REVIEW OF THE METHODOLOGY CONTAINED IN ANNEX V OF THE RENEWABLE ENERGY DIRECTIVE (2009/28/EC) AND REPLICATED IN ANNEX IV OF THE FUEL QUALITY DIRECTIVE (2009/30/EC): Deliverable 1 – Critical Review of the JRC Proposal

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Deliverable 1 – Critical Review of the JRC Proposal

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Executive Summary

1. This critical review of data in the proposal of the Joint Research Centre (JRC) for updating typical and default data in the European Commission's (EC's) Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) was prepared for the European Renewable Ethanol Association, ePURE. The context of this critical review is provided by summarising the background to relevant aspects of the RED and FQD. The aims and objectives of conducting the critical review of the JRC proposal as a whole and assessing its suitability for regulatory purposes are established.

2. The context for the JRC proposal provided by the greenhouse gas (GHG) emissions calculation methodology in the RED/FQD is set out. Problems with this methodology for regulatory purposes are established and subsequent influence on the JRC proposal is outlined.

3. The derivation of default values, for use in place of actual values, from typical values in the calculation of net GHG emissions savings of biofuels and bioliquids is explained. Since the term "typical" is not defined in either the EC or JRC documentation, a definition is put forward which emphasises the representativeness of the data. This and other criteria for assessing the data in the JRC proposal are elaborated.

4. The limitations of the currently-available draft version of the JRC proposal are identified. In particular, it is noted that this version is incomplete, that it contains mistakes in references to sources of information as well as missing references, and that the notes provided on the data presented have inadequate details about information from original sources and how such information have been used and combined. Failure to present subsequent typical and default values in this version of the JRC proposal is unhelpful for judging the relative importance of changes in these values.

5. From overall assessment of the JRC proposal, it is concluded that its main purpose has been to collect new data rather than the necessary task of assembling representative and coherent data for generating typical and default values. Instead, it would appear that information from diverse, possibly-unrelated and potentially-incompatible sources and models have been mixed together. Additionally, much of the information consists of nominal values selected from single sources or limited numbers of sources. This does not provide a sound basis for deriving truly representative data.

6. Assessment of specific pathway data and relevant GHG emissions factors in this critical review focuses on the current means of providing bioethanol, consisting of the production of bioethanol from wheat, maize, sugar beet and sugar cane. It is concluded that, instead of representing the EU-27 supply of bioethanol from these particular feedstocks, as might be expected, the data used for deriving typical and default values were based, specifically, on EU-27 wheat and maize cultivation, and Brazilian sugar cane cultivation. Additionally, data for the conversion of these feedstocks to bioethanol are based on an unrepresentative mix of information for the processing of wheat (from the UK, Canada and/or the USA, and Germany), maize (from the EU and USA), sugar beet (only from

Germany) and sugar cane (only from Brazil).

7. It would appear that coherent datasets, which include information that is interdependent, have not been used for cultivation data. It is suggested that, as a minimum, coherent datasets should have been formulated for crop yields, chemical nitrogen (N) fertiliser application rates and soil nitrous oxide (N_2O) emissions, with possible extension to include diesel oil consumption rates and, ideally, all other cultivation inputs and soil carbon dioxide (CO_2) emissions.

8. Additionally, it is noted that the JRC proposal relies quite significantly on modelling. This necessarily includes the modelling of soil N_2O and CO_2 emissions that are unlikely to be measured in the regulatory context. However, no evidence is presented that the soil N_2O emissions model, incorporating the Global crop- and site-specific Nitrous Oxide emission Calculator (GNOC), and the Acidification and Liming model, which simulates soil CO_2 emissions, have been validated with actual measurements from field trials. This raises doubts about whether these models, which are clearly sophisticated, are actually more accurate and reliable than existing procedures.

9. Agricultural lime ($CaCO_3$) application rates, also simulated by the Acidification and Liming model, have not been comprehensively verified with actual survey data. It is noted that, in the absence of coherent and comprehensive statistics on other cultivation inputs, information has been combined together from disparate sources for different periods of time, resulting in potential inconsistencies.

10. The JRC proposal uses an EU-27 supply model for deriving the GHG emissions factor for the provision of chemical N fertilisers. Instead of deriving relevant GHG emissions factors from the mix of different types of chemical N fertiliser that are actually used in cultivation, modelling addresses only a mix of ammonium nitrate and urea. Hence, the subsequent GHG emissions factor for chemical N fertilisers might not be entirely representative for the EU-27 and it has been incorrectly applied to cultivation outside the EU.

11. The JRC proposal adopts generic pathway data for bioethanol production based mainly on individual examples of installations. This means that subsequently-derived typical values for the GHG emissions of bioethanol production are likely to be illustrative rather than representative. Instead, pathway data should have been based on information which reflects the current or recent bioethanol industry, its plants and their actual performance.

12. Taking the findings of these assessments, this critical review concludes that, although a considerable amount of information and results from modelling have been assembled in the JRC proposal, most of the data presented are not suitable for regulatory purposes since they are not strictly representative and, hence, do not provide a sound basis for the derivation of typical and default values.

Contents

1. INTRODUCTION

1.1 Background

The Renewable Energy Directive, or RED (Ref. 1), and Fuel Quality Directive, or FQD (Ref. 2), of the European Commission (EC) require the "economic operators" of installations producing biofuels and bioliquids, including bioethanol, to achieve minimum net greenhouse gas (GHG) emissions savings[1] relative to specified "fossil fuel comparators". The specific requirements for minimum net GHG emissions savings is currently between 35% and 60% depending on the date of initial operation of a biofuel or bioliquid installation and on specified timescales for improvements[2] (Ref 1; Article 17, Para. 2). Minimum net GHG emissions savings are set within the context of a target contribution from renewable energy sources, including biofuels and bioliquids, in the consumption of energy by the European Union (EU) transport sector. At the moment, the minimum target contribution is 10% which was initially set out in the EC Renewable Energy Road Map (Ref. 3) and was re-stated in the RED (Ref. 1; Para. 13).

Both the RED and the FQD present the calculation methodology which should be used to determine total GHG emissions associated with the production and use of biofuels. The calculation methodology is presented as an equation consisting of a series of terms which represent or reflect the GHG emissions or savings of stages in the production and use of biofuels. Taken as a complete collection of stages, these are referred to, generally, as "pathways". Whilst economic operators are encouraged to report actual net GHG emissions savings associated with their biofuels, it is recognised that practical problems might be encountered. Hence, as an alternative, default values are provided which can be adopted partly or wholly in the determination of net GHG emissions savings by economic operators.

The original RED required the EC to report on both default values, and typical values from which these are derived, for GHG emissions calculations associated with biofuels by 31 December 2012 and for every two years thereafter (Ref. 1; Article 19, Para. 5). Additionally, the possibility of adapting the calculation methodology and the default values to "technical and scientific progress" was raised in the RED (Ref. 1; Article 19, Para. 7). This requirement was elaborated, in terms of the updating of default values in a subsequent Communication (Ref. 4). As part of this process, the Joint Research Centre (JRC) at Ispra, Italy, were engaged to update typical and default values. Following a series of consultation activities, the JRC published a draft report on proposed data for new typical and default values in 2013 (Ref. 5). It is on this specific version of the JRC proposal that current work for the European

[1] Net GHG emissions of a given biofuel or bioliquid are specified as the difference between the total GHG emissions of the fossil fuel comparator, E_F, and the total GHG emissions of the biofuel or bioliquid, E_B, divided by the total GHG emissions of the fossil fuel comparator, E_F, or $(E_F - E_B)/E_F$.

[2] The currently required minimum net GHG emissions savings from biofuels and bioliquids is 35% for existing installations, which increases to 50% from 1 January 2017, and will be 60% from 1 January 2018 for installations which start on or after 1 January 2017.

Renewable Ethanol Association, ePURE, focuses, with particular reference to those essential issues that affect the European bioethanol industry.

1.2 Aims and Objectives

The aims of this current work are:

- to conduct a critical review of the JRC proposal as a whole by addressing its methodology, models, assumptions and data, and its compliance or otherwise of the principles and best practices of life cycle assessment (LCA), and

- to assess the suitability of the JRC proposal for regulatory purposes taking into account the realities of actual biofuel and bioliquid production.

The objectives required to achieve these aims consist of:

- setting the context for GHG emissions calculations in the RED/FQD and the JRC proposal with reference to LCA principles and best practice,

- explaining the nature of typical and default values within the RED/FQD within this context,

- summarising the general procedures adopted by the JRC for obtaining proposed data for new typical values,

- establishing criteria for determining the suitability of proposed data for application within RED/FQD regulation,

- assessing new pathway data and GHG emissions factors in the JRC proposal with these criteria, and

- formulating conclusions about the overall suitability of the JRC proposal.

2. CONTEXT FOR GREENHOUSE GAS EMISSIONS CALCULATIONS

Before addressing the main aims and objectives of this critical review, it is necessary to set this work in an appropriate context. The methodology for undertaking GHG emissions calculations described in the RED/FQD are a form of LCA. Hence, it is relevant to ask whether the approach adopted in the JRC proposal conforms with the “principles or laws of LCA” and whether the data presented are derived from “correct” LCA studies. In order to appreciate the potentially-involved answers to these deceptively simple questions, it is necessary to understand the nature and application of LCA. The principles of LCA, on which best practice is based, are formally established in ISO 14040 series; specifically, ISO 14040 (Ref. 6). A major consequence of these principles is that the methodology adopted should satisfy the explicit purpose or “goal” of the LCA. Furthermore, the LCA should have sufficient transparency so that it is possible to judge, independently, whether its adopted methodology is consistent with its goal. Clearly, any LCA study or calculation which does not specify its goal does not conform with these widely recognised principles of LCA, and, without knowledge of the goal, it is not possible to determine whether an LCA study is "correct" and in compliance with best practice.

This presents two basic problems for the RED/FQD and the JRC proposal. First, the RED/FQD do not state, explicitly, clearly and comprehensively, the purpose of the GHG emissions calculations[3], and, second, without such necessary goal specification, it is not possible to decide, directly, whether the LCA sources for data in the JRC proposal are appropriate. However, the existence of these particular problems does not mean that reasonable inferences and conclusions cannot be drawn with regard the JRC proposal and its relevance to the RED/FQD. In particular, careful examination of the RED/FQD has led many LCA practitioners to conclude that, since it has been devised, primarily, for regulatory purposes, its GHG emissions calculation methodology should consist of a specific type of LCA known as attributional LCA (see, for example, Refs. 7 and 8). The reason for this conclusion is that it is abundantly apparent that, within the RED/FQD, "responsibility" for GHG emissions is being attributed to the economic operators of installations which produce biofuels and bioliquids.

Unfortunately, the GHG emissions calculations methodology described in the RED/FQD does not consist of a single type of LCA. Instead, it is a mixture or hybrid of attributional LCA and so-called consequential LCA which is commonly used in policy analysis to determine the overall impact of decision-making. These two types of LCA have distinctly different goals and, hence, employ fundamentally different methodologies. The hybrid nature of the methodology set out in the RED/FQD is apparent in many instances. Probably the most prominent example is that it uses co-product allocation, which is a facet of attributional LCA, whilst adopting a substitution credit approach to the evaluation of excess electricity from cogeneration, which is a feature of consequential LCA. In effect, the RED/FQD methodology is attempting to meet two goals, namely regulation and policy analysis, simultaneously which is, of course, impossible and contrary to the principles of LCA.

It is highly likely that this unfortunate situation has arisen because of earlier developmental work in the form of the JEC Well-to-Wheel (WTW) studies (see, for example, Ref. 9) which were obviously undertaken for policy analysis. The significance of this is that there are apparent links between the JEC WTW studies, in terms of their general approach and data sources, and the typical and default values presented in the RED/FQD. Whatever the actual details of this genesis, the fact remains that there is a far from perfect basis to the GHG emissions calculation methodology in the RED/FQD and, therefore, to the existing typical and default values. Clearly, this less-than-ideal basis creates a

[3] At a stretch, it might be contended that the purposes of deriving net GHG emissions savings for biofuel and bioliquids is for "measuring compliance with the requirements of this Directive (RED) concerning national targets", "measuring compliance with renewable energy obligations" and satisfying "eligibility for financial support for the consumption of biofuels and bioliquids" (Ref. 1; Article 17 Paras 1 and 2). However, this broad range of multiple purposes conflates both regulatory and policy aims which cannot be addressed simultaneously by means of a single indicator.

challenging context in which to assess the updating of these values in the JRC proposal by means of the strict and rigorous interpretation and application of established LCA principles and best practice.

Despite this fundamental drawback, the JRC proposal would appear to follow the GHG emissions calculation methodology set out in the RED/FQD. It must, however, be appreciated that this methodology is far from prescriptive. Within the principles of LCA, the explicitly stated purpose of the calculations would automatically determine the details of the methodology. Unfortunately, without such clear goal definition, the RED/FQD provides a highly-generalised and patently-incomplete list of what should and should not be included in the calculations. This means that coverage of GHG emissions associated with specific pathway stages is not definitive. For example, it is stated that GHG emissions associated with biofuel crop cultivation shall include "emissions from…the cultivation process itself, from the collection of raw materials, from waste and leakages; and from the production of chemicals or products used in…cultivation" (Ref. 1; Annex V, Part C, Para. 6). This and other explanations in the RED/FQD are sufficiently vague and, consequently, are open to interpretation.

In the absence of rigorous goal definition or comprehensive guidance in the RED/FQD, it would appear that the JRC proposal has applied its own, implicit interpretation. In this regard, it could be argued that the JRC proposal has expanded its coverage to ensure that sources of GHG emissions that were overlooked in previous JEC WTW studies are now included in the calculations. However, such logic is neither explained nor elaborated in the JRC proposal. As part of the process of reporting on typical and default values, the RED specifies the correction of these values (Ref. 1; Article 19, Para. 6) and modification of the GHG emissions calculation methodology based on technical and scientific progress (Ref. 1; Article 19, Para. 7). In its introduction, the JRC proposal states that the RED reporting process includes "updating existing values" and that "the existing input database" was updated at the request of the EC's Directorate-General for Energy (Ref. 5; Page 16). Furthermore, the aims of consultation with experts included ensuring that "data sources were current" (Ref. 5; Page 18). Hence, it can be concluded that a major part of the intended purpose of the JRC proposal is to update data used in the calculation of typical and default values. Compliance with the principles of LCA is not addressed in the JRC proposal since this is principally a matter of whether the calculation methodology in the RED/FQD is "fit for purpose".

3. TYPICAL AND DEFAULT VALUES

The stated intention of the default values in the RED is to "avoid disproportionate administrative burden on economic operators" who are producing biofuels and bioliquids under a regulatory regime which emphasises reductions in associated GHG emissions (Ref. 1; Para. 82, and Ref. 4; Section 3). Such default values can be used by economic operators as alternatives to actual values that must be estimated using relevant data with the specified calculation methodology. In this regard, the main expected burden on economic operators is likely to be the collection and analysis of such data rather than the calculations themselves.

Default values are available for a number of the elements in the specified equation for deriving and reporting of total GHG emissions associated with the production and use of biofuels and bioliquids, E_b. As specified in the RED (Ref. 1; Annex V) and the FQD (Ref. 2; Annex IV), these elements relate to:

- extraction or cultivation of raw materials (e_{ec}),
- carbon stock changes caused by land-use change (e_l),
- processing (e_p),
- transport and distribution (e_{td}),
- fuel in use (e_u),
- soil accumulations via improved agricultural management (e_{sca}),
- carbon capture and geological storage (e_{ccs}),
- carbon capture and replacement (e_{ccr}), and
- excess electricity from cogeneration (e_{ee}).

In this critical review, the "extraction or cultivation of raw materials" is equivalent to the cultivation of crops used to produce bioethanol. Default values are provided for cultivation, for processing and any excess electricity from cogeneration, and transport and distribution. For reasons explained shortly, both typical and default values are given for processing and any excess electricity from cogeneration. Although economic operators can choose to adopt default values to any relevant element of the RED/FQD equation, it is important to appreciate that this choice will be affected by practical considerations. In particular, an economic operator of a biofuel installation would normally have access to real data on processing. Indeed, economic operators would prefer to use data which reflect the actual design and operation of their own installation rather than a generalised representation that might have been used to derive typical and default values. In contrast, economic operators might not be able to access actual data on cultivation from their suppliers. Consequently, economic operators are more likely to be concerned about the derivation and updating of default values for cultivation rather than for processing.

Whilst it is possible for economic operators to mix both actual and default values in calculations for their reported net GHG emissions savings, there are, in effect, penalties for doing so. This is because default values are intentionally "conservative" and, in some cases, if reported net GHG emissions savings are based entirely on default values, an economic operator can fail to reach the minimum net GHG emissions savings required for classification of a product as a biofuel within the context of the RED and FQD. The approach adopted for deriving these conservative default values has been described briefly (Ref. 4; Sub-Section 3.1). It depends on the typical values of GHG emissions associated with elements of the RED/FQD equation. In particular, typical values of GHG emissions associated with processing and excess electricity from cogeneration have been increased by 40%. Given the nature of the typical values for cultivation, and transport and distribution, these form the unadjusted basis for the default values. Consequently, it can be seen that typical values play a crucial role in the preparation of default values.

Although not documented explicitly, it is apparent that the approach to the derivation of typical values is similar to that used in earlier and ongoing JEC Well-to-Wheels (WTW) studies (see, for example, Ref. 9). In particular, this involved assembling generic pathways for biofuels and bioliquids, and populating these with data usually obtained from industry or published sources. This approach can be generalised as consisting of:

- specifying the nature of the generic pathway,
- determining its details, consisting mainly of mass balances and data on important inputs, and
- converting such information into GHG emissions by means of relevant emissions factors.

4. PROCEDURES FOR THE JRC PROPOSAL

The procedures adopted by the JRC for obtaining proposed data for new typical and default values involved a mixture of data collection and model development, followed by consultation with LCA practitioners, economic operators in the EU biofuel and bioliquids industry and other relevant stakeholders. In particular, detailed discussions on biofuel pathways and emissions factors that are used to determine the contributions of elements to the RED/FQD equation for these pathways were held at a workshop of invited experts at Ispra on 22 and 23 November 2011. These discussions took place within a framework of important issues identified for resolution by the JRC.

It should be noted that the JRC proposal which emerged from these activities is specifically referred to as an “input database” for calculating typical and default values. There are two important aspects to this input database:

- specification of the generic biofuel and bioliquid pathways, and
- determination of GHG emission factors.

Biofuel and bioliquid pathways are specified by describing the stages that they contain, and by establishing main mass balances of biofuel or bioliquid crops or feedstocks, intermediate products and any co-products, and the final biofuel or bioliquid and their co-products for these stages along with data on other prominent inputs and outputs. It is important to realise that the current version of the JRC proposal only presents the new data for the generic pathways and the GHG emissions factors. It does not contain the subsequent typical and default values that would be obtained from the new data. It appears that such typical and default values have not been published officially so far. Such publication would have assisted in understanding the impact of changes in the new data, judging their relative importance and interpreting the nature of the new typical and default values.

Consultation undertaken in developing the JRC proposal seems to have consisted mainly of inviting opinions and contributions from LCA practitioners, industry experts and other stakeholders on updating of pathway data and GHG emissions factors, and on specific modelling approaches developed by the JRC. Whilst updating as a means of replacing earlier with more recent data was a prominent concern of such consultation and subsequent discussions, it was apparent that seeking consensus on modelling approaches was also an important consideration. However, it is apparent that the effectiveness of these necessary activities was not assisted by the lack of clearly-expressed criteria for assessing the suitability of proposed data and models in the essential context of deriving new typical and default values for the RED/FQD.

5. DATA ASSESSMENT CRITERIA

In order to assess the suitability of the new data in the JRC proposal, it has been necessary to devise relevant criteria. Given that these data contribute to the preparation of proposed default values, it is essential that these address the meaning of “typical” in the values from which these are derived. There is no definition of typical values in the RED, FQD, any of the supporting documentation, or, indeed, the JRC proposal. In the absence of this, the Oxford English Dictionary defines typical as “having the distinctive qualities of a particular type of…thing” or “representative as a symbol” (Ref. 10). Hence, it is reasonable to expect that typical values should be derived from representative pathways and representative emissions factors.

The way in which relevant data would be representative depends on the intended application of the default values as replacements for actual values by economic operators of installations that produce biofuels and bioliquids. Consequently, typical values for, say, bioethanol production in the EU would be expected to be based on data which represent the circumstances of the entire industry, both in terms of actual pathways and relevant GHG emissions factors. Additionally, it should be noted that the new data are intended to update previous data used in deriving existing typical values provided. Therefore, typical values should be based on data which represent current circumstances. Since there might be difficulties in obtaining data which are truly “current”, it might be acceptable to relax requirements adopting data which represent “most recent” circumstances. It should also be noted that illustrative data cannot be uncritically adopted as being representative. Such data may be derived from nominal values in single or a limited number of sources. In this context, a nominal value is defined as being “stated or expressed but not necessarily corresponding exactly to the real value” (Ref. 10).

One particularly pertinent consideration for the derivation of representative data concerns the use of statistical information. Agricultural statistics for a relevant region, such as the EU-27, would seem to be an appropriate source of information on which to base representative data for biofuel crop production. Similarly, suitable statistics might also provide an appropriate basis in deriving many GHG emissions factors. However, it is necessary to take into account the realities of the biofuels and bioliquids industry in adopting such statistics. Agricultural statistics for individual years can display considerable fluctuations due to the vagaries of the weather and other underlying factors. In order to smooth out such fluctuations and avoid misrepresentation by using unusual statistics for any one given year, it is common practice to adopt “moving averages” over a specified period of, say 3 or 5 years. Hence, it might seem reasonable to expect that this approach would be applied consistently in deriving representative data.

In addition to this very important criterion of “representativeness”, there are supplementary criteria which determine the suitability of data for deriving typical and default values. These consist of “transparency” and “consistency”. Transparency is an essential issue which governs whether the relevant details behind pathway data and GHG emissions factors are known and, hence, whether they can be assessed accordingly. Complete transparency requires that all data, sources, assumptions and calculation methods are accessible for independent assessment. However, this is rarely achieved in practice and reference to reputable published material is often regarded as an acceptable if limited alternative in practical situations. In instances in which even limited details are not provided then it is not possible to judge whether the data are suitable and, hence, they must be regarded as lacking adequate transparency.

Consistency refers to whether data have been derived in the coherent manner from complementary sources. In terms of pathway data, consistency is an important criterion regarding combinations of data, or so-called datasets, which are interdependent. Most importantly, in biofuel crop cultivation, yield can, to varying degrees, be dependent on the nitrogen (N) fertiliser application rate, the application rates of other agrichemicals, pesticides, etc., as well as farming practices which can affect the diesel fuel consumption rate. For consistency, such interdependent data should be obtained as complete datasets from single sources statistics. Another important aspect of consistency, which applies to both pathway data and GHG emissions factors, is whether they adequately reflect current or recent circumstances. For example, this would determine whether pathway data are based on the existing range of biofuel plants and their supporting activities, and, in the case of GHG emissions factors whether these are based on the existing mix of supply or provision.

There is also a further consideration which is “significance”. Some data make greater contributions to the derivation of typical and default values than others. It is possible to determine the relative contributions of such data from examples of GHG emissions calculations (see, for example, Ref. 11). To avoid distractions by considering many relatively minor issues, it is essential to focus on those data which make the most impact on typical and default values. These data are indicated as having high significance with others graded as either moderate or low significance. For convenience, the specification and qualifications of significance and other criteria for assessing the new data in the JRC proposal are summarised in Table 1.

Table 1 Data Assessment Criteria

Data Assessment Criteria	Specification and Qualifications
Significance	This indicates the relative contribution that specified data make to total GHG emissions associated with bioethanol production. Low: A relatively minor contribution generally around or less than 1% of total GHG emissions. Moderate: A noticeable but not dominating contribution generally between around 1% and 10% of total GHG emissions. High: A very major or dominating contribution generally greater than around 10% of total GHG emissions.
Representativeness	This specifies whether the data represent current or recent circumstances that are relevant to the pathway or GHG emissions factor under consideration with qualifications summarised accordingly. Unrepresentative data can consist of nominal values for individual examples of pathway data or GHG emissions factors. Representative data suitable for the production of typical values can be in the form of statistics based on ranges or results derived from models.
Transparency	This refers to public accessibility of information, assumptions, sources and calculations used for specified data. Low: Non-existent or very limited access to relevant details used in specified data. Moderate: Access to essential details but not all details used in specified data. High: Complete or almost complete access to all details used in specified data.
Consistency	This summarises whether the data have been derived in a coherent manner and/or from complementary sources. Where relevant, this indicates whether pathway data are or are not part of definitely-required, possibly-required or ideally-required coherent datasets. In other instances, this indicates whether values are or are not based on ranges of data that reflect relevant current or recent circumstances.

To assist identification of the key concerns in the assessment of data in the JRC proposal, simple "traffic light" shading has been adopted. This is summarised in Table 2. The shading has been applied separately to assessment criteria and their qualification for each data entry examined in this critical review.

Table 2 "Traffic Light" Shading for Data Assessment

Traffic Light Shading	Explanation
(red)	Issue of serious concern: High significance for calculation of greenhouse gas emissions; unrepresentative data, low transparency in derivation; or major inconsistency.
(orange)	Issue of intermediate concern: Moderate significance for calculation of greenhouse gas emissions; possibly unrepresentative data; moderate transparency in derivation; or possible inconsistency.
(green)	Issues of minor concern: Low significance for calculation of greenhouse gas emissions; likely representative data; high transparency in derivation; or likely consistency.

6. ASSESSMENT OF PROPOSED DATA FOR NEW DEFAULT VALUES

6.1 Assessment Framework

This critical review of the proposed data in the JRC proposal for deriving new typical and default values focuses on current means of producing bioethanol in the EU and elsewhere, consisting of bioethanol production from EU wheat, EU maize, EU sugar beet and Brazilian sugar cane. Given the considerable and diverse scope to the JRC proposals, this critical review does not address proposed new means of producing bioethanol, nor other means of producing biofuels and bioliquids. However, similar assessment can be applied to these other pathways. Additionally, some of the subsequent conclusions obtained from this assessment will also be relevant to these other pathways. It should be noted that one important reason why new bioethanol technologies, such as lignocellulosic processing of straw and wood have been excluded from this critical review is that it is not possible to devise representative data for pathways that have yet to be implemented. As such, illustrative data can only be obtained for these future pathways that are based on specific examples of each technology and incorporate speculative information performance which might or might not be substantiated in actual commercial circumstances.

Before presenting the main findings of this assessment, it is necessary to emphasise the limitations of the currently-available draft version of the JRC proposal (Ref. 5). This is because these limitations create difficulties in undertaking a systematic, thorough and detailed assessment of all necessary aspects of the proposed data. It is clear that the current JRC proposal is incomplete since certain data are missing from the draft version. For the pathways considered here, missing data are recorded in this assessment. It is also apparent that there are mistakes in referencing sources used to generate data in the JRC proposal. In some instances, the references seem to be incorrect and, in other instances, the references are missing. Such errors can be significant as they prevent proper evaluation of the nature of the original data and whether it is, ultimately, suitable for deriving typical and default values. There are also instances of typographical mistakes although these are not necessarily important.

Whilst it would be expected that such errors and omissions will eventually be corrected in the final version, there are two very fundamental aspects of the JRC proposal which need to be appreciated in relation to this assessment. First, in many instances, the full information required to evaluate the nature and, hence, suitability of the proposed data is not provided. For example, although sources might be referenced and can be accessed, the way in which the information they provided might have been used to generate proposed data is either not summarised in adequate detail or, indeed, not explained at all. This occurs frequently and, when it does, it undermines independent assessment. Second and most crucially, it is again necessary to emphasise that the current version of the JRC proposal does not actually present any typical and default values. Instead, it only provides the data from which such typical and default values could be derived. Consequently, any assessment is restricted to the evaluation of the data presented for relevant pathways. To assist understanding of the outcomes, this assessment is organised into the evaluation of relevant pathway data and to related GHG emission factors.

6.2 Pathway Data

Pathway data provided in the JRC proposal consist of what can be mainly characterised as mass balances and major inputs. For the most part, assessment of such data has been presented for bioethanol production from wheat, maize, sugar beet and sugar cane in Appendix A (Tables A1 to A4, respectively). These consist of all the pathway stages specified in the JRC proposal from crop cultivation to bioethanol available at the production installation. The assessment of heat supply to all bioethanol processes, and bioethanol transport, depot and filling station operations are also provided in Appendix A (Tables A5 and A6, respectively). In general, this reflects the approach adopted in the JRC proposal.

Before discussing the other main outcomes of the assessment of pathway data, it is necessary to consider the overall representativeness of such data with respect to the typical and default values in the RED/FQD. Given the expressed purpose of the RED/FQD default values, it might be expected that these would represent the supply of biofuels and bioliquids in the EU rather than production in any one country or region. For bioethanol, in particular, current supply in the EU can be characterised, qualitatively, as follows:

- bioethanol from wheat: installations inside the EU-27 processing a mix of indigenous and imported wheat,

- bioethanol from maize: installations inside the EU-27 processing indigenous maize, and imports from installations outside the EU-27 processing indigenous maize,

- bioethanol from sugar beet: installations inside the EU-27 processing indigenous sugar beet, and

- bioethanol from sugar cane: imports from installations outside the EU-27 processing indigenous sugar cane.

However, the pathway data presented in the JRC proposal might not necessarily be suitable for deriving typical and default values which would represent EU-27 bioethanol supply from specific feedstocks in all instances.

In the case of wheat, the information in the JRC proposal strongly suggests that the pathway data are for wheat cultivation in the EU-27 alone. This is because the sources cited for wheat cultivation all refer to EU data (Ref. 5; Page 138); and the indication that data for all important inputs to cultivation, such as fertilisers, pesticides, etc., and diesel fuel were obtained from a "database of EU agriculture" (Ref. 5; Page 135) which also seems to have provided data on wheat yields (Ref. 5; Page 62). In contrast, it is apparent that this conflicts with the statement that average cereal pathway data are for a "mix in EU ethanol supply" (Ref. 5: Page 137). Additionally, it is unlikely that the pathway data for the conversion of wheat to bioethanol is representative of EU-27 bioethanol supply from this particular feedstock since they consist of a combination of information from the United Kingdom (UK), Canada and/or the United States of America (USA) and Germany (Ref. 5; Page 142).

For bioethanol production from maize, the relevant pathway data for cultivation in the JRC proposal are clearly labelled as "maize cultivation in the EU" (Ref. 5; Pages 144 and 145), and, again, all the sources cited for maize cultivation refer to EU information. Consequently, there are no pathway data for maize cultivation outside the EU-27 such as, for example, in the USA. On the contrary, it should be noted that pathway data from the USA is cited prominently for the conversion of maize to bioethanol (Ref. 5; Page 146). This implies that, at best, a mix of pathway data from the EU and USA have been used to represent maize conversion to bioethanol. Hence, it seems unlikely that these pathway data adequately represent the EU-27 supply of bioethanol from maize.

The cultivation and processing pathway data for bioethanol production from sugar beet rely on information from the EU. This is appropriate since the EU-27 supply of such bioethanol is most likely to be from EU-27 installations which process indigenous sugar beet. However, whilst the pathway data might, for the most part, represent EU-27 sugar beet cultivation (Ref. 5; Page 151), the information for conversion to bioethanol is dominated by sources from Germany (Ref. 5; Pages 152 and 153). Therefore, taken together, such pathway data might not completely represent the EU-27 supply of bioethanol from sugar beet.

Given the size of its long-established sugar cane and bioethanol industries, Brazil can dominate trade in bioethanol from sugar cane globally and, in particular, to the EU. Probably reflecting this, the JRC proposal relies, almost entirely, on Brazilian pathway data on sugar cane cultivation and its conversion to bioethanol (Ref. 5; Pages 159 to 162). However, a number of other countries can also supply bioethanol derived from sugar cane to the EU-27. Evidence supporting the exclusive choice of Brazilian bioethanol from sugar cane as representative of EU-27 supply from this particular source is not presented in the JRC proposal. Hence, although the pathway data seems likely to represent the EU-27 supply of bioethanol from sugar cane, this is not entirely conclusive.

Before summarising the other main outcomes of the assessment of pathway data, it is essential that the general approach adopted in the JRC proposal is re-iterated. In similarity with the JEC WTW studies (see, for example, Ref. 9), generic pathways have been established as a basis for the derivation of typical and default values. Whilst this generic approach is often adopted in policy analysis, it can be criticised as lacking the statistical relevance needed to represent actual circumstances. For example, it is apparent that real biofuel and bioliquid installations often adopt individual technical features which cannot be adequately reflected in individual generic examples. At best, the generic approach is illustrative rather than statistically representative and, at worst, potentially subjective instead of essentially objective. Hence, this suggests a basic weakness in the approach adopted in the JRC proposal since any typical values derived from subsequent pathway data will not necessarily represent actual practices in the current or recent EU biofuels and bioliquids industry.

Additionally, it is apparent that the main purpose of the JRC proposal has, in fact, been to collect new data rather than to assemble representative and coherent data for the generation of typical and default values. This means that information is sometimes combined from different sources that might or might not may or may not be compatible, thereby undermining the consistency of the proposed data. This is particularly apparent with the cultivation data assessed in Tables A1 to A4. In order to produce representative data from which typical values can be derived, certain information should form part of a coherent dataset which is statistically-relevant for a chosen location, such as the EU-27 or Brazil. Ideally, crop yield should form part of such a coherent dataset with all cultivation input rates and soil GHG emissions. At the very least, there needs to be coherence between the yield, the N fertiliser application rate and soil N_2O emissions. It is apparent that this is not the case for the crops considered in Tables A1 to A4.

The lack of essential coherence can be demonstrated by considering, specifically, the data with high and moderate significance for total GHG emissions associated with bioethanol production. In many instances, representative statistics are accessed for data on yield, N fertiliser application rates and diesel fuel consumption. Unfortunately, some of these statistics are for different years and it is not clear whether or how these have been reconciled. In particular, 3 year moving averages, covering 2000 to 2002, have been obtained from the Common Agricultural Policy Regional Impact Analysis (CAPRI) database for EU wheat and sugar beet yields and their respective diesel oil consumption rates, whilst their respective N fertiliser application rates were derived from Food and Agriculture Organisation (FAO) statistics for "approximately" 2000. Similarly with Brazilian sugar cane data, the essential dataset is incoherent because a 6 year moving average yield provided by local statistics between 1998 and 2003 is mixed with an N fertiliser application rate from FAO statistics in 2000 and nominal values for diesel oil consumption rates in 2004 and 2008. The situation with maize cultivation is even less coherent as the source of EU maize yield is unspecified. Furthermore, it should be noted that the types of N fertiliser that make up the cited application rates are not specified and yet they are subsequently used in conjunction with GHG emissions factors for an assumed combination of ammonium nitrate and urea. Whilst such incoherence might reflect the limitations of existing statistics, it indicates that the data might not be consistently representative and, as such, do not reflect the realities of actual bioethanol production.

Soil N_2O emissions are also a part of the definitely-required coherent dataset for representative crop cultivation data. In the regulatory context, soil N_2O emissions from the application of chemical N fertilisers and organic fertilisers, and from the incorporation of crop residues are rarely measured directly. Instead, these soil N_2O emissions are usually modelled. In contrast to the simplest model, consisting of the so-called Tier 1 approach of the Inter-Governmental Panel on Climate Change (IPCC) to soil N_2O emissions (Ref. 12), the JRC proposal derives results using the Global crop- and site-specific Nitrous Oxide emission Calculator (GNOC) which is a more sophisticated model (Ref. 13). Given the relative potential importance of soil N_2O emissions and the complexities of the modelling approach, a separate critical review of the JRC soil N_2O emissions model is presented in Appendix B.

It is difficult to reach completely definitive conclusions on the suitability, or otherwise, of this modelling approach due to lack of information on actual data and calculations. However, specific concerns over major aspects of the modelling approach can be identified. In particular, the Stehfest and Bouwman model (Ref. 14), which has a central role in the modelling approach, is based on very limited data for specific crops, especially for sugar beet and possibly for sugar cane, and is thought to contain large uncertainties. It is not clear whether the modelling approach uses strictly compatible data on N fertiliser types and application rates, and crop yields. Additionally, there are uncertainties about assumptions regarding the application of organic fertilisers (manures) and the incorporation of crop residues, such as straw, which do not seem to be based on actual statistics. Most significantly, no evidence has been presented that the JRC soil N_2O emissions model, in total or in part, has been validated thoroughly with actual field measurements and relevant statistics. Hence, it is not known whether its sophistication generates more accurate, reliable or representative results than existing calculation procedures, such as the much simpler IPCC Tier 1 approach.

If the wider crop cultivation dataset is considered, there are further concerns about the mixing of data from different sources which are unlikely to be coherent. Of particular concern is the derivation of agricultural lime (aglime) or $CaCO_3$ fertiliser[4] application rates and subsequent soil CO_2 emissions by means of the JRC acidification and liming model. A separate critical review of the JRC acidification and liming model is provided in Appendix C. Whilst it is necessary to model soil CO_2 emissions, the extension of simulation to the

[4] Referred to as $CaCO_3$ fertiliser but possibly consisting of limestone ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$).

estimation of aglime application rates is due to the absence of consistent statistics for all relevant countries addressed by the JRC proposal. Again, the lack of many actual details in this modelling approach prevent definitive, independent judgement of its suitability for deriving typical and default values. However, it is apparent that evidence is needed to demonstrate, conclusively, that aglime application rates simulated by the modelling approach accurately reflect actual survey data. Furthermore, the rules adopted by the modelling approach for estimating soil CO_2 emissions from the acidifying effect of N fertilisers and neutralisation by aglime need to be validated by actual field measurements. Without such supporting evidence, the JRC acidification and liming model must be regarded as unproven.

It is noticeable that the CAPRI database provides pathway data, directly, for at least three types of data for EU biofuel pathways in the JRC proposal; diesel fuel consumption rates and crop protection chemical or "pesticide" application rates[5], and electricity consumption rates for wheat and maize drying. In general, the CAPRI database provides specific agricultural data on a geographical basis[6] across the EU (Ref. 15). Some of these data are derived from statistics and others are simulated.

Actual statistics for diesel fuel consumption are not available. Hence, these are simulated in the CAPRI database by mapping quoted rates for agricultural operations from a German agricultural handbook (Ref. 16) onto the distribution of soil types across the EU-27 (Ref. 15; Page 212). Verification of the rates of diesel fuel consumption for agricultural operations and their applicability across the EU might be considered to be necessary. However, it is likely that this information is based on standard performance data, consisting of diesel fuel consumption rates and work rates for tractors and other common agricultural machinery in widespread use throughout the EU and elsewhere.

It would appear that crop protection chemical application rates from the CAPRI database are derived from national consumption data from FAO statistics (Ref. 15; Page 215). However, electricity consumption rates for EU wheat and maize drying are simulated using standard data, related to levels of pre- and post-drying moisture contents, from the German agricultural handbook (Ref. 16). This involved using moisture content data from harvesting statistics for Germany and extrapolating results, using climate information, to other EU Member States (Ref. 15; Page 215). This might raise questions again about verifying the validity of drying data and its applicability across the EU. However, a more significant concern is that diesel fuel, liquefied petroleum gas and other fuels rather than electricity are in common use for cereal drying in many EU Member States. Consequently, the pathway data incorporated into the JRC proposal for wheat and maize drying is unlikely to be representative.

There are similar concerns for data on EU wheat, maize and sugar beet handling and storage which includes nominal values for electricity consumption

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5 "Pesticides" are taken as the combination of all crop protection chemicals including herbicides, fungicides, etc.

6 The main geographical basis adopted in the CAPRI database is the regional-level administrative unit referred to as NUTS2. However, in some instances, data are mapped on 1 km x 1 km grid cells.

rates from single unrepresentative sources. However, it should be noted that these data have low significance in terms of contributions to total GHG emissions associated with bioethanol production. Related considerations apply to the contributions of EU wheat, maize and sugar beet transport. Unrepresentative data on losses, assumed to be zero, are mixed with nominal values for road transport distances, although the overall contributions to total GHG emissions are low. There are similar concerns for the Brazilian transport of sugar cane which makes a moderate contribution to total GHG emissions.

Bioethanol production data also consist of a mix of information from different sources which might or might not may or may not be consistent. In terms of high to moderate significance, the most prominent data for bioethanol production are the ratios of feedstock input to bioethanol output, the ratios of co-product output to bioethanol output (for distillers' dark grains and solubles, DDGS, with wheat and maize and beet pulp with sugar beet), and the steam consumption rates. In some instances, nominal values are combined together from different sources which might or might not may or may not be compatible. However, the most important cause for concern is that there is no indication that these data are representative of all relevant bioethanol plants in the EU. Although it is likely that data are more representative of Brazilian production of bioethanol from sugar cane because they appear to be based on statistics, it should be noted that the sources used are for 2003/2004 so that they cannot be regarded as truly current. Problems with the mixing of information from potentially incompatible sources and their unrepresentative nature affect all the other data provided for EU bioethanol production from wheat, maize and sugar beet in the JRC proposal. There also concerns that the other data for Brazilian bioethanol production from sugar cane which, although apparently based on statistics, do not necessarily reflect current or recent practice.

The approach adopted in the JRC proposals for evaluating GHG emissions for biofuel production, in general, involves converting assumed steam consumption rates using data for generic processing heat supply. The options covered in the JRC proposal consist of natural gas-fired boilers, and natural gas-, lignite and wood chip-fired combined heat and power (CHP). The options actually addressed in the JRC proposal are is incomplete given that the list includes the supplementary use of biogas from beet pulp in natural gas-fired boilers and CHP units in EU plants producing bioethanol from sugar beet, and the use of hard coal-fired CHP units in EU plants producing bioethanol from maize. Additionally, the extensive use of bagasse for firing CHP units in Brazilian plants producing bioethanol from sugar cane is not accommodated explicitly. In all instances where data are provided for the bioethanol processing heat supply options, nominal values for fuel consumption rates have been used from single sources which might or might not may or may not represent current or recent configurations in EU bioethanol plants. In some cases, inadequately referenced sources have been used or original information has been modified in unspecified ways. Consequently, the data presented in the JRC proposal on bioethanol process heat supply can only be regarded as illustrative rather than representative.

The pathway data on bioethanol transport, and depot and filling station operation are of low significance in terms of their contributions to total GHG emissions. However, it is apparent that all these data consist of nominal values obtained from single sources. As such, they cannot be considered as conclusively representative for the supply of bioethanol in the EU.

6.3 Emissions Factors

This assessment of GHG emissions factors in the JRC proposal has been restricted to those which are relevant to the estimation of total GHG emissions associated with bioethanol production from EU wheat, maize and sugar beet, and from Brazilian sugar cane (see Appendix D). The outcomes of this assessment are presented in Table D1 for relevant fuels and electricity, in Table D2 for credits for excess electricity from bioethanol CHP (cogeneration) units, in Table D3 for chemical fertilisers, pesticides and seeds, in Table D4 for bioethanol production chemicals, and in Table D5 for feedstock, bioethanol and other product transport.

In only a limited number of cases, in which relevant GHG emissions factors have been based on production or supply models incorporating appropriate statistics, can the subsequent data in the JRC proposal be regarded as representative. In most other instances, nominal values for GHG emissions have been adopted, often from single sources which might or might not may or may not be representative of current or recent circumstances in the EU and, where necessary, elsewhere. The outcomes of the assessments in Tables D1 to D5 can be considered in more detail in the light of their likely contributions to the total GHG emissions associated with bioethanol production.

The GHG emissions factor for the provision of diesel fuel is based on EU-27 production statistics and, hence, it would seem to be representative for use with EU bioethanol production. Unfortunately, the model used to derive this GHG emissions factor is currently unpublished so it is not possible to access and check the modelling approach and its assumptions. Notes in the JRC proposal suggest that the model mixes marginal and average data in the model which would be a cause for concern. However, diesel oil provision makes a relatively small contribution to the total GHG emissions factor which includes, crucially, fuel combustion. In relation to this, it should be noted that the significantly larger contribution from combustion emissions given in the JRC proposal is from an unspecified source. Similar concerns can be expressed about the GHG emissions factors for the provision and combustion of natural gas and lignite. No sources are specified for the GHG emissions factors for the provision and combustion of hard coal. No data are provided on the GHG emissions factors for the provision and combustion of wood chips and bagasse although these have low significance in the estimation of total GHG emissions for bioethanol.

Very detailed modelling for estimating GHG emissions factors for the provision of low voltage (0.4 kV) and medium voltage (MV) electricity is presented in the JRC proposal. This modelling is based on EU-27 statistics for 2009 which is the latest year for which complete information was available. Hence, these emissions factors for electricity can be considered as representative for all biofuel and bioliquid production in the EU. However, it should be noted that the subsequent contribution of electricity to total GHG emissions associated with the production and supply of bioethanol in the EU is of low significance.

A much more significant contribution can results from the application of GHG emissions credits for excess electricity from cogeneration in bioethanol plants. The reason for this is that, as CHP units are normally sized to the heat demands of the bioethanol plant, considerable excess electricity can be generated. The impact on the total GHG emissions of bioethanol is diluted somewhat due to the credit procedure adopted in the RED (Ref. 1) and FQD (Ref. 2). This credit procedure is based, effectively, on assumptions about replacement generation. Nevertheless, the resulting GHG emissions credit can be moderately significant and, hence, their derivation is important. Unfortunately, the data presented in the JRC proposal for these credits are inadequate. Nominal values obtained from a single source are used as a basis for electricity from natural gas-fired combined cycle gas turbine (CCGT) plants, and lignite- and wood chip-fired steam turbine plants. Consequently, these data can only be regarded as illustrative rather than representative. No data are provided in the JRC proposal for electricity generated from natural gas- and biogas-fired CCGT plants, and hard coal-fired and bagasse-fired steam turbine plants.

The GHG emissions factor for the provision of chemical N fertiliser is of most significance in the calculation of total GHG emissions associated with bioethanol production. Consequently, a separate critical review of the JRC model used in deriving this GHG emissions factor is provided in Appendix E. In the JRC proposal, relevant GHG emissions factors for a range of years (actual value for 2007, interpolated value for 2011 and forecast value for 2020) are derived from this model of chemical N fertiliser supply in the EU-27. Hence, it might appear that these GHG emissions factors are suitably representative. Unfortunately, this is not entirely correct as these GHG emissions factors refer to a mix of only two types of chemical N fertiliser; ammonium nitrate and urea. In practice, there are many other types of chemical N fertilisers, each with different GHG emissions factors for their provision. However, it has been necessary for the JRC proposal to adopt approximate GHG emissions factors because the application rates, summarised in the pathway data, are based on FAO statistics which do not provide a breakdown of types of chemical N fertilisers. This somewhat undermines the overall approach adopted in the JRC proposal. It should also be noted that the resulting GHG emissions factor for the provision of chemical N fertiliser in the EU-27 has subsequently been used for pathways in other countries, such as sugar cane cultivation in Brazil.

GHG emissions factors for the provision of aglime ($CaCO_3$)), potash (K_2O) and phosphate (P_2O_5)) fertilisers, and pesticides are of moderate to low significance. Even so, these GHG emissions factors can only be regarded as illustrative rather than representative because they are all obtained from a single source based on pre-1997 information. It would also appear that the JRC proposal does not contain GHG emissions factors for the provision of wheat, maize, sugar beet and sugar cane seeds. Although these are not serious omissions, they further emphasise that the current version of the JRC proposal is incomplete.

With the exception of the GHG emissions factor for the provision of ammonia (NH_3), which is probably representative as it is based on EU industry statistics for 2010, the GHG emissions factors for all other relevant chemicals used in bioethanol production consist of nominal values obtained from single sources which are unlikely to represent the actual current or recent mix of supply in the EU-27 and Brazil. Some of the GHG emissions factors are derived from inadequately specified sources (lime or CaO provision) or possibly out-of-date information (sulphuric acid or H_2SO_4 and lubricant provision). In the case of alpha-amylase and glyco-amylase provision, the GHG emissions factors appear to have been derived from North American data. Although this assessment casts doubt on the GHG emissions factors presented in the JRC proposal for all bioethanol production chemicals, it should be recognised that their contribution to the total GHG emissions will be low.

The JRC proposal contains GHG emissions factors for a range of transport options including road transport for crops, products and bioethanol in the EU-27 and Brazil, maritime transport, rail transport and pipeline transport. The list of modes of transport is not necessarily complete as the GHG emissions factors presented do not actually relate to the inland waterway transport of wheat, maize, sugar beet and bioethanol. However, it is possible that the GHG emissions factors cited in the JRC proposal for inland waterway transport could be adopted for these crops and products. For all other transport GHG emissions factors, nominal values have been used, often from single sources for specific vehicle sizes or types. As such, the GHG emissions factors are not really representative of the actual EU-27 and Brazilian mix of vehicle sizes and performance. However, it needs to be appreciated that crop and bioethanol transport make relatively low contributions to total GHG emissions associated with bioethanol production.

7. CONCLUSIONS

This critical review of the methodology, models, assumptions and data presented in the JRC proposal for updating typical and default values for GHG emissions associated with the production of bioethanol for the EU began with a description of the background provided by the RED and FQD. The aims have been summarised as conducting a critical review of the JRC proposal as a whole and assessing its suitability for regulatory purposes. Subsequent objectives have been elaborated in terms of explaining the nature of typical and default values; summarising the general procedures adopted by the JRC; establishing criteria for determining the suitability of the proposed pathway data and relevant GHG emissions factors; applying these criteria in the assessment of pathway data and GHG emissions factors; and formulating conclusions about the overall suitability of the JRC proposal.

The unsuitable nature of the GHG emissions calculation methodology in the RED/FQD, which consists of a hybrid of types of LCA rather than rigorous application of attributional LCA consistent with regulatory purposes, has been set out. This has presented a challenging context in which to assess the updating of typical and default values in the JRC proposal against the strict LCA principles and best practice.

The procedure by which default values are derived from typical values which, in turn, are produced by combining relevant pathway data and GHG emissions factors has been explained. Since the term “typical” is not defined in the RED, FQD, supporting EC documentation nor the JRC proposal, it has been necessary to put forward a definition which emphasises representativeness of the data. This contrasts with nominal values obtained from a limited number of specific sources which are likely to be illustrative rather than representative. The main criterion for assessing the suitability of data in the JRC proposal is, therefore, representativeness. This has been supplemented with criteria concerning transparency and consistency. Furthermore, the outcomes of subsequent assessment have been qualified in terms of the significance of data in terms of their relative contribution to the total GHG emissions associated with bioethanol production.

The limitations of the currently-available draft version of the JRC proposal have been pointed out. In particular, it has been noted that this version is incomplete as well as containing mistakes in references to sources of information as well as missing references. These limitations affect the full and proper evaluation of the data provided in the JRC proposal. Whilst notes are provided, it has been concluded that, frequently, they fail to include adequate details of the information from original sources and how these have been combined together to derive the data presented in the JRC proposal. It is also apparent that the JRC proposal does not actually contain the typical and default values which would be derived from the data presented. This would have been helpful for judging relative importance of changes in data.

In terms of deriving RED/FQD typical and default values, it might be expected that pathway data would reflect the supply of biofuels and bioliquids to the EU-27. However, it has been demonstrated that this is not necessarily the case for current bioethanol pathways. In particular, the pathway data for bioethanol production from wheat is only based on EU-27 cultivation rather than a mix of indigenous and imported feedstocks. Pathway data for bioethanol production from maize only reflects cultivation in the EU-27 rather than cultivation in all those countries which provide the EU-27 supply of bioethanol from this feedstock. Whilst pathway data for bioethanol production from sugar beet are correctly based on EU-27 cultivation, conversion data are entirely reliant on information from Germany specifically. Pathway data for bioethanol production from sugar cane are based on information from Brazil which, as a potential major exporter, is likely to represent EU-27 supply but only if other countries do not provide bioethanol from this particular feedstock.

Overall assessment of the JRC proposal has led to the conclusion that its main purpose has been to collect new data rather than to assemble representative and coherent data for generating typical and default values. The need for coherent datasets, consisting of interdependent values that should not be collected from diverse and possibly unrelated sources and models, has been raised as a crucial issue in the preparation of truly representative data on which to based suitable typical and default values. However, it has been noted that, in many instances, information from different sources, which might or might not may or may not be compatible, has been mixed together to derive data in the JRC proposal. This does not conform with best practice in the application of LCA to GHG emissions calculations.

The combination of potentially-inconsistent information might not be particularly significant, in terms of relatively low contributions to the total GHG emissions associated with bioethanol production, for some data. However, for many of the data presented in the JRC proposal, it has been established that there are serious concerns about validity. In particular, it would appear that coherent datasets have not been used for cultivation data. At a minimum, crop yield, N fertiliser application rates and soil N_2O emissions should form part of a coherent dataset. If possible, inclusion in a coherent cultivation dataset should be extended to diesel oil consumption rates, and, ideally, all cultivation inputs and soil GHG emissions should be part of a properly representative dataset. It is apparent that, at any of these levels, this has not been the case for the JRC proposal.

It is apparent that, in addition to accessing statistics and other sources of information, the JRC proposal places considerable reliance on modelling to provide data for deriving typical and default values. In particular, modelling has been used to determine soil N_2O emissions, aglime application rates and their subsequent soil CO_2 emissions, and GHG emissions factors for the provision of chemical N fertilisers. The use of models for estimating soil N_2O and CO_2 emissions is unavoidable, especially in a regulatory context. However, the provision of evidence on the validation of these models with actual measured data has been identified as a fundamental requirement. Validation of GNOC for estimating soil N_2O emissions is particularly essential to ensure that it is regarded as a more accurate and reliable means than existing procedures rather than just a more complex and sophisticated model.

The JRC proposal uses an EU-27 supply model for deriving the GHG emissions factor for the provision of chemical N fertilisers. However, it is known that the subsequent GHG emissions factor is for a mix of ammonium nitrate and urea rather than for specific types of chemical N fertilisers. It appears that this has been necessary because of the lack of information on such fertilisers in the statistics adopted for data on application rates. It has been concluded that this is a potentially-important deficiency for data which can make significant contributions to the total GHG emissions associated with bioethanol production.

Another area of concern that has been identified is the use of generic pathway data for bioethanol production rather than data which reflect the current or recent bioethanol industry, its plants and their actual performance as a statistically-relevant whole. In many instances, data for these generic pathways has been based on single or limited sources which provide nominal values that would be considered as illustrative rather than representative.

Taken together, it has been concluded that most of the data in the JRC proposal are not suitable for regulatory purposes since they are not representative and, hence, do not provide a sound basis for the derivation of typical and default values.

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APPENDIX A: Pathway Data for Proposed Default Values

Table A1 Pathway Data: Bioethanol from European Union Wheat

Pathway Data	Significance	Representativeness	Transparency	Consistency
Wheat Cultivation				
Wheat Yield	High	EU-27 representative statistic (CAPRI database average for 2010 – 2011?)	Low (actual yield in kg/ha used not clear)	Not part of definitely-required coherent dataset
N Fertiliser Application Rate	High	EU-27 representative statistic for unspecified type of N fertiliser (FAO 2006/07?)	Moderate (types of N fertilisers unspecified)	Not part of definitely-required coherent dataset
Soil N_2O Emissions	High	Possibly representative simulation for EU-27 derived from JRC Model (GNOC)	Low (model workings not accessible and validated)	Not part of definitely-required coherent dataset
Diesel Oil Consumption Rate	Moderate	EU-27 representative statistic (CAPRI database average for 2010 -2011?)	Moderate (data given but weighting not explicit)	Not part of possibly-required coherent dataset
Soil CO_2 Emissions	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
$CaCO_3$ Fertiliser Application Rate	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
K_2O Fertiliser Application Rate	Low	EU-27 representative statistic (EFMA 2008)	Moderate (statistical source but details not explicit)	Not part of ideally-required coherent dataset
P_2O_5 Fertiliser Application Rate	Low	EU-27 representative statistic (EFMA 2008)	Moderate (statistical source but details not explicit)	Not part of ideally-required coherent dataset
Pesticide Application Rate	Low	EU-27 representative statistic (CAPRI database average for 2010 – 2011?)	Moderate (data given but combining unclear)	Not part of ideally-required coherent dataset
Seed Sowing Rate	Low	Unrepresentative data (nominal value for UK 1996)	Moderate (sources specified but choice unclear)	Not part of ideally-required coherent dataset

Table A1 Pathway Data: Bioethanol from European Union Wheat (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Wheat Drying				
Wheat Input/Wheat Output	Low	Unrepresentative data (nominal 0% losses in drying)	Low (unclear source and choice of data))	Not based on EU-27 range of drying losses
Electricity Consumption Rate	Low	EU-27 representative statistic (CAPRI database average for 2010 - 2011?)	Moderate (statistical data but details unclear)	Not based on EU-27 range of drying fuels (assumes all electricity)
Wheat Handling and Storage				
Wheat Input/Wheat Output	Low	Unrepresentative data (nominal 0% losses in handling and storage)	Low (unclear source and choice of data))	Not based on EU-27 range of handling and storage losses
Electricity Consumption Rate	Low	Unrepresentative data (nominal value for DE 1997)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current range of handling and storage techniques
Wheat Transport				
Wheat Input/Wheat Output	Low	Unrepresentative data (nominal 1% losses in transport)	Low (unclear source and choice of data))	Not based on EU-27 range of transport losses
Road Transportation	Low	Unrepresentative data (nominal values for DE 2001 and 2012)	Low (choice and combining of data unexplained)	Not based on EU-27 range of transport modes and distances

Table A1 Pathway Data: Bioethanol from European Union Wheat (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Bioethanol Production				
Wheat Input/ Bioethanol Output	Moderate	Unrepresentative data (nominal value for single UK plant in 2010)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
DDGS Output/ Bioethanol Output	Moderate	Unrepresentative data (nominal value for UK 2004)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Steam Consumption Rate	Moderate	Unrepresentative data (nominal value for UK 2004)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Electricity Consumption Rate	Low	Unrepresentative data (Nominal value for UK 2004)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
NaOH Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
NH_3 Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
CaO Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Alpha-amylase Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Glyco-amylase Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants

Table A2 Pathway Data: Bioethanol from European Union Maize

Pathway Data	Significance	Representativeness	Transparency	Consistency
Maize Cultivation				
Maize Yield	High	EU-27 representative statistic (CAPRI database average for 2010 - 2011?)	Low (actual yield in kg/ha used not clear)	Not part of definitely-required coherent dataset
N Fertiliser Application Rate	High	EU-27 representative statistic for unspecified type of N fertiliser (FAO 2006/07?)	Moderate (types of N fertilisers unspecified)	Not part of definitely-required coherent dataset
Soil N_2O Emissions	High	Possibly representative simulation for EU-27 derived from JRC Model (GNOC)	Low (model workings not accessible and validated)	Not part of definitely-required coherent dataset
Diesel Oil Consumption Rate	Moderate	EU-27 representative statistic (CAPRI database average for 2010 -2011?)	Moderate (data given but weighting not explicit)	Not part of possibly-required coherent dataset
Soil CO_2 Emissions	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
$CaCO_3$ Fertiliser Application Rate	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
K_2O Fertiliser Application Rate	Low	EU-27 representative statistic (IFA 2010)	Moderate (statistical source but combining of data not explicit)	Not part of ideally-required coherent dataset
P_2O_5 Fertiliser Application Rate	Low	EU-27 representative statistic (IFA 2010)	Moderate (statistical source but combining of data not explicit)	Not part of ideally-required coherent dataset
Pesticide Application Rate	Low	EU-27 representative statistic (CAPRI database average for 2010 - 2011?)	Moderate (data given but combining unclear)	Not part of ideally-required coherent dataset
Seed Sowing Rate	Low	EU-27 representative statistic (FAO 2009)	Moderate (statistical source but choice unclear)	Not part of ideally-required coherent dataset

Table A2 Pathway Data: Bioethanol from European Union Maize (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Maize Drying				
Maize Input/Maize Output	Low	Unrepresentative data (0% losses in drying from unspecified source)	Low (unclear source or choice of data)	Not based on EU-27 range of drying losses
Electricity Consumption Rate	Low	EU-27 representative statistic (CAPRI database average for 2010 – 2011?)	Moderate (statistical data but details unclear)	Not based on EU-27 range of drying fuels (assumes all electricity)
Maize Handling and Storage				
Maize Input/Maize Output	Low	Unrepresentative data (nominal 0% losses in handling and storage)	Low (unclear source or choice of data)	Not based on EU-27 range of handling and storage losses
Electricity Consumption Rate	Low	Unrepresentative data (nominal value for DE 1997)	Low (apparent extrapolation from wheat data unexplained)	Not based on EU-27 current range of handling and storage techniques
Maize Transport				
Maize Input/Maize Output	Low	Unrepresentative data (nominal 1% losses in transport)	Low (unclear source or choice of data)	Not based on EU-27 range of transport losses
Road Transportation	Low	Unrepresentative data (nominal values for DE 2001 and 2012)	Low (choice and combining of data unexplained)	Not based on EU-27 range of transport modes and distances

Table A2 Pathway Data: Bioethanol from European Union Maize (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Bioethanol Production				
Maize Input/Bioethanol Output	Moderate	Unrepresentative data (nominal value for US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
DDGS Output/Bioethanol Output	Moderate	Unrepresentative data (nominal value for US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Steam Consumption Rate	Moderate	Unrepresentative data (nominal value for US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Electricity Consumption Rate	Low	Unrepresentative data (nominal value for US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
NaOH Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
NH_3 Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
CaO Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Alpha-amylase Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Glyco-amylase Consumption Rate	Low	Unrepresentative data (nominal value for maize CA/US 2009)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants

Table A3 Pathway Data: Bioethanol from European Union Sugar Beet

Pathway Data	Significance	Representativeness	Transparency	Consistency
Sugar Beet Cultivation				
Sugar Beet Yield	High	EU-27 representative statistic (CAPRI database average for 2010 - 2011?)	Low (actual yield in kg/ha not specified)	Not part of definitely-required coherent dataset
Diesel Oil Consumption Rate	High	EU-27 representative statistic (CAPRI database average for 2010 -2011?)	Moderate (data given but weighting not explicit)	Not part of possibly-required coherent dataset
N Fertiliser Application Rate	Moderate	EU-27 representative statistic for unspecified type of N fertiliser (FAO 2006/07?)	Moderate (types of N fertilisers unspecified)	Not part of definitely-required coherent dataset
Soil N_2O Emissions	Moderate	Possibly representative simulation for EU-27 derived from JRC Model (GNOC)	Low (model workings not accessible and validated)	Not part of definitely-required coherent dataset
Soil CO_2 Emissions	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
$CaCO_3$ Fertiliser Application Rate	Low	EU-27 representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
K_2O Fertiliser Application Rate	Low	EU-27 representative statistic (EFMA 2008)	Moderate (statistical source but details not explicit)	Not part of ideally-required coherent dataset
P_2O_5 Fertiliser Application Rate	Low	EU-27 representative statistic (EFMA 2008)	Moderate (statistical source but details not explicit)	Not part of ideally-required coherent dataset
Pesticide Application Rate	Low	EU-27 representative statistic (CAPRI database average for 2010 - 2011?)	Moderate (data given but combining not clear)	Not part of ideally-required coherent dataset
Seed Sowing Rate	Low	Unrepresentative data (nominal value for DE 1998)	Moderate (data possibly accessible but choice unclear)	Not part of ideally-required coherent dataset

Table A3 Pathway Data: Bioethanol from European Union Sugar Beet (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Sugar Beet Handling and Storage				
Sugar Beet Input/Sugar Beet Output	Low	Unrepresentative data (nominal 0% losses in handling and storage)	Low (unclear source and choice of data)	Not based on EU-27 range of handling and storage losses
Electricity Consumption Rate	Low	Unrepresentative data (Nominal value for DE 1997)	Moderate	Not based on EU-27 range of handling and storage
Sugar Beet Transport				
Sugar Beet Input/Sugar Beet Output	Low	Unrepresentative data (nominal 1% losses in transport)	Low (unclear source and choice of data)	Not based on EU-27 range of transport losses
Road Transportation	Low	Unrepresentative data (nominal values for DE 1998, 2001 and 2012)	Low (apparent extrapolation from wheat data unexplained)	Not based on EU-27 range of transport modes and distances
Bioethanol Production				
Sugar Beet Input/Bioethanol Output	High	Unrepresentative data (nominal values for DE 1997 and 1998)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Steam Consumption Rate	High	Unrepresentative data (nominal values for DE 1997 and 1998)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Beet Pulp Output/Bioethanol Output	Moderate	Unrepresentative data (nominal values for DE 1997 and 1998)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants
Electricity Consumption Rate	Low	Unrepresentative data (nominal values for DE 1997 and 1998)	Low (choice and combining of data unexplained)	Not based on EU-27 current range of plants

Table A4 Pathway Data: Bioethanol from Brazilian Sugar Cane

Pathway Data	Significance	Representativeness	Transparency	Consistency
Sugar Cane Cultivation				
Sugar Cane Yield	High	Brazilian representative statistic (BR 2005/06)	Moderate (actual yield specified but choice not explained)	Not part of definitely-required coherent dataset
Soil N_2O Emissions	High	Possibly representative simulation for BR? derived from JRC Model (GNOC)	Low (model workings not accessible and validated)	Not part of definitely-required coherent dataset
Diesel Oil Consumption Rate	Moderate	Unrepresentative data (nominal values for BR 2004 and 2008)	Moderate (combining of data not explained)	Not part of possibly-required coherent dataset
N Fertiliser Application Rate	Moderate	BR representative statistic for unspecified type of N fertiliser (FAO ~ 2000)	Moderate (types of N fertilisers unspecified)	Not part of definitely-required coherent dataset
Soil CO_2 Emissions	Low	BR representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
$CaCO_3$ Fertiliser Application Rate	Low	BR representative simulation derived from JRC Model (Acidification and Liming)	Moderate (model details given but not fully validated)	Not part of ideally-required coherent dataset
K_2O Fertiliser Application Rate	Low	BR representative statistic (FAO 2010)	Moderate (statistical source but combining of data not explicit)	Not part of ideally-required coherent dataset
P_2O_5 Fertiliser Application Rate	Low	BR representative statistic (FAO 2010)	Moderate (statistical source but combining of data not explicit)	Not part of ideally-required coherent dataset
Pesticide Application Rate	Low	Unrepresentative data (nominal value for BR 1996)	Low (choice and combining of data not explicit)	Not part of ideally-required coherent dataset
Vinasses Application Rate	Low	Unrepresentative data (nominal value for BR 2008)	Low (choice and combining of data not explicit)	Not part of ideally-required coherent dataset
Filter Mud Cake Application Rate	Low	Unrepresentative data (nominal value for BR 2008)	Low (choice and combining of data not explicit)	Not part of ideally-required coherent dataset
Seed Sowing Rate	Low	Unrepresentative data (nominal value for BR 2008)	Low (choice and combining of data not explicit)	Not part of ideally-required coherent dataset

Table A4 Pathway Data: Bioethanol from Brazilian Sugar Cane (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Sugar Cane Transport				
Sugar Cane Input/Sugar Cane Output	Moderate	Unrepresentative data (nominal 0% losses in transport)	Low (unclear source and choice of data)	Not based on BR range of transport losses
Road Transportation	Moderate	Unrepresentative data (nominal value for BR 2004)	Low (unclear source and choice of data)	Not based on BR range of road distances
Bioethanol Production				
Sugar Cane Input/Bioethanol Output	Moderate	BR representative statistic (BR 2005/2006)	Moderate (data accessible but choice and combining unclear)	Not based on BR current range of plants
Electricity Consumption Rate	Low	BR representative statistic (BR 2005/2006)	Moderate (data accessible but choice unexplained)	Not based on BR current range of plants
CaO Consumption Rate	Low	BR representative statistic (BR 2005/2006)	Moderate (data accessible but choice and combining unclear)	Not based on BR current range of plants
H_2SO_4 Consumption Rate	Low	BR representative statistic (BR 2002/2003)	Moderate (data accessible but choice unexplained)	Not based on BR current range of plants
Cyclohexane Consumption Rate	Low	BR representative statistic (BR 2002/2003)	Moderate (data accessible but choice unexplained)	Not based on BR current range of plants
Lubricant Consumption Rate	Low	BR representative statistic (BR 2002/2003)	Moderate (data accessible but choice and combining unclear)	Not based on BR current range of plants

Table A5 Pathway Data: Bioethanol Process Heat Supply

Pathway Data	Significance	Representativeness	Transparency	Consistency
Natural Gas-fired Boiler and Imported Grid Electricity				
Natural Gas Input/Heat Output	High	Unrepresentative data (nominal value of 90% thermal efficiency from single source: DE 2005?)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current range of plants
Electricity Input/Heat Output	Low	Unrepresentative data (nominal value of from single source: DE 2005?)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current range of plants
Natural Gas- and Biogas-fired Boiler and Imported Grid Electricity				
Natural Gas Input/Heat Output	High	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Biogas Input/Heat Output	Low	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Electricity Input/Heat Output	Low	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Natural Gas-fired Combined Heat and Power				
Natural Gas Input/Heat Output	High	Unrepresentative data (nominal value from inadequately referenced single DE source?)	Low (source and choice of data unclear)	Not based on EU-27 current range of plants
Electricity Output/Heat Output	High	Unrepresentative data (nominal value from inadequately referenced single DE source?)	Low (source and choice of data unclear)	Not based on EU-27 current range of plants
Natural Gas- and Biogas-fired Combined Heat and Power				
Natural Gas Input/Heat Output	High	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Biogas Input/Heat Output	Low	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Electricity Output/Heat Output	Low	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants

Table A5 Pathway Data: Bioethanol Process Heat Supply (continued)

Pathway Data	Significance	Representativeness	Transparency	Consistency
Lignite-fired Combined Heat and Power				
Lignite Input/Heat Output	High	Unrepresentative data (nominal value from single source: UK 2004 with unspecified modifications)	Low (choice of data and modification unexplained)	Not based on EU-27 current range of plants
Electricity Output/Heat Output	High	Unrepresentative data (nominal value from single source: UK 2004 with unspecified modifications)	Low (choice of data and modification unexplained)	Not based on EU-27 current range of plants
Hard Coal-fired Combined Heat and Power				
Hard Coal Input/Heat Output	High	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Electricity Output/Heat Output	Low	No data provided	Low (data unavailable)	Not based on EU-27 current range of plants
Wood Chip-fired Combined Heat and Power				
Wood Chip Input/Heat Output	Low	Unrepresentative data (nominal value from single source: UK 2004 straw data with unspecified modification)	Low (choice of data and modification unexplained)	Not based on EU-27 current range of plants
Electricity Output/Heat Output	Low	Unrepresentative data (nominal value from single source: UK 2004 straw data with unspecified modification)	Low (choice of data and modification unexplained)	Not based on EU-27 current range of plants
Bagasse-Fired Combined Heat and Power				
Bagasse Input/Heat Output	Low	No data provided	Low (data unavailable)	Not based on BR current range of plants
Electricity Output/Heat Output	Low	No data provided	Low (data unavailable)	Not based on BR current range of plants

Table A6 Pathway Data: Bioethanol Transport, Depot and Filling Station

Pathway Data	Significance	Representativeness	Transparency	Consistency
Bioethanol Transport (to European Union)				
Bioethanol Input/Bioethanol Output (BR road transport)	Low	Unrepresentative data (nominal 0% losses in road transport)	Low (unclear source and choice of data)	Not based on BR range of road transport losses
Road Transportation	Low	Unrepresentative data (nominal value for BR 1996 and 1998)	Low (choice of data unexplained)	Not based on BR range of road distances
Bioethanol Input/Bioethanol Output (BR/EU ship transport)	Low	Unrepresentative data (nominal 0% losses in ship transport)	Low (unclear source and choice of data)	Not based on BR range of ship transport losses
Ship Transportation	Low	Unrepresentative data (nominal value for BR 1996 and 1998)	Low (choice of data unexplained)	Not based on BR range of ship distances
Bioethanol Transport (in European Union)				
Bioethanol Input/Bioethanol Output (EU road transport)	Low	Unrepresentative data (nominal 0% losses in road transport)	Low (unclear source and choice of data)	Not based on EU-27 range of road transport losses
Road Transportation	Low	Unrepresentative data (nominal value from unspecified source)	Low (unclear source and choice of data)	Not based on EU-27 range of road distances
Bioethanol Depot				
Bioethanol Input/Bioethanol Output	Low	Unrepresentative data (nominal 0% losses in depot for FR 2002)	Low (unexplained choice of data)	Not based on EU-27 range of depot losses
Electricity Consumption Rate	Low	Unrepresentative data (nominal value for FR 2002)	Low (unexplained choice of data)	Not based on EU-27 range of depots
Bioethanol Filling Station				
Bioethanol Input/Bioethanol Output	Low	Unrepresentative data (nominal 0% losses in filling stations for FR 2002)	Low (unexplained choice of data)	Not based on EU-27 range of filling station losses
Electricity Consumption Rate	Low	Unrepresentative data (Nominal value for FR 2002)	Low (unexplained choice of data)	Not based on EU-27 range of filling stations

APPENDIX B: Critical Review of JRC Soil Nitrous Oxide Emissions Model

The Global crop- and site-specific Nitrous Oxide emission Calculator (GNOC) has been developed originally by the JRC to evaluate soil N_2O emissions for specific crops at specific sites where certain parameters are known (Ref. 13). GNOC has been used in a modelling approach to determine representative estimates of soil N_2O emissions, specified in terms of g N_2O per MJ of feedstock, for each relevant biofuel and bioliquid crop in the JRC proposal (Ref. 5). In order to be representative, estimates are modelled as average soil N_2O emissions for each crop in each relevant region. Unfortunately, relevant regions have not been specified explicitly and comprehensively for each respective pathway in the JRC proposal. However, in terms of current bioethanol pathways, it appears that the relevant region for the EU production of bioethanol from wheat, maize and sugar beet is the aggregate of Member States which constituted the EU-27[7]. For the EU supply of bioethanol for sugar cane, the only relevant country that has been selected in the JRC proposal is Brazil.

Since actual measurements of soil N_2O emissions are not currently available, and are unlikely to be available in the foreseeable future, for all farms producing relevant biofuel crops, modelling is unavoidable. Such modelling is necessary for all sources of soil N_2O emissions. These sources consist of the application of chemical N fertilisers (mineral or artificial fertilisers) and organic N fertilisers (manures), and the incorporation of crop residues (below ground material and any above ground material that has not been removed). It is well-known that soil N_2O emissions are influenced by a large number of site-specific factors which prospective models must take into account. Site-specific factors for any given crop include the crop type and yield; the chemical and organic N application rates; the amounts and N content of crop residues incorporated; cultivation practices; soil properties; and climate and weather[8].

Under the ideal circumstances, all important factors, in suitable datasets, for all farms producing any given biofuel crop, in relevant regions over a particular period of time, would be available and used as a basis for the site-specific modelling soil N_2O emissions. However, such datasets do not exist or are not accessible, especially on the scale necessary to represent entire countries or regions. As an alternative, the JRC has adopted a modelling approach which incorporates GNOC by, in effect, simulating various sources of N associated

[7] EU-27 consists of Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

[8] There is an important distinction between climate and weather, and this also affects soil N_2O emissions. Climate is a general consideration which reflects average atmospheric conditions experienced over an extended period of time, such as seasonally, annually, decadally, etc., at broader scales, such as globally, continentally, regionally, etc. Weather is the more immediate (hourly, daily, weekly, etc.) and localised expression of specific atmospheric conditions. A number of field experiments, such as those of the MIN-NO Project ("Minimising Nitrous Oxide Intensities of Arable Products" Project No. RD-2010-3474, www.hgca.com), have indicated that actual soil N_2O emissions are strongly influenced by the timing of chemical N fertiliser applications and subsequent weather events, such as particularly wet or dry spells.

with biofuel crop cultivation on the required scale by overlaying mapping data and other geographically-related statistics from a variety of different publications. Simulated N sources, in the form of chemical and organic N fertiliser application rates and crop residue incorporation rates, are used in different models to estimate soil N_2O emissions. In particular, GNOC is used to estimate soil N_2O emissions from the application of chemical N fertilisers. By aggregating subsequent results, regionally-averaged estimates of soil N_2O emissions, in g N_2O per MJ of feedstock, are generated for each biofuel crop.

This modelling approach, which is intended to generate representative estimates of soil N_2O emissions, is dictated by the availability and nature of geographical data for the biofuel crops and regions under investigation. It is apparent that soil type has been regarded as a very important factor in determining soil N_2O emissions. This is probably due to the perceived significance of chemical N fertiliser application to total soil N_2O emissions. Consequently, maps of soil properties, with a grid cell resolution of 5 minutes x 5 minutes (approximately 10 km x 10 km), form the essential basis of the modelling approach. This requires replication or simulation of mapping information at a similar resolution for all other factors, including crop yield and chemical and organic N fertiliser application rates, and crop residue incorporation rates. The fundamental aspects of relevant N sources, combined with necessary reliance on different sources of data and modelling relationships, mean that this modelling approach is quite complicated. Hence, in order to explain the main details of this modelling approach and to comment on them critically, it has been necessary to breakdown it down into 10 discrete Steps (see below). Given specific focus on bioethanol supply in the EU, these critical comments relate to EU cultivation of wheat, maize and sugar beet, and, in specific instances, to sugar cane cultivation in Brazil.

After establishing the common mapping basis for the modelling approach in Step 1, relevant data on N sources are simulated in Steps 2 to 4, which are combined with soil property mapping data assembled in Step 5, to enable soil N_2O emissions to be modelled in Steps 6 to 8. A weighting procedure is then applied in Step 9 and an updating process is used in Step 10 to derive final estimates of regionally-averaged total soil N_2O emissions for biofuel crops in 2006/07. By examining the information in the JRC proposal and other accessible supporting documentation, the main details of these Steps have been identified and elaborated where possible. Within limitations of currently-available transparency, these main details have been critically reviewed. This reveals a mixture of major and minor concerns in many of the Steps which constitute this modelling approach. These concerns relate to assumptions, approximations and extrapolations which can introduce potential uncertainties, inaccuracies or errors into the modelling approach, thereby undermining confidence in the reliability of its outcomes. Without further information on actual data and calculations, it is not possible to reach definitive conclusions on the significance of all the concerns raised in Steps 1 to 10 and, subsequently, to determine the suitability or otherwise of this modelling approach.

Whist recognising these constraints, it is important to draw particular attention to comments which have been raised in other literature about the Stehfest and Bouwman (S&B) Model (Ref. 14) which forms a crucial part of the JRC soil N_2O

emissions model (see Step 6). This model was developed to assist the evaluation of soil N_2O emissions in national GHG emissions inventories. It has been variously described as a “statistical” or “empirical” model which is based on a dataset of soil N_2O emissions obtained from published field measurements. Some of its potential limitations were pointed out in the application of the S&B Model to the evaluation of total GHG emissions for biofuels (Ref. 17). In connection with the contribution of estimated soil N_2O emissions to total GHG emissions, it was stated that “…there are large uncertainties” the most important of which are “those in the statistical model…” It is openly recognised that such uncertainties are mainly attributable to the diverse quality of the dataset, particularly a lack of necessary detail and/or consistency in the original information. This view would appear to be supported by other, more recent studies (see, for example, Ref.18).

The necessary coverage of the dataset is also potentially limited, especially with regard to some arable crops relevant to biofuel production. In terms of crops for bioethanol production, it appears that the S&B Model is based on 188 measurements for maize, 106 measurements for wheat, 13 measurements for sugar cane, and only 2 measurements for sugar beet (Ref. 19). This raises concerns about the reliability of the relationships for soil N_2O emissions in the S&B Model, especially for sugar beet and sugar cane. Such concerns about the limitations in the measurements used in the S&B Model have been pointed out by the European Commission previously in 2010 (Ref. 20). In particular, in discussing the uncertainties of the S&B Model, it is stated that “crop type is recognised as an important parameter for N_2O emissions, however, the sample of measurements used as the basis of the model is not extensive enough to cover all crops.” This, combined with the grouping of many crops for the production of biofuels and bioliquids within a very broad “other crops” category in the S&B Model, led to the strong suggestion that “this work does not now provide the basis for binding legislative proposals.” It is not apparent what has changed since this assessment in 2010 to justify the application of the S&B Model for estimating soil N_2O emissions in the JRC proposal.

Despite existing constraints for independent assessment in this critical review, it is necessary to establish whether the modelling approach currently adopted in the JRC proposal represents, accurately, soil N_2O emissions associated with crops cultivated for the supply of biofuels and bioliquids in the EU. Ideally, comprehensive validation of the overall JRC soil N_2O emissions model would be undertaken. However, basic practical considerations and cost implications mean that this is unlikely, at any time in the foreseeable future. Hence, a more realistic test would be to validate the results of each important Step in the modelling approach. In particular, this would involve comparing simulated estimates of chemical and organic N fertiliser application rates, and crop residue incorporation rates with actual data for individual countries or areas where relevant data exist. It would also involve comparing estimated soil N_2O emissions from modelling, especially GNOC, with actual field measurements. Other critical assumptions, mainly used in extrapolations (see Step 1; Steps 2b to e, Steps 3a and b, Step 4b and Step 6c), could also be investigated by means of sensitivity analysis. Currently, it is not apparent that such validation or similar testing has been conducted on this modelling approach. Hence, it is concluded that the suitability of this modelling approach to soil N_2O emissions is unproven.

Step	Main Details	Critical Comments
1	Accessing 10’ x 10’ grid cell maps of relevant countries with cultivated areas and yields of relevant crops for 2000, mainly derived as averages from annual statistics between 1997 and 2003 (Ref. 21).	(a) These maps, which are mainly based on sub-national (administrative or political units) FAO statistics (Refs. 22 and 23), are probably accurate for crop areas, since they also incorporate remote sensing observations (which involve identification of types of crops and measurements of respective land areas), but they might be less robust for crop yields due to a procedure involving the application of single values of yield to entire grid cells, thereby failing to reflect actual yield variations within grid cells.

Step	Main Details	Critical Comments
2	Preparing equivalent 10' x 10' grid cell maps of chemical N fertiliser application rates for relevant crops in relevant countries in 2000.	(a) Original chemical N fertiliser application rates are obtained from FAO statistics (Ref. 24) which only provide single national values and do not specify the types of chemical N fertilisers applied (see implications of this in Step 6).
		(b) These FAO statistics (Ref. 24) are incomplete for the EU-27 (statistics are missing for Belgium, Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, Romania and Slovenia) and, hence, a procedure has been adopted to estimate missing national chemical N application rates using total chemical N fertiliser consumption statistics from the IFA (Ref. 25) and, presumably, national cultivation areas from FAO statistics (Ref. 22). However, it is not clear whether IFA statistics indicate how much chemical N fertiliser is applied to each crop. Hence, the validity of this procedure for obtaining missing data in a reliable manner is unknown.
		(c) Additionally, FAO statistics (Ref. 24) for maize appear to be aggregated into "other cereals" for certain EU-27 Member States (Denmark, Finland, Ireland, Sweden and United Kingdom). There is no explanation the procedure for obtaining these missing statistics. Hence, the reliability of subsequent results for maize is unknown.
		(d) National values of chemical N fertiliser application rates are "disaggregated…using crop area and yield data" from the maps used in Step 1 (Ref. 21), and using information on soil carbon content (Ref. 26) into 10' x 10' grid cells. This disaggregation procedure is not explained. However, standard relationships between yield and chemical N fertiliser application rates for different soil types might have been used for each crop. Such standard relationships do not replicate variations in actual chemical N fertiliser application rates within grid cells. Hence, in order to establish a convincing case for using these maps, a full explanation of this procedure and subsequent demonstration of the accuracy of the indicated chemical N fertiliser application rates are required.
		(e) There is a special adjustment to the chemical N fertiliser application rates for wheat cultivation. This adjustment is based on the assumption that chemical N fertiliser application rates for feed wheat cultivation (used for bioethanol production) are lower than those for bread wheat cultivation. This is based on data from the UK (Ref. 27). Additionally, it is assumed that feed wheat yields are higher than those of bread wheat yields, again based on UK data (Ref. 28). Further assumptions are made about the ratios of feed wheat, bread wheat and surplus bread wheat that is sold as feed wheat based on UK data (Ref. 27). These assumptions are combined to reduce simulated chemical N fertiliser application rates by 7% by applying these UK-based assumptions across the EU. No evidence is presented to justify this extrapolation.

Step	Main Details	Critical Comments
3	Preparing equivalent 10' x 10' grid cell maps for organic N fertiliser application rates for relevant crops in relevant countries in 2000.	(a) National values for total organic N fertiliser application rates have been obtained from the EDGAR database (Ref. 29). However, single values for each country have been distributed equally to all crops and their cultivation areas. Hence, this approach fails to capture actual values for organic N fertiliser application rates by crop in specific grid cells within relevant countries.
		(b) Unresolved deliberations about the correct procedure for accounting organic N fertiliser application (all or nothing) to crop cultivation result in an arbitrary compromise based on no logical justification to consider 50% of the estimated amounts of manure in subsequent calculations.
4	Preparing equivalent 10' x 10' grid cell maps for crop residue N input rates for relevant crops in relevant countries in 2000.	(a) The amounts of residues available for each crop in each country have been estimated in each grid cell from the same spatial data for cultivated areas and yields used in the maps in Step 1. This has mainly involved using the default data for crop residues provided by the IPCC (Ref. 30). These IPCC default values consist of single, highly-generalised or "global" estimates of the amounts of above- and below-ground crop residues, and their dry matter and N contents for certain crop types. These values do not indicate variations in these estimates for different countries and grid cells within these countries.
		(b) The amount of N available from crop residues depends on whether the above-ground residues are incorporated into the soil (or, alternatively, removed for other purposes). The IPCC default values do not provide any information on percentage incorporation rates. Unless actual incorporation rates have, somehow, been determined for each crop in each grid cell for each country, then these maps cannot represent actual crop residue N input rates accurately.
		(c) IPCC default values are available for wheat and maize but not for sugar beet and sugar cane. Since it is not explained how such missing values are addressed, it would appear that the maps for crop residue N input rates are incomplete.
		(d) It is noted that trash burning prior to sugar cane harvesting has been taken into account (Ref. 5) and the relevant source is specified (Ref. 31) but the actual data (and relevant year) are not explained. Such data affect estimation of any trash incorporation and N_2O combustion emissions (see Step 8).
5	Accessing 10' x 10' grid cell maps for soil properties in relevant countries in 2000.	(a) The source of these soil property maps is the Harmonized World Soil Database (HWSD) (Ref. 26). It is assumed that these maps can provide, without significant modification, relevant values for soil organic content, soil pH, soil texture and climate required by the Stehfest and Bouwman (S&B) Model (Ref. 16) used in Step 6.

Step	Main Details	Critical Comments
6	Deriving estimates of soil N_2O emissions from the application of chemical N fertilisers for relevant crops in relevant countries.	(a) Derivation of soil N_2O emissions from maps of simulated chemical N fertiliser application rates (from Step 2) is based on the Stehfest and Bouwman (S&B) Model (Ref. 14) which consists of relationships based on the statistical analysis of 1,008 field measurements. Whilst this is a larger dataset than earlier work, which was originally conducted for deriving IPCC default values for national GHG emissions inventories, it is relatively limited in the context of the range of parameters addressed. These consist of soil organic content (8 options), soil pH (3 options), soil texture (3 options), climate (4 options) and vegetation classes (6 options). Mathematically, these options result in a possible 8 x 3 x 3 x 4 x 6 = 1,728 combinations. Although all possible combinations might not be realistic, this still suggests that, in order to derive robust relationships to account for the effect of all these parameters, a much larger number of field measurements would be required, particularly as a suitable range of chemical N fertiliser application rates will need to be accommodated by the statistical analysis.
		(b) The statistical test of the suitability of any relationship derived from measurements is the correlation coefficient. Hence, it would be expected that the validity of the S&B Model and justification of its application in this context would be supported by explicit demonstration that relevant relationships have high values of correlation coefficients.
		(c) The S&B Model uses 6 quite broad vegetation classes and the JRC have made assumptions about which biofuel crop is a part of these vegetation classes. In particular, wheat is included in the “cereals” class but maize, sugar beet and sugar cane are included in “other” class. Whether this ensures that subsequent relationships in the S&B Model are appropriate for these specific biofuel crops is not explained.
		(d) Although the S&B Model takes into account the effect of a number of factors on soil N_2O emissions from chemical N fertiliser application, it does not cover the potential impact of all known factors. It is apparent that this is dictated by the original purpose of the S&B Model which was to improve on procedures for evaluating soil N_2O emissions in IPCC national GHG emissions inventories. Such procedures require similar basic data or statistics to be available in each IPCC reporting country and, hence, the role of these in the modelling of soil N_2O emissions is given particular prominence. However, other factors which might also have significant effects on soil N_2O emissions have not been taken into account because of the lack of national data and statistics. These factors include, amongst other considerations, the type of chemical N fertiliser, the type of cultivation practices (conventional tillage, minimum tillage, no tillage, etc.) and the timing of chemical N fertiliser application with respect to subsequent weather events (especially wet or dry spells).

Step	Main Details	Critical Comments
7	Deriving estimates of soil N_2O emissions from the application of organic N fertilisers (manures) for relevant crops in relevant countries	(a) The IPCC Tier 1 method (Ref. 30) is adopted for estimating soil N_2O emissions from the application of organic N fertilisers using rates simulated in Step 3. The IPCC Tier 1 method is, in effect, a simple linear relationship between the estimated soil N_2O emission and amount of N available in the manure applied. Hence, no other factors that might influence these soil N_2O emissions are taken into account. This clearly contrasts with the procedure adopted for the evaluating soil N_2O emissions from chemical N fertiliser application and, hence, it could be regarded as being inconsistent.
8	Deriving estimates of soil N_2O emissions from the incorporation of residues for relevant crops in relevant countries	(a) The IPCC Tier 1 method (Ref. 30) is adopted for estimating soil N_2O emissions from the incorporation of crop residues simulated in Step 4. The IPCC Tier 1 method is, in effect, a simple linear relationship between the estimated soil N_2O emission and amount of N available in the incorporated residues. Hence, no other factors that might influence these soil N_2O emissions are taken into account. This clearly contrasts with the procedure adopted for the evaluating soil N_2O emissions from chemical N fertiliser application and, hence, it could be regarded as being inconsistent.
		(b) Procedures and data for inclusion of trash burning prior to sugar cane harvesting in estimation of soil N_2O emissions are not explained.
9	Weighting results to reflect the proportion of relevant crops from relevant countries to the supply of biofuels in the EU in 2000	(a) The details of the weighting procedure are not provided and the sources used are not stated.
10	Adjusting results for relevant crops from relevant countries in 2006/07	(a) The adjustment procedure, which apparently uses yield and chemical N fertiliser application rates for 2006/07, and this choice of year are not explained. Since it seems that other data incorporated into the GNOC approach have not been similarly adjusted, this implies that inconsistencies might have been introduced into the final results.

APPENDIX C: Critical Review of JRC Acidification and Liming Model

The main features of the JRC acidification and liming model are summarised in the JRC proposal (Ref. 5). This model has been devised to address GHG emissions which were either not, or only partially, addressed by the earlier JEC WTW studies (Ref. 32) which, in effect, formed the basis of the typical and default values presented in the RED and FQD (Ref. 1 and 2). These emissions comprise CO_2 emissions from soil and GHG emissions associated with the provision of agricultural lime, or aglime, consisting of limestone ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$). In the existing typical and default values, soil CO_2 emissions were not included and, where specified, it was assumed that "lime" applications were in the form of calcined limestone (CaO). When evaluating actual values for biofuel crop cultivation with lime applications, these are often accounted as ground limestone which results in soil CO_2 emissions according to the IPCC assumptions for national GHG emissions inventories (Ref. 30). This is based on the stoichiometric equation in which all the CO_2 in the aglime, assumed to be $CaCO_3$, is released during neutralisation reactions in the soil and emitted to the atmosphere on the basis of 0.44 kg CO_2/kg $CaCO_3$.

The JRC acidification and liming model has adopted a different and much more complicated approach. In particular, it is recognised that soil CO_2 emissions can arise from two different sources; one involving the neutralising effect aglime and the other based on the acidifying effect of chemical N fertilisers and organic N fertilisers (manure) on naturally-occurring carbonates within the soil. The approach required to accommodate the effect on soil CO_2 emissions of both these sources is necessarily complex because, in practice, there are a number of different reasons why aglime is applied to crops. These include neutralisation of the acidifying effect of N fertiliser application as well as controlling existing soil acidity. As a consequence, the JRC acidification and liming model has rules about the estimation of soil CO_2 emissions which depend on the soil acidity (characterised by its pH), and the application rates of aglime, and chemical and organic N fertilisers.

These rules incorporate important assumptions about the interactions between aglime and soils with different acidity/basicity (pH), the acidifying effect of N fertilisers and necessary neutralisation by aglime and the subsequent amounts of CO_2 released. The assumptions are based on various scientific studies and their interpretation by the JRC. Different outcomes are obtained by using these studies, especially for estimating soil CO_2 emissions from N fertiliser neutralisation. Hence, it has been necessary for the JRC to average these diverse outcomes in formulating rules within the acidification and liming model. It is also acknowledged by the JRC that the assumptions do not take into account neutralising reactions which do not result in soil CO_2 emissions and do not address the different acidification potential of chemical N fertilisers other than ammonium nitrate and urea. Without evidence from actual field measurements, it is not known whether the interpretation and application of these assumptions by the JRC in formulating the subsequent rules in this model are correct and reliable. Consequently, this part of the acidification and liming model must be regarded, currently, as scientifically unproven.

It will be appreciated that, in order to determine soil CO_2 emissions by means of the rules within the JRC acidification and liming model, it is necessary to establish application rates for chemical and organic N fertilisers, and aglime. The model adopts the same approach to simulating chemical and organic N fertiliser application rates as that used in the JRC soil N_2O emissions model. As a result, this part of the acidification and liming model is subjected to the same uncertainties identified previously (see Appendix B). For consistency, it is also necessary to determine aglime application rates on the same mapping basis of grid cells. However, an additional problem is introduced to this approach because equivalent FAO statistics are not available for aglime application rates (in contrast to the chemical N fertiliser application rates in FAO statistics; Ref. 24). Hence, an alternative means of estimating aglime application rates had to be devised by the JRC.

The main source of basic data for estimating aglime application rates consists of annual consumption statistics reported for 2000 under the United Nations Framework Convention on Climate Change (UNFCCC) and recorded in the Emissions Database for Global Atmospheric Research (EDGAR) (Ref. 29). Since such statistics are only submitted by so-called Annex 1 countries to the UNFCCC, a separate procedure, involving the simulation of aglime application rates from soil pH and chemical N fertiliser application rates, had to be adopted for non-Annex 1 countries. However, all EU-27 Member States are Annex 1 countries and some non-Annex 1 countries, such as Brazil[9], provide annual aglime consumption statistics, so that appropriate statistics were available for all relevant countries producing bioethanol from wheat, maize, sugar beet and sugar cane in connection with the required typical and default values.

Unfortunately, annual aglime consumption statistics do not necessarily indicate the amount of aglime applied to land for growing arable crops. This is because aglime can also be applied to grassland, forest and lakes for a variety of purposes. Consequently, it was necessary for the JRC to subtract any use of aglime other than for arable crop cultivation. The actual sources of such data required to do this are not completely explicit although it is implied that some countries specify the share of aglime consumption which is used for non-arable crop applications. However, it is noted that only 5 EU Member States (Czech Republic, Norway, Germany, Ireland and the UK) appear to do this and sources of data for this adjustment in other countries are unclear. The drawbacks of relying on these statistics, as presented in EDGAR, are recognised by the JRC but their use is justified on the basis that this is the only known global database for aglime application rates.

The adjusted national statistics on total aglime consumption for arable crop cultivation from EDGAR are used as a means to calibrate aglime application rates simulated from the neutralisation requirements of soils. This is based on aglime application rates recommended by the Agricultural Lime Association (ALA) for different soil pH, texture and organic content, and agricultural land use (arable or grassland) (Ref. 33). These recommended rates were combined with grid cell maps for soil properties, from the Harmonized World Soil

[9] However, it is noted by the JRC that aglime consumption statistics for Brazil in 2000, specifically, might be anomalous and could lead to possible over-estimation.

Database (Ref. 26), and equivalent maps of cultivated areas and yields of relevant crops for relevant countries in 2000 (Ref. 21). It will be noted that the same sources of mapping data are used in the JRC soil N_2O emissions model (see Appendix B) which means that there should be consistency between the two modelling approaches. Subsequent results, consisting of simulated aglime application rates for grid cells, are then calibrated against the adjusted national aglime consumption statistics. Although this calibration process is not explained, it presumably involves summing simulated aglime applications rates across a country's harvested arable crop area, comparing this with the total aglime consumption for such crop cultivation for the country, and adjusting all simulated rates pro-rata if there is any discrepancy with total aglime consumption.

Following such calibration, simulated aglime application rates are obtained for specific crops in particular countries. It is possible to test the reliability of this simulation procedure by comparing results for countries which conduct farming surveys and publish actual national aglime application rates for specific crops. This is undertaken in the JRC proposal using published survey data for the UK, and with studies and modelling work in Germany.

With the UK data, an average aglime application rate for all crop-bearing arable land in 2000 of 0.34 t $CaCO_3$/ha.a is obtained and compared with a simulation of 0.28 t $CaCO_3$/ha.a from the JRC acidification and mining model. This amounts to an under-estimate of approximately 18%. Whilst this might not be regarded as a significant difference, much larger discrepancies are apparent from comparison of survey data and simulations for individual crops. In particular, the aglime application rate for sugar beet from survey data is 1.10 t $CaCO_3$/ha.a compared with a simulation of 0.26 t $CaCO_3$/ha.a which is a very sizeable under-estimate of approximately 76%.

The testing with data from Germany are even less convincing as a nationally simulated aglime application rate for all arable crops of 0.48 t $CaCO_3$/ha.a is compared with a regional application rate for wheat and rye of between 0.54 and 0.71 t $CaCO_3$/ha.a, a cited study default value for all crops of approximately 0.63 t $CaCO_3$/ha.a, and apparent modelling, based on nutrient deficiencies, of between 0.29 and 0.45 t $CaCO_3$/ha.a for arable land. Although this might support the statement in the JRC proposal that the simulations are "in the range of what is mentioned in the literature" (Ref. 5), this cannot be regarded as an overwhelming endorsement of the modelling approach that has been adopted. More conclusive testing would involve comparison with actual survey data for specific crops in more countries and a systematic evaluation of simulated results based on the relative magnitude of any discrepancies.

After calibration, simulated aglime application rates are available for each map grid cell of land used for arable crop cultivation in relevant countries for2000. The JRC rules described earlier are then applied to estimate soil CO_2 emissions. In addition to the simulated aglime application rates, estimated chemical and organic N fertiliser application rates, presumably derived from Steps 2 and 3, respectively, of the JRC soil N_2O emissions model (see Appendix B), are combined with soil pH data to derive estimate soil CO_2 emissions for each map grid cell. These estimates are then used to determine the soil CO_2 emissions associated with biofuel crops, presumably, by means of the same weighting procedure as Step 9 of the JRC soil N_2O emissions model (see Appendix B). Unfortunately, the details of this procedure are not explained in the JRC proposal. Although not stated, it is assumed that, for consistency, the estimated soil CO_2 emissions are updated to 2006/07 values by the same process as Step 10 of the JRC soil N_2O model (see Appendix B).

Since many of the actual details of the JRC acidification and liming model are not provided, it is not possible to form a definitive, independent judgement of its suitability for deriving typical and default values. However, it would seem that there are two crucial tests which would determine whether the JRC acidification and liming model is appropriate for the purposes of the JRC proposal. Both of these tests have been identified in this critical review. The first test is whether simulation of aglime application rates produces results which are accurately reflected by actual survey data. The second test is whether the rules for estimating soil CO_2 emissions produce results which are supported by actual field measurements. Until these tests have been performed and passed successfully, it must be concluded that the JRC acidification and liming model is currently unproven.

NORTH ENERGY

APPENDIX D: Emissions Factors for Proposed Default Values

Table D1 Greenhouse Gas Emissions Factors for Relevant Fuels and Electricity

Emissions Factors	Significance	Representativeness	Transparency	Consistency
Diesel Oil Provision	Moderate	EU-27 representative simulation (JRC model)	Moderate (some modelling details and assumptions accessible)	Based on mix of marginal and average data for EU-27
Diesel Oil Combustion	Moderate	Standard data but unspecified	Low (source unknown)	Unknown
Natural Gas Provision	Moderate	Assumed EU-27 representative simulation (JRC model)	Moderate (some modelling details and assumptions accessible)	Based on detailed modelling with statistics
Natural Gas Combustion	Moderate	Standard data but unspecified details and source	Low (source unknown)	Unknown
Lignite Provision	Moderate	Assumed EU-27 representative simulation (JRC model)	Low (modelling details and assumptions inaccessible)	Unknown
Lignite Combustion	Moderate	Standard data but unspecified	Low (source unknown)	Unknown
Hard Coal Provision	Moderate	Assumed EU-27 representative simulation (JRC model)	Low (modelling details and assumptions inaccessible)	Unknown
Hard Coal Combustion	Moderate	Standard data but unspecified	Low (source unknown)	Unknown
Wood Chip Provision	Low	Data not provided	Low (data unavailable)	Unknown
Wood Chip Combustion	Low	Data not provided	Low (data unavailable)	Unknown
Biogas Combustion	Low	Data not provided	Low (data unavailable)	Unknown
Bagasse Combustion	Low	Data not provided	Low (data unavailable)	Unknown
Electricity Supply (0.4 kV)	Low	EU-27 representative statistics (JRC model for 2009)	High (modelling details and assumptions accessible)	Based on detailed modelling with statistics
Electricity Supply (MV)	Low	EU-27 representative statistics (JRC model for 2009)	High (modelling details and assumptions accessible)	Based on detailed modelling with statistics

Table D2 Greenhouse Gas Emissions Credits for Excess Electricity Credit from Combined Heat and Power (cogeneration)

Emissions Credits	Significance	Representativeness	Transparency	Consistency
Natural Gas-fired Combined Cycle Gas Turbine Electricity	Moderate	Unrepresentative data (nominal value for DE 2010)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current range of plants
Natural Gas- and Biogas-fired Combined Cycle Gas Turbine Electricity	Moderate	Data not provided	Low (data unavailable)	Not based on EU-27 current range of plants
Lignite-fired Steam Turbine Electricity	Moderate	Unrepresentative data (nominal value for DE 2010)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current range of plants
Hard Coal-fired Steam Turbine Electricity	Moderate	Data not provided	Low (data unavailable)	Not based on EU-27 current range of plants
Wood Chip-fired Steam Turbine Electricity	Moderate	Unrepresentative data (nominal value for DE 1999)	Moderate (some data accessible but choice and details unexplained)	Not based on EU-27 current range of plants
Bagasse-fired Steam Turbine Electricity	Moderate	Data not provided	Low (data unavailable)	Not based on BR current range of plants

Table D3 Greenhouse Gas Emissions Factors for Chemical Fertilisers, Pesticides and Seeds

Emissions Factors	Significance	Representativeness	Transparency	Consistency
N Fertiliser Provision (EU)	High	EU-27 representative interpolation (JRC model for EU mix of ammonium nitrate and urea 2011)	Moderate (some but not all modelling details and assumptions accessible)	Based on mix rather than specific types of N fertilisers
N Fertiliser Provision (BR)	Moderate	Data not provided	Low (data unavailable)	Not based on BR supply mix of types of N fertilisers
$CaCO_3$ Fertiliser Provision (EU and BR)	Moderate	Unrepresentative data (nominal value for DE 1994)	Moderate (data accessible but choice unexplained)	Not based on EU-27/BR supply of $CaCO_3$ fertiliser
K_2O Fertiliser Provision (EU and BR)	Low	Unrepresentative data (nominal value for one type of K_2O fertiliser DE 1997)	Moderate (data accessible but choice unexplained)	Not based on EU-27/BR supply mix of K_2O fertilisers
P_2O_5 Fertiliser Provision (EU and BR)	Low	Unrepresentative data (nominal value for one type of P_2O_5 fertiliser DE 1997)	Moderate (data accessible but choice unexplained)	Not based on EU-27/BR supply mix of P_2O_5 fertilisers
Pesticide Provision (EU and BR)	Low	Unrepresentative data (nominal value for one type of pesticide DE 1997)	Moderate (data accessible but choice unexplained)	Not based on EU-27/BR supply mix of pesticides
Wheat Seed Provision (EU)	Low	Data not provided	Low (data unavailable)	Not based on EU-27 supply of wheat seed
Maize Seed Provision (EU)	Low	Data not provided	Low (data unavailable)	Not based on EU-27 supply of maize seed
Sugar Beet Seed Provision (EU)	Low	Data not provided	Low (data unavailable)	Not based on EU-27 supply of sugar beet seed
Sugar Cane Seed Provision (BR)	Low	Data not provided	Low (data unavailable)	Not based on BR supply of sugar beet seed

Table D4 Greenhouse Gas Emissions Factors for Bioethanol Production Chemicals

Emissions Factors	Significance	Representativeness	Transparency	Consistency
NaOH Provision (EU)	Low	Unrepresentative data (nominal value for membrane production DE 2000)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current supply mix of NaOH
NH_3 Provision (EU)	Low	Possibly EU-27 representative data (EMFA 2010)	Low (details unavailable as source not accessible)	Unknown
CaO Provision (EU and BR)	Low	Unrepresentative data (nominal value for unspecified process, location and year)	Moderate (data accessible but choice unexplained)	Not based on EU-27/BR current supply mix of CaO
Alpha-amylase Provision (EU)	Low	Unrepresentative data (nominal value for CA/US 2009)	Low (details limited and choice unexplained)	Not based on EU-27 current supply mix of alpha-amylase
Glyco-amylase Provision (EU)	Low	Unrepresentative data (nominal value for CA/US 2009)	Low (details limited and choice unexplained)	Not based on EU-27 current supply mix of alpha-amylase
H_2SO_4 Provision (BR)	Low	Unrepresentative data (nominal value for DE 1996)	Low (details limited and choice unexplained)	Not based on BR current supply mix for H_2SO_4
Cyclohexane Provision (BR)	Low	Unrepresentative data (nominal value for BR 2004?)	Low (details limited and choice unexplained)	Unknown as source not specified
Lubricant Provision (BR)	Low	Unrepresentative data (nominal value for DE 1996)	Low (details limited and choice unexplained)	Not based on BR current supply mix for lubricants

Table D5 Greenhouse Gas Emissions Factors for Crop and Bioethanol Transport

Emissions Factors	Significance	Representativeness	Transparency	Consistency
Road Transport (EU Crops/Bioethanol)	Low	Unrepresentative data (nominal values for single truck size for DE 1996, 2003 and 2007)	Low (choice and combining of data unexplained)	Not based on EU-27 current freight road transport mix
Road Transport (BR Sugar Cane)	Low	Possibly representative data (nominal values for mix of truck sizes for BR 2004)	Moderate (data accessible but choice unexplained)	Not based on entire BR current mix of truck sizes
Maritime Transport (BR Bioethanol)	Low	Unrepresentative data (nominal value for single product tanker size for NO 2009/2012)	Low (choice and combining of data unexplained)	Not based on BR/EU mix of product tanker sizes
Inland Waterway Transport (EU Crops)	Low	No data provided for wheat, maize and sugar beet transport by barge	Low (data not available)	Not based on EU-27 current mix of barge sizes
Inland Waterway Transport (EU Bioethanol)	Low	No data provided for bioethanol transport by barge	Low (data not available)	Not based on EU-27 current mix of barge sizes
Rail Transport (EU)	Low	Unrepresentative data (nominal values for diesel train US 2010 and electric train DE 2010)	Moderate (data accessible but choice unexplained)	Not based on EU-27 current mix of rail freight transport
Pipeline Transport (EU)	Low	Unrepresentative data (nominal value for FR 2002)	Low (data limited and choice unexplained)	Not based on EU-27 current pipelines

APPENDIX E: Critical Review of JRC Chemical Nitrogen Fertiliser Provision Emissions Factor Model

The GHG emissions associated with the provision of chemical N fertilisers can make a significant contribution to the total GHG emissions of the cultivation of certain biofuel crops and, indeed, to the total GHG emissions of the production of certain biofuels. Hence, it is necessary to ensure that the GHG emissions factor for chemical N fertiliser provision is suitable for the derivation of typical and default values in the RED/FQD. In the JRC proposal, a modelling approach is adopted to obtain this emissions factor for 2011 (Ref. 5). The model is based on the supply of chemical N fertilisers in the EU and the emissions factor reflects a mix of chemical N fertilisers, consisting of ammonium nitrate and urea. These particular types of chemical N fertilisers are regarded as the only components of the mix of supply in the EU.

Estimated GHG emissions factors are available for the EU manufacture of ammonium nitrate and urea in 2006 using industry data from FertilizersEurope, formerly the European Fertilizer Manufacturers' Association (EFMA: Ref. 34). These GHG emissions factors have been combined with assumptions about the supply, and associated GHG emissions, of these chemical N fertilisers from outside the EU, specifically ammonium nitrate from Russia and urea from Egypt. This has enabled an average GHG emissions factor for the EU mix of chemical N fertilisers to be generated for 2007, apparently based on ammonium nitrate supply of 59% from the EU and 5% from Russia, and urea supply of 9% from the EU and 27% from Egypt. Estimated GHG emissions factors are also available for the manufacture of both these chemical N fertilisers with "Best Available Technology" (BAT). This takes into account expected improvements in the industry, including N_2O emissions abatement implemented into nitric acid production which is an essential part of ammonium nitrate provision. It has been forecast that ammonium nitrate and urea will be produced entirely with BAT by 2020. This has enabled an average GHG emissions factor for the EU mix of chemical N fertilisers to be generated for 2020. The estimated average GHG emissions factor for the EU mix of chemical N fertilisers in 2011 has been interpolated from the averages for 2007 and 2020. It appears that this 2011 interpolated GHG emissions factor for chemical N fertilisers is used in the subsequent derivation of typical and default values for relevant biofuels in the JRC proposal.

Although a modelling approach is necessary for obtaining suitable GHG emissions factors for the provision of chemical N fertilisers, there are a number of drawbacks in the JRC model. The model only considers ammonium nitrate and urea in the mix of chemical N fertiliser supply. However, it is known that many different types of chemical N fertilisers are supplied and used by farmers. There can be distinct differences in the GHG emissions factors of these types of chemical N fertilisers as shown in Table E1. It would be more appropriate to derive the GHG emissions factor on the weighted average of the supply of all types of chemical N fertiliser. However, it is appreciated that the necessary statistics might not be accessible to do this. Indeed, it is recognised in the JRC proposal that the suitable statistics are not available especially for chemical N fertiliser imports into the EU.

Table E1. Examples of Total Greenhouse Gas Emissions Factors for the Provision of Different Chemical Nitrogen Fertilisers

Type of Chemical Nitrogen Fertiliser	Total Greenhouse Gas Emissions Factor[(a)] (g eq. CO_2/ kg N)	Source
Mix of N Fertiliser Use (EU 2007)	6,336	Ref.5
Mix of N Fertiliser Use (EU 2011 interpolation)	5,582	Ref. 5
Mix of N Fertiliser (EU 2020 forecast)	3,887	Ref. 5
Ammonium Nitrate (EU 2006)	6,186	Ref. 34
Ammonium Nitrate (Best Available Technology)	2,714	Ref. 34
Urea (EU 2006)	1,566	Ref. 34
Urea (Best Available Technology)	1,130	Ref. 34
Ammonium Sulphate (EU 2002)	1,619	Ref. 35
Ammonium Sulphate (Modern Technology)	667	Ref. 35
Calcium Ammonium Nitrate (EU 2006)	6,161	Ref. 34
Calcium Ammonium Nitrate (Best Available Technology)	2,828	Ref. 34
Monoammonium Phosphate (EU 2002)	2,818	Ref. 35
Diammonium Phosphate (EU 2006)	3,888	Ref. 34

Note

(a) Assuming GWPs of 23 kg eq. CO_2/kg CH_4 and 296 kg eq. CO_2/kg N_2O.

It is also apparent that the JRC model is based on the overall supply of chemical N fertilisers in the EU. However, it is quite possible that this does not reflect the actual mix of such fertilisers applied to specific biofuel crops. This deficiency in relevant information undermines the attempt to use representative data in the derivation of typical and default values. It should also be noted that determination of a GHG emissions factor for a mix of chemical N fertilisers instead of specific types of such fertilisers is intimately connected to the approach adopted in the JRC soil N_2O emissions model. This approach was necessary due to deficiencies in national statistics on applications rates which do not specify particular types of chemical N fertilisers (see Appendix B; Step 2a). Finally, as noted in the JRC proposal (Ref. 5; Page 56), the GHG emissions factor for the EU mix of chemical N fertilisers is applied in the derivation of typical and default values for biofuel crops grown outside the EU, such as Brazilian sugar cane. This is inappropriate as, strictly speaking, similar GHG emissions factor models should also have been developed for these other countries.

REFERENCES

1. “Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC” European Commission, Brussels, Belgium, 2009.

2. “Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 Amending Directive 98/70/EC as Regards the Specification of Petrol, Diesel and Gas-oil and Introducing a Mechanism to Monitor and Reduce Greenhouse Gas Emissions and Amending Council Directive 1999/32/EC as Regards the Specification of Fuel Used by Inland Waterway Vessels and Repealing Directive 93/12/EEC” European Commission, Brussels, Belgium, 5 June 2009.

3. “Communication from the Commission to the Council and the European Parliament: Renewable Energy Road Map – Renewable Energies in the 21st Century: Building a More Sustainable Future” COM (2006) 848, Commission of the European Communities, Brussels, Belgium, 10 January 2007.

4. “Communication from the Commission on Voluntary Schemes and Default Values in the EC Biofuels and Bioliquids Sustainability Scheme” European Commission, Brussels, Belgium, 2010.

5. “Assessing GHG Default Emissions from Biofuels in EU Legislation: review of the input database to calculate ‘default GHG emissions’ following expert consultation” by R. Edwards, D. Mulligan, J. Giuntoli, A. Agostini, A. Boulamanti, R. Koeble, L. Marelli, A. Moro and M. Padella JRC Scientific and Policy Report EUR 25595 EN, Draft Version, Joint Research Centre, Ispra, Italy, 2013.

6. "Environmental Management – Life Cycle Assessment – Principles and Framework" BS EN ISO 14040, British Standards Institute, London, United Kingdom, 2006.

7. “Consequential and Attributional Approaches to LCA: a Guide to Policy Makers with Specific Reference to Greenhouse Gas LCA of Biofuels” by M. Brander, R. Tipper, C. Hutchinson and G. Davis, Technical Paper TP-090403-A, Ecometrica Press, Edinburgh, United Kingdom, www.ecometrica.co.uk, April 2009.

8. “Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policy Makers” by R. J. Plevin, M. A. Delucchi and F. Creutzig, Journal of Industrial Ecology, published online (DOI:10.1111/jiec.12074) on 8 November 2013.

9. “Well-to-Tank Report Version 4.0: JEC Well-to-Wheels Analysis: Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context” by R. Edwards, J.-F. Larivé, D. Rickeard and W.

Weindorf, JRC Technical Report EUR 26028 EN, Joint Research Centre, Ispra, Italy, 2013.

10. “Oxford English Dictionary” Oxford University Press, Oxford, United Kingdom, www.oed.com, accessed 30 December 2013.

11. “BioGrace GHG Calculation Tool; version 4c” BioGrace Harmonised Calculation of Biofuel Greenhouse Gas Emissions in Europe, www.biograce.net.

12. "IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4: Agriculture, Forestry and Other Land Use” edited by S. Eggleston, L. Buendia, K. Miwa, T. Ngara and K. Tanabe, Institute for Global Environmental Strategies, Kanagawa, Japan, www.ipcc-nggip.iges.org.jp.

13. “The Global Nitrous Oxide Calculator – GNOC – Online Tool Manual: Version 1.2.2” by L. Marelli and R. Koeble, Joint Research Centre, Ispra, Italy, 18 October 2013.

14. “N_2O and NO Emissions from Agricultural Fields and Soils Under Vegetation: Summarizing Available Measurement Data and Modelling of Global Annual Emissions” by E. Stehfest and L. Bouwman, Nutrient Cycling and Agroecosystems, Issue 74, p. 207 – 228, 2006.

15. “CAPRI Model Documentation, 2012” edited by W. Britz and P. Witzke, Institute for Food and Resource Economics, University of Bonn, Germany, www.capri-model.org.

16. “KTBL Agricultural Handbook: Data for Farm Management Calculations” Munster, Germany.

17. “The Contribution of N_2O to the Greenhouse Gas Balance of First-Generation Biofuels” by E. M. W. Smeets, L. F. Bouwman, E. Stehfest, D. P. van Vuuren and A. Posthuma, Global Change Biology, Volume 15, Issue 1, p. 1 -23, January 2009.

18. “Differentiation of Nitrous Oxide Emissions Factors for Agricultural Soils” by J. P. Lesschen, G. L. Velthof, W. de Vries and J. Kros, Environmental Pollution, Volume 159, Issue 11, p. 3215 – 3222, November 2011.

19. “N_2O and NO Emissions from Agricultural Fields and Soils Under Vegetation: N_2O and NO Emissions Data Set” Netherlands Environmental Assessment Agency, www.pbl.nl, accessed 21 February 2014.

20. “Report from the Commission of the European Parliament and of the Council on the Feasibility of Drawing up Lists of Areas in Third Countries with Low Greenhouse Gas Emissions from Cultivation” COM (2010) 427 final, European Commission, Brussels, Belgium, 10 August 2010.

21. “Farming the Planet. 2: The Geographical Distribution of Crop Areas and Yields in 2000” by C. Monfreda, N. Ramankutty and J. A. Foley, Center for

Sustainability and the Global Environment, Nelson Institute for Environmental Studies, University of Wisconsin, Madison, United States of America, 2008.

22. “FAOSTAT 2005: FAO Statistical Databases” Food and Agriculture Organisation of the United Nations, Rome, Italy, 2006.

23. “FAO Agro-Maps” Food and Agriculture Organisation of the United Nations, Rome, Italy, 2006.

24. “FAO N Fertiliser Rate (kg/ha) per Crop and Country” Food and Agriculture Organisation of the United Nations, Rome, Italy, 2010.

25. “IFADATA: International Fertilizer Industry Association Statistics” www.fertilizer.org, 2010.

26. “Harmonized World Soil Database: Version 1.1” Food and Agriculture Organisation of the United Nations, Rome, Italy, and International Institute for Advanced Systems Analysis, Vienna, Austria 2009.

27. Personal communication from Roger Sylvester-Bradley of ADAS UK to Robert Edwards, JRC, 2013.

28. “HGCA Recommended Winter Wheat Varieties, 2013” http://www.hgca.com/document.aspx?fn=load&media_id=8326&publicationId=6392.

29. “Emissions Database for Global Atmospheric Research; EDGAR v4.1” Joint Research Centre, Ispra, Italy, http://edgar.jrc.ec.europa.eu, July 2010.

30. "IPCC Guidelines for National Greenhouse Gas Inventories: Volume 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application” by C. De Klein, R. S. A. Novoa, S. Ogle, K. A. Smith, P. Rochette, T. C. Wirth, B. G. McConkey, A. Mosier, K. Rypdal, M. Walsh and S. A. Williams, Institute for Global Environmental Strategies, Kanagawa, Japan, www.ipcc-nggip.iges.org.jp, 2006.

31. “Greenhouse Gas Emissions in the Production and Use of Ethanol from Sugar Cane in Brazil: The 2005/06 Averages and a Prediction for 2020” by I. C. Macedo, J. E. A.Seabra and J. E. A. R. Silva, Biomass and Bioenergy, Vol. 32, p. 582 – 595, 2008.

32. “Well-to-Tank Report Version 2c: JEC Well-to-Wheels Analysis: Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context” by R. Edwards, J.-F. Larivé, V. Mahieu and P. Rouveirolles, Joint Research Centre, Ispra, Italy, March 2007.

33. “ALA Lime Application Recommendations” Agricultural Lime Association, London, United Kingdom, http://aglime.org.uk, February 2012.

34. “GHG Emissions and Energy Efficiency in European Nitrogen Fertiliser Production and Use” by F. Brentrup and C. Palliére, Proceedings of the International Fertiliser Society, No. 639, York, United Kingdom, 2008.

35. "Energy Consumption and Greenhouse Gas Emissions in Fertiliser Production" by T. K. Jenssen and G. Kongshaug, Proceedings of the International Fertiliser Society, No. 509, York, United Kingdom, April 2003.