



Institute for Sustainability,
Health and Environment

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Evaluation Methods for CO₂

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Joint CATCH Interest Group &
Polis Environmental & Health Working Group Meeting

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University of the
West of England

bettertogether

Presentation Overview

- International policy context
- International targets: where they come from and what they mean
- Why city-scale carbon management?
- Estimating carbon emissions: how and why
- Transport emission estimation methodologies
- Principles of emission estimation
- What this means for meeting targets
- Conclusions



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International policy context

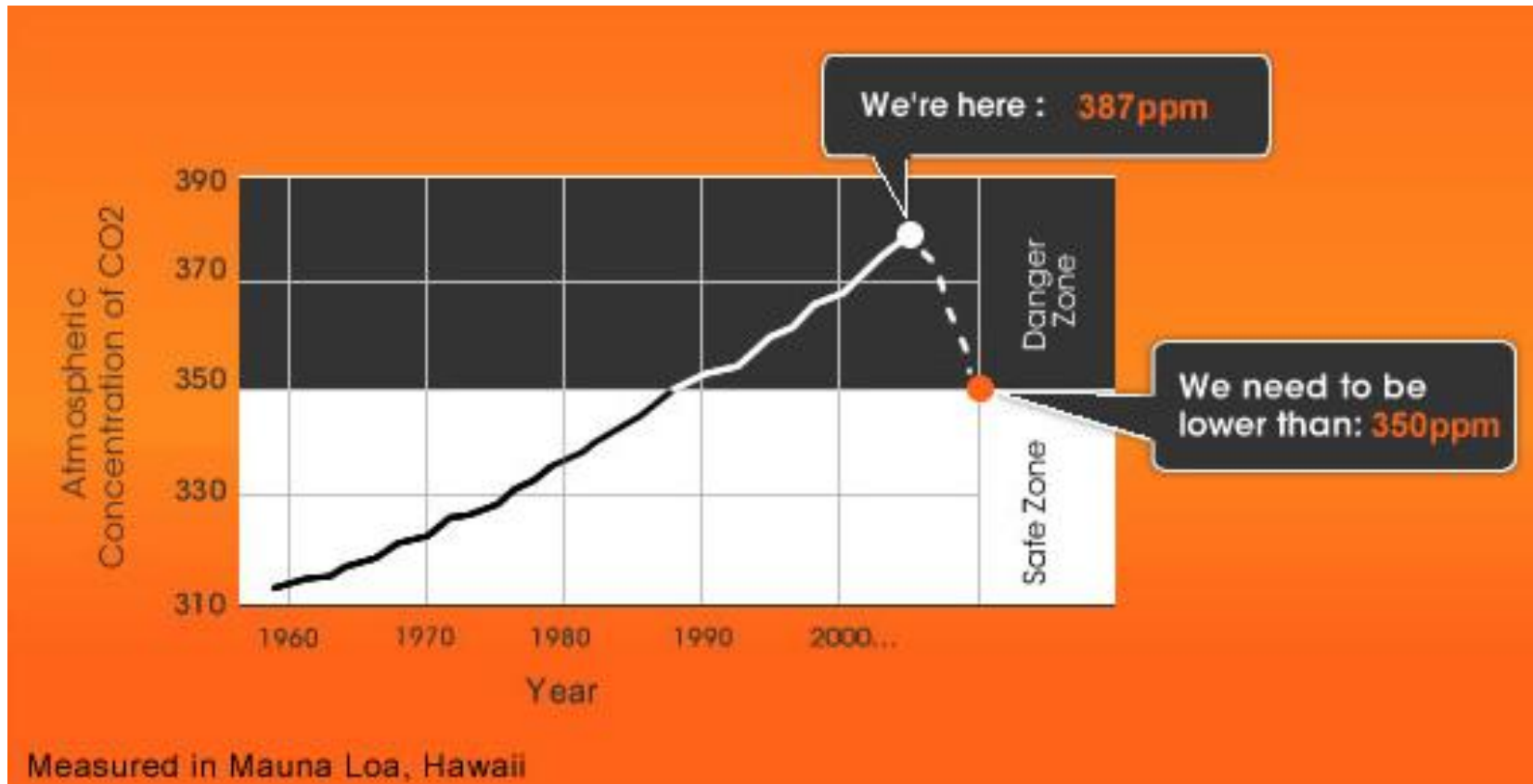


- 1992: United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature at the Rio Earth Summit.
1994: Entered into force.
- “Common but differentiated responsibility”.
- No binding targets, timetables or powers: few countries made any effort to meet targets.
- Recognised stronger agreement needed: 1997 Kyoto Protocol
 - Aimed to reduce emissions of a basket of 6 greenhouse gases (GHG) over the commitment period 2008-12.
 - *Legally binding* targets set for 37 industrialized countries and the European Community
 - EU-15 ‘burden sharing’ arrangement -8%
- 2005: entered into force.
- Dec 2009: Copenhagen Accord – recognizes the scientific case for keeping temperature rises below 2°C, but does not contain commitments for reduced emissions that would be necessary to achieve that aim.
- Dec 2010: Mexico...?

Emission reduction targets

- Current position:
 - **50% reduction in global emissions** by 2050 to limit warming to 2 degrees.
 - Peak 2016, reduce 3-4% per year: 3% = 2.2 degrees; 4% = 2.1 degrees.
 - **Equivalent to 80% in West.**
- The international response is not compatible with the latest science:
 - Level of CO₂ in atmosphere currently at 387ppm (NASA).
 - James Hansen: CO₂ will need to be reduced to at most 350ppm.
 - To limit warming to 2 degrees (46% chance), emissions need to stabilise at a maximum of 450ppm CO₂e. Global emissions must peak by 2015, then fall 6-8% a year from 2020-40, leading to “full decarbonization sometime soon after 2050” (Anderson and Bows, 2008)
 - The peak year will influence the trajectory: late and steep/early and shallow
 - Current policies will not deliver 450ppm: stabilisation much below 650ppm is improbable
- CURRENT AGREEMENTS HEADING FOR 750ppm

CO₂ in the atmosphere



<http://www.350.org/>

EU Directives and Targets identified

- The Directive **2003/87/CE** establishes a scheme for greenhouse gas emission allowance trading within the Community (hereinafter referred to as the 'Community scheme') in order to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner.
- The Directive **2004/101/CE** Linking the Kyoto project-based mechanisms to the Community scheme, while safeguarding the latter's environmental integrity, gives the opportunity to use emission credits generated through project activities
- The Directive **2004/156/CE** provides the guide lines for monitoring and the communication of GHG emissions coming from activities.
- The Directive **2007/589/CE** establishes guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC.

Greenhouse gas emissions reduction targets for 2020

- *The European Union has formalized its support for the Copenhagen Accord on climate change and presented its commitments for emission reduction targets.*
- *These consist of a unilateral commitment to reduce the EU's overall emissions by **20% of 1990 levels** and a conditional offer to increase this cut to 30% provided that other major emitters agree to take on their fair share of a global reduction effort.*



EU-27 CO₂: % change 1990-2007

Total emissions (sectors 1-7, excluding 5. LULUCF)

International maritime transport

International aviation

6. Waste

4. Agriculture

3. Solvent and Other Product Use

2. Industrial Processes

1.B. Fugitive Emissions from Fuels

1.A.5. Other (Not elsewhere specified)

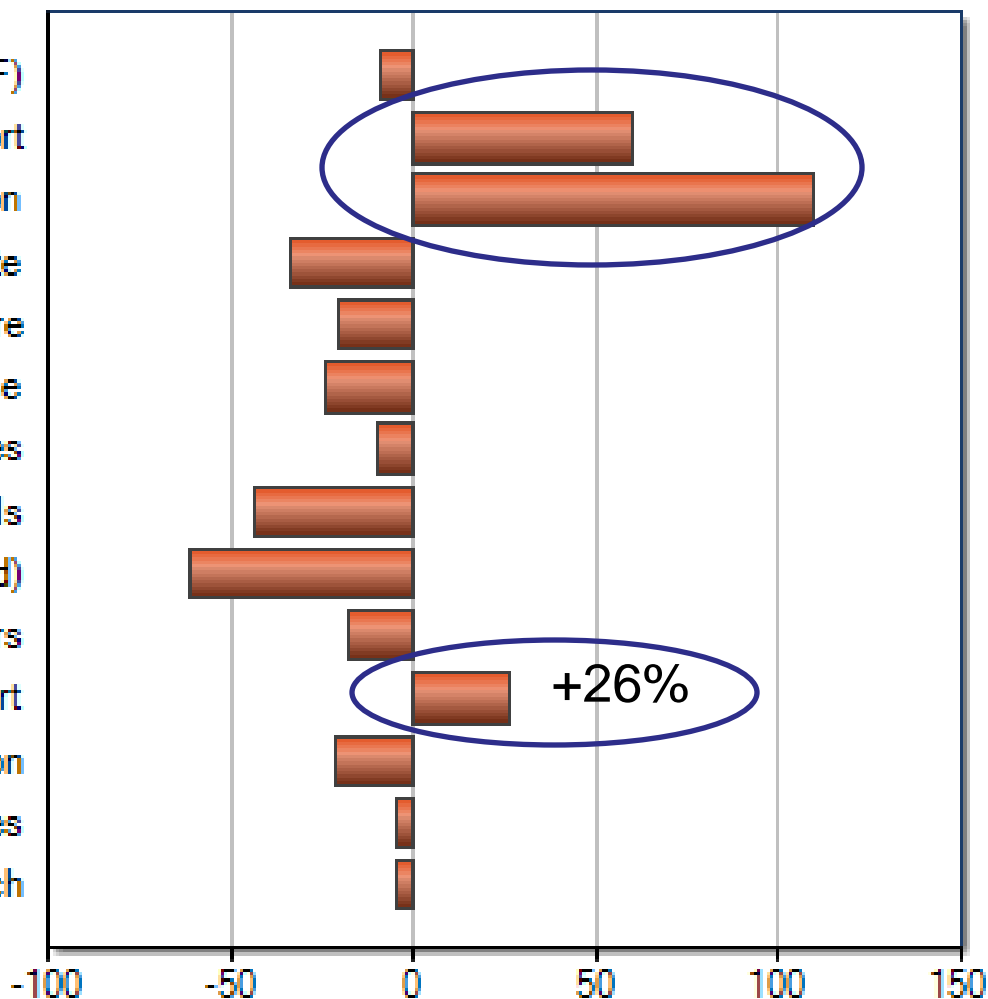
1.A.4. Other Sectors

1.A.3. Transport

1.A.2. Manufacturing Industries and Construction

1.A.1. Energy Industries

1.A. Fuel Combustion - Sectoral Approach



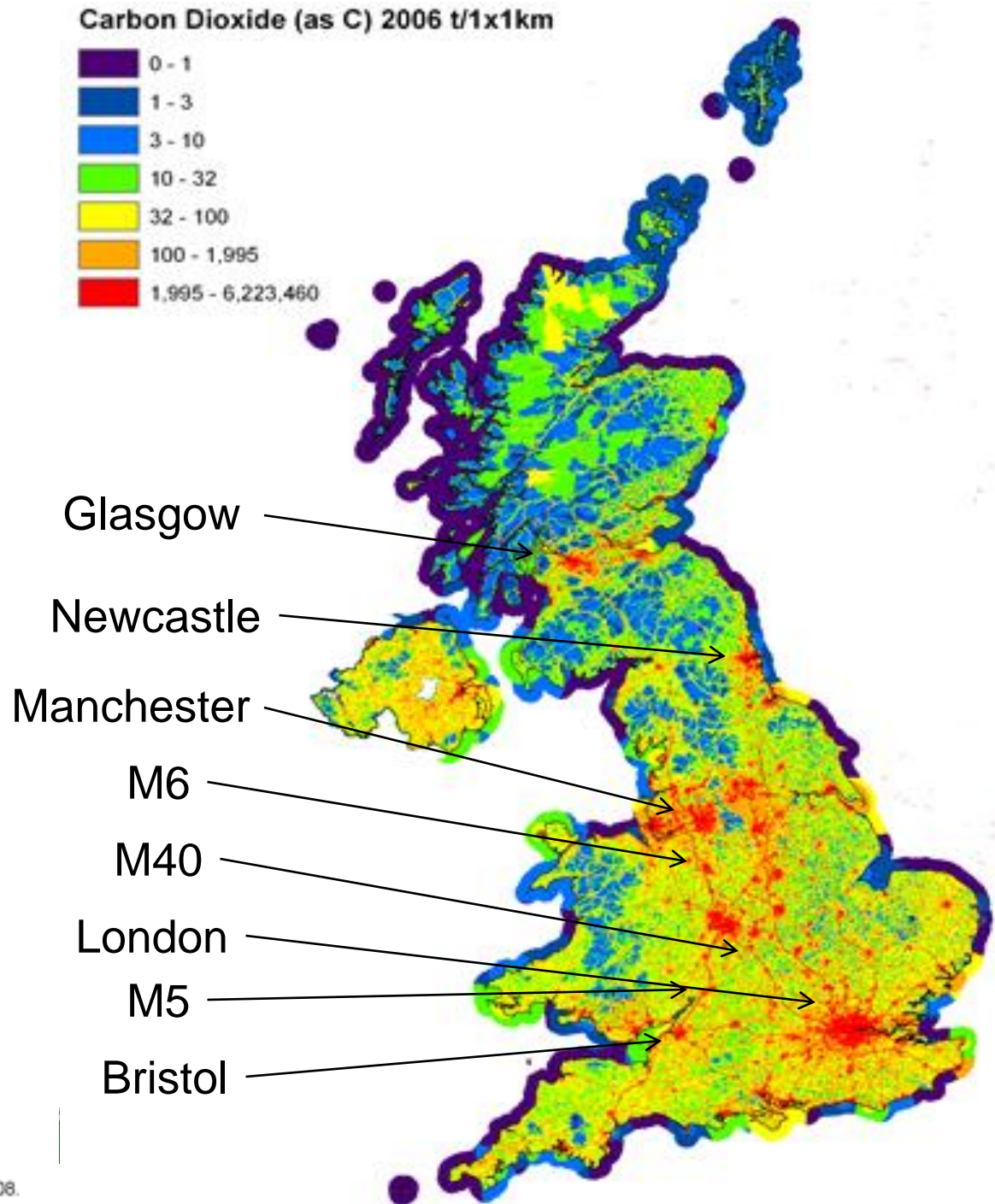
<http://dataservice.eea.europa.eu/>

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Cities and carbon emissions

- Clear spatial concentration in cities and along major roads



Managing a city's carbon emissions

- To monitor, prioritise and reduce CO₂ emissions requires an understanding of where it is coming from and how much is emitted: the 'carbon footprint'.
- Allows us to project and assess the impact of local decision-making.
- But, *"Our understanding of [greenhouse gas] emissions at the level of... cities, urban agglomerations and their surrounding and interconnected regions is still in its infancy"* (Dhakal, 2008).
- **No standardised city-scale methodology** (Kennedy *et al.*, 2009; Bastianoni *et al.*, 2004; Satterthwaite, 2008)
- ICLEI; World Resources Institute Greenhouse Gas Protocol; Greenhouse Gas Regional Inventory Protocol (GRIP - Manchester University); individual approaches...



Estimating carbon emissions

- IPCC Guidelines for National Greenhouse Gas Inventories:
 - Internationally agreed methodology intended for use by countries to estimate greenhouse gas emissions to report to the UNFCCC, under the Kyoto Protocol.
 - The most widely used methodology for estimating greenhouse gas emissions at the country level.
 - Requires reporting on all greenhouse gases (so not just CO₂).
 - Includes all *anthropogenic* emissions and removals, based on national territories, including overseas territories that have ratified the Kyoto Protocol.
 - Uses the calendar year to produce a consistent time series.
 - Reported in a standardised emissions table with a written report, making it consistent across countries.
- City emission estimates generally based on IPCC methodology.

2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Japan: IGES.

<http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html>

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Emission reporting sectors



ENERGY



INDUSTRIAL
PROCESS AND
PRODUCT USE



AGRICULTURE,
FORESTRY AND
OTHER LAND USE



WASTE

e.g. Indirect
emissions

OTHER

- GHG emission and removal estimates are divided into five main sectors, which are groupings of related processes, sources and sinks.
- Transport included in 'Energy': fuel sales data.
- Each sector comprises individual categories (e.g. transport fuel) and sub-categories (e.g. cars).
- Emissions from fuel use in ships and aircraft engaged in international transport is not included in national totals, but is reported separately.

Emission source types

- *Point sources* - emission estimates are provided on an individual plant or emission outlet (usually large), usually in conjunction with data on location, capacity or throughput, operating conditions etc.
- *Area sources* - smaller or more diffuse sources of pollution are provided on an area basis either for administrative areas, such as counties, regions etc, or for regular grids (for example 50x50 km grids).
- *Line sources* - in some inventories, vehicle emissions from road transport, railways, inland navigation, shipping or aviation etc are provided for sections along the line of the road, railway-track, sea-lane etc.



Carbon, CO₂, CO₂e

- Reporting emissions can take several different forms, and it is often unclear or confusing what is being reported
- Emissions can be reported as amounts of:
 - carbon dioxide (CO₂)
 - carbon (C)
 - carbon dioxide equivalent (CO₂e).

GWP is the Global Warming Potential of the greenhouse gas: The GWP of a gas is its ability to absorb or trap heat, compared to CO₂.

tonnes C x 44/12 = tonnes CO₂
tonnes CO₂ / 44/12 = tonnes C
tonnes GHG x GWP = tonnes CO₂e.

- CO₂e reporting includes of the basket of greenhouse gases.

Gas	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFCs	140-11,700
PFCs	6,500-9,200
SF6	23,900

Emission factors

Emission = Activity x Emission Factor (IPCC, 2006)

- This simple equation is used, for instance, for calculating energy sector fuel emissions (emission = amount of fuel used x emission factor of fuel).
- Derived from measurements of a number of sources, representative of a particular source sector.
- Examples:
 - the amount in tonnes of CO₂ emitted per kilometre from a certain size vehicle.
 - the amount in tonnes of CO₂ emitted from a power station per tonne of coal burned.
- Information comes from government departments, trade associations, research institutes, energy suppliers...
- IPCC also provides standardized emission factors for tier 1 (most basic level) reporting.



Unlimited complexity!

- **Activity:** amount of fuel used, or distance travelled
- **Emission factor:** affected by a number of variables.
Estimates often use IPCC factors, or country/region-specific

- vehicle type
- fuel
- age
- engine size
- engine efficiency
- catalytic converters
- speed
- load
- tyre pressure
- air conditioning
- open windows
- driving style

basic

detailed

extensive!



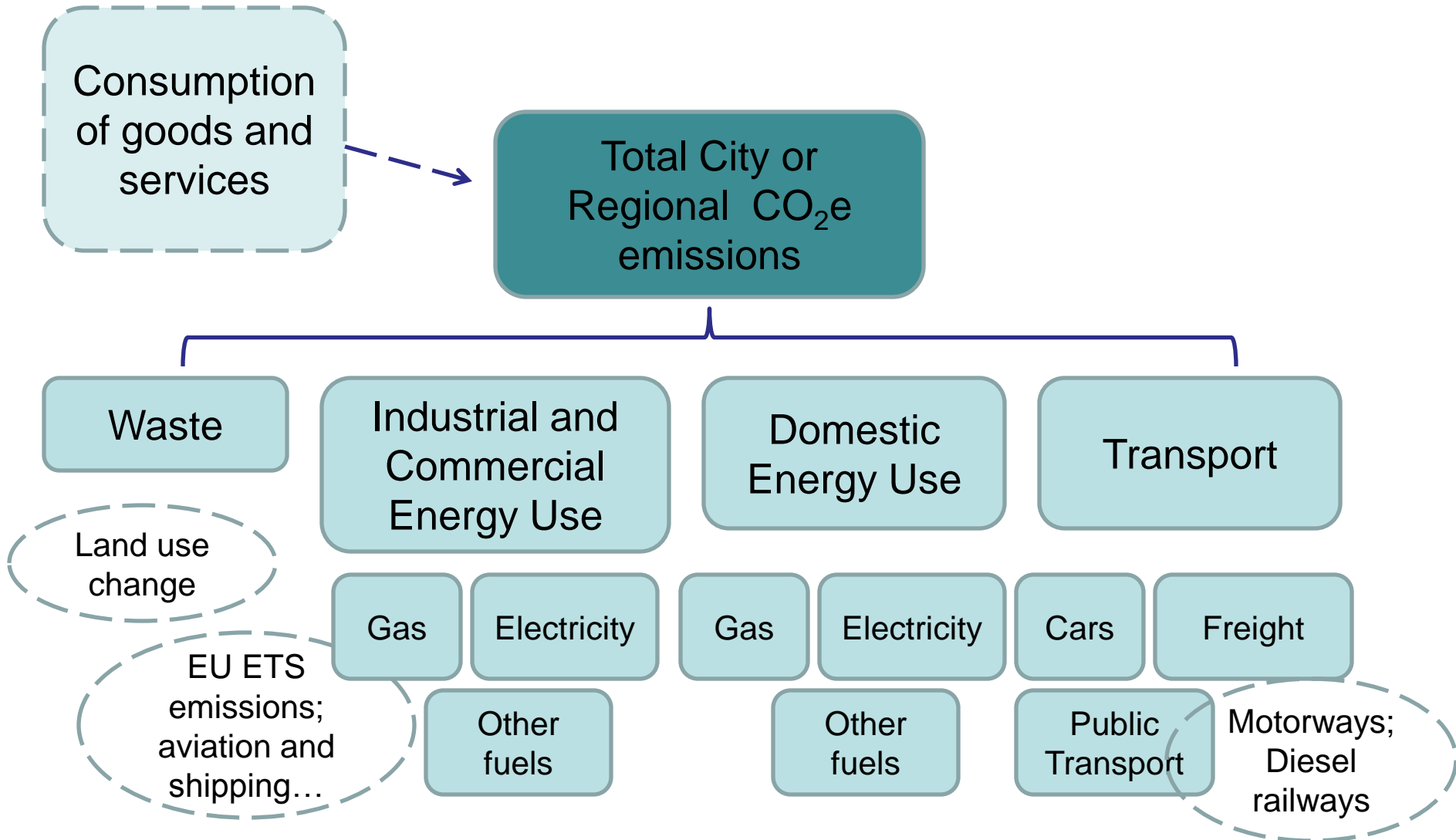
Estimating carbon emissions for whole sectors or regions *accurately* is therefore extremely complex! But what level of complexity is required? Many different methodologies available with varying assumptions and levels of detail.

Emission Inventories

- Emission estimates are often collected together into an **inventory** which usually also contain supporting information on:
 - locations of the sources
 - emission measurements where available
 - emission factors and their source
 - capacity, production or activity rates
 - operating conditions
 - methods of measurement or estimation
(UNECE/EMEP, 2007)
- By summing all the emissions categories, a total emission can be estimated
- Example inventories:
 - World: **IPCC/UNFCCC** methodology for Kyoto targets
 - Europe: **CORINAIR** methodology for reporting a variety of air pollutants to the European Environment Agency
 - UK-wide: National Atmospheric Emissions Inventory (**NAEI**) reports on air pollutants, and the UK Greenhouse Gas Inventory (**GHGI**) on CO₂
 - Regional: '**Local and Regional CO₂ Emissions Estimates**,' from UK Department of Energy and Climate Change

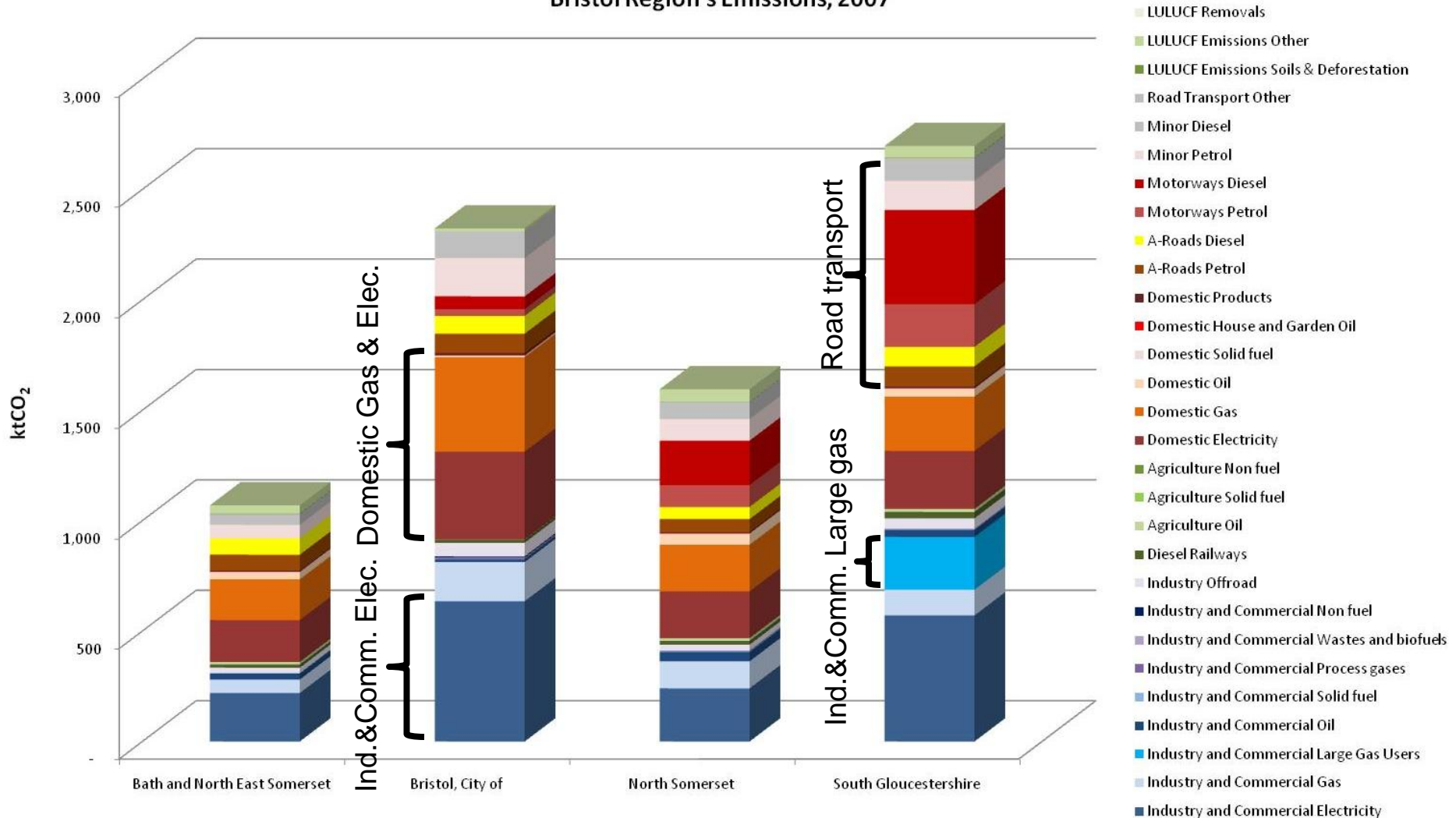


A city-region emission inventory



Local CO₂ emission profile

Bristol Region's Emissions, 2007

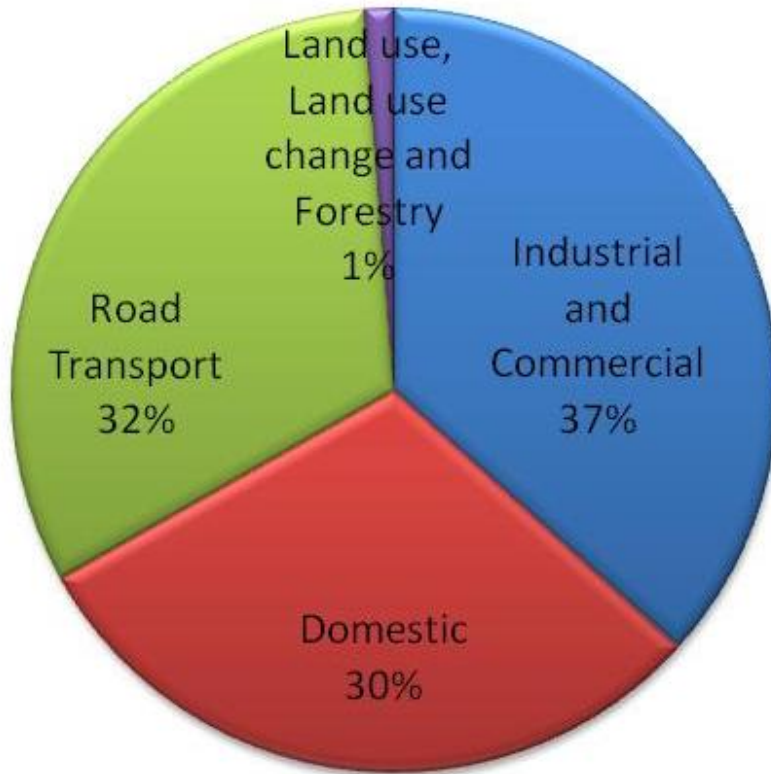


From AEA/Defra Local and Regional CO₂ Emissions Estimates for 2005-2006. Available at

<http://www.defra.gov.uk/environment/statistics/globalatmos/download/regionalrpt/local-regionalco2emissions05-06.xls>

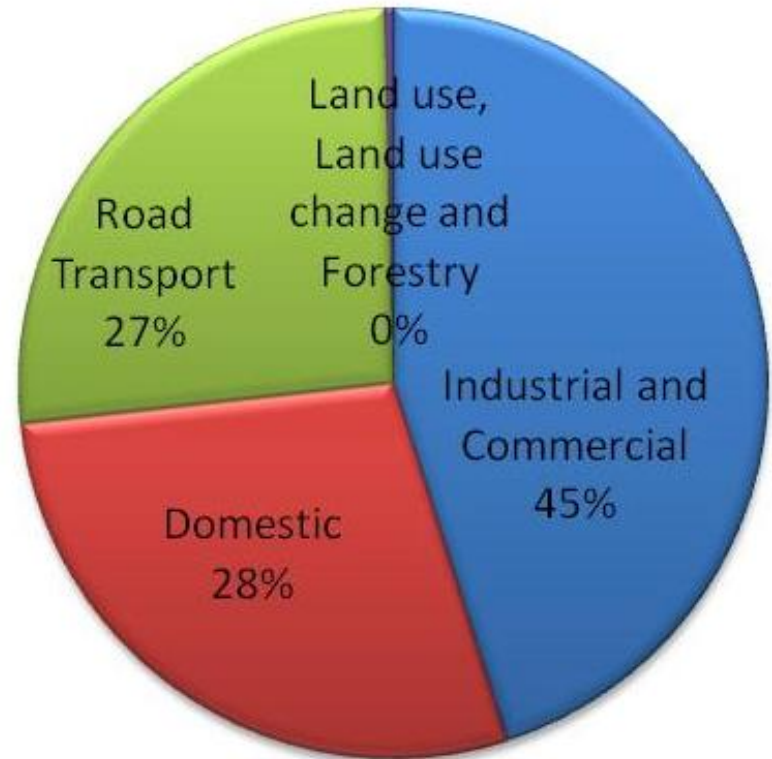
Comparisons

Bristol City Region



Total emissions
7,611,000 tonnes CO₂

United Kingdom

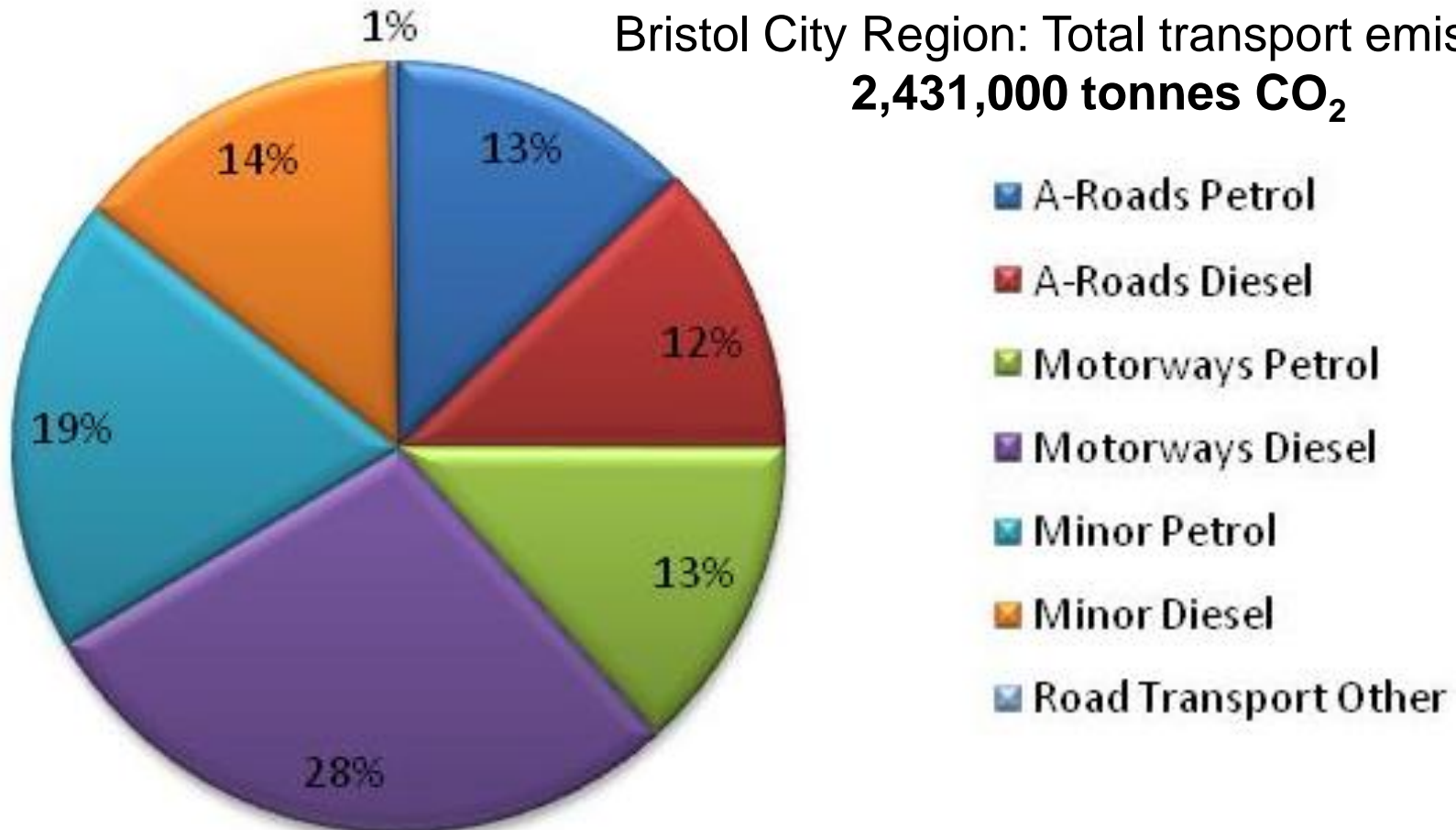


Total emissions
513,215,570 tonnes CO₂

From AEA/Defra Local and Regional CO₂ Emissions Estimates for 2005-2007. Available at <http://www.defra.gov.uk/environment/statistics/globalatmos/download/regionalrpt/local-regionalco2emissions05-06.xls>

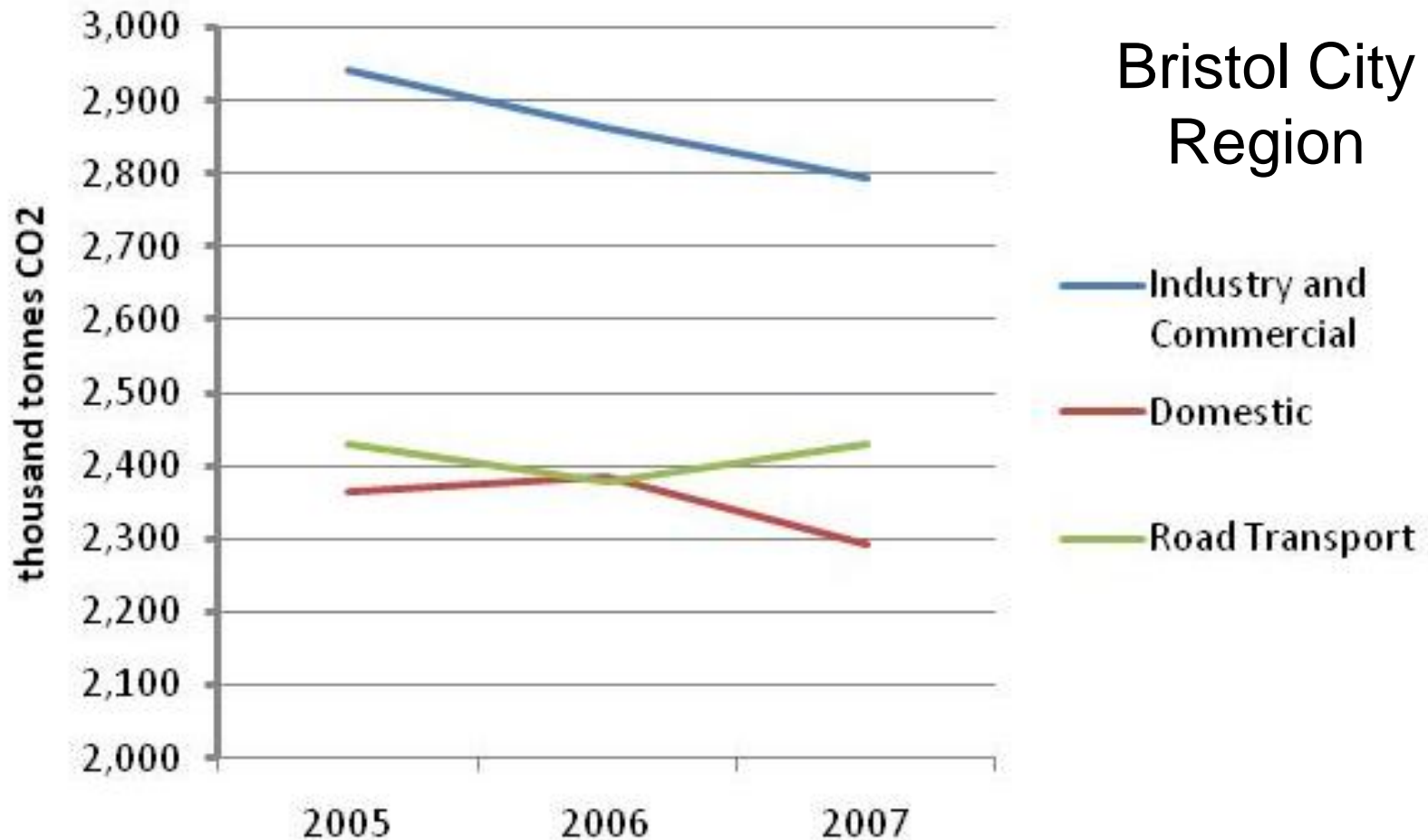
Detailed sector split

Bristol City Region: Total transport emissions
2,431,000 tonnes CO₂



From AEA/Defra Local and Regional CO₂ Emissions Estimates for 2005-2007. Available at
<http://www.defra.gov.uk/environment/statistics/globalatmos/download/regionalrpt/local-regionalco2emissions05-06.xls>

Changes over time



From AEA/Defra Local and Regional CO₂ Emissions Estimates for 2005-2007. Available at

<http://www.defra.gov.uk/environment/statistics/globalatmos/download/regionalrpt/local-regionalco2emissions05-06.xls>

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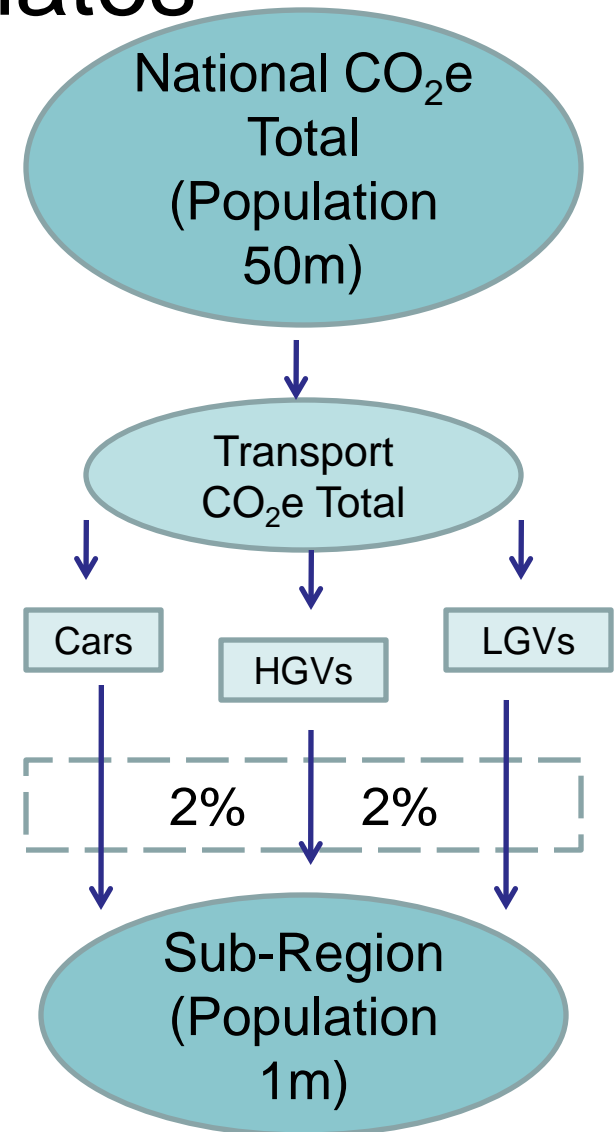
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Local transport emission estimates

- National transport emission estimates based on fuel consumption data (included within 'energy' category of UNFCCC inventories).
- No standard city-scale or sub-regional emission estimation methodology.
- Transport emissions are difficult to estimate as they do not have fixed meters and fuel sources like electricity or gas.
- They have to be modelled using a series of assumptions.
- No modelling is perfect!
- 3 ways to estimate transport emissions:
 1. Top-down pro-rata allocation
 2. Hybrid method using local data
 3. Bottom-up aggregation

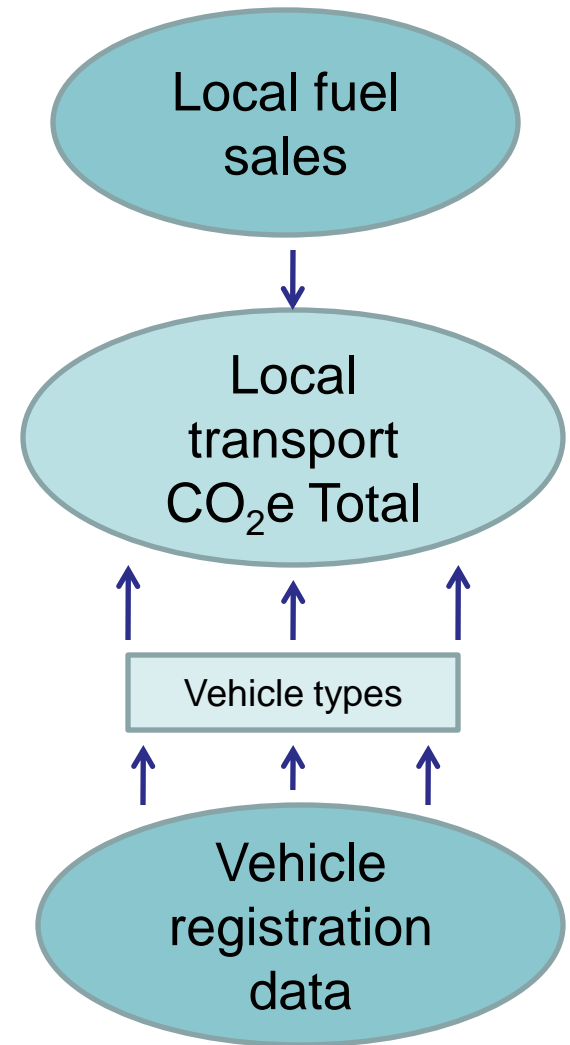
1. Top-down estimates

- This involves taking a national emission total and disaggregating to the local scale.
- Could do this based on population, vehicle registration numbers, fuel sales...
- **Advantages:** relatively simple as national totals exist (UNFCCC and EU reporting); will sum to national total so no issues with discontinuity or double-counting
- **Disadvantages:** does not reflect local circumstances and therefore local policy-making – assumes uniform transport patterns across all regions.



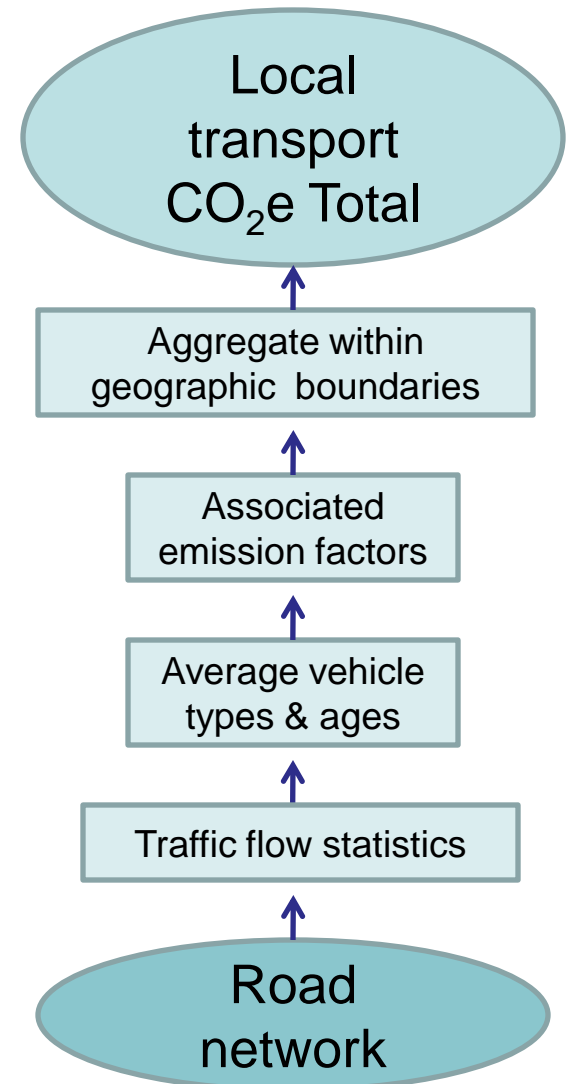
2. Hybrid method with local data

- This involves a hybrid top-down/bottom-up approach, using local data:
 - Fuel sales in local area
 - Vehicle registrations in local area
- **Advantages:** much more locally-specific, based on real data from the city/region – local fleet-composition and fuel sales; potential for locally-specific emission factors if vehicle fleet is known; excludes corridor traffic.
- **Disadvantages:** more time-consuming; requires the data being available; potential issues with double-counting (fuel bought in the region could be driven outside); does not capture spatial distribution of vehicle emissions; does not capture vehicles coming into the region i.e. freight, if not registered there; does not capture fuel tourism – hauliers buying fuel outside the border.



3. Bottom-up aggregation

- This involves an emission calculation based on spatial activity data (Vehicle kms travelled) and assumptions about the vehicle fleet.
- This is the approach used in the UK for local and regional CO₂ estimates.
- IPCC recognises the approach but favours fuel-sales.
- Data required includes:
 - Average annual daily flow statistics by vehicle type at points in road network (junctions etc.)
 - Knowledge of road network, and important links to estimate distances travelled
 - Average speeds across network
 - Vehicle fleet composition, by type, and age (Euro emission standard as a proxy), with associated average emission factors



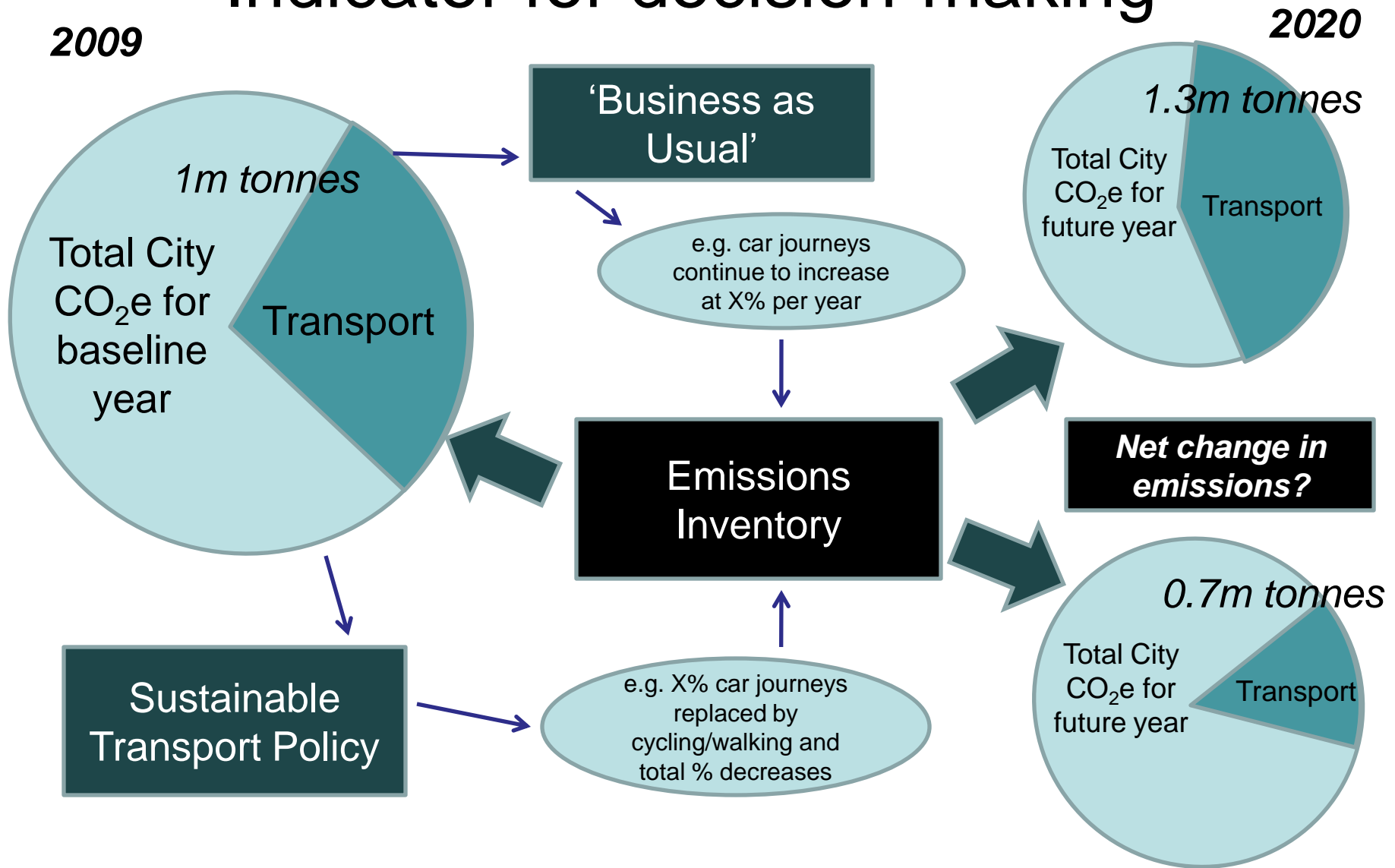
3. Bottom-up aggregation (2)

- Method:
 - Daily flow statistics for road network points are used to estimate vehicle kms for each road link (regional averages for minor roads).
 - Vehicle kilometres for each road link are multiplied by the appropriate emissions factors according to the vehicle types recorded there (age and fuel type is assumed to be the same proportion nationally), and average speed per vehicle type on that road link.
 - Once emissions have been modelled to the road network, it is split out into 1km² grids that can be overlaid with local authority boundaries to distribute the emissions accordingly.
- In the UK dataset, the total UK aggregated emissions using the modelling are now within 3% of those estimated from actual fuel sales.
- **Advantages:** MUCH more locally-specific, based on real data on travelling within the city/region; gives the spatial distribution of emissions; matches fuel sales data quite closely; takes account of vehicle variables and road speeds; includes 'fuel tourism'
- **Disadvantages:** more time-consuming; requires the data being available; the composition of the vehicle fleet is assumed to be consistent across the country; traffic statistics for minor roads are all estimated – particularly a problem for uncertainty in rural areas; does not consider corridor traffic as opposed to resident traffic, so may wrongly allocate 'passing through' emissions, e.g. motorways

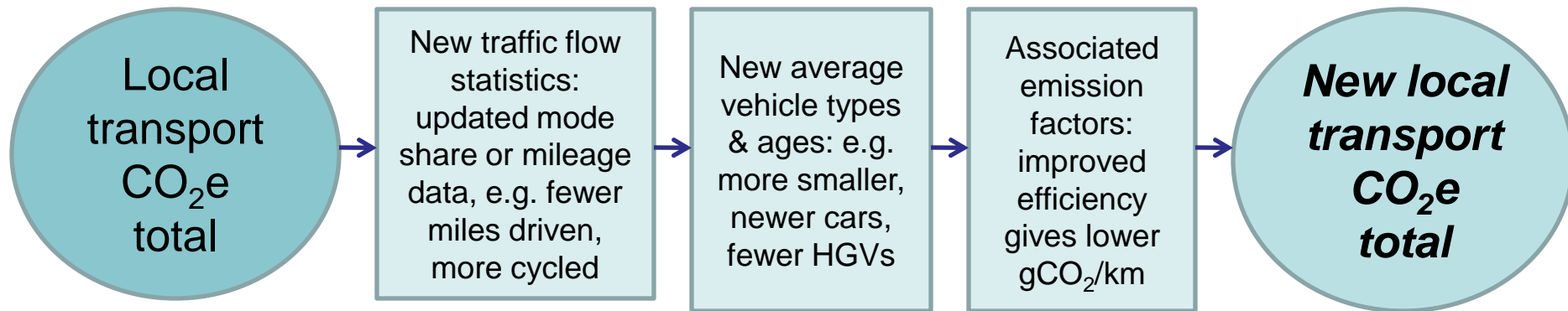
Principles of emissions estimation

- Transparency of assumptions
- Clear boundaries (geographic, sources, sectors)
- Inclusion of all sources within defined categories and boundaries
- Consistency in measurement and reporting (between years, gases and categories)
- Replicability
- Accuracy (including an uncertainty assessment)
- Appropriate and transparent choice or calculation of emission factors and units (C, CO₂, CO₂e)
- ***Comparability (within and between cities, regions, countries)***

Indicator for decision-making



Setting and meeting targets



- A simple process of re-running calculations using new numbers
- Allows us to assess the contribution different policies might make to overall reductions and meeting targets: i.e. whether planned improvements or measures will add up
- Can help set a target by showing what a policy-package adds up to in carbon-terms
- Will show the CO₂ impact of decisions, but only as good as the assumptions put in:
 - can be used to calculate how many fewer car VKMs are required to meet a target, or what the carbon implications of fewer VKMs are, but will not guarantee fewer VKMs!

Projecting emissions: UK transport example

	2008	2020
Number of private cars	27,021,000	35,127,300
Average miles/year/private car	12,000	12,000
gCO ₂ /km (average for all cars in 2008)	146.3	95
gCO ₂ /mile	235.4	152.9
kgCO ₂ /average car/year	2,825.36	1,834.65
Total UK private car tCO ₂	76,344,169	64,446,377
Total UK private car tCO ₂ with 10% biofuel		58,001,739

*Predicted
30%
growth
private
cars*

*Assuming
no
reduction
in mileage*

UK target

52.5% of UK domestic transport emissions from **passenger cars**

Based on above assumptions, passenger car emissions are projected to decrease 24%

This equates to an 13% reduction in total transport CO₂ by 2020

Conclusions

- To monitor, prioritise and reduce CO₂ emissions, and compare performance, requires an understanding of where it is coming from and how much is emitted: an emissions inventory.
- Estimating carbon emissions is complex, and the level of accuracy depends on the detail of available data and the assumptions made.
- Emission inventories are fairly accurate at the National level and there is a lot of guidance available.
- At the local scale, there is no consistent agreed methodology for emissions estimation.
- Transport is a particularly complex sector to estimate. Can be done through fuel sales or VKM. Fuel sales may be more comparable nationally/internationally, but won't capture spatial patterns of transport and actual journeys.
- Carbon emission estimates are only one piece of the sustainability-jigsaw. They are a tool for decision-making, for assessment, monitoring, reporting and prioritisation of actions, but not the whole picture.
- Knowing local transport emissions is useful, but emissions don't tell us why people are travelling, or bring about reductions without supporting policy and action.

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