

# A methodology and tool for calculating the carbon intensity of biofuels

Draft final report

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*Prepared by E4tech, ECCM and Themba*



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# 1 Introduction

In June this year a feasibility study was conducted by E4tech, ECCM and Imperial College London on carbon and wider environmental and social certification for renewable transport fuels. The study showed that it would be both possible and beneficial to develop a common methodology for calculating the greenhouse gas emissions (GHG) of biofuels.

A number of studies have produced well-to-tank and well-to-wheels analyses of GHG emissions from biofuels, but these studies differ in calculation methodologies and assumptions. They also do not offer an interface that allows stakeholders to perform their own calculations. Therefore, there is considerable interest in the development and use of a common methodology and related calculation tool. The methodology would give a standardised, agreed method for determining the GHG emissions from biofuel chains. A tool could then be developed, based on the methodology, which would be used to calculate the GHG emissions from biofuel chains, as well as identify and promote chains with lower emissions. The tool could also be used for reporting on the carbon intensity of biofuels chains, and eventually for the certification of the carbon intensity of biofuels.

LowCVP would like to support carbon certification in the biofuels industry, by supporting the stepwise development of a common carbon calculation methodology and related calculation tool(s). To this end, this document describes the development of a simple methodology and tool, for one biofuel chain, to demonstrate that a carbon intensity calculation methodology can be applied in practice. This enables stakeholders to visualise how such a methodology would work, and helps determine the ease with which biofuels' carbon intensity can be calculated and verified. The process of developing a tool also identifies the main areas of uncertainty and sensitivity in carbon calculation.

## 1.1 Objectives

The objectives of this work are to:

- **Inform policymaking** – develop a standardised, agreed method for determining the greenhouse gas emissions from biofuel chains, and demonstrate that this can be applied in practice. Also, help to determine the ease with which this carbon intensity result can be verified. This will help to establish the practicality of linking carbon reporting and certification to policy mechanisms such as an RTFO.
- **Support industry understanding and engagement** – develop standardised calculation methods and assumptions for one chain, then enable stakeholders to visualise how such a methodology would be applied using a software tool that allows them to perform their own calculations.
- **Identify uncertainty** – identify and address the main areas of uncertainty and sensitivity in carbon intensity calculation.
- **Encourage innovation** – develop methods and tools that help identify and promote chains with lower emissions.
- **Develop the basic structure of the methodology and tool** – eventually these could be used for reporting and certification of the carbon intensity of a range of biofuels relevant to the UK.
- **Demonstrate applicability of the tool to an example biofuel chain** – test the practical application of the methodology and tool to the carbon intensity calculation of wheat to ethanol chains.
- **Describe the key next steps in developing a standard methodology for reporting and certification within an RTFO.**

## 1.2 Structure of this document

This document is divided into several sections:

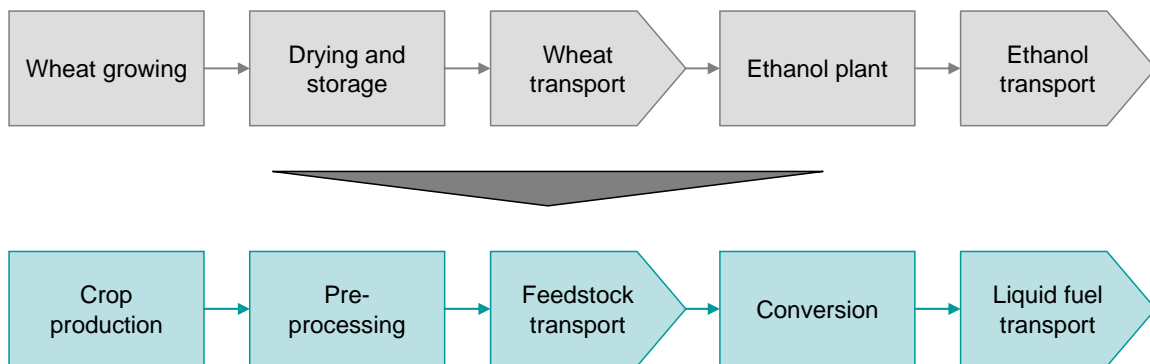
- **Structuring the methodology** – describes the steps needed to calculate the carbon intensity of renewable transport fuel chains, and considers how the steps can be applied to all types of renewable transport fuel chains.
- **Tool requirements** – discusses how a tool could be built around the methodology steps defined above, which is simple to use and appropriate for several types of user. Here we also consider how a tool can be designed to be flexible enough to characterise all types of chain, yet rigid enough to produce robust, verifiable results.
- **Methodology for the wheat to ethanol chain** – the wheat to ethanol chain is used as an example for a more detailed description of the methodology. For each step of the chain, we define boundaries of the calculation, before discussing the types of data needed, and the ease of providing or selecting that data. We also consider uncertainty, and the requirements for verification and updating default data. The methodology and tool requirements for other types of chain are also noted.
- **Conclusions and next steps** – summarises the achievements of this study and provides recommendations on next steps required for the development of a standard methodology for reporting and certification within the RTFO.
- **Appendix** – contains worksheets with the calculation steps for biofuel chains derived from the methodology, and a description and user guide of the tool developed for the wheat to ethanol chain.

## 2 Structuring the methodology

### 2.1 Wheat to ethanol chain

The feasibility study for carbon certification of biofuels carried out earlier this year introduced the principal concepts behind fuel chain (well-to-wheels) modelling of biofuel chains, with particular detail on the wheat to ethanol chain. The well-to-wheels emissions of the wheat to ethanol chain have been established by several recent studies, most notably the LowCVP wheat to ethanol study, and the JRC/EUCAR/CONCAWE study. The results of the LowCVP study have also been developed into an interactive tool, in work undertaken by ECCM and Themba for the HGCA.

In all of these studies, there are basic stages in the production chain for ethanol, shown by the first (grey) chain in the figure below. To develop a tool that can also be used for other renewable fuel chains, we need to create a general methodology. Generalising from the wheat to ethanol chain gives chain steps shown in the second (green) chain.



However, before discussing how each of these steps should be treated in the methodology, it is important to consider whether these steps could apply to other chains, whether further steps are needed, and what implications this might have for a common calculation methodology and a calculation tool.

### 2.2 Other chains

The table below shows a range of examples of renewable transport fuel chains that could be used in the UK. The chains were chosen to cover a range of feedstocks, conversion processes and fuel types. For each one, the table shows which chain steps, in which order, might be required to calculate the chain's carbon intensity. For each step, we have also noted whether there is a similar step in the wheat to ethanol chain, or whether the step would need to be considered in a different way in a calculation tool.

Chain \ Step	Sugar beet to ethanol	Rapeseed to biodiesel	Waste vegetable oil to biodiesel	Short rotation coppice to ethanol	Wood residues to FT biodiesel	Straw to ethanol	Green MSW to biogas	Wind to hydrogen
<b>Crop growing</b>	Yes. Similar to wheat	Yes. Similar to wheat	No	Yes. Multi year growing cycle.	No	No	No	No
<b>Other feedstock type</b>	No	No	Yes. May want to include avoided disposal/ alternative use	No	Yes. May want to include avoided disposal/ alternative use	Yes. May need to include replacement fertiliser inputs	Yes. May want to include avoided disposal/ alternative use	Electricity generation
<b>Pre-processing</b>	No – all done in field	Possible drying and storage	No	Possible drying and storage	No	Possible drying and storage	No	No
<b>Feedstock transport</b>	Yes	Yes	Collection	Yes	Collection	Yes	Collection	Electricity transmission and distribution
<b>Further pre-processing</b>	No	Possible crushing – could also be part of conversion. By-product: rape meal	Possible filtering	No	Possible chipping, drying storage	No	Possible separation	No
<b>Further feedstock transport</b>	No	Oil transport	Possible	No	Possible	No	Possible	No
<b>Conversion</b>	Yes. Fermentation. By-product: pulp	Yes. Esterification. By-product: glycerine	Yes. Esterification. By-product: glycerine	Yes. Lignocellulosic hydrolysis and fermentation. By-product: lignin	Yes. Gasification and FT process	Yes. Lignocellulosic hydrolysis and fermentation. By-product: lignin	Yes. Anaerobic digestion	Yes. Electrolysis
<b>Product transport</b>	Yes – liquid fuel transport	Yes – liquid fuel transport	Yes – liquid fuel transport	Yes – liquid fuel transport	Yes – liquid fuel transport	Yes – liquid fuel transport	Yes – could involve liquefaction, pipeline as well as other methods	Maybe – could involve liquefaction, pipeline as well as other methods – or none if on-site
<b>Product storage</b>	No	No	No	No	No	No	Possible. Plus possible additional energy use in dispensing	Possible. Plus additional energy use in dispensing
<b>End use</b>	May need to consider – blend level	May need to consider – blend level	May need to consider – blend level	May need to consider – blend level	Probably not considered – similar to fossil diesel	May need to consider – blend level	May need to consider – different engine	May need to consider – different engine
<b>Chains with similar steps</b>	Wheat grain, corn, sugarcane	Soy bean, palm kernels	Animal fats	Other woody crops, miscanthus. FT diesel production from same resources.	Agricultural residues, green MSW	Other agricultural residues, wood residues, green MSW	Other wet solid biomass residues and wastes	Other electricity sources

The table shows that the five steps identified for the wheat to ethanol chain could be used to cover most of the steps in the other chains. These steps could be used more than once in the fuel chain – for example, a pre-processing step could be used twice. However, there are three other types of step that would be needed to cover these entirely:

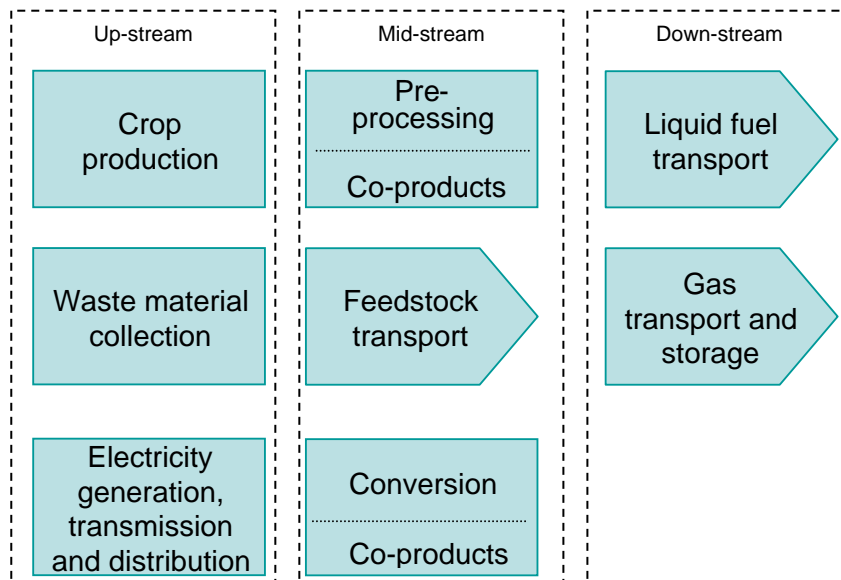
- Waste material collection - this would cover collection of the waste, and could cover any avoided disposal of waste material. Considering this as a separate step means that users of waste materials do not have to adapt to a methodology designed for



- crop feedstocks. Waste material collection from multiple points is also sufficiently different from point to point transport of a feedstock that a separate step would be needed. Agricultural residues could be covered within the crop production module, as the data inputs needed are more similar to this than to waste material collection.
- Gas transport and storage – this is sufficiently different from transport of liquid and solid fuels as to require a separate step, which could cover compression, pipeline transport, and additional energy requirements for fuel dispensing.
  - Electricity generation – this would be needed for renewable hydrogen production from electricity.

End use adjustment would be needed where use of the fuel leads to a significant difference in end use efficiency compared to conventional vehicles, such as biogas or hydrogen vehicles. However, this might not require a separate module, as it might not require user input. The energy content of fuels and vehicle efficiencies used can be built in to the summary sheet of the methodology and tool, in order to provide results in terms of carbon intensity per kilometre travelled, as well as per litre of gasoline equivalent, per GJ of fuel, or per tonne.

The figure below shows the eight modules of the calculation methodology.



### **3 Tool requirements**

Once the methodology for calculating the carbon intensity of renewable transport fuel chains has been determined, it is important that it can be applied easily using a simple set of calculations that can be integrated into a calculation tool. The methodology and tool structure must be flexible enough to be able to be used for different chains, though rigid enough to be simple to use, and to be verifiable.

The tool developed as part of this project is a simple demonstration tool to illustrate the applicability of the methodology, and a concept of the tool structure. Future tool developments could be based on improved structures and programming platforms.

#### **3.1 Structure**

Using a combination of any number of the eight modules of the calculation methodology, any fuel chain could be defined. The chain could involve multiple processing and transport stages, in any order, and the emissions from each stage can be added to calculate a final carbon intensity figure related to a batch of fuel.

#### **3.2 Users**

It is essential to consider at an early stage who will be using the tool, to ensure that the structure is appropriate for each type of user. We envisage that there are several possible types of user:

- Those at the beginning of the chain, such as growers or collectors of waste material. These entities are likely to cover between one and three modules of the chain – for example, one farmer may grow, pre-process and transport a crop, whereas another may be involved with growing only, with transport of the crop being undertaken by another party.
- Intermediaries. These may cover any number of pre-processing and transport modules, or may not be present at all in some chains. These entities may need to collect and manipulate data from those at an earlier stage of the chain.
- Conversion plants. These users need a tool which can do two things: firstly, collect and manipulate data from those at an earlier stage of the chain – for example, aggregate feedstock batches from several farmers – and secondly, allow them to input data about the conversion plant itself.

In order to ensure the “competence” of the users, training on data collection and reporting, calculation procedures and tool use could be envisaged. Measures to support the application of the methodology should also consider its global applicability. Higher standards in applying the methodology may be required if it is linked to economic incentives.

#### **3.3 Data input and transfer**

Different users need to fill in data for different numbers and combinations of modules in the biofuel chain. To accommodate this, and as an initial demonstration of how the methodology could be translated into a tool, we have suggested a tool structure that allows each user to fill in only a single sheet (analogous to a single Excel worksheet), but within that sheet, to select which modules they wish to cover. At the end of the sheet, a summary would be provided, showing which modules had been completed, and the carbon intensity

of the batch of feedstock or fuel so far. The sheet, or relevant information contained in it, could then be passed on to the user at the next stage of the chain. It is not being suggested that this tool would be the single method for tracking of physical products – however, the sheets, or relevant information, contained in them could be passed on with any other documents such as the grain passport.

A conversion plant operator, for example, would be able to include each of the sheets accompanying each batch of feedstock, or related information, in the tool. This would produce a summary of feedstock input, and the average carbon intensity of the feedstock input. The conversion plant operator would then fill in one sheet, with data for the conversion process module, and any subsequent modules.

This type of aggregation could occur at more than one point in the chain; for example in chains with two conversion steps such as crushing and then esterification in the RME chain. If at any point the user had no upstream data for a batch of feedstock or fuel, they could enter single default values for that batch. This is likely in the early stages of use of this type of tool, before all stakeholders provide data and regularly use the tool. Also, in the early stages, when data in certain regions may be scarce, data available for certain batches of feedstock could be used as a proxy for batches for which data is not available, as long as it can be demonstrated that the feedstock supply chains do not have significant differences.

It will not be necessary to perform calculations for each batch of feedstock or fuel. For example, calculations for batches of wheat from a same field may not need to be performed every year, unless significant changes take place in the crop production stage. Similarly, data and calculations at the conversion stage will only need to be modified when significant changes take place in the conversion process.

Finally, it is important to note that the sheets could also be made available in paper form, which users without computers can fill in with the same information as the electronic version. The calculations for different stages of the fuel chain could then be performed on paper or the data passed on to users down the chain using a software tool.

The tool's flexibility is increased by allowing 'other' inputs to each module – for example, other process inputs or co-products and their carbon intensity. To maintain standardisation, there will need to be guidelines for tool use with each chain, published by an expert group referred to here as the 'methodology unit'. For example, these could specify that for a particular chain, the amount of a chemical used in processing should be stated, and a carbon intensity provided in the guidelines be used. Flexible tool inputs have the advantage that the tool itself would need to be modified less frequently, as new chains and processes could be included. Accompanying guidelines have the disadvantage of being more complicated for some users, but users would benefit from guidance in applying the tool to their chain.

## 4 Methodology for the wheat to ethanol chain

### 4.1 Methodology development and updating

The general methodology structure for calculating carbon intensity of biofuels chains has been set out in section 2, in terms of the modules needed, and will be described in more detail below, in terms of what data is needed for each module, in the particular case of wheat to ethanol chains.

The specific methodology for each chain will require detailed development by an expert group – here termed the ‘methodology unit’. The methodology unit could consist of a core group of experts dedicated to the development and maintenance of the methodology, and a broader group of international experts that would be consulted on specific issues and act as a forum for generating consensus on the methodology. The methodology unit will require generic expertise on biofuel life cycle analysis, as well as ad hoc expertise on issues related to specific biofuel chains. The institutional framework within which this could sit is not discussed in this report.

The methodology unit’s major role would be in defining the calculation steps and data that would be used within the methodology. This includes default data, that could be used where the user does not provide data inputs, and constants used within the methodology. Three types of data are possible inputs to this methodology.

- Actual data - real data about the fuel chain, supplied by the user of the tool;
- Selected defaults – data chosen by the user from a range of possible values, defined by the methodology unit as those that are most common for an input parameter, e.g. fuel type used in a conversion plant and related specific emissions;
- Single default – data used where no actual data is provided by the user, and no choice of selected defaults is made, or where it is not possible for a user to provide data e.g. nitrous oxide emissions from agriculture.

The selected and single defaults would need to be selected from research and industry data, and agreed upon. A table defining all the pieces of selected and single default data, and other constants, together with their sources, used in the methodology would need to be published along with the methodology. Defaults for parameters that were known to be uncertain, to change quickly, or to which the results were particularly sensitive would need to be reviewed regularly, a revised table published, and updates to the tool published. However, data should not be reviewed too often as to be disruptive to a reporting or certification scheme. Various stakeholders have suggested that the selected and single default data need to be conservative, in order to promote use of actual data. This is an issue that will need to be debated further.

Other roles of the methodology unit would be:

- to produce and update a description of the methodology structure
- to produce and update user guidelines for the tool for each fuel chain type
- to define rules on how the tool should be used (e.g. how often input data is reviewed)

## 4.2 Notes on boundaries and data sources by stage

### 4.2.1 Feedstock production

#### Basic data

Basic data inputs consist of data needed to normalise the emissions throughout the model, e.g. to convert everything into carbon intensity per tonne of product, and to choose between defaults, e.g. based on location. The data are simple to provide and to verify with a high degree of accuracy, and will be needed for all crop-based chains.

Input	Unit	Data types	Notes
Crop type	-	A selection between crop types would be made. If no crop type were selected, then the highest emission pathway for the end product would be assigned as the single default.	More detail could be introduced <sup>1</sup> , i.e. the specific variety, in order to derive information needed for co-product allocation e.g. protein, gluten, energy content
Yield	t/ha	Actual data preferred Selected default for each crop	The single default values could be set at average values for different geographic locations. However, they may need to be reviewed and lowered if they are not representative of what is happening in practice, e.g. energy crops largely grown on less productive land
Country	-	Selection between countries made Single default for country with lowest yield for the crop	Needed for choice of yield defaults, and possibly other defaults such as nitrous oxide emissions
Batch size	t	Actual data required	This is needed to enable different feedstock batches to be combined. No default possible.

If no crop type were selected, then the highest emission pathway for the end product would be assigned as the single default.

Yields will increase over time, with improved farming practices and crop varieties, and so the single default yields would need to be updated periodically (e.g. every 3 to 5 years). This could be done easily from data that is currently collected, e.g. through Eurostat. However, it could also become apparent that crops were being grown on marginal land, with low yields, in which case the single default would need to be reduced.

#### N<sub>2</sub>O and CH<sub>4</sub> emissions from soils

Emissions from soils have been identified in all previous work as an important contributor to carbon emissions, but one which is difficult to measure directly, in which there is significant variation, and about which there is considerable uncertainty.

The JRC/Eucar/Concawe, LowCVP and HGCA studies all use data derived from the JRC's GREASE model, which establishes emissions for different soil types, weather patterns, crops and agricultural practices across the EU. The LowCVP study and HGCA model used a single estimate of the average UK emissions, at 4.36 kgN<sub>2</sub>O/ha.

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<sup>1</sup> The methodology and related tools will be flexible enough to allow for user-defined inputs. If an auditing process were put in place in relation to reporting and certification based on the methodology, the user would be required to provide evidence on the validity of user-defined inputs. The methodology unit could provide information and guidance on user defined inputs.

No actual data could be provided by farmers on soil emissions. The alternatives are either to use a single default soil emission factor (as above) or to require more detail to enable a more appropriate soil emission factor to be selected, for example, about the farm location, or about the soil and farming practices.

Given that the highest emissions, those from wet, peaty soils, can be an order of magnitude greater than from some other soil types (as described in the JRC/Eucar/Concawe report), then using a single fixed factor, set at an average value could significantly underestimate emissions in some cases.

It may be possible to provide simple qualitative data, that would be easy for the farmer to provide, and which would allow selection of an emissions factor based, for example, on the GREASE model outputs. The farmer could input the farm's location to enable the NUTS3 region to be determined, and the value for that region used. In this case, the single default value could be the NUTS3 region with the highest emissions value. This option requires further investigation.

Input	Unit	Data types
Farm location	E.g. postcode	Selected defaults depending on location Single default for where no location is specified – emissions from highest emission soils

Where no GREASE data, or similar data, is available (for example, for a different crop type or outside the EU) then the grower would need to be assigned a provisional number set by the methodology unit until the new area or crop has attributed values. Given the high degree of sensitivity of the emissions results to emissions from soils (as identified in previous studies) these inputs would be likely to be contentious, and so require considerable attention from the methodology unit to obtain more accurate values as quickly as possible.

The approach to dealing with nitrous oxide emissions will need to be simple, while capturing any significant differences between regions. The soil emissions values would need to be updated periodically (e.g. every 1 to 2 years) in the light of new scientific methods and results.

### **Fertiliser, lime, pesticide and seed inputs**

The emissions associated with fertiliser production and use are well established as a significant contributor to the emissions of the wheat to ethanol chain, and so have been included in all other studies of this type. Fertiliser inputs are easy to provide from farm records, with a low degree of uncertainty and would be simple to verify. There is also good agreement from previous studies on the emissions factors that can be used to calculate the emissions from the most common fertiliser types, including the emissions from transporting them to the farm.

In practice, the emissions from different fertiliser compositions, produced by different manufacturers in different locations, can vary considerably. The most accurate way to account for these emissions would therefore be to require the farmer to state the fertiliser type, manufacturer and CO<sub>2</sub> emissions, if stated. However, this information is not currently available from fertiliser manufacturers, and may not be calculated using a standard methodology. The method we propose here, therefore, is to use agreed standard emission

factors (single defaults), but to allow the user to input actual manufacturer's figures if available (actual data).

To allow for any other soil/crop inputs that may be specific to other chains, a user-defined input could also be included.

<b>Input</b>	<b>Unit</b>	<b>Data types</b>
Mass of N fertiliser	kg/ha/crop	Actual data Single default
CO <sub>2</sub> factor of N fertiliser	kgCO <sub>2</sub> /kg	Actual data Single default
Mass of P or P <sub>2</sub> O <sub>5</sub> fertiliser	kg/ha/crop	Actual data Single default
CO <sub>2</sub> factor of P or P <sub>2</sub> O <sub>5</sub> fertiliser	kgCO <sub>2</sub> /kg	Actual data Single default
Mass of K or K <sub>2</sub> O fertiliser	kg/ha/crop	Actual data Single default
CO <sub>2</sub> factor of K or K <sub>2</sub> O fertiliser	kgCO <sub>2</sub> /kg	Actual data Single default
Mass of lime	kg/ha/crop	Actual data Single default
CO <sub>2</sub> factor of lime	kgCO <sub>2</sub> /kg	Actual data Single default
Pesticide input	kg/ha/crop	Actual data Single default
Pesticide CO <sub>2</sub> factor	kgCO <sub>2</sub> /kg	Actual data Single default
Seed material	kg/ha/crop	Actual data Single default
Seed CO <sub>2</sub> factor	kgCO <sub>2</sub> /kg	Actual data Single default
Other input type	-	Actual data required
Other input	kg/ha/crop	Actual data required
Other input CO <sub>2</sub> factor	kgCO <sub>2</sub> /kg	Actual data A single default value for each of these would be provided in accompanying guidelines

Note that all input values are per crop rotation, to allow for multi-year cropping for crops such as short rotation coppice. There will also need to be advice in the accompanying guidelines on how farmers should account for fertiliser application on rotation crops – i.e. what share of fertiliser applied during the rotation should be attributed to the biofuel feedstock. Also, the single default values should be country-specific, thus taking into account the differences in climatic conditions and agricultural practices. While a number of well-to-wheels studies consider all the input categories listed in the table above, not all these input categories may be significant enough to require user-defined inputs. For those categories that are considered to have a minor contribution to emissions, single defaults could be suggested and users could be made aware of the relatively small impact of using actual data.

The single default data for each input, and the range of inputs in the guidelines for other chains, would need to be reviewed on a fairly regular basis (e.g. every 2 to 3 years), with changes in fertiliser sources and manufacturing processes, and new types of inputs for different crops.

## Machinery inputs to cultivation and harvesting

The emissions from this stage are only likely to be from the liquid fuel used in cultivation and harvesting machinery, and therefore have been represented in all other studies by diesel consumption. This is simple to record and to verify. In order to allow for fuels of different carbon intensities to be used in this machinery, the CO<sub>2</sub> factor of the fuel used should also be able to be changed. This section has minimal requirements for methodology updates, as the majority of users would be likely to input actual data, and the carbon emissions factor for diesel fuel is unlikely to change substantially in the short term.

Input	Unit	Data types
Fuel type	-	Selection: diesel , other (specified) Single default – diesel
Fuel consumption	l/ha/crop	Actual data Single default
Fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Selected default for each fuel type Actual data can be entered

## Excluded components

- **Land use change** - As discussed in the previous feasibility study, where land use change (either deforestation or conversion of other high carbon density ecosystems such as grassland) is associated with biofuel production, there are large emissions from loss of above ground stocks of biomass and from soil carbon. These are generally much greater than GHG emissions from the rest of the chain, and could negate for decades the benefits from avoided use of fossil fuels. As a result, this type of tool is not appropriate for crops grown on land that has changed use in this way. Land use change therefore cannot be included in the calculations; however, yes/no questions could be added at the beginning of the tool to flag different types of land-use changes. If the responses indicated land-use changes that could lead to significant GHG emissions, then an option may be not to allow the user to use the methodology and tool. Land use change is best addressed through policy mechanisms separate from any requirement for carbon intensity monitoring – for example through land conservation and planning. These will also cover changes in land use for purposes other than biofuels. However, there is a need for further work in this area to determine how biofuels produced on land that has undergone change is use resulting in significant emissions will be treated under the RTFO. For example, the question needs to be addressed of whether biofuels produced from land previously used for pasture or under savannah or forest could be excluded from the RTFO on carbon emissions grounds, or whether they would be assigned particular default values for reporting or certification purposes.
- **Alternative land uses** - The LowCVP study on wheat to ethanol includes a credit for avoided management of set-aside land. Questions on alternative land uses are not, however, included in this methodology, as it would be impossible to verify what the land would be being used for if it were not being used for crop growth for biofuels. Also, the avoided emissions from the alternative uses would be impossible for the farmer to provide, thus requiring selected defaults, and the calculations required for all of alternative uses would add considerable complexity.
- **Equipment manufacture** – the energy and materials needed to manufacture the equipment used in growing and harvesting the biofuels has not been included. These emissions have not been included in other similar studies, as they are generally accepted to be small compared with those associated with biofuel production, and because the data available on them are not comprehensive or



reliable. The energy and materials in construction of the machinery and conversion plants in the other stages of biofuel chains will also be excluded.

#### 4.2.2 Pre-processing

This includes diesel input to drying, and electricity input to storage, e.g. to operate fans. These can be easily determined and standard CO<sub>2</sub> factors used. As described above, we have also included here the option to change the CO<sub>2</sub> factors – for example in the case of biodiesel use on the farm, or of low carbon electricity use. To allow for any other pre-processing inputs that may be specific to other chains, a user-defined input could also be included.

Input	Unit	Data types	Notes
Batch weight after pre-processing	t	Actual data	This is needed to normalise emissions from crop growing, and to track the feedstock batch through the chain
Fuel type	-	Selected defaults: Diesel, gas, other (specified) Single default - diesel	
Fuel input	unit/ batch	Actual data Selected default for each fuel type	There will be more than one of these inputs to allow for use of several fuels
Fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /unit	Selected default for each fuel type Actual data	
Other input type	-	Actual data	E.g. chemicals
Other input	unit/batch	Actual data	
Other input CO <sub>2</sub> factor	kgCO <sub>2</sub> /unit	Actual data Single default values for these would be provided in accompanying guidelines	

Updating of default input types, input consumption and emissions factors for these inputs would not be needed very regularly, as they are a relatively small component of overall fuel chain emissions, and should not change frequently for fuel inputs. One exception to this would be the CO<sub>2</sub> intensity of electricity generation, which may change considerably over time, and should be updated frequently (e.g. every 3 to 5 years).

#### 4.2.3 Feedstock transport

This module represents transport of any biomass feedstock or pre-processed feedstock to a conversion plant. The methodology therefore needs to be able to cover feedstocks with different densities, transported by different transport modes, potentially using fuels of different carbon intensities, over different distances.

The user can very easily provide the feedstock type and transport mode as selected defaults, and transport distance as actual data, which together will enable calculation of the transport CO<sub>2</sub> emissions. However, it is important to have the option to provide actual data to change the carbon intensity of the fuel used to allow use of lower carbon fuels. Also, the option to change the feedstock density, could be important in order to use the tool for other feedstock types.

Default data for transport distances may need to be changed if after a period of use of the methodology it became clear that many users were using the default distance because

they had transport distances longer than this. Transport fuel consumption would only need to be updated every few years as vehicle efficiencies improved, and similarly for CO<sub>2</sub> emissions factors for fuels. However, default data for transport fuel consumption data in l/tonne-km are not particularly accurate, as they have to average out over different truck loadings, and depend on the type of vehicle used.

Input	Unit	Data types
Feedstock type	-	Selected defaults: wheat (wet), wheat (dry), straw etc
Transport mode	-	Selected defaults: road, sea, rail Single default: road
Transport distance	km	Actual data Selected default based on mode chosen
Transport fuel consumption	l/t km	Selected default based on feedstock type and mode
Transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Selected default based on mode chosen Actual data
<b>OR</b>		
Transport fuel type	-	Selected defaults: diesel, HSFO etc
Transport fuel consumption	l	Actual data
Transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Selected default based on fuel chosen Actual data

The transport distance and fuel consumption include return travel for road transport. Return travel is not included for rail and sea transport, for which it is considered less likely for the train or ship to travel back empty.

#### 4.2.4 Conversion

As described in the previous feasibility study, emissions from biomass conversion to biofuel are an important contributor to the emissions of biofuel chains. Many contributors to plant emissions, such as fossil fuel use, are also relatively easy to determine and to verify, from plant records. Other factors, such as co-product use, require simple input data from the user, but have widely varying contributions to overall emissions depending on the assumptions made on allocation.

##### Basic data

For this module, the selection of a selected or single default plant type at the outset allows use of default data throughout. Users could otherwise introduce their own data.

The selected defaults here are qualitative plant types – for example the type of fuel and boiler used. For wheat to ethanol the plant types used are as defined in the LowCVP study, enabling values from this study to be used (plus possibly an option for a coal fired plant, as will be included in the updated JRC/Eucar/Concawe study). The single default would be the selected default plant type with the highest overall CO<sub>2</sub> emissions. The question about setting conservative defaults is particularly important here – if the default plant type data are based on average values, there is a risk that many plants may actually be below the average, and have no incentive to report.

Given that emissions from the conversion plant are a major component of the wheat to ethanol chain, it would be necessary for the methodology to be updated to change default data or include new default plant types, and potentially determine the new single default, if new plant types entered into widespread use.

For conversion plants for other chains, the methodology would need to include basic plant types, where these were well known, and had a reasonable degree of standardisation. If this were not the case, actual data would be required. To help verification, the tool could include cross-checks on plants using actual data – for example checking that yield did not appear to be unfeasibly high, or energy inputs unfeasibly low.

Input	Unit	Data types	Notes
Product type	-	E.g. ethanol, biodiesel	
Plant type	-	Actual plant data Selected defaults: six plant configuration options as in LowCVP (a-c2 - including use of gas, grid electricity or straw as fuel inputs, plus possibly coal) Single default of plant type with highest emissions	
Plant yield	t product/t feedstock	Actual data Selected default based on plant type Single default based on default plant type	
Plant location (country)	-	Actual data Single default	Needed for CO <sub>2</sub> allocation for electricity and co-products

## Inputs

This section covers all plant inputs except the principal feedstock: energy inputs and other inputs such as chemicals.

Input	Unit	Data types	Notes
Type of energy use	-	Selected defaults: Gas, coal, oil, straw, electricity, Or selection based on plant type Single default based on default plant type	There will be more than one of these inputs to allow for use of several fuels
Amount of energy use	unit	Actual data Selected default based on plant type Single default based on default plant type	
Energy CO <sub>2</sub> factor	gCO <sub>2</sub> /unit	Actual data Selected default based on energy type and location Single default based on energy type and location	Country specific for electricity generation
Other input type	-	Actual data, specified by user	
Other input	Unit	Actual data, specified by user	
Other input CO <sub>2</sub> factor	gCO <sub>2</sub> /unit	Single default provided in guidelines	

Alternative CO<sub>2</sub> factors could be input by the user if they were using lower carbon electricity or other energy source.

Other input categories are included to allow for non-standard processes, and for other chains where there may be other materials input to the process. Single default emissions factors for other inputs should be provided in accompanying guidelines.

Emissions factors for these inputs would need to be reviewed regularly, as they are an important component of overall fuel chain emissions, and may change considerably, especially the CO<sub>2</sub> intensity of electricity generation.

Extra input data is required if the plant uses straw, as the transport of the straw to the plant must be considered. This would also be the case if other biomass types were used to fuel conversion plants, in which case user-defined data could be used or the tool itself could be

used to calculate their carbon intensity. Extra input data have been included for straw only, as this is the most likely biomass input for energy to the conversion process for wheat to ethanol. (Note: No additional fertiliser input to replace the straw removed from the field has been included. If the straw has come from the land on which the energy crop was grown, this fertiliser input will already have been accounted for. If it has come from another source, the additional fertiliser use is beyond the boundaries of this calculation – but may be accounted for under another carbon intensity calculation.)

<b>Input</b>	<b>Unit</b>	<b>Data types</b>
Straw transport mode	-	Selection between modes (road, sea, rail) Single default: road
Straw transport distance	km	Actual data Selected default based on mode chosen
Straw transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Actual data Selected default based on mode chosen
<b>OR</b>		
Transport fuel type	-	Selected defaults: diesel, HSFO etc
Transport fuel consumption	l	Actual data
Straw transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Actual data Selected default based on mode chosen

## Co-products

The allocation of CO<sub>2</sub> credits to co-products from conversion plants has a significant effect on the fuel chain carbon intensity, for the wheat to ethanol chain, and for other chains.

In the LowCVP feasibility study, it was decided that it would be best to use the most appropriate allocation method for each co-product, rather than deciding on one method for all co-products and chains. The range of allocation methods will not be discussed here, but would need to be considered in detail by the methodology unit for each co-product of each biofuel chain. For the wheat to ethanol chain, the substitution method has been agreed as being most appropriate: allocating carbon savings to co-product electricity and DDGS based on the emissions that would be created in providing the services derived from the co-products by an alternative route.

The type, properties (such as energy or protein content), volume and use of co-products produced are needed. The type and volume should be very easy for the conversion plant operator to provide. The properties of the co-products for the wheat to ethanol chain are likely to be reasonably consistent using current conversion plant types, and so can be assigned single defaults.

If the conversion process produced other co-products than those for which data is provided in the methodology and tool, extra details such as the energy content or protein content, would be needed to determine how much of an alternative feedstock they would displace. Also, other uses of co-products could be accounted for by allowing the user to input actual data for co-product CO<sub>2</sub> allocation, although this would be difficult for a user to determine without significant work. The actual end use of the co-product may also be difficult to verify.

There is an argument that the electricity exported is as a result of using more fuel for the process than is needed for ethanol production alone, and therefore electricity exported should not be credited to the ethanol chain. If that fuel (gas, straw etc) were not used in the plant, it would be being used for fuel elsewhere. However, some credit must be given

for electricity export – plants using gas CHP use more gas than those using a gas boiler alone, and attributing all of the emissions from the increased gas input to the ethanol production, whilst giving no credit for the electricity produced, would not be correct. Concawe deals with this by assuming that the only electricity benefit gained from the conversion plant is providing an opportunity for CHP, as opposed to conventional generation. The credit given is therefore based on generation of the same amount of electricity with the same fuel in a non-CHP scheme. Similarly, we suggest that credits be based on a substitution approach involving an alternative use of the fuel considered.

In the UK, the electricity export would be credited by receiving ROCs anyway, or elsewhere could fall under emissions trading schemes – and therefore allocation to the ethanol could be seen as double counting. Also, the emissions from the straw use would be very low, and so their allocation would not have a significant effect on the carbon intensity of the ethanol.

In this area, there is a significant need for regular methodology updates (e.g. every 1 to 2 years): to determine which products are being substituted, and so which emissions are avoided. It would also be necessary to add in new co-product uses if they became widespread.

Input	Unit	Data types
Electricity export	kWh/t product	Actual data Selected default based on plant type Single default based on default plant type
Electricity CO <sub>2</sub> allocation	gCO <sub>2</sub> /kWh	Selected default based on energy type and location Single default based on energy type and location
Co-product type	-	Actual data Selected default based on plant type Single default based on default plant type
Co-product mass	unit/t product	Actual data Selected default based on plant type Single default based on default plant type
Co-product CO <sub>2</sub> allocation	kgCO <sub>2</sub> /unit	Single default based on coproduct type and location

#### 4.2.5 Secondary transport

In the feasibility study, it was suggested that GHG emissions from the transportation of ethanol from factory to duty point be excluded as these are a relatively small component and may be more onerous in terms of quantification when considering complex transport routes, blending, movement by pipeline. However, this stage is included in the Concawe, LowCVP and HGCA models, and would be important when considering imported fuels. It will also be important for gaseous fuels. Incorporating this stage now adds relatively little complexity, and prepares users for considering this step in the future. If data were difficult to collect, default values would be used.

As with feedstock transport, secondary transport needs to include the factors:

Input	Unit	Data types
Fuel type	-	Selected defaults: ethanol, biodiesel
Transport mode	-	Selected defaults: road, sea, rail, air Single defaults based on plant location UK: Road Non UK: Sea plus road
Transport distance	km	Actual data

		Single defaults based on plant location UK: Road Non UK: Sea plus road
Transport fuel consumption	l/tkm	Single default based on feedstock type and mode
Transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Actual data Selected default based on mode chosen
<b>OR</b>		
Transport fuel type	-	Selected defaults: diesel, HSFO etc
Transport fuel consumption	l	Actual data
Transport fuel CO <sub>2</sub> factor	kgCO <sub>2</sub> /l	Actual data Selected default based on fuel chosen

### 4.3 Translating the methodology into calculation worksheets and tools

The methodology for calculating the carbon intensity of biofuels illustrated in the previous section can be translated into a series of calculation worksheets that define the calculation steps needed to calculate the carbon intensity of each fuel chain module. The calculation worksheets' format is inspired by the Government's "Standard Assessment Procedure" (SAP) for the energy rating of buildings.

SAP is based on a methodology described in the Building Regulations. The calculation steps are defined in published SAP worksheets - though in practice most people calculating SAP use one of the approved SAP calculation programs. These are computer programs, which are approved by the Building Research Establishment (BRE). SAP programs are used to enter data on the size of the house, its insulation levels, its ventilation system and its heating and hot water systems. The SAP rating can then be submitted for Building Regulations approval and is checked by the local Building Control department. (SAP information and worksheets can be found at the following link: <http://projects.bre.co.uk/sap2005>)

The calculation worksheets for calculating the carbon intensity of biofuel chains are provided in Appendix 1. These calculation worksheets have been incorporated into a demonstration excel-based software tool that allows carbon intensity calculations for user-defined wheat to ethanol chains based on input from users at different stages in the fuel chain. A description of the calculation tool is provided in Appendix 2.

The calculation tool has been reviewed by a small number of biofuels producers and suppliers on the steering group. The reviewers have indicated that the methodology, structure of the calculations, level of data requirement and its availability, cover all significant issues and practical with regard to implementation. Comments received have been considered in refining the methodology and calculation worksheets presented in this report.

### 4.4 Conclusions

This study has developed a common methodology for assessing the GHG intensity of renewable transport fuels. The aspiration is that the methodology be used as a basis for the reporting of GHG emissions, and relative savings compared with fossil fuels, from renewable transport fuel supplies under an RTFO. This could eventually be linked to the issuing of RTFO certificates based on the fuels' GHG emissions savings relative to fossil baselines.

In particular, this study:

- Defines the framework for a standard methodology for calculating the carbon intensity of renewable transport fuels.
- Discusses the requirements that carbon intensity calculation tools will need to satisfy to be applied in practice.
- Discusses the methodology development and update needs, and the importance and role of a methodology unit.
- Describes in detail the methodology for wheat to ethanol chains.
- Translates the methodology into calculation worksheets and a demonstration calculation tool for wheat to ethanol.
- Demonstrates the validity of the approach through steering group validation and review of the demonstration tool by biofuel producers and suppliers.

Some suggested next steps for developing further a common methodology for assessing the carbon intensity of renewable transport fuels are:

- Extension of the methodology to RME biodiesel chain.
- “Field trials” of the methodology and tool involving different users to
  - demonstrate their practical implementation;
  - improve the methodology / tool structure.
- Development of a plan for linking the methodology to reporting and carbon certification within the RTFO.
- Definition of the terms of reference and set-up of the ‘methodology unit’.

# Appendix 1: Worksheets

White Boxes – actual data

Grey boxes – selected or single default values or actual data  
If actual data is used here, the source should be stated

## FEEDSTOCK PRODUCTION

### Basic data

Crop type  (select from list: wheat, sugar beet, sugar cane etc)

Country  (needed for selection of single default yield data if none is given)

Yield [t/ha]  Y

Batch size [t]  b1

### Soil emissions

Location (leads to selection of data)	Emissions factor [kgCO <sub>2</sub> e/ha]			
<input type="text"/>	→ <input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (1)

### Inputs

	Mass of input [kg/ha]	x	Emissions factor [kgCO <sub>2</sub> e/kg]			
N fertiliser	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (2)
P fertiliser	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (3)
K fertiliser	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (4)
Lime	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (5)
Pesticide	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (6)
Seed material	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (7)
Other (multiple)	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (8)

### Machinery inputs

	Fuel consumption [l/ha]	x	Emissions factor [kgCO <sub>2</sub> e/l]			
<input style="border: 1px solid black; padding: 2px;" type="text" value="e.g. Diesel"/>	<input type="text"/>	x	<input style="background-color: #cccccc;" type="text"/>	÷	Y	= <input type="text"/> (9)

### Total emissions from feedstock production

(1) + (2) + (3) + (4) + (5) + (6) + (7) + (8) + (9) =	<input style="border: 2px solid black; width: 100px; height: 20px;" type="text"/> (A)
---	---



**PRE-PROCESSING**

Batch weight after pre-processing [t]  b2

Fuel/input type	Fuel/input consumption [unit/batch]		Emissions factor [kgCO2e/unit]		
<input type="text" value="e.g. Diesel"/>	<input type="text"/>	x	<input type="text"/>	÷ b2 =	<input type="text"/> (11)
<input type="text" value="e.g. Electricity"/>	<input type="text"/>	x	<input type="text"/>	÷ b2 =	<input type="text"/> (12)
<input type="text" value="e.g. Chemical"/>	<input type="text"/>	x	<input type="text"/>	÷ b2 =	<input type="text"/> (13)

**Total emissions from feedstock pre-processing**

Pre-processing emissions per t feedstock (after processing) = (11) + (12) + (13) =  (B)

**Emissions**  
**[kgCO2e/t]**

**FEEDSTOCK TRANSPORT**

Complete either:

Feedstock type	<input type="text"/>	(select from list: wheat (wet), wheat (dry), straw etc )		
Transport mode	<input type="text"/>	(select from list: road, rail, sea )		
Transport distance [km]	<input type="text"/>	x	Fuel consumption [l/tkm]	<input type="text"/>
			x	Emissions factor [kgCO <sub>2</sub> e/l]
				=
				<input type="text"/> (C)
			(this is feedstock and mode dependent)	(this is mode dependent)

OR

Feedstock batch size [t]	<input type="text"/>	b3		
Fuel type	<input type="text"/>	(select from list: diesel, HSFO etc)		
Fuel consumption [l/batch transported]	<input type="text"/>	x	Emissions factor [kgCO <sub>2</sub> e/l]	<input type="text"/>
			÷ b3	=
				<input type="text"/> (C)

## CONVERSION

### Plant characteristics

Plant type

(description or selection from a set of default plants)

Plant location  (country, leads to electricity CO2 emission factor)

Plant yield (t product/t dry feedstock)  (Z)

### Inputs

Fuel/input type (straw)      Fuel consumption [unit/t product]      Emissions factor [kgCO2e/unit]      (except

*e.g. Gas*            x            =       (17)

*e.g. Electricity*            x            =       (18)

*e.g. Chemical*            x            =       (19)

Straw input (if used)

Transport mode  (select from list: road, rail, sea )

Transport distance [km]      Fuel consumption [l/tkm]      Emissions factor [kgCO2e/l]      Straw transport emissions [kgCO2e/t straw]

     x            x            =       (s)

Straw input [t straw/t product]

Straw transport emissions [kgCO2e/t<sub>s</sub>]

     x      (s)      =       (20)

### Co-products

Output [unit/t product]

Emissions credit [kgCO2e/unit]

Electricity export            x            =       (21)

Co-product 1 (e.g. heat)            x            =       (22)

Co-product 2 (e.g. DDGS)            x            =       (23)

### Total emissions from conversion

**Emissions**  
[kgCO2e/t product]

Conversion emissions per tonne product  
= (17) + (18) + (19) + (20) - (21) - (22) - (23)

(D)

**SECONDARY TRANSPORT**

Transport mode  (select from list: road, rail, sea. )

Transport distance [km]  x Fuel consumption [l/tkm]  x Emissions factor [kgCO<sub>2</sub>e/l]  =  (E)

(this is product and mode dependent) (this is mode dependent)

**OR**

Product batch size [t]  f

Fuel type  (select from list: diesel, HSFO etc)

Fuel consumption [l/batch transported]  x Emissions factor [kgCO<sub>2</sub>e/l]  ÷ f =  (E)

**Emissions [kgCO<sub>2</sub>e/t]**

**TOTAL EMISSIONS**

**Conversion of emission from original units into product units**

Emission from crop growing  $(A) \times (b1/b2) \times Z = \boxed{\phantom{000000}}$  (F)

Emission from pre-processing  $(B) \times Z = \boxed{\phantom{000000}}$  (G)

Emission from feedstock transport  $(C) \times Z = \boxed{\phantom{000000}}$  (H)

Emission from conversion  $\phantom{(C) \times Z} = \boxed{\phantom{000000}}$  (D)

Emission from secondary transport  $\phantom{(C) \times Z} = \boxed{\phantom{000000}}$  (E)

**Total emissions**

Per tonne of product **Emissions [kgCO2e/t product]**  
 $(F) + (G) + (H) + (D) + (E) = \boxed{\phantom{000000}}$  (I)

Per GJ of product **Emissions [kgCO2e/GJ]**  
 $(I) \times \text{Energy content product [GJ/ t]} = \boxed{\phantom{000000}}$  (J)

Per litre of gasoline equivalent **Emissions [kgCO2e/l<sub>gasoline</sub>]**  
 $(I) \times g = \boxed{\phantom{000000}}$  (K)

Where g is a conversion constant, selected for each product, and originally calculated from

$$g = \frac{1}{1000} \times \text{Product density [l/kg]} \times \frac{\text{Energy content gasoline [GJ/t]}}{\text{Energy content product [GJ/t]}}$$

## **Appendix 2: Wheat to ethanol demonstration tool**

# 1 Tool structure and data flow

## 1.1 Tool structure

The tool has a modular structure, built around 6 modules:

Module A - Crop production

Module B - Pre-processing

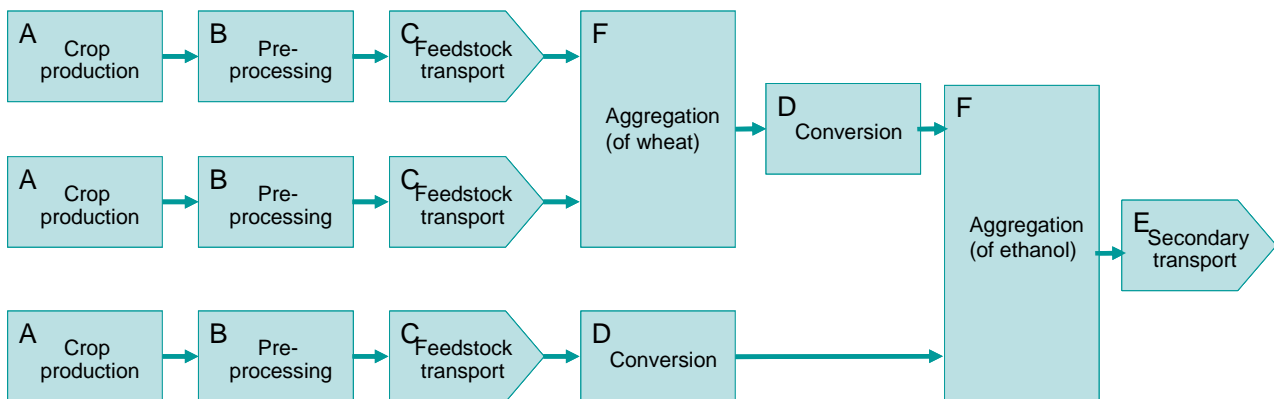
Module C - Feedstock transport

Module D - Conversion

Module E - Secondary transport

Module F - Aggregation of multiple contributions

In particular, Module F “Aggregation of multiple contributions” can be used to merge multiple batches obtained through different sub-chains, such as in the following example:



### 1.1.1 Data management

The tool can be used by different types of players along the fuel chain. For example, in the wheat to ethanol chain, a plant is likely to take in wheat from a number of farmers. The farmers would each supply the data for the crop production and possibly pre-processing modules of the tool to an intermediate transport operator or to the plant directly – either by filling in one sheet of the tool or a paper version of the worksheet. The crop production and pre-processing modules could be filled in by each farmer once per harvest or at longer intervals if suitable. If the plant did not have data for one farmer, the plant manager could set up an input sheet for that batch of wheat using default data only. The plant manager would then use an aggregation module to sum all the batches of feedstock input, and this module would give an average carbon intensity of a tonne of feedstock input to the plant. The plant manager would then fill in the conversion module for the plant. This is likely to only need to be done relatively infrequently, maybe a few times during the plant lifetime to account for any changes in plant operation, or whenever the default data were updated. This would produce a carbon intensity per tonne of ethanol. This figure would then accompany each batch of ethanol passed on to the secondary transport stage, and sold to fuel suppliers.

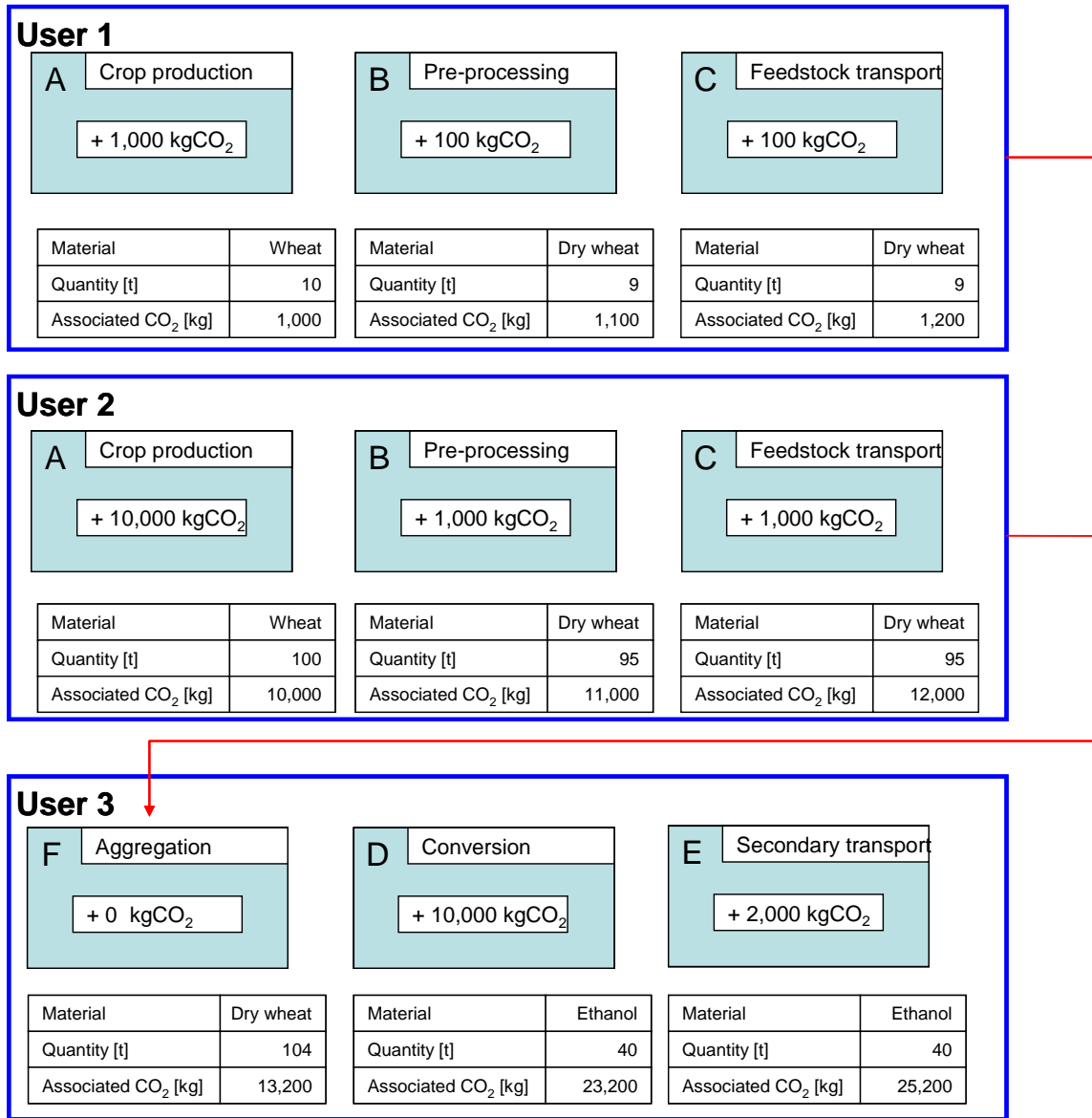
### 1.1.2 Calculation flow

Each module receives as input:

- the quantity of feedstock or ethanol, expressed in tons, from the previous step in the chain; the exception is module A “Crop production”, which can only be in the first step of the chain;

- the total CO<sub>2</sub> emissions, expressed in kg, associated with that quantity of feedstock or ethanol.

The following example provides an illustration of how the batch sizes and values of associated CO<sub>2</sub> are carried through a fuel chain.



## 1.2 User guide

The demonstration version of the tool developed within this study comprises:

- 1 library of default values
- 1 start page
- 3 (or 4) user sheets
- 1 summary sheet

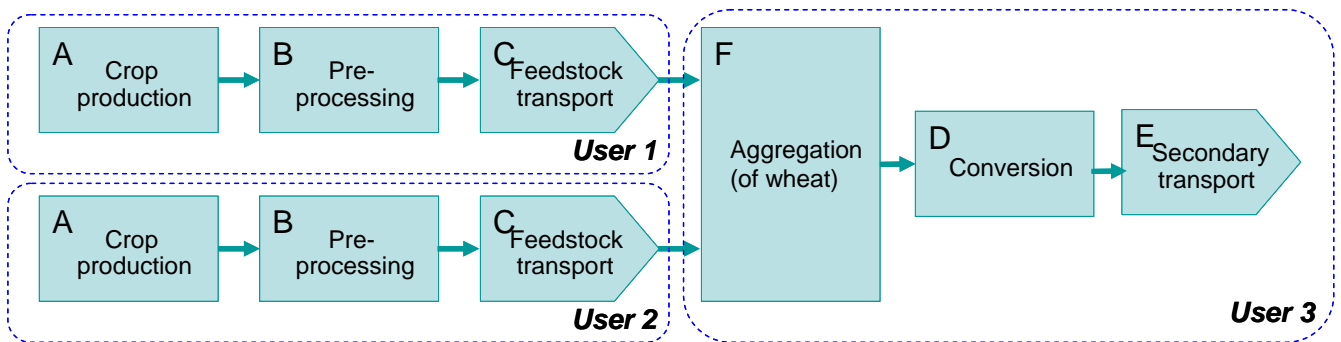
In each user sheet, it is possible to define 5 fuel chain steps: for each step, the user can choose among the 6 chain modules available.

The user can select the desired module from the drop down menu on the top left corner of the step. Then the desired module is automatically loaded and the user can fill in the data. There is also the possibility for the user to define batches of feedstock or ethanol for which the CO<sub>2</sub> content is already known: in the summary sheet, the user can input size and CO<sub>2</sub> content of up to 4 different batches.



### 1.2.1 Example: how to define a fuel chain

The following example guides the user on how to select the right modules to build a fuel chain. Let us assume the following fuel chain:



The first user is a farmer covering the stages of growing, drying and transporting the wheat to the conversion plant, who will fill in the sheet User 1 in the following way:

- Step 1: select Module A and fill in the relevant data
- Step 2: select Module B and fill in the relevant data
- Step 3: select Module C and fill in the relevant data.

The second user is another farmer covering the same fuel chain stages, who will fill in the sheet User 2 in a similar way:

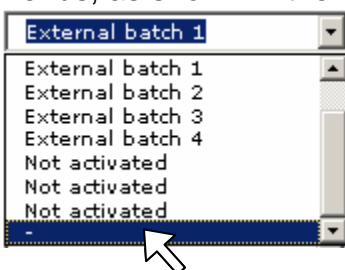
- Step 1: Module A
- Step 2: Module B
- Step 3: Module C

The third user is the manager of an ethanol plant, who will fill in the sheet User 3 in the following way:

- Step 1: select Module F and choose to merge the two feedstock batches from User 1 and User 2 (more on how to do this in the following paragraph)
- Step 2: select Module D and fill in the data relevant to the conversion process
- Step 3: select Module F and fill in the data relevant to ethanol transport

### 1.2.2 Example: how to aggregate different feedstocks or fuels

Module F allows merging multiple feedstock or fuel batches. In Module F the user can select, from the drop-down menus in the left-hand side columns, the different batches to be merged. To leave blank, select the “-” option which is the last one in the drop-down menus, as shown in the following picture:



**Step 1** - Aggregation of multiple contributions

**Module F - Aggregation of multiple contributions**

Select inputs	Quantities	Total CO2 emissions
User 1	[t]	0
User 2	[t]	0
External batch 1	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0
-	[t]	0

Select available contributions from the drop-down menus

Quantities and CO2 emissions are loaded automatically

The values of batch size and CO<sub>2</sub> emissions associated to the batches are loaded automatically.

Please note that the tool does not automatically perform consistency checks on the type of materials aggregated: therefore, it is up to the user to ensure that he is merging compatible items (i.e. wheat with wheat, or ethanol with ethanol).

### 1.2.3 Example: how to add external batches of feedstock or fuel

It is also possible to define external batches of feedstock or fuel, without the need to build them bottom-up through the fuel chain.

For instance, let us assume that the conversion plant manager (User 3 in the previous example), in addition to the two dry wheat feedstocks received from User 1 and User 2, needs to add another 20 tons of dry wheat, whose CO<sub>2</sub> associated emissions are 1,000 kg. Then User 3 can very easily do so, by going in the sheet Summary and defining an external batch in the first table, as follows:

**A**

**Emissions**

Name	Final batch size [t]	Total emissions [kg CO2]	Unit emissions	
User 1	0	-	-	#DIV/0! KgCO2 / t
User 2	0	-	-	#DIV/0! KgCO2 / t
User 3	0	-	-	#DIV/0! KgCO2 / t
External batch 1	20.00	1,000.00	50.00	KgCO2 / t
External batch 2	-	-	-	#DIV/0! KgCO2 / t
External batch 3	-	-	-	#DIV/0! KgCO2 / t
External batch 4	-	-	-	#DIV/0! KgCO2 / t
Not activated	-	-	-	#DIV/0! KgCO2 / t
Not activated	-	-	-	#DIV/0! KgCO2 / t
Not activated	-	-	-	#DIV/0! KgCO2 / t

Define quantity and total CO2 associated emissions

Unit CO2 emissions are calculated automatically

<-- Insert here size and CO2 content of <

<-- Insert here size and CO2 content of <

<-- Insert here size and CO2 content of <

<-- Insert here size and CO2 content of <

Please note that all values used in the examples above are purely illustrative.