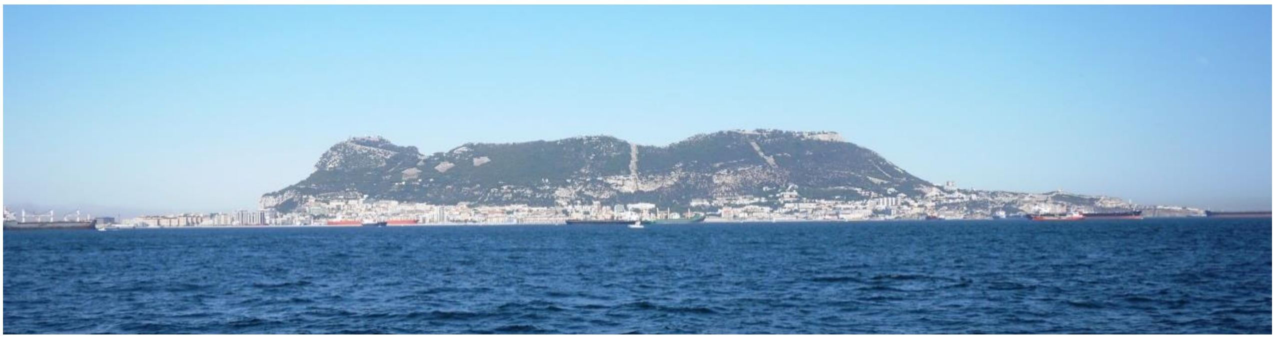
Department of the Environment and Climate Change

HM Government of Gibraltar

A City-Level Greenhouse Gas Inventory for Gibraltar



Report for HM Government of Gibraltar

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Executive summary

Cities are a large problem and a significant opportunity in the management of global greenhouse gas (GHG) emissions. Globally, there is increasing focus on accounting and management of emissions at the city level. Organisations such as the United Nations Environment Programme (UNEP), International Council for Local Environmental Initiatives (ICLEI), C40 Cities, CDP (formerly the Carbon Disclosure Project), World Mayors Council on Climate Change, World Resources Institute (WRI), and carbon*n* Cities Climate Registry are all championing the city scale as a key area on which to focus GHG accounting and mitigation activities.

The first step in managing GHG emissions effectively at the city (or community) scale and making informed decisions to contribute to global mitigation efforts, is to have a good understanding of these emissions – the major sources, activities and relative contributions of different activities. Existing emissions data captured and reported through the UK Greenhouse Gas Inventory (GHGI) for Gibraltar do not give a complete picture of Gibraltar's GHG impact and mitigation activities. Its primary purpose is to monitor and report emissions **produced** on a territorial basis and is compiled following the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines to meet the UK's reporting commitments under the United Nations Framework Convention on Climate Change (UNFCCC). It is not the most useful approach or format for estimating and reporting emissions for Gibraltar because it does not take account of activities outside of the geographic boundary or disaggregate information to a spatial resolution that is useful locally to enable targeted policy action, for instance electricity use.

This project set out to compile a detailed bottom-up inventory of GHGs for Gibraltar for the most recent year, 2013. It considered emissions from all sources, including stationary combustion by end user (power generation and consumption); mobile combustion (by road, marine, and shipping); waste disposal and wastewater; industrial process and product use (IPPU) emissions; and indirect emissions associated with Gibraltar's supply chain (for instance, imports of food, construction materials and other goods). It followed as closely as possible, new methodological guidelines for city inventories by the British Standards Institute (PAS 2070) and the Greenhouse Gas Protocol's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (Greenhouse Gas Protocol, 2014).

Emissions are calculated for the 'basket' of six Kyoto greenhouse gases (GHGs), reported as carbon dioxide equivalent (CO_2e) and are categorised by 'scope'. Scope 1 emissions are directly emitted in boundary; scope 2 emissions are indirect from inboundary consumption of electricity; scope 3 emissions are indirect and out of boundary emissions.

There are various levels of reporting, and this inventory also distinguishes between these different accounting approaches. The GPC has two reporting levels, known as BASIC and BASIC+, the latter including a greater number of sources, in particular some Scope 3 indirect emission sources. It is recommended that cities aim to report BASIC+ emissions. Transboundary transport emissions are included under BASIC+ reporting, and this includes water-borne navigation. However, in the case of Gibraltar, much of this is international shipping (non-bunkering), and is excluded from the BASIC+ results presented in this report due to its very large impact on overall totals, and the lack of potential local influence. This sub-set can therefore be considered Gibraltar's 'manageable emissions'. This is shown in Figure i.

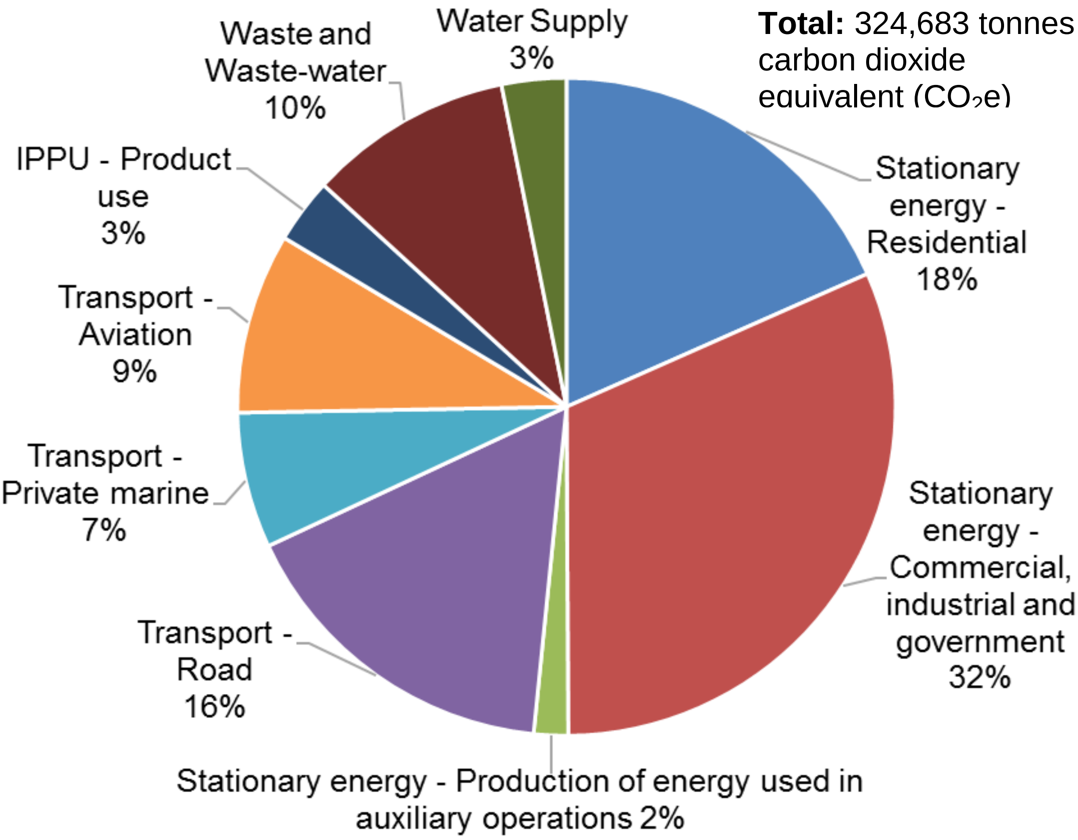

Figure i: BASIC+ emissions attributable to Gibraltar (under the GPC's BASIC+ reporting, excluding transboundary international shipping)

The PAS 2070 'Direct Plus Supply Chain' (DPSC) method includes additional sources again, in particular indirect upstream emissions from fuel (processing, refining and transportation), and from the supply chain.

Sources that are deemed to be 'outside of scopes' (i.e. they are reported for information, but are not deemed to be within the influence or responsibility of the city – such as bunker fuel) would dominate emissions overall if included in emission totals, with bunkering alone making up nearly 60% of emissions when all are combined.

The results for BASIC+ excluding transboundary maritime navigation are much more aligned to those expected for a city, with stationary energy dominating, accounting for 52% of emissions. This is particularly the case in Gibraltar given the relative carbon inefficiency of electricity generation. Transportation also contributes about one third of emissions, with 16% from road transport sources. Waste and IPPU are smaller, at 10% and 3% respectively, and water supply 3%. When comparing emissions with other global cities, however per capita BASIC-level emissions are used. For Gibraltar this equates to over 9 tonnes per person.

Overall, including all sources, the largest contributor of emissions in the Gibraltar city inventory is water-borne navigation, accounting for 52% of total emissions. This includes shipping emissions (excluding ships solely visiting for bunkering) and private boats. Transport is therefore the largest overall source, accounting for 57% of emissions, of which 3.1% are from road transport. Stationary energy is responsible for 9.7% of emissions, waste 1.9% and IPPU 0.6%. Indirect sources of emissions are large contributors, with emissions from the supply chain accounting for 17% of overall emissions, and the upstream impacts of fuel 13%.

CO_2 is the dominant GHG emitted. Scope 1 emissions are largely dominated by road transport fuel use, but also a noticeable contribution from hydrofluorocarbons (HFCs) from product use (such as air-conditioning units).

Scope 2 emissions from electricity consumption are also large, due to the reliance on electricity for all energy needs and generation technology. Because gas oil is used to generate electricity, the emissions per kilowatt hour (kWh) are considerably higher than, for example, the UK. The implied emission factor based on fuel consumption in power stations and total output is 0.9804kg/kWh in Gibraltar, compared with the UK grid factor of 0.4943kg/kWh[1].

Scope 3 emissions are largest overall across scopes (excluding 'outside of scopes'), due primarily to shipping activity (excluding bunkering) and upstream fuel emissions (such as processing, refining and transporting).

An emissions inventory is an ongoing tool for understanding and reporting emissions, and allows the identification of major sources and priority areas for mitigation. It can be seen from the results presented above that there are some areas where mitigation efforts should be focussed in order to reduce greenhouse gas emissions.

Stationary energy, as the highest contributor to overall manageable emissions, should be given priority. In particular, the industrial, commercial and government sectors, as the highest end user category. Road transport is not one of the larger sources, but is significant given the small size of the territory and the potential for interventions to reduce vehicle use. Waste emissions are high compared to other city inventories, mostly from solid waste disposal at landfill sites. This is also an area of considerable local influence. Finally, individual industries that are high energy users, such as water supply, should be identified and ways to reduce energy consumption investigated.

This inventory has been compiled using the best available data and methods, however there remains potential for improvement, and subsequent inventories should seek to build on the work undertaken here, and improve the accuracy, reliability, and coverage of data.

[1] www.ukconversionfactorscarbonsmart.co.uk/

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1 Introduction

Cities are a large problem and a significant opportunity in the management of global greenhouse gas (GHG) emissions. The 2008 World Energy Outlook estimated that cities accounted for over 70% of global GHG emissions[2], yet they also offer unique mitigation opportunities, due to the concentration of people and activities in a geographically small area. Globally, the focus has increasingly shifted towards accounting and management of emissions at the city scale. Organisations such as the United Nations Environment Programme (UNEP), International Council for Local Environmental Initiatives (ICLEI), C40 Cities, CDP (formerly the Carbon Disclosure Project), World Mayors Council on Climate Change, World Resources Institute (WRI), and carbon*n* Cities Climate Registry are all championing the city scale as a key area on which to focus GHG accounting and mitigation activities.

The first step in managing GHG emissions effectively at the city (or community) scale and making informed decisions to contribute to global mitigation efforts, is to have a good understanding of these emissions – the major sources, activities and relative contributions of different activities. However, until recently, one of the overwhelming problems was the lack of a common methodology for GHG accounting at the city scale. National GHG inventory data are based on guidance and methods from the Intergovernmental Panel on Climate Change (IPCC) and are reported based on geographical boundaries and the point of production. Adopting this approach for a city does not accurately reflect a city's impact on GHG emissions, nor does it help local decision-makers to assess the potential for GHG mitigation actions. Constraining city-level inventories to national-level approaches would not enable an accurate representation to be made of the impact of activities outside the city boundary (e.g. manufacturing industry, energy supply or management and disposal of city waste). Furthermore, national inventory methods attribute emissions to a specific source (and location) rather than the end users that drive the demand for those emissions (e.g.in national inventories, emissions from electricity generation are allocated to the power stations rather than the multitude of end-user sectors, such as industry, commerce and residential users). Not only is this misleading for reporting on community-scale GHGs, but it is unhelpful for local policy development, targeting mitigation actions and demonstrating success.

Existing emissions data captured and reported through the UK Greenhouse Gas Inventory (GHGI) for Gibraltar do not give a complete picture of Gibraltar's GHG emissions or the impact and potential for local mitigation actions. The primary purpose of the UK GHGI is to monitor and report GHG emissions produced on a territorial basis. To meet the UK's reporting commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and be comparable to other national inventories, the UK GHGI must be compiled and reported according to IPCC Guidelines for national inventories. Therefore, it does not take account of activities outside of the geographic boundary or disaggregate information to a spatial and sector resolution that is useful locally to enable targeted policy action, for instance monitoring electricity use to be able to appraise energy efficiency policies. Reports in summer 2012, based on data from the US Energy Information Administration,

[2] www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

claimed that Gibraltar had the highest per capital carbon footprint in the world[3]. This was largely due to the volumes of bunker fuel sold to large marine cargo vessels[4] compared with a small population. This presents a distorted view of GHG emission sources under local control in Gibraltar. Therefore, there was a need for an alternative, city 'activity-based' approach to measure and report community-scale GHG emissions, particularly if Gibraltar is to realise its aspirations of becoming 'carbon neutral'.

This project set out to compile a detailed bottom-up inventory of GHGs for Gibraltar for the most recent year – 2013. It considered emissions from stationary combustion by end user (power generation and consumption), mobile combustion (by road, marine and shipping), waste disposal and recycling, water supply, industrial emissions and indirect emissions associated with Gibraltar's supply chain (for instance, imports of food, construction materials and other goods). It follows, as closely as possible, the new methodological guidelines produced by the British Standards Institute (PAS 2070) and the Greenhouse Gas Protocol's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Draft Version 2.0.

[3] www.theguardian.com/environment/2012/jul/16/gibraltar-carbon-emissions-distorted-table

[4] Bunker fuels refer to the storage and sale of fuels – typically gas oil and fuel oil – at national boundaries, in this case the trade of shipping fuels at the Port of Gibraltar.

2 Reporting standards

2.1 Overview

As noted in the introduction, inventory methods that cities have used have varied in what emission sources and greenhouse gases (GHGs) are included, how emissions sources are defined and categorised, and how transboundary emissions are treated. This inconsistency makes comparisons between cities difficult; raises questions around data quality; and limits the ability to aggregate local, subnational and national government GHG emissions data.

It has been recognised that, to allow for more credible reporting, meaningful benchmarking and aggregation of climate data, greater consistency in GHG accounting is required. In response to this challenge, there are two new methodologies that provide guidance on city-scale GHG inventories. These offer a robust and clear framework that builds on existing methodologies for calculating and reporting city-scale GHG emissions:

- 'Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Draft Version 2.0 – July 2014'. This is produced by the Greenhouse Gas Protocol and supported by the World Resources Institute, C40 Cities, the International Council for Local Environmental Initiatives (ICLEI) and the World Bank.
- 'PAS 2070:2013+A1:2014 (Incorporating Amendment No. 1), Specification for the assessment of greenhouse gas emissions of a city. Direct plus supply chain and consumption-based methodologies' produced by the British Standards Institution and sponsored by the Greater London Authority. This is also now accompanied by 'Application of PAS 2070 – London, United Kingdom. An assessment of greenhouse gas emissions of a city' and accompanying data, the development of which the Ricardo-AEA team supported.

2.2 Difference from national emissions reporting

City emission standards differ from national reporting methodologies (as required for reporting to the United Nations Framework Convention on Climate Change (UNFCCC)) in several fundamental ways, which reflect the unique circumstances of cities. Although adhering to basic principles of good practice in inventory compilation and reporting, the sources and sectors, and their categorisation are quite different. City-level emission inventories are not primarily focused on emissions from within the geographic boundary, as in a national inventory, but with emissions attributable to activities within the city. Therefore, a city-level inventory includes emissions that occur geographically outside the city (such as out of boundary waste disposal and transboundary transport). The focus on emission 'responsibility' also means that activities occurring in or near the city that are not the responsibility of the city can be excluded to give a more accurate picture of the city's impact. Figure 2-1 shows, in simple terms, the difference in accounting approaches.

This 'responsibility' is broadly identified by means of 'scopes'. Scopes 1 and 2 are those sources occurring as a result of activities within the city boundary by and within the city. Scope 3 sources are those occurring, usually outside of the city boundary, as a consequence of activities. There is more detail on this in Section 3.4.

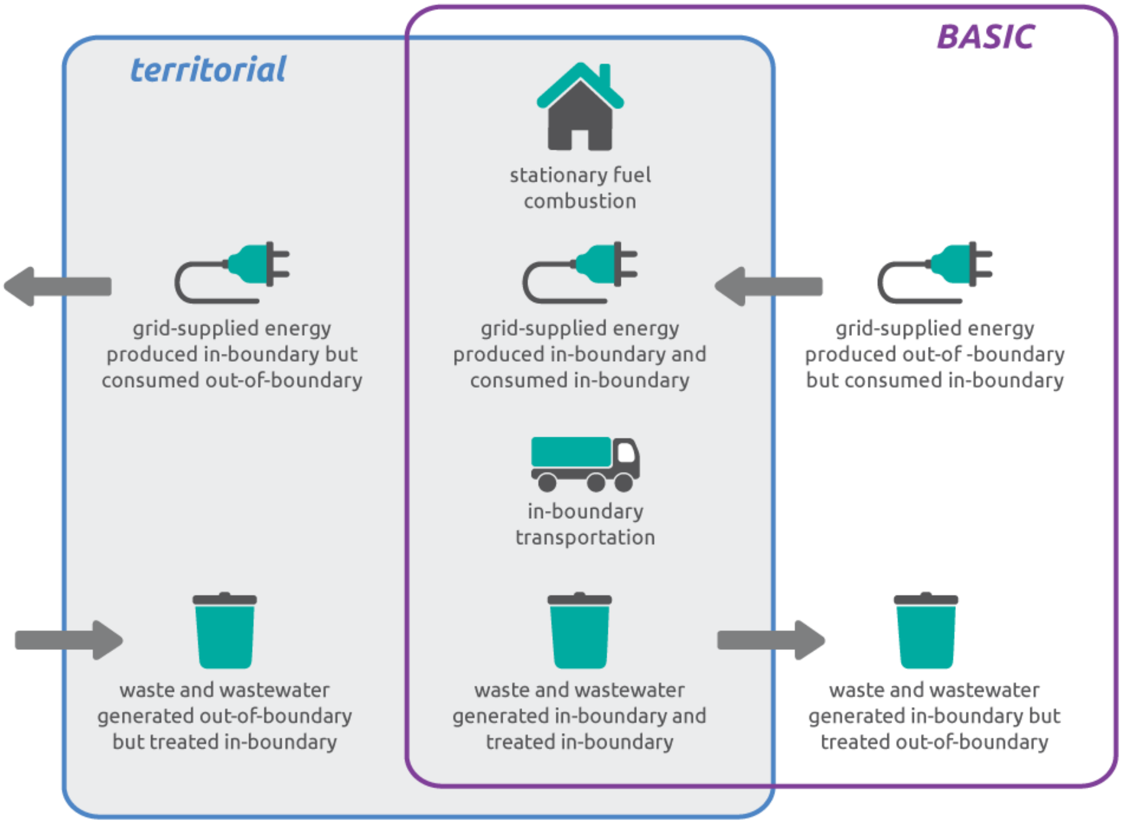

Figure 2-1: Comparison between territorial accounting approach and GPC (figure taken from GPC v2.0 p22)

Existing emissions data captured and reported through the UK Greenhouse Gas Inventory (GHGI) for Gibraltar is not compatible with producing an accurate picture of the GHG impact of the community's activities and, therefore, the prioritisation of mitigation activities. The primary purpose of the UK GHGI is to monitor and report emissions from the UK as a whole, on a territorial basis. Therefore, it focuses on emissions produced and does not take account of activities outside of the geographic boundary or those at a spatial resolution that are useful locally. There is no end-user allocation of electricity (for example, in the existing inventory for Gibraltar), which would enable more targeted policy making and a better understanding of large users. Therefore, there is a need for an alternative, city 'activity-based' approach to measure and report emissions, particularly if Gibraltar is to realise its aspirations of becoming 'carbon neutral'.

For Gibraltar, several key sources of emissions fall into the 'outside of scopes' category for a city inventory. These would be reported in a national inventory and, therefore, highlight the benefit of this alternative inventory approach. A substantial emission source in Gibraltar is from fuel bunker activities for international shipping. The recent (summer 2012) reports based on data from the US Energy Information Administration claimed that Gibraltar has the highest per capita carbon footprint in the world[5] due to the large volumes of bunker fuel sold compared to a small population. Taking a city-inventory approach, bunker fuel can be excluded from the inventory totals as a source beyond the responsibility of the community. Emissions associated with exported fuel in vehicles are also excluded.

[5] www.theguardian.com/environment/datablog/2012/jun/21/world-carbon-emissions-league-table-country

Although methodologically more challenging to estimate (see methodology details below), it is important to attempt to differentiate between fuel used locally and that immediately exported by the many vehicles that cross the border to take advantage of cheaper fuel prices in Gibraltar.

However, it should be noted that the city inventory includes all sources reported under a national ‘territorial’ approach and can be used to enhance territorial reporting.

2.3 Standards and their approaches

The new city inventory methodologies attempt to address some of the challenges that the city-scale presents, including the lack of defined boundaries (in many cases, although not in Gibraltar); fluid boundaries with flows of people, goods and services; lack of end-user disaggregation; and exclusion of out-of boundary impacts. Both methodologies mentioned in Section 2.1 are similar in their categorisation of sources and emphasis on the need for transparency, replicability, consistency, comparability and robustness of reporting.

Table 2-1 summarises the key features of the different reporting levels under both methodologies.

In general terms, PAS 2070 was the more detailed methodology for practitioners, although the recent GPC update has provided considerably more detail on approaches to calculations. PAS 2070 is more prescriptive in the methodological approaches it gives for each sector, with explicit ‘rules’ for accounting. However, the updated GPC now provides more guidance on compiling emissions for sectors (with greater explanation at a more basic level) and more signposting to guidance and sources of information. Therefore, PAS 2070 can be considered better aimed at the experienced inventory compiler, seeking specific guidance on inclusions, exclusions and categorisation of sources, whereas GPC is more appropriate for a city-level practitioner with less experience of inventory compilation.

PAS 2070 offers only two approaches – ‘direct plus supply chain’ (DPSC) and ‘consumption-based’ (CB). DPSC has greater reporting requirements in terms of source inclusion than its GPC equivalent. Therefore, it sets a higher bar than the GPC in terms of the minimum reporting requirements, which are approximately aligned with ‘BASIC+’ under the GPC, with no equivalent of ‘BASIC’. DPSC also includes supply chain emissions which GPC does not. Table 2-1 shows how the standards align in reporting approach and Figure 2-2 shows the inclusion of emission sources by approach.

There is expected to be a strong similarity in the proposed ‘EXPANDED’ consumption-based approach (to be published in 2016) and CB (PAS 2070) approaches which take an econometric approach, using expenditure data in an environmental input-output model.

Table 2-1: Comparison of GPC and PAS 2070 methods

GPC (2.0)	PAS 2070:2014
'BASIC': Covers all scope 1 and scope 2 emissions of stationary units, mobile units, wastes, and industrial processes and product use (IPPU), and waste sector scope 3 emissions.	
BASIC+: Covers GPC 2012 BASIC and AFOLU, and mobile units' scope 3 emissions.	
	Direct plus supply chain: 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, heating and/or cooling, transboundary travel, and supply chains from consumption of key goods and services produced outside the city boundary (e.g. water supply, food and building materials).
EXPANDED: Covers the entirety of scopes 1, 2, and 3 emissions including transboundary emissions due to the exchange/use/consumption of goods and services.	**Consumption based:** Captures direct and life-cycle GHG emissions for all goods and services consumed by residents of a city (that is, 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. The CB methodology uses data on expenditures by its resident households, governments located within the boundary and business capital expenditure. It reflects complex international supply chains and the impact of a city beyond its boundary.

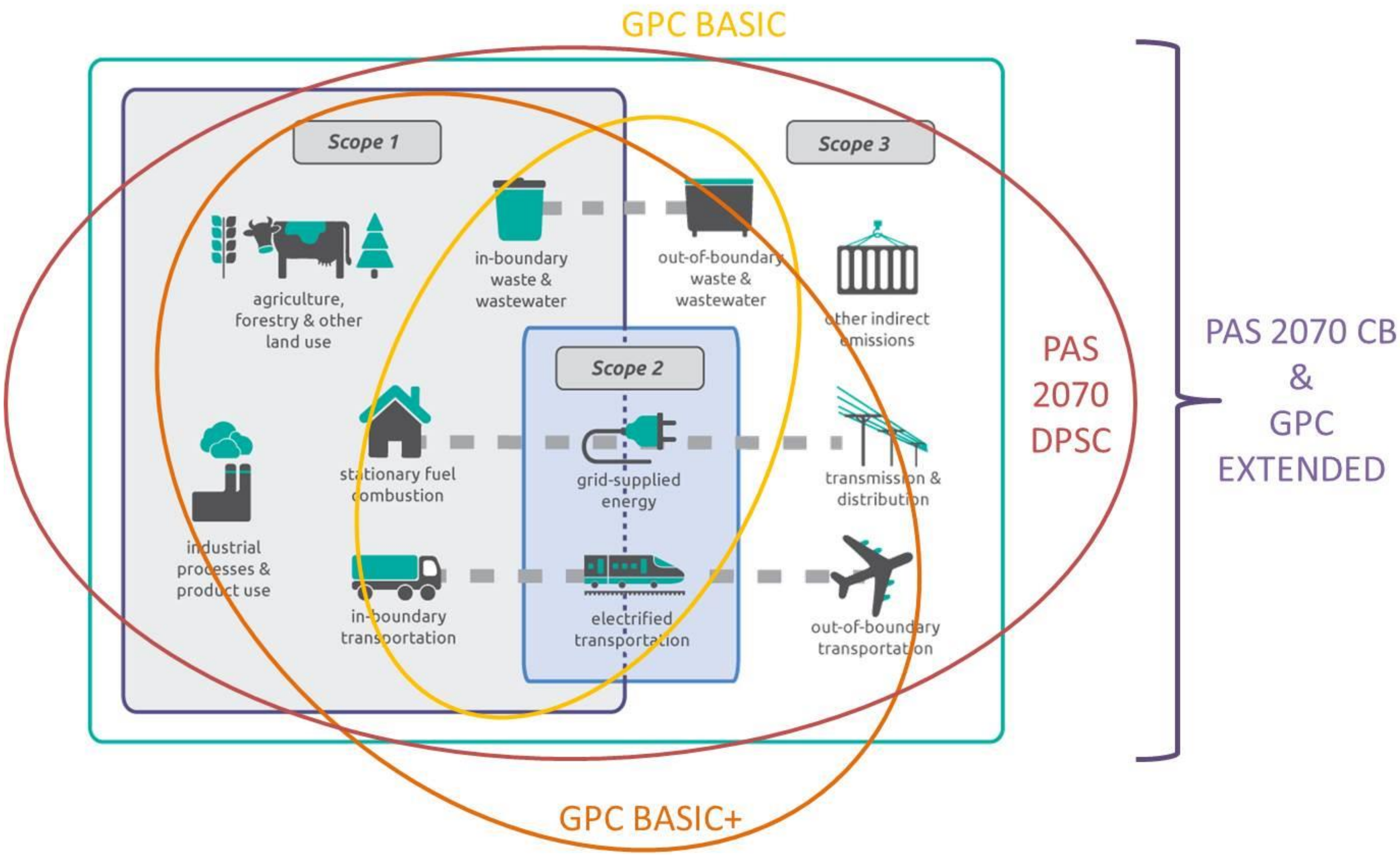

Figure 2-2: GPC diagram (taken from the GPC v2.0 p19) showing emission sources and scopes, with circles added to show the extent of the different GPC and PAS 2070 methods

2.4 Project approach

This project has used GPC and PAS 2070 guidance in compiling and reporting GHGs for Gibraltar. Given their similarities, their use is complementary and, by referring to both, the strengths of each can be utilised. For example, as discussed above, PAS 2070 is stronger on specific methodological requirements for compilation in each sector, and the publication of a case study of its use in London[6] helps to support methodological decisions when used in practice. In addition, the PAS 2070 reporting requirements under DPSC have a greater coverage of sources than the GPC (for example, explicitly including indirect emissions). The GPC, on the other hand, is stronger on reporting (for example, providing a reporting output template for emission results), and provides more context and information on background issues such as notation keys, scopes, data quality, and clarifying inventory language and terms.

As Ricardo-AEA has a team of experienced inventory compilers, the requirements set out in PAS 2070 were predominantly used to inform this work. In addition, the desire to include supply chain emissions has led to greater alignment with the DPSC approach set out in PAS 2070 although all other sources are included in both methods.

Therefore, the inventory includes emissions from the following sources – all but indirect and out of boundary emissions are included in both reporting standards.

- Stationary energy (electricity consumption, including imports from the former Ministry of Defence power station, now Gibraltar Mechanical and Electrical Services Ltd.(GMES).
- Transportation (all scopes – in and out of boundary).
- Waste disposal (all scopes – in and out of boundary).
- Industrial processes and product use (IPPU).
- Agriculture, forestry and other land use (AFOLU).
- Other indirect emissions (including supply chain).
- Out of boundary emissions (bunkering, fuel export and electricity generation to avoid double counting, including at GMES power station).

The results are reported using GPC templates. This is shown in Table 2-2, which also indicates the reporting level of each source (note: BASIC+ includes all BASIC, and DPSC includes all BASIC and BASIC+).

Section 4 gives details of the methodologies used for each inventory sector.

[6] data.london.gov.uk/dataset/application-pas-2070-london-case-study

Table 2-2: Emissions reporting format by source, scope and standard, as recommended by the GPC (taken from the GPC v2.0). Colours indicate categorisation of sources by scope and reporting level.

GPC reference number	Reporting level	Scope	GHG emissions source
I			**STATIONARY ENERGY SOURCES**
I.1			**Residential buildings**
I.1.1	BASIC	1	Emissions from inboundary fuel combustion
I.1.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.1.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.2			**Commercial and institutional buildings/facilities**
I.2.1	BASIC	1	Emissions from inboundary fuel combustion
I.2.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.2.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.3			**Manufacturing industry and construction**
I.3.1	BASIC	1	Emissions from inboundary fuel combustion
I.3.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.3.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.4			**Energy industries**
I.4.1	BASIC	1	Emissions from inboundary production of energy used in auxiliary operations
I.4.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.5			**Agriculture, forestry and fishing activities**
I.5.1	BASIC	1	Emissions from inboundary fuel combustion
I.5.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.5.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.7			**Fugitive emissions from mining, processing, storage, and transportation of coal**
I.7.1	BASIC	1	Inboundary fugitive emissions
I.8			**Fugitive emissions from oil and natural gas systems**
I.8.1	BASIC	1	Inboundary fugitive emissions
II			**TRANSPORTATION**
II.1			**On-road transportation**
II.1.1	BASIC	1	Emissions from inboundary transport
II.1.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.1.3	BASIC+	3	Emissions from transboundary journeys
II.2			**Railways**
II.2.1	BASIC	1	Emissions from inboundary transport
II.2.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.2.3	BASIC+	3	Emissions from transboundary journeys
II.3			**Water-borne navigation**
II.3.1	BASIC	1	Emissions from inboundary transport
II.3.2	BASIC	2	Emissions from consumption of grid-supplied energy

GPC reference number	Reporting level	Scope	GHG emissions source
II.3.3	BASIC+	3	Emissions from transboundary journeys
II.4			**Aviation**
II.4.1	BASIC	1	Emissions from inboundary transport
II.4.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.4.3	BASIC+	3	Emissions from transboundary journeys
II.5			**Off-road**
II.5.1	BASIC	1	Emissions from inboundary transport
II.5.2	BASIC	2	Emissions from consumption of grid-supplied energy
III			**WASTE**
			Solid waste disposal
.1.1	BASIC	1	Emissions from waste generated and treated within the city
III.1.2	BASIC	3	Emissions from waste generated within but treated outside of the city
			Biological treatment of waste
III.2.1	BASIC	1	Emissions from waste generated and treated within the city
III.2.2	BASIC	3	Emissions from waste generated within but treated outside of the city
			Incineration and open burning
III.3.1	BASIC	1	Emissions from waste generated and treated within the city
III.3.2	BASIC	3	Emissions from waste generated within but treated outside of the city
			Wastewater treatment and discharge
III.4.1	BASIC	1	Emissions from wastewater generated and treated within the city
III.4.2	BASIC	3	Emissions from wastewater generated within but treated outside of the city
IV			**Industrial processes and product use**
IV.1	BASIC+	1	Inboundary emissions from industrial processes
IV.2	BASIC+	1	Inboundary emissions from product use
V			**Agriculture, forestry and other land use**
V.1	BASIC+	1	Inboundary emissions from livestock
V.1	BASIC+	1	Inboundary emissions from land
V.1	BASIC+	1	Inboundary emissions from other agriculture
			Sub-total agriculture, forestry and other land use
VI			**Other indirect emissions**
VI.1	DPSC	3	Other indirect emissions

2.5 Accounting and reporting principles

Any inventory should include quality assurance/quality control (QA/QC) activities. The five key principles enshrined in the Intergovernmental Panel on Climate Change (IPCC) reporting guidelines, **transparency**, **consistency**, **comparability**, **completeness** and **accuracy** (TCCCA) should be adhered to in compiling inventory data and reports. The GPC also has five principles, although 'comparability' has been replaced with 'relevance' and a more city-specific definition (see Box 2-1).

- **Transparency** means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information.
- **Consistency** means that an inventory should be internally consistent in all its elements with inventories of other years. An inventory is consistent if the same methodologies are used for the base and all subsequent years, and if consistent datasets are used to estimate emissions or removals from sources or sinks.
- **Comparability** means that estimates of emissions and removals reported by Parties in inventories should be comparable among Parties. For this purpose, Parties should use the methodologies and formats agreed by the COP for estimating and reporting inventories. The allocation of different source/sink categories should follow the split of the IPCC Guidelines, at the level of its summary and sectoral tables. Replaced by 'relevance' in the GPC.
- **Completeness** means that an inventory covers all sources, sinks and gases included in the IPCC Guidelines, and other existing relevant source/sink categories that are specific to individual Parties and, therefore, may not be included in the IPCC Guidelines. Completeness also means full geographic coverage of sources and sinks of a Parties.
- **Accuracy** is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as is practicable. Appropriate methodologies should be used, in accordance with the IPCC good practice guidance, to promote accuracy in inventories.
- **Relevance** means that the reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the city boundary. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational and national regulations. The principle of relevance applies when selecting data sources, and determining and prioritising data collection improvements. Replaced by comparability in the GPC.

Box 2-1: Principles of inventory compilation

2.6 Data quality and notation keys

Data collection is an integral part of developing and updating a GHG inventory. Data will likely come from a variety of sources and will vary in quality, format and completeness. In many cases, data will also need to be adapted for the purposes of the assessment. The IPCC, GPC and PAS 2070 all recognise these challenges and set out good practice data collection principles.

Not all data will be perfect, and there will be gaps, assumptions and limitations with data that are available. To recognise and report these limitations, it is good practice to use notation keys, as recommended in IPCC Guidelines, and an accompanying explanation to justify exclusion or partial accounting of GHG emission source categories. The notation keys used are shown in Table 2-3. When collecting emissions data, it is important to establish first whether a source exists, and then the data availability and quality.

- If the source does not exist, ‘NO’ is used to indicate it is ‘not occurring’. For example, in Gibraltar, there is no rail transport and no agriculture.
- If the activity does occur in the city, and data are available, then the emissions should be estimated. However, if the data are also included in another emissions source category or cannot be disaggregated, the notation key ‘IE’ would be used to indicate ‘included elsewhere’ and avoid double counting. The category in which they are included should be identified. For example, in Gibraltar emissions from water are included under stationary energy as the only emissions attributable to water are from the consumption of electricity.
- If the data are not available and, therefore, the emissions are not estimated, the notation key ‘NE’ would be used to indicate ‘not estimated’.

Table 2-3: Use of notation keys (adapted from 2006 IPCC Guidelines, Chapter 8)

Notation key	Definition	Explanation
NO	Not occurring	An activity or process does not occur or exist within the city.
IE	Included elsewhere	GHG emissions for this activity are estimated and presented in another category of the inventory. That category should be noted in the explanation.
NE	Not estimated	Emissions occur but have not been estimated or reported; justification for exclusion should be noted.

For data that exist, an assessment of quality is then made. In this project, two approaches are used to indicate data quality:

- IPCC tier: the IPCC Guidelines use the concept of ‘tiers’ when estimating emissions.
  - Tier 1 are simple methods with default values.
  - Tier 2 are similar, but with country-specific emission factors and other data.
  - Tier 3 are more complex approaches, possibly models. However, they should be compatible with lower tiers.

  This is indicated by ‘T1’, ‘T2’ or ‘T3’ identifying the Tier to which the method used conforms.
- Qualitative assessment: using expert judgement to assign a rating of high (H), medium (M) or low (L) quality to the data.

2.7 Double counting

It is important to be aware of and seek to avoid double counting of emissions. The notation key IE helps to identify those sources that occur elsewhere in the inventory and are, therefore, only to be included in totals once. The most obvious source to be aware of is energy generation, which is reported under Scope 1 emissions, but also reported in disaggregated form under Scope 2 emissions. Gibraltar is unusual as a city in generating all its own electricity within its boundary. Therefore, generation and consumption (plus losses and use by the generation facilities) should be equal and generation is reported as an information item only. This can be used as a useful check to ensure double counting has not occurred in this instance.

Indirect emissions from the supply chain are also a source of possible double counting. As discussed in more detail in the methodology section (4.6), raw import data were used in preference to data provided in a previous carbon footprint study (Larsen, et al 2013) as it was not possible to identify the contribution of sources such as transportation and stationary energy to these life-cycle emission calculations.

2.8 Accuracy

Most major emission sources within the Gibraltar inventory ultimately fall under electricity consumption or fuel consumption (road and marine), for which accurate totals are available from the power stations and import statistics respectively. Therefore, these data sources act as the high level ‘fuel balance’ that is allocated across different sources from available activity data. This ensures that there is a high level of reliability in the total emission figures and double counting is avoided. Any uncertainty is then associated with the activity data and allocation methods. Accuracy here is important for policy purposes, but less important for understanding the total GHGs emitted.

3 Assessment boundaries

This section sets out the reporting boundaries and requirements of the inventory.

3.1 Geographical boundaries

This inventory is defined geographically by the territorial boundary of Gibraltar, as shown in Figure 3-1.

Figure 3-1: Map of Gibraltar showing geographic extent, main transport routes and land use classifications[7]

[7]Original by Eric Gaba, label/legend edits by Jeff Dahl - adapted from: Image: Gibraltar map-en.svg Map created using screenshots of Google Earth satellite imagery from a point of view located at 1.18 km of altitude (available imagery of November 2007)) en.wikipedia.org/wiki/Gibraltar#mediaviewer/File:Gibraltar_map-en-edit2.svg

3.2 Temporal scale

This inventory covers all atmospheric emissions during calendar year 2013. Where 2013 data were not available, the most recent year's data have been used and the timescale noted accordingly. In particular, these are:

- Population: 2012 figure (2013 not yet available).
- Gross domestic product (GDP): 2012 figure (2013 not yet available).
- Household numbers: 2012 figure (2013 not yet available).
- Import and export statistics: 2011 (most recent available data).

3.3 Greenhouse gases and reporting

Emissions of the following 'basket of 6' greenhouse gases (GHGs), excluding direct removals of GHGs from the atmosphere (e.g. carbon sequestration in the soil and vegetation of parks and gardens), are required to be included in the assessment. These GHGs are regulated under the Kyoto Protocol.

- Carbon dioxide (CO_2), excluding CO_2 emitted from biogenic carbon sources[8].
- Methane (CH_4), including CH_4 derived from biogenic sources of carbon.
- Nitrous oxide (N_2O).
- Hydrofluorocarbons (HFCs).
- Perfluorocarbons (PFCs).
- Sulfur hexafluoride (SF_6).

The International System of Units (SI units) is used for measuring and reporting activity data, and all GHG emissions data are reported as metric tonnes of CO_2 equivalents (CO_2e). CO_2e accounts for the global warming potential (GWP) when measuring and comparing GHG emissions from different gases. Individual GHGs are converted into CO_2e by multiplying by the 100-year GWP coefficients given in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines (see Table 3-1). These are taken from the IPCC.[9]

Table 3-1: Global warming potentials (GWP) used in calculations, adapted from IPCC 2006 Guidelines.

Industrial designation or common name	Chemical formula	Lifetime (years)	Radiative efficiency (W m^{-2} ppb^{-1})	Global warming potential for given time horizon (100 years)
Carbon dioxide	CO_2		1.4×10^{-5}	1
Methane	CH_4	12	3.7×10^{-4}	25
Nitrous oxide	N_2O	114	3.03×10^{-3}	298

[8] The GPC reporting tables include reporting biogenic carbon dioxide denoted 'CO_2(b)'. As land use, land use change and forestry (LULUCF) emissions are NO, this is not reported.

[9] Climate Change 2001: The Scientific Basis Contribution of Working Group I to the Third Assessment Report of the IPCC, (TAR), (ISBN 0521 80767 6), Section 6.12.2, Direct GWPs).

3.4 Sources and scopes

Table 3-2 indicates the sources included in the inventory under each emission scope, and Figure 3-2 shows this is diagrammatic format.

Table 3-2: Sources included in the inventory under each emission scope

Scope	Definition
Scope 1	All GHG emissions from sources located **within the boundary** of the city: • Stationary fuel combustion. • Direct industrial processes and product use (IPPU) emissions. • Electricity generation (information item only). • Mobile fuel combustion: – Road vehicles inboundary. – Marine vessels inboundary. – Aircraft inboundary. – Rail inboundary[10] . • Waste disposal. • Agriculture, forestry and other land use.
Scope 2	All GHG emissions occurring **as a consequence** of the use of grid-supplied **electricity**, heating and/or cooling within the city boundary: • Industrial electricity consumption. • Commercial/other non-domestic electricity consumption. • Electricity consumption for key users (for example, water[11]).
Scope 3	All other GHG emissions that occur **outside the city boundary** as a result of activities within the city's boundary: • Mobile fuel combustion: – Road vehicles transboundary. – Marine vessels transboundary. – Aircraft transboundary. – Rail transboundary[12]. • Waste disposal and wastewater treatment.
Indirect emissions (scope 3)	Emissions associated with consumed goods and services within the city. Key categories to include are: • Food and drink. • Water[13]. • Construction.

[10] Not applicable in Gibraltar
[11] In Gibraltar, water emissions are included under Scope 2 as emissions are solely those associated with electricity consumption for desalination plant and pumping. No mains water is imported.
[12] Not applicable in Gibraltar
[13] Usually included under scope 3. See footnote 2.

Outside of scopes	Sources that occur in or within the vicinity of Gibraltar, but which occur indirectly as a result of activities outside the control or influence of the community. These sources are reported as information items and not included in the overall emission total: • Export of road transport fuels. • Marine fuel bunkering. • Former Ministry of Defence, now Gibraltar Mechanical and Electrical Services Ltd. (GMES) power station: electricity imports and exports.

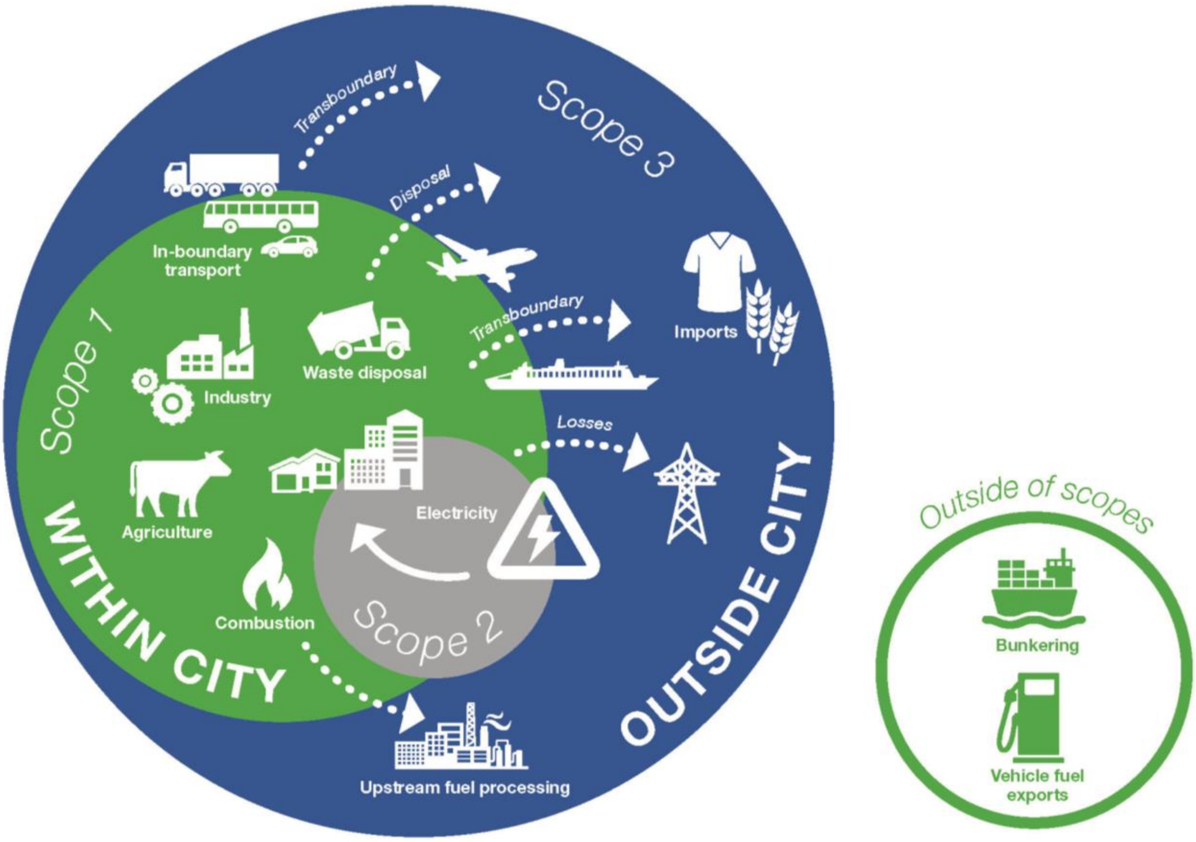

Figure 3-2: Gibraltar's emission sources by scope

4 Calculation methodologies by emission source

4.1 Stationary energy

Stationary energy is a significant part of any inventory. This is generally divided into two categories – emissions from stationary combustion of fuel, and emissions from generation and consumption of grid supplied electricity.

Stationary energy sources appear in all reporting scopes as shown in Box 4-1.

Scope 1: Emissions from inboundary emissions from fuel combustion and fugitive emissions.

- Combustion of fuels in buildings and industry.
- Conversion of primary energy sources in refineries and power plants (including production of electricity used by the power plant).
- Fossil resource and exploration within the city boundary.
- Fugitive emissions from fuel systems.

Scope 2: Emissions from the consumption of grid-supplied electricity, steam, heating and cooling.

Scope 3: Other out-of-boundary emissions.

- Transmission and distribution losses of electricity, steam, heating and cooling (not occurring in Gibraltar).

Box 4-1: Stationary energy sources

Unless stated otherwise, calculation methodologies for stationary energy sources are all consistent with the Energy Sector (volume 2) in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Emissions.

4.1.1 Energy industries: electricity generation

Electricity is the major energy source for Gibraltar and is the only energy industry present. Gibraltar is self-sufficient in electricity and operates as a ‘closed system’ (that is, there are no imports or exports from neighbouring regions). This allows for a very accurate calculation of the electricity-related emissions for Gibraltar.

The exception is a small amount of importing and exporting of electricity between the Gibraltar Electricity Authority (GEA) and the former Ministry of Defence, now Gibraltar Mechanical and Electrical Services Ltd. (GMES) power station. However, following the GPC guidelines, emission estimates from electricity generation are reported separately as an information item, taking account of imports and exports between the GEA and GMES. Figure 4-1 shows how electricity generation is allocated by scope.

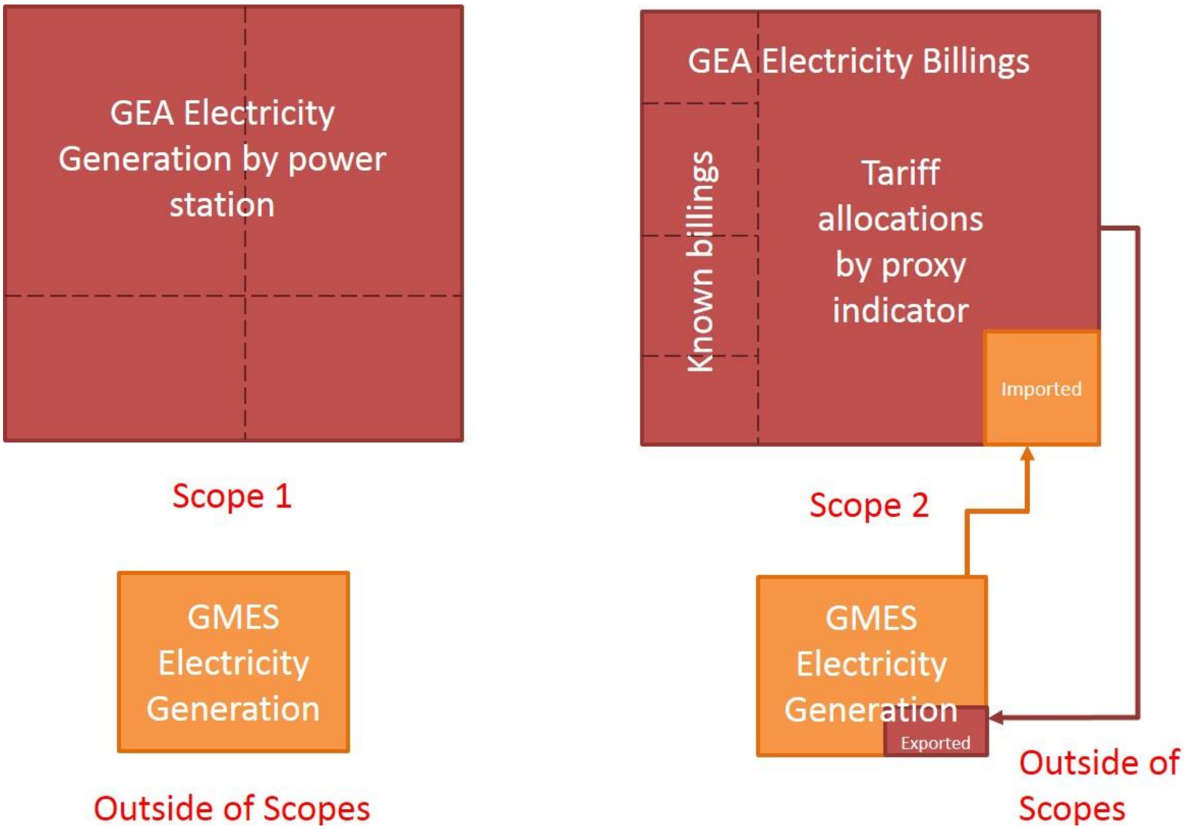

Figure 4-1: Electricity allocation by scope

4.1.1.1 Summary of method

Electricity production includes two categories, which should add up to total emissions from fuel combusted for energy generation:

1. Electricity generation sold and distributed: this comprises emissions from all fuel use for electricity generation from main activity producers.
2. Auxiliary energy use on the site of energy production facilities.

The process of estimating emissions from electricity generation is shown in Figure 4-2.

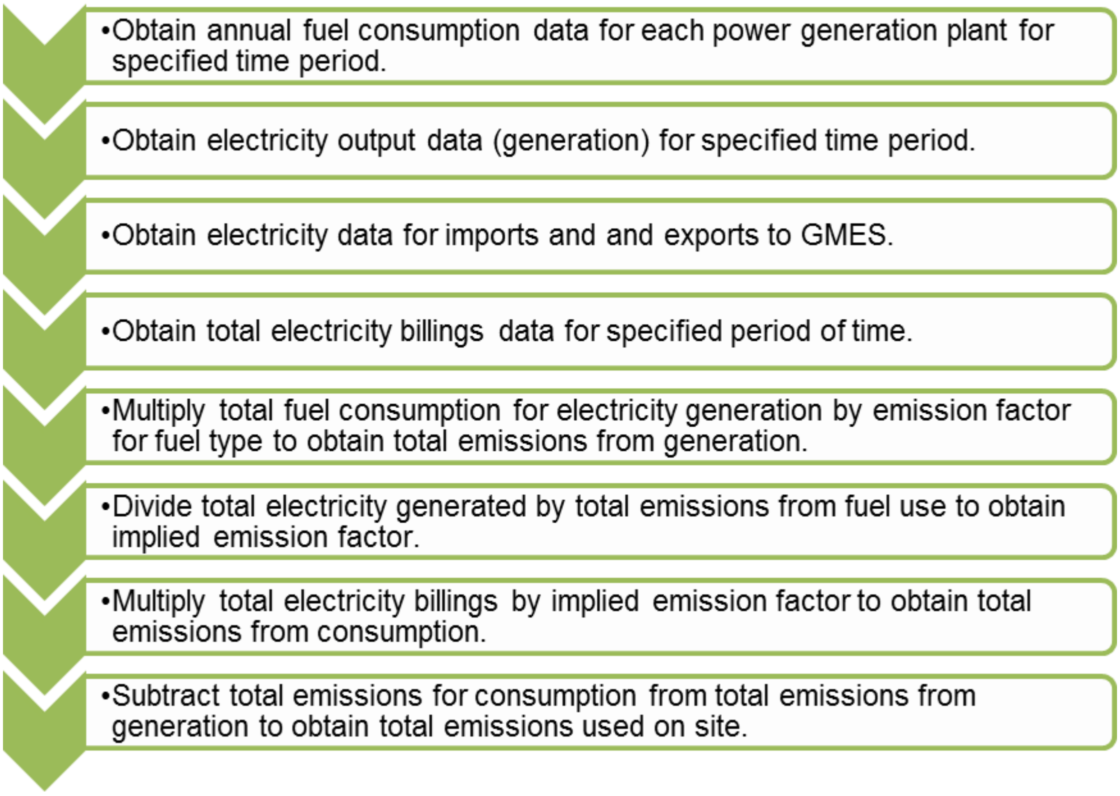

Figure 4-2: Process of estimating emissions from electricity generation

4.1.1.2 Raw data

Raw data were obtained from the GEA and consisted of electricity output, fuel use, fuel type and time period of reporting. There were some inconsistencies and uncertainties in total generation, so data from the Gibraltar Abstract of Statistics were used to provide headline figures for generation and billings (consumption).

Gibraltar's power stations are:

- Waterport power station (since partially burned down, but operational in inventory year 2013).
- North Mole Turbines (Figure 4-3).
- South District Power Station (OESCO plus some skid-mounted generation).
- GMES power station.

All power stations use gas oil. Emission factors for fuels are taken from the UK National Atmospheric Emissions Inventory (NAEI) (2012 data) and are shown in Table 4-1.

Table 4-1: Emission factors for power station gas oil fuel (from UK NAEI)

Pollutant	Unit	Emission factor
Carbon	kt/Mt fuel consumed	870
Methane (CH_4)	kt/Mt fuel consumed	0.14
Nitrous oxide (N_2O)	kt/Mt fuel consumed	0.027

4.1.1.3 Determining emissions

To calculate emissions from electricity generation, total annual fuel use by type can be simply summed and multiplied by the relevant emission factor for each pollutant. This figure is then multiplied by the pollutant's global warming potential (GWP) to give total carbon dioxide equivalent (CO_2e) emissions in tonnes.

To calculate emissions from electricity generation, an implied emission factor calculated from known activity data is required. Total fuel consumption from all power stations is multiplied by the fuel emission factor for each pollutant, and then multiplied by its GWP (or 44/12 to convert from carbon to CO_2). This gives the total emissions from generation, which is then split up based on whether the generated power is used by GMES or Gibraltar. As emissions here are calculated from consumption of a known quantity and type of fuel, and not from other activity data, it is possible to aggregate emissions.

Following Equation 4-1, the sum of emissions for Gibraltar is then divided by the total electricity used in Gibraltar (billed plus power station own use of power) to give an implied emission factor (IEF) in CO_2e per gigawatt hour (GWh). The IEFs used in the inventory are shown in Table 4-2. This IEF can then be multiplied by total electricity consumed (billings data) to give emissions from energy consumed (see Equation 4-2). The difference in GWh and emissions between electricity generated and electricity billed can then be assigned to consumption at the power generation plant.

$$\mathrm{IEF}_{\mathrm{CO_2e}} = \sum \frac{\mathrm{Fuel}_{\mathrm{PS}} * (\mathrm{EF} * \mathrm{GWP})}{\mathrm{G}_{\mathrm{GWh}}}$$

IEF = Implied emission factor

PS = Power station

EF = Emission factor

GWP = Global warming potential

G = Generation

Equation 4-1: Calculation for implied emission factor for power generation

$$\mathrm{CO_2e_B} = \mathrm{B}_{\mathrm{GWh}} * \mathrm{IEF}_{\mathrm{CO_2e}}$$

IEF = Implied emission factor

B = Electricity billings

Equation 4-2: Calculation for emissions from consumed electricity

Table 4-2: Implied emission factors for Gibraltar's power generation

Pollutant	Unit	IEF	IEF factor (CO_2e)
Carbon	kt/GWh	0.27	0.98
CH_4	kt/GWh	4.18E-05	0.001
N_2O	kt/GWh	8.35E-06	0.002
Total	**kt/GWh**		**0.98**

Figure 4-3: Turbines at North Mole

Figure 4-4: New skid-mounted generators at North Mole (2014)

4.1.2 Allocating emissions based on electricity consumption

Allocation of emissions from electricity generation to the end user uses data on total electricity consumption in Gibraltar and the IEF calculated for generation as the basis for calculations. Gibraltar is unusual in that all electricity consumed is also generated within the boundary. Therefore, total emissions data are allocated across different sectors.

4.1.2.1 Overview

A summary of the process is illustrated in Figure 4-5

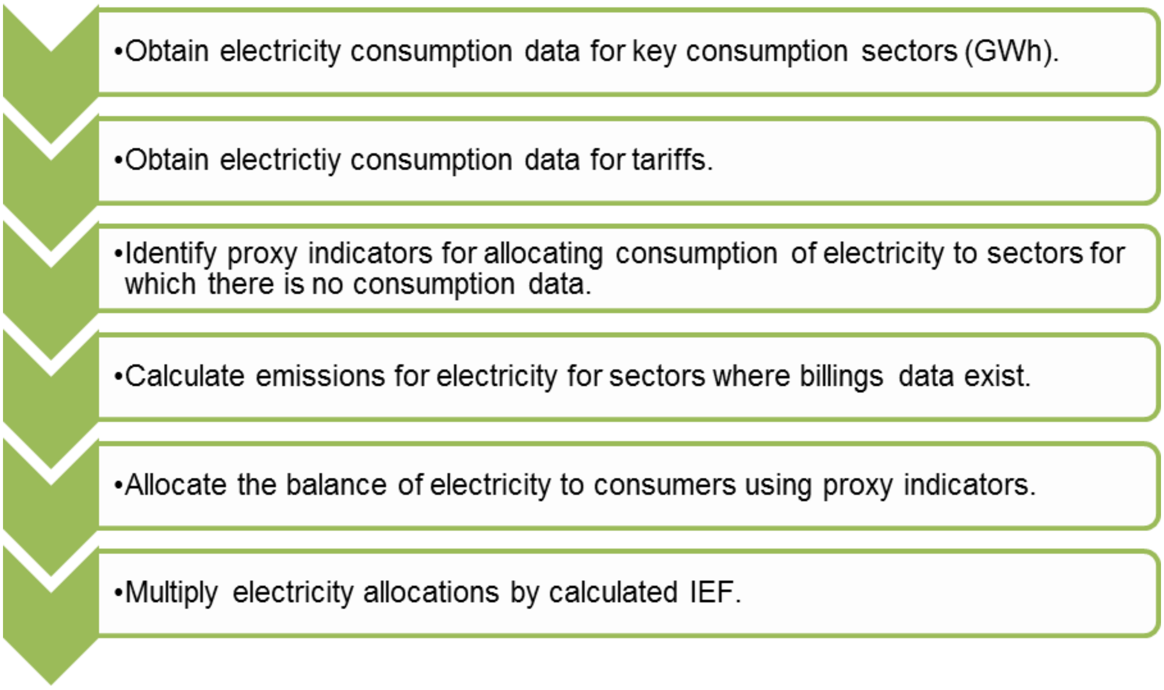

Figure 4-5: Summary of the process of calculating emissions

4.1.2.2 Raw data

A number of data sources were used in compiling estimates of emissions from electricity consumption. These were:

- GWh billings by tariff supplied by AquaGib (see Table 4-3).
- Electricity consumption data for key sectors, including hotels, restaurants, gambling and water supply.
- Proxy data on employment by sector from the 2013 Abstract of Statistics (Table 8.02 Number of Employee Jobs by Industry, October 2013), see Table 4-4. This shows proportion of employees by sector and allocation of industries to tariffs.

4.1.2.3 Determining activity

Electricity consumption data need to be allocated to end users through known consumption or an allocation based on a proxy indicator. Known consumption for sectors include domestic (residential) consumers (from AquaGib tariff data); hotel and restaurant billings data (from AquaGib – incomplete but gaps filled through extrapolation); gambling premises electricity billings data; and AquaGib water electricity billings. Some of these data were unlabelled, but it was assumed they were annual consumption data for 2013 consistent with the data request. This is subtracted from the total billings data.

Table 4-3: AquaGib electricity tariffs

Tariff number	Tariff name	Description	End-user allocation
1	Lighting	Tariff for lighting only	Other
2	Power	Tariff for power only – examples include temporary sockets	Other
3	Domestic	Residential properties only	Residential
4	Commercial	Majority of public sector and commercial premises	Various
5	Industrial maximum demand	Energy-intensive users, in particular bakeries	Other
6A	Off-peak	Power during off-peak hours only	Other
6B	Off-peak	Power during off-peak hours only	Other

Table 4-4: Employment numbers by industry, used as proxy data for electricity allocation

Industry	2013 employment	Industry type (to allocate to tariff)	% of total
Shipbuilding	286	Other	1.25
Other manufacture	207	Other	0.90
Electricity and water supply	283	Other	1.24
Construction	2,133	Other	9.31
Wholesale and retail trade	3,227	Commercial	14.09
Hotels and restaurants	1,333	Commercial	5.82
Transport and communication	1,325	Commercial	5.78
Financial intermediation	2,026	Commercial	8.84
Real estate and business activities	2,640	Commercial	11.52
Public administration and defence	2,262	Public sector	9.87
Education	997	Public sector	4.35
Health and social work	2,013	Public sector	8.79
Other services	4,175	Other	18.23
Total	**22,907**		**100**

Remaining billings data are then allocated to sectors based on employment numbers, and this employment data was used as a multiplier to billings data within tariff categories as shown in Table 4-4. The difference in GWh between electricity billings and generation is allocated to electricity use at generation sites. The assumption is made that this difference is due to electricity use at sites, although this is based on anecdotal evidence only.

4.1.2.4 Determining emissions

Emissions are calculated by multiplying the GWh assigned to each end-user sector as above, by the IEF for each pollutant and its GWP, to give a value of CO_2 e by end-user sector.

4.1.3 Other stationary fuel combustion

Scope 1 emissions from combustion of fuels in power stations in Gibraltar are covered above.

There is believed to be a small amount of stationary fuel combustion, in the form of bottled gas, in some restaurants[14]. However, there are no data available to confirm this or to provide an estimate of emissions. Therefore, this source is not estimated (NE).

It is also understood that some hotels have solid or liquid fuel (such as gas oil or fuel oil) combustion capacity (such as back-up generators). However, no data were available for this study. Therefore, this source is NE.

The Gibraltar Health Authority (GHA) maintains underground supplies of liquid fuel for standby generators in case of power cuts. However, no data were available for this study, therefore this source is NE.

There is no stationary fuel combustion in households as all energy requirements are met through electricity, so this source is not occurring (NO).

There is no fossil resource or exploration in Gibraltar, so this source is NO.

4.1.4 Upstream emissions

In addition to the greenhouse gas (GHG) emissions resulting directly from the generation of electricity, there are also indirect/well to tank (WTT) emissions resulting from the production, transportation and distribution of the fuels used in electricity generation (Scope 3) – gas oil in the case of Gibraltar. Average indirect/WTT emission factors for electricity have been calculated using the corresponding fuels' indirect/WTT emission factors and data on the total fuel consumption by type of generation, using life-cycle data from the European Commission Joint Research Centre (JRC)[15] published by Defra[16]. These figures are shown in Table 4-5.

[14] Pers. Comm. Department of the Environment, Government of Gibraltar

[15] European Commission Joint Research Centre (2013) Well-To-Wheels analysis of future automotive fuels and powertrains in the European context. Well-to-Tank Appendix 4 - Version 4.0 http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2013/wtt_appendix_4_v4_july_2013_final.pdf

[16] Defra (2013) Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors July 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224437/pb13988-emission-factor-methodology-130719.pdf

Table 4-5: Upstream fuel emission factors

Fuel type	Total GHG emissions, kg CO_2e/tonne			
	CO_2	CH_4	N_2O	CO_2e (total)
Aviation turbine fuel	609	47	0.2	656
DERV	630	61	0.0	691
Motor spirit (petrol)	584	32	0.4	616
Gas oil	624	61	0.0	685
Fuel oil	564	44	0.2	608

4.2 Transport

The transport sector covers a wide range of emission sources, including road, rail (not present in Gibraltar), air and water, and consists of inboundary and transboundary sources (see Figure 4-6). In the case of Gibraltar, some transport sources (exported road and marine bunker fuels) are also estimated, but excluded from totals.

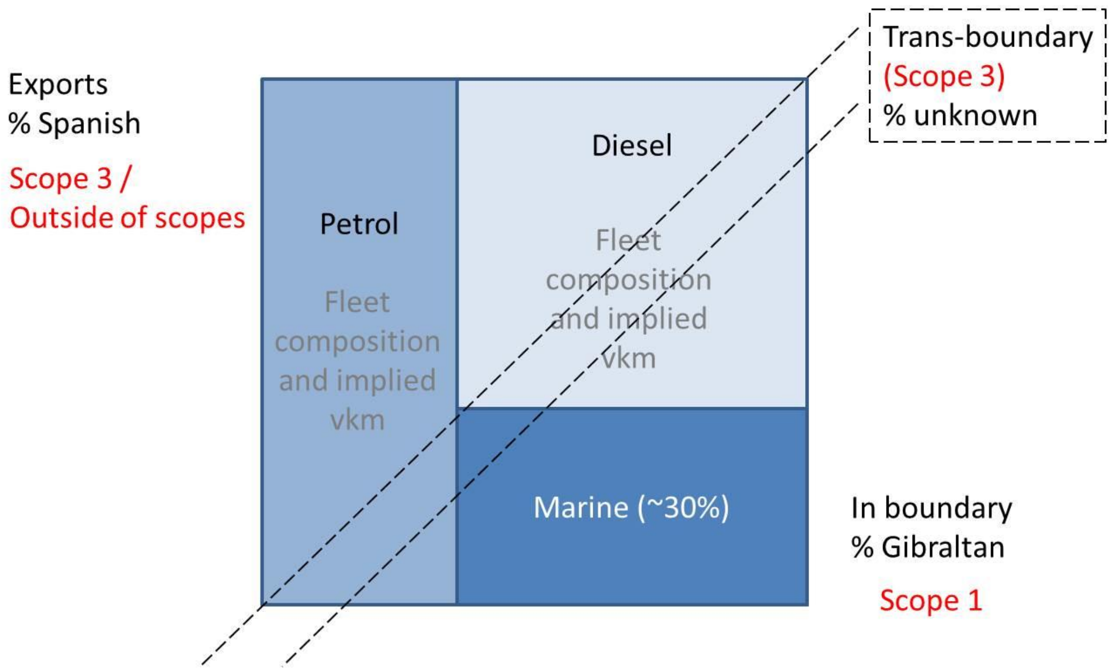

Figure 4-6: Fuel import allocation diagram

Figure 4-7: Gib Oil fuel station

4.2.1 Road transport

Road transport emissions have been calculated from Gibraltar's fuel import statistics for 2013. This effectively provides an 'energy balance' for total road transport fuel consumption. As a result, the emissions total can be calculated very accurately by allocating to Gibraltar the proportion of fuel remaining when exports have been subtracted. A proportion of this imported fuel also goes to private marine use. The allocation of this is discussed in section 4.2.2. Although there is uncertainty in allocation, the overall fuel total and, therefore, emissions remains accurate. Figure 4-6 shows how the total fuel import data are allocated by mode.

Road transport emissions from fuel used by Gibraltarian vehicles are assigned to Scope 1.

Road transport emissions from fuel used by non-Gibraltarian vehicles are assigned to outside of scopes.

There is no way of differentiating transboundary transport (Scope 3).

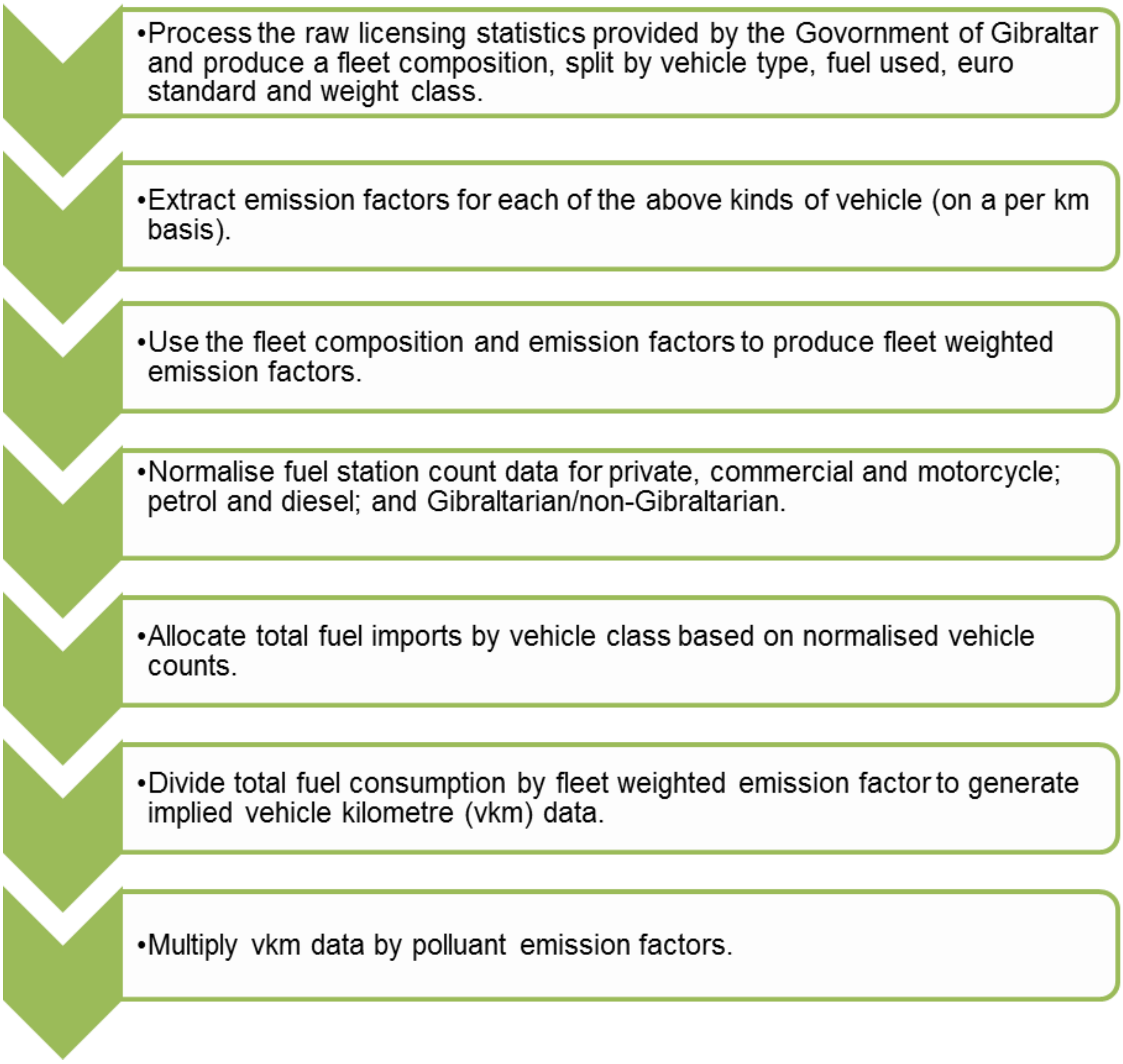

Figure 4-8: Road transport method summary

4.2.1.1 Overview

Figure 4-8 gives a brief overview of how estimates of emissions due to road transport have been made. A more detailed explanation is given in the following sections.

For the highest emitting sources, Gibraltar-specific data have been sought and used. In some cases, for less significant sources, emission factors have been taken from the UK inventory. Generally speaking, these assumptions are based on factors that are unlikely to vary much between Gibraltar and the UK or the impact of any significant differences would be small.

4.2.1.2 Raw data

The licensing statistics provided by the Government of Gibraltar give a number of key pieces of information, allowing the nature of the road transport situation in Gibraltar to be determined. Particular data used were:

- The type of vehicle:
  - This allowed a decision on what kind of vehicle the record corresponded to and, in some cases, allowed a decision to be made about the fuel or weight class.
- Registration date:

  - This helped determine when vehicles were likely to have been manufactured and, hence, what European emission standard they will have been required to meet.
- The fuel type (that is, petrol or diesel vehicles).
- Cylinder capacity:
  - This was used to help determine the weight classes of the vehicles.
- The model and make:
  - Used to spot-check some assumptions.

The fuel import data from 2003/13 provided the high-level energy balance to allocate by mode and sector. Data for 2013 are shown in Table 4-6.

Table 4-6: Gibraltar fuel import data for 2013

Year	Fuel	Thousands of Litres
2013	Motor spirits	14,472
2013	Gas oil	23,452

In addition, surveys of fuel stations carried out by the Department of the Environment over a 17-day period (for approximately a 1-hour period at each of four stations) captured the vehicle type (commercial, private (assumed car) and motorcycle), the fuel type and the licence plate, which was used to determine if the vehicle was Gibraltarian or other (mostly Spanish).

4.2.1.3 Determining activity

Road transport emissions are most accurately estimated from fuel consumption when the carbon content, and thus CO_2 emitted when combusted, is accurately known (although other pollutants are more greatly affected by the method of combustion). There are reliable data from the fuel import statistics for this. However, for a local-scale inventory, an understanding of how these emissions are allocated across modes by activity is more useful for informing policy. In this inventory, the fuel import data have been allocated.

Fuel import data (by motor spirit (petrol) and gas oil (diesel)) for 2013 included gas oil for marine use prior to June only. Therefore, this marine fuel needed to be removed from the import data totals for allocation to the marine sector.

It was assumed that 30% of gas oil imports was used for marine vessels[17] and so 30% of the amount of gas oil attributable to the year to June (assumed monthly constant) was assigned to marine (scaled up for the rest of the year) and removed from the road transport total. This is shown in Table 4-7. This assumption is supported by the trends in fuel imports data provided by the Government of Gibraltar for 2003/13. In particular, before 2007, these data only capture fuel used by road vehicles. Between 2007 and June 2013 the coverage expanded to include fuel used by small (less than 250 gross tonnage) marine vessels. During these years, there is a significant step change in the diesel figures, with petrol continuing to follow a relatively smooth trend. A significant fuel use by marine vessels (we have estimated 30%) therefore underlies this step change.

[17] Anecdotal evidence from the Department of the Environment

Table 4-7: Fuel import data scaled and allocated for marine and road use

Fuel type	Fuel imports (thousands of litres)	Scaled up to include marina fuel use for the whole year	DUKES[18] litres/ tonne	Conversion to kt	Road fuel use (kt)	Marine fuel use (kt)
Motor spirit	14,472	14,472	1,368	10.6	10.8	0
Gas oil	23,452	26,511	1,172	22.6	15.8	6.8

In the absence of vehicle activity data (e.g. mileage by mode) to assign fuels to vehicle classes, vehicle fleet data were used to calculate activity data (vkm travelled) by category.

Using the fleet data described above, it was possible to build a basic fleet composition. Some further processing of these data was done to provide further disaggregation (for example, the types of catalysts used in heavy duty vehicles) of the fleet and to fill perceived gaps/errors in the Gibraltar licensing statistics. This processing was done with the aid of the Gibraltar Abstract of Statistics and the UK NAEI estimates.

Fuel station survey data were then processed and normalised to give a frequency of vehicle type (shown in Table 4-8) and, therefore, a fuel-use split. These fuel-use splits were then applied to total fuel use by type (as above), to give fuel use in kt by vehicle type – Gibraltarian and non-Gibraltarian.

Due to the lack of specific activity data for journey types (inboundary and transboundary, and Gibraltarian and non-Gibraltarian vehicles) all fuel use by Gibraltarian vehicles was assigned as inboundary. All fuel use by non-Gibraltarian vehicles was assigned to out of boundary with no explicit transboundary proportion (although some of the inboundary fuel may be transboundary by Gibraltarians crossing the frontier).

[18] Digest of UK Energy Statistics (www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes).

Table 4-8: Normalised vehicle frequencies by type

Vehicle type	Fuel	Gibraltarian /non-Gibraltarian	Normalised vehicle frequencies by filling station			
			CEPSA (1)	PETROIL (2)	GIB OIL (3)	PETROIL (4)
Private vehicle	Diesel	Gibraltarian	17	33	71	20
Commercial vehicle	Diesel	Gibraltarian	7	13	28	19
Private vehicle	Petrol	Gibraltarian	20	87	146	72
Commercial vehicle	Petrol	Gibraltarian	6	18	25	19
Motorcycle	Petrol	Gibraltarian	9	32	0	57
Private vehicle	Diesel	Non-Gibraltarian	197	76	54	8
Commercial vehicle	Diesel	Non-Gibraltarian	16	5	10	2
Private vehicle	Petrol	Non-Gibraltarian	187	92	56	13
Commercial vehicle	Petrol	Non-Gibraltarian	8	1	2	0
Motorcycle	Petrol	Non-Gibraltarian	78	76	0	17
Scaling factors			1.26	1.36	1.75	1.56

4.2.1.4 Determining emissions

The emission factors used for Gibraltar are the same as those used in the UK NAEI road transport projections models (Transport Research Laboratory (TRL) emission factors for fuel consumption, N_2O and CH_4; and the United Kingdom Petroleum Industry Association (UKPIA) for carbon content of fuel). It has been assumed that all traffic in Gibraltar is urban and that any traffic attributed to the City of Gibraltar, but done by vehicles registered outside (for example, people who travel into Gibraltar from Spain) will have a similar fleet composition and driving pattern as that of Gibraltarians.

Because the UK NAEI calculates carbon from fuel combustion on a mass of fuel basis, a fuel consumption factor is used to convert the carbon emission factor from a fuel mass-based factor to a journey distance-based factor.

Using the fleet composition, a very large set of emission factors (for each vehicle type, fuel, weight class, and European emission standard and catalyst type) can be reduced down to a handful of fleet-weighted emission factors for each vehicle type, as shown in Table 4-9.

Emissions are then calculated for each pollutant by multiplying the implied vkm travelled (shown in Table 4-10) by the fleet weighted emission factors.

Table 4-9: Fleet-weighted emission factors

Vehicle type	Weighted emission factor (g/km)		
	CO_2	CH_4	N_2O
Petrol cars	182	0.017	0.006
Diesel cars	181	0.002	0.010
Petrol LGVs*	215	0.014	0.011
Diesel LGVs	197	0.003	0.010
HGV** (rigid)	544	0.033	0.012
HGV (articulated)	973	0.069	0.024
Bus	745	0.067	0.016
Moped	40	0.043	0.001
Motorcycle (two-stroke)	77	0.044	0.002
Motorcycle (four-stroke)	73	0.110	0.002

*Light goods vehicle (LGV) ** Heavy goods vehicle (HGV)

Table 4-10: Calculated fleet-weighted fuel consumption and vkm

Gibraltarian/ non-Gibraltarian	Vehicle type	Fuel type	Fuel consumption (g/km)	Total calculated fuel consumption (kt)	Implied mvkm* travelled
Gibraltarian	Private vehicle	Petrol	57.93	5.17	89
Gibraltarian	Commercial vehicle	Petrol	68.63	1.07	16
Gibraltarian	Motorcycle	Petrol	20.61	1.46	71
Gibraltarian	Private vehicle	Diesel	57.64	6.12	106
Gibraltarian	Commercial vehicle	Diesel	72.64	2.90	40
Non-Gibraltarian	Private vehicle	Petrol	57.93	3.42	59
Non-Gibraltarian	Commercial vehicle	Petrol	68.63	0.11	2
Non-Gibraltarian	Motorcycle	Petrol	20.61	1.63	79
Non-Gibraltarian	Private vehicle	Diesel	57.64	8.71	151
Non-Gibraltarian	Commercial vehicle	Diesel	72.64	0.90	12

*million vehicle kilometres

4.2.2 Marine – private boats

As noted above, a proportion of gas oil included in the fuel import data is used by private boats. This has been estimated at 30% of total demand in 2013[19]. Emissions have been estimated using the emission factors for marine gas oil. As activity data in this sector are not available, there is no way of allocating to specific activities within the private marine sector.

Figure 4-9: There are a large number of private boats in Gibraltar, but no activity data are available

4.2.3 Shipping

Shipping generates a large proportion of Gibraltar's emissions in the national inventory because of the considerable amount of bunkering activity and the fact the Gibraltar is a large international port near a major shipping lane. In this inventory, shipping is divided into two main categories: bunkering, and non-bunkering (that is, ships that call at Gibraltar with a purpose other than just obtaining fuel).

Shipping emissions from non-bunkering traffic are assigned to scope 3.

Shipping emissions from bunkering traffic are assigned to outside of scopes.

4.2.3.1 Overview

Figure 4-10 gives a brief overview of how estimates of emissions due to shipping have been made. A more detailed explanation is given below.

[19] From the Department of the Environment, Government of Gibraltar

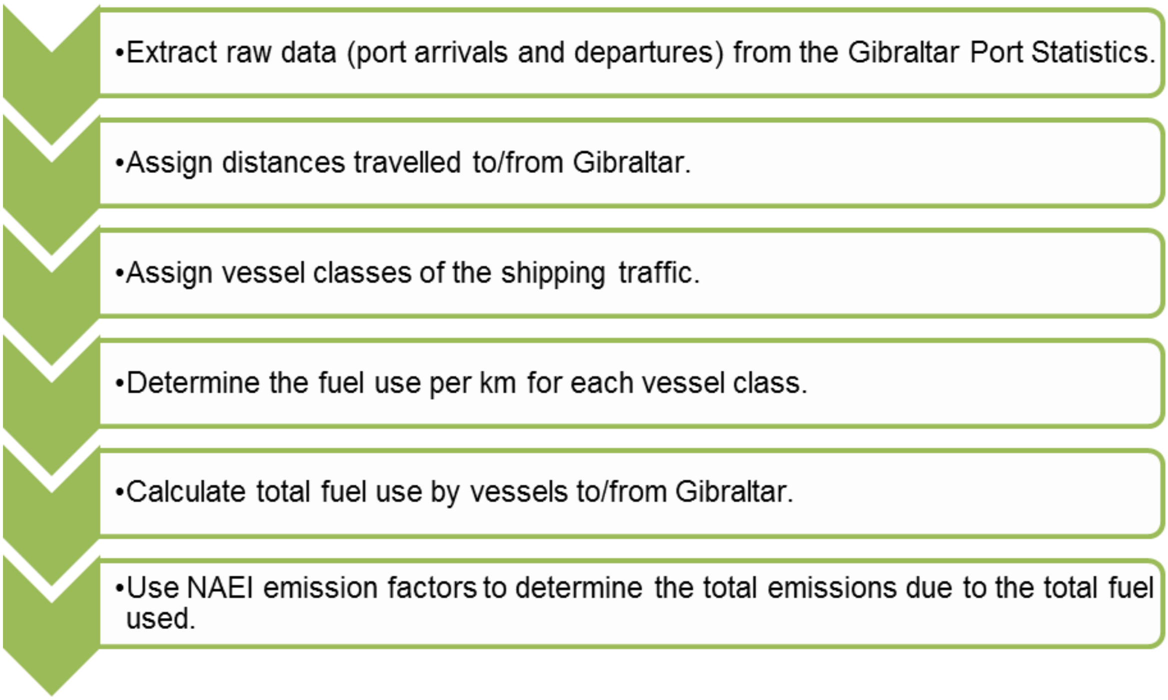

Figure 4-10: Process of estimating emissions from shipping

4.2.3.2 Raw data

The raw dataset used is the Gibraltar Port Authority statistics on shipping movements (www.gibraltarport.com/shipping-movements). This consists of a list of movements to and from Gibraltar, in particular stating a vessel's final destination, port of origin, ship type and purpose of visit. These key pieces of information allow each record to be assigned:

- A distance (km) travelled to/from Gibraltar.
  - Calculated using http://ports.com/sea-route to estimate the distance in nautical miles and converted to km.
- The ship class.
  - The given ship type was assigned to one of the below groups of ship, allowing the use of Tables 3-4 and 3-7 in the EMEP/EEA air pollutant emission inventory guidebook 2013[20] section 1.A.3.d Navigation. (See Table 4-11).
  - Some of the ship types provided in the port statistics were given by three-letter codes, these have been converted using the vessel classifications given in www.ship-tracking.co.uk/Document%20Chest/Movements/VTS%20vessel%20types.pdf
- Whether the activity is linked with bunkering.
  - Because it is unclear whether emissions due to the activity of vessels using the bunkering services provided at Gibraltar should be included as under the responsibility of the City of Gibraltar it is important to determine if the emissions are associated with bunkering or not.
  - The purpose of visit given makes it very easy to determine whether the visit is linked to bunkering.

[20] www.eea.europa.eu/publications/emep-eea-guidebook-2013

Table 4-11: Ship classifications

Ship types	
Tanker	Tug
Roll-on, roll-off ship	Supply
Container ship	Yacht
Cargo ship	Fishing vessel
Reefer	Bulk/carrier ship
Passenger/cruise ship	

The activity for ships travelling both to and from Gibraltar has been calculated, but only one direction (departing) should be included in Gibraltar's emission total as per the British Standards Institute (PAS 2070) and the Greenhouse Gas Protocol's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC).

4.2.3.3 Determining activity

The key activity data of interest are the mass of fuel used, as this is the activity for which emissions factors are available within the UK NAEI. After processing the raw data from the port statistics, the activity dataset is in km. To convert this to a fuel use, it is possible to use the following to calculate fuel use using Equation 4-3:

- Fuel use per unit energy given in table 3-4 of the shipping chapter of the EMEP/EEA air pollutant emission inventory guidebook 2013 (shown here in Table 4-12).
- The engine type weightings provided in table 3-7 of the guidebook (shown here in Table 4-13).
- The main engine power in table 3-6 of the guidebook (shown here in Table 4-14).
- The average speeds in table 3-14 of the guidebook (shown here in Table 4-15).

$$\text{Fuel use (t)} = \frac{\text{Distance travelled(km)} * \text{Power (kW)} * \text{Fuel use factor(t/kWh)}}{\text{Average speed (km/hour)}}$$

Equation 4-3: Calculation for shipping emissions

Figure 4-11: Bunkering ships

Table 4-12: Tier 2 emissions factors for shipping from the EMEP/EEA air pollutant emission inventory guidebook 2013 (appears as Table 3-4 in guidebook)

Tier 2 emission factors for NO_x, NMVOC, PM and specific fuel consumption for different engine types/fuel combinations

Tier 2 default emission factors							
Engine type	**Fuel type**	**NO_x 2000** (kg/tonne)	**NO_x 2005** (kg/tonne)	**NO_x 2010** (kg/tonne)	**TSP - PM_{10}** (kg/tonne)	**$PM_{2.5}$** (kg/tonne)	**Specific fuel consumption** (g fuel/kWh)
Gas turbine	BFO	20.0	19.3	18.6	0.3	0.3	305
	MDO/MGO	19.7	19.0	18.3	0.0	0.0	290
High-speed diesel	BFO	59.6	57.7	55.6	3.8	3.4	213
	MDO/MGO	59.1	57.1	55.1	1.5	1.3	203
Medium-speed diesel	BFO	65.7	63.4	61.3	3.8	3.4	213
	MDO/MGO	65.0	63.1	60.6	1.5	1.3	203
Slow-speed diesel	BFO	92.8	89.7	86.5	8.7	7.8	195
	MDO/MGO	91.9	88.6	86.5	1.6	1.5	185
Steam turbine	BFO	6.9	6.6	6.4	2.6	2.4	305
	MDO/MGO	6.9	6.6	6.4	1.0	0.9	290

Source: Entec (2002), Entec (2007), emission factors calculated in kg/tonne of fuel using specific fuel consumption.

BFO –Bunker Fuel Oil, MDO –Marine Diesel Oil, MGO –Marine Gas Oil
BC fraction of PM (f-BC); BFO: 0.12, MDO/MGO: 0.31. Source: for further information see Appendix A

Table 4-13: Engine type weightings from the EMEP/EEA air pollutant emission inventory guidebook 2013 (appears as Table 3-7 in guidebook)

Percentage of installed Main Engine power by engine type/fuel class (2010 fleet)

Ship category	SSD MDO /MGO	SSD BFO	MSD MDO /MGO	MSD BFO	HSD MDO /MGO	HSD BFO	GT MDO /MGO	GT BFO	ST MDO /MGO	ST BFO
Liquid bulk ships	0.87	74.08	3.17	20.47	0.52	0.75	0.00	0.14	0.00	0.00
Dry bulk carriers	0.37	91.63	0.63	7.29	0.06	0.02	0.00	0.00	0.00	0.00
Container	1.23	92.98	0.11	5.56	0.03	0.09	0.00	0.00	0.00	0.00
General cargo	0.36	44.59	8.48	41.71	4.30	0.45	0.00	0.10	0.00	0.00
Ro Ro Cargo	0.17	20.09	9.86	59.82	5.57	2.23	2.27	0.00	0.00	0.00
Passenger	0.00	3.81	5.68	76.98	3.68	1.76	4.79	3.29	0.00	0.02
Fishing	0.00	0.00	84.42	3.82	11.76	0.00	0.00	0.00	0.00	0.00
Others	0.48	30.14	29.54	19.63	16.67	2.96	0.38	0.20	0.00	0.00
Tugs	0.00	0.00	39.99	6.14	52.80	0.78	0.28	0.00	0.00	0.00

SSD - Slow Speed Diesel, MSD – Medium Speed Diesel, HSD - High Speed Diesel, GT – Gas Turbine, ST – Steam Turbine; MDO –Marine Diesel Oil, MGO –Marine Gas Oil, BFO –Bunker Fuel Oil

Source: Trozzi, 2010

Table 4-14: Main engine power from EMEP/EEA air pollutant emission inventory guidebook 2013 (appears as Table 3-6 in guidebook)

Estimated average main engine power (total power of all engines) by ship category

Ship category	Main engine power (kW)	
	1997 fleet	2010 fleet
Liquid bulk ships	6.695	6.543
Dry bulk carriers	8.032	4.397
Container	22.929	14.871
General cargo	2.657	2.555
Ro Ro Cargo	7.898	4.194
Passenger	3.885	10.196
Fishing	837	734
Other	2.778	2.469
Tug	2.059	2.033

Source: Trozzi, 2010

Table 4-15: Average speeds from the EMEP/EEA air pollutant emission inventory guidebook 2013 (appears as Table 3-14 in guidebook)

Table 3-14 Assumptions for the average cruise speed and average duration of in-port activities

Ship Type	Ave.Cruise Speed (km/h)	Manoeuvring time (hours)	Hotelling time (hours)
Liquid bulk ships	26	1.0	38
Dry bulk carriers	26	1.0	52
Container	36	1.0	14
General Cargo	23	1.0	39
Ro-Ro Cargo	27	1.0	15
Passenger	39	0.8	14
Fishing	25	0.7	60
Other	20	1.0	27

Source: Elaboration from Entec (2002)

These calculations allow the generation of the following activity data shown in Table 4-16 and Table 4-17.

Non-bunkering can be subtracted from the total to give the total for bunkering.

Table 4-16: Activity data for all port traffic

All traffic	Total distance travelled ('000 km)		Number of journeys		Fuel-oil consumption (kt)		Gas-oil consumption (kt)	
	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar
Tank	7,895	8,056	2,171	2,171	377.6	385.3	18.0	18.4
Roll-on, roll-off	158	151	91	91	4.2	4.0	0.9	0.9
Container	1,286	1,598	448	448	102.7	127.6	1.4	1.7
Cargo	1,722	1,882	527	527	33.9	37.0	5.1	5.6
Reefer	893	795	170	170	17.6	15.6	2.6	2.4
Passenger	102	91	69	69	4.9	4.4	0.9	0.8
Cruise	117	184	108	108	5.7	8.9	1.0	1.6
Tug	130	183	50	50	0.2	0.3	2.5	3.5
Supply	36	32	10	10	0.1	0.0	0.7	0.6
Fish	11	12	3	3	0.0	0.0	0.1	0.1
Bulk	12,938	12,051	2,782	2,782	632.5	589.1	6.8	6.3
Carrier	1,966	2,198	535	535	96.1	107.5	1	1.2
Other	1,578	1,650	369	369	73.9	77.5	2.4	2.6
Total	**28,839**	**28,896**	**7,338**	**7,338**	**1,349**	**1,357**	**43.4**	**45.6**

Table 4-17: Activity data for non-bunkering traffic only

Non-bunkering port traffic only	Total distance travelled ('000 km)		Number of journeys		Fuel-oil consumption (kt)		Gas-oil consumption (kt)	
	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar	To Gibraltar	From Gibraltar
Tank	2,408	2,658	731	731	115.2	127.1	5.5	6.1
Roll-on, roll-off	56	35	55	55	1.5	0.9	0.3	0.2
Container	160	189	78	78	12.7	15.1	0.2	0.2
Cargo	228	250	73	73	4.5	4.9	0.7	0.7
Reefer	77	86	20	20	1.5	1.7	0.2	0.3
Passenger	68	64	46	46	3.3	3.1	0.6	0.6
Cruise	109	156	101	101	5.3	7.6	0.9	1.3
Tug	84	122	35	35	0.1	0.1	1.6	2.3
Supply	21	21	6	6	0.0	0.0	0.4	0.4
Fish	4	4	1	1	0.0	0.0	0.0	0.0
Bulk	1,168	1,111	289	289	57.1	54.3	0.6	0.6
Carrier	467	522	140	140	22.8	25.6	0.2	0.3
Other	344	381	110	110	15.9	17.6	0.8	1.0
Total	**5,193**	**5,599**	**1,685**	**1,685**	**240.0**	**258.0**	**12.1**	**14.0**

4.2.3.4 Determining emissions

With the fuel use (for both gas oil (marine diesel oil) and fuel oil (bunkers fuel oil) activity data, NAEI emission factors for the use of gas oil and fuel oil in shipping were applied to calculate emissions from the relevant pollutants, this is shown in Table 4-18.

Table 4-18: Emission factors for shipping from UK NAEI

Fuel type	Emission factors (kt/Mt fuel)		
	CO_2	CH_4	N_2O
Fuel oil	3,223	0.05	0.08
Gas oil	3,190	0.05	0.08

Only emissions from ship departures are included in the inventory as per PAS 2070 guidelines.

4.2.4 Aviation

Gibraltar is served by its own airport located within its boundary (Figure 4-12). There is also a nearby airport at Malaga, which is sometimes used when flights are diverted or as an alternative to flying directly into Gibraltar. However, no information is available for Malaga airport so Gibraltar Airport only is included here. Emissions are estimated for the 'landing/take-off cycle' (LTO) and cruise phases of flights. Only departing aircraft are included in the inventory as per PAS 2070 guidance.

Aviation emissions from LTO are allocated to scope 1 (inboundary).

Aviation emissions from the cruise phase are allocated to scope 3 (transboundary).

4.2.4.1 Overview

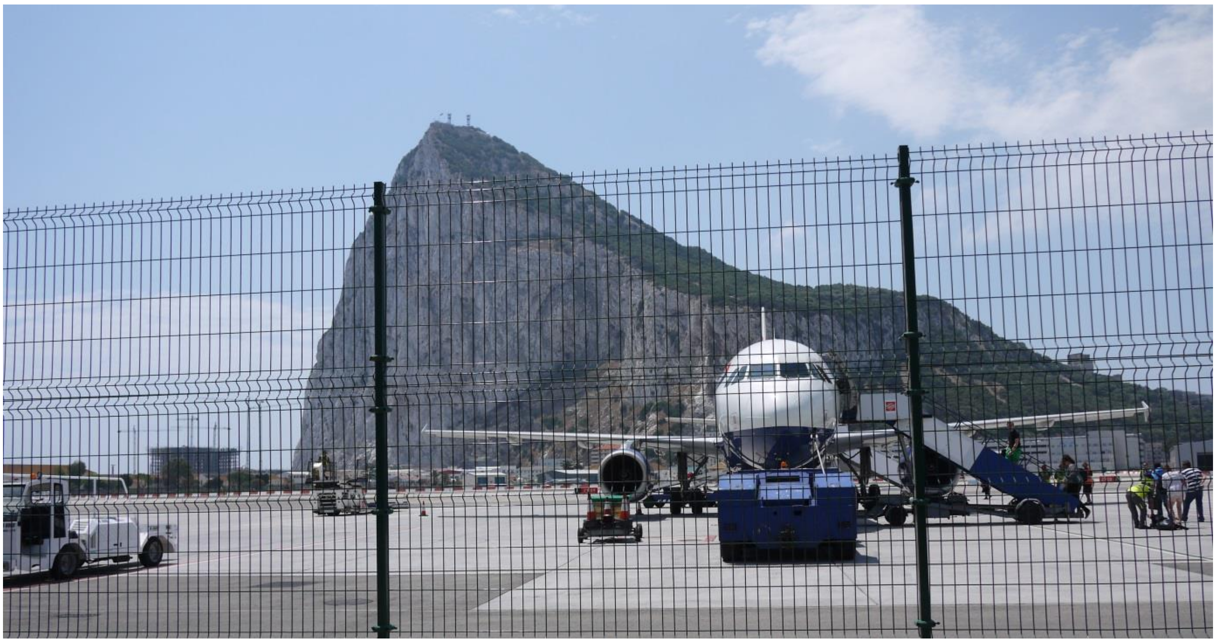

Figure 4-12: Gibraltar's International Airport

Figure 4-13 gives a brief overview of how estimates of emissions due to aviation have been made; a more detailed explanation is given in the following sections.

- Obtain data on annual flight movements and aircraft type.
- Calculate the cruise distance to the destination airports.
- Identify fuel consumption for aircraft types for LTO and cruise phases.
- Apply emission factors for LTO and cruise phases to calulated fuel consumption.
- Divide LTO phase by two to allocate to landing and take-off.

Figure 4-13: Aviation methodology flow diagram

4.2.5 Raw data

The raw data for estimating emissions have come from the Civil Aviation Authority (CAA), which provides a detailed log of all the journeys between Gibraltar and the UK. As we know that flights at Gibraltar are almost exclusively to/from the UK, this can be treated as a complete dataset.

4.2.6 Determining activity

It was assumed that all aircraft are Boeing 737-400s. Previously, in the NAEI, it was assumed there was a split between Boeing 737-specific type not specified and Airbus A320s. These are similar aircraft with the same capacity, and comparable emissive and fuel consumption rates.

A distance of 1,000 nautical miles (nm) is assumed in the selection of cruise and LTO emission factors (based on fuel consumption over this distance) from the EMEP/EEA air pollutant emission inventory guidebook 2013. This is slightly longer than the distance between Gibraltar and Heathrow, so is probably representative of a journey to a variety of UK airports (which includes Birmingham, Manchester, Luton, Heathrow and Gatwick). Based on Gibraltar aircraft statistics[21] it is clear that almost all (over 99%) of air traffic is to/from the UK.

[21] www.gibraltar.gov.gi/images/stories/PDF/statistics/2014/Air_Traffic_Survey_Report_2013.pdf

Emission factors for phases of flight for a Boeing 737-400 from the EMEP/EEA air pollutant emission inventory guidebook 2013 aviation chapter[22] are shown in Table 4-19 (Table 3-11 from Chapter 1.A.3.a Aviation).

Table 4-19: Illustrative dataset for Boeing 737-400 from the EMEP/EEA air pollutant emission inventory guidebook 2013

B737-400	Phase of flight	Standard flight distances (nm)				(1nm = 1.852 km)		
		125	250	500	750	1,000	1,500	2,000
Fuel (kg)	Flight total	1,603.1	2,268	3,612.8	4,960.3	6,302.6	9,187.7	12,167.6
	LTO	825.4	825.4	825.4	825.4	825.4	825.4	825.4
	Taxi out	183.5	183.5	183.5	183.5	183.5	183.5	183.5
	Take off	86	86	86	86	86	86	86
	Climb out	225	225	225	225	225	225	225
	Climb/cruise /descent	777.7	1,442.6	2,787.4	4,134.9	5,477.2	8,362.3	11,342.2
	Approach landing	147.3	147.3	147.3	147.3	147.3	147.3	147.3
	Taxi in	183.5	183.5	183.5	183.5	183.5	183.5	183.5

4.2.7 Determining emissions

The calculation for emissions is shown in Equation 4-4.

$$Emissions = \sum (LTO\ fuel\ use * LTO\ EF), (Cruise\ fuel\ use * fuel\ EF)$$

LTO = Landing/take-off cycle

EF = Emission factor

Equation 4-4: Equation for aviation emission estimation

The number of flights was multiplied by the 1,000 nm emission factors in Table 4-20 to generate total fuel consumption for phases of flight, as shown in Table 4-21. The emission factors in Table 4-21 were then used to calculate total emissions. The fuel use factors assume jet kerosene from tables 3.6.4 and 3.6.5 of the 2006 IPCC Guidelines; Emission factors for LTO cycle are taken from table 3-5 in the EMEP/EEA air pollutant emission inventory guidebook 2013 for a Boeing 737-400: examples of aircraft types and emission factors for LTO cycles as well as fuel consumption per aircraft type, kg/LTO.

It is assumed that emissions from all aircraft departing Gibraltar Airport are allocated to Gibraltar. This is because, although there may be some use of the airport by non-Gibraltarian residents/visitors, these numbers are impossible to determine with any

[22] www.eea.europa.eu/publications/emep-eea-guidebook-2013/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation

accuracy, it is assumed the majority of visitors arriving at Gibraltar Airport are likely to be resident or visiting. Emissions from the LTO cycle are divided by two and allocated half each to landing and take-off at origin and destination. Only the departure emissions are estimated to be included in the inventory for Gibraltar.

Table 4-20: Total annual fuel consumption by aircraft

Phase of flight	Unit	Value
LTOs	Number	1,411
Total fuel consumption	Kt	8.89
Of which cruise	Kt	7.73
Total fuel consumption	TJ	390
Of which cruise	TJ	339

Table 4-21: Emission factors for aircraft phases by pollutant

Phase of flight	Pollutant	Unit	Emission factor
Cruise	Carbon	kt/TJ fuel	0.0195
Cruise	CH_4	kt/TJ fuel	NO
Cruise	N_2O	kt/TJ fuel	0.000002
LTO	Carbon	kt/LTO	0.00071
LTO	CH_4	kt/LTO	0.0000001
LTO	N_2O	kt/LTO	0.0000001

4.3 Industrial processes and product use

The industrial processes and product use (IPPU) sector covers GHG emissions from a range of activities. The main emission sources are releases from industrial processes that chemically or physically transform materials (e.g. blast furnaces in the iron and steel industry, and ammonia and other chemical products manufactured from fossil fuels used as chemical feedstock). During these processes, many different GHGs, including CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) can be produced. Emissions also occur from the use of products such as solvents, aerosols and inhalers, and anaesthetics.

4.3.1 Summary

Industrial processes specifically covered by the GPC and PAS 2070 include:

- Production and use of mineral products.
- Production and use of chemicals.
- Production of metals.

None of these activities occur in Gibraltar, so this source is NO.

Product use in the GPC and PAS 2070 covers:

- Lubricants and paraffin waxes used in non-energy products.
- HFC gases used in electronics production.
- Fluorinated gases used as substitutes for ozone-depleting substances.

4.3.2 Separating IPPU GHG emissions and energy-related GHG emissions

Allocation of emissions from the use of fossil fuels between the stationary energy and IPPU sectors can be complex. The GPC follows IPCC Guidelines[23], which define ‘fuel combustion’ in an industrial process context as ‘the intentional oxidation of material within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.’

Therefore:

- If the fuels are combusted for energy use, the emission from fuel uses shall be counted under stationary energy.
- If the derived fuels are transferred for combustion in another source category, the emissions shall be reported under stationary energy.
- If combustion emissions from fuels are obtained directly or indirectly from the feedstock, those emissions shall be allocated to IPPU.
- If heat is released from a chemical reaction, the emissions from that chemical reaction shall be reported as an industrial process in IPPU.

In the case of Gibraltar, in the stationary combustion category all fuels are combusted for energy use so emissions are accounted for in this sector and not IPPU.

4.3.3 Determining activity

The industrial processes identified above are NO, so no data are available.

N_2O emissions from medical anaesthetics have been estimated using a report produced by NHS England that estimated emission per head.

In product use, emissions of fluorinated gases (the so-called F-gases) have been estimated based on a scaling of UK data using an appropriate indicator. The source categories of these emissions and the indicators used are shown in Table 4-22.

Estimates of N_2O emissions from anaesthetics have also been included using the factor for emissions per head in England in 2012 (0.030679kg N_2O/person/year).

[23] Box 1-1 from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 3 IPPU, Chapter 1 introduction.

Table 4-22: F-gas emission sources and activities

Source	Activity	Indicator
Aerosols – halocarbons	Non-fuel combustion	Population
Firefighting	Non-fuel combustion	GDP*
Foams	Non-fuel combustion	GDP
Metered dose inhalers	Non-fuel combustion	Population
One component foams	Non-fuel combustion	GDP
Sporting goods	Non-fuel combustion	Population
Commercial refrigeration	Refrigeration and air-conditioning – lifetime	GDP
Domestic refrigeration	Refrigeration and air-conditioning – lifetime	Population
Industrial refrigeration	Refrigeration and air-conditioning – lifetime	GDP
Mobile air-conditioning	Refrigeration and air-conditioning – lifetime	Number of vehicles
Refrigerated transport	Refrigeration and air-conditioning – lifetime	GDP
Stationary air-conditioning	Refrigeration and air-conditioning – lifetime	Population
Commercial refrigeration	Refrigeration and air-conditioning – manufacture	GDP

*Gross domestic product (GDP)

4.3.4 Estimating emissions

Emissions have been estimated by multiplying the factor for the UK by the associated indicator for Gibraltar (GDP, population, etc.).

4.4 Waste

The waste profile of Gibraltar is unique due to the territory's location, restricted land area, high population density and absence of heavy industry. The majority of waste generated in Gibraltar is municipal, largely arising at households and commercial premises.

Waste arisings in Gibraltar are grouped into the following categories:

- Municipal solid waste (MSW).
- Construction and demolition waste (C&D).
- Waste electrical and electronic equipment (WEEE).
- End-of-life vehicles (ELVs).
- Clinical waste.
- Shipping waste.
- Hazardous waste.
- Bulky waste.
- Batteries.
- Tyres.

Emissions from waste are allocated by scope to the location they are emitted.

Therefore, the treatment of biological waste, MSW and some incineration in Spain are allocated to scope 3.

Emissions from incineration in Gibraltar are scope 1.

Emissions from wastewater are out of boundary so allocated to scope 3.

This report has applied the methodologies recommended under the 2006 IPCC Guidelines for the estimation of GHG emissions from waste. Where possible, quantities of CO_2, CH_4 and N_2O have been estimated from the following sources based on activities during 2013:

- Solid waste disposal.
- Biological treatment of solid waste.
- Incineration.

4.4.1 Summary

Figure 4-14 gives a brief overview of how waste emissions have been estimated, with a more detailed explanation provided in the following sections.

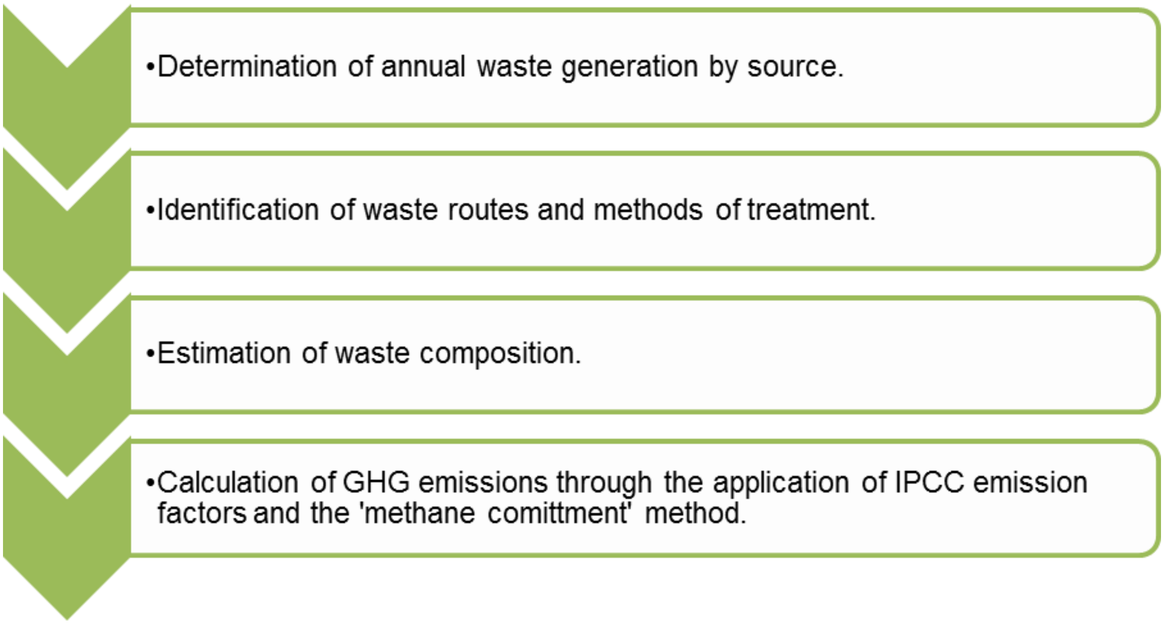

Figure 4-14: Waste methodology flow diagram

4.4.2 Raw data

4.4.2.1 Municipal solid waste

Municipal waste, generated at households, commercial premises and state-run facilities, such as schools and hospitals, is collected six days a week by a waste management contractor. This waste is then transported in bulk to the Complejo Medioambiental, Sur de Europa, in Los Barrios, Spain via a temporary waste transfer station in Gibraltar.

At Los Barrios, waste is manually and mechanically sorted to remove the recyclable fraction. Biological waste is also removed for composting and the remaining fraction is disposed of to landfill.

Data on the total quantity of MSW arisings by weight for Gibraltar have been provided by the Government of Gibraltar, as shown in Table 4-23).

Table 4-23: MSW arisings in Gibraltar in 2013

Month	Refuse (tonnes)	Households (tonnes)	Mattresses (tonnes)
January 2013	1,663	789	5.7
February 2013	1,253	670	4.4
March 2013	1,355	750	–
April 2013	1,566	903	–
May 2013	1,200	660	–
June 2013	1,470	821	2.1
July 2013	1,668	869	7.7
August 2013	1,419	674	0.0
September 2013	1,398	733	2.7
October 2013	1,635	1,079	2.6
November 2013	1,437	921	8.0
December 2013	1,423	768	2.1
Total	**17,486**	**9,637**	**35.2**

4.4.2.2 Clinical waste

Gibraltar's clinical waste is generated by a number of sources including dental and veterinary practices, and medical premises. In 2008, a new incinerator was commissioned in Gibraltar for the sole purpose of treating clinical waste. Although the incinerator has adequate capacity for the treatment of all clinical waste arisings within the boundary, maintenance issues will occasionally result in clinical waste being exported to an incinerator in Spain.

Table 4-24 details the quantity of clinical waste arisings in 2013, provided by the Government of Gibraltar. For the purposes of this assessment, is has been assumed 1 litre of clinical waste has an equivalent weight of 1kg.

Table 4-24: Clinical waste arisings in Gibraltar in 2013

Month	Clinical waste – local incineration (t)	Clinical waste – exported incineration (t)
January 2013	207	52
February 2013	168	78
March 2013	202	52
April 2013	220	26
May 2013	198	78
June 2013	192	26
July 2013	195	52
August 2013	197	52
September 2013	192	78
October 2013	43	156
November 2013	155	130
December 2013	193	26
Total	**2,162**	**804**

4.4.2.3 Recycled waste

As Gibraltar does not contain the necessary waste management infrastructure to recycle waste, any waste materials suitable for recycling are exported. Table 4-25 provides a summary of waste quantities exported for recycling in 2013.

Table 4-25: Quantities of recycled data exported from Gibraltar in 2013

Waste stream	Quantity exported for recycling (kg)
Glass	153,248
Mixed packaging	70,720
Paper/cardboard	132,495
WEEE	344,143*

*Due to a lack of weighing facilities at the main collection site the recorded weight is expected to represent a fraction of the actual weight of exported WEEE.

Figure 4-15: Gibraltar is actively trying to recycle much of its waste

For the purposes of this study, it has been assumed the following waste streams are re-used or recycled by waste operators in Spain. Therefore, they have not been factored into the GHG calculations:

- Glass.
- Mixed packaging.
- Paper and cardboard.
- Rubber.
- WEEE.
- Scrap metal.
- Lead car batteries.
- Bulky waste (e.g. mattresses, furniture).
- Textiles.
- C&D waste.

This is because any GHGs associated with the treatment of waste for recycling are assigned to the industry (and location) of the recycling activity as they become the raw materials for another industry.

4.4.3 Determining activity

4.4.3.1 Composition of MSW

To determine the fraction of degradable organic carbon (DOC), the composition of MSW arisings have been estimated by applying the results of the 2006 Waste Characterisation Study to the total reported MSW detailed above. The study was completed by the Department of the Environment[24]. It analysed MSW from four collection routes in Gibraltar (residential, commercial, shipping waste and industrial) recording the waste type, weight and bulk density.

The waste categories have been grouped into three assumed treated groups; biological treatment, landfill and recycled. A summary of the results and the treatment groups are provided in Table 4-26.

[24] www.environmental-agency.gi/WasteManagementPlan2013.pdf

Table 4-26: Results of the 2006 Waste Characterisation Study and assumed treatment groups

Waste category	Results of the 2006 Waste Characterisation Study (sum of the four collection routes)		Assumed treatment route
	Total weight from all four locations (tonnes)	Weight (%)	
Organic	204.5	24.6	Biological treatment
Papers and cardboard	280.1	33.7	Recycled
Composites	35.3	4.2	Landfill
Textiles	43.0	5.2	Recycled
Dense plastics	62.8	7.5	Recycled
Plastic film	69.2	8.3	Recycled
Glass	36.8	4.4	Recycled
Metals	36.4	4.4	Recycled
Special municipal waste	41.4	5.0	Landfill
Unclassified combustibles	10.0	1.2	Landfill
Unclassified incombustibles	4.8	0.6	Landfill
Fines	8.0	1.0	Landfill
Total	**832.3**	**100.0**	**-**

4.4.4 Determining emissions

4.4.4.1 Solid waste disposal

Emissions of CH_4 from landfilling MSW have been calculated using the ‘Methane Commitment’ method. This allows emissions to be estimated based on the quantity of waste sent to landfill in a single year by adopting a mass balance approach. Prior to this, it was necessary to determine the ‘methane generation potential’ of the waste landfilled. The formulas for each are provided in Equation 4-5 and Equation 4-6.

$$L_0 = W \times MCF \times DOC \times DOC_F \times F \times 16/12$$

Shorthand	Description
L_0	Methane generation potential (tonnes of CH_4)
W	Mass of waste deposited (tonnes)
MCF	Methane correction factor based on type of landfill site (managed, unmanaged, etc.)
DOC	Degradable organic carbon (tonnes of carbon/tonnes of waste)
DOC_F	Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade)
F	Fraction of methane in landfill gas
16/12	Stoichiometric ratio between methane and carbon

Equation 4-5: Formula for the calculation of 'methane generation potential'

$$CH_4 \text{ emissions} = M_{waste} \times L_0 \times (1-f_{rec}) \times (1-OX)$$

Shorthand	Description
CH_4 emissions	Total CH_4 emissions (tonnes)
M_{waste}	Mass of solid waste sent to landfill in inventory year (tonnes)
L_0	Methane generation potential (tonnes of CH_4)
f_{rec}	Fraction of methane recovered at the landfill (flared or energy recovery)
OX	Oxidation factor

Equation 4-6: 'Methane commitment' calculation of CH_4 emissions from landfill

4.4.4.2 Biological treatment

The emissions of CH_4 and N_2O from the biological treatment of waste have been calculated using emission factors provided in the 2006 IPCC Guidelines (Chapter 4: Biological Treatment of Solid Waste[25]). These are detailed in Table 4-27.

As the Los Barrios waste treatment facility only provides composting as a form of biological treatment, it has been assumed this is the sole method of biological treatment.

Table 4-27: Biological waste treatment emission factors

GHG	Emission factor
CH_4	10g per kg of waste treated
N_2O	0.6g per kg of waste treated

4.4.4.3 Clinical waste incineration

The emission of CH_4 and N_2O from the incineration of clinical waste has been calculated using emission factors provided in the 2006 IPCC Guidelines (*Chapter 5: Incineration and Open Burning of Waste*[25]). CO_2 emissions have also been calculated as per the 2006 IPCC Guidelines, through estimating waste composition

[25] www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

variables. The emission factors and compositional estimates are provided in Table 4-28.

Table 4-28: Clinical waste incineration emission factors and compositional variables

GHG	Emission factor	Variable
CH_4	0g per kg of waste treated	
N_2O	0.6g per kg of waste treated	
CO_2		Fraction of carbon in the dry matter = 60% (default)
		Fraction of fossil carbon in the total carbon = 40% (default)
		Oxidation factor – 100% (default)

4.4.5 Wastewater

Wastewater in Gibraltar is pumped out to sea with no treatment. However, Gibraltar has recently given preferred bidder status to a joint venture between Northumbrian Water Services and Modern Water Services. This will result in the construction of a water treatment facility that is expected to be operational by 2016.

Emissions from pumping are reported under stationary combustion scope 2 emissions (consumption of electricity). Emissions from wastewater have been calculated by scaling UK data. These are:

- Biochemical oxygen demand (BOD) and nitrogen content on a per person per day basis.
- Tonnes of N_2O per million people.

The IPCC CH_4 conversion factor for wastewater to sea/lakes/rivers was used to estimate CH_4. This is likely to overestimate emissions as it assumes anaerobic decomposition in stagnant water, and ocean decomposition is likely to be much less stagnant and, therefore, undergoes higher aerobic decomposition with lower associated emissions. N_2O emission assumptions do not account for denitrification in sewage treatment or alternative disposal methods (e.g. to land, incineration). It is assumed that all sewage is discharged in raw form to sea. The emission factors used are shown in Table 4-29.

Table 4-29: Emission factors for wastewater decomposition

Pollutant	Unit	Emission factor
CH_4	kt/kt BOD	0.06
N_2O	Per 1 million people	77.2

The equation for CH_4 is shown in Equation 4-7 and for N_2O in

Equation 4-8.

$$CH_4 = BOD_{PPPD} * days\,per\,year * Population * EF_{CH_4}$$

Equation 4-7: Calculation method for wastewater CH_4

$$N_2O = \frac{(t\ N_2O\ per\ million * Population)}{1{,}000{,}000}$$

Equation 4-8: Calculation method for N_2O from wastewater

4.5 Agriculture, forestry and other land use

Gibraltar has no notable agriculture, so this emission source has not been estimated, so this emission source is noted as NO.

Gibraltar is also regarded as having no emissions from land use, land use change and forestry (LULUCF), so this emission source is also noted as 'NO'.

4.5.1 LULUCF approach

LULUCF emission estimation is concerned with *changing* carbon stocks in the land and vegetation. Under the IPCC Guidelines, lands are classified as forest land, cropland, grassland, wetlands, settlements and other land. In Gibraltar, much of the land is classified as settlement (remaining settlement). The upper rock includes areas of scrub and patches of woodland, and the 2010 Global Forest Resources Assessment Country Report by the Forestry Department of the Food and Agriculture Organization of the United Nations, classifies this as 'other land'[26]. Under the IPCC Good Practice Guidance for LULUCF (2003)[27], change in carbon stocks and non-CO_2 emissions and removals are not considered for the category Other Land Remaining Other Land. Therefore no calculation of carbon stocks have been made for this land area.

There are small areas of parkland in settlement areas, some of which are new, but these are very small. The carbon stocks have not been estimated, consistent with the IPCC 2006 guidelines Tier 1 approach. Future updates of this inventory could consider including estimates of these.

A Tier 1 method assumes no change in carbon stocks in live biomass in Settlements Remaining Settlements, in other words, the growth and loss terms balance[28]. If the category Settlements Remaining Settlements is determined to be a key category, then appropriate activity data should be collected and/or emission factors appropriate to the region developed and a Tier 2 or 3 approach adopted. However, given the geography of Gibraltar – rock, scrubland and dense settlement – it is unlikely that there will be future significant land use change that will result in emissions. There has been some land reclamation in Gibraltar, from sea to settlement. However, under the LULUCF guidance, this is not land use change, but new land. The implication of this is only for an increase in land area (and possible emissions in future from changing use) rather than emissions from reclamation and additional land.

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[26] http://www.fao.org/docrep/013/al514E/al514E.pdf

[27] http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_7_Other_land.pdf

[28] www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_08_Ch8_Settlements.pdf 8.2.1.1 p.8.7

4.6 Indirect emissions from the supply chain

Scope 3 emissions are those that are produced outside the city boundary as a result of activities occurring within the city boundary or from transboundary activities that cross the city boundary. At a simple level, this includes travel in and out of the city, but there are more complex flows that cross the city boundary, in particular the goods and services that are imported and consumed or used. Measuring these emissions allows cities to take a more holistic approach to tackling climate change by assessing the GHG impact of their supply chains, and identifying areas of shared responsibility for upstream and downstream GHG emissions.

There are two approaches that can be taken to measure these emissions. First, a consumption-based (CB) inventory of all emissions including those of key imported goods and services that uses using econometric data (an environment input-output analysis). Second, a process-based method that quantifies life-cycle GHG emissions associated with key supply chain categories.

Figure 4-16 shows a summary of the steps taken to estimate emissions by a process-based method.

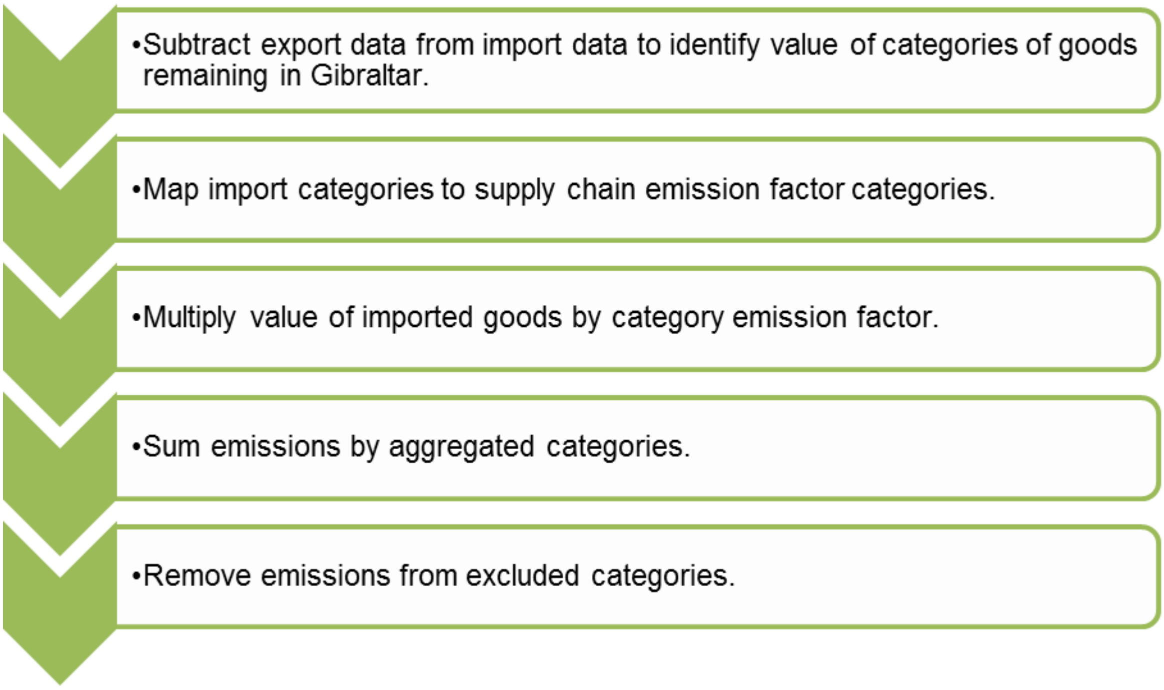

Figure 4-16: Steps in process-based method used to estimate supply chain emissions

4.6.1 Review of previous studies

A previous study estimated emissions from a CB approach[29] as follows (Table 4-30).

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[29] Larsen, H.N., Solli, C., and Hung, C (2013) *The Carbon Footprint of Gibraltar. Developing a consumption-based greenhouse gas inventory*. MiSA.

Table 4-30: Headline results of Larsen et al. (2013) Carbon Footprint of Gibraltar study

Total: Housing	**69.83**
Rent	13.78
Electricity	11.73
Water	6.15
Telephone	13.61
Service Charges	6.06
Satellite TV & Internet	4.35
Household Insurance	1.3
Alterations to Dwellings	12.84

This city inventory project has used a process-based approach and not the data from the carbon footprint study for the following reasons:

- To avoid duplicating previous CB work.
- To provide a useful comparison to previous work.
- The majority of available methodological guidance is focused on a more conventional activity-based method of emissions estimation.
- Activity data are more detailed for a direct plus supply chain (DPSC) inventory than a CB inventory. This results in a more detailed activity-based output, which is more compatible with policy and reporting needs.
- The data and results published in the CB carbon footprint study will likely result in double-counting of emissions from, for example, energy use for transportation, storage, retail, processing and product cooking.
- The data from the carbon footprint study have been calculated using the Gibraltar Family Expenditure Survey 2011 (actual survey data from 2008/09). For the carbon footprint of governmental services, the service categories and spending in each category from the Abstract of Statistics 2008 was used. This has limitations:
  - The data are 6 years old.
  - The data do not clearly cover key indirect emission categories such as construction.
  - The data only cover household expenditure, so will exclude expenditure of visitors, of which there are many in Gibraltar, and which are included within the inventory boundary.

4.6.2 Approach and assumptions

Measurement and reporting of other scope 3 categories – such as GHG emissions embodied in fuels, water, food and construction materials – is optional under the GPC, but mandatory under the DPSC method in PAS 2070. The GPC does not have guidance on reporting emissions from the supply chain, but PAS 2070 outlines the following:

"The goods and services included in the assessment in 7.7.1 to 7.7.3 are either of exceptional importance to life in cities (e.g. water), or are known to make a material contribution to the GHG emissions of cities that have been the subject of previous and published GHG emissions assessments. However, other goods and transboundary services that meet the material contribution threshold in 7.7.4, are also included in the assessment."

The major categories to be included under PAS 2070 are:

- Water.
- Food and drink.
- Construction materials.
- Other – which make a material contribution (i.e. 2% or more of DPSC total).

Water is included under stationary energy. This is because, due to the local nature of the system and no imports, emissions related to water production and distribution are only as a result of electricity consumption, so this category is excluded in indirect emissions.

Figure 4-17: Gibraltar is undergoing many construction projects and the materials for these generate indirect GHG emissions

As discussed above, the Carbon Footprint of Gibraltar study does not include enough transparent data on these key categories, so a process-based approach was taken. However, the Carbon Footprint of Gibraltar study was used to inform the key categories for reporting, in particular to provide guidance for categories that might exceed the 2% threshold. The results of this are shown in Table 4-31 (note this appears as Table 7 in the original report). These indicate that clothing and rent are potential key categories. Other categories over 2% include much energy already assessed by other parts of the PAS 2070 DPSC methodology, such as travel and transport, and electricity.

It is unclear what 'Rent' includes, but the data indicate that rent did not include energy (Family expenditure survey 2011 p.28). Therefore, it can be assumed that rent can be excluded because the money is passed along a chain and recounted (i.e. money is spent by a developer to build a property, then by a new owner to buy the property, then by a tenant to rent the property). Some of this money may have a carbon footprint associated with financial service provision, but this would probably be below 2%. Clothing has been included as a key category.

Table 4-31: Results of the Carbon Footprint of Gibraltar study (Appears as Table 7 in original report)[30]

Table 7: Carbon Footprint inventory of consumption sub-categories

Household Carbon Footprint, detailed structure	£ per capita	Kg CO_2e. per £	Excl. TTM	kg CO_2e. per capita	Total GHG emission [t]
Food and beverages	2 036	0.88	0.70	1788	52 634
Food, away from home	1 119	0.41	0.29	454	13 371
Tobacco and cigarettes	95	1.10	0.27	104	3 071
Clothing	739	0.72	0.27	532	15 653
Footwear	184	0.69	0.39	127	3 731
Furniture	109	0.67	0.42	73	2 136
Household appliances	224	0.76	0.65	170	4 997
Other household goods	64	0.67	0.42	43	1 251
Rent	257	1.48	1.48	380	11 183
Electricity	219	6.13	6.13	1342	39 487
Water	115	1.05	0.90	121	3 561
Telephone, TV and internet	335	0.35	0.27	117	3 431
Other household services	137	0.49	0.49	67	1 980
Alterations to dwellings	240	0.56	0.46	135	3 982
Entertainment	228	0.35	0.34	80	2 366
Hairdressers	173	0.47	0.47	81	2 380
Educational	51	0.28	0.28	14	415
Medical	175	0.34	0.34	59	1 725
Other services	184	0.52	0.52	96	2 833
Leather and fancy goods	129	0.60	0.33	77	2 264
Books and periodicals	64	0.61	0.48	39	1 154
Toys and stationary goods	197	0.78	0.74	154	4 522
Medicines and surgical goods	87	0.88	0.74	77	2 267
Toiletries and cosmetics	225	0.61	0.46	138	4 074
Optical and photographic goods	75	0.66	0.54	50	1 459
Cleaning materials	61	1.37	1.01	83	2 454
Misc. other goods	137	0.67	0.43	92	2 701
Motor vehicle spares and accessories	56	0.92	0.85	52	1 532
Motor vehicles and running costs	1 034	1.72	1.72	1775	52 228
Other travel and transport	492	1.52	1.51	748	22 006
Money spend abroad and cash gifts	548	0.61	0.46	332	9 776
Mortgage interest payments and rates	473	0.15	0.11	71	2 095
Not included in FES					35 531
Household Carbon Footprint, tonnes					314 252
Per capita. tonnes per capita					**10.68**

30 Larsen, H.N., Solli, C., and Hung, C (2013) *The Carbon Footprint of Gibraltar. Developing a consumption-based greenhouse gas inventory*. MiSA.

4.6.3 Raw data

To estimate emissions from the supply chain, the Gibraltar Imports and Exports Statistics 2001 (confidential) were obtained from HM Government of Gibraltar Statistics Office. This report contained information on the value (£000s) for 98 import and export categories. Import costs are inclusive of carriage, insurance and freight (CIF) and exports are free on board (FOB) (i.e. the costs exclude CIF). This ensures that there is no double counting of transportation emissions (transboundary emissions are allocated to the place of departure, so will be included elsewhere in the Gibraltar inventory).

4.6.4 Determining emissions

Emissions from imported goods for Gibraltar were determined by the following equation (Equation 4-9):

$$CO_2e = \sum (import\ £000's) - (export\ £000's) * Emission\ Factor_{kg\ CO_2e/£}$$

Equation 4-9: Calculation of indirect supply chain emissions

Values of exports were first subtracted from imports to leave a value of goods remaining in or consumed in Gibraltar. The 98 categories of goods were then mapped onto supply chain categories published as part of the Department for Environment, Food and Rural Affairs' (Defra) CB emissions reporting[31]. 'Table 13: Indirect Emissions from the Supply Chain'[32] can be used to produce indicative estimates of the GHG emissions relating to the production of goods and services purchased by a company or organisation. These are compiled for the UK so are indicative for Gibraltar only, and some categories may be an under or overestimate depending on local circumstances. They also represent the average emissions relating to each product group, and the emission factors relating to specific products within the group may be quite different.

There are 106 different classifications of product and service based on Standard Industry Classification (SIC) codes. Once mapped onto the SIC codes, the relevant emission factor for that category was extracted and multiplied by the value of goods to produce an emission value (tCO_2e) and summed. The 98 import categories were then aggregated into the categories shown in Table 4-32.

[31] www.gov.uk/government/publications/uks-carbon-footprint

[32] www.gov.uk/government/uploads/system/uploads/attachment_data/file/312783/Table_13_Indirect_emissions_from_supply_chain_2007-2011.xls

Table 4-32: Aggregated indirect emission categories, ordered by largest to smallest emission source

Aggregated import category	Includes
Luxury products	Perfumes, tobacco products, leather goods, precious metals and stones, watches, toys and artwork
Food and drink	All categories of edible foods
Fuels	Mineral fuels: this is excluded to avoid double counting
Industrial	Organic and inorganic chemicals, explosives, base metals, fertilisers and radioactive materials
Construction	Plaster, cement, iron and steel, and carpets
General products	General articles made from plastics, wood, ceramic or paper
Transport items	Vehicles ships, boats, trains and parts thereof
Electronics	Sound, television, and photographic and surgical equipment
Clothing and textile products	All articles made of textiles
Household products	Furniture, glassware, tools and cutlery, and basket ware
Chemical products	Pharmaceuticals, soaps, detergents and miscellaneous chemical products
Plants	Any articles of living plants
Metal products	Any finished articles of metal
Miscellaneous products	Umbrellas, musical instruments, arms and ammunition

Luxury products have been reported separately due to the very large amount of expenditure on these goods. Gibraltar’s tax status means there are a large number of purchases of such luxury products by visitors due to cheaper prices. Although much of this is likely to be ‘exported’, it will be small quantities by large numbers of visitors so it may not get picked up by export statistics if taken out as part of personal allowance. This is the likely explanation for such a high value and this category should therefore be reported separately in the inventory as it skews the overall supply chain emission results.

Fuels data includes that already captured through the fuel import data (the basis of the road transport inventory). Therefore, this category is excluded, although it is likely to include some items not captured (such as products of fuel distillation, bituminous substances and mineral wastes that are included in this category, but cannot be differentiated).

5 Results

This section sets out the results of the Gibraltar city greenhouse gas (GHG) inventory. As detailed in the methodology section above, this inventory considered all sources attributable to Gibraltar, following the methods published by the British Standards Institute (PAS 2070) and the Greenhouse Gas Protocol's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC).

The inclusion of different sources in the reported total varies by chosen reporting standard, and these sources also vary in their level of potential influence: Gibraltar has limited control over the emissions associated with water-borne navigation, for example, whereas power generation can be much more easily affected through local decision-making. Water-borne navigation emissions dominate the results, discussed below, and overshadow other sources for which Gibraltar has more influence. With this in mind, the results section presents the results both as a whole – total emissions for Gibraltar across all sources – and distinguishes between different reporting levels and sources, including presenting a sub-set of BASIC+ emissions (the recommended reporting level) excluding international transboundary shipping.

5.1 Summary

Total emissions for Gibraltar in 2013 by different reporting level are shown in Figure 5-1. Sources included within each reporting level are detailed in Table 2-2 and summarised in Table 5-1 below. Emissions included within each higher reporting level are cumulative from lower levels. It is current best practice for cities to report BASIC+ emissions wherever possible, and this chart represents emission sources as classified by the GPC and PAS 2070.

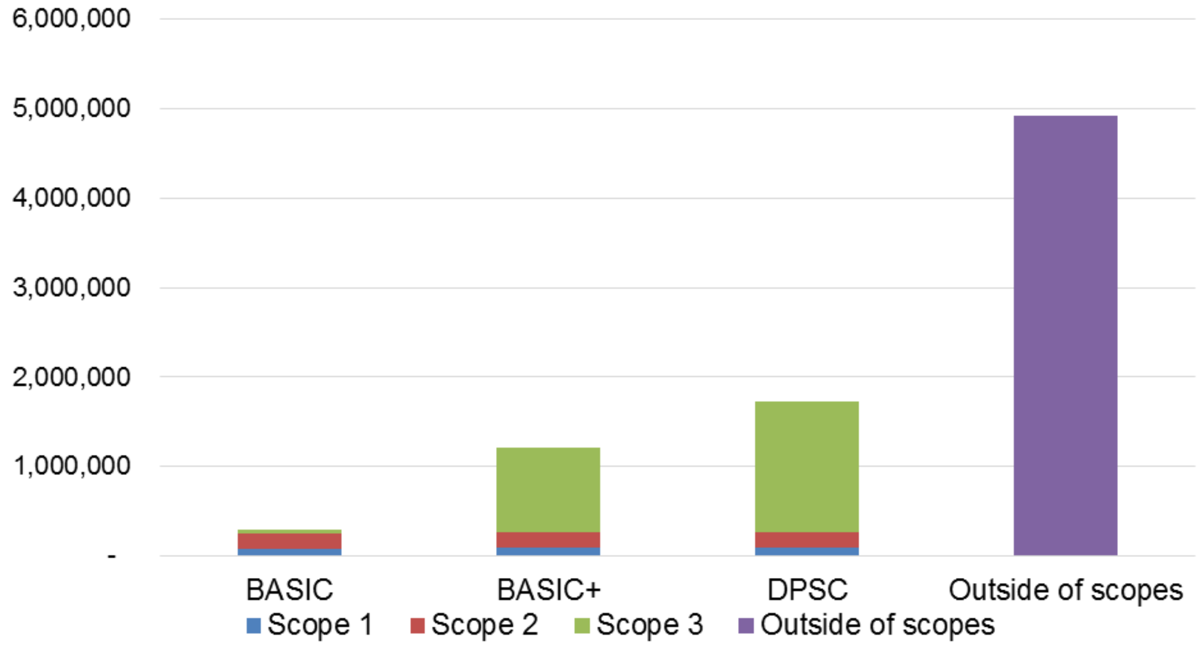


Figure 5-1: Total emissions by scope and reporting level

Table 5-1: Classification of emission categories by scope and reporting level. Note, these are cumulative, and higher reporting levels include those sources in lower levels

Scope	BASIC	BASIC+	DPSC	Outside of scopes
Scope 1	Emissions from inboundary fuel combustion Emissions from inboundary production of energy used in auxiliary operations Inboundary fugitive emissions Emissions from inboundary transport Emissions from waste and wastewater generated and treated within the city	Inboundary emissions from industrial processes Inboundary emissions from product use Inboundary emissions from livestock Inboundary emissions from land Inboundary emissions from other agriculture		
Scope 2	Emissions from consumption of grid-supplied energy			
Scope 3	Emissions from waste and wastewater generated within but treated outside of the city	Transmission and distribution losses from grid-supplied energy Emissions from transboundary journeys	Upstream fuel emissions Food and drink imports Water[1] Construction materials (imports) Other supply chain emissions	
Outside of scopes				Electricity generation[2] International bunkers Vehicle fuel exports

[1] Water is excluded from stationary combustion sources and reported under goods and services
[2] Reported for information only. Electricity emissions are allocated to the end-user

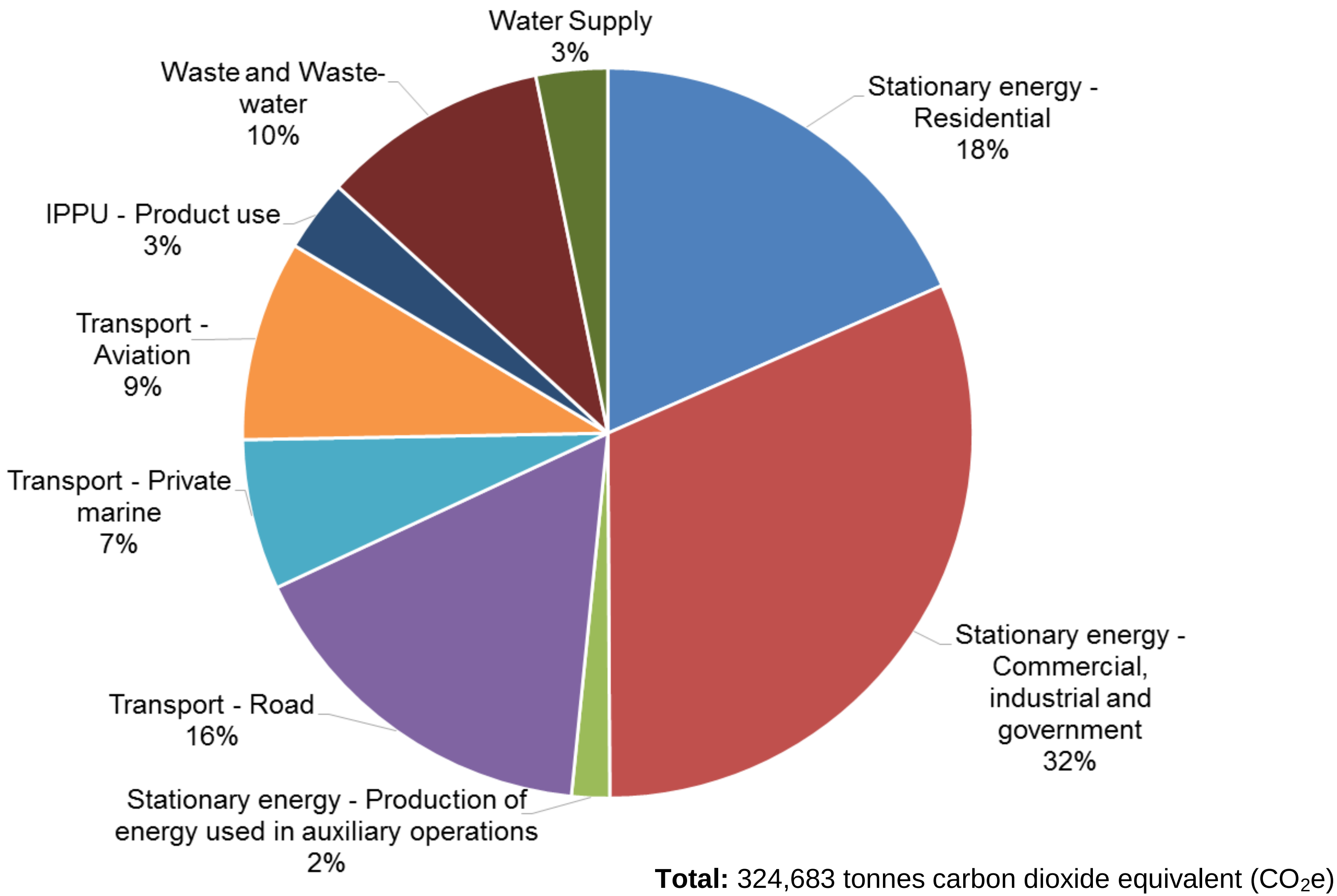
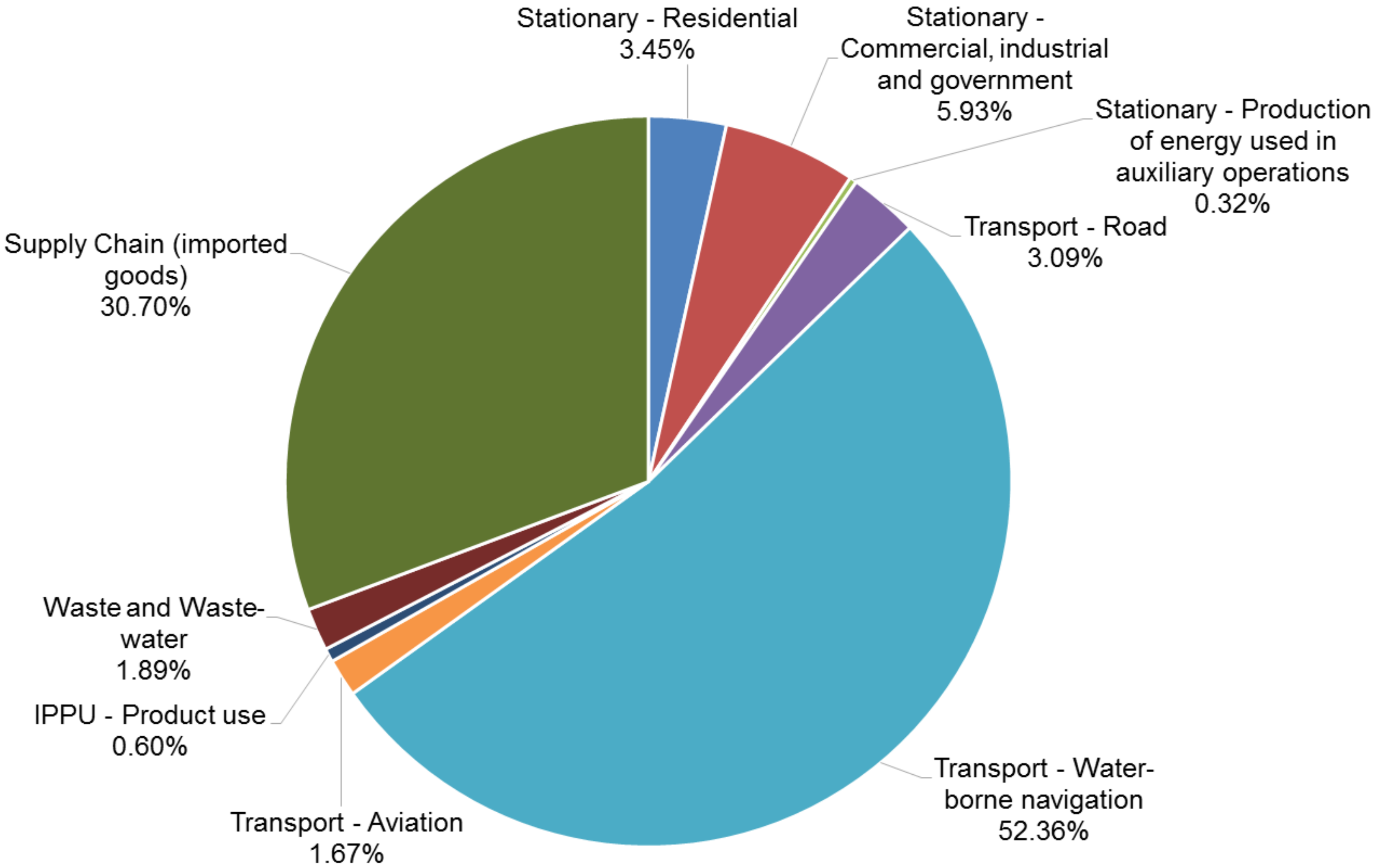


Figure 5-2: Gibraltar's manageable emissions by source category for 2013 (under the GPC's BASIC+ reporting, excluding transboundary water-borne navigation)



Total: 1,727,836 tonnes carbon dioxide equivalent (CO_2e)

Figure 5-3: Gibraltar's total emissions (with excluded sources) by source category for 2013

Table 5-2: Total emissions for Gibraltar in 2013 by source.
Sources shaded dark grey show those excluded under the recommended BASIC+ level of reporting, including water-borne navigation.

NO = not occurring NE = not estimated IE = included elsewhere

Sector		GHG emissions (tonnes of CO_2 equivalent (CO_2e))				% of total
		Scope 1	Scope 2	Scope 3	Total	
Stationary	Residential buildings	NO	59,649	NE	59,649	3.5
	Commercial, industrial and government buildings and facilities[1]	NO	102,422	NE	102,422	5.9
	Manufacturing industry and construction	NO	IE	NE	–	0.0
	Agriculture, forestry and fishing activities	NO	NO	NA	–	0.0
	Emissions from inboundary production of energy used in auxiliary operations	5,460	NO	NE	5,460	0.3
	Fugitive emissions from mining, processing, storage, and transportation of coal	NO	NO	NO	–	0.0
	Fugitive emissions from oil and natural gas systems	NO	NO	NO	–	0.0
	Sub-total	5,460	162,071	–	167,531	9.7
Transport	Road	53,405	NO	IE	53,405	3.1
	Railways	NO	NO	NO	–	0.0
	Water-borne navigation	21,642	NO	*882,980*	904,622	52.4
	Aviation	1,918	NO	26,917	28,835	1.7
	Sub-total	76,964	–	909,898	986,862	57.1
IPPU	Inboundary emissions from industrial processes	NO	NO	NO	–	0.0
	Inboundary emissions from product use	10,367	NO	NO	10,367	0.6
	Sub-total	10,367	–	–	10,367	0.6
AFOLU	Sub-total	NO	NO	NO	NO	NO

Sector		GHG emissions (tonnes of CO_2 equivalent (CO_2e)) Scope 1	Scope 2	Scope 3	Total	% of total
Waste	Solid waste disposal	NO	NO	25,025	25,025	1.5
	Biological treatment of waste	NO	NO	2,858	2,858	0.2
	Incineration and open burning	2,196	NO	816	3,012	0.2
	Wastewater treatment and discharge	NO	NO	1,718	1,718	0.1
	Sub-total	2,196	–	30,417	32,613	1.9
Supply chain	*Upstream fuel emissions*	NO	NO	*229,160*	229,160	13.3
	Food and drink imports	NO	NO	*48,081*	48,081	2.8
	Water[1]	NO	10,291	NO	10,291	0.6
	Construction	NO	NO	*25,661*	25,661	1.5
	Other	NO	NO	*217,270*	217,270	12.6
	Sub-total	–	10,291	520,172	530,463	30.7
Total		**94,987**	**172,362**	**1,460,487**	**1,727,836**	100.0

[1] Water is excluded from stationary combustion sources and reported under goods and services

Table 5-3: Emissions outside of scopes

Outside of Scopes		GHG emissions (tCO_2e)	% of total (incl. outside of scopes)
Stationary	Electricity generation	177,820	2.7%
Transport	Maritime bunkering	3,989,891	60.0%
	Road fuel exports	47,225	0.7%
Indirect	Upstream emissions from outside scopes fuel use (ground and maritime)	703,763	10.6%
Total		**4,918,700**	**74%**

5.2 Total emissions for Gibraltar

Total emissions for Gibraltar, from all calculated sources are presented in Table 5-2, Figure 5-3 and Figure 5-3 above.

Overall, the largest contributor of emissions in the Gibraltar city inventory is water-borne navigation, accounting for 52% of emissions. This includes shipping emissions (excluding ships solely visiting for bunkering) and private boats[33]. Transboundary transportation sources are included in BASIC+ reporting, but have been excluded from the chart in Figure 5-2 to better represent emissions attributable to and influenced by the community. Emissions from private boats are captured under Scope 1.

Stationary energy is responsible for 9.7% of emissions, waste 1.9% and industrial processes and product use (IPPU) 0.6%.

Table 5-4: Total emissions by gas and scope

Reporting by scope	Total GHG emissions (tCO_2e)	Gases (tCO_2e)						
		CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3
Scope 1	94,987	83,153	234	1,508	10,087	5	–	–
Scope 2	172,362	171,741	184	438	–	–	–	–
Scope 3	1,460,487	1,114,716	45,409	9,350	–	–	–	–
Outside of scope	4,918,700							

CO_2 = carbon dioxide, CH_4 = methane, N_2O = nitrous oxide, HFC = hydrofluorocarbons, PFC = perfluorocarbons SF_6 = sulfur hexafluoride, NF_3 = nitrogen trifluoride

Table 5-5: Emissions by gas and reporting standard

Reporting level	Total GHG emissions (tCO_2e)	Gases (tCO_2e)						
		CO_2	CH_4	N_2O	HFC	PFC	SF_6	
GPC BASIC	287,399	255,600	28,137	3,661	–	–	–	–
GPC BASIC+	1,207,663	1,157,849	28,484	11,238	10,087	5.48	–	–
PAS 2070 DPSC	1,727,836	1,369,609	45,826	11,295	10,087	5.48	–	–

GPC = Greenhouse Gas Protocol's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

Emission by scope and gas are shown in Table 5-4. As expected, carbon dioxide (CO_2) is the dominant GHG emitted. Scope 1 emissions are largely dominated by

[33] The total UK shipping emissions (including international shipping) reported for 2012 was 12.3Mt CO_2e, but as activity is concentrated in a small number of large international ports, there will be several large international ports in the UK with similar or larger levels of activity as that seen in Gibraltar. This information was used as a check of the results.

road transport fuel use, but there is also a noticeable contribution from hydrofluorocarbons (HFCs) from product use (such as air-conditioning units).

Scope 2 emissions from electricity consumption are also large, due to the reliance on electricity for all energy needs and generation technology. Because gas oil is used to generate electricity, the emissions per kilowatt hour (kWh) are considerably higher than, for example, those in the UK. The implied emission factor based on fuel consumption in power stations and total output in Gibraltar is 0.9804kg/kWh, compared to the UK grid factor of 0.4943kg/kWh[34].

Scope 3 emissions are largest overall across scopes (excluding 'outside of scopes'), due primarily to shipping activity (excluding bunkering) and upstream fuel emissions.

Emission by reporting level are shown in Table 5-5. This shows a very large difference in emissions under the GPC's BASIC and BASIC+ reporting levels. This is due to the inclusion of additional sources in BASIC+ that are very significant in Gibraltar, almost entirely transboundary (scope 3) emissions from shipping and with lesser contributions from aviation, and HFCs from product use. The British Standards Institute PAS 2070 direct plus supply chain (DPSC) reporting level shows a significant increase again (by 40% from BASIC+) due to the inclusion of upstream emissions from fuel (as above) and supply chain imports, which account for 13% each of the total inventory.

Sources that are deemed to be 'outside of scopes' (i.e. they are reported for information, but are not deemed to be within the influence or responsibility of the city, such as bunker fuel) would dominate emissions overall (74% of overall total) if included in emission totals, with bunkering alone making up nearly 60% of emissions when all are combined. For this reason they are excluded from reporting. These are shown in Table 5-3.

5.3 Total manageable emissions for Gibraltar

As noted above, BASIC+ is the recommended reporting approach for city-level emissions under the GPC. This excludes emissions from the supply chain (captured under the PAS 2070 DPSC approach). Transboundary transport emissions are included under BASIC+ reporting however, and this includes water-borne navigation. This is a particularly large source for Gibraltar, and one that the community has little influence over. It also dominates the results, making it difficult to identify the impact of smaller, more manageable local sources. For this reason, international water-borne navigation (scope 3, transboundary) has been excluded from the presented total. Under BASIC+, supply chain emissions have also been excluded, with the exception of water, where emissions had been reallocated from stationary energy.

This sub-set can therefore be considered Gibraltar's 'manageable emissions', shown in Figure 5-3 above.

When these sources are removed, the inventory results are much more aligned to those expected for a city, with stationary energy dominating, accounting for 52% of emissions. This is particularly the case in Gibraltar given the relative carbon inefficiency of electricity generation. Transportation also contributes about one third of

[34] www.ukconversionfactorscarbonsmart.co.uk/

emissions, with 16% from road transport sources. Waste and IPPU are smaller, at 10% and 3% respectively, and water supply 3%.

When compared to the results in Figure 5-4 from the carbon*n* Cities Climate Registry (cCCR)[35], Gibraltar's emissions are of a similar order of magnitude to those expected for a city. The proportions for transportation, IPPU, waste and stationary energy (residential, commercial and industrial, taking into account the limited industrial use in Gibraltar) are found to be largely consistent. Interestingly, waste is higher than this comparable data, suggesting that waste disposal methods (particular landfilled waste) could be improved.

On a per capita basis, Gibraltar's BASIC emissions equate to just over 9.5 tonnes per person (BASIC emissions include those from in-boundary energy use, in-boundary transport and waste disposal only).

The World Bank published 'Representative GHG Baselines for Cities and their Respective Countries'[36] for 2011, showing that city per capita emissions vary widely, from less than one tonne in the poorest countries, to over 20 tonnes for Sydney, Australia. It should be noted that these data stem from a variety of methods, but show that on a global scale, Gibraltar's per capita emissions fall in the middle of the range.

The values shown in Table 5-6 are emission totals and corresponding per capita emissions for a selection of the smallest cities (by population) reporting emissions to the CDP[37]. These data are reported to have been compiled consistent with GPC methods (presumed to be 'BASIC'). However, the lack of supporting documentation that is publicly available means that this should be treated as indicative only. This indicates that Gibraltar has relatively high emissions per capita, compared with these smallest reporting cities. However, it is important to acknowledge Gibraltar's small resident population, its unique geographical situation compared to most global cities, and the impacts and limitations this places upon emissions.

Table 5-6: Indicative per capita GPC BASIC emissions for global cities

City	tCO_2e	Population	Per capita emissions (tCO_2e)
City of Copenhagen, Denmark	2,124,000	569,557	3.73
Comune di Venezia, Italy	1,418,344	270,843	5.24
City of Burlington, USA	287,536	42,282	6.80
Almada, Portugal	246,916	173,298	1.42
Gibraltar	279,927	30,000	9.58

[35] Carbon*n* Cities Climate Registry 2013 Annual Report http://citiesclimateregistry.org/fileadmin/user_upload/cCCR/cCCR_2014/cCCR-2013-annual-report.pdf

[36] http://siteresources.worldbank.org/INTUWM/Resources/GHG_Index_Mar_9_2011.pdf

[37] Available from CDP Cities 2013, www.cdp.net

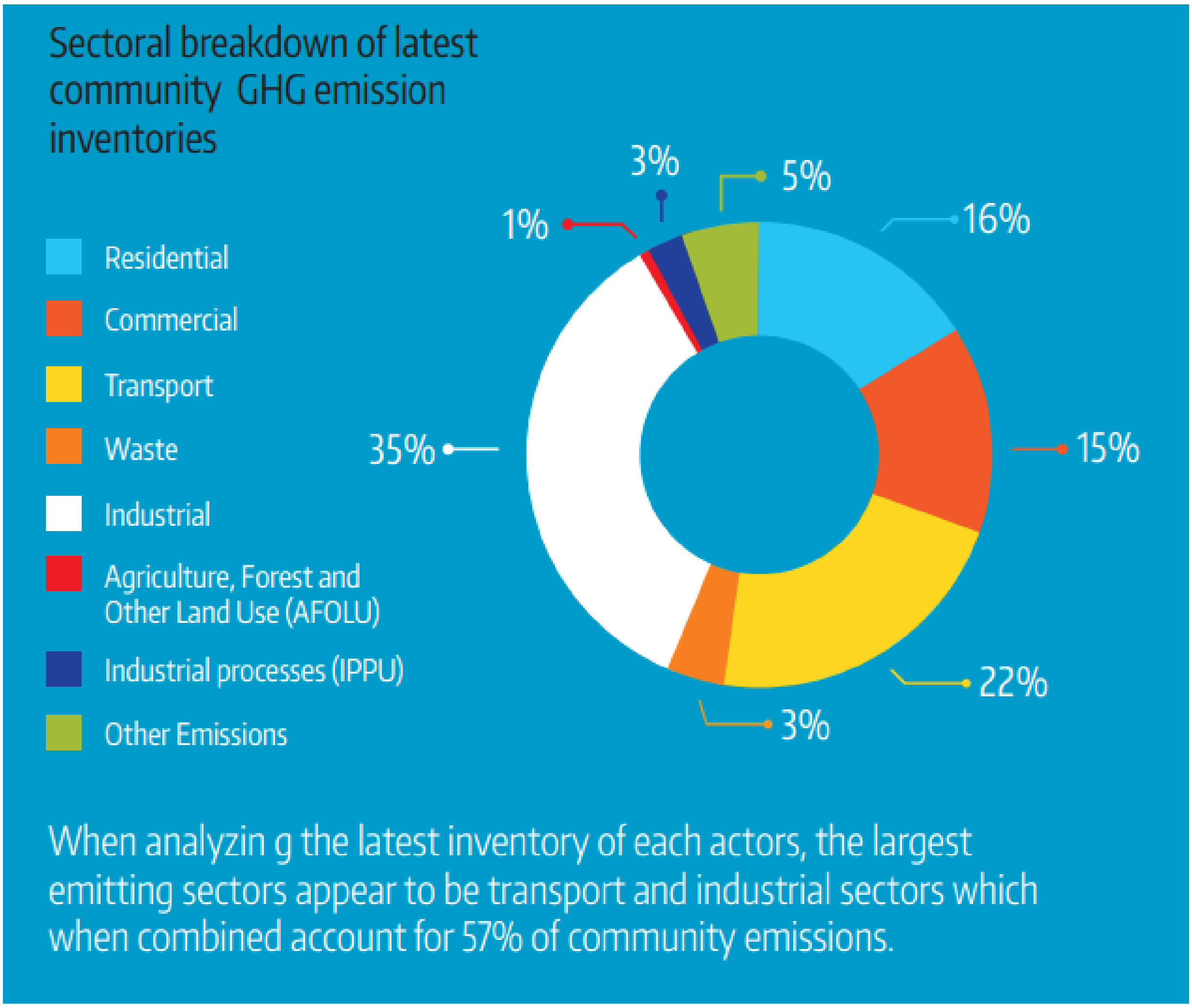


Figure 5-4: Sectoral breakdown of latest community GHG emission inventories from Carbonn Cities Climate Registry (cCCR) report

5.4 Reducing emissions in Gibraltar

An emissions inventory is an ongoing tool for understanding and reporting emissions, and allows the identification of major sources and priority areas for mitigation. Section 6.1 discusses in more detail the role of an inventory, and the setting of goals by a city. However, from the results presented it can be seen that there are some areas where efforts should be focussed. Recommendations are therefore as follows:

- Stationary energy (in this instance entirely electricity production) is the highest contributor to manageable emissions, and as such efforts should be focussed on both reducing consumption and decarbonising supply. A full assessment of both supply side mitigation options, and demand-side efficiency, should be undertaken.
- For transport, aviation and private marine are difficult to influence. However, road transport, although relatively small compared to sources such as stationary energy, is significant given the small size of the territory. Road transport emissions would also be possible to influence through local policy

measures. Gibraltar should therefore consider ways to reduce road transport, particularly car use.

- Waste and wastewater are relatively large compared to other cities. The majority of waste emissions are from solid waste to landfill. Gibraltar should therefore undertake research to identify ways to both reduce overall waste, increase recycling, and find alternative lower impact disposal methods.
- Individual industries that are high energy users should be identified and ways to reduce energy consumption investigated. In particular, energy use for water supply (including desalination, purification and pumping) is accountable for 3% of the total emissions, which is significant for one industry.

It is beyond the scope of this work to make detailed recommendations for mitigation measures beyond identifying the above major sources. However, it is recommended that should Gibraltar want to make significant improvements to its total emissions, a separate and detailed study of mitigation options and potential reductions in different sectors should be carried out.

5.5 Inventory accuracy

In compiling the Gibraltar City Inventory, there are a number of assumptions that have had to be made in the compilation and calculations that will have impacts on the accuracy of the data. The largest sources have been calculated with a high level of confidence, due to the presence of, for example, energy imports statistics, detailed shipping records and the clearly bounded nature of activities (such as electricity generation). Some of the more minor assumptions relate to interpretation of data (such as units or fuel types where not consistent with the International System of Units (SI units), for instance). Most assumptions relate to methods of allocation within sectors, so the total inventory is associated with low uncertainty, but the sector allocations are more uncertain.

All assumptions have been documented in the relevant methodology section, but Table 5-7 summarises some of the main assumptions and possible impacts on the data. A formal uncertainty analysis was not undertaken on the inventory as it was beyond the scope of this work, but should be considered for future years.

Table 5-7: Summary of assumptions and impact on inventory totals

Emission or data source	Assumption	Possible impact	Improvement
Proxy indicators	2012 values used as 2013 values not available	It is unlikely that using 2012 values for proxy indicators (such as gross domestic product (GDP) and population) will have had a large impact on emission sources but it will be important to update to the correct year when available	Latest year data for key indicators
Fuel import data for mobile combustion	Assumed that 30% of gas oil was used in private boats and the rest for road vehicles	The overall fuel balance for the inventory will remain unchanged as this is an allocation issue. However, due to only a partial year inclusion of marine fuel use in the 2013 data, the data were scaled to give a whole-year approximation which will introduce uncertainty. However, overall, the private marine proportion of the transport emissions within the inventory is relatively minor	Fuel import data should be captured not only by fuel type, but also by purpose/end use (marine or road) to enable accurate disaggregation
Electricity allocation to end users	Electricity could only be allocated accurately for some users (domestic was based on tariffs and others were based on billings data) requiring allocation by proxy indicator	Ultimately, the total electricity emissions remain unchanged as this is an allocation issue. It is possible that some users have been over or under estimated and the emissions details possible for each end user is limited	Billings data for other key sectors (such as public sector buildings, hospital, port, airport, retail) to allow better allocation

Emission or data source	Assumption	Possible impact	Improvement
Transport activity data	Transport emissions were calculated by generating implied fuel consumption data based on the vehicle fleet. Actual information on vehicle movements was not available, so it was not possible to establish the proportion of travel inboundary and out of boundary. It was therefore assumed that all fuel sold to Gibraltarian vehicles was used inboundary and all non-Gibraltarian out of boundary	It is likely that the allocation of emissions is inaccurate. The implied vehicle kilometres (vkm) are for Gibraltarian vehicles and are higher than would be expected for a region of this size. Therefore, it is likely this is an over estimate of inboundary emissions. It is probable that some proportion of the Gibraltarian fuel sales should be allocated to transboundary emissions, but it is not possible to distinguish. The lack of vehicle activity data also makes it difficult to account for off-road vehicles and public transport. The fuel import data provide the overall fuel balance, but in the transport sector some of this is allocated to ‘outside of scopes’ as it is deemed to be ‘exported’ by non-Gibraltarian drivers. Therefore, the proportion of emissions from fuel imported that is allocated to Gibraltar is possibly over estimated. We also do not estimate the amount of fuel bought by Gibraltarians while outside of Gibraltar, which will lead to a small under estimate	Data on household travel habits, in particular activity data to enable a better understanding of annual distance travelled by vehicle type (car/heavy goods vehicle (HGV)/light goods vehicle (LGV)/bus motorcycle, and private, commercial, public) would enable a better characterisation of vehicle emissions and improved allocation to end users

Emission or data source	Assumption	Possible impact	Improvement
Aviation activity data	Aviation was calculated on a bottom-up basis and was based on the number of flights, assumptions on the plane class and the expected distance flown. 'Unscheduled' flights were omitted as they were evidently linked to very small planes, for which we had limited emissions and fuel consumption estimates	There is some uncertainty on how much fuel would be used on journeys, the actual distance travelled and the validity of some of our assumptions. Additionally, the omission of the 'unscheduled' flights will lead to a small under estimate	Access to fuel sales in Gibraltar would enable verification of bottom-up calculated fuel use data. This would reduce uncertainty as fuel sold gives a strong indication of the fuel use on outgoing journeys. This would also remove the possible under estimate due to the omission of unscheduled flights
Private marine emissions	Due to a lack of data, it was assumed that 30% of fuel oil imports were sold for private marine uses. Data had to be scaled up to give a whole year when imports for marine fuels ceased part way through. However, the 30% assumption is broadly supported by trends in the data	This assumption is supported by analysis of historical data trends. However, it is possible that this is not an accurate estimation of marine fuel use and total fuel imports after scaling	Activity data, such as fuel sales at marine filling stations, would improve calculations of this emission source significantly
Shipping activity data	Activity data for ships were calculated through calculations of distance travelled to and from other ports. This provided an indicator of fuel consumption per journey	It is possible that the ship classes and average fuel consumptions taken form the EMEP/EEA air pollutant emission inventory guidebook 2013 do not accurately match the ships visiting Gibraltar. However, it is likely that any impact here is small	Bunkering volumes would help to provide a check and fuel balance
Shipping activity data	Where it wasn't clear which port was being referred to in the port statistics (around 30% of cases), we assumed it to be the average distance to the known ports	This increases the uncertainty in the distance travelled estimates and, hence, fuel consumption estimates	Data on fuel sales would provide a quality check. Complete, clear records of destination ports would reduce the need for assumptions to be applied

Emission or data source	Assumption	Possible impact	Improvement
IPPU activity data	No data existed on IPPU emissions for Gibraltar so these were estimated using UK data and proxy indicators (population, GDP)	It is possible that the Gibraltarian case differs from the UK, particularly for air-conditioning units, which may be under estimated. Indicator data were also not up to date	Latest year indicator data and Gibraltar-specific information on relevant product use, e.g. numbers of air-conditioning units, solvent use, etc.
Waste water emission calculation	Emissions were calculated using a default emission factor for wastewater to sea, lakes and rivers	It is likely that this has resulted in an over estimate of CH_4 as sea water is less stagnant than lakes and inland waterways, so there will likely be less anaerobic decomposition	This is a very small inventory source. Improvements to estimates would require a level of work beyond the significance of the source
Waste composition data and disposal	The composition of municipal solid waste (MSW) arisings were estimated by applying the results of the 2006 Waste Characterisation Study to the total reported MSW – 55%. Therefore, this assumption is based on waste collection data, rather than final processing in Spain. In general, the waste sector has a lot of assumptions about composition and disposal/treatment methods	It is probable that the fraction of waste recycled has been over estimated and emissions are, therefore, an under estimate. There are also assumptions about waste treatment in Spain which could result in uncertainty of the estimates. Overall, this is one of the smaller sources, so is less of a priority. However, it is possible that should the recycled fraction be lower, the source would have a greater overall emission share	Data from final processing rather than composition of waste exported should be obtained to improve this estimate. This is one of the inventory emission sources where local activity and decisions can have a significant impact. Therefore, effort should be made to better characterise waste and understand disposal processes

6 Recommendations

This chapter sets out a series of recommendations following the compilation of this city-level greenhouse gas (GHG) inventory for Gibraltar. These recommendations include:

- Setting mitigation goals and prioritising activity.
- Improving inventory compilation and future year reporting.
- Quality assurance, quality control (QAQC) and verification.

6.1 Mitigation goals and activities

The main uses of the inventory are to guide mitigation activity, enable the setting of goals for reduction and track progress over time. Setting reduction or ‘mitigation’ goals can help cities focus efforts on key emission sources, identify innovative mitigation solutions, demonstrate leadership and reduce long-term costs. This is all part of an interconnected process – an inventory should not be considered a one-off activity, but a live source of data and information to inform decision-making and monitor progress.

6.1.1 Role of an inventory

An inventory identifies those sources that are highest emitting and should, therefore, be the priority for mitigation action as well as a priority source for the use of more detailed (higher tier) methods. In the case of city inventories, the identification of sources and emissions by scope also enables an additional level of understanding for mitigation: those sources emitted directly within the boundary that have a greater possibility of management versus those emitted indirectly as a result of activity and are less possible to influence (because, for instance, there is no control over the waste disposal process outside the boundary, numbers of ships visiting, how many vehicle journeys are made or the GHG intensity of imported goods).

6.1.2 Setting goals and evaluating performance

The Greenhouse Gas Protocol’s Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (v2.0 2014) provides some guidance on setting goals and evaluating performance, and identifies four types of goal that can provide the basis against which emissions and emissions reductions are tracked and reported. These are:

1. Base year goals.
2. Fixed level goals.
3. Intensity goals.
4. Baseline scenario goals.

More detail on these scenario types is shown in Box 6-1.

Base year goals represent a reduction in emissions relative to an emissions level in a historical base year. They are typically framed in terms of a percent reduction of emissions, rather than an absolute reduction in emissions.

Fixed levels goals represent a reduction in emissions to an absolute emissions level in a target year. For example, a fixed level goal could be to achieve 200 million tonnes CO_2e by 2020. The most common type of fixed level goals are carbon neutrality goals, which are designed to reach zero net emissions by a certain date (though such goals often include the purchase and use of offset credits to compensate for remaining emissions after annual reductions). Fixed levels goals do not include a reference to an emissions level in a baseline scenario or historical base year.

Intensity goals represent a reduction in emissions intensity relative to an emissions intensity level in a historical base year. Emissions intensity is emissions per unit of output. Examples of units of output include gross domestic product (GDP), population and energy use. Intensity goals are typically framed in terms of a percent reduction of emissions intensity, rather than an absolute reduction in emissions intensity.

Baseline scenario goals represent a reduction in emissions relative to a baseline scenario emissions level. They are typically framed in terms of a percent reduction of emissions from the baseline scenario, rather than an absolute reduction in emissions. A baseline scenario is a set of reasonable assumptions and data that best describe events or conditions that are most likely to occur in the absence of activities taken to meet a mitigation goal (business as usual).

Box 6-1: Goal types explained (from the GPC v2.0 2014)

All goal types, except for fixed level goals, require inventories to provide information at the base year and target year for the goal setting and evaluation although even fixed level goals need a mechanism for demonstrating achievement of the specified level. Table 6-1 gives examples of different goal types and minimum inventory need.

Gibraltar will need to identify which kinds of goals are most appropriate and which information from the inventory will be used to track these goals. The current ambition of carbon neutrality will need to be carefully defined with particular reference to inclusion and exclusion of sources. As discussed in section 5 (Results) and 5.4 (Reducing emissions in Gibraltar), goals should be set with reference to those sources identified as highest polluting, and with the most ability to influence.

It is most common for cities to set base-year or fixed-level goals.

Table 6-1: Examples of city goal types and inventory need, adapted from the GPC v 2.0 (2014)

Goal type	Example	Minimum inventory need
Base-year goals		
Single-year goal	London (UK): By 2025 60% GHG emissions reduction on 1990 levels	Inventory for 1990 and 2025
Multi-year goal	Wellington (New Zealand): Stabilise from 2000 by 2010, 3% GHG emissions reduction by 2012, 30% by 2020, 80% by 2050	Inventory for 2000, 2010, 2012, 2020 and 2050
Fixed level goals	Carbon-neutral is another type of fixed level goal type. Melbourne (Australia) set a target to achieve zero net carbon emissions by 2020, and plans to achieve the goal through internal reductions and purchasing offsets	In the case of Melbourne, inventory required to determine quantity of offsets necessary to cover remainder of emissions
Intensity goals		
Per capita goal	Belo Horizonte (Brazil): 20% GHG emissions reduction per capita until 2030 from 2007 levels	Inventory for 2007 and 2030
Per GDP goal	China is the major country adopting GHG emissions reduction per unit of GDP goal for cities. For example, Beijing: 17% reduction per unit of GDP in 2015 from 2010 levels	Inventory for 2010 and 2015
Baseline scenario goals	Singapore pledged to reduce GHG emissions to 16% below business-as-usual (BAU) levels by 2020 if a legally binding global agreement on GHG reductions is made. In the meantime, Singapore started implementing measures to reduce emissions by 7% to 11% of 2020 BAU levels	Inventory for 2020 and a projected BAU inventory for 2020

6.2 Improving inventory compilation and future year reporting

Inventories are very much intended to be a ‘live’ reporting tool and, as such, should be subject to regular revision and improvement. There are two particular aspects that should be considered by Gibraltar for ongoing improvement of compilation and future reporting of the inventory. These are:

- Improved activity data collection and management, including sectoral allocations.
- Recalculations and tracking emissions over time.

6.2.1 Improved activity data collection and management

Any inventory has scope for improvement of data collection and management. The collection of data is often the most time consuming and challenging aspect of the inventory, so adequate time needs to be dedicated to this stage. The challenge is often that third parties hold the information that is required or that it is not available at all. Important sources of data for an inventory include:

- Activity data (AD) sources:
  - National statistics:
    - Energy balance.
    - Production statistics.
    - Population data/housing data.
  - Industrial/commercial/public surveys/censuses.
  - Bottom-up data (e.g. from industrial installations or trade associations).
  - Surveys.
  - Proxy data (even from other countries).
- Emission Factor (EFs) Sources:
  - International defaults.
  - Country-specific factors.
  - Use of data from other countries with similar national circumstances.
  - Intergovernmental Panel on Climate Change (IPCC) Emission Factor Database.

However, data are often not perfect or cannot be obtained. Common problems faced include:

- Lack of awareness of what data might be available.
- Lack of structured data sharing processes.
- Timeliness – key datasets are not available at the time required.
- Sharing data may be viewed as losing power by individuals, departments or organisations.
- Restrictions on statistics data prior to official release.
- Commercially sensitive data (e.g. from individual companies or installations).
- Keeping up with the policy cycle – new measures and targets can be developed and implemented very quickly, sometimes without consulting data and technical experts.

A number of mechanisms can be used to obtain and improve data. These include ‘gentleman’s agreements’, data supply agreements (DSAs) and legal agreements (with/without penalties). The most appropriate mechanism for obtaining data depends on the source and the owner of the data. In most instances, a DSA will be the most appropriate mechanism. This clearly defines scope and format of data, states the time for delivery of data, requests information about uncertainty – this is often not considered at all, and sets out the requirements for commercial confidentiality (i.e. that if the data are commercially sensitive they will remain confidential). An example is shown in Table 6-2. It is vital to clearly express the data required – units, scope, boundaries, time period, sources and activities. It should also be requested that each data source is provided with an explanatory note and a contact for any queries. Failure to do so often results in incomplete data, the wrong data and a lack of transparency of how the data was compiled.

Table 6-2: Example data supply agreement from the UK GHG Inventory

Data required	Key data provider	Deadline each year	Comments
Access to the SEPA SPRI inventory for previous years data	SEPA	15 August	Electronic version of Scottish pollutant Release Inventory (SPRI), including emissions where below reporting threshold. Could you please include site details such as address, post codes, grid references and permit numbers please.
Previous years EU-ETS installation-specific fuel use and characterisation data for all sites in Scotland	SEPA	15 August	EU ETS activity data, calorific values, carbon factors, oxidation factors and carbon emissions by fuel and installation for fossil fuels, 2005-onwards EU ETS activity data, calorific values, carbon factors, oxidation factors and carbon emissions by fuel and installation for bio fuels, 2005-onwards EU ETS activity data, carbon factors, and carbon emissions by installation for process emissions, 2005-onwards Note: Confidentiality of data will be respected and any issues that prevent the data being provided will be highlighted at the earliest opportunity and aggregated data provided where applicable

The Government of Gibraltar will need to ensure it sets up systems for regular data collection. Key to this will be the establishment of DSAs with data providers. Where no agreement or relationship exists, a process of engagement will be required. In most instances, a DSA will suffice, but legislation should be considered for key sources. In particular, transport activity data are poor and action should be taken to obtain improved information from this sector. The vehicle testing centre may be appropriate here or via the annual compilation of the Abstract of Statistics. Surveys should also be considered to improve understanding of bottom-up activity.

The steps for compiling inventory data are shown in Figure 6-1. The Government of Gibraltar will need to establish responsibilities for these different steps, either internally or through an external inventory agency, and put in place the necessary structures to obtain data in future years.

Appendix 1 sets out the minimum data requirements needed for estimation of emissions in each sector, and the data required for disaggregation and verification. In addition, Appendix 2 provides a QA/QC template to be accompanied by each data request, for the data provider to complete to ensure transparency.

- Prioritise effort on highest emitting sources.
- Identify data available, assess method options, review data gaps, repeat review of method options in order to decide on method and data needs.
- Engage stakeholders - meetings, calls, emails, guidance notes.
- Establish legal, contractual, formal or informal data supply mechanisms.
- Implement systems to govern data quality – accuracy, scope (e.g. site boundaries), timeliness, indication of uncertainty.
- Archive data and make available across the team for review.
- Quality check (sense check, scope, completeness, time series consistency) all data as they arrives/inputted to local files.
- Annually re-assess the data needs and priorities for improvement.

Figure 6-1: Steps to compiling an inventory: key roles

6.2.2 Recalculations and tracking emissions over time

It is important to track emissions over time to provide information on historical emissions trends, and the effects of policies and actions to reduce emissions at the city level.

As far as is possible, the time series should be calculated using the same methods, data sources and boundary definitions in all years to ensure consistency. Using different methods, data or applying different boundaries in a time series could introduce bias because the estimated emissions trend will reflect real changes in emissions or removals and the pattern of methodological refinements.

Significant changes may occur in cities over time, which will alter the historical emissions profile, making meaningful comparisons over time difficult. To maintain consistency over time, historical emissions data from a base year inventory will have to be recalculated. This should also occur if methods change and data improve.

The GPC sets out examples of the kinds of significant changes a city might experience that should trigger a recalculation. These are set out below and examples given in Table 6-3.

Structural changes in the assessment boundary. This may be triggered by adjustment in a city's administrative boundary, or changes in inclusion or exclusion of activities within the city boundary. For example, a category previously regarded as insignificant has grown to the point where it should be included in the inventory. However, no emissions recalculations are needed for activities that either did not exist in the base year, or reflect a natural increase or decrease in city activities ('organic growth').

- For Gibraltar, it will be necessary to track land use activities, particularly land reclamation as an extension of the territory and the emission implications of greater land area over time. The treatment of sources such as international bunkering, shipping and road vehicle fuel export may also be possible areas for change to assessment boundary (inclusion/exclusion) over time. Sources that have not been estimated should also be considered for inclusion.

Changes in calculation methodology or improvements in data accuracy. A city might report the same sources of GHG emissions as in previous years, but measure or calculate them differently. Changes resulting in significant emission differences should be considered as recalculation triggers, but any changes that reflect real changes in emissions do not trigger a recalculation. Sometimes, the more accurate data input may not reasonably be applied to all past years, or new data points may not be available for past years. The city may then have to back cast these data points, or the change in data source may simply be acknowledged without recalculation. This acknowledgement should be made in the report each year to enhance transparency. Otherwise, new users of the report in the two or three years after the change may make incorrect assumptions about the city's performance.

- There is a likelihood that Gibraltarian activity data can be improved over time to give more accurate estimates. This is dealt with in more detail below, but it will be necessary to perform recalculations should this occur. Of particular importance will be any improved transport data given the dominance of the source.

Discovery of significant errors. A significant error or a number of cumulative errors that are collectively significant, should also be considered as a reason to recalculate emissions.

- QAQC procedures on this inventory should have minimised errors, but should an error have occurred, recalculations will be required.

Table 6-3: Examples of recalculation triggers, from GPC v2.0 (2014)

Trigger	Example change	Recalculation needed	No recalculation needed
Changes in assessment boundary	A community is included in or set aside from a city's administrative boundary	X	
	Change in goal boundary from BASIC to BASIC+, or from six GHGs to seven GHGs	X	
	Shut down of a power plant		X
	Build of a new cement factory		X
Changes in calculation methodology or improvements in data accuracy	Change in calculation methodology for landfilled municipal solid waste (MSW) from *Mass Balance Method* to the *First Order Decay Method*	X	
	Adoption of more accurate local emission factors, instead of a national average for scope 2 emissions	X	
	Change in electricity emission factor due to energy efficiency improvement and growth of renewable energy utilisation		X
Discovery of significant errors	Discovery of mistake in unit conversion in formula used	X	

Whether recalculation is needed depends on the significance of the changes. The determination of a significant change may require taking into account the cumulative effect on base year emissions of a number of small changes.

The Government of Gibraltar should consider recalculations in the next inventory cycle if or when improved data become available. This is particularly the case for the transport sources where there is greater uncertainty in the allocation, particularly for inboundary and out of boundary emissions.

6.3 QAQC and verification

Data collection is an integral part of developing and updating a GHG inventory. This includes gathering existing data, generating new data and adapting data for inventory use. Table 6-4 sets out the methodological principles of data collection that underpin good practice.

Table 6-4: Good practice data collection principles

Good practice data collection principles
• **Establish collection processes** that lead to continuous improvement of the datasets used in the inventory (resource prioritisation, planning, implementation, documentation, etc.)
• **Prioritise improvements** on the collection of data needed to improve estimates of key categories which are the largest, have the greatest potential to change or have the greatest uncertainty
• **Review data collection activities** and methodological needs on a regular basis to guide progressive and efficient inventory improvement
• **Work with data suppliers** to support consistent and continuing information flows

6.3.1 Quality control

Quality control (QC) is a set of technical activities that measure and control the quality of the inventory as it is being developed. They are designed to:

- Provide routine and consistent checks to ensure data integrity, correctness and completeness.
- Identify and address errors and omissions.
- Document and archive inventory material and record all QC activities.

QC activities include accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source categories, activity and emission factor data, and methods.

A number of QC checks were undertaken in the compilation of the inventory. These included:

- Mass balance checks – fuel data ‘used’ versus fuel data ‘supplied’ for Gibraltar should balance.
- Implied Emission Factors (IEFs) – checks against UK GHG inventory to ensure the order of magnitude is what would be expected.
- Spreadsheet functions – manual checks that formulae are working as expected.
- Consistent labelling, file revisions (e.g. dated file extensions).
- Documentation on spreadsheets, with details of calculation method, assumptions, emission factors and data quality.

6.3.2 Quality assurance

Quality assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably performed by independent third parties, should take place when an inventory is finalised following the implementation of QC procedures. Reviews verify that data quality objectives were met and that the inventory represents the best possible estimates of emissions – and sinks given the current state of scientific knowledge and data available.

Several QA reviews were undertaken by internal inventory experts for the calculations for each sector and of methodologies used across the inventory.

6.3.3 Verification

Verification can be used to increase credibility of publicly reported emissions information with external audiences and increase confidence in the data used to develop climate action plans, set GHG targets and track progress.

Verification involves an assessment of the completeness, accuracy and reliability of reported data. It seeks to determine if there are any material discrepancies between reported data and data generated from the proper application of the relevant standards and methodologies. It does this by making sure that the reporting requirements have been met, that the estimates are correct and that the data sourced are reliable.

No verification was carried out on this report or the underlying data, due a lack of defined verification processes and bodies to carry this out. However, following the draft publication of this report an informal review was undertaken by Michael Doust, C40 Cities’ Head of Measurement and Planning and a GPC and PAS 2070 author.

Appendix 1: Data recommendations

The table below sets out the data requirements for each of the main sectors. It shows the minimum top-level data required for emission calculation, and the data required to enable a disaggregation of the data by end user and/or category. The Data for Verification column shows the data required to cross-check and verify the disaggregation of data.

Cells in grey indicate data that was not available for the Gibraltar 2013 inventory.

Sector	Minimum top level data	Data for disaggregation	Data for verification
Power	Fuel consumption for power (electricity) generation by fuel type - Gibraltar power station - Imported and exported	Electricity produced in Gibraltar (total) Electricity consumed by sector (e.g. residential, commercial, Government/public services, Industrial) - Billings by tariff or end-user - Meter readings	Total power (electricity) generation
Fuels/ combustion	Total fuel consumption by fuel type (non-electricity generation)	Fuel combustion locations End user sales / permits Total use by purpose (cooking stove, boiler etc.)	Not applicable
Transport (road)	Fuel import data by fuel type	Gibraltar vehicle licencing statistics End-user activity split : fuel use by vehicle type and purpose (including in and out of boundary – crossings of the Frontier) Fuel sold	Vehicle kilometre (vkm) data, by vehicle type and purpose
Marine (private)	Fuel import data	Fuel sold Fleet composition Fuel usage by marine use (boat type)	Not applicable
Shipping *(data publicly*	Port activity - Number of ships - Types	Ship details (each) - Purpose - Class	Fuel sold

Sector	Minimum top level data	Data for disaggregation	Data for verification
available on internet)	- Distance (origin/ destination)	- Tonnage Purpose for calling (bunkers/non-bunkers)	
Off-road	Fuel sold	Licencing statistics for off-road fleet Fleet composition Fuel use by vehicle type	Vehicle kilometre (vkm) data or hours of use
Aviation *(from CAA)*	Numbers of flights and destinations Distances flown (origin/destination)	Fleet data (aircraft types)	Fuel sold
Waste	Total tonnage of waste Disposal methods	Tonnes / type - Biological content - Waste treatment process	Not applicable
Wastewater	Total volume of wastewater Biological content Treatment streams	Wastewater volume by sector	Population Average wastewater and biological content per person
Industrial Processes and Product Use	Numbers of products by type (e.g. A/C units, refrigerators, vehicle A/C) Volumes of N_2O (hospital)	Numbers of products by end use sector	Population GDP Average product use / number per person / GDP

Appendix 2: QA/QC Sheet

All data provided should include the following Quality Control information:

QC information required	Description of information required
Compiler	*Who compiled this data?*
Date created	*When was this data created/compiled?*
Source of data	*Where has this data come from?*
Data provided to	*Who has this data been provided for?*
Data purpose	*What has this data been provided for? Does this affect its use?*
Checked by	*Has this data been checked by anyone? How has it been checked?*
Data range	*Time (e.g. date range)* *Geographic scope* *Installations/activities*
Notes/disclaimers	*Any other important information that the data recipient should be aware of? Are there missing years? Is this an estimate? Is this confidential?*

Data should be clearly labelled with appropriate units and time coverage, with any relevant information on the technology or activity in question.

Common units and their nomenclature, and conversions between units are shown in Appendix 3. These units should be used when providing data wherever possible.

Appendix 3: Common units and conversions

Metric prefix		Symbol	Number	Standard form
Abbreviation	Kilo	k	1,000	10^3
	Mega	M	1,000,000	10^6
	Giga	G	1,000,000,000	10^9
	Tera	T	1,000,000,000,000	10^{12}
	Peta	P	1,000,000,000,000,000	10^{15}

Unit		GJ	kWh	therm	toe	kcal
Energy	Gigajoule, GJ		277.78	9.47817	0.02388	238,903
	Kilowatt-hour, kWh	0.0036		0.03412	0.00009	860.05
	Therm	0.10551	29.307		0.00252	25,206
	Tonne oil equivalent, toe	41.868	11,630	396.83		10,002,389
	Kilocalorie, kcal	0.00000418	0.0011627	0.00003967	0.00000010	

Unit		L	m^3	cu ft	Imp. gallon	US gallon	Bbl (US,P)
Volume	Litres, L		0.001	0.03531	0.21997	0.26417	0.006290
	Cubic metres, m^3	1000		35.315	219.97	264.17	6.2898
	Cubic feet, cu ft	28.317	0.02832		6.2288	7.48052	0.17811
	Imperial gallon	4.5461	0.00455	0.16054		1.20095	0.028594
	US gallon	3.7854	0.003785	0.13368	0.83267		0.023810
	Barrel (US, petroleum), bbl	158.99	0.15899	5.6146	34.972	42	

Unit		kg	tonne	ton (UK)	ton (US)	lb
Weight/mass	Kilogram, kg		0.001	0.00098	0.00110	2.20462
	tonne, t (metric ton)	1000		0.98421	1.10231	2204.62368
	ton (UK, long ton)	1016.04642	1.01605		1.12000	2240
	ton (US, short ton)	907.18	0.90718	0.89286		2000
	Pound, lb	0.45359	0.00045359	0.00044643	0.00050	

Unit		m	ft	mi	km	nmi
Length / distance	Metre, m		3.2808	0.00062137	0.001	0.00053996
	Feet, ft	0.30480		0.000	0.0003048	0.00016458
	Miles, mi	1609.34	5280		1.60934	0.86898
	Kilometres, km	1000	3280.8	0.62137		0.53996
	Nautical miles, nmi or NM	1852	6076.1	1.15078	1.852	

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