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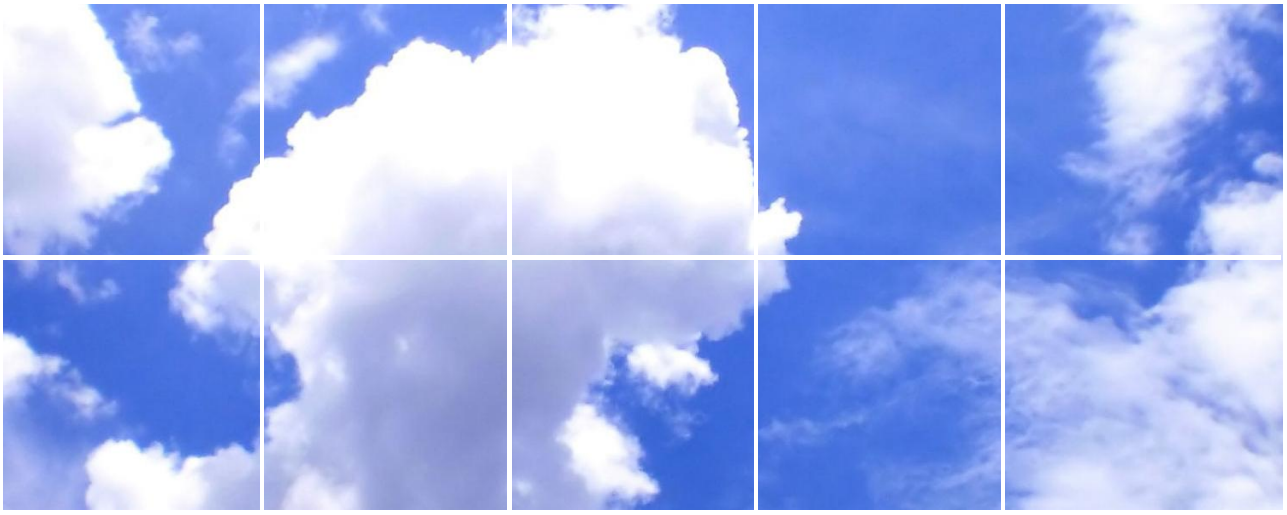

End User GHG Inventories for England, Scotland, Wales and Northern Ireland:1990, 2003 to 2007

Report to the Department for Energy and Climate Change, The Scottish Government, The Welsh Assembly Government and The Northern Ireland Department of Environment.

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Executive Summary

The climate change policy agenda has been changing rapidly at Devolved Administration Government level within the UK in the last year, with significant new challenges to data management and reporting now developing through new legislation, strategy documents and policy instruments. The Climate Change (Scotland) Act (2009), the One Wales Commitment and associated Welsh Strategy (2008), and the Northern Ireland Executive's Programme for Government (2008-11), outline each of the Devolved Administrations' aims, objectives and duties in reducing GHG emissions.

Each of the devolved Governments tailor their climate change policy legislation and policies to target their specific local and regional priorities. The development of end user GHG inventories enables better interrogation of the impacts of energy efficiency policies, as these impact upon both primary and secondary fuel use within the UK and DAs. The development of end user inventories provides a different picture of consumption patterns within the UK, compared to the production-based data presented in the recent by source inventory report, "*Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland 1990-2007*" (AEA, 2009).

This report presents estimates of end user greenhouse gas emission inventories for the constituent countries of the UK. Separate end user greenhouse gas emission inventories have been estimated for England, Scotland, Wales and Northern Ireland for the years 1990 and 2003 to 2007. The greenhouse gases reported are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

The estimates are consistent with the data presented within the 2007 UK Greenhouse Gas Inventory (Jackson et al., 2009), and the report "*Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland 1990-2007*" (AEA, 2009).

The purpose of the end user calculations is to allocate emissions from fuel and electricity producers to the energy users; this allows the emission estimates for a consumer of energy to include the emissions from the production of the refined fuel or electricity they use.

Emissions from offshore sources are not allocated to any country in the disaggregated inventories, and are reported separately within an "Unallocated" inventory category. These offshore emissions are primarily those from oil and gas exploration and production activities, i.e. energy supply activities. The end user calculation allocates these emissions to end use sectors in each of the DAs according to fuel use patterns.

Data Sources and Inventory Methodology

The DA end user GHG inventories are derived from the DA by source GHG inventories as a starting point. These are compiled, where possible, using the same methodology has been used to calculate emission estimates as for the UK Inventory. However, for many emission sources the data available for constituent country emissions are less detailed than for the UK as a whole, and for some sources country-level data are not available at all.

In particular, complete sets of fuel consumption data are not available for England, Wales, Scotland or Northern Ireland. In order to make emission estimates for fuel consumption, therefore, the available data has been supplemented with surrogate statistics.

Regional energy statistics are published annually by the Department for Energy and Climate Change (DECC) within the quarterly *Energy Trends*[1] publication. These regional statistics are limited in their detail when compared to UK-level energy statistics, but do provide estimated fuel use data for England, Scotland, Wales and Northern Ireland for the following source sectors:

- Industry and Commercial
- Agriculture
- Residential

The DECC regional energy statistics have been developed in recent years to provide estimates of fuel use and CO_2 emissions data at Local Authority (LA) level across the UK. The latest available data include LA solid and liquid fuel use estimates for 2003 to 2006, with gas and electricity data also being available up to 2007.

The additional data requirements for the DA end user inventories include:

- Electricity use by sector by DA
- Transfers of electricity between the DAs
- Transfers of other fuels between the DAs

Activity data on the DA-specific electricity generation, consumption and imports-exports balance (within the UK and to/from Europe) are available from the DECC publication "Energy Trends." This is not available for all years, and the sector breakdown is limited and therefore other data or surrogate statistics have been used to fill any gaps. It has not been possible to find data about the transfers of other fuels. These data gaps lead to additional uncertainty within the estimates.

Note that the end user methodology for the electricity sector is based on the available data on the DA-specific, year-specific generation fuel mix of the electricity supply. Therefore, where a DA may have a lower than UK-average carbon intensity of electricity generation (e.g. due to a high proportion of renewable or nuclear generation) then the emissions distributed for the users of that electricity (either directly within the DA, or via the exports to other DAs) will be associated with lower CO_2 emissions than if a UK-average electricity generation factor was applied. Conversely, where the DA electricity generation fuel mix has a higher than UK-average carbon intensity, then the emissions from end users will be higher than if a UK-average factor was applied.

DA End User GHG Inventories: Summary of Results

The end user analysis presents a different distribution pattern of emissions between the DAs when compared against the by source inventory approach. The allocation of emissions to England and Northern Ireland is higher in the end user inventories, whereas the allocation to Wales and Scotland is lower. There are no emissions that remain unallocated, since all of the offshore emissions are from energy supply sources (i.e. from the oil and gas exploration and production sector) and these emissions are all allocated on to the end user sectors within the DAs.

The study shows that the UK distribution of regional net GHG emissions by end user in 2007, expressed in terms of total CO_2 equivalent emissions of the "basket of 6" GHGs, is:

(The share of the "by source" GHG inventories in 2007 is indicated in brackets.)

• England	81.5%	(77.8%)
• Scotland	7.9%	(8.6%)
• Wales	6.8%	(7.4%)
• Northern Ireland	3.8%	(3.4%)
• Unallocated	0.0%	(2.8%)

[1] The latest available data are taken from the December 2008 Energy Trends, http://www.berr.gov.uk/files/file49202.pdf

For the reasons highlighted above, and explored further within the report, the uncertainties associated with these emissions are high, and the results should therefore be treated as indicative. It must be noted that this is the first time that DA end user GHG inventories have been compiled using the methodology presented in this report. The challenges to DA end user inventory data accuracy outlined above indicate that further research is needed to augment the current approach and data, to reduce uncertainties in future work.

The key study recommendations for future research include:

- Research to improve DA-specific energy production and consumption data across all fuels, aimed at the delivery of complete and detailed energy balance information for England, Scotland, Wales and Northern Ireland.

- Development of information on fuel transfers between DAs, especially for the non-electricity fuels. To reduce the uncertainties in the DA end user model outputs, more information is needed on the production of refined fuels (petroleum fuels from refineries, solid fuel from collieries, gas production) and the transfers around the UK to point of consumption.

- Research and development of energy data reporting systems to deliver more detailed (i.e. DA-specific and sector-specific) electricity consumption data. Ongoing research by DECC may deliver such improvements for recent years. Further work to identify more suitable data to improve the “regional drivers” for electricity use in 1990 is also needed, to improve the sector estimates from the base year.

- Through consultation with the oil and gas industry and regulators, it may be possible to derive more detailed emission allocations to the (i) oil and (ii) gas industries from the emissions reported by the upstream extraction and production sector. Currently there is limited detailed information on these emissions sources and how to best allocate the energy sector emissions equitably amongst end users of refined oils and gaseous fuels.

Glossary

ABI	Annual Business Inquiry
ATOC	Association of Train Operating Companies
BERR	(UK) Department for Business, Enterprise & Regulatory Reform
CHP	Combined heat and power
DA	Devolved Administration
DECC	(UK) Department of Energy & Climate Change
DEFRA	(UK) Department of Environment, Food and Rural Affairs
DUKES	Digest of UK Energy Statistics
EU ETS	European Union Emissions Trading Scheme
EUMM	European Union Monitoring Mechanism
FGD	Flue gas desulphurisation
GHG	Greenhouse gases
GHGI	Greenhouse gas inventory
GVA	Gross Value Added (economic activity indicator)
GWh	Giga Watt Hour (unit of energy)
GWP	Global Warming Potential (radiative forcing rating of a GHG, relative to CO_2 = 1)
IAG	Inter-Departmental Analysts Group
IPPC	Integrated Pollution Prevention and Control
IPCC	Intergovernmental Panel on Climate Change
ISR	Inventory of Statutory Releases (the DoE's inventory of annual emissions from IPPC regulated industry in NI)
ktC	Kilo tonne of carbon
$ktCO_2$	Kilo tonne of carbon dioxide
ktC-e	Kilo tonne of carbon-equivalent (amount of a GHG having accounted for GWP)
$ktCO_2$-e	Kilo tonne of carbon dioxide-equivalent (having accounted for the GWP)
LA-IPPC	Local Authority Integrated Pollution Prevention and Control
LPG	Liquefied petroleum gas
MPP	Major Power Producers (i.e. power station operators)
NAEI	National Air Emissions Inventory
NI	Northern Ireland
ONS	Office for National Statistics
SG	Scottish Government
UNFCCC	United Nations Framework Convention on Climate Change
WAG	Welsh Assembly Government

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A copy of this report and related data may be found on the website maintained by AEA for DECC:

http://www.naei.org.uk

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Document Revision History	
Version	Comment
Draft for comment	Initial draft sent to DECC and DAs for feedback.
Issue 1	First Issue of report, including amendments from stakeholder feedback.

1 Introduction

1.1 Background: DA End User GHG Inventories

In 1999, the Department of Environment, Transport and the Regions, together with the Department of Environment for Northern Ireland, the Scottish Executive and the National Assembly for Wales funded a joint research project carried out by AEA Energy & Environment to provide the first estimates of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 inventories for the four Constituent Countries of the UK for 1990 and 1995. Over recent years this information has been annually updated and the GHG Inventories for the Devolved Administrations (DAs) now presents annual emission estimates for 1990, 1995 and 1998 to 2007. This enables comparison of current emissions against the Base Years of the Kyoto Protocol (1990 for CO_2, CH_4, N_2O; 1995 for the fluorinated gases) to review progress within the UK towards emission reduction targets under the Kyoto Protocol.

Following devolution, the responsibility for the implementation of policies and measures to address climate change and enable the UK to meet its GHG emission reduction targets (under the UNFCCC and the Kyoto Protocol) were shared out between UK central Government and the Governments of the Devolved Administrations. Responsibility for certain policies and measures is retained by UK central Government ("Reserved Policies & Measures") whilst for others responsibility has been passed to the DAs ("Devolved Policies & Measures"). Therefore, to support DA-level policy development and to monitor the effectiveness of existing policies and measures, information on emissions, derived for England, Northern Ireland, Scotland and Wales is required.

The existing DA GHG inventories already meet these requirements to some extent, providing detailed DA-specific data on emissions from sources such as agriculture, road, rail and air transport, waste management activities and major industrial point sources (i.e. energy intensive and IPPC-regulated industries). However, these inventories are "production-based" inventories, rather than "consumption-based" (i.e. where region A produces electricity or refined fuels that are subsequently "exported" and consumed in region B, the emissions from the energy transformation or refining sources are assigned to region A). In this report, for simplicity, the term "by source" is used to describe production based processes and inventories, such as the DA GHG inventories, to facilitate the differentiation between production based and end user inventories.

To provide additional insight, therefore, into "consumption-based" data, and hence give arguably a more representative picture of the effectiveness of some policies (e.g. on energy efficiency in residential and commercial sectors), the development of end user DA GHG inventories has been commissioned. This report summarises the outputs from the first programme of development of the end user DA GHG inventories. A calculation model based on a Gaussian Elimination approach has been constructed, capable of delivering end user estimates from a range of source data. Significant progress has been made to develop an integrated model that re-distributes emissions from by source energy sectors to end users across the DAs, which is capable of reflecting DA-specific fuel transformation processes (i.e. electricity generation, oil refining, coal and gas production and delivery). However, further research is required to identify or develop new data on non-electricity fuel transfers between DAs, to utilise the full detail of the model and deliver more accurate, representative end user inventories.

The purpose of the end user calculations is to re-allocate emissions from energy production and transformation processes to the energy end user sectors; this approach ensures that the emission estimates at the point (sector) of energy demand fully reflect the direct emissions from the fuel use as well as the indirect emissions from the upstream fuel processing sources such as fuel extraction, refining, transformation, storage and delivery. Therefore, the end user emission estimates enable a more comprehensive analysis of the true trends in energy consumption, as driven by the end user sectors, and are hence more useful in the evaluation of energy efficiency policies and measures.

The DA end users model enables the DA-specific fuel mix, plant design, efficiency and utilisation to be reflected in the inventory data, as well as providing a more accurate picture of final energy consumption; for example, where fuels are extracted, processed and transformed in one DA for subsequent export and consumption in another DA, the end user approach passes on the emissions to the point of consumption, to better reflect energy demand patterns within the UK.

1.2 Definition of an End User Inventory

The end user GHG inventories differ from the by source emission inventories, as within the end user calculations emissions from fuel producers are re-allocated to fuel users. The end user calculation therefore allows estimates to be made of emissions for a consumer of fuel, which also include the emissions from producing the fuel the consumer has used. The scope of emissions included in the end user estimates are illustrated below using the residential and road transport sectors as examples:

End user emission estimates for the **residential** sector include:

1. Direct emissions from domestic premises, for example, from burning gas, coal or oil for heating and cooking.

2. Emissions from power stations generating the electricity used by domestic consumers; emissions from the production of oil-based fuels including refining, storage, flaring and crude oil extraction; emissions from coal mining sources including colliery fuel use, fugitive methane emissions from open and closed mines and emissions from coal storage and transport; and emissions from the extraction, storage and distribution of mains gas.

End user emission estimates for the **road transport** sector include:

1. Direct fuel combustion emissions from vehicle exhausts.

2. An estimate of emissions from the production of petroleum fuels, including emissions from exploration and production of crude oil, refinery combustion and process sources, oil storage and loading / unloading emissions, oil industry flaring, and emissions from the distribution and supply of motor fuels.

1.3 Key Source Sectors Re-Distributed To Generate the End User GHG Inventories

Many source sectors of GHG emissions that are reported within the production-based DA GHG inventories already calculated on an annual basis for the DAs are entirely consistent with the concept of an end users approach. For example, estimates of major emission sources such as agriculture, waste activities and land use, land use change and forestry, are all consistent with the end user approach. The direct emissions from fuel use in domestic, commercial, many industrial and transport sectors also form a component of the end user emissions by sector.

However, where fuels are transformed or refined on one site and then utilised across the UK, the emissions associated with the transformation / refining need to be re-distributed to build up the end user GHG inventories. Hence to construct end user GHG inventories for the DAs, a method must be developed that enables the re-distribution of GHG emissions from primary production sites including:

- Power stations;
- Oil wells and refineries;
- Coal Mines;
- Gas extraction and treatment sites.

The emissions from these sources must be re-distributed to where the final use of the electricity or refined fuel occurs, within sectors such as domestic, commercial, industrial and road, rail and air transport.

2 Methodology

2.1 Overview of the End User Calculation Method

The aim of the end user Emission Calculator is to reallocate GHG emissions from the **Energy Sector** to **End Users**, where:

"**Energy Sector**" includes all emission sources associated with the extraction, processing and delivery of fuels, including the processing of primary fuels such as coal and gas, as well as the refining and fuel transformation processes associated with the production of refined petroleum fuels and electricity. e.g. emissions from refineries, power stations, collieries, offshore oil and gas extraction, gas processing and gas leakage from pipelines.

"**End Users**" are those sectors that drive the energy sector demand where final conversion / consumption of the energy takes place, e.g. for heating, lighting, cooking in buildings, to propel vehicles, to fuel industrial manufacturing processes and so on.

There are many feedback processes between energy sector sources, and hence the estimation of end user emissions necessitates two stages of calculations:

Stage 1: Energy Loops

Firstly, there are energy conversions and feedback loops within the energy sector itself. The first step in the end users calculations aims to determine the final emissions total for each sub-set of the energy sector, to then be disaggregated on to the end users of that processed fuel.

For example, total GHG emissions from coal-fired electricity generation should include an estimate of emissions from the coal extraction, storage and transport associated with the power station feedstock, as well as the coal combustion emissions in the boilers. Meanwhile, some of the electricity generated at power stations will be used within collieries, and so there is a two-way exchange of emissions between collieries and power stations. Similar relationships exist across the energy sector.

Stage 2: Energy Exit

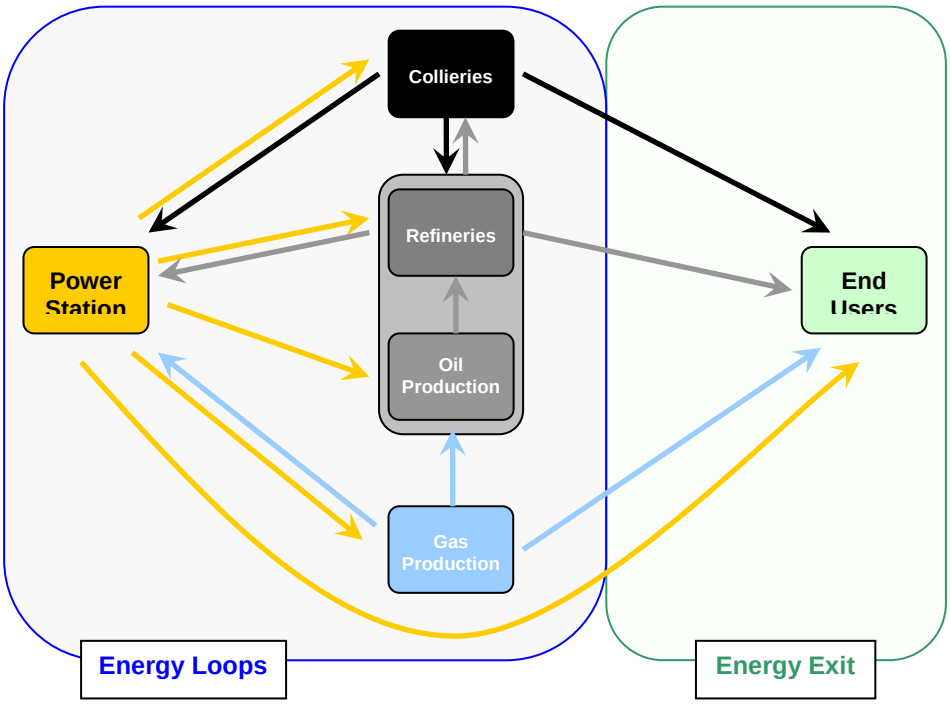
The second step of the end users calculations is to disaggregate the energy sector emissions across the energy end users, according to consumption by sector and by fuel.

These loops and energy flows are outlined in the diagram below.

Whilst the end user calculations are simple to present as a conceptual model, it is not always possible to quantify the reallocation of the emissions directly from all the energy sector producers to their respective end users. To complete the calculations accurately requires detailed energy use and emissions data across all sources and consumers.

At the UK level, there exists a well-documented and detailed energy balance that provides many of the required data inputs to achieve an accurate end user estimate. However, the existing UK system of reporting emissions from the upstream oil and gas exploration and production sector is not sufficiently detailed to enable distinction between upstream processing emissions for (i) natural gas production, and (ii) oil production. Hence the emissions re-allocation to end users from the consumption of petroleum fuels and natural gas cannot be conducted without making some assumptions, which introduce uncertainty.

Figure 2.1: Energy Flows in an End User Model



2.2 DA End User Emission Calculator: Design, Method and Assumptions

2.2.1 Energy Sector GHG Emission Sources

The energy sector GHG emissions fall into 7 source categories:

- Coke production
- Coal production
- Gas production
- Electricity production
- Oil production
- Smokeless Solid Fuel (SSF) production
- Town Gas production

In the development of the DA end user model, the system has been designed to enable complete isolation of each of the DA energy sectors, prior to the final emission disaggregation step. Conceptually, this model can accommodate DA-specific energy sector data, to accurately reflect the local conditions of plant design, fuel mix, utilisation, efficiency of production and so on. Through the detail of the design and the Gaussian elimination method, were data available to represent the DA-specific efficiency of fuel transformation and production, then the end user calculations could be conducted at this very detailed level.

There are five separate “regions” across which the energy sector falls: England, Scotland, Wales, Northern Ireland and “Unallocated” (i.e. offshore). The DA end user model has been designed to redistribute energy transformation emissions across 35 energy supplier sectors (i.e. across 5 regions

each with 7 energy types: coal, coke, gas, electricity, oil, SSF, and town gas). The model design enables calculations to take account of energy transfers or exports between all energy suppliers. However, to conduct the end user calculations using the full potential of the model would require input data to cover all the imports and exports of energy sector commodities between DAs for all seven fuel types.

In the course of this initial study, the AEA team has focussed on developing the model to achieve the most accurate end user disaggregation of the power sector emissions, as these constitute around 75% of total energy sector emissions. DECC also now publish estimated electricity imports and exports between the DAs, for all years from 2003 onwards, within the periodic publication "Energy Trends". In comparison, the study team has not found any equivalent data on fuel transfers between DAs of any of the solid, liquid and gaseous fuels; there are limited survey data on oil and coal imports to Northern Ireland, but these provide insufficient detail (in isolation) to be directly useful in the end user model.

In the absence of import-export data for solid, liquid and gaseous fuels, the detail of the DA end user model approach has had to be diluted; for all non-electricity fuels, the model has been modified to take a UK-wide approach to the energy sectors. In effect, the model only operates for 5 x DA-specific electricity production sectors and 6 x UK-average fuel-specific energy production sectors (i.e. one UK energy sector for each of: coke, coal, gas, oil, SSF and town gas).

There are pros and cons to this simplification of the model:

- X The model does not deliver DA end user emission estimates that truly reflect the local efficiency of fuel production and conversion across the UK. For example, if the Grangemouth refinery is designed and operated such that it is the most efficient oil refinery in the UK, the data will not reflect the fact that oil used in Scotland is slightly less carbon intensive than from other parts of the UK.

- √ In the absence of detailed energy import-export data between DAs (and from / to outside of the UK), the approach provides a "fair" representation of the UK energy sector emissions for each fuel, giving useful information across all of the DAs on the true picture of energy consumption in major end users sectors such as domestic, commercial and industrial processing.

- √ The model can be adapted to take account of new energy transfer data as it becomes available; the underlying more detailed functionality effectively remains dormant in the absence of new data on energy transfers for non-electricity fuels.

In the course of the model development, several different approaches to running the model at the full level of detail (i.e. 35 energy supplier categories) were attempted, inputting different assumptions to derive estimates of the inter-DA non-electricity fuel transfers and disaggregating the "offshore" emissions. An overview of the model outputs from different approaches is included within Appendix 2, as an indicative sensitivity analysis of the model to the different scenarios of energy transfer estimates, keeping the electricity method functioning as within the final version of the model.

2.2.2 Disaggregation Method for Energy Sector Emission Sources

The end user approach divides energy sector emission sources into 7 categories to align with the energy sectors outlined above. For each of these groups, emissions from the energy sector source categories are distributed across the end user sectors according to the total energy consumption of the relevant group of fuels in each end user sector.

For example, the emissions from the coal energy sector are made up from the by source GHG emission estimates from four source categories, and these are re-distributed across end user sectors according to the total energy use of anthracite and coal combined in each end user sector.

Table 2.2 Energy Sector Emission Sources and Fuels Used for their Re-distribution

Energy Sectors	Emission sources to be redistributed to End Users	Fuels used for the redistribution
1. Coke	Gasification processes	Coke
	Coke production	
2. Coal	Coal storage & transport	Coal
	Collieries	Anthracite
	Deep-mined coal	
	Open-cast coal	
3. Natural gas	Gas separation plant (combustion)	Natural gas
	Gas leakage	
	Gas production	
4. Electricity	Nuclear fuel production	Electricity
	Power stations	
5. Petroleum	Off shore flaring	Naphtha
	Offshore loading	Burning oil (premium)
	Offshore oil & gas (venting)	Burning oil
	Offshore oil & gas (well testing)	Aviation turbine fuel
	Offshore oil and gas	Aviation spirit
	Offshore own gas use	Derv
	Oil terminal storage	Fuel oil
	Onshore loading	Gas oil
	Petroleum processes	OPG
	Refineries (Combustion)	Refinery misc.
	Refineries (drainage)	Petrol
	Refineries (flares)	Petroleum coke
	Refineries (process)	Wide-cut gasoline
	Refineries (road/rail loading)	Vaporizing oil
	Refineries (tankage)	LPG
	Refinery (process)	
	Ship purging	
6. Solid Smokeless Fuels	Solid Smokeless fuel production	Solid Smokeless Fuels
7. Town gas	Town gas manufacture	Town gas

Note that all of the emissions from offshore oil & gas processes are allocated for re-distribution against the petroleum-based fuels, with only the emissions from gas-specific processes re-distributed according to end user gas use patterns. This is an imperfection in the method defined by the current lack of detail from the upstream oil and gas industry emission estimates, which does not allow emissions to be divided according to gas and oil exploration and production separately.

2.2.3 Data Inputs from the By Source DA GHG Inventories

The DA end user model has been developed to integrate with the existing DA by source GHG emission inventory work and the underlying UK-wide activity and emissions data held within the NAEI database; many of the necessary data inputs for the end user calculations arise directly from the by source GHG data and the NAEI database, including:

- A table of regional emissions is used to generate an estimated regional table of DA-specific fuel use by sector, covering all of the energy sector and end user sector emissions sources.

The existing "regional drivers" can be used to provide estimates of DA fuel use, working from UK-wide energy statistics for each sector.

- Emission estimates from non-energy sources. These are transferred directly from the by source inventory data to the end user inventory data, as there are no additional considerations of upstream emissions to account for in the end user data. Examples include agricultural emissions from livestock and agricultural soils, land use, land use change and forestry emissions, waste methane emissions, and all fluorinated gas emissions.

- DA "regional drivers" for electricity use within end user sectors. The existing drivers used for disaggregating direct emissions from several sources have been used for the disaggregation of electricity emissions also. Examples include the use of regional drivers on coal production to estimate electricity use by DA within collieries, and the use of iron and steel production from Electric Arc Furnaces to estimate electricity use by DA within the iron and steel sector (only for 1990, as more detailed data have been obtained for 2003 onwards from the ISSB).

- UK-wide activity data for all fuels (i.e. including electricity), including data for energy transformation and end user sectors.

2.2.4 Calculation Steps

The DA end user model performs calculations in three stages, and separately for each gas (CO_2, CH_4 and N_2O) in each year:

1) Import source data and construct a matrix of energy and emissions estimates for each DA, for both the 7 energy sector categories and the 21 end user sectors.
2) Gaussian elimination step to resolve the set of simultaneous equations to re-apportion the energy sector emissions within the "Energy Loops", to prepare the revised set of energy sector emission estimates for subsequent re-distribution to the end user sectors.
3) Re-distribution of emissions from the energy sectors across the end user sectors according to the estimated energy use by fuel, by DA, by sector. Aggregation of these emissions from fuel use and reporting by sector.

A more detailed breakdown of these calculation stages is outlined in the table below, together with comments on data used, assumptions needed and options for future development to reduce uncertainties. Screenshots of some of the calculation sheets within the end user model are also presented in Appendix 3.

Table 2.3 DA End User Model Calculation Steps

Step	Process	Comment
1	**Import source data, construct matrix of activity and emissions data**	
1.1	Import tables from the NAEI database that (i) link emission sources to either one of the 7 energy sectors, or one of the 21 end user sectors, and (ii) link each activity (fuel) type to align with one of the 7 energy sector categories.	These allocations are as used in the UK end user calculations. Table 2.2 provides the "fuels to energy sectors" allocation.
1.2	Generate an activity data matrix that covers the 7 energy sectors and the 21 end user sectors, for each of the 7 fuel types and for each DA. This uses UK activity data from the NAEI database, and regional driver information (i.e. regional % of UK totals) from the by source DA GHGI work. (See Appendix 3, figures A3.1 and A3.2 for an example matrix from 2007 CO_2 analysis.)	Uncertainties in the activity matrix stem from assumptions that have to be made to estimate DA-specific fuel uses. Future development of DA-specific energy data would reduce such uncertainties.
1.2.1	(Sub-task.) Import data on fuel imports and exports, both into and out of the UK and for transfers between DAs.	UK-level import and export data are published by DECC, as are inter-DA transfers of electricity (from 2003 onwards). Uncertainties arise from assumptions to estimate DA

Step	Process	Comment
		electricity transfers in 1990. For other fuels, a UK-wide approach has been used in this research.
1.2.2	(Sub-task.) DA estimates of electricity use by sector are added in to complete the matrix, as all of the direct fuel use estimates by DA by sector can be estimated from existing information from the by source GHGI work. The derivation of DA estimates for electricity consumption by all sectors has been a major component of this research study. A series of new DA "drivers" for electricity use have been developed.	The derivation of DA electricity use estimates is discussed in Section 2.3. Uncertainties arise from assumptions to estimate sector-specific detail of DA electricity use, especially in 1990.
1.2.3	(Sub-task.) The method derives activity-based estimates of energy use within each DA, and for electricity use aligns them with the reported emissions at the DA-specific level. This ensures that the subsequent calculations and re-distributions reflect the DA-specific fuel mix etc, for the electricity sector. A UK-wide approach is taken for other fuels, with the activity matrix all functioning through one UK "pot" of activity and emissions.	The lack of inter-DA fuel transfer information for non-electricity fuels limits the method, and a UK average approach is used in the current model. The development of DA fuel transfer data would enable full use of the model, to enable DA-specific energy sector performance to be reflected.
2	**Gaussian elimination to calculate the energy sector emission estimates**	
2.1	From the activity data matrix, the fractions of energy supplied from each DA energy sector to each DA sector (including both the other energy sectors and the end user sectors, but excluding own use) are calculated.	
2.2	The above step in the model creates a series of simultaneous equations that link the activities between energy sectors. Each equation is similar the example below: Electricity sector emissions = direct power station emissions PLUS emissions from the coal industry (to supply the coal used in power generation) PLUS emissions from the refineries (to supply and refine the oil) PLUS emissions from the gas industry (to supply the gas) PLUS ….etc *(to include all energy sectors)* The Gaussian elimination then solves these equations to derive new estimates for the final emissions from each of the fuel sector categories (i.e. the outputs from the solution of the "Energy Loops" outlined in Section 2.1.)	
2.3	The outputs from the Gaussian elimination provides the final emissions for each energy sector and for each DA, to then be re-distributed across the end user sectors, according to the energy use fractions derived in the activity data matrix.	
3	**Re-distribution of energy sector emissions and aggregation of all emissions in end user sectors**	
3.1	The total emissions from each energy sector (including at DA-specific level for electricity) are re-distributed across all end user sectors and DAs. The Gaussian elimination provides the energy sector estimates of emissions to be re-distributed, for 6 x UK-wide fuel use sectors, and the 5 DA-specific electricity sectors. The model constructs an emissions matrix to take the energy sector emissions and re-distribute them across the DA-specific end user sectors. The fractions of energy use of the fuels (as aligned to the 7 fuel categories) are used to distribute the energy sector	Uncertainty in the re-distribution of offshore oil & gas emissions stems from the inability to derive emission estimates that are specific to gas production and oil production. All "oil & gas" emission sources from upstream sources are re-distributed according to oil consumption patterns. Only the gas-specific sources (from gas separation, processing and leakage from the delivery system) are re-distributed on to end users of gas.

Step	Process	Comment
	emissions across the 21 end user sectors for each DA, and these are added to the direct emissions for those end user categories, which come through from the by source DA GHGI work. (See Appendix 3, figures A3.3 and A3.4 for an example matrix from 2007 CO_2 analysis.)	Research to estimate the division of "oil and gas" upstream emissions sources and allocate them more equitably between "oil" and "gas" would improve the accuracy of the calculations.
3.2	The emissions data are summed and presented by end user sector for each DA. The model output sheet summarises the re-distributed emissions by DA and by end user sector, for the gas and year that has been selected. (See Appendix 3, figure A3.5 for an example output sheet from 2007 CO_2 analysis.) The model must then be re-run for calculations of other gases and years, to compile the time-series of inventories.	

2.2.5 Calculation Method: Specific Points of Note

Comments on the calculation methodology used to allocate emissions according to DA end users are listed below:

- Emissions from each energy sector are allocated to end user sectors according to the proportion of the total energy use (taking account of all of the end user sectors across all DAs) by each end user sector, using the groupings of fuels outlined in table 2.2 above. This approach (i.e. aggregated across a series of fuels in some cases) is used to enable estimates to be made for broad energy use sectors (such as petroleum refining) where different products are made in a refinery. It would not be practicable to develop fuel-specific distributions;

- Some emissions are allocated to an "exports" category. This category represents emissions from within the UK from fuel production (e.g. from a refinery or coal mine), where the processed fuels are subsequently exported or sent to bunkers for use outside the UK. These emissions are accounted within the UK (and DA) by source GHG inventories, and are retained within the exports line of the end user inventories. The DA inventories presented here do not include any emission estimates from international shipping and aviation, but if they were to be included within the analysis, then the end user emission estimates would be assigned to the exports category;

- Where fuels are processed outside of the UK, imported and consumed within the UK (e.g. electricity imported from France, refined oil products imported from outside of the UK, gas imported from sources across the EU and beyond), no emissions from the upstream fuel extraction, processing, transformation and delivery are accounted for within either the UK and DA by source GHG inventories, or within the end user GHG inventories. Within the DA model, the electricity imports from France are all attributed to the England power sector, as the electricity enters the grid in England, and as such England benefits from a small amount of "emission-free" electricity within its end user emission estimates;

- Some of the output of a refinery is not used as a fuel but used as process industry feedstock or as lubricants. This is not currently treated separately and the emissions from their production (which are small) are allocated to users of petroleum fuels. This is partly due to lack of data in the database used to calculate the inventory, and partly due to the lack of a clear, transparent way of separating emissions from the production of fuels and from the production of non-fuel petroleum products.

- The end user methodology for the electricity sector is based on the available data on the DA-specific, year-specific generation fuel mix of the electricity supply. Therefore, where a DA may have a lower than UK-average carbon intensity of electricity generation (e.g. due to a high proportion of renewable or nuclear generation) then the emissions distributed for the users of that electricity (either directly within the DA, or via the exports to other DAs) will be associated with lower CO2 emissions than if a UK-average electricity generation factor was applied. Conversely, where the DA electricity generation fuel mix has a higher than UK-average carbon intensity, then the emissions from end users will be higher than if a UK-average factor was applied.

2.3 Data Sources

There are several key data sources that have been researched to meet the new requirements of the DA end users model. These are outlined below, with gaps and imperfections in available data highlighted, as these data deficiencies require assumptions to be made or introduce methodological limitations.

2.3.1 Electricity Generation: DA-specific Data, Imports and Exports

The re-distribution of the electricity sector emissions between DAs to the point of consumption rather than the point of generation is the most significant factor in deriving end user emission inventories from the existing by source DA GHG inventories. Over the time series since 1990, emissions from electricity generation vary between 75 - 78% of total energy sector emissions to be disaggregated across end user categories.

Therefore, one of the main foci for the research has been to ensure that emissions from electricity generation are estimated (i.e. taking account of the energy sector feedback loops) and re-distributed based on the best available data.

DA-specific energy use data across all fuels is more readily available for recent years, whilst the data for the earlier years of the time series back to 1990 is significantly more limited in most cases. Due to the significance of 1990 as the Base Year for the UK's reduction targets under the Kyoto Protocol (for CO_2, CH_4 and N_2O), the study has focussed on deriving data for that year, as well as the years from 2003 onwards.

Electricity Generation and Inter-DA Transfers: 2003 onwards
In recent years, DECC has published DA-specific electricity generation (by fuel), transfers between DAs and hence overall consumption estimates for the DAs. These data are available from 2003 onwards and are published annually within the December issue of Energy Trends (DECC, 2008b).

These inter-DA imports and exports of electricity are the source data that enable the DA end user model to re-distribute the electricity sector emissions according to the DA-specific patterns of fuel mix, generation and supply efficiencies.

Electricity Generation and Inter-DA Transfers: 1990
For 1990, there is very little source data on DA-specific electricity generation and consumption from a wide range of publications that the study team has reviewed. As a consequence, the balance of DA electricity generation and consumption for 1990 has had to be estimated from data that covers 1989 and 1990. In 1990, the Northern Ireland electricity grid was self-contained, with no direct links to the rest of the UK. Hence there are no electricity exports / imports to consider, and the distribution of electricity sector emissions directly to Northern Ireland electricity consumers is a straightforward calculation. Within Great Britain, however, it is necessary to derive estimates for imports and exports between England and Wales, and between England and Scotland.

DUKES 1991 includes data on electricity generated by the 15 regional electricity companies in 1989, and also includes a limited breakdown of end use of electricity by region. From these data, estimates

can be derived for the 1989 consumption of electricity in England, Scotland, Wales and Northern Ireland for domestic users, and for industrial and commercial users.

UK electricity generation data (GWh) for 1990 are published within the DUKES 2008 Long Term Trends tables (DECC, 2008a). Details of the electricity generation by fuel and by DA during 1986 to 1990 are also recorded in Hansard (Hansard, 1991), within a written response to questions from Alex Salmond. The response includes information on UK-wide fuel-specific generation (i.e. the % share of UK electricity generated by coal, oil, nuclear and renewables), and the DA-specific share of the UK generation by fuel (England and Wales data are reported together) for the years prior to 1990.

From these data, the fuel-specific and total electricity generated in Scotland for 1986 to 1989 can be estimated, and similar estimates for England and Wales combined can also be derived. Within the 1991 Electricity Supply Handbook, estimates of electricity generated by power station for 1988 and 1989 are provided, and from these data it is possible to split out the England and Wales electricity generation totals for 1989.

Estimates of electricity transfer within the GB network in 1990 have then been calculated, by assuming:

- The England, Wales and Scotland share of GB generation in 1990 is similar to that in 1989;
- The % losses between DA-specific electricity generated and electricity consumed is the same across all DAs.

These calculations indicate that both Scotland and Wales were net exporters to England in 1990, with 3220 GWh transferred from Scotland to England and 3500 GWh transferred from Wales to England. These data are subject to uncertainty due to the series of assumptions made, although the evidence from the late 1980s indicates that the DA-specific share of generation was steady within Great Britain. These data have been used within the 1990 end user calculations presented here; further research may identify 1990 DA-specific data, but consultation with the regional energy data experts within the DECC energy statistics team did not indicate any additional data sources to those researched by the study team.

2.3.2 Electricity Consumption: DA Sector Estimates

Step 1.2.2 in the compilation method table above requires the development of estimates of electricity use by sector, by DA. There is very limited DA-specific electricity use data, and in most cases the study has developed new “regional drivers” from proxy data / activity information to allocate UK electricity consumption by sector across the DAs. The data sources used to derive to regional drivers by DA sector are outlined in the table below, with an indication of the limitations of the data and any recommendations for future research. Note that the sector detail of electricity consumption estimates is one of the main limiting factors on the overall detail and accuracy of the DA end user inventories; the presentation of estimates by 21 end user categories reflects the limit of the data usefulness at this stage.

The DA electricity use data for several sectors have been estimated based on analysis conducted by AEA and Cambridge Econometrics in the development of the REEIO model (Sajwaj, 2009). The estimates are calculated based on the analysis of regional economic activity data (determined as GVA) across 41 economic sectors, and year-specific electricity consumption totals for the industrial and commercial sectors within the electricity supply grids aligned with 9 English Government Office Regions, Wales, Scotland and Northern Ireland. This analysis has been conducted for 1990, 2000 and 2005.

The use of GVA as an indicator of electricity use across different economic sectors is subject to uncertainty, and has been used where study team has not found more definitive data.

In the analysis of the “other industry” electricity use DA estimates, the DA-specific electricity totals for all “industrial and commercial” sectors (from DUKES 1991 and Energy Trends) are used to constrain

the total DA electricity consumption for each year, with all other sector-specific estimates used to determine the "other industry" driver by difference. This method ensures that whilst the use of uncertain sector-specific regional drivers (such as those based on GVA indicators) may introduce uncertainty to specific sector emission estimates, the overall DA emissions from electricity use will be correct. Hence the use of uncertain regional drivers may affect sector allocations but not the overall emissions at DA-level.

Table 2.4 DA Sector Electricity Consumption: Regional Drivers

Sector	Regional Driver Data	Comment
Agriculture	All years: Employment on Agricultural Holdings: Total Labour Force - Seasonal or Casual, Defra, Digest of Agricultural Statistics.	Also used in the by source DA GHGIs to disaggregate direct fuel use in this sector. Employment data may not be a good indicator. Ongoing work by DECC to develop more detailed electricity data may provide a more accurate analysis (for recent years only).
Collieries	All years: Coal production data totals from the sum of deep mined coal production and open cast coal production, by mass, using data from the Coal Authority, UK Mineral Statistics, DUKES, Scottish Energy Statistics, and the Digest of Welsh Statistics.	Total coal production may not be a good indicator. As above, ongoing work by DECC may provide better data for recent years. Research into industry fuel use statistics may provide some new data, or perhaps a better indication of the relative electricity consumption per unit production of deep-mined versus open cast coal extraction.
Domestic	1990: DUKES 1991 provides electricity sales data by regional generation companies to the domestic sector. These have been aggregated to provide DA totals, and the 1989 consumption patterns assumed to be representative of 1990 consumption. 2003 onwards: DECC Energy Trends (December 2008) provides data on DA-specific electricity consumption in the domestic sector for 2004 onwards. The 2004 domestic sector consumption patterns have been assumed to be representative for 2003 also.	Ongoing work by DECC may lead to revisions of the electricity allocations to the domestic sector at both UK and DA level. Further research may identify specific data for 2003, to remove the assumption that 2004 patterns are representative. Note that prevailing temperatures and weather conditions could have marked impacts on the DA-specific domestic electricity consumption year-to-year.
Exports	All years: Inter-DA transfers are covered in Section 2.3.1 above. DECC DUKES data includes summaries of the UK-level electricity imports and exports between UK, France and the Republic of Ireland, and the breakdown at DA-specific level is provided within Energy Trends. For 1990, the Northern Ireland grid was isolated, and hence all imports/exports are allocated to England.	No further research needed.
Gas Production	All years: Regional GVA data for the gas supply industry, through the REEIO model work, have been used to derive drivers for 1990, 2000 and 2005. The 2005 split has been assumed to apply across 2003 to 2007 inclusive.	Scope for further research / consultation with the industry to determine a more accurate method. The ongoing DECC work may also provide better data for recent years.
Blast furnaces and Iron & steel combustion plant	1990: Production of steel from electric arc furnaces, by mass, from ISSB annual statistics. 2003 onwards: Region-specific electricity consumption data from across the iron and steel industry has been provided by the ISSB.	Some scope for review of the method for 1990, but the data for recent years is of good quality.
Commercial and Miscellaneous	All years: Regional GVA data for the commercial sector, through the REEIO model work, has been used to derive drivers for 1990, 2000 and 2005. The 2005 split has been assumed to apply across 2003 to 2007 inclusive.	Scope for further research / consultation to determine a more accurate method. The ongoing DECC work may also provide better data for recent years.

Sector	Regional Driver Data	Comment
Other Industry	All years: The driver for other industry electricity use by DA is calculated by difference, from the sum of all other sector estimates and the DA-specific electricity consumption totals that are available from DUKES 1991 (for 1989 data, used for 1990) and from DECC Energy Trends (for 2003 onwards).	No further research needed.
Public	All years: Regional GVA data for the public sector, through the REEIO model work, has been used to derive drivers for 1990, 2000 and 2005. The 2005 split has been assumed to apply across 2003 to 2007 inclusive.	Scope for further research / consultation to determine a more accurate method. The ongoing DECC work may also provide better data for recent years.
Rail	All years: The existing regional drivers for the rail industry, based on reported gas oil use by train operating companies, have been used.	There is considerable scope for improvement here, but note that rail sector electricity consumption is less than 1% of the UK total.
Refineries	All years: The DA data on CO_2 emissions from refineries has been used as an indicator of electricity use.	There is scope for more research and consultation with industry, although this approach is regarded as a reasonably good indicator for refinery electricity use, which comprises just over 1% of the UK total electricity use. The ongoing DECC work may also provide better data for recent years.

3 Results and Discussion

The results from the analysis are presented below. The discussion concentrates on the differences in distribution across the DAs of the by source and by end user emissions, and the differences in the trends using the two approaches.

The limitations of the analysis conducted to date has been outlined in the earlier chapters. Therefore all of the data presented here must be considered as experimental. Further work is needed to refine the method and identify or develop new data to address gaps and provide additional detail, in order that assumptions can be over-written, the full detail of the model calculations be utilised and the uncertainties on the final data be minimised.

The outputs of the current version of the DA end users model are provided in detail in Appendix 1. Screenshots of the main calculation sub-sheets of the end user model are provided in Appendix 3. Note also that a preliminary assessment of the breakdown of end user emissions by energy sector, taken from intermediate steps in the electricity and non-electricity model calculations, are presented in Appendix 4. This appendix includes summary tables and figures that indicate the DA balance of emissions from generation and consumption of the electricity and non-electricity fuels over the time series. These data are regarded as indicative only at this stage, but provide a limited insight into the relative contributions of the electricity and non-electricity sectors in determining the overall end user emission estimates for each DA.

Note on the Format of Data Presentation
The model has been designed to output data across 21 End User Categories, consistent with UK-level end user analysis for air quality pollutants; this data presentation is slightly more detailed than the National Communication (NC) format used to report UK GHG end user emissions, and the output format has been built into the model design. Aggregation of these data to NC categories is not a straightforward task, as there is not a direct one-to-many mapping formula for some of the industrial categories. The use of the 21-category format enables a more detailed review of the model outputs than the NC format, and this is useful at this stage of the model development to allow some closer inspection of the disaggregation of energy sector emissions.

Depending on the most useful format of data presentation, the DA end user model can be adjusted to output to different formats, but it is impractical at this stage to deliver any more detailed DA end user data that the 21 categories used here, as the available model input data are insufficiently detailed.

3.1 DA End User GHG Emissions Data

The study shows that the UK distribution of regional net GHG emissions by end user in 2007, expressed in terms of total CO_2 equivalent emissions of the "basket of 6" GHGs, is[2]:

(The share of the "by source" GHG inventories in 2007 is indicated in brackets.)

- England 81.5% (77.8%)
- Scotland 7.9% (8.6%)
- Wales 6.8% (7.4%)
- Northern Ireland 3.8% (3.4%)
- Unallocated 0.0% (2.8%)

[2] Note that these summary data are based on the end user inventories, discounting the exported emissions from each DA, to provide a direct comparison of DA emissions considering energy consumption patterns and other direct emission sources.

The estimated trends in the end user DA GHG inventories from the Kyoto Protocol Base Year (1990 for CO_2, CH_4 and N_2O, and 1995 data for the fluorinated gases) to 2007, are:

(The emission trends against the Kyoto Protocol Base Year from the "by source" DA GHG inventories are indicated in brackets.)

- England emissions have reduced by 18.5% (19.6%)
- Scotland emissions have reduced by 23.5% (19.9%)
- Wales emissions have reduced by 16.4% (14.7%)
- Northern Ireland emissions have reduced by 13.0% (12.6%)

The data above, comparing the end user DA GHG inventories against the by source DA GHG inventories, provides an insight into the difference between energy consumption and energy production emission patterns within the UK. The data indicate that:

- England has a greater share of energy consumption emissions compared to the production-based data presented in the by source inventories, and has achieved slightly lower emission reductions since the Base Year than the by source inventories indicate;

- Northern Ireland also has a greater share of energy consumption emissions compared to the production-based data presented in the by source inventories, and the end user data show that Northern Ireland has achieved slightly higher emission reductions since the Base Year than the by source inventories indicate;

- Both Scotland and Wales have a lesser share of energy consumption emissions compared to the production-based data presented in the by source inventories, and each have achieved slightly higher emission reductions since the Base Year than the by source inventories indicate.

These results are consistent with several key underlying factors at DA level, including:

- DA electricity transfer data indicates that in most years, **England** is a net importer of electricity from both Wales and Scotland (as well as from France);

- In most years, **Scotland** is a net exporter of electricity to both England and Northern Ireland, and also hosts a significant share of upstream oil and gas sector infrastructure, such as major oil and gas terminals and the Grangemouth refinery;

- In most years, **Wales** is a net exporter of electricity to England, and has a high percentage share of both oil and solid fuel process industries (i.e. refineries and collieries);

- **Northern Ireland** has no fuel transformation industry other than electricity generation; there are no collieries, refineries or major upstream oil & gas infrastructure in Northern Ireland;

3.1.1 England End Users GHG Inventories

The outputs from the DA end user model are summarised below:

Table 3.1.1a England End User GHG Inventories: 1990, 2003 to 2007 (kt CO_2-e)

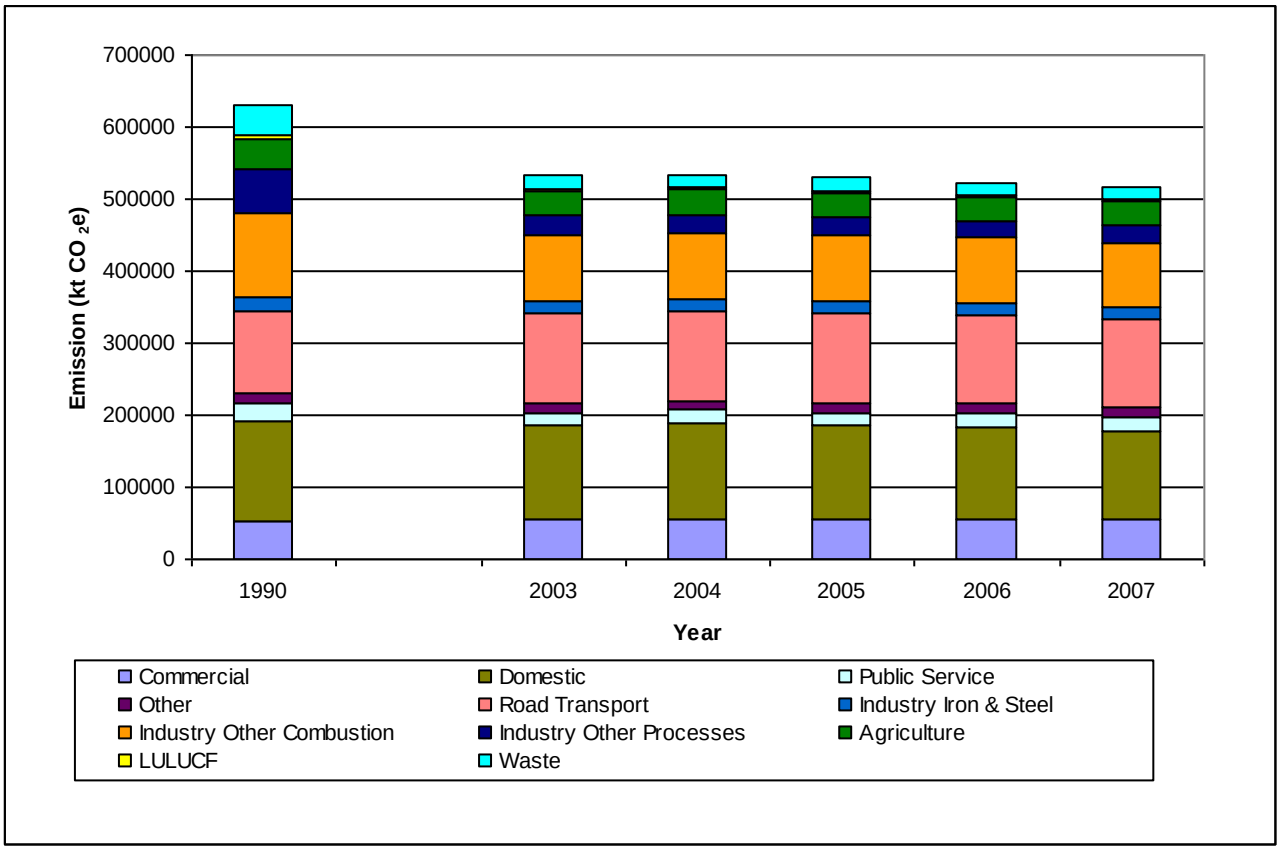
Sector	Base Year	1990	2003	2004	2005	2006	2007
Commercial	54,215	53,005	55,153	55,622	54,919	55,255	54,800
Domestic	138,797	138,462	131,058	133,524	129,944	128,283	123,860
Public Service	26,306	26,306	17,750	18,626	18,443	18,224	17,388
Rail Transport	3,573	3,573	3,500	3,582	3,653	3,721	3,750
Road Transport	111,777	111,777	125,324	125,575	126,014	122,288	123,393
Water Transport	3,099	3,099	3,139	3,028	3,502	4,585	4,111
Air Transport Support	292	292	464	492	521	511	519
Military Transport (Air & Water)	5,449	5,449	3,074	3,144	3,025	2,893	3,687
Industry Iron & Steel	21,143	21,143	15,867	15,737	15,616	16,481	16,720
Industry Other Combustion	114,796	114,796	92,282	91,390	93,280	91,661	89,421
Industry Other Processes	63,400	61,559	26,986	26,081	24,787	23,350	24,182
Agriculture	41,307	41,307	33,885	34,100	33,304	32,309	31,580
Land Use, Land Use Change and Forestry	5,737	5,737	3,675	3,368	3,178	3,157	3,143
Miscellaneous	740	740	1	1	1	1	1
Exports	41	41	1,004	411	429	571	1,187
Aviation Take-off and Landing – Domestic	340	340	431	471	514	467	422
Aviation Take-off and Landing – International	-	-	-	-	-	-	-
Aviation Cruise - Domestic	551	551	928	1,002	1,112	1,046	975
Aviation Cruise - International	-	-	-	-	-	-	-
Water Transport - International	-	-	-	-	-	-	-
Waste	41,665	41,665	19,786	18,425	18,133	18,033	17,986
Total	**633,228**	**629,842**	**534,304**	**534,578**	**530,376**	**522,836**	**517,125**

Table 3.1.1b Emission Trends by Sector: England End User GHG Inventories
(Significant source sectors are indicated by the shaded rows.)

Sector	Base Year to 2007 Trend	2006 to 2007 Trend	% Share of DA 2007 EUI
Commercial	1.1%	-0.8%	10.6%
Domestic	-10.8%	-3.4%	24.0%
Public Service	-33.9%	-4.6%	3.4%
Rail Transport	4.9%	0.8%	0.7%
Road Transport	10.4%	0.9%	23.9%
Water Transport	32.6%	-10.3%	0.8%
Air Transport Support	77.7%	1.5%	0.1%
Military Transport (Air & Water)	-32.3%	27.5%	0.7%
Industry Iron & Steel	-20.9%	1.4%	3.2%
Industry Other Combustion	-22.1%	-2.4%	17.3%
Industry Other Processes	-61.9%	3.6%	4.7%
Agriculture	-23.5%	-2.3%	6.1%
Land Use, Land Use Change and Forestry	-45.2%	-0.4%	0.6%
Miscellaneous	-99.9%	0.0%	0.0%
Exports	2785.0%	107.8%	0.2%
Aviation Take-off and Landing – Domestic	24.0%	-9.6%	0.1%
Aviation Take-off and Landing – International			0.0%
Aviation Cruise - Domestic	76.8%	-6.8%	0.2%
Aviation Cruise - International			0.0%
Water Transport - International			0.0%
Waste	-56.8%	-0.3%	3.5%
Total	**-18.3%**	**-1.1%**	**100.0%**

Note that the base year to 2007 emission trends when the emission exports are discounted show that England end user emissions have reduced by **18.5%**. This compares to the reported reduction in the "by source" GHG inventory of **19.6%** over the same period.

Figure 3.1.1 England End User GHG Emissions: 1990, 2003-2007 (kt CO_2-e)



3.1.2 Scotland End Users GHG Inventories

The outputs from the DA end user model are summarised below:

Table 3.1.2a Scotland End User GHG Inventories: 1990, 2003 to 2007 (kt CO_2-e)

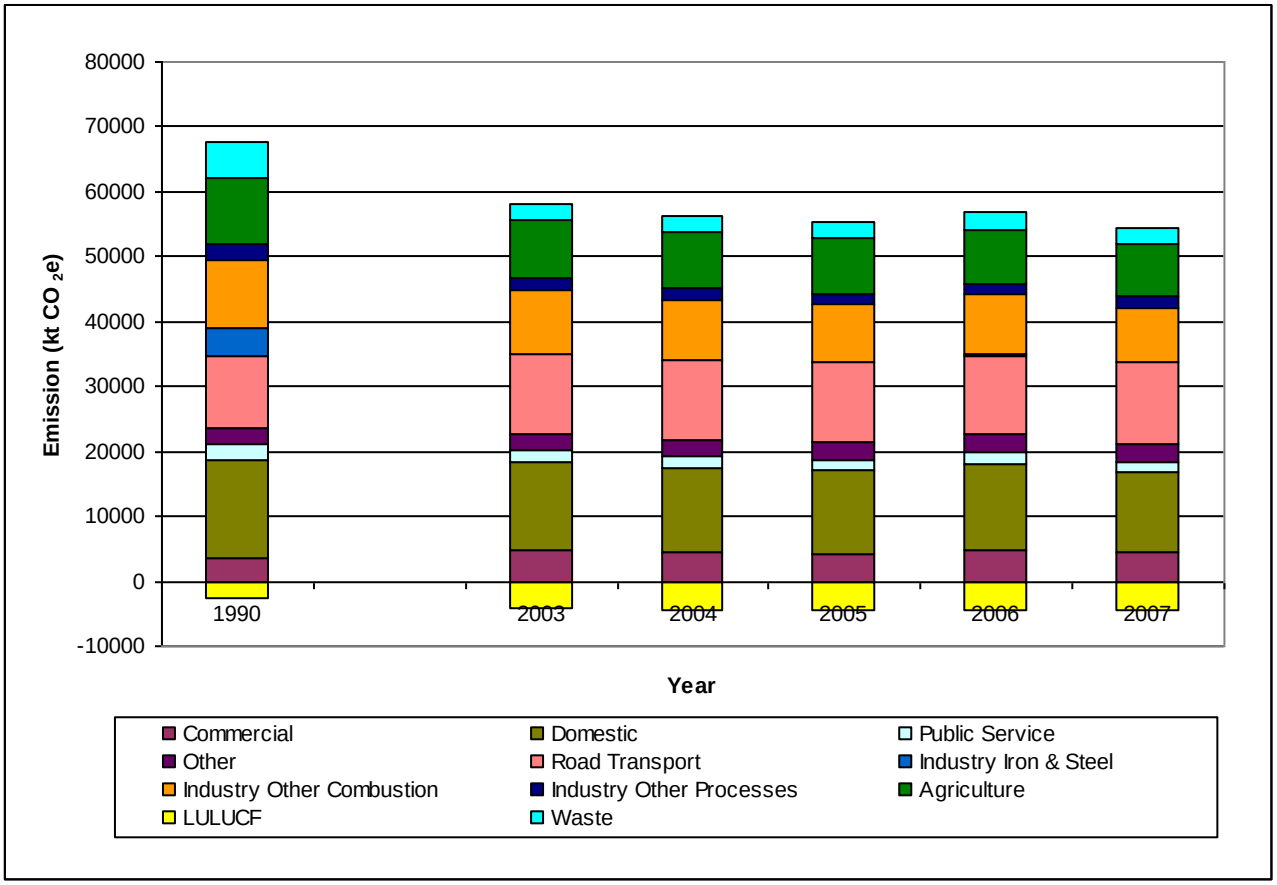
Sector	Base Year	1990	2003	2004	2005	2006	2007
Commercial	3,754	3,607	4,772	4,393	4,262	4,676	4,339
Domestic	14,980	14,944	13,695	13,111	12,715	13,364	12,473
Public Service	2,543	2,543	1,811	1,775	1,747	1,844	1,663
Rail Transport	352	352	390	397	398	419	417
Road Transport	11,119	11,119	12,297	12,344	12,429	12,205	12,488
Water Transport	1,143	1,143	937	883	972	1,163	1,050
Air Transport Support	51	51	71	71	75	77	80
Military Transport (Air & Water)	560	560	293	300	286	272	347
Industry Iron & Steel	4,224	4,224	83	77	73	84	83
Industry Other Combustion	10,542	10,542	9,776	9,115	8,753	9,228	8,488
Industry Other Processes	2,363	2,421	1,813	1,843	1,637	1,669	1,612
Agriculture	10,123	10,123	8,899	8,727	8,521	8,423	8,054
Land Use, Land Use Change and Forestry	-2,518	-2,518	-4,193	-4,599	-4,581	-4,451	-4,440
Miscellaneous	22	22	0	0	0	0	0
Exports	-	-	-	-	-	-	-
Aviation Take-off and Landing – Domestic	124	124	212	217	232	210	200
Aviation Take-off and Landing – International	-	-	-	-	-	-	-
Aviation Cruise - Domestic	264	264	551	577	624	589	556
Aviation Cruise - International	-	-	-	-	-	-	-
Water Transport - International	-	-	-	-	-	-	-
Waste	5,745	5,745	2,571	2,492	2,490	2,624	2,643
Total	**65,392**	**65,269**	**53,978**	**51,722**	**50,633**	**52,396**	**50,052**

Table 3.1.2b Emission Trends by Sector: Scotland End User GHG Inventories
(Significant source sectors are indicated by the shaded rows.)

Sector	Base Year to 2007 Trend	2006 to 2007 Trend	% Share of DA 2007 EUI
Commercial	15.6%	-7.2%	8.7%
Domestic	-16.7%	-6.7%	24.9%
Public Service	-34.6%	-9.8%	3.3%
Rail Transport	18.4%	-0.6%	0.8%
Road Transport	12.3%	2.3%	24.9%
Water Transport	-8.1%	-9.7%	2.1%
Air Transport Support	56.1%	3.2%	0.2%
Military Transport (Air & Water)	-38.0%	27.8%	0.7%
Industry Iron & Steel	-98.0%	-1.9%	0.2%
Industry Other Combustion	-19.5%	-8.0%	17.0%
Industry Other Processes	-31.8%	-3.4%	3.2%
Agriculture	-20.4%	-4.4%	16.1%
Land Use, Land Use Change and Forestry	76.4%	-0.3%	-8.9%
Miscellaneous	-99.5%	-0.1%	0.0%
Exports			0.0%
Aviation Take-off and Landing – Domestic	61.1%	-4.8%	0.4%
Aviation Take-off and Landing – International			0.0%
Aviation Cruise - Domestic	110.9%	-5.5%	1.1%
Aviation Cruise - International			0.0%
Water Transport - International			0.0%
Waste	-54.0%	0.7%	5.3%
Total	**-23.5%**	**-4.5%**	**100.0%**

The base year to 2007 emission trends when the emission exports are discounted are unchanged in Scotland, having reduced by **23.5%**. This compares to the reported reduction in the "by source" GHG inventory of **19.9%** over the same period.

Figure 3.1.2 Scotland End User GHG Emissions: 1990, 2003-2007 (kt CO_2-e)



3.1.3 Wales End Users GHG Inventories

The outputs from the DA end user model are summarised below:

Table 3.1.3a Wales End User GHG Inventories: 1990, 2003 to 2007 (kt CO_2-e)

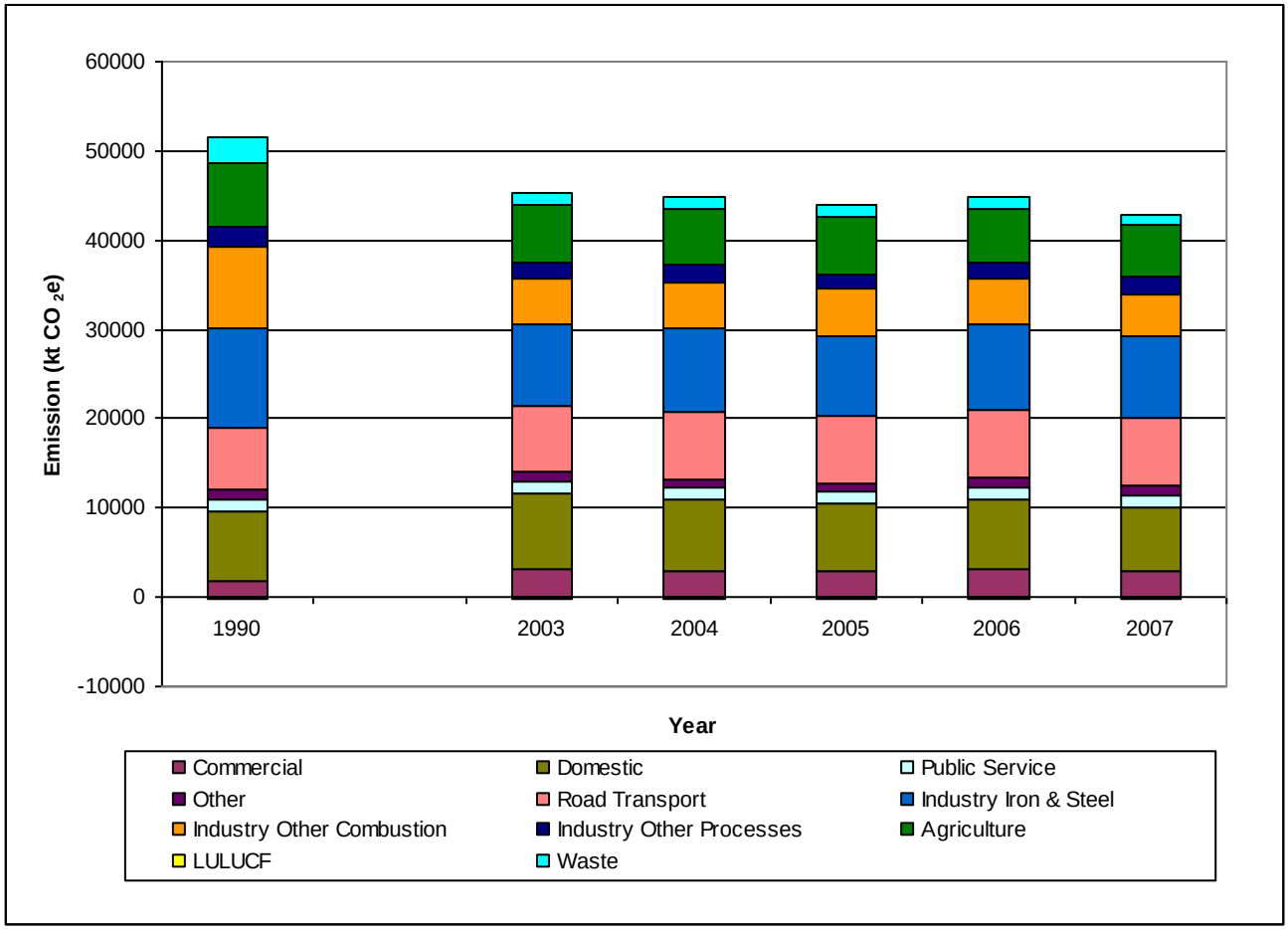
Sector	Base Year	1990	2003	2004	2005	2006	2007
Commercial	1,897	1,837	3,219	2,872	2,826	3,067	2,861
Domestic	7,790	7,770	8,443	8,049	7,691	7,892	7,221
Public Service	1,452	1,452	1,396	1,297	1,283	1,366	1,250
Rail Transport	300	300	311	345	344	362	357
Road Transport	6,791	6,791	7,476	7,566	7,598	7,456	7,590
Water Transport	515	515	446	480	529	649	583
Air Transport Support	4	4	6	6	5	6	5
Military Transport (Air & Water)	270	270	139	143	135	128	156
Industry Iron & Steel	11,267	11,267	9,036	9,290	8,832	9,685	9,244
Industry Other Combustion	8,967	8,967	5,185	5,297	5,392	4,995	4,727
Industry Other Processes	2,095	2,257	1,824	1,827	1,590	1,876	1,861
Agriculture	7,086	7,086	6,519	6,383	6,371	6,108	5,749
Land Use, Land Use Change and Forestry	-237	-237	-191	-231	-226	-193	-198
Miscellaneous	0	0	0	0	0	0	0
Exports	-	-	-	-	-	-	-
Aviation Take-off and Landing – Domestic	1	1	7	6	5	5	6
Aviation Take-off and Landing – International	-	-	-	-	-	-	-
Aviation Cruise - Domestic	2	2	15	13	12	14	16
Aviation Cruise - International	-	-	-	-	-	-	-
Water Transport - International	-	-	-	-	-	-	-
Waste	2,918	2,918	1,376	1,353	1,361	1,311	1,309
Total	**51,118**	**51,201**	**45,207**	**44,695**	**43,749**	**44,726**	**42,738**

Table 3.1.3b Emission Trends by Sector: Wales End User GHG Inventories
(Significant source sectors are indicated by the shaded rows.)

Sector	Base Year to 2007 Trend	2006 to 2007 Trend	% Share of DA 2007 EUI
Commercial	50.8%	-6.7%	6.7%
Domestic	-7.3%	-8.5%	16.9%
Public Service	-13.9%	-8.5%	2.9%
Rail Transport	19.1%	-1.4%	0.8%
Road Transport	11.8%	1.8%	17.8%
Water Transport	13.2%	-10.1%	1.4%
Air Transport Support	27.8%	-2.9%	0.0%
Military Transport (Air & Water)	-42.1%	22.6%	0.4%
Industry Iron & Steel	-18.0%	-4.6%	21.6%
Industry Other Combustion	-47.3%	-5.4%	11.1%
Industry Other Processes	-11.2%	-0.8%	4.4%
Agriculture	-18.9%	-5.9%	13.5%
Land Use, Land Use Change and Forestry	-16.3%	3.0%	-0.5%
Miscellaneous	-11.9%	-0.2%	0.0%
Exports			0.0%
Aviation Take-off and Landing – Domestic	466.4%	13.6%	0.0%
Aviation Take-off and Landing – International			0.0%
Aviation Cruise - Domestic	962.8%	12.9%	0.0%
Aviation Cruise - International			0.0%
Water Transport - International			0.0%
Waste	-55.1%	-0.1%	3.1%
Total	**-16.4%**	**-4.4%**	**100.0%**

The base year to 2007 emission trends when the emission exports are discounted are unchanged in Wales, having reduced by **16.4%**. This compares to the reported reduction in the "by source" GHG inventory of **14.7%** over the same period.

Figure 3.1.3 Wales End User GHG Emissions: 1990, 2003-2007 (kt CO_2-e)



3.1.4 Northern Ireland End Users GHG Inventories

The outputs from the DA end user model are summarised below:

Table 3.1.4a Northern Ireland End User GHG Inventories: 1990, 2003 to 2007 (kt CO_2-e)

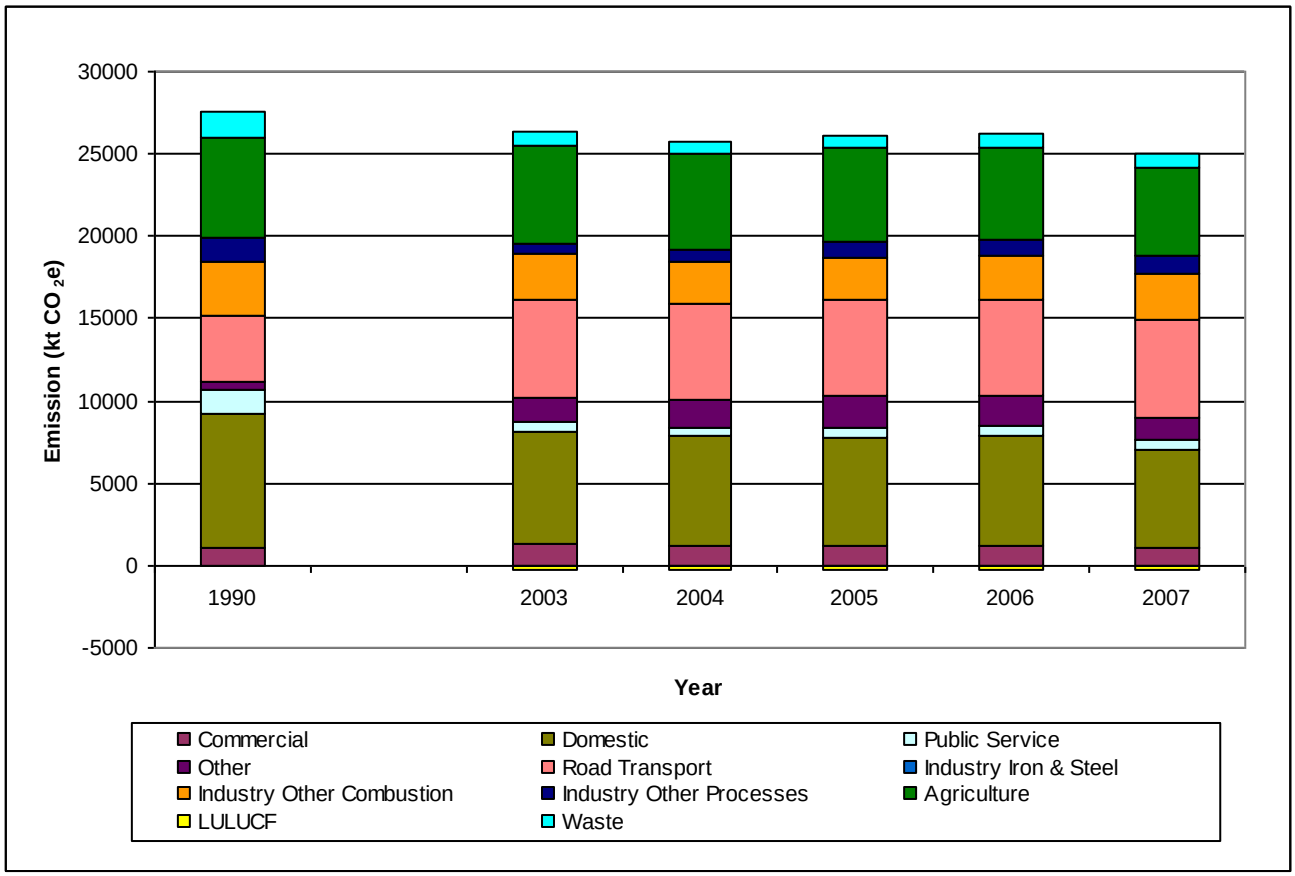
Sector	Base Year	1990	2003	2004	2005	2006	2007
Commercial	1,089	1,060	1,277	1,234	1,241	1,222	1,081
Domestic	8,146	8,135	6,857	6,597	6,464	6,603	5,975
Public Service	1,432	1,432	622	593	624	613	534
Rail Transport	97	97	97	100	99	100	105
Road Transport	3,943	3,943	5,887	5,772	5,814	5,772	5,908
Water Transport	183	183	186	187	215	280	246
Air Transport Support	10	10	11	10	11	12	12
Military Transport (Air & Water)	135	135	82	84	81	79	100
Industry Iron & Steel	-	0	0	0	0	0	0
Industry Other Combustion	3,279	3,279	2,780	2,601	2,549	2,720	2,812
Industry Other Processes	1,467	1,467	697	709	996	1,032	1,106
Agriculture	6,102	6,102	5,947	5,784	5,641	5,586	5,348
Land Use, Land Use Change and Forestry	-28	-28	-290	-281	-281	-295	-285
Miscellaneous	0	0	0	0	0	0	0
Exports	-	-	874	1,058	1,331	1,148	724
Aviation Take-off and Landing – Domestic	41	41	64	71	82	83	74
Aviation Take-off and Landing – International	-	-	-	-	-	-	-
Aviation Cruise - Domestic	89	89	157	165	180	176	183
Aviation Cruise - International	-	-	-	-	-	-	-
Water Transport - International	-	-	-	-	-	-	-
Waste	1,647	1,647	792	763	797	815	835
Total	**27,632**	**27,592**	**26,041**	**25,447**	**25,843**	**25,948**	**24,760**

Table 3.1.4b Emission Trends by Sector: Northern Ireland End User GHG Inventories
(Significant source sectors are indicated by the shaded rows.)

Sector	Base Year to 2007 Trend	2006 to 2007 Trend	% Share of DA 2007 EUI
Commercial	-0.8%	-11.6%	4.4%
Domestic	-26.7%	-9.5%	24.1%
Public Service	-62.7%	-12.9%	2.2%
Rail Transport	8.1%	4.8%	0.4%
Road Transport	49.8%	2.4%	23.9%
Water Transport	34.1%	-12.3%	1.0%
Air Transport Support	28.7%	0.2%	0.0%
Military Transport (Air & Water)	-25.5%	27.1%	0.4%
Industry Iron & Steel			0.0%
Industry Other Combustion	-14.2%	3.4%	11.4%
Industry Other Processes	-24.7%	7.1%	4.5%
Agriculture	-12.4%	-4.3%	21.6%
Land Use, Land Use Change and Forestry	914.4%	-3.6%	-1.1%
Miscellaneous	-6.7%	0.3%	0.0%
Exports		-37.0%	2.9%
Aviation Take-off and Landing – Domestic	81.9%	-10.6%	0.3%
Aviation Take-off and Landing – International			0.0%
Aviation Cruise - Domestic	104.9%	3.8%	0.7%
Aviation Cruise - International			0.0%
Water Transport - International			0.0%
Waste	-49.3%	2.5%	3.4%
Total	-10.4%	-4.6%	100.0%

Note that the base year to 2007 emission trends when the emission exports are discounted show that Northern Ireland end user emissions have reduced by **13.0%**. This compares to the reported reduction in the "by source" GHG inventory of **12.6%** over the same period.

Figure 3.1.4 Northern Ireland End User GHG Emissions: 1990, 2003-2007 (kt CO_2-e)



3.2 Sector Analysis

The sector-specific data provide an insight into the impacts of the end user methodology, and a limited analysis of the outputs from the current DA end user model is presented below. Although the data are regarded as experimental, the trends and sector-specific differences between the by source and end user estimates provide some useful information to help inform future development focus for the DA end user approach.

Across all sectors, the sector-specific electricity estimates for each DA are uncertain, especially in the 1990 data where very limited sector-specific information is available. This must be taken into consideration when using the data to inspect the reported emission trends. It is likely that the trends reported in the 2003 to 2007 data are subject to lower uncertainty.

Note that where variable percentage increases are evident between DAs, from the comparisons of by source emissions and the end user estimates, this is due to factors including:

- The DA-specific direct fuel-mix in the sector, including both primary fuels and electricity;
- The carbon intensity of the electricity generated in each DA; and
- The carbon intensity of electricity imported from other DAs and used in a DA.

The uncertainties in fuel allocations, and the range of factors that affect the end user estimates makes it difficult to provide a detailed analysis of the sector emissions and trends outlined below.

3.2.1 Commercial Sector

The outputs from the DA end user model are summarised below:

Table 3.2.1 Commercial Sector DA End Users Data: 1990, 2003-2007

End Users Emissions (kt CO_2-e)		1990	2003	2004	2005	2006	2007
Commercial	England	53,005	55,153	55,622	54,919	55,255	54,800
Commercial	Scotland	3,607	4,772	4,393	4,262	4,676	4,339
Commercial	Wales	1,837	3,219	2,872	2,826	3,067	2,861
Commercial	Northern Ireland	1,060	1,277	1,234	1,241	1,222	1,081

DA % of End User Emissions		1990	2003	2004	2005	2006	2007
Commercial	England	89.1%	85.6%	86.7%	86.8%	86.0%	86.9%
Commercial	Scotland	6.1%	7.4%	6.9%	6.7%	7.3%	6.9%
Commercial	Wales	3.1%	5.0%	4.5%	4.5%	4.8%	4.5%
Commercial	Northern Ireland	1.8%	2.0%	1.9%	2.0%	1.9%	1.7%

End Users / By Source		1990	2003	2004	2005	2006	2007
Commercial	England	510%	324%	331%	337%	359%	357%
Commercial	Scotland	338%	278%	258%	258%	299%	279%
Commercial	Wales	297%	397%	359%	353%	409%	388%
Commercial	Northern Ireland	724%	482%	384%	362%	380%	335%

The high percentage increase in the end users data compared to the by source data indicates the large contribution of the electricity component in the DA end user estimates. The use of electricity for heating, lighting and operating equipment has a marked effect on the emissions attributed to this sector, when compared to the emissions in the by source inventories which only include estimates from direct fuel use in the sector, which are likely to be predominantly from operating boilers for heating.

The significance of the commercial sector estimates within each DA end user inventory in 2007 is variable, ranging from 4% in Northern Ireland, 7% in Wales, 9% in Scotland up to 11% in England.

3.2.2 Domestic Sector

The outputs from the DA end user model are summarised below:

Table 3.2.2 Domestic Sector DA End Users Data: 1990, 2003-2007

End Users Emissions (kt CO_2-e)		1990	2003	2004	2005	2006	2007
Domestic	England	138,462	131,058	133,524	129,944	128,283	123,860
Domestic	Scotland	14,944	13,695	13,111	12,715	13,364	12,473
Domestic	Wales	7,770	8,443	8,049	7,691	7,892	7,221
Domestic	Northern Ireland	8,135	6,857	6,597	6,464	6,603	5,975

DA % of End User Emissions		1990	2003	2004	2005	2006	2007
Domestic	England	81.8%	81.9%	82.8%	82.9%	82.2%	82.8%
Domestic	Scotland	8.8%	8.6%	8.1%	8.1%	8.6%	8.3%
Domestic	Wales	4.6%	5.3%	5.0%	4.9%	5.1%	4.8%
Domestic	Northern Ireland	4.8%	4.3%	4.1%	4.1%	4.2%	4.0%

End Users / By Source		1990	2003	2004	2005	2006	2007
Domestic	England	217%	179%	179%	181%	186%	188%
Domestic	Scotland	193%	176%	167%	168%	180%	173%
Domestic	Wales	168%	175%	164%	165%	176%	171%
Domestic	Northern Ireland	164%	175%	169%	170%	167%	162%

The percentage increase in the end users emissions data compared to the by source data indicates the additional contribution of the electricity component in the DA end user estimates. The increase is not as large as that reported for the commercial sector. Across all years, England shows the highest percentage increase in emissions when compared to the by source emissions, and this may reflect either higher consumption of electricity in the domestic sector in England, or perhaps a slightly more carbon-intensive fuel mix in the electricity generation sector in England.

The domestic sector estimates of electricity use in 1990 for each DA are based on sales data from regional electricity companies for 1989, scaled to the 1990 UK domestic electricity use total. In addition, the Regional Energy Statistics published by DECC for recent years does provide a domestic sector estimate of electricity use for each DA. Therefore, these sector estimates are associated with lower uncertainty than many of the other sectors.

The reported trends in end user emissions since 1990 show that:

- England emissions have declined by 11%
- Scotland emissions have declined by 17%
- Wales emissions have declined by 7%
- Northern Ireland emissions have declined by 27%

The higher reduction in Northern Ireland reflects the effect of the shift in fuel mix in the domestic sector, as the gas network has developed since 1999. The resultant growth in gas use in Northern Ireland has displaced more carbon intensive fuels (oils, solid fuels) in both direct heating and in the electricity generation sector.

Across all of the DAs, this sector is a very considerable emission source; in England, Scotland Northern Ireland, the domestic sector is estimated to comprise 24-25% of the total end user emissions in 2007, whilst in Wales the figure is somewhat lower at 17%, partly due to the greater influence of iron and steel and industrial emissions in Wales.

3.2.3 Public Sector

The outputs from the DA end user model are summarised below:

Table 3.2.3 Public Sector DA End Users Data: 1990, 2003-2007

End Users Emissions (kt CO_2-e)		1990	2003	2004	2005	2006	2007
Public Service	England	26,306	17,750	18,626	18,443	18,224	17,388
Public Service	Scotland	2,543	1,811	1,775	1,747	1,844	1,663
Public Service	Wales	1,452	1,396	1,297	1,283	1,366	1,250
Public Service	Northern Ireland	1,432	622	593	624	613	534

DA % of End User Emissions		1990	2003	2004	2005	2006	2007
Public Service	England	82.9%	82.3%	83.6%	83.5%	82.7%	83.5%
Public Service	Scotland	8.0%	8.4%	8.0%	7.9%	8.4%	8.0%
Public Service	Wales	4.6%	6.5%	5.8%	5.8%	6.2%	6.0%
Public Service	Northern Ireland	4.5%	2.9%	2.7%	2.8%	2.8%	2.6%

End Users / By Source		1990	2003	2004	2005	2006	2007
Public Service	England	238%	203%	195%	196%	203%	210%
Public Service	Scotland	205%	211%	189%	187%	208%	206%
Public Service	Wales	189%	324%	276%	271%	305%	306%
Public Service	Northern Ireland	292%	497%	379%	312%	321%	300%

Similar to the commercial sector, the high percentage increase in the end users data compared to the by source data indicates the dominance of the electricity component in the DA end user estimates. The use of electricity for heating, lighting and operating equipment has a marked effect on the emissions attributed to this sector, when compared to the emissions in the by source inventories which only include estimates from direct fuel use in the sector, which are likely to be predominantly from operating boilers for heating.

The magnitude of the public sector estimates within each DA end user inventory in 2007 is quite low across the UK, ranging from 2.2% in Northern Ireland, 2.9% in Wales, 3.3% in Scotland up to 3.4% in England.

The 1990 electricity estimates in particular are uncertain, and the trends are therefore subject to high uncertainty, but there is a notably much higher reported reduction in emissions in the Northern Ireland public sector, where emissions are estimated to have declined by over 60% since 1990. Although the absolute level of this decline may be subject to uncertainty, it is likely that it reflects the shift in fuel mix due to the growth of the gas network in Northern Ireland since 1999, and the resultant move away from more carbon-intensive fuels for both direct heating and electricity generation.

3.2.4 Road Transport

The outputs from the DA end user model are summarised below:

Table 3.2.4 Road Transport DA End Users Data: 1990, 2003-2007

End Users Emissions (kt CO_2-e)		1990	2003	2004	2005	2006	2007
Road Transport	England	111,777	125,324	125,575	126,014	122,288	123,393
Road Transport	Scotland	11,119	12,297	12,344	12,429	12,205	12,488
Road Transport	Wales	6,791	7,476	7,566	7,598	7,456	7,590
Road Transport	Northern Ireland	3,943	5,887	5,772	5,814	5,772	5,908

DA % of End User Emissions		1990	2003	2004	2005	2006	2007
Road Transport	England	83.6%	83.0%	83.0%	83.0%	82.8%	82.6%
Road Transport	Scotland	8.3%	8.1%	8.2%	8.2%	8.3%	8.4%
Road Transport	Wales	5.1%	5.0%	5.0%	5.0%	5.0%	5.1%
Road Transport	Northern Ireland	3.0%	3.9%	3.8%	3.8%	3.9%	4.0%

End Users / By Source		1990	2003	2004	2005	2006	2007
Road Transport	England	120%	126%	125%	125%	122%	122%
Road Transport	Scotland	120%	126%	125%	125%	122%	122%
Road Transport	Wales	120%	126%	125%	125%	122%	122%
Road Transport	Northern Ireland	120%	126%	125%	125%	121%	122%

In many end user sectors, the fuel mix within each DA will vary and hence the impact of the end users methodology will also vary quite markedly as the additional emissions associated with different fuel groups combine to derive the total end user estimate. This is reflected in the range of percentage increases from by source to end user estimates in the tables shown above for the commercial, domestic and public sectors, where all primary fuels and electricity are used throughout the UK.

In the road transport sector, however, all of the fuels used are derived from petroleum processing, and hence the effects of the end user method can be seen in isolation for the petroleum sector from the data above. In each year, the end user emissions for all DAs are around 120 to 126% higher than the by source estimates. This increment is a slight over-estimate, as the majority of the upstream oil and gas processing emissions from offshore sources are allocated to petroleum processing within the end users method due to lack of detailed data (whilst gas consumption carries forward a slight under-estimate in the end users methodology).

Despite this methodological limitation, the end user estimates for the road transport sectors are associated with lower uncertainty than for many sectors, due to the good quality of the DA-specific by source inventory estimates. The percentage increment in the end user emissions compared to the by source estimates is also reflected in several other less significant source sectors where petroleum-derived fuels dominate, including aviation, shipping and military transport.

Across all DAs, the road transport sector is another large emission source in the end user GHG inventories; in England, Scotland and Northern Ireland in 2007, the road transport sector comprised around 24-25% of the end user inventory total, whilst in Wales the road transport sector is estimated at 18% of the end use inventory total due to the greater influence of the iron and steel and industrial emissions in Wales compared to other DAs.

The reported trends in the road transport sector since 1990 show that in Great Britain the end emissions from the sector have increased by between 10-12%, whilst the growth in road transport emissions in Northern Ireland is marked, rising to 50% since 1990.

3.2.5 Industrial Combustion

The outputs from the DA end user model are summarised below:

Table 3.2.5 Industrial Combustion DA End Users Data: 1990, 2003-2007

End Users Emissions (kt CO_2-e)		1990	2003	2004	2005	2006	2007
Industry Other Combustion	England	114,796	92,282	91,390	93,280	91,661	89,421
Industry Other Combustion	Scotland	10,542	9,776	9,115	8,753	9,228	8,488
Industry Other Combustion	Wales	8,967	5,185	5,297	5,392	4,995	4,727
Industry Other Combustion	Northern Ireland	3,279	2,780	2,601	2,549	2,720	2,812

DA % of End User Emissions		1990	2003	2004	2005	2006	2007
Industry Other Combustion	England	83.4%	83.9%	84.3%	84.8%	84.4%	84.8%
Industry Other Combustion	Scotland	7.7%	8.9%	8.4%	8.0%	8.5%	8.0%
Industry Other Combustion	Wales	6.5%	4.7%	4.9%	4.9%	4.6%	4.5%
Industry Other Combustion	Northern Ireland	2.4%	2.5%	2.4%	2.3%	2.5%	2.7%

End Users / By Source		1990	2003	2004	2005	2006	2007
Industry Other Combustion	England	236%	207%	214%	217%	223%	227%
Industry Other Combustion	Scotland	193%	196%	189%	167%	185%	185%
Industry Other Combustion	Wales	204%	167%	153%	166%	172%	178%
Industry Other Combustion	Northern Ireland	217%	314%	292%	260%	294%	322%

The percentage increase in the end users data compared to the by source data indicates the high contribution of the electricity component in the DA end user estimates. The use of electricity for heating, lighting and operating equipment has a marked effect on the emissions attributed to this sector.

The significance of the industrial combustion estimates within each DA end user inventory in 2007 is quite variable, ranging from 11% in Northern Ireland and Wales, to 17% in Scotland and England.

This sector is another large emission source across all DAs, and the reported trends show that since 1990:

- England emissions have declined by 22%
- Scotland emissions have declined by 19%
- Wales emissions have declined by 47%
- Northern Ireland emissions have declined by 14%

Note however that this sector is perhaps the most difficult to analyse with certainty, partly due to the variable mixture of fuels used within each DA in this sector, but also due to the underlying methodology whereby the other industry electricity estimates are used to balance the total DA electricity consumption data. Where other sector estimates are based on limited economic indicator data or other proxy information, the total electricity use in each DA is known to a greater level of certainty across all years. Therefore, the inventory method uses this category as the balance between the sum of the other sectors and the reported DA total. More research is needed to reduce the uncertainties in sector electricity data across the DAs, especially for 1990, and this will all impact upon the estimates for this sector.

3.2.6 Other Significant Source Sectors

There are several other source sectors in the end user DA inventories that are summarised here:

- Industrial process emissions in the 2007 end user inventories account for 3.2% of Scottish emissions, 4.4% of Welsh emissions, 4.5% of Northern Irish emissions and 4.7% of English emissions. The end user estimates are only slightly higher than the by source estimates, typically estimated at around 105-110% of the by source emissions due to a small allocation of electricity use to the sector. The reported trends since 1990 are therefore very similar to those from the by source inventories, with estimated reductions of 61% in England, 33% in Scotland, 18% in Wales and 25% in Northern Ireland.

- Iron and steel industry emissions in the 2007 end user inventories account for 22% of the emissions in Wales and 3% of emissions in England. Compared to the by source emissions, the end users data are around 30% higher. Electricity use data for the sector are derived from regional data provided by ISSB for 2003 onwards and production estimates in 1990. Recent trends are therefore associated with low uncertainty, whilst the trends since 1990 are less certain. Since 1990, emissions in Wales have declined by 18%, emissions in England have declined by 21% and in Scotland have declined by almost 100% due to the closure of the Ravenscraig steelworks in 1992, which leaves only a handful of small secondary processing sites still operating in Scotland.

- Agriculture emissions in the 2007 end user inventories account for 16% of Scottish emissions, 13% of Welsh emissions, 22% of Northern Irish emissions and only 6% of English emissions. The end user estimates are only slightly higher than the by source estimates, typically estimated at around 105-108% of the by source emissions due to a small allocation of electricity use to the sector. The reported trends since 1990 are therefore very similar to those from the by source inventories, with estimated reductions of 24% in England, 20% in Scotland, 19% in Wales and 12% in Northern Ireland.

- The end user estimates for the waste sector and for the land use, land use change and forestry sources and sinks are all unchanged within the end user inventories, and are directly allocated from the by source GHG inventories with no additional emissions from the end user methodology. No allocation of electricity use to these industries has been made.

3.3 Data Uncertainties and Recommendations for Future Research

The uncertainties in the end user GHG inventories stem from several sources:

- **Uncertainty in the underlying data of direct fuel consumption patterns within the UK.** The by source emission inventory data for the DAs are the starting point for the end user inventory analysis, and there is significant uncertainty in the accuracy of fuel use patterns within the UK across the 1990-2007 time series, at the DA-specific, source-specific level. The uncertainties from the by source data compilation method are brought forward to this analysis of end user estimates. The sources of uncertainty in these source data stem primarily from a lack of detailed DA-specific activity data and are discussed in detail within the recent DA by source GHG inventory report, "*Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland 1990-2007*" (AEA, 2009). Further work is therefore recommended to improve DA-specific energy production and consumption data across all fuels, aimed at the delivery of complete and detailed energy balance information for England, Scotland, Wales and Northern Ireland. Research to develop more accurate energy data for the DAs is planned via the improvement programme for the UK and DA inventories.

- **Lack of inter-DA import-export data, for both primary and secondary fuels.** Within the periodic Energy Trends publication, DECC publish electricity import-export data between England, Scotland, Wales, Northern Ireland and Europe (France and the Republic of Ireland), and these data are available from 2003 onwards but not for the whole time series back to 1990. These data are pivotal to the end user analysis, as the emissions from the power stations constitute around 75% of all energy sector emissions that must be re-allocated in the end user method. However, there are no equivalent comprehensive and consistent inter-DA fuel import-export data for fuels such as refined oils, gases and solid fuels. As a result, the re-distribution of emissions from the extraction, processing and delivery of these fuels to end users within the DAs must make best use of limited available data and rely on additional assumptions to estimate the tracking of fuel transfers between DAs. At the DA-level, there are data estimates for total fuel consumed, and emission estimates from fuel processing / refining / transformation processes. Comparing these two datasets enables a preliminary estimate of the inter-DA fuel transfers, but the analysis relies upon assumptions of UK-average emissions per unit production of fuels, which infers UK-average plant utilisation and efficiency. Further research to derive more DA-specific data on fuel transformation industry outputs and the development of better data to track fuel imports and exports (both within the UK and directly to the DAs from outside of the UK) is recommended. To reduce the uncertainties in the DA end user model outputs, more information is needed on the production of refined fuels (petroleum fuels from refineries, solid fuel from collieries, gas production) and the transfers around the UK to point of consumption.

- **Limited data on electricity consumption and generation at DA-level for 1990.** For recent years, DECC publish estimates of electricity generation and inter-DA electricity imports and exports, but these data are not available for the early part of the time series. The end user emission estimates for 1990 presented in this report are based on analysis of available data from publications in the early 1990s on electricity generation (Electricity Supply Handbook 1991) and consumption (DUKES 1991) by regional electricity companies. Complete data for 1990 have not been found, and the results presented for 1990 are therefore associated with high uncertainty; the DA end user GHG emission estimates for 1990 are regarded as experimental data and indicative only. Previous studies have been identified that provide estimates of electricity consumption by sector that are based on available proxy data such as economic indicators (i.e. regional sector GVA), and these have been used to estimate the 1990 sector electricity consumption data where data gaps are evident. The scope for further research into deriving better data for 1990 is unclear, especially due to the significant re-structuring of the industry in the intervening years, but further research into other literature sources may provide some additional data.

- **Limited data on electricity consumption by sector at DA-level across the time series.** The DECC Regional Energy Statistics (DECC, 2008b) present a limited sector breakdown of electricity use within each DA. In order to calculate end user sector emission estimates at DA-level to the same level of detail as those presented for the UK, additional data are needed to supplement the DECC Regional Energy Statistics. Research for this study has identified several useful supplementary data sources to enable disaggregation of UK sector electricity consumption data across the four DAs. However, there is some degree of uncertainty regarding the scope and accuracy of the DA-specific estimates of sector electricity use. For several sectors that are high priorities for DA Government policy development (e.g. the public and commercial sectors), proxy data such as employment statistics and economic activity indicators (GVA) have been used as the best available data to estimate the DA share of UK sector electricity consumption. Further work to develop more sector-specific, DA-specific electricity consumption data are recommended, although such work is likely to be limited due to issues of commercial confidentiality. Ongoing research by DECC may deliver such improvements for recent years.

- **Combined data for emissions from the offshore exploration and production data for oil and gas.** The emissions data from offshore oil and gas sector emissions are reported together via the DECC Oil and Gas Environmental Emissions Monitoring System (EEMS). There are no separate emission estimates from the upstream gas and oil production processes, and hence the offshore emissions cannot be allocated accurately across end users of natural gas and

petroleum products. Some oil and gas processes are aligned specifically to the gas industry, and emissions from these processes have been allocated accordingly. For most other oil & gas sector processes, the emissions have been allocated within the end users model to petroleum fuel users. This will introduce some degree of error to the final estimates, as the patterns of gas and oil use will differ between DAs and across sectors. Through consultation with the oil and gas industry and regulators, it may be possible to derive more detailed emission allocations to the (i) oil and (ii) gas industries from the emissions reported by the upstream extraction and production sector. Currently there is limited detailed information on these emissions sources and how to best allocate the energy sector emissions equitably amongst end users of refined oils and gaseous fuels.

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