Manchester: A Certain Future, *CO_2 Monitoring Group*

City of Manchester

Global Protocol for Community-Scale GHG Emission Inventories (GPC)

2015 Inventory

This report and inventory have been conducted by Joe Blakey (Sustainable Consumption Institute, The University of Manchester) with assistance from the Manchester: A Certain Future CO_2 Monitoring Group which is convened and directed by Ali Abbas.

All errors remain my own. Any positions expressed are not necessarily representative of the CO_2 Monitoring Group

Cover image by Joe Blakey

Contents

Executive Summary

- The **Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is a carbon accounting reporting standard** that was committed to in the *Manchester Climate Change Strategy 2017-50.*

- GPC offers **an alternative perspective on the part the City of Manchester can play in planetary decarbonisation**. Distinct from previous carbon accounts, **GPC accounts for transboundary transport emissions and emissions arising from waste disposal beyond the inventory boundary** (under reporting level 'GPC BASIC+').

- The City of Manchester's carbon footprint under the GPC BASIC+ approach, accounting 100% of departing passenger flights from Manchester International Airport (MIA), is estimated at **6,352,840 metric tonnes CO2e for the year 2015**
    - A **35.5% responsibility for MIA emissions** – adopting the percentage of City of Manchester ownership - yields a footprint **4,395,880 metric tonnes CO2e.**
    - A **19% responsibility for MIA emissions** – the percentage of the Greater Manchester population in the City of Manchester ownership - yields a footprint **4,395,880 metric tonnes CO2e.**
    - **Excluding aviation emissions** yields a footprint of **3,319,332 metric tonnes CO2e**

- **Overall emissions arising from departing flights from Manchester International Airport are 1.25 greater than** scope 1 and scope 2 emissions combined (**emissions occurring directly from the City of Manchester and from the energy it consumes**).

- As a sector, **transport requires the greatest level of decarbonisation.**

- Aviation emissions comprise 48% of the GPC BASIC+ 100% aviation footprint. With MIA passengers predicted to more than double by 2050, **aviation emissions have the potential to offset any decarbonisation made by the City of Manchester across other emission sources, even these other emissions become 'carbon neutral' by 2050.**

    - As such, **if aviation is not included in zero-carbon targets, statements such as 'carbon neutral energy' are preferable to 'carbon neutral Manchester' which might blind the public to the necessary task of reducing aviation emissions**, the growth of aviation is likely to (at least in part) offset carbon neutral savings across other sectors.

- **Emissions from vehicles operating within the City of Manchester are 1.2 times greater than transboundary emissions occurring from vehicles registered in the city.** Influencing how people travel within the city is therefore just as important as managing how people travel beyond it.

- **Emissions from waste remain a vital area for intervention.** The GPC accounting requirements mean that waste that is sent to energy recovery is reported under stationary energy. Consequently, **the carbon footprint of waste is obscured in this inventory.**

- This inventory is **complementary** to the Greater Manchester Combined Authority (GMCA) **SCATTER 2050**[1] project (*Setting City and Area Targets and Trajectories for Emission Reduction to 2050),* which also uses GPC and will be launched at the Green Summit[2], in that it:
    - Provides a City of Manchester GPC footprint where the Greater Manchester data is not currently available.
    - Highlights areas where data is unavailable or is of low quality. Support for these areas would improve the relevance of GPC inventories to local practices.
    - Observes reporting 'silences' that could be accounted separately by the City of Manchester CO_2 Monitoring Group to offer a more rounded perspective of the City's footprint.
    - Accounts for full-flight aviation emissions for all passenger flights leaving Manchester International Airport, whereas the SCATTER 2050 project is only expected to count these emissions up to 1,000 feet.

- As City of Manchester emissions are likely to be disaggregatable from the GMCA SCATTER GPC footprint, **the City of Manchester CO_2 Monitoring Group could focus its efforts on plugging 'blind spots'** including:
    - Scope 3 emissions
    - Emissions from waste that are obscured in the GPC inventory
    - Complete flight aviation emissions inventory.

- **There are numerous categories across which data quality might be improved.** This will assist in our knowledge of local processes and our strategising of what interventions should be made. These are listed on page 14,

[1] https://blog.anthesisgroup.com/core-cities-webinar-setting-low-carbon-targets
[2] http://www.tyndall.ac.uk/news/mayor-manchester-launches-low-carbon-city-toolkit-tyndall-manchester

Introduction

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is a framework for reporting city-wide GHG emissions. GPC is a collaboration between the GHG Protocol at World Resources Institute (WRI), the C40 Cities Climate Leadership Group (C40) and ICLEI – Local Governments for Sustainability (ICLEI). It is consistent with the 2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories. The reporting standard exists: to support climate action planning; to assist in conducting emissions, to assist in setting targets and tracking progress; to ensure consistency between cities following internationally agreed principles; to enable inventories to be aggregated; and to demonstrate the role cities can play in tackling climate change.

The adoption of GPC signifies a significant step from the territorial-based accounting that underpinned the *IPCC (1996, 2006) Guidelines for National Greenhouse Gas Inventories* which considered those "emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (IPCC, 1996: 5). This inventory reports GPC BASIC+, the reporting requirements for which are listed in Table 1 and 2. GPC BASIC+ reporting expands on the territorial-based approach, notably considering emissions arising from waste created within the territory but treated outside its boundary and also considering transboundary transport. To this end, GPC presents a different "sense of the stakes" (Sunstein, 2005, p. 129), offering an alternative perspective on the part the City of Manchester can play in the path to planetary decarbonisation. The City of Manchester has a precedent for considering its footprint from alternate accountancy perspectives, having previously considered its embodied-emissions (Berners-Lee, Hatter, & Hoolohan, 2011), providing an array of alternative perspectives is useful in illuminating action on decarbonisation from a different angle that might not be visible or 'count' under the approach mandated by the IPCC.

The move toward also accounting for the City of Manchester's footprint with GPC presents an opportunity to expand both the conversation on how the city decarbonises and its formal commitments to decarbonisation. This report responds to the *Manchester Climate Change Strategy 2017-50* commitment to the adoption of GPC as an accountancy approach (Manchester Climate Change Agency, 2017). Moreover, the greater scope of GPC offers an opportunity to consider the more ambitious goal of Manchester becoming a "zero carbon city by 2050" (ibid: 7) from the expanded perspective that it offers. This inventory also comes at a time when Greater Manchester Combined Authority (GMCA) are piloting the *Setting City and Area Targets and Trajectories for Emission Reduction to 2050* (SCATTER 2050) project which will draw upon the GPC methodology and will be rolled-out amongst the Core Cities Group. It is intended that the City of Manchester will be able to be disaggregated from this dataset and this inventory serves as a stopgap until this is available. As such this inventory can be considered somewhat of a scoping project for what GPC might mean for the City of Manchester, also considering what data would improve the quality of (Greater/) Manchester GPC inventories and what areas and perspectives that remain 'uncounted' by the GMCA SCATTER approach that the CO_2 Monitoring Group could account for separately.

GPC BASIC	GPC BASIC+	GPC Other Scope 3
Scope 1 and scope 2 emissions from stationary energy and transportation, along with scope 1 and scope 3 emissions from waste	Everything considered within the BASIC reporting level, along with emissions from IPPU, AFOLU and transboundary transportation – where relevant.	Any other emissions occurring outside the geographic boundary as a result of city activities.

Table 1 GPC Reporting Levels

SCOPE 1	SCOPE 2	SCOPE 3
Direct GHG Emissions	Indirect GHG Emissions	Other Indirect GHG Emissions
Those emissions that occur directly within the City of Manchester boundaries	Those emissions produced in the generation of energy consumed within the City of Manchester	Those emissions associated with the production and transportation of other goods and services consumed within the City of Manchester. Also including the transmission and distribution losses of energy consumed within the City of Manchester.

Table 2 Definition of Accounting Scopes

Scope of Accounting

Emissions Source	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and Institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	NO	NO	NO
Energy generation supplied to the grid	x		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	NE	NE	NE
Fugitive emissions from mining, processing, storage, and transportation of coal	NO		NE
Fugitive emissions from oil and natural gas systems	NO		NE
TRANSPORTATION			
On-road	✓	RE	✓
Railways	✓	✓	✓
Waterborne navigation	NE	NE	NE / ✓[3]
Aviation	✓*[4]	✓*[2]	✓*[2]
Off-road	NO	NO	NO
WASTE			
Disposal of solid waste generate in the city	NO		✓
Disposal of solid waste generated outside the city	x		
Biological treatment of waste generated in the city	NO		✓
Biological treatment of waste generate outside the city	x		
Incineration and open burning of waste generated in the city	NO		✓
Incineration and open burning of waste generated outside the city	x		
Wastewater generated in the city	NO		✓
Wastewater generated outside the city	x		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial process	NO		NE
Product use	NE		NE
AGRICULTURE, FORESTRY AND PRODUCT USE (AFOLU)			
Livestock	NE		NE
Land	NE		NE
Other agriculture	NE		NE
OTHER SCOPE 3			
Other Scope 3			NE

Key									
NO Not Occurring	**NE** Not Estimated	**RE** Reported Elsewhere	✓ Accounted in this inventory	**x** Not counted in this inventory	GPC BASIC	GPC BASIC+ (When reported with GPC BASIC)	GPC Other Scope 3	N/A	Req. for territorial total but not for GPC

Table 3 GPC levels of accounting and emissions sources reported for this inventory

[3] Full datasets are not available to consider waterborne navigation from the city; however, emissions from goods leaving the Port of Manchester are included.
[4] This inventory departs from GPC guidance in that it measures full flight emissions from aircraft departing from Manchester International Airport.

Results and Analysis

The City of Manchester's carbon footprint under the GPC BASIC+ approach, accounting 100% of departing passenger flights from Manchester International Airport (MIA), is estimated at 6,352,840 metric tonnes CO_2e for the year 2015. The emissions from MIA comprise 48% of this footprint and serve as a stark reminder of the critical role of aviation emissions in decarbonisation. Compounding this further, the UK Aviation Forecast predicts that MIA passengers will more than double to 56 million per annum by 2050 (against 23 million per annum in 2015) (Department of Transportation, 2017). If aviation emissions remain proportionate to passenger growth, this has the potential to offset all other emission reductions achieved by the City, even if these other emissions sources become 'zero carbon'.

This is not to say that Manchester International Airport is solely the responsibility of the City of Manchester – but rather to indicate the relative importance of reducing aviation to other emissions that can be associated with the City. For instance, overall emissions arising from departing flights from Manchester International Airport are 1.25 greater than scope 1 and scope 2 emissions combined (emissions occurring directly from the City of Manchester and from the energy it consumes). There are many other perspectives on the City of Manchester's responsibility for aviation emissions, though not definitive, the follow examples are included to present a more rounded picture. A 35.5% responsibility for MIA emissions – adopting the percentage of City of Manchester ownership - yields an overall footprint 4,395,880 metric tonnes CO_2e. A 19% responsibility for MIA emissions – the percentage of the Greater Manchester population in the City of Manchester ownership - yields a footprint 4,395,880 metric tonnes CO_2e. Finally, excluding aviation emissions yields a footprint of 3,319,332 metric tonnes CO_2e. Figure 1 visually depicts these figures and provides a breakdown of the categories. Further reflections on MIA's footprint can be found in the separate *Manchester International Airport Estimate of Aviation Emissions, 2014-2015* report.

On-road transportation comprises a further 20% of the GPC BASIC+ 100% aviation footprint or 37% if aviation is excluded. This makes it the next most significant source of CO_2e emissions. It should be noted that there is an unresolved element of double counting between scope 1 and scope 3 emissions. Also notable is that emissions from vehicles operating within territorial boundaries of the City of Manchester are 1.2 times greater than transboundary emissions occurring from vehicles registered in the city. Influencing how people travel within the city is therefore just as important as managing how people travel beyond it.

Emissions from waste are largely obscured by how they are classified in GPC. A large proportion of waste in Manchester is incinerated; however this is used in energy recovery outside the inventory boundary in Bolton. These emissions are counted as energy generation scope 1 emissions within GPC and so the emissions associated with this are uncounted in this inventory. In the case of Manchester, GPC inventories, risks underselling the importance of reducing waste in reducing carbon emissions. The consequences of this are compounded by the demand-side consumption-based emissions (themselves uncounted given that 'other scope 3' is not estimated) that reducing waste could also facilitate.

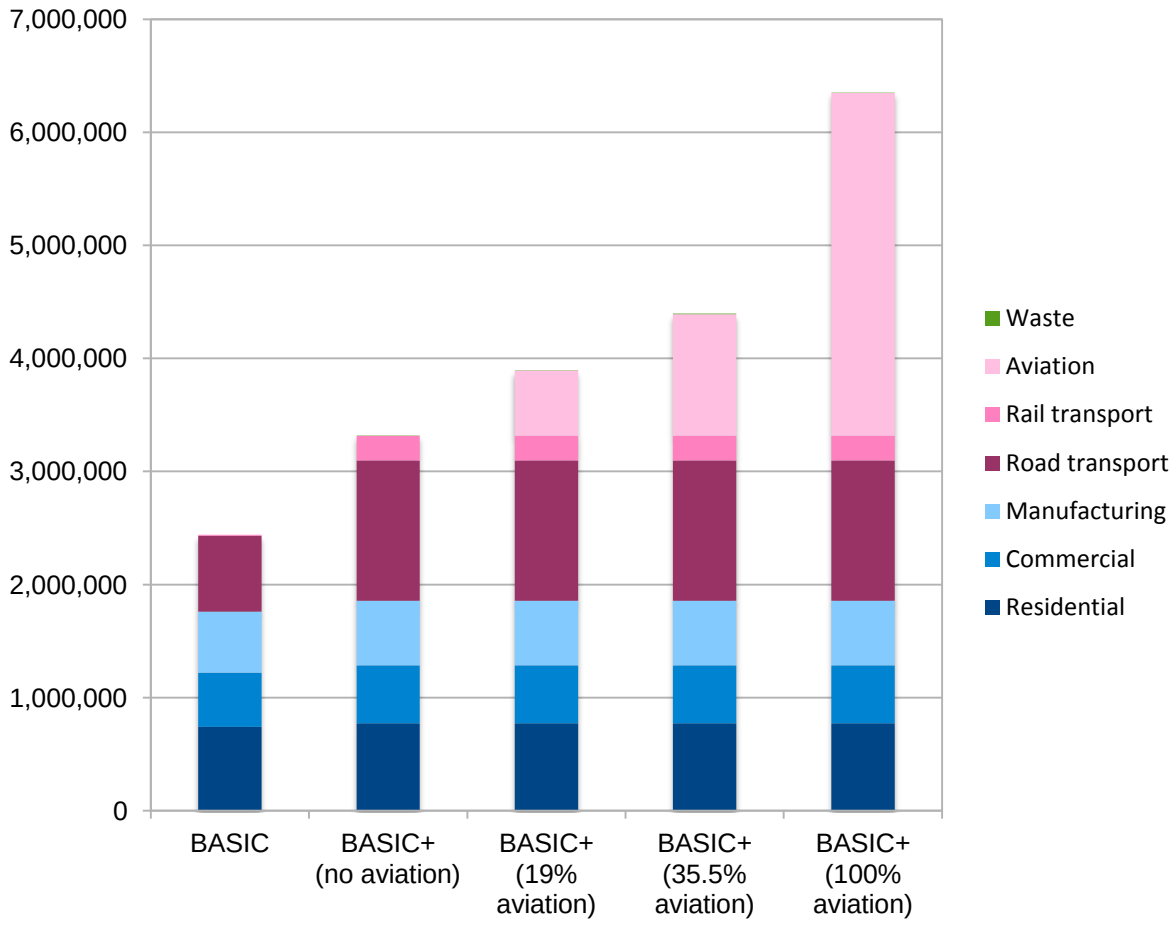

Figure 1 Emissions by GPC Reporting Levels, incorporating different levels of aviation responsibility

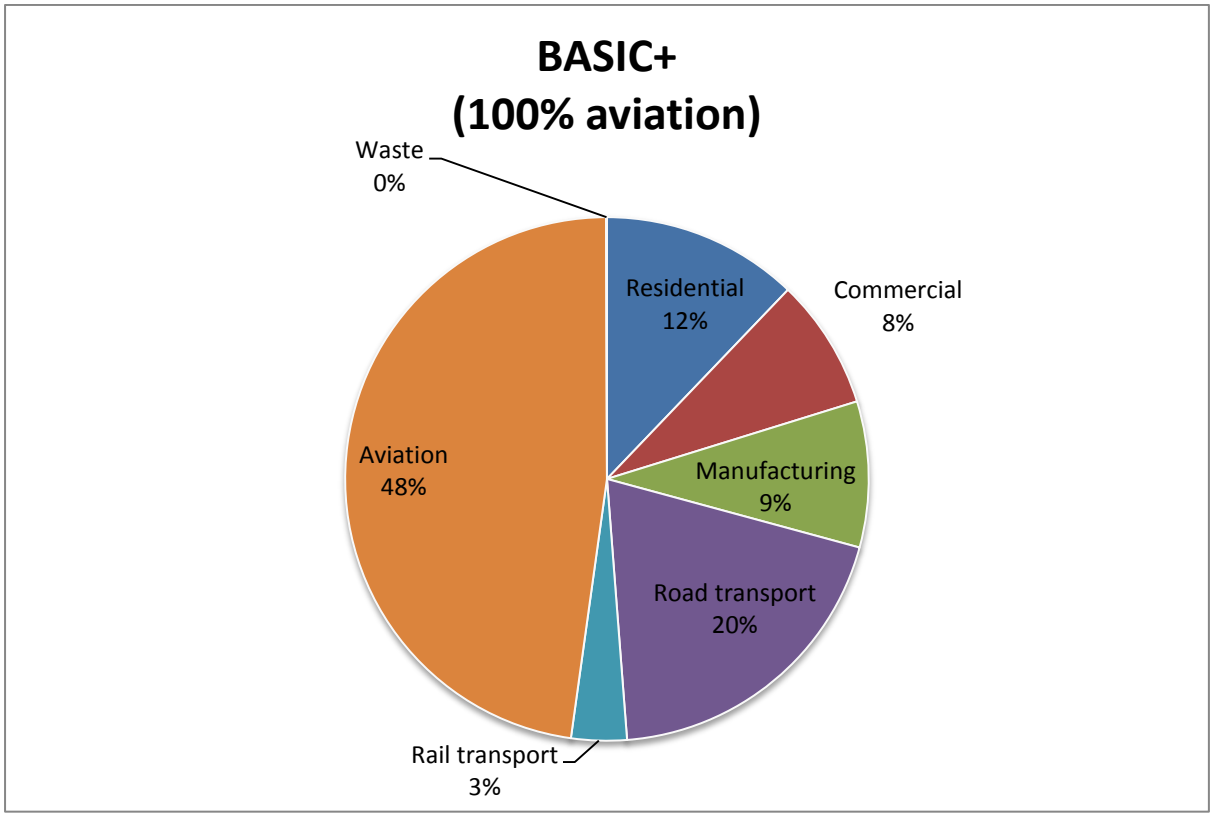

Figure 2 City of Manchester GPC BASIC+ (100% aviation) footprint

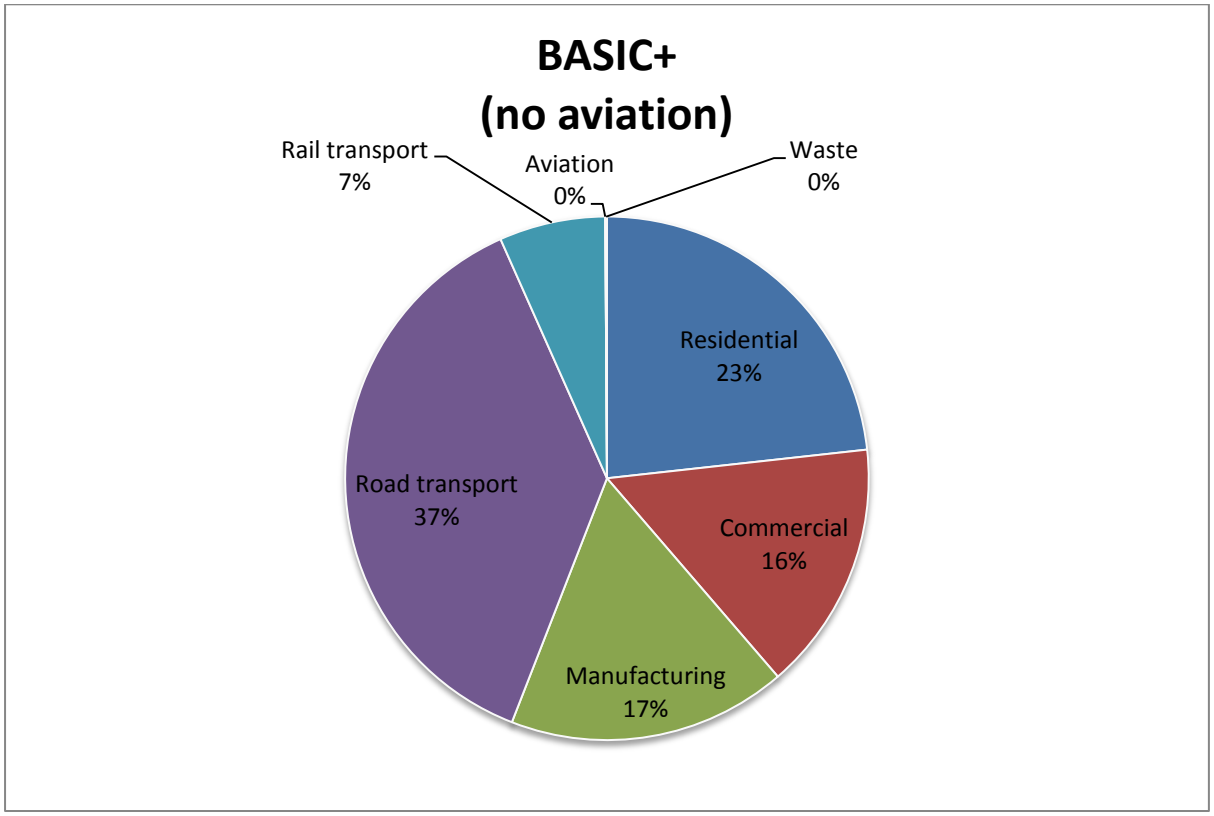

Figure 3 City of Manchester GPC BASIC+ (0% aviation) footprint

GHG Emissions Source (By Sector)		Total GHGs (metric tonnes CO2e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
STATIONARY ENERGY	Energy use (all emissions except I.4.4)	711,645	1,050,425	95,011	1,762,069	1,857,080	1,857,080
	Energy generation supplied to the grid (I.4.4)						
TRANSPORTATION	(all II emissions)	679,108	70	3,813,135	679,178	4,492,312	4,492,312
WASTE	Waste generated in the city (III.X.1 and III.X.2)	0		3,447	3,447	3,447	3,447
	Waste generated outside city (III.X.3)	0					
IPPU	(all IV emissions)	0				0	0
AFOLU	(all V emissions)	0				0	0
OTHER SCOPE 3	(all VI emissions)						0
TOTAL		**1,390,753**	1,390,753	1,050,494	3,911,593	2,444,694	6,352,840

GPC ref No.	GHG Emissions Source (By Sector and Sub-sector)	Total GHGs (metric tonnes CO2e)			
		Scope 1	Scope 2	Scope 3	Total
I	STATIONARY ENERGY				
I.1	Residential buildings	390,772	349,418	31,605	771,796
I.2	Commercial and institutional buildings and facilities	127,537	352,706	31,902	512,145
I.3	Manufacturing industries and construction	193,025	347,687	31,448	572,160
I.4.1/2/3	Energy industries	NO	NO	NO	0
I.4.4	Energy generation supplied to the grid	NO			
I.5	Agriculture, forestry and fishing activities	310	614	56	979
I.6	Non-specified sources	NO	NO	NO	0
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			0
I.8	Fugitive emissions from oil and natural gas systems	NO			0
SUB-TOTAL	(city induced framework only)	**711,645**	**1,050,425**	**95,011**	**1,857,080**
II	TRANSPORTATION				
II.1	On-road transportation	671,788	0	570,188	1,241,976
II.2	Railways	7,320	70	210,418	217,808
II.3	Waterborne navigation	NE	NE	0	0
II.4	Aviation	RE	NE	3,032,529	3,032,529

II.5	**Off-road transportation**	NO	NO	NO	0
SUB-TOTAL	(city induced framework only)	**679,108**	**70**	**3,813,135**	**4,492,312**
III	**WASTE**				
III.1.1/2	**Solid waste generated in the city**	NO		1,627	1,627
III.2.1/2	**Biological waste generated in the city**	NO		265	265
III.3.1/2	**Incinerated and burned waste generated in the city**	NO		0	0
III.4.1/2	**Wastewater generated in the city**	NO		1,555	1,555
III.1.3	**Solid waste generated outside the city**	NO			
III.2.3	**Biological waste generated outside the city**	NO			
III.3.3	**Incinerated and burned waste generated outside city**	NO			
III.4.3	**Wastewater generated outside the city**	NO			
SUB-TOTAL	(city induced framework only)	**0**		**3,447**	**3,447**
IV	**INDUSTRIAL PROCESSES and PRODUCT USES**				
IV.1	**Emissions from industrial processes occurring in the city boundary**	NO			0
IV.2	**Emissions from product use occurring within the city boundary**	NE			0
SUB-TOTAL	(city induced framework only)	**0**			**0**
V	**AGRICULTURE, FORESTRY and OTHER LAND USE**				
V.1	**Emissions from livestock**	NE			0
V.2	**Emissions from land**	NE			0
V.3	**Emissions from aggregate sources and non-CO2 emission sources on land**	NE			0
SUB-TOTAL	(city induced framework only)	**0**			**0**
VI	**OTHER SCOPE 3**				
VI.1	**Other Scope 3**			NE	0
TOTAL	(city induced framework only)	**1,390,753**	**1,050,494**	**3,911,593**	**6,352,840**

Table 4 GPC Summary Tables

Recommendations

For Policy and Advocacy

- This analysis suggests that airport growth is difficult to reconcile with 'zero-carbon' or 'carbon neutral' commitments. If aviation is not considered within the carbon neutral target, it is imperative that such statements are transparent and refer not to the city processes at large, but to specific subsectors or scopes. As such statements such as 'carbon neutral energy' are preferable to 'carbon neutral Manchester' which might blind the public to other high emitting practices such as aviation, the growth of which is likely to (at least in part) offset carbon neutral savings across other sectors.

- A consideration for transboundary transport extends the previous territorial scope significantly. Even with aviation emissions discounted, this constitutes a significant broadening of what emissions 'count' and signals the necessity of further action on transport practices in particular.

- Transport is the greatest sector to decarbonise, with aviation the greatest sub sector, followed by road transport.

- Emissions from vehicles operating within territorial boundaries of the City of Manchester are 1.2 times greater than transboundary emissions occurring from vehicles registered in the city. Influencing how people travel within the city is therefore just as important as managing how people travel beyond it.

Accounting 'Blind spots'

- As City of Manchester emissions are likely to be disaggregatable from the GMCA SCATTER GPC footprint, to this end, it may not be necessary to complete future inventories. Consequently, it is useful to account for blind spots that this inventory has highlighted:

    - Scope 3 waste emissions largely escape the GPC account due to their use in energy generation beyond the city boundary. It would be useful to have an understanding of these emissions as the GPC inventory currently obscures emissions occurring from waste.

    - Other Scope 3 is currently not reported. It might be useful to consider this as an 'add-on' to the Greater Manchester SCATTER inventory in future years.

    - Similarly, as the SCATTER inventory is only to report aviation emissions up to 3,000 feet, it would be useful to continue accounting the emissions for MIA.

For Improving Data Availability

Categories marked with an * should be considered of most importance.

- **Modelling aviation emissions is a time-consuming process. This data could instead be sourced from Manchester International Airport (MIA). Moreover, the approach utilised in this report departs from GPC guidance in that, for simplicity, it models flights from MIA alone. Further data surrounding flight details of City of Manchester residents would be invaluable in conforming fully to the standard.

- *DBEIS provide data on sub-national electricity and gas consumption statistics and sub-national residual fuel consumption statistic. For the categories 'Commercial and Institutional Buildings and Facilities', 'Manufacturing Industries and Construction' and 'Agricultural, Forestry and Fishing Activities' require disaggregation by some other proxy measure (e.g. GVA, DUKES data). Reporting – or otherwise sourcing - these datasets in a less-aggregated form would improve the quality of this inventory.

- Relatedly, there is a further 1-year delay in DBEIS sub-national residual fuel statistics than sub-national electricity and gas statistics. This requires upscaling or further delay when calculating both Stationary Energy and Transport categories.

- **Transboundary (Scope 3) on-road transportation emissions are estimated using national-scale statistics on the average journey length travelled by residents. This is a major source of carbon emissions, yet data is not specific to local practices. Data on local fuel sales and/or resident vehicle use would greatly improve the quality of this data and allow the tracking of any locally-specific change that would be obscured at the national scale.

- *Railway electricity usage is disaggregated from the sub-national electricity statistics dataset using DUKES date. This data could be sourced directly as disaggregating with DUKES (national trends) might obscure change within this category.

- Waterborne emissions are not estimated due to a lack of data across all scopes. As such further data is required on moorings, fuel usage and movement of boats through and from the City of Manchester.

- Energy industries are not currently considered in the City of Manchester inventory as of the lack of energy industries in the city. However, there is at least one instance of Combined Heating and Power (CHP) within the city boundary which currently is not reported[5] - further data on CHP will be vital as it is further adopted.

[5] https://www.theade.co.uk/case-studies/building-chp/christie-hospital

- Though relatively expected to be negligible, data on Off-Road Transportation including airport ground support equipment, chain saws and forklifts is currently excluded due to lack of data.

- Waste composition statistics at a Greater Manchester level would improve waste emission calculations.

- Disaggregated statistics on waste that is anaerobically digested and composed (both are aggregated in WasteDataFlow statistics).

- Wastewater calculations require the most data manipulation owing to lack of data. Information on the following would expedite the process and improve the quality of the output:

    - Organics in domestic wastewater
    - The organic component removed as sludge in Davyhulme Treatment Works.
    - The organic content of this sludge.
    - Amount of domestic wastewater discharged from the City of Manchester in a given year.
    - The organic content of domestic wastewater from the City of Manchester.
    - Amount of industrial wastewater discharged from the City of Manchester in a given year.
    - The degradable chemical material in industrial wastewater discharged from the City of Manchester.

- Land-usage change emissions (AFOLU) are currently uncounted but presumed negligible relative to the broader footprint. Data on land use types and land use change would be useful in estimating these emissions.

- There are opportunities to improve data on the use of aerosols, mobile air conditioning and commercial refrigeration in the IPPU category. These are currently not estimated owing to the lack of this data and presumed negligible.

Methodology

I Stationary Energy

I.1 Residential Buildings

SCOPE 1

Gas consumption from residential buildings was calculated from 2015 DBEIS sub-national electricity and gas consumption statistics[6] .

Coal, Petroleum and MSF statistics were sourced from the 2014 sub-national residual fuel consumption statistics[7] and were scaled to 2015 using sectoral DUKES statistics[8].

SCOPE 2

Electricity consumption from residential buildings was calculated from 2015 DBEIS sub-national electricity and gas consumption statistics.

SCOPE 3

Scope 3 electricity consumption emissions refer to transmission and distribution losses. This utilised the 2015 sub-national electricity and gas consumption statistics but applies the grid-wide emissions factor for T&D losses[9].

I.2 Commercial and Institutional Buildings and Facilities

SCOPE 1

Statistics for Petroleum, Coal, Gas and MSF consumption were sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and the 2014 sub-national residual fuel consumption statistics respectively.

2014 Petroleum data was scaled to 2015 using DUKES data **Including GVA could improve this

Coal data was disaggregated for these sectors and scaled from 2014 to 2015 using a combination of DUKES data and GVA data[10].

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[6] https://www.gov.uk/government/collections/sub-national-gas-consumption-data
[7] https://www.gov.uk/government/statistical-data-sets/estimates-of-non-gas-non-electricity-and-non-road-transport-fuels-at-regional-and-local-authority-level
[8] https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2016-
[9] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016
[10] https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgvaibylocalauthorityintheuk

Gas data was disaggregated for these sectors using DUKES data.

SCOPE 2

Electricity statistics were sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and disaggregated using DUKES data.

SCOPE 3

Electricity T&D losses utilised the 2015 DBEIS sub-national electricity and gas consumption statistics but applies the grid-wide emissions factor for T&D losses.

I.3 Manufacturing Industries and Construction

SCOPE 1

Statistics for Petroleum, Coal, Gas and MSF consumption were sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and the 2014 sub-national residual fuel consumption statistics

2014 Petroleum data was scaled to 2015 using DUKES data **Including GVA could improve this

Coal data was disaggregated for these sectors and scaled from 2014 to 2015 using a combination of DUKES data and GVA data .

Gas data was disaggregated for these sectors using DUKES data. s respectively.

SCOPE 2

Electricity statistics were sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and disaggregated using DUKES data.

SCOPE 3

Electricity T&D losses utilised the 2015 DBEIS sub-national electricity and gas consumption statistics but applies the grid-wide emissions factor for T&D losses.

I.4 Energy Industries

Not considered

I.5 Agricultural, Forestry and Fishing Activities

SCOPE 1

Statistics for gas and petroleum consumption were sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and the 2014 sub-national residual fuel consumption statistics

2014 Petroleum data was scaled to 2015 using DUKES data

Gas consumption data was disaggregated for these sectors using a combination of DUKES and GVA data.

SCOPE 2

Gas consumption data was sourced from the 2015 DBEIS sub-national electricity and gas consumption statistics and disaggregated for these sectors using a combination of DUKES and GVA data.

SCOPE 3

Electricity T&D losses utilised the 2015 DBEIS sub-national electricity and gas consumption statistics but applies the grid-wide emissions factor for T&D losses.

I.6 Non Specified Sources

Not Estimated

I.7 Fugitive Emissions From Mining, Processing, Storage and Transportation of Coal

Not Estimated

I.8 Fugitive Emissions From Oil and Natural Gas Systems

Not Estimated

II Transport

II.1 On-Road Transportation

SCOPE 1

For emissions within boundary, the BEIS Sub-national road transport consumption data[11] was drawn upon. This has been upscaled from 2014 using population growth.

SCOPE 2

Reported under stationary energy

SCOPE 3

The total distance driven by vehicles registered in Great Britain in 2015 was 316.7 billion miles[12]. This can be downscaled to Manchester using vehicle registration statistics. Moreover, the vehicle types must be disaggregated to approximate the miles driven in those that are diesel and those that are petrol.

The disaggregation utilised the aforementioned BEIS road transport consumption data to separate out an overall figure of miles driven by diesel (171.3 billion miles) and petrol (145.4 billion miles) vehicles respectively. These figures were then downscaled to Manchester utilising vehicle licensing statistics[13] to suggest that around.7 billion miles driven in City of Manchester-registered diesel and petrol vehicles respectively, a total of 1.4 billion miles in all – though on average diesel vehicles completed longer journeys.

Emissions were calculated using per mile emissions factors provided by Carbon Neutral Calculator[14]

II.2 Railways

SCOPE 1

Petroleum consumption

2014 sub national residual fuel statistics[15] for petroleum were utilised and scaled by national rail passenger increase[16].

[11] https://www.gov.uk/government/collections/road-transport-consumption-at-regional-and-local-level
[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/524261/annual-road-traffic-estimates-2015.pdf
[13] https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01#table-veh0101
[14] http://www.carbonneutralcalculator.com/Carbon%20Offset%20Factors.pdf

SCOPE 2

Electricity consumption

Total sub-national total final energy consumption statistics were utilised to ascertain data on Manchester's industrial-and commercial electricity consumption[17]. This was disaggregated for railway use by utilising the proportion of national industrial and commercial electricity consumption that is used in rail transport, this is sourced from DUKES data[18].

SCOPE 3

T&D Losses

T&D loses were calculated by applying the grid emissions factor to the scope 2 electricity activity data.

Transboundary journeys

64.4 billion km were travelled by rail passengers in 2015 in Great Britain[19]. This was disaggregated to those journeys travelled from Manchester by considering the number of people travelling through ticket turnstiles at Manchester stations [20](Piccadilly, Victoria, Oxford Road) as a proportion of those collectively passing through turnstiles in Great Britain[21]

II.3 Waterborne Navigation

SCOPE 1

Not Estimated - Data is not available to estimate emissions from canal boats moored or passing through the city.

SCOPE 2

Not Estimated - Data is not available to estimate electricity emissions from canal boats moored in the city.

SCOPE 3

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[15] https://www.gov.uk/government/statistical-data-sets/estimates-of-non-gas-non-electricity-and-non-road-transport-fuels-at-regional-and-local-authority-level
[16] https://www.gov.uk/government/statistics/rail-factsheets-2016
[17] https://www.gov.uk/government/collections/total-final-energy-consumption-at-sub-national-level
[18] https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2016-main-chapters-and-annexes
[19] http://orr.gov.uk/__data/assets/pdf_file/0015/22056/passenger-rail-usage-2015-16-q4.pdf
[20] https://dataportal.orr.gov.uk/displayreport/report/html/af0a338f-cb90-4b8a-b413-403d5c917857
[21] https://dataportal.orr.gov.uk/displayreport/report/html/02136399-b0c5-4d91-a85e-c01f8a48e07e

Not Estimated - Data is not available to estimate emissions from canal boats moored in the city, but making journeys elsewhere.

Manchester Port might ultimately be slightly beyond the City of Manchester, but given that it is considered within scope 3 - and as its name implies - it *serves* the City of Manchester. Data for tonnes of freight leaving the port was sourced from the Department for Transport statistics[22].

II.4 Aviation

Aviation accounted separately but included within inventory. See separate report[23] for full inventory.

Owing to the mode for accounting, all aviation emissions are reported as scope 3. Complexities preclude inclusion of an estimate of aviation journeys from City of Manchester residents from all airports. In lieu of this, the transboundary departing passenger flight footprint of the City of Manchester airport is included. As such, no separation between scope 1 and scope 3 emissions is made.

II.5 Off-Road Transportation

Not Estimated, presumed negligible.

[22] https://www.gov.uk/government/statistical-data-sets/port04-individual-port-traffic#table-port0431
[23] http://joeblakey.com/MaCF-MIAEmissions20142015.pdf

III Waste

III.1 Solid Waste Disposal

SCOPE 1

A visual inspection of the Environment Agency authorised landfill map confirmed that no sites lie in-boundary[24]

SCOPE 2

Not Applicable

SCOPE 3

Solid Waste Disposal Data was collected from WasteDataFlow[25], a web based system for municipal waste data reporting by UK local authorities to government.

CH4 emissions have been calculated using the 'Methane Commitment method'. This method estimates landfill emissions based on waste disposal for the inventory year, adopting a mass-balance approach.

Before emissions can be calculated, the waste composition must be taken in to account to calculate the degradable organic content of waste and its methane generation potential.

Calculating the degradable organic content of waste

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F)$$

Where, the fraction of solid waste is …

A = Food

B = Garden waste and plant debris

C = Paper

D = Wood

E = Textiles

F = Industrial waste

[24] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683&y=355134&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=waste#x=381164&y=389133&lg=1,10,&scale=6

[25] http://www.wastedataflow.org/

G = Plastics

The waste composition statistics have been adapted from Defra[26]

Calculating the Methane Generation Potential

$$L_0 = W \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12}$$

Where …

L_0 = Methane Generation Potential (tonnes of CH4)

W = Mass of waste deposited (tonnes)

DOC = Degradable organic carbon (tonnes of carbon / tonnes of waste)

DOC_F = Fraction of DOC that ultimately degrades

F =Fraction of methane in landfill gas

16/12 = Stoichiometric ration between methane and carbon

MCF = Methane Correction Factor

Following IPCC guidance[27], the default MCF value for a managed anaerobic site was selected, along with the default value of 0.5 for F and DOC_F.

Methane Commitment calculation of CH4 emissions from landfill

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

Where …

CH_4 emissions = Total CH4 emissions in tonnes

F_{rec} = Fraction of methane recovered at the landfill (flared or energy recovery)

M_{waste} = Mass of solid waste sent to landfill in inventory year (tonnes)

OX = Oxidation factor

L_0 = methane generation potential (tonnes of CH_4)

[26] http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=15133
[27] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

F_{rec} assumed to be 0 and OX assumed to be 0.1 according to IPCC guidelines

III.2 Biological Treatment of Waste

Once again, WasteDataFlow statistics were drawn upon. Within WasteDataFlow waste treatment by anaerobic digestion and composting has not been disaggregated (neither for the City of Manchester Waste Collection Authority or Greater Manchester Waste Disposal Authority). To this end, WRAP figures for the organics processing industry were utilised[28]

No anaerobic digesters are in operation within the City of Manchester, excluding the Heineken AD reactor that processes brewery effluent[29] and the MBT-AD plant on Reliance Street, Manchester [30]. Curbisde garden and food waste does not get added to the MBT-AD stream and, as the AD component of the MBT-AD stream is used for energy recovery, this is reported under stationary energy. Household food and garden waste is composted at one of four In-Vessel Composting (IVC) facilities in Greater Manchester, located in Stockport, Rochdale, Bolton and Trafford[31]. As such, all biological treatment is reported under scope 3.

SCOPE 1

Not Occurring

SCOPE 2

Not Applicable

SCOPE 3

As reported above, all household food and garden waste is composted.

Ch_4 emissions from composting were calculating with the below formula.

$$CH_4 emissions = M \times EF \times 10^{-3} - R$$

N_2O emissions from composting were calculated with the below formula

$$N_2O\ emissions = M \times EF \times 10^{-3}$$

Where …

M = mass of organic waste composted (tonnes)

EF – emissions factor composting

[28] http://www.wrap.org.uk/sites/files/wrap/ASORI%202012.pdf
[29] http://www.wrap.org.uk/content/operational-ad-sites-map
[30] https://www.gmwda.gov.uk/energy-and-waste-management/mechanical-biological-treatment-facilities/
[31] https://www.gmwda.gov.uk/energy-and-waste-management/vessel-composting-facilities/

R = total amount of CH4 recovered (tonnes)

For CH_4, EF has been assumed to be 10 on the basis of IPCC guidance[32], R assumed to be 0. For N_2O, EF has been assumed to be 0.6 on IPCC guidance.

III.3 Incineration and Open Burning

All residual waste is processed between five MBT plants by GMWDA[33], whilst four of these have AD facilities, the fifth, in Bolton serves as a Thermal Recovery Facility (TRF)[34]. GWDA WasteDataFlow statistics confirm that 35.13% of household collected waste is sent for energy recovery. However, as per GPC guidance, and given that all incinerated waste in Greater Manchester is used in electricity generation, this is not included under waste.

III.4 Wastewater Treatment and Discharge

Wastewater is treated at Davyhulme Sewage Waste Treatment plan, Trafford and so falls under scope 2 emissions

SCOPE 1

Not Occuring

SCOPE 2

Not Applicable

SCOPE 2

Wastewater CH_4 emissions were calculated using the following equations

$$CH_4 emissions = \sum_i [(TOW_i - S_i)EF_i - R_i]$$

Where,

CH_4 emissions = Total CH4 emissions in tonnes

TOW_i = Organic content in wastewater

For domestic wastewater: total organics in wastewater in inventory year

For industrial wastewater: total organically

[32] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

[33] https://manchester.gov.uk%2Fdownload%2Fmeetings%2Fid%2F19754%2F2_greater_manchester_waste_disposal_authority_presentation&usg=AOvVaw3YLW-fHVYWDlqN_rZcAZvS

[34] http://www.recycleforgreatermanchester.com/wp-content/uploads/2017/03/TRF-Fact-Sheet.pdf

degradable material in wastewater from industry in inventory year

EF_i = Emissions factor

S_i = Organic component removed as sludge in inventory year

R_i = Amount of CH_4 recovered in inventory year

I = Type of wastewater

For domestic wastewater: income group for each wastewater treatment and handling system

For industrial wastewater: total organically degradable material in wastewater from industry in inventory year

$$TOW_i = P \times BOD \times I \times 365$$

$$EF_i = B_o \times MCF_j$$

Where,

TOW_i = For domestic wastewater: total organics in wastewater in inventory year.

I = Correction factor for additional industrial BOD discharged into sewers

P = City's population in inventory year

EF_i = Emission factor for each treatment and handling system

BOD = City-specific per capita BOD in inventory year (g/per person/per year)

B_o= Maximum CH_4 producing capacity (kg Ch4/kg BOD)

MCF_j = Methane correction factor

Calculation of total organics in domestic wastewater (TOW)

BOD was assumed to be 60g[35] and the City of Manchester population in 2015 was 540,000[36], as such the total organics in domestic wastewater was calculated to be 4.7 million tonnes.

Calculation of domestic emissions factor (EF)

[35] http://www.fwr.org/WQreg/Appendices/uwwtreport2.pdf

[36] http://www.manchester.gov.uk/downloads/download/6773/state_of_the_city_report_2017_whole_document

For the domestic emissions factor, the default maximum CH4 producing capacity of 0.6 was adopted from GPC guidance[37], the Methane Correction Factor was selected from IPCC guidance as 0.3 for centralised, aerobic treatment for a not well managed and overloaded site. This was selected the basis of Davyhulme Wastewater Treatment Works is an activated sludge aerobic treatment plant[3839], but is overloaded[40] and currently in the process of modernisation[41]. As such, the emissions factor was calculated as 0.18.

Calculation of domestic CH_4 emissions

In calculating domestic emissions, the organic component removed as sludge is scaled from Davyhulme procession approximately 100,000 tonnes of sludge per year in their digestion plant[42], but producing around 200,000 tonnes per year[43].

Davyhulme produces 5,569 litres of treated water per second[44], or 175.7 billion litres of water a year. This is equivalent to 175.7 million tonnes of water. One can estimate therefore, by combining this figure with the sludge, that Davyhulme treats 175.9 million tonnes of water per year. The average amount of wastewater per person per day is on average is 150 litres[45], or 54,750 litres per year. For the City of Manchester (of 540,000 people), this equivalent to 29.6 billion litres of water per year or 29.6 million tonnes.

As such, an approximation of sludge produced from the City of Manchester can be scaled using these figures, producing a figure of 33,655 tonnes, of which 16,828 is unprocessed. The organic content of this sludge has been assumed to be 40% on the basis of discussions with an academic expert working on Davyhulme. A figure of 6,731 tonnes of organic matter removed as sludge can therefore be derived.

Ch4 recovered from residual wastewater is assumed to be 0.

Calculation of industrial CH_4 emissions from wastewater

A similar methodology was utilised for industrial wastewater.

In 2009, a survey of Commercial and Industrial waste was conducting in Greater Manchester, revealing that 4,431 tonnes of chemical waste were disposed of in waste water[46]. 1,659 tonnes

[37] http://c40-production-images.s3.amazonaws.com/other_uploads/images/143_GHGP_GPC_1.0.original.pdf?1426866613
[38] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[39] http://www.waterprojectsonline.com/case_studies/2013/UU_Davyhulme_2013.pdf
[40] http://wwtonline.co.uk/features/davyhulme-makes-advances-with-thermal-hydrolysis-#.WjK-uPnDJNo
[41] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[42] http://www.renewableenergyworld.com/news/2014/09/sludge-treatment-at-u-k-facility-turns-waste-into-black-gold.html
[43] http://wwtonline.co.uk/features/davyhulme-makes-advances-with-thermal-hydrolysis-#.WjK-uPnDJNo
[44] https://www.unitedutilities.com/help-and-support/about-us/greater-manchester/davyhulme-treatment/
[45] http://www.waterwise.org.uk/pages/faqs.html
[46] https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiw

through machinery and equipment manufacturing and 2,772 tonnes from other services. The GVA of Greater Manchester in 2009 (£50,714 million) and the GVA of the City of Manchester in 2015 (£17,030 million) can be utilised to scale these figures to the City of Manchester in 2015. A more accurate approach would scale by sectoral GVA.

As such, one can estimate 557 tonnes of chemical waste in Manufacturing being disposed of in the City of Manchester through wastewater, and 930.9 tonnes of other waste being disposed of through wastewater – a total of 1,488 tonnes. It is this figure that is taken as the degradable chemical material in industrial wastewater.

Due to the lack of data availability for industry wastewater, the proportion of sludge produced of the overall organic content of domestic waste was utilised to estimate that 677.5 tonnes of industrial sludge were removed.

B_o was taken as 0.25 kg CH_4/kg COD as per GPC guidance.

Indirect N_2O emissions from wastewater effluent

$$N_2O\ emissions = [(P \times Protein \times F_{NPR} \times F_{IND-COM}) - N_{SLUDGE}] \times EF_{EFFLUENT} \times \frac{44}{28} \times 10^{-3}$$

Where,

N_2O emissions = Total N_2O emissions in tonnes

P = Population served

Protein = Annual per capita protein consumption kg / person / yr

$F_{NON-CON}$ = Factor to adjust for non-consumed protein

F_{NPR} = Fraction of nitrogen in protein

$F_{IND-COM}$ = Factor for industrial and commercial co-discharged into the sewer system

N_{SLUDGE} = Nitrogen removed with sludge Kg N/yr

$EF_{EFFLUENT}$ = Emissions factor for N2O emissions from discharged to wastewater in kg N_2O-N per kg N_20

44/28 = The conversion of kg N2O-N into kg N_2O

$F_{NON-CON}$ was taken to be 1.4, F_{NPR} was taken to be 0.16, $F_{IND-COM}$ was taken to be 1.25, N_{SLUDGE} taken to be 0 and $EF_{EFFLUENT}$ was taken to be 0.005 as per GPC guidance.

The population of the City of Manchester in 2015 was taken to be 540,000. Protein consumption in the UK is 0.104 kg per person per day[47], this equates to 37.986 kg per person per annum.

[47] http://chartsbin.com/view/1155

IV Industrial Processes and Product Use (IPPU)

IV.1 Industrial Processes

SCOPE 1

No major mineral production industries or chemical production industries have been identified within the city boundary. Any small-scale use is expected to be negligible in relation to the overall footprint. As such IPPU Industrial Processes emissions are listed as Not Occurring. There may be opportunities to improve the data on these processes.

SCOPE 2

Not Applicable

SCOPE 3

Not Estimated

IV.2 Product Use

SCOPE 1

No major fuel and solvent use, electronics production industries or industries that use fluorinated substitutes have been identified within the city boundary. Any small-scale use is expected to be negligible in relation to the overall footprint. There may be opportunities to improve the data on these processes using a bottom up use to consider product use of aerosols, commercial refrigeration and mobile air conditioning emissions according to a consumption-based perspective. It is for this reason that IPPU Product Use is listed as Not Estimated.

SCOPE 2

Not Applicable

SCOPE 3

Not Estimated

V. Agriculture, Forestry and Other Land Use (AFOLU)

V.1 Livestock

SCOPE 1

There are no significant agricultural activities within the City of Manchester and any livestock emissions are considered negligible. It is for this reason that this category is listed as Not Occurring.

SCOPE 2

Not Applicable.

SCOPE 3

Not Occurring.

V.2 Land

SCOPE 1

Not Estimated owing to difficulties in obtaining datasets - expected to be negligible with respect to the broader inventory. This is an area for future improvement.

SCOPE 2

Not Applicable

SCOPE 3

Not Estimated.

V.3 Aggregate Sources

SCOPE 1

Not occurring. There are no large-scale sources of rice cultivation, liming, urea application or fertiliser use. Small-scale application poses a negligible though notable area for future improvement.

SCOPE 2

Not Applicable

SCOPE 3

Not Estimated.

VI. Other Scope 3

Not Estimated

List of References

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