Methodology for the Generation of UK Emission Factors for Use in the National Calculation Methodologies

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Methodology for the Generation of UK Emission Factors for Use in the National Calculation Methodologies

Executive Summary

This paper describes the methodology used to generate a consistent set of carbon dioxide equivalent emission factors for all significant types of energy used in buildings in the UK, which includes the impact of all significant greenhouse gas (GHG) emissions arising from fuel combustion, at the point of use, and upstream extraction, production and transportation sources.

The methodology has been developed for use with the National Calculation Methodologies (NCMs) for buildings (SAP and SBEM). The emission factors are based on the most recent annual energy use and emissions data available and it is the intention to fix them for the duration of the relevant version of the NCMs. This paper sets out the key principles and describes the calculation procedure.
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1 Introduction

The SAP 2005 emission factors take account of the majority of upstream emission sources (which generally excludes transport emissions) and cover only CO$_2$ emissions and not other greenhouse gases.

This paper describes a revised methodology for generating a consistent set of emission factors for all significant types of energy used in buildings in the UK which includes the impact of all significant greenhouse gases (GHG) and provides more comprehensive coverage of upstream sources. It sets out the key principles, describes the calculation procedures and identifies appropriate data sources.
2 Scope of Greenhouse Gas Emissions

2.1 System boundary

Carbon dioxide equivalent emission factors used for building performance assessments need to reflect the impact of all significant greenhouse gas (GHG) emissions arising upstream along the supply chain as well as emissions arising from combustion at the point of use. This requires the use of a life cycle assessment (LCA) approach to capture the cumulative environmental impact, in terms of CO$_2$eq$^1$, across the relevant product life stages, from extraction of raw materials, through to combustion. This section describes the scope of emission sources included in this revised methodology.

In addition to CO$_2$ from fuel combustion, the key energy related sources of greenhouse gases are:

- methane (CH$_4$) arising from fuel combustion and fugitive emissions from agriculture, fuel production and distribution, and
- nitrous oxide (N$_2$O) from fuel combustion and fertilizer use$^2$.

Although the volume of these gases generated from fuel and power production is generally much smaller than for CO$_2$, they can be significant when measured in terms of CO$_2$eq because their global warming potential is much greater. The global warming potentials used here are based on a 100 year time horizon taken from the most recent IPCC report$^{3,4}$:

<table>
<thead>
<tr>
<th>Greenhouse Gas</th>
<th>CO$_2$</th>
<th>CH$_4$</th>
<th>N$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming Potential</td>
<td>1</td>
<td>25</td>
<td>298</td>
</tr>
</tbody>
</table>

The scope of emission sources includes all upstream emissions of CO$_2$, CH$_4$ and N$_2$O arising:

- directly from the processing itself – **fugitive emissions**, 
- from fuel used during processing and distribution– **direct emissions from fuel combustion**, and
- from electricity used during processing – **emissions from electricity generation (indirect combustion emissions)**

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$^1$ CO$_2$ equivalent, which measures the environmental impact of other greenhouse gases in terms of their global warming potential compared to CO$_2$.

$^2$ This is relevant for fuels from biomass sources where the use of fertilizers results in additional N$_2$O emissions from the soil.

$^3$ Climate Change 2007: The Physical Science Basis: Contribution of Working Group 1 to the Fourth Assessment Report, Intergovernmental Panel on Climate Change.

$^4$ These are slightly different to the earlier IPCC values adopted for reporting under the Kyoto protocol.
The emission factors will therefore include CO$_2$, CH$_4$ and N$_2$O arising from the above sources, which occur during activities that take place within the system boundary shown below.

![Figure 1: System Boundary for Greenhouse Gas Emissions from Delivered Energy Use](image)

The system boundary is deemed to start when production begins: for fossil fuels this will be extraction, and for fuels derived from biomass this will be cultivation. For waste products this will be transportation from the location where the waste is produced.

The final stage included in the boundary will be combustion in the user’s building.
2.2 Exclusions

The system boundary specifically excludes:

A. Upstream processes prior to the planting, such as previous/alternative land uses;

B. Emissions arising from process and delivery infrastructure, such as the emissions arising from the energy and materials used to build agricultural machinery, oil rigs, power stations, transmission networks and vehicles used to transport fuels. This also excludes energy and materials used for maintenance of vehicles or machinery;

C. Emissions arising from the production of materials used in any of the energy production processes, e.g., fertilisers and fuel additives;

D. Emissions that may subsequently arise from disposing of any post combustion material e.g., ash

E. Emissions from the construction and manufacture of buildings and appliances are also excluded.

Thus the emissions factors represent the difference between providing and not providing one kWh of energy to the premises concerned, all infrastructure already being in place.
3 Methodology for calculating production overhead emissions

The calculation of production overhead emissions requires information on the annual energy flow through the production chain for each fuel. Figure 2 shows the various processing steps and energy flows that need to be considered for each type of delivered energy. The schematic indicates the various changes that can occur along the production chain, specifically:

- transfer to next processing stage, which are indicated by the wider black arrows;
- losses (for example leakage from natural gas pipelines);
- energy that is used during each of the processes; and
- the net annual change in the fuel stock.

In this diagram the width of the arrows relates to the amount of fuel and not all stages will be relevant for a particular energy source.

Figure 2 : Generic Energy Flow Diagram for Delivered Energy
The most recent version of the Digest of United Kingdom Energy Statistics provides information on the energy flows for most fuels used in buildings, but for some less common fuels, notably biofuels, other data sources are required. For some fuels this data may be obtained from other sources, e.g., data collected by the Renewable Fuels Agency, or from additional information supplied by industry.

Relevant greenhouse gas emissions (encompassing fugitive process emissions, direct emissions from fuel combustion, and emissions from electricity use) that arise from either the process itself, or from transportation and transfer between processes need to be identified and the emissions quantified, as shown in Figure 3.

![Energy Flow Diagram showing emission sources](image)

Figure 3: Energy Flow Diagram showing emission sources
Process emissions (in terms of kgCO₂eq) from each of the process stages and corresponding transport emissions for each are calculated. Therefore the emissions evaluation is broken down as follows:

- **Planting / growing stage emissions**
- **Planting / growing transport emissions**

- **Harvesting / extraction emissions**
- **Harvesting / extraction transport emissions** (e.g. transport to primary fuel processing or to final use)

- **Primary fuel processing / process emissions**
- **Primary fuel processing / transport emissions** (e.g. transport to secondary fuel production or to final use)

- **Secondary fuel production / transformation process emissions**
- **Secondary fuel production / transformation transport emissions** (e.g. transport to final use)

Both the process stage emissions and the associated transport emissions identified above are defined by aggregating the following emission types as previously defined:

- **Fugitive emissions:** these encompass emissions arising directly during the production process and covers emissions of N₂O from soils (arising from the application of nitrogen fertilizer and other gases that escape during processing e.g., methane leaks from pipelines, methane leakage from coal mines and stored coal, etc.;

- **Direct emissions from fuel combustion during the process:** these include all emissions arising from any other fuel used during the production process and covers energy use for exploration, extraction, processing and distribution via pipelines;

- **Emissions associated with electricity used during process:** these include all emissions arising from delivered electricity used during the production process and covers energy use for extraction, processing and distribution via pipelines.

For UK produced fuels, the most recent version of the National Atmospheric Emissions Inventory provides annual emissions data for fugitive emissions. Emissions from most energy production processes, transportation and distribution systems will be calculated based on the

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5. Carbon sequestered during plant growth is not taken into account because it will be exactly balanced by the carbon released on combustion, which is also excluded from consideration on the same basis.

6. There is not likely to be any transport associated with this stage unless seedlings are produced offsite before being transplanted to their final position. Pre-planting transport (e.g. bringing seeds to site) is outside of the scope defined here.
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averaged distances transported and an appropriate emission factor for the relevant mode of transport\(^7\).

Calculating the emissions associated with the imported fuels requires a detailed knowledge of the energy supply chain in each country that fuel is imported and that information may be difficult to access or not be available. In such cases it will be appropriate to substitute UK based process and transportation emissions data where the production processes are not significantly different to the UK processes.

So for example, separate production overhead emission factors would be calculated for electricity imported from France and for imported liquid natural gas (LNG), but it might be appropriate to apply the UK production emission factor to imported petroleum products. However, transportation emissions associated with the additional distances travelled will be taken into account for imported fuels. In instances where fuels are imported from a range of countries the average distance covered may be estimated based on the origin of the majority of imports.

Process emission factors are then calculated by dividing the emissions for each category by the amount of delivered energy they relate to. Aggregating the emission factors that relate to a particular process stage (e.g. harvesting) and any associated transport emissions provides an initial process emission factor. This is then adjusted to take account of losses that occur over the fuel supply chain and also of any reported statistical difference between energy supply and demand, but any stock changes and transfers to other supply chains do not impact on the production emission factor. There may be cases, in particular in relation to biofuels data, where the emission factors may be calculated as aggregated factors for specific emissions produced by different additional processes or activities of the fuel chain, for example, storage and drying, in addition to other standard processing stages.

The calculation module used to generate the production emission factor for each process stage is shown below, where input data is required for the blue cells when available.

<table>
<thead>
<tr>
<th>Process Stage</th>
<th>UK produced fuels</th>
<th>imported fuels</th>
<th>exports</th>
<th>Average UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>th tonnes CO(_2)eq</td>
<td>kgCO(_2)eq GWh</td>
<td>th tonnes CO(_2)eq</td>
<td>kgCO(_2)eq GWh</td>
</tr>
<tr>
<td>Process</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>direct emissions</td>
<td>1</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>indirect emissions</td>
<td>2</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>Transport</td>
<td>3</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>direct emissions</td>
<td>4</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>indirect emissions</td>
<td>5</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>production and transport</td>
<td>6</td>
<td>-</td>
<td>A/B</td>
<td>-</td>
</tr>
<tr>
<td>statistical difference</td>
<td>7</td>
<td>Sum</td>
<td>C1:C6</td>
<td>-</td>
</tr>
<tr>
<td>available</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>transfer</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>stock change</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UK supply</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>sum loss</td>
<td>12</td>
<td>10+11+12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 4: Calculation module for process stage emission factors

- Columns A (for UK production) and D (non UK production) record the CO\(_2\)eq in thousand of tonnes emitted by each emission type;

\(^7\) E.g., Defra Company Reporting Guidelines provide emission factors for different modes of transport in terms of kgCO\(_2\) per tonne.km
Column B (for UK production) and E (non UK production) contain the amount of fuel generated/produced by the process, expressed in GWh, to which the CO₂eq emissions refer for each emission type;

Column C is obtained by dividing A/B thus providing the ratio of kg CO₂eq / kWh;

Column G records any relevant amount of exports of the fuel produced in the UK (these are recorded as negative and are deducted in the final calculation);

Column I calculates the amount of fuel consumption in the UK by adding the UK production and imports and deducting the exports;

Column J calculates the average kg CO₂eq / kWh for the UK fuel consumption only which then allows Column G to be calculated to obtain the total emissions for the UK fuel consumption;

Any losses and statistical differences are then considered to calculate a revised amount of GWh consumption, which is applied to the total emissions of CO₂eq to obtain the final fuel production emissions factor. This is therefore defined as the kg CO₂eq emissions of the fuel consumption in the UK per kWh;

Subsequent transfers and stock changes do not affect the emission factor for the UK supply of fuel.

In the following example upstream emission factors for imported fuels (Column F) are assumed to be the same as for UK fuels except for direct emissions associated with transport, which are assessed separately. Also, the indirect process emissions relate to more than one energy supply stream, hence the emissions are divided by the total energy supply that they relate to.

<table>
<thead>
<tr>
<th>Process Stage</th>
<th>UK produced fuels</th>
<th>Imported fuels</th>
<th>exports</th>
<th>Average UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>th tonnes CO₂eq</td>
<td>GWh</td>
<td>kgCO₂eq</td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>kgCO₂eq / kWh</td>
<td>GWh</td>
<td>kgCO₂eq / kWh</td>
</tr>
<tr>
<td>Fugitive emissions</td>
<td>22</td>
<td>1,241</td>
<td>0.0175</td>
<td>0.0175</td>
</tr>
<tr>
<td>Direct emissions</td>
<td>1</td>
<td>1,241</td>
<td>0.0011</td>
<td>0.0011</td>
</tr>
<tr>
<td>Indirect emissions</td>
<td>8</td>
<td>1,794</td>
<td>0.0044</td>
<td>0.0044</td>
</tr>
<tr>
<td>Fugitive emissions</td>
<td>2</td>
<td>1,241</td>
<td>0.0018</td>
<td>0.0018</td>
</tr>
<tr>
<td>Direct emissions</td>
<td>5</td>
<td>1,241</td>
<td>0.0041</td>
<td>45</td>
</tr>
<tr>
<td>Indirect emissions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Production and transport</td>
<td>1,241</td>
<td>0.0290</td>
<td>126</td>
<td>3,280</td>
</tr>
<tr>
<td>Losses</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Statistical difference</td>
<td>161</td>
<td>4,461</td>
<td>0.0361</td>
<td></td>
</tr>
<tr>
<td>Transfer</td>
<td>161</td>
<td>4,461</td>
<td>0.0361</td>
<td></td>
</tr>
<tr>
<td>Stock change</td>
<td>220</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UK Supply</td>
<td>4,682</td>
<td>0.0361</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5: Example process emission factor calculation

The overall production emission factor for an energy supply chain is calculated now by aggregating the emission factors for all the relevant process stages going back to primary fuel source.

Finally, the delivered energy emissions factor is the sum of the production emissions factor calculated as described above and the fuel combustion emissions factor.
4 Summary of Principles

This section summarises the principles that are to be employed in implementing the described methodology.

1. Carbon dioxide emission factors will include, where appropriate, relevant emissions of the three main energy-related greenhouse gases, carbon dioxide (CO\textsubscript{2}), methane (CH\textsubscript{4}) and nitrous oxide (N\textsubscript{2}O), expressed as carbon dioxide equivalents.

2. Such emission factors will be expressed in terms of kgCO\textsubscript{2}eq /kWh gross delivered energy based on their relative global warming potential (GWP) over a 100 year time horizon.

3. Emissions factors used will be annual average values for the UK fuel supply. In instances where detailed information on the composition of UK fuel supply is not available assumptions will be made based on available data sources\textsuperscript{a}.

4. Carbon dioxide emission factors will remain fixed for the life of the relevant version of the National Calculation Method, typically three years. Unless there is, and in agreement with stakeholders, overriding need to amend the values based on evidence that values will change significantly over the period remaining until the next review of the National Calculation Method.

5. The annual average value for the most recently available year will be used for all forms of delivered energy, unless there are authoritative projections that indicate that the value will change significantly over life of the relevant version of the National Calculation Method. In which case, the projected value relating to the average of the life of the National Calculation Method version will be used instead.

6. Emission factors for the combustion of fossil fuels from the most recently available version of the National Atmospheric Emissions Inventory (NAEI) will be adopted for the final user combustion component. For other fuels alternative authoritative data sources will be used.

7. For fuels derived from biomass sources, combustion CO\textsubscript{2} emissions will be exactly offset by the carbon sequestrated during plant growth\textsuperscript{a}, but combustion emissions of CH\textsubscript{4} and N\textsubscript{2}O plus all other relevant production emission sources will need to be taken into account.

8. For both UK produced and imported fuels, all fuel chain supply emissions that are directly part of the production process will be taken into account. These include emissions arising from combustion of fuels from all production activities, from cultivation and extraction through to delivery to the final user, and from direct emissions arising from fuel production, transformation, transportation and fugitive emissions. They exclude emissions associated with the infrastructure and machinery used in these processes.

\textsuperscript{a} Biomass sources will have recently absorbed the CO\textsubscript{2} that they emit on combustion so they are not a net contributor to atmospheric CO\textsubscript{2} levels.
9. Data on the energy production emissions for stationary sources (production and transformation processes) for the most recent year available will be sourced from the NAEI, and will be applied to the relevant energy production data reported in the Digest of United Kingdom Energy Statistics or from other authoritative sources as applicable.

10. For mobile sources (transportation) emissions will be calculated based on the typical distances travelled in the UK and average emission factors by mode of transport from Defra’s company reporting guidelines and the relevant volume of fuel transported as reported in the Digest of United Kingdom Energy Statistics.

11. In addition to emissions arising from stationary and mobile sources, emissions arising from electricity used during UK fuel production activities will also be included in the energy production emissions. These will be based on energy industry electricity consumption data reported in the most recent version of the Digest of UK Energy Statistics, and the annual average emission factor for delivered electricity.

12. For imported fuels where production methods are similar and relevant data on upstream emissions is not available, production emissions from stationary sources will be assumed to be the same as those produced in the UK. Where there is no equivalent UK production, for example imports of LNG Liquid Natural Gas, alternative authoritative data sources will be used.

13. For fuels derived from waste streams, consideration of production emissions does not extend to the primary process which generated the waste, only emissions from subsequent processing and distribution are considered.

14. For imported fuels, in addition to energy production emissions, emissions associated with the additional distances covered before the fuel enters the UK will be taken into account. These will be based on averaged distances from the most significant countries/regions that the imports are from, the volume of fuel imported as reported in the Digest of United Kingdom Energy Statistics and the appropriate transport emission factors. When these are not available, other authoritative sources will be used.

15. Emissions associated with the generation of any co-products during the energy production chain process will be allocated between the products based on the ratio of the relative value of the products, when the co-product is considered a viable product on its own and is not classified as final not recoverable waste.

16. Where building appliances can use dual fuels, the emissions for each fuel will be derived separately, using the methodology described herein, and combined into a single value based on the ratio of fuels used. If this ratio cannot be clearly defined, such as for the simultaneous use of bituminous coal and wood, it will be based on the ratio of the market share of each fuel.

17. Where a building appliance uses a fixed fuel blend, a specific emission factors for the blend can be calculated based on the proportion of each fuel (by gross energy content) and the emission factors for the specific fuels used in the blend.

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10 DEFRA company reporting guidelines

11 Waste is defined as any substance or object the holder discards, intends to discard or is required to discard, Waste Framework Directive (European Directive 2006/12/EC)