnes CO_2e)
Fuel	Fuel use (litres)
a	Fuel type (petrol or diesel)
b	Vehicle type
c	Type of journey (passenger or freight)
EF	Emission factor

Transboundary (passenger only)

$$GHG = \frac{\sum[Fuel_a \times 52 \times H / P_a] \times EF_a - B_1}{1\ 000}$$

GHG	GHG emissions (metric tonnes CO_2e)
Fuel	Average weekly household expenditure on fuels for personal transport (GBP)
a	Fuel type (petrol or diesel)
P	Average price of fuel (GBP/litre)
H	Number of households in London
EF	Emission factor ($kgCO_2e$/litre)
B_1	Direct GHG emissions from inboundary transport of people

Figure 7 – Calculation flowcharts, roads



B1. Direct GHG emissions from inboundary transport of goods and people

A transport model developed by Transport for London – the organization responsible for London's transport system – has been used to estimate the quantities of diesel and petrol used by various modes of motorized road travel: motorcycle, taxi, car, large goods vehicle, bus, coach, lorry (rigid and articulated). This combines travel activity data with fleet composition. The latter provides an indication of the vehicle mix by engine size, vehicle size and age, engine and exhaust treatment technology, Euro emission standards and fuel type. Data provided by the model are multiplied by technology-specific national emission factors provided by the UK GHG Conversion Factors to estimate GHG emissions from road transport within London.

For further details on the methodology used to estimate GHG emissions from inboundary road travel, see: GLA (2013). *London Atmospheric Emissions Inventory 2010: Methodology Document*. Web published at: http://data.london.gov.uk/datastore/package/london-atmospheric-emissions-inventory-2010

B2. Indirect GHG emissions from inboundary transport of goods and people

Indirect GHG emissions from inboundary transport of goods and people applies to alternative fuel vehicles that do not emit tailpipe GHG emissions, such as electricity or hydrogen, where the fuel is "generated" elsewhere. In 2010, there were less than five hydrogen vehicles in London and electric vehicles accounted for 0.1% of cars sold in London [29]. As these numbers are very small and insignificant compared to the number of fossil fuel powered vehicles on London's roads, GHG emissions associated with their travel have not been estimated.

B3. Indirect GHG emissions from transboundary transport of goods and people

The model used in B1 does not include transboundary journeys and there are no other transport models available to estimate the quantities of fuel used or distances travelled by various modes of motorized road travel. Instead, total fuel sales for London are determined. Data required for this method is only available for passenger travel, and so GHG emissions from transboundary freight travel have not been estimated.

Fuel sales for passenger travel are estimated by multiplying the average household expenditure on motor oils from the Government's annual Family Spending survey by the number of households in London. This is split into petrol and diesel sales according to the same proportion for personal transport in B1, divided by the average price of petrol and diesel in 2010 and converted to GHG emissions using national emission factors provided by the UK GHG Conversion Factors. Finally, inboundary GHG emissions from B1 are subtracted to avoid double counting.

PAS 2070 uses the origin-destination model for calculating GHG emissions from transboundary travel. For journeys by road (and railways) this requires one half of each two-way (outbound and return) journey to be included in the assessment. The approach used above is consistent with this requirement as it only considers the transboundary part of journeys made by residents of the city, and excludes visitors to the city. In the absence of other data, these are assumed to be equal.

B4. Indirect GHG emissions from upstream activities

WTT emission factors are applied to the activity data in B1 and B3 above to calculate GHG emissions from upstream activities associated with fuel use for road travel.

[29] Society of Motor Manufacturers and Traders (2014). *Cars sold in London*. Data provided by Transport for London.

Summary

Table 12 – GHG emissions from road transport

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Passenger	1	Direct, from inboundary travel	Motorcycle (petrol)	28	m-litres fuel	0.06			M
			Car (petrol	1 204	m-litres fuel	2.70			M
			Car (diesel)	492	m-litres fuel	1.27			M
			Taxi	66	m-litres fuel	0.15			M
			Bus	152	m-litres fuel	0.39			M
			Coach	51	m-litres fuel	0.13			M
		Sub-total				**4.71**			
	2	Indirect, from inboundary travel	Electric vehicles	0		0.00	NE	Number of electric vehicles very low	
		Sub-total				**0.00**			
	3	Indirect, from transboundary travel		509	m-litres fuel	1.19			L
		Indirect, from upstream activities		AS ABOVE		1.28			M
		Sub-total				**2.47**			
	Sub-total					**7.17**			
Freight	1	Direct, from inboundary travel	Large goods vehicle (petrol)	13	m-litres fuel	0.03			M
			Large goods vehicle (diesel)	231	m-litres fuel	0.60			M
			Rigid	206	m-litres fuel	0.53			M
			Artic	104	m-litres fuel	0.27			M
		Sub-total				**1.43**			
	2	Indirect, from inboundary travel	Electric vehicles	0		0.00	NE	Number of electric vehicles very low	
		Sub-total				**0.00**			

Table 12 – GHG emissions from road transport *(continued)*

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Freight	3	Indirect, from transboundary travel		0	m-litres fuel	0.00	NE	No data available	
		Indirect, from upstream activities		AS ABOVE		0.32			M
		Sub-total				**0.32**			
	Sub-total					**1.75**			
Total						**8.92**			

RAILWAYS

1 Assessment boundary

All rail travel within London – National Rail and services managed by Transport for London – and half of all transboundary return journeys made by National Rail or Eurostar that begin or end within London.

2 Activity data

Fuel data for inboundary rail travel, and distance travelled for transboundary rail travel, disaggregated by type of travel (passenger or freight) and destination (inboundary, UK or international).

3 Emission factor

UK GHG Conversion Factors

4 Calculation

Inboundary

$$GHG = \frac{\sum[Fuel_{a,b,c} \times EF_a]}{1\,000}$$

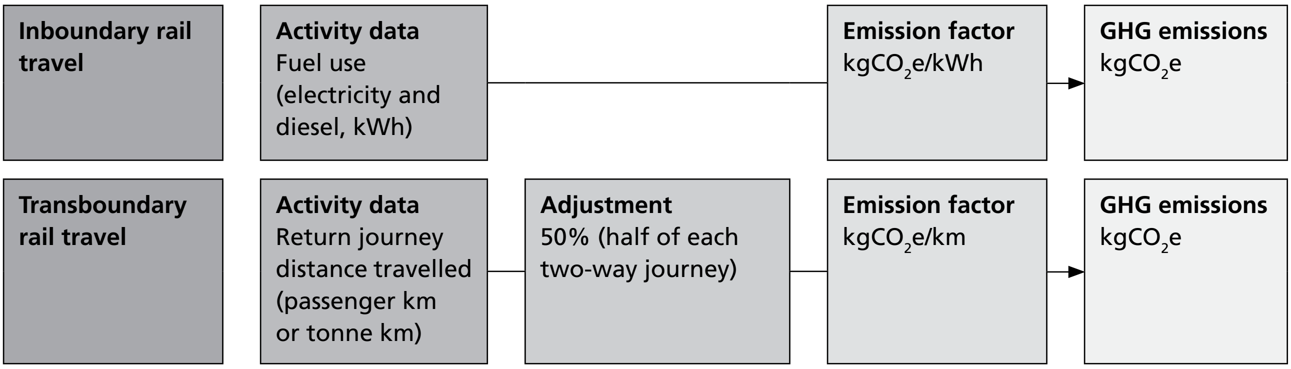
GHG	GHG emissions (metric tonnes CO_2e)
Fuel	Fuel use (kWh)
a	Fuel type (electricity or diesel)
b	Mode of railway
c	Type of journey (passenger or freight)
EF	Emission factor (tCO_2e/kWh)

Transboundary

$$GHG = \frac{\sum[Distance_{a,b} \times EF_{a,b}]}{1\,000}$$

GHG	GHG emissions (metric tonnes CO_2e)
Distance	Distance travelled – half of each two-way return journey (passenger km; tonne km)
a	Type of journey (passenger or freight)
b	Destination (domestic or international – latter for passenger travel only)
EF	Emission factor ($kgCO_2e$/pkm; $kgCO_2e$/tkm)

Figure 8 – Calculation flowcharts, railways



GHG emissions from rail travel are associated with electricity and diesel use depending on the type of train. The first step is to identify all types of rail travel in the city, and determine journey boundaries by allocating as either inboundary or transboundary travel. For London, inboundary travel includes all National Rail services operating within London: London Overground, London Underground, Docklands Light Railway (DLR), and London Tramlink. Transboundary travel includes all National Rail and Eurostar services operating outside of London, where journeys begin or end within the city boundary. The latter will need to be apportioned to London based on the proportion of travel serving the city. Next, the quantity of fuel consumed/electricity used will need to be determined. For London, inboundary GHG emissions are based on fuel use data whilst GHG emissions from transboundary travel are based on distances travelled disaggregated by destination. Both are multiplied by an appropriate emission factor.

B1. Direct GHG emissions from inboundary transport of goods and people

The London Atmospheric Emissions Inventory (LAEI) provides fuel use data for all inboundary rail travel, disaggregated by mode of rail travel, type of travel (passenger and freight) and fuel source. This is multiplied by technology-specific national emission factors provided by the UK GHG Conversion Factors.

For further information on the methodology used in the London Atmospheric Emissions Inventory (LAEI), see: GLA (2013). *London Atmospheric Emissions Inventory 2010: Methodology Document*. Web published at: http://data.london.gov.uk/datastore/package/london-atmospheric-emissions-inventory-2010

B2. Indirect GHG emissions from inboundary transport of goods and people

See B1.

B3. Indirect GHG emissions from transboundary transport of goods and people

Passenger kilometre data for all rail journeys in Great Britain, with London as the origin and/or destination, are based on ticket sales and obtained from the Association of Train Operating Companies [30]. The emission factors used are based on total electricity and diesel consumption by the railways for the year and the total number of passenger kilometres.

[30] www.atoc.org

International rail data, limited to passenger travel on Eurostar trains [31], are estimated by multiplying the number of passengers by the average journey distance from London to Paris/Brussels (weighted according to the timetable), and apportioned to London according to the share of passengers with London as their origin and destination [32].

Data on transboundary transport of goods in Great Britain are provided in tonne-kilometres by the Office of Rail Regulation – this takes into account the weight of the freight carried and distance travelled. They are allocated to London based on the origin-destination split of transboundary passenger journeys.

All distance travelled data is divided by two to ensure only one half of each two-way (outbound and return) journey is included in the assessment. All activity data is multiplied by technology-specific national emission factors provided by the UK GHG Conversion Factors. Finally, inboundary GHG emissions from B1 and B2 are subtracted to avoid double counting.

B4. Indirect GHG emissions from upstream activities

WTT emission factors are applied to the activity data in B1, B2 and B3 above to calculate GHG emissions from upstream activities associated with fuel use for rail travel.

[31] Eurostar is the high-speed train service linking St Pancras International, Ebbsfleet International, Ashford International, Paris, Brussels, Lille, Calais, Disneyland Resort Paris, Avignon and the French Alps.
[32] Due to the limited availability of data and for the purposes of this assessment, it has been assumed that the all Eurostar passengers travel between London and Paris or Brussels. Other stations are therefore, not included in the calculation. However, this is not expected to have a significant impact.

Summary

Table 13 – GHG emissions from railways

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Passenger	1	Direct, from inboundary travel	Rail	311	GWh	0.09			M
		Sub-total				**0.09**			
	2	Indirect, from inboundary travel	Rail incl. London Overground	838	GWh	0.41			M
			London Underground	1363	GWh	0.66			M
			Docklands Light Railway	46.4	GWh	0.02			M
			London Tramlink	11.6	GWh	0.01			M
		Sub-total				**1.10**			
	3	Indirect, from transboundary travel	National rail	13.6	b-pkm	0.06			M
			Eurostar	1.21	b-pkm	0.00			L
		Indirect, from upstream activities	Various	AS ABOVE		0.19			M
		Sub-total				**0.25**			
	Sub-total					**1.43**			
Freight	1	Direct, from inboundary travel	Rail	143	GWh	0.04			M
		Sub-total				**0.04**			
	2	Indirect, from inboundary travel		0		0.00	NE	Activity data not available – assumed to be small	
		Sub-total				**0.00**			
	3	Indirect, from transboundary travel	Rail	2.71	b-tkm	0.04			L
		Indirect, from upstream activities	Various	AS ABOVE		0.02			M
		Sub-total				**0.06**			
	Sub-total					**0.10**			
Total						**1.53**			

WATER-BORNE NAVIGATION

1 Assessment boundary

Inboundary water-borne navigation and transboundary waterborne navigation departing from the Port of London and major ports within an approximate 100km radium of London. All travel is apportioned to London.

2 Activity data

Fuel use data for inboundary travel, and distance travelled by departing ships for transboundary travel, disaggregated by fuel type, type of travel (passenger or freight) and destination (domestic, or international).

3 Emission factor

UK GHG Conversion Factors

4 Calculation

Inboundary

$$GHG = \frac{\sum[Fuel_{a,b} \times EF_a]}{1\ 000}$$

GHG GHG emissions (metric tonnes CO_2e)
Fuel Fuel use (litres)
a Fuel type (diesel oil, gas oil)
b Type of journey (passenger or freight)
EF Emission factor ($kgCO_2e$/litre)

Transboundary

$$GHG = \frac{\sum[Distance_{a,b} \times N_a \times EF]}{1\ 000}$$

GHG GHG emissions (metric tonnes CO_2e)
Distance Distance travelled by departing ships (pkm; tkm)
a Port
b Type of journey (passenger or freight)
N % travellers to/from London
EF Emission factor ($kgCO_2e$/km)

Figure 9 – Calculation flowcharts, water-borne navigation

Inboundary	**Activity data** Fuel use (litres)		**Emission factor** $kgCO_2e$/litre	**GHG emissions** $kgCO_2e$
Transboundary	**Activity data** Distance travelled by departing ships (pkm and tkm)	**Adjustment** Proportion of travel serving the city	**Emission factor** $kgCO_2e$/pkm; $kgCO_2e$/tkm	**GHG emissions** $kgCO_2e$

B1. Direct GHG emissions from inboundary transport of goods and people

The river Thames, which flows through London from west to east, is a busy transport corridor, being used for commuter services, sightseeing ferries and commercial activities. Inboundary transport on other inland waterways does occur but on a much smaller scale than that on the river Thames and is not estimated due to lack of data.

The London Atmospheric Emissions Inventory (LAEI) is used to calculate GHG emissions from inboundary navigation. The LAEI identifies passenger and commercial services, and publishes data on fuel use by these services. Emission factors from the UK GHG Conversion Factors are used.

B2. Indirect GHG emissions from inboundary transport of goods and people

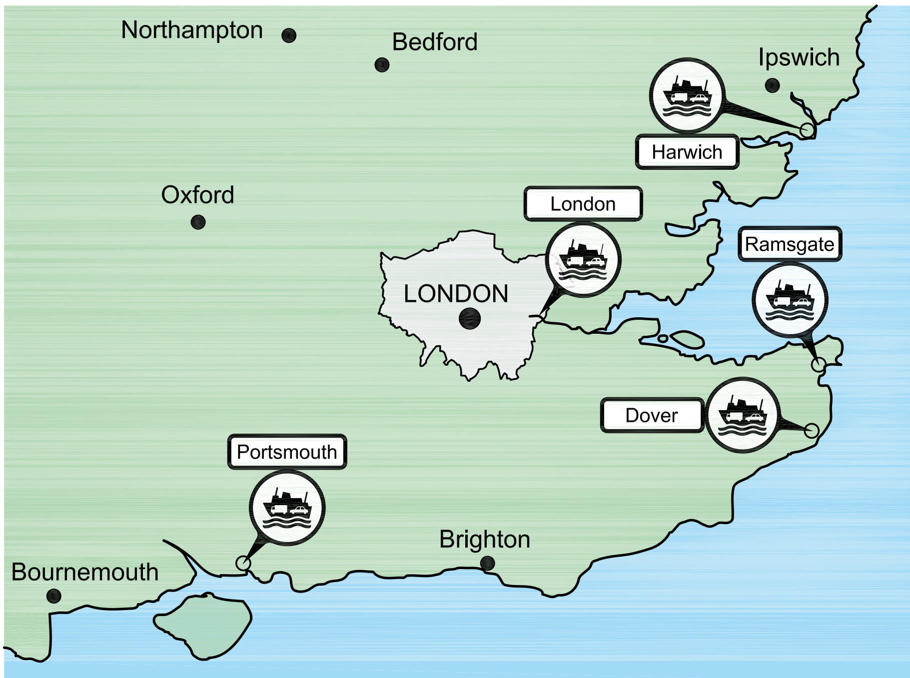
Not occurring.

B3. Indirect GHG emissions from transboundary transport of goods and people

London's port is known as the Port of London, which stretches along the tidal Thames and includes many individual wharfs, docks, terminals and facilities. The port handles cruise liners, ro-ro ferries and cargo ships, with the bulk of activities taking place downstream.

Two passenger routes are identified within the Port of the London and a further fifteen passenger routes from major ports within an approximate 100 km radius of London: Harwich, Dover, Ramsgate and Portsmouth. Data on the number of departing passengers from these ports are available from the Department of Transport and distances to destination ports have been estimated using an online route planner. Consistent with the origin-destination model used by PAS 2070 for calculating GHG emissions from transboundary travel, only the outbound portion of a two-way (outbound and return) journey by water (and air) is included in the assessment. Emission factors from the UK GHG Conversion Factors are used.

Figure 10 – Map of seaports



Similar data for freight travel are not available due to data confidentiality. GHG emissions from transboundary commercial travel are therefore not estimated.

PAS 2070 requires GHG emissions from shipping to be allocated to London, based on the proportion of travel serving the city at the identified ports. Due to limited availability of data, it is assumed that all activity at the Port of London serves the city, whilst travel at the other major ports is allocated to London based on its share of the population of England and Wales.

B4. Indirect GHG emissions from upstream activities

WTT emission factors are applied to the activity data in B1 and B3 above to calculate GHG emissions from upstream activities associated with fuel use in water-borne navigation.

Summary

Table 14 – GHG emissions from water-borne navigation

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Passenger	1	Direct, from inboundary travel	Fuel loaded	6.19	m-litres fuel	0.02			H
		Sub-total				**0.02**			
	2	Indirect, from inboundary travel		0		0.00	NO		
		Sub-total				**0.00**			
	3	Indirect, from transboundary travel		112	m p-km	0.01			H
		Indirect, from upstream activities		AS ABOVE		0.01			M
		Sub-total				**0.02**			
	Sub-total					**0.04**			
Freight	1	Direct, from inboundary travel	Fuel loaded	9	GWh	0.00			H
		Sub-total				**0.00**			
	2	Indirect, from inboundary travel		0		0.00	NO		
		Sub-total				**0.00**			
	3	Indirect, from transboundary travel		0		**0.00**	NE	Activity data not available due to data confidentiality	
		Indirect, from upstream activities		AS ABOVE		**0.00**			M
		Sub-total				**0.00**			
	Sub-total					**0.00**			
Total						**0.04**			

AVIATION

1 Assessment boundary

Air travel originating from all local and international airports in London, and international airports serving London based outside the city. Travel is apportioned to London based on origin/destination of passengers.

2 Activity data

Fuel loaded onto departing aircraft for inboundary air travel, and distance travelled by departing aircraft for transboundary air travel, disaggregated by type of travel (passenger or freight) and destination (inboundary, domestic, short haul or long haul).

3 Emission factor

UK GHG Conversion Factors

4 Calculation

Inboundary

$$GHG = \frac{\sum[Fuel_a \times EF]}{1\,000}$$

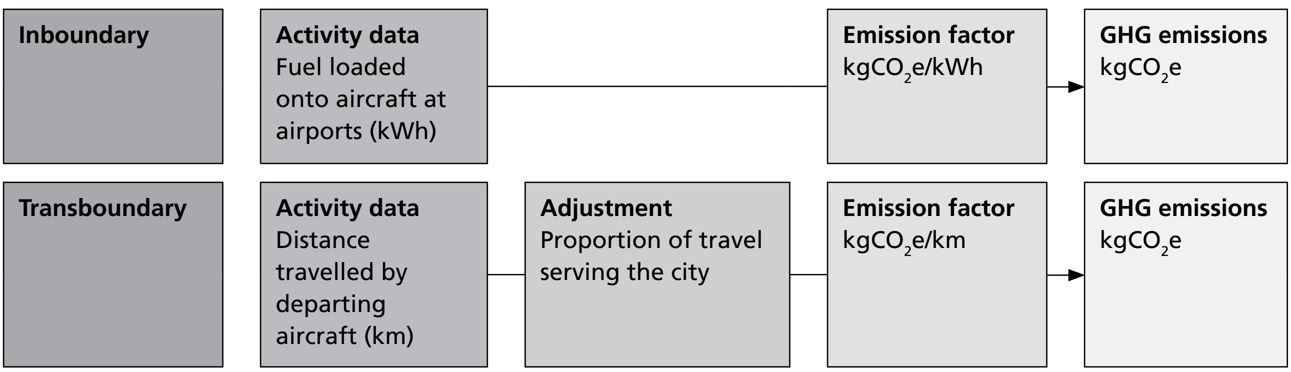
GHG	GHG emissions (metric tonnes CO_2e)
Fuel	Fuel loaded onto departing aircraft (tonnes of aviation turbine fuel)
a	Airport
EF	Emission factor ($kgCO_2e/tATF$)

Transboundary

$$GHG = \frac{\sum[Distance_{a,b,c} \times N_a \times EF_{b,c}]}{1\,000}$$

GHG	GHG emissions (metric tonnes CO_2e)
Distance	Distance travelled by departing aircraft (km)
a	Airport
b	Type of journey (passenger or freight)
c	Destination (domestic, short or long haul)
N	% travellers to/from London
EF	Emission factor ($kgCO_2e/km$)

Figure 11 – Calculation flowcharts, aviation



GHG emissions from aviation originate from the burning of fossil fuels in aircraft engines. The first step to calculate GHG emissions associated with aviation is to identify all airports in the city and other major airports servicing the city. This includes smaller local airports and heliports, as well as international airports. Next, the boundaries of travel at each of these airports needs to be determined (the destination of departing aircraft). In the case of London, all travel at international airports is assumed to be either domestic, short haul or long haul, i.e. transboundary transport, whilst all travel at local airports and heliports is assumed to be limited to inboundary transport.

For transboundary travel, where airports serve multiple cities and regions, it is necessary to determine the proportion of air travel at each airport serving the city, i.e. those flights used by residents, workers and visitors. Activity data can be collected as either fuel loaded onto aircraft at the airport or distance travelled by departing aircraft – only the outbound portion of a two-way (outbound and return) journey is included in the assessment.

B1. Direct GHG emissions from inboundary transport of goods and people

The London Atmospheric Emissions Inventory (LAEI) is used to calculate GHG emissions from inboundary air travel. The LAEI identifies six local airports and heliports, and publishes data on aviation turbine fuel loaded onto aircraft at these airports. All travel is assumed to be passenger travel. An emission factor from the UK GHG Conversion Factors is used.

B2. Indirect GHG emissions from inboundary transport of goods and people

Not occurring.

B3. Indirect GHG emissions from transboundary transport of goods and people

London has two large airports (London Heathrow and London City), with a further three large airports servicing the city located outside the city boundary (London Gatwick, London Luton, London Stansted). Other airports were considered but did not meet the materiality threshold.

Figure 12 – Map of airports

Data for distance travelled by departing aircraft from the five airports, disaggregated by passenger and freight travel and destination (domestic, short haul and long haul) are supplied by FlightGlobal [33], and apportioned to London based on survey data provided by the UK Civil Aviation Authority [34] on the origin/destination patterns of terminating passengers at major UK airports.

The IPCC divides aircraft operations into two main parts:

a) the landing take-off (LTO) cycle, which includes all activities near the airport that take place below 1 000 m altitude [35] (taxi-in and out, take-off, climb-out and approach-landing);
b) cruise, which includes all activities above 1 000 m.

The Tier 1 methodology assumes that 10% of fuel is used in the LTO phase of the flight, whilst the Tier 2 methodology calculates GHG emissions from the LTO and cruise phases separately, based on the number of LTOs and default emission factors or fuel use factors per LTO, and subtracting GHG emissions or fuel used in the LTO phase of the flight from total GHG emissions or fuel used. Whilst PAS 2070 does not require the separation of GHG emissions into LTO and cruise phases, in this case study the Tier 1 methodology has been applied to travel departing from London Heathrow and London City – the two inboundary international airports – in order to the identify the Scope 1 element of transboundary aviation GHG emissions.

B4. Indirect GHG emissions from upstream activities

WTT emission factors are applied to the activity data in B1 and B3 above to calculate GHG emissions from upstream activities associated with fuel used in aviation.

[33] www.flightglobal.com
[34] www.caa.co.uk
[35] IPCC (2001). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (pp.93–102). Web published at www.ipcc-nggip.iges.or.jp/public/gp/english

Results

Table 15 – GHG emissions from aviation

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Passenger	1	Direct, from inboundary travel	Aviation turbine fuel loaded onto departing aircraft at local airports	1 519	tonne	0.005			H
		Direct, from LTO phase of transboundary travel	London Heathrow	AS BELOW		0.95			L
			London City	AS BELOW		0.02			L
		Sub-total				**0.97**			
	2	Indirect, from inboundary travel		0		0.00	NO		
		Sub-total				**0.00**			
	3	Indirect, from transboundary travel (GHG emissions from London Heathrow and London City exclude LTO phase)	Distance travelled by departing aircraft at:						
			London Heathrow	349.74	m-km	8.54			H
			London City	14.96	m-km	0.18			H
			London Gatwick	81.91	m-km	1.63			H
			London Stansted	38.00	m-km	0.54			H
			London Luton	16.43	m-km	0.24			H
			Sub-total			**11.13**			
		Indirect, from upstream activities	Aviation turbine fuel	AS ABOVE		0.00			M
			Distance travelled	AS ABOVE		2.50			M
		Sub-total				**13.63**			
	Sub-total					**14.60**			
Freight	1	Direct, from inboundary travel		0		0.00	NO	No inboundary freight travel by air	
		Direct, from LTO phase of transboundary travel	London Heathrow	AS BELOW		0.01			L
			London City	AS BELOW		0.00			L
		Sub-total				**0.01**			
	2	Indirect, from inboundary travel		0		0.00	NO		
		Sub-total				**0.00**			

Table 15 – GHG emissions from aviation *(continued)*

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Freight	3	Indirect, from transboundary travel (GHG emissions from London Heathrow and London City exclude LTO phase)	Distance travelled by departing aircraft at:						
			London Heathrow	1.71	m-km	0.06			H
			London City	0.00	m-km	0.00	NO	No freight travel from London City	
			London Gatwick	0.05	m-km	0.00			H
			London Stansted	0.56	m-km	0.02			H
			London Luton	0.25	m-km	0.01			H
			Sub-total			**0.09**			
		Indirect, from upstream activities	Distance travelled	AS ABOVE		0.02			M
		Sub-total				0.11			
	Sub-total					**0.12**			
Total						**14.72**			

C. Industrial Processes and Product Use (IPPU)

IPPU		Cross reference
C1	Industrial processes	7.4.1.2
C2	Product use	7.4.1.3

1 Assessment boundary

Point sources of direct GHG emissions from industrial processes for 2006 IPCC Guidelines categories 2A to 2C occurring within the city boundary, and GHG emissions resulting from industrial product use for 2006 IPCC Guidelines categories 2D to 2G within the city's boundaries [36].

2 Activity data, 3 Emission factor, 4 Calculation

Data from the UK National Atmospheric Emissions Inventory (NAEI) to identify all significant point sources of GHG emissions from industrial processes 2A to 2C and 2H, and estimate GHG emissions from product use categories 2D to 2G occurring within the city's boundaries, apportioned according to population. The NAEI provides data in units of GHG emissions.

[36] All end-use energy consumption in industrial facilities are reported under 7.2 Stationary sources.

IPPU GHG emissions arise from non-energy related industrial processes, such as the production of minerals and chemical, and use of industrial products, such as aerosols and air conditioning. The UK National Atmospheric Emissions Inventory (NAEI) [37] has been used to determine GHG emissions from both industrial processes and product use in London. GHG emissions are reported in Table 16 according to the 2006 IPCC Guidelines categories 2A to 2G, which cover the requirements of PAS 2070. Note that GHG emissions from combustion of fossil fuels at industrial facilities are covered in A1.

C1. Industrial processes

To estimate direct GHG emissions from industrial processes, it is necessary to identify all relevant activity occurring within the city boundary. Ricardo-AEA, who lead a consortium which develops and maintains the NAEI, were asked to determine the production and use of mineral products, production and use of chemicals, and the production of metals in London based on data submitted to the NAEI. They identified no significant point sources of GHG emissions.

C2. Product use

Direct GHG emission sources of industrial product uses are more numerous and diverse. As such, they are calculated by apportioning GHG emissions data for the relevant product use categories from the NAEI to London according to population share.

Summary

Table 16 – GHG emissions from IPPU

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Industrial processes	1	2A Mineral industry	Data from NAEI	0		0.00	NO	No emissions identified	
		2B Chemical industry	Data from NAEI	0		0.00	NO	No emissions identified	
		2C Metal industry	Data from NAEI	0		0.00	NO	No emissions identified	
		2H Other	Data from NAEI	0		0.00	NO	No emissions identified	
		Sub-total				0.00			
Product use	1	2D Non-energy products	Data from NAEI	0		0.00	NO	No emissions identified	
		2E Electronics industry	Data from NAEI	0		0.00	NO	No emissions identified	
		2F Product uses as substitutes for ozone depleting substances	Data from NAEI – scaled using population	NO ACTIVITY DATA		1.83			M
		2G Other product manufacture and use		NO ACTIVITY DATA		0.08			M
		Sub-total				1.91			
Total						**1.91**			

[37] http://naei.defra.gov.uk

D. Agriculture, forestry and land use (AFOLU)

AFOLU		Cross reference
D1	GHG emissions from land (forest land, cropland, grassland, wetland, settlements and other) not managed for commercial food production	7.5.1.1
D2	GHG emissions from land use for commercial food production	7.5.1.2

GHG emissions from AFOLU are amongst the most complex categories for GHG accounting. Limited guidance exists and PAS 2070 recommends scaling national inventories to the city using IPCC methodologies. This assessment only measures Scope 1 GHG emissions, not those associated with the manufacture of nitrogen fertilizers, which account for a large portion of agricultural emissions. IPCC guidelines allocate these emissions to IPPU.

D1 captures GHG emissions from AFOLU categories, excluding CH_4 and N_2O emissions associated with land managed for commercial food production, which are estimated separately in D2. PAS 2070 does not measure CO_2 emissions arising from biogenic carbon sources, except where these arise from land-use change.

D1. GHG emissions from land not managed for commercial food production

1 Assessment boundary

GHG emissions from land use in London not used for commercial food production, where there is no land-use change, and from direct land-use change not more than 20 years prior to undertaking the assessment, on the basis of equal allocation to each year of the 20 year period, based on IPCC's publication *Good practice guidance for land use, land use change and forestry* (2003). GHG emissions arising from indirect land-use change, and CH_4 and N_2O emissions associated with commercial food production, are not included.

2 Activity data, 3 Emission factor

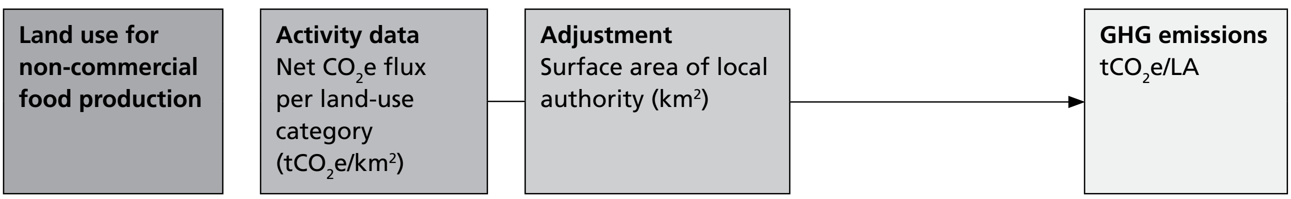
Net annual CO_2e flux per km^2 for land use categories not used for commercial food production at local authority level, multiplied by the surface area of 33 local authorities in London.

4 Calculation

$$GHG = \sum[Area_{LA} \times Flux_{LU,LA}]$$

GHG GHG emissions (metric tonnes CO_2e)
Size Surface area of local authority (km^2)
Flux Net annual CO_2 flux per land use category (tCO_2e/km^2), disaggregated by local authority
LA Local authority
LU Land-use category

Figure 13 – Calculation flowchart, land not managed for commercial food production



To estimate GHG emissions from AFOLU in London, data on net annual CO_2e flux per km^2 for different land-use categories at local authority level are used. This data, used for the UK GHG Inventory and provided by the UK Centre for Ecology and Hydrology (CEH) [38], is based on the *IPCC Good Practice Guidance for Land Use, Land Use change and Forestry* (2013) [39]. Land-use categories are identified as either commercial food production or non-commercial food production. The net CO_2e fluxes per land-use category for the 33 local authorities in London, excluding CH_4 and N_2O emissions associated with land managed for commercial food production, are multiplied by the surface area of each local authority and added together.

For further detail on the methodology, see: Hallsworth, S. and Moxley, J. *Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector.* Centre for Ecology and Hydrology, 2013. Web published at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/211882/110713_Mapping_LULUCF_emissions.pdf

[38] CEH prepares annual estimates of the uptake (removal from atmosphere) of CO_2 by afforestation and net loss or gain of CO_2 from soils (emissions to or removals from the atmosphere) for inclusion in the UK GHG Inventory. Emissions are estimated using dynamic models of change in stored carbon driven by land-use change data. For forestry, the model deals primarily with plant carbon and is driven by the area of land newly afforested each year. Changes in soil carbon are driven by estimated time series of land-use transitions between semi-natural, cultivated (farm), woodland and urban. Land use, land-use change and forestry (LULUCF) emissions and removals have been estimated for every year in the time series.

[39] www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

D2. GHG emissions from land use for commercial food production

1 Assessment boundary

CH_4 and N_2O emissions from all farmed land used for food production from crops and livestock on commercial holdings in London.

2 Activity data

Farmed area by land-use category and crop type, and livestock numbers.

3 Emission factor

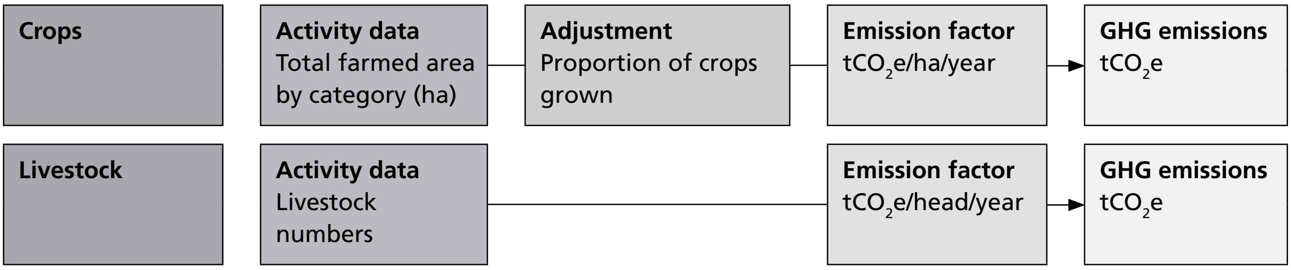
UK National GHG Inventory

4 Calculation

$$GHG = \sum[Land \times C_a \times EF_a] + \sum[L_b \times EF_b]$$

GHG	CH_4 and N_2O emissions (metric tonnes CO_2e)
Land	Total land area used for growing (ha)
C	% of land used by crop
a	Crop type
L	Number of livestock
b	Type of livestock
EF	Emission factor (tCO_2e/ha/year for crops; tCO_2e/head/year for livestock)

Figure 14 – Calculation flowcharts, land use for commercial food production



There are 12 064 hectares of farmland in London, representing approximately 8% of London's land area. Of the 472 registered holdings, 60% cover 5 hectares or less. London's commercial farmland is primarily used for the production of arable and horticultural crops, and includes seven dairy farms (GLA (2006). *Mayor's Food Strategy* [40]).

To estimate non-CO_2 GHG emissions from commercial food production, a breakdown of farmed area (in hectares) and livestock numbers on commercial agricultural holdings in London was obtained from the UK Department for Environment, Food and Rural Affairs (DEFRA). Farmed area is broken down into four categories – cereals, arable crop (excluding cereals), fruit and vegetables, and grassland – and livestock data consist of cattle, sheep, pigs and poultry. The data on farmed area are further disaggregated into key crops, using the National Inventory categories, based on the proportion of crops grown nationally (except where it is reasonable to assume that a crop is not grown in London [41]).

[40] www.london.gov.uk/sites/default/files/FoodStrategySummary2006.pdf

[41] For example, it is assumed that no sugar beet is grown in London because it would not be economic to transport beet from London to the nearest factory.

Emissions factors per hectare of crop grown and per head of livestock are sourced from the UK National GHG Inventory and applied to the activity data to obtain overall GHG emissions from land used for commercial food production in London. These are reported in brackets in Table 17 below and not counted towards the total GHG emissions assessed by the DPSC methodology to avoid double counting with GHG emissions associated with economic final consumption of food and drink (PAS 2070:2013+A1:2014, **7.5.2.1**).

Summary

Table 17 – GHG emissions from AFOLU

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
	1	Land not managed for commercial food production	Net CO_2e flux per km^2	NO ACTIVITY DATA		0.03			M
		Land managed for commercial food production	Crops grown	9 971	Ha	(0.01)	IE	Included in Food and drink (F2)	H
			Livestock	22 568	#	(0.01)	IE	Included in Food and drink (F2)	H
		Sub-total				0.03			
Total						0.03			

E. Waste and wastewater treatment

Waste wastewater treatment		Cross reference
E1	Waste	7.6.1
E2	Wastewater	7.6.2

E1. Waste

1 Assessment boundary

Waste generated within the city boundary and disposed within the city boundary; waste generated outside the city boundary and disposed within the city boundary; and waste generated within the city boundary and disposed outside the city boundary.

2 Activity data

Quantity of waste generated, disaggregated by type (household; commercial and industrial; construction, demolition and excavation), disposal route (landfilling; incineration; biological treatment), and location of origin and treatment. Note that waste disposal does not include recycling or reuse.

3 Emission factor

UK GHG Conversion Factors

4 Calculation

$$GHG = \frac{\sum[Waste_{a,b} \times EF_{a,b}]}{1\,000}$$

GHG	GHG emissions (metric tonnes CO_2e)
Waste	Waste generated (tonnes)
a	Disposal route (landfilling; incineration; biological treatment)
b	Type of waste (household; commercial and industrial; construction)
EF	Emission factor ($kgCO_2e$/tonne)

Figure 15 – Calculation flowchart, waste

To calculate GHG emissions from waste, it is necessary to determine the quantity of waste generated within the city boundary by type and disposal route. The latter may take place within and outside the city. For London, data on the quantity of household, commercial and industrial, and construction, demolition and excavation waste generated within the city boundary, are taken from consultancy reports using national and local authority data [42] and allocated to the three primary disposal routes: landfilling, incineration and biological treatment. UK GHG Conversion Factors are used to provide emission factors for all disposal routes by waste type. These exclude biogenic CO_2 as required by PAS 2070:2013+A1:2014, **4.2.2**.

[42] Household waste data are from local authorities which have responsibility in the UK for collecting and disposing municipal waste; commercial and industrial waste and demolition, construction and excavation waste data are from national regulatory bodies.

Where categories for waste type do not align with those set out in PAS 2070, assumptions will have to be made about the origin of the waste. Where specific emission factors are not available, GHG emissions from landfill, incineration and biological treatment can be determined based on the composition of waste (and in particular the fraction of organic and fossil carbon content), information about the management of these facilities, and default IPCC emission factors. For further detail please refer to the GPC.

PAS 2070 also requires cities to determine the quantity of waste the city generates that is treated within or outside the city boundary, as well as the quantity of waste originating outside the city boundary that is treated within the city boundary. The same sources identified above are used to determine the proportion of waste generated in London that is treated within the city boundary as well as the proportion of waste treated in London that is generated within the city boundary. Due to limited availability of data, average figures across the different waste types and disposal routes have been used. It is assumed that 30% of waste generated within the city boundary is disposed within the city boundary; 70% of waste generated within the city boundary is disposed outside the city boundary and 24% of waste disposed within the city boundary is generated outside the city boundary. The latter, equal to approximately 10% of the GHG emissions from waste generated within London, is reported separately in Table 19 below to avoid to double counting.

Waste is also used to generate energy and care must be taken to avoid double counting with A1 Direct GHG emissions from fuel combustion and A2 Indirect GHG emissions from the generation of grid-supplied electricity, district heating or cooling. In this assessment, it is assumed that all waste incineration facilities are used to generate grid-supplied energy. GHG emissions from waste incineration are, therefore, reported in brackets in the summary table below and not counted when aggregating overall GHG emissions from waste. The emission factors used for landfilling exclude GHG emissions from landfill gas used to generate energy and so there is no risk of double counting. There is insufficient data on the energy outputs and uses from biological waste treatment facilities. As a result, it is assumed there is no double counting with A1 or A2 [43].

Summary

Table 18 – GHG emissions from waste

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Household	1	Waste generated within the city boundary and disposed within the city boundary	Landfill	386 136	tonnes	0.11			M
			Incineration	214 968	tonnes	(0.00)	IE	Included in stationary (A2)	M
			Biological treatment	140 832	tonnes	0.00			M
		Sub-total				0.11			
	3	Waste generated within the city boundary and disposed outside the city boundary	Landfill	900 984	tonnes	0.26			M
			Incineration	501 592	tonnes	(0.01)	IE	Included in stationary (A2)	M
			Biological treatment	328 608	tonnes	0.00			M
		Sub-total				0.27			
	Sub-total					0.38			

[43] A1 includes waste and renewables as a fuel type (for the industrial and commercial sector only). However, no double counting with GHG emissions from the waste sector is assumed as: (a) the energy data is difficult to align with the waste data; and (b) waste and renewables contribute 0.06% to overall GHG emissions in A1.

Table 18 – GHG emissions from waste *(continued)*

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Commercial and industrial	1	Waste generated within the city boundary and disposed within the city boundary	Landfill	293 100	tonnes	0.06			M
			Incineration	189 900	tonnes	(0.00)	IE	Included in stationary (A2)	M
			Biological treatment	439 950	tonnes	0.01			M
		Sub-total				0.07			
	3	Waste generated within the city boundary and disposed outside the city boundary	Landfill	683 900	tonnes	0.14			M
			Incineration	443 100	tonnes	(0.01)	IE	Included in stationary (A2)	M
			Biological treatment	1 026 550	tonnes	0.02			M
		Sub-total				0.16			
	Sub-total					0.23			
Construction, demolition and excavation	1	Waste generated within the city boundary and disposed within the city boundary	Landfill	0	tonnes	0.00	NO	No CDE waste	
			Incineration	374 490	tonnes	(0.01)	IE	Included in stationary (A2)	M
			Biological treatment	0	tonnes	0.00	NO	No CDE waste	
		Sub-total				0.00			
	3	Waste generated within the city boundary and disposed outside the city boundary	Landfill	0	tonnes	0.00	NO	No CDE waste	
			Incineration	873 810	tonnes	(0.02)	IE	Included in stationary (A2)	M
			Biological treatment	0	tonnes	0.00	NO	No CDE waste	
		Sub-total				0.00			
	Sub-total					0.00			
Total						0.60			

Table 19 – GHC emissions from waste generated outside the city boundary and disposed within the city boundary

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Waste from outside the city boundary	1	Direct	Landfill	214 496	tonnes	0.05		Information item	M
			Incineration	246 113	tonnes	0.01		Information item	M
			Biological treatment	183 405	tonnes	0.00		Information item	M
		Sub-total				0.01			

E2. Wastewater

1 Assessment boundary

Wastewater generated within the city boundary and treated within the city boundary; wastewater generated outside the city boundary and treated within the city boundary; and wastewater generated within the city boundary and treated outside the city boundary.

2 Activity data

Quantity of wastewater generated, disaggregated by customer and location of treatment facility.

3 Emission factor

Wastewater management company

4 Calculation

$$GHG = \frac{\sum[Water \times EF]}{1\,000}$$

GHG GHG emissions (metric tonnes CO_2e)
Water Volume of wastewater generated in London (Ml/year)
EF Emission factor ($kgCO_2e/Ml$)

Figure 16 – Calculation flowchart, wastewater

The treatment of wastewater in London is managed by Thames Water, the largest of the UK's water and wastewater management companies. Activity data on daily volumes of wastewater collected and treated for residential and non-residential customers are obtained from Thames Water's June returns to Ofwat [44], the UK Government's water services regulator. Data on wastewater collected is provided by sub-region, and the London regions are added together to arrive at a total volume of wastewater generated annually within the city boundary. An aggregated emission factor for the treatment of wastewater from Thames Water is used.

In order to allocate GHG emissions to Scope 1 or Scope 3, PAS 2070 requires cities to identify whether the GHG emissions associated with the treatment of wastewater arise within the city boundary or outside the city boundary. Data on the location and size of large sewage treatment works are used to determine how much of London's wastewater is treated within, and outside, the city boundary. It is assumed that all inboundary wastewater treatment capacity is used for inboundary wastewater and as such no wastewater generated outside the city boundary is assumed to be treated and discharged within the city boundary.

The majority of GHG emissions from wastewater treatment come from the use of energy to pump and treat wastewater. For facilities located within the city boundary these GHG emissions are already included in A1 and A2. To avoid double counting, therefore, these GHG emissions are reported in brackets in the summary table below and not counted when aggregating overall GHG emissions from wastewater treatment. Since an aggregated emission factor is used, non-energy related GHG emissions need to be calculated separately. N_2O emissions, the other significant source of GHG emissions from wastewater treatment, are estimated based on the population of London and typical annual emissions on a per capita basis from a wastewater treatment plant with nitrification/denitrification [45].

[44] Ofwat (2010). *Past information on company performance (June returns)*. Web published at: www.ofwat.gov.uk/regulating/junereturn

[45] For detail on GHG emission calculation methodologies for different wastewater treatment processes please refer to the GPC.

Summary

Table 20 – GHG emissions from wastewater

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	($mtCO_2e$)			
Residential	1	Direct	Wastewater treated inboundary, N_2O	516 499	m-litres	0.02			M
		Sub-total				0.02			
	2	Direct and indirect, from generation of grid-supplied energy	Wastewater treated inboundary, non-N_2O	AS ABOVE		(0.14)	IE	Included in stationary (A2)	M
		Sub-total				0.00			
	3	Indirect	Wastewater treated out of boundary, non-N_2O	102 614	m-litres	0.03			M
			Wastewater treated out of boundary, N_2O			0.00			M
		Sub-total				0.03			
	Sub-total					0.05			
Commercial and industrial	1	Direct	Wastewater treated inboundary, N_2O	17 742	m-litres	0.00			M
		Sub-total				0.00			
	2	Direct and indirect, from generation of grid-supplied energy	Wastewater treated inboundary, non-N_2O	AS ABOVE		(0.00)	IE	Included in stationary (A2)	M
		Sub-total				0.00			
	3	Indirect	Wastewater treated out of boundary, non-N_2O	3 525	m-litres	0.00			M
			Wastewater treated out of boundary, N_2O			0.00			M
		Sub-total				0.00			
	Sub-total					0.00			
Total						0.05			

Table 21 – GHG emissions from wastewater generated outside the city boundary and treated and discharged within the city boundary

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Wastewater from outside city boundary	1.2	Direct, and direct and indirect from generation of grid-supplied energy		0	m-litres	0.00	NO	Information item (assumes no wastewater from outside city boundary is treated inboundary)	

F. Goods and services

Goods and services		Cross reference
F1	Water provision	7.7.1
F2	Food and drink	7.7.2
F3	Construction	7.7.3
F4	Other	7.7.4

F1. Water provision

1 Assessment boundary

Mains water supply within the city boundary from sources within the city boundary, mains water supply outside the city boundary from supplies within the city boundary and mains water supply within the city boundary from sources outside the city boundary.

2 Activity data

Quantity of mains water provision, disaggregated by customer and origin of supply.

3 Emission factor

Water supply companies

4 Calculation

$$GHG = \frac{\sum[Water_a \times EF_a]}{1\ 000}$$

GHG GHG emissions (metric tonnes CO_2e)
Water Volume of water supplied in London (Ml/year)
a Water supply company
EF Emission factor ($kgCO_2e/Ml$)

Figure 17 – Calculation flowchart, water provision

Whereas Thames Water manages all wastewater in London, water provision is managed by four companies: Thames Water, Veolia Water, Essex & Suffolk Water and Sutton and East Surrey Water. Activity data on water supplied are sourced from the companies' June 2010 returns to Ofwat. An aggregated emission factor for the provision of water from Thames Water is used for all four companies.

As for wastewater, PAS 2070 requires the assessment to disaggregate activity data between residential and non-residential customers and identify whether GHG emissions associated with the provision of water arise within the city boundary or outside the city boundary. Due to limited availability of data, these are allocated according to the same proportions as for wastewater treatment. Furthermore, it has been assumed there is no mains water supply outside the city boundary from sources within the city boundary.

GHG emissions from the provision of water are energy-related. For inboundary facilities, these emissions are already included in the assessment in A1 and A2. They are therefore reported in brackets in the summary table below to avoid double counting.

Summary

Table 22 – GHG emissions from water provision

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Residential	1, 2	Direct and indirect	Water supplied inboundary	693 586	m-litres	(0.20)	IE	Included in stationary (A1 and A2)	M
	3	Indirect	Water supplied out of boundary	137 796	m-litres	0.04			M
	Sub-total					0.04			
Commercial	1, 2	Direct and indirect	Water supplied inboundary	23 825	m-litres	(0.01)	IE	Included in stationary (A1 and A2)	M
	3	Indirect	Water supplied out of boundary	4 733	m-litres	0.00			M
	Sub-total					0.00			
Total						0.04			

Table 23 – GHG emissions from mains water supply outside the city boundary from supplies within the city boundary

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
Water supply from outside city boundary	1, 2	Direct and indirect		0	m-litres	0.00	NO	Information item (assumes no water provision outside city boundary from inboundary sources)	

F2. Food and drink

F2.1. Cradle to gate GHG emissions associated with economic final consumption of food and drink within the city

PAS 2070 uses economic final consumption data to calculate GHG emissions associated with food and drink, as used in the CB methodology. This assumes that GHG emissions from the food and drink life cycles correlate well with expenditure (and therefore economic final consumption) on food and drink. The methodology is given in PAS 2070:2013+A1:2014, **8**.

Assessment of GHG emissions associated with economic final consumption of food and drink includes GHG emissions from supply of food and drink consumed by city residents only. Consumption by visitors to the city is excluded. However, it is assumed that the omission of GHG emissions from supply of food and drink to visitors is approximately balanced by the inclusion of GHG emissions from supply of food and drink to residents when they are outside of the city.

F2.2. Direct GHG emissions from food production on a non-commercial basis within the city

1 Assessment boundary

Direct GHG emissions from food production on a non-commercial basis – allotments and gardens – within the city boundary.

2 Activity data

Land area of allotments and gardens used for growing crops, and yield factors for the most common type of crops grown.

3 Emission factor

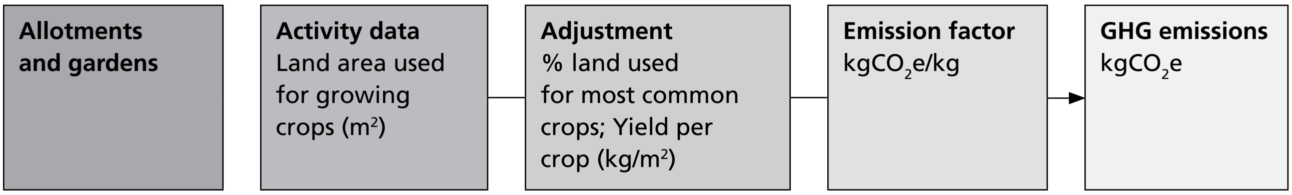
WWF-UK

4 Calculation

$$GHG = \frac{\sum[\text{Land} \times N_a \times \text{Yield}_a \times EF_a]}{1\,000}$$

GHG	GHG emissions (metric tonnes CO_2e)
Land	Total land area used for growing (m^2)
N	% of land used by crop
Yield	Average yield of crop (kg/m^2)
a	Crop type
EF	Emission factor ($kgCO_2/kg$)

Figure 18 – Calculation flowchart, food production on a non-commercial basis within the city



The first step in calculating GHG emissions from non-commercial food production is to identify all the growing spaces in the city. In the case of London, these spaces are assumed to be limited to allotments and back gardens. Next, the area used for growing crops needs to be determined. This is based on the overall number, and average size, of allotment sites in London, and the total area of back gardens used for mixed vegetation and the proportion of households in London who grow their own fruit and vegetables [46].

Finally, the most common types of home-grown crops are identified, and their average yield factors used to convert the area of allotments and gardens used for non-commercial food production into quantities of fruit and vegetables produced annually. These are converted into GHG emissions using emission factors per kg of produce sourced from WWF-UK [47].

[46] Due to limited data availability it is assumed that the proportion of households in London who grow their own fruit and vegetables (14%) is equal to the percentage of the area of back gardens used for mixed vegetation (12%) that is used for growing fruit and vegetables.

[47] WWF-UK (2009). *How low can we go?* Web published at: www.wwf.org.uk/wwf_articles.cfm?unewsid=3666

Summary

Table 24 – GHG emissions from food and drink

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
	1	Direct, from non-commercial food production	Produce from allotments	11 814	tonne	0.01			M
			Produce from gardens	5 027	tonne	0.00			M
		Sub-total				0.01			
	3	Cradle to gate	MR-EEIO model	NO ACTIVITY DATA		10.71			L
Total						10.71			

F3. Construction materials

1 Assessment boundary

Cradle to gate GHG emissions from use of cement and steel materials within the city boundary.

2 Activity data

Quantity of cement and steel materials used nationally apportioned to London based on its share of the value of construction output.

3 Emission factor

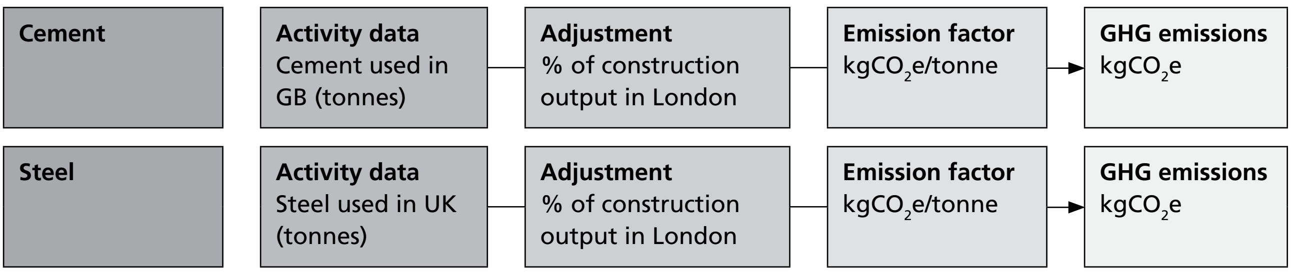
UK GHG Conversion Factors

4 Calculation

$$GHG = \frac{\sum[Material_a \times N \times EF_a]}{1\ 000}$$

GHG GHG emissions (metric tonnes CO_2e)
N Share of domestic construction output
Material Quantity of domestic construction material used (tonne)
a Type of construction material (cement and steel)
EF Emission factor ($kgCO_2e$/tonne)

Figure 19 – Calculation flowcharts, construction materials



To determine the quantity of cement and steel used in London, the best data for the purposes of this assessment was available at a national scale, from both government and industry sources. These were apportioned to London based on the city's share of the value of construction output [48]. The latter is provided by government, which breaks the value of construction output down by region, including London. No significant cement and steel production facilities are identified in London, therefore avoiding any double counting with A. Stationary sources of GHG emissions. Emissions factors from the UK GHG Conversion Factors are used.

F4. Other goods and services that make a material contribution to city GHG emissions

No other goods and services were identified that make a material contribution to the aggregated GHG emissions using the DPSC methodology. The results of the CB methodology were used for this purpose. Whilst these identify consumption categories which make a contribution of ≥2% to overall emissions, they are either already included in the DPSC assessment or defined in such a way that they do not align clearly with a good or service. Further work is therefore needed to understand how the contribution of other goods and services to London's GHG emissions using the DPSC methodology.

Summary

Table 25 – GHG emissions from construction materials

Sub-sector	Scope	GHG emission source	Activity data			GHG	Notation key	Explanation	Data quality
			Description	Quantity	Unit	$mtCO_2e$			
	1	Direct, from inboundary production		0		0.00	NO	No point sources identified	
	3	Indirect, from out of boundary production	Cement	2 101 127	tonne	1.78			L
			Steel	336 381	tonne	0.49			L
		Sub-total				2.27			
Total						2.27			

[48] This can also be apportioned based on relative populations or other indication of economic activity of the geographic areas.

5 CB methodology

The CB methodology offers a different perspective to the DPSC methodology used for measuring a city's GHG emissions. The CB methodology considers the emissions that occur due to the consumption activities of London residents, including all the emissions associated with the production of goods and services throughout their complete supply chain. Conceptually, consumption-based inventories can be thought of as: consumption equals production-based emissions minus the emissions from the production of exports plus the emissions from the production of imports (Consumption = Production – Exports + Imports).

The University of Leeds is responsible for producing consumption-based GHG emissions accounts (CBA) for the UK Government using environmentally extended multi-region input-output (EE-MRIO) analysis, to link the flows of goods and services described in monetary terms, with the emissions generated in the process of production. It has provided estimates for London's GHG assessment using the same methodology to ensure consistency with national accounting.

Household expenditure data are provided at regional level by the Office of National Statistics through their annual family spending survey and report [49]. Data for capital and government expenditure are taken from Input-Output Supply and Use Tables, also from the Office for National Statistics [50]. These data are currently only available at the national level, and are allocated to London according to population. Final demand data and the EEIO are aligned, as such there is no need to make adjustments for inflation, taxes or otherwise. The EE-MRIO model used is proprietary and can therefore not be made available.

For further detail on the specific model used to calculate London's GHG emissions, see: Minx, J., Baiocchi, G., Wiedman, T., Barrett, J., Creutzig, F., Feng, K., Forster, M., Picheler, P., Weisz, H. and Hubacek, K. Carbon footprints of cities and other human settlements in the UK. *Environmental Research Letters*. 2013, **8**(035039).

For further detail on EE-MRIO, see: Wiedmann, T., Wilting, H., Lutter, S., Palm, V., Giljum, S., Wadeskog, A., and Nijdam, D. *Development of a methodology for the assessment of global environmental impacts of traded goods and services*. Environment Agency publication, 2009. Web published at www.skep-network.eu

Table 26 provides a detailed breakdown of the results using the CB methodology using COICOP categories [51].

[49] ONS (2012). *Family Spending 2011: A report on the living costs and foods survey 2010*. Web published at: www.ons.gov.uk. Note, household spending on domestic energy consumption is updated with the stationary energy data used for the DPSC methodology.

[50] ONS (2012). *Input-Output Supply and Use Tables, 2012 Edition*. Web published at: www.ons.gov.uk

[51] The Classification of individual consumption by purpose (COICOP), is an international classification developed by the United Nations Statistics Division to classify and analyze individual consumption expenditures incurred by households.

Table 26 – GHG emissions using the CB methodology, disaggregated by COICOP category

Sector	COICOP categories		Sub-category	GHG emissions $mtCO_2e$		
				CO_2	Non-CO_2	GHG
Households	01	Food and non-alcoholic beverages	Food	2.91	6.27	9.18
			Non-alcoholic beverages	0.22	0.16	0.38
			Sub-total	3.13	6.42	9.56
	02	Alcohol and tobacco	Alcoholic beverages	0.54	0.60	1.15
			Tobacco	0.02	0.01	0.03
			Sub-total	0.57	0.62	1.18
	03	Clothing and footwear	Clothing	0.23	0.07	0.30
			Footwear	0.03	0.01	0.04
			Sub-total	0.26	0.08	0.34
	04	Housing, fuel and power	Actual rentals for households	0.45	0.09	0.54
			Imputed rentals for households	0.94	0.22	1.16
			Maintenance and repair of the dwelling	3.91	1.49	5.40
			Water supply and miscellaneous dwelling services	0.64	0.32	0.96
			Electricity, gas and other fuels	18.87	0.84	19.71
			Sub-total	24.81	2.96	27.78
	05	Household goods and services	Furniture, furnishings, carpets etc.	0.52	0.13	0.65
			Household textiles	0.27	0.10	0.37
			Household appliances	0.14	0.03	0.17
			Glassware, tableware and household utensils	1.37	0.53	1.89
			Tools and equipment for house and garden	0.48	0.15	0.63
			Goods and services for household maintenance	0.32	0.49	0.81
			Sub-total	3.10	1.43	4.53
	06	Health	Medical products, appliances and equipment	0.76	0.31	1.07
			Out-patient services	0.22	0.07	0.29
			Hospital services	0.16	0.05	0.21
			Sub-total	1.14	0.43	1.57
	07	Transport	Purchase of vehicles	0.92	0.19	1.12
			Operation of personal transport equipment	9.58	0.93	10.52
			Transport services	7.45	0.36	7.81
			Sub-total	17.96	1.49	19.44
	08	Communication	Postal services	0.17	0.03	0.20
			Telephone and telefax equipment	0.01	0.00	0.02
			Telephone and telefax services	0.80	0.19	0.99
			Sub-total	0.99	0.22	1.21

Table 26 – GHG emissions using the CB methodology, disaggregated by COICOP category *(continued)*

Sector	COICOP categories		Sub-category	GHG emissions $mtCO_2e$		
				CO_2	Non-CO_2	GHG
Households	09	Recreation and culture	Audio-visual, photo and info processing equipment	0.46	0.10	0.57
			Other major durables for recreation and culture	0.23	0.07	0.29
			Other recreational equipment etc.	2.09	4.15	6.24
			Recreational and cultural services	1.13	0.31	1.43
			Newspapers, books and stationery	0.74	0.22	0.96
			Sub-total	4.64	4.85	9.49
	10	Education	Education	0.38	0.08	0.46
			Sub-total	0.38	0.08	0.46
	11	Restaurants and hotels	Catering services	2.41	1.36	3.77
			Accommodation services	0.76	0.43	1.19
			Sub-total	3.17	1.79	4.95
	12	Miscellaneous goods and services	Personal care	0.62	0.15	0.77
			Personal effects	0.33	0.08	0.42
			Social protection	0.56	0.18	0.75
			Insurance	0.63	0.12	0.75
			Financial services	0.58	0.12	0.70
			Other services	0.58	0.15	0.73
			Sub-total	3.31	0.80	4.11
	Sub-total			63.45	21.17	84.62
Capital				11.62	4.76	16.38
Government				8.75	3.11	11.86
Other [52]				0.93	0.31	1.25
Total				84.75	29.35	114.10

For further detail on the above analysis, see: Barrett, J. *Consumption based Greenhouse Gas Emissions for London (2008 to 2010)*. University of Leeds, 2013. Web published at: http://www.london.gov.uk.

[52] The category "other" refers to a number of miscellaneous expenditure items that are difficult to assign to one of the main categories. These include expenditure by not for profit institutions serving households (NPISH) such as charities and museums. In addition this category includes changes in stock within capital items.

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