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: Deliverable 3 – Critical Comparison of Calculation Methodologies

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Deliverable 3 – Critical Comparison of Calculation Methodologies

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Executive Summary

1. This critical comparison of the methodologies used to calculate actual values and to derive existing and proposed default values for greenhouse gas (GHG) emissions associated with biofuels and bioliquids under the European Commission's (EC's) Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) was prepared for the European Renewable Ethanol Association, ePURE.

2. The aims of this comparison are to assess compliance of the actual methodology with critical reviews of the Joint Research Centre (JRC) proposal and existing and proposed default values, to identify any differences between these methodologies, and to determine whether any methodology can be considered to be superior.

3. The summary and critical review of the RED/FQD methodology uncovers a number of important deficiencies which undermine its practical application in estimating actual values and its use in deriving existing and proposed default values. Fundamentally, these deficiencies are due to failures in applying the strict principles of life cycle assessment (LCA) during the development of the RED/FQD methodology.

4. In particular, the lack of any clear purpose, or goal, for the methodology means that regulatory and policy objectives are conflated, leading to contradictory choices over the inclusion or exclusion of sources of GHG emissions, and how some of these are calculated.

5. As a consequence, there is heavy reliance on special rules, for certain aspects of biofuel and bioliquid production, and lists of examples, as means of explaining the composition of contributions to GHG emissions. Overall, the nature of this prescriptive yet incompletely-definitive approach means that the RED/FQD methodology is open to interpretation. This causes differences between its application to estimating actual values and its subsequent use in deriving existing and proposed default values.

6. One prominent difference is the mixed use of the DeNitrification DeComposition (DNDC) model and Intergovernmental Panel on Climate Change (IPCC) Tier 1 method in estimating soil nitrous oxide emissions for derivation of existing default values and the adoption of the Global crop- and site-specific Nitrous Oxide emission Calculator (GNOC) in preparing proposed default values. Whilst being allowable as an IPCC Tier 3 method, it is not apparent that the latter has been validated with actual measurements for all relevant biofuel and bioliquid crops, in compliance with IPCC requirements.

7. Despite sharing the same methodological framework, each methodology has its flaws and, hence, no one methodology can be regarded as superior. This can only be properly resolved by adopting a methodology which is firmly based on LCA principles including, crucially, a clearly-stated and fully-articulated regulatory goal that automatically and comprehensively establishes which sources of GHG emissions should be included in all calculations, and how they should be calculated.

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) establish the methodology for economic operators of biofuel and bioliquid installations to report their associated greenhouse gas (GHG) emissions as actual values. This methodology is set around an equation for determining associated GHG emissions consisting of specific contributory elements (Ref. 1; Annex V, Section C, and Ref. 2; Annex IV, Section C). The details of the actual value calculation methodology have been elaborated further in a communication on practical implementation (Ref. 3). Additionally, default values, based on typical values for contributions to associated GHG emissions, are provided to assist economic operators as an intended means of avoiding a disproportionate administrative burden of data collection and analysis (Ref. 1; Para 82, and Ref. 4; Section 3). The RED contains the requirement on the EC to report, regularly, on the updating of default values, and the typical values on which they are based (Ref. 1; Article 19, Para. 5). To this end, the EC's Joint Research Centre (JRC) at Ispra, Italy, has prepared updated typical and default values in the form of a proposal (Ref. 5), referred to subsequently as the JRC proposal.

1.2 Aims and Objectives

The aims of this current work for the European Renewable Ethanol Association, ePURE, are:

- to assess whether the actual value methodology complies with the critical reviews of the JRC proposal and the existing and proposed default values,
- to establish whether the actual value methodology is the same as the methodologies applied in deriving existing and proposed default values, and
- to determine, if the methodologies are different, whether the actual value methodology is in any way superior to either that used for obtaining existing or proposed default values.

The objectives required to achieve these aims consist of:

- summarising and critically reviewing the key features of the actual value methodology,
- investigating the key features of the methodologies that might have been applied in the preparation of existing and proposed default values, and
- comparing the key features of these methodologies.

2. METHODOLOGY FOR ACTUAL VALUES

2.1 Key Features of the Actual Value Methodology

The elements of the equation required to calculate the GHG emissions associated with biofuels and bioliquids as specified in the RED and FQD consist of:

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

The compositions of these elements are not defined specifically. Instead, these are described by general comments on coverage in the relevant supporting text in the RED (Ref. 1; Annex V, Section C) and FQD (Ref. 2; Annex IV, Section C) and elaboration further in the communication on practical implementation (Ref. 3; Section 3.3 and Annex II). In effect, guidance often takes the form of generalised lists of sources of GHG emissions that could possibly be included in, or excluded from calculations.

The extraction or cultivation of raw materials, or "biomass feedstocks", is the first stage in a "pathway" for production of a biofuel. The RED/FQD calculation methodology states that emissions from extraction or cultivation of raw materials, e_{ec}, "shall include emissions from the extraction or cultivation process itself; from the collection of raw materials; from wastes and leakages; and from the production of chemicals or products used in extraction or cultivation". In the communication on practical implementation, it is noted that emissions from cultivation will typically include seeds, fuel, fertiliser, pesticide and soil nitrous oxide (N_2O) emissions. It is indicated that cultivation emissions can be derived using averages from "smaller geographical areas than those used in the calculation of the default values". Given the wording of the methodology in the RED/FQD, there is a possibility that emissions associated with the transport of biomass feedstocks to biofuel installation can be included in the calculation equation element e_{ec} rather than e_{td}. However, cultivation emissions should exclude the absorption of carbon dioxide (CO_2) during crop growth.

The RED/FQD methodology does not establish the means used to calculate soil N_2O emissions due to biofuel or bioliquid crop cultivation. Instead, the communication on practical implementation states that either the Tier 1, 2 or 3 methods provided by the Inter-governmental Panel on Climate Change (IPCC) can be used in calculating direct and indirect soil N_2O emissions (Ref. 6). This means that it is left to the economic operator to decide whether to use standard emissions factors for converting the nitrogen (N) contents of sources of N_2O emissions, such as applied artificial and organic fertilisers (manures), and incorporated crop residues into N_2O emissions (Tier 1 method); or more detailed emissions factors for specific artificial and organic N fertilisers and incorporated crop residues for specific countries or regions (Tier 2 method); or approaches based on measurements or modelling (Tier 3 method). Additionally, it should be noted that neither the RED/FQD nor the communication on practical implementation specify, explicitly, which sources of soil N_2O emissions should be taken into account.

A specific rule is provided for annualising emissions due to carbon stock changes, e_l, in the soil as a consequence of direct land use change (dLUC). Subsequently, guidelines have been published on the calculation of land carbon stocks (Ref. 7). These are very detailed guidelines with extensive default data for different types of land use on different soil types with different climatic conditions. This assists estimation of net carbon stock changes and resulting annualised CO_2 emissions when land is converted from a previous use to the cultivation of a biofuel of bioliquid crop. Additionally, the RED/FQD methodology specifies a so-called “bonus” emission saving, to be subtracted in calculations, for biomass obtained from restored degraded land.

No details for the calculation of emissions savings from accumulating soil carbon due to improved agricultural management, e_{sca}, are given in the RED or FQD. However, the meaning of “improved agricultural management” is listed by examples in the communication on practical implementation. It is a requirement that any estimates of soil carbon accumulation, leading, in effect, to CO_2 emissions savings in calculations, should be supported by evidence although its precise nature of this is not specified.

The RED/FQD methodology states that emissions from processing, e_p, shall include “emissions from the processing itself; from waste and leakages; and from the production of chemicals or products used in processing”. If electricity consumed by the biofuel or bioliquid processing installation is obtained from the grid, then an emissions factor must be used which reflects the emissions associated with electricity generated and distributed in a relevant defined region. Alternatively, if the electricity is obtained from a specific power only plant, the emissions factor should represent this accordingly.

Since the energy required in biofuel or bioliquid processing can be supplied by a combined heat and power (CHP) unit which has the potential to produce surplus electricity, it has been necessary to address this eventuality in the calculation methodology. This is done for emissions associated with excess electricity from cogeneration, e_{ee}, by means of a rather convoluted procedure involving the derivation of an emissions saving or “credit”. Instead of assuming that excess electricity displaces, say, local grid electricity using an emissions factor which reflects this, the credit is based on the emissions from a hypothetical power only plant which uses the same fuel as the CHP unit in the biofuel or bioliquid processing installation. No guidance is provided on the assumed net thermal efficiency of this power only plant which strongly influences the subsequent emissions factor for the excess electricity credit.

Two elements of the equation for calculating GHG emissions accommodate the possibility of capturing CO_2 emissions from processing. This is particularly relevant for bioethanol installations which are based on fermentation. This is accounted by emissions savings due to carbon capture and geological storage, e_{ccs}, and carbon capture and replacement, e_{ccr}. So-called “biogenic” CO_2 from fermentation has, originally, been derived from biomass which has absorbed CO_2 from the atmosphere. Hence, its storage in geological formations, in effect, extracts CO_2 from the atmosphere, resulting in an emissions saving equivalent to the amount of CO_2 captured and stored. The apparent basis of expected emissions savings with carbon capture and replacement is that such biogenic CO_2 displaces so-called “fossil” CO_2 obtained from coal, natural gas, oil, etc. Such fossil CO_2 is assumed to be used in processes or incorporated into products that, eventually, would release it into the atmosphere. Hence, it is argued that displacing fossil CO_2 by biogenic CO_2 avoids emissions to atmosphere, thereby generating emissions savings. In both cases of carbon capture, the methodology described in the RED/FEQ implies that emissions associated with CO_2 capture and either geological storage or conversion for subsequent use are taken into account in emissions from processing, e_p.

Co-product allocation is a procedure which can affect the division of emissions at any part of a biofuel or bioliquid production pathway where more than one product is produced. However, it applies, most often, to emissions from extraction or cultivation of raw materials, e_{ec}, and to emissions from processing, e_p. Although various co-product allocation procedures are possible, the calculation methodology in the RED/FQD opts, chiefly, on allocation by energy content. In principle, this allocation procedure is quite straightforward since it involves deriving allocation percentages based on the amounts and net calorific values of the co-products in question. The application of net calorific values is elaborated in the communication on practical implementation.

However, such co-product allocation is not applied universally, as would be expected, throughout the RED/FQD calculation methodology. Instead, it is qualified extensively and, it might seem at first consideration, in a potentially arbitrary manner. In particular, agricultural crop residues which might, in fact, be collected during harvesting for other uses are excluded from co-product allocation. Although possible agricultural residues are listed as “including straw, bagasse, husks, cobs and nut shells”, such listing is not adequately comprehensive. The exclusion from co-product allocation also applies to “wastes” from processing which are not specifically defined and, therefore, could possibly include low value materials that are recovered for further use. The most significant exclusion from the co-product allocation procedure in the RED/FQD calculation methodology is excess electricity from cogeneration in biofuel and bioliquid installations. This can be a very significant co-product and yet it is addressed by an entirely separate approach, as described previously, which is based, effectively, on a “substitution credit” or “counterfactual”.

Emissions from transport and distribution, e_{td}, relate to the transportation of biomass feedstocks to the biofuel or bioliquid installation (unless already incorporated in the emissions from extraction or cultivation of raw materials, e_{ec}), the transportation of semi-finished materials, such as intermediate biofuel or bioliquid products, and the storage and distribution of finished materials, which are assumed to consist of biofuels and bioliquids for use by final consumers. The term "transportation" would appear to be quite clear so it would not be expected that this would include other activities, such as handling, drying and storage, associated with the transfer of biomass feedstocks between cultivation and processing. The term "distribution" is not defined in the RED/FQD so that it is unclear whether any emissions associated with blending depot and/or filling station operations involved in delivering biofuels or bioliquids to final users should be included in calculations.

It is stated in the RED/FQD calculation methodology that "emissions from the fuel in use, e_u, shall be taken as zero for biofuels and bioliquids". Although not actually explained, it is likely that this is based on the presumption that, since biofuels and bioliquids are derived from biomass, the CO_2 emissions from combustion are balanced by CO_2 absorption during the original growth of this biomass. Strictly speaking, any other GHG emissions, such as N_2O, from biofuel and bioliquid combustion should be taken into account although these are comparatively small.

For all stages in biofuel and bioliquid production pathways, it is established in the RED/FQD calculation methodology that "emissions from the manufacture of machinery and equipment shall not be taken into account". Given its potentially broad coverage, this would apply to all agricultural machinery, transport vehicles, and production plants. Although not stated, this would also seem to imply that emissions associated with the maintenance, repair and eventual decommissioning of all machinery and equipment are excluded from these calculations.

2.2 Critical Review of the Actual Value Methodology

Whilst it is not the purpose of this particular work to undertake a comprehensive critique of the RED/FQD calculation methodology, it is necessary to identify important deficiencies in this methodology since these can have significant consequences for the methodologies that have been used to derive existing and proposed default values. Unless these deficiencies are understood properly, meaningful comparison of the methodologies is not possible. By necessity, this critical review of the RED/FQD calculation methodology begins with fundamental considerations and moves on to specific issues, some of which are related to practical implementation in Member States (MSs) of the European Union (EU).

Although not stated explicitly in the RED/FQD, the calculation methodology is an application of life cycle assessment (LCA) and, as such, should adhere to the established principles of this particular technique. These principles are presented formally in International Standard ISO 14040 (Ref. 8) which includes the pre-eminent and most fundamental requirement that the "goal" or purpose of any LCA should be clearly stated. This requirement is not just a formality. It is an essential starting point for any type of LCA calculations. This is because a clearly-stated and fully-elaborated goal not only determines all aspects of how the calculations should be performed, it also influences the final result and, therefore, its meaning in relation to the original goal. The goal is, in effect, a carefully constructed "question" to which the subsequent LCA provides the appropriate "answer". As with all types of assessment, there are very many different questions which can be posed and, hence, there are very many different answers.

Unfortunately, the goal of the GHG emissions calculations described in the RED/FQD methodology is not set out openly. Instead, it is only possible to infer the purpose of these calculations in the RED/FQD and that purpose would appear to be regulatory. This inference can be drawn from the explanation of the choice of co-product allocation procedure rather than from any explicitly stated goal. In particular, in discussion of co-product allocation, it is argued that the use of substitution credits is inappropriate for "the regulation of individual economic operators and individual consignments of transport fuels" (Ref. 1; para. 81, page 25). Additionally, a distinction is drawn between assessment for regulatory purposes and for policy analysis. Consequently, it would seem the purpose of the RED/FQD methodology is, primarily, regulation.

In the field of LCA, clear differences are known to exist between "attributional" LCA, which is relevant for regulation, and "consequential" LCA, which is necessary for policy analysis (see, for example, Refs. 9 and 10). In particular, regulation carries the concept that, in relation to LCA, "ownership" of GHG emissions is being attributed to an economic operator or group of operators who, in the current context, are supplying biofuels and bioliquids. This leads to the possible goal of subsequent calculations that they determine the GHG emissions over which those who supply biofuels and bioliquids can exert a demonstrable degree of concurrent economic control or influence.

With such a stated goal, or similarly articulated purpose that is fit for its intended purpose, all aspects of the calculation methodology are automatically determined for any means of producing any type of biofuel or bioliquid from any form of biomass. Basing the calculation methodology on basic principles via goal definition establishes, without contradiction, the start and end point of the biofuel or bioliquid production pathway under consideration, the "systems boundary", which is an imaginary line drawn around the processes for which emissions must be evaluated, and other important aspects, such as the appropriate co-product allocation procedure.

Hence, what has to be included in or excluded from the GHG emissions calculations methodology is governed, in this instance, by those activities over which the suppliers of a given biofuel or bioliquid can "exert a demonstrable degree of economic control or influence". Obviously, this means that emissions directly arising from all processes organised by all economic operators involved in the supply of a biofuel or bioliquid from its original biomass have to be taken into account. It is also reasonable to conclude that emissions associated with the products and services purchased for biofuel or bioliquid production by these economic operators should be included in calculations. Furthermore, it can be argued that emissions associated with purchases made previously, such as those for machinery and equipment, should be excluded from these calculations.

So far, there would be no conflict with the RED/FQD calculation methodology[1]. However, this is not the case with a number of important considerations; co-product allocation, and treatment of excess electricity from cogeneration, biogenic CO_2 captured for sale as a replacement for fossil CO_2, and residues and wastes. Whilst the choice of co-product allocation procedure is very important, it is also potentially controversial and its discussion is not directly relevant to the current critical review. Instead, its application is arbitrary since certain co-products, such as excess electricity from cogeneration, captured biogenic CO_2, and residues and wastes, are treated by separate procedures in the calculation methodology.

A strict consequence of adopting the stated regulatory goal for the calculation methodology is that the allocation procedure should be applied to all co-products regardless of their nature. Hence, co-product allocation should also apply to excess electricity from cogeneration, any CO_2 captured and sold, and residues and wastes which have, in fact, any subsequent uses. With the goal of using the calculation methodology for regulation only, it is inconsistent to apply different approaches to different types of co-product from biofuel and bioliquid production pathways. It is, of course, possible that these types of co-products have been treated differently in the calculation methodology for reasons other than regulation.

For instance, the nature of the exceptional approaches to these particular co-products suggests that their treatment is based on policy rather than regulatory objectives. Indeed, the particular approach for deriving an emissions credit for excess electricity from cogeneration seems to have been informed by earlier JEC Well-to-Wheel (WTW) studies (see, for example, Ref. 12) which clearly address policy analysis by means of consequential LCA. Specific treatment of excess electricity from cogeneration associated with biofuel and bioliquid production appears to be mainly concerned with the question about whether or not it is more appropriate, in terms of GHG emissions, to use a given fuel in a CHP unit to produce a biofuel or bioliquid rather than to generate electricity from a separate power only plant (Ref. 12; page 36). Regardless of the merits, or otherwise, of this particular approach, its adoption in the RED/FQD calculation methodology conflates regulatory with policy objectives.

Similar reasons seem to be behind the special treatment in the RED/FQD calculation methodology afforded to CO_2 which is capture and sold, and to residues and wastes. The credit offered for such CO_2 appears to be based on a policy objective to encourage the capture and sale of biogenic CO_2. The basis for excluding agricultural residues from the co-product allocation procedure would appear to have less to do with the regulation of biofuels and bioliquids produced from crops and more to reflect a policy for encouraging biofuel and bioliquid production from such residues. Such a policy is, of course, entangled with concerns over avoiding indirect land use change (iLUC). However, this issue should be addressed properly through the policy framework and not

[1] It should be noted that, whilst this would also be correct for the inclusion of emissions associated with dLUC (although an issue arises over how far back in time such land use change should be considered), any emissions from indirect land use change (iLUC), or surrogate means of accommodating these, should be categorically excluded.

through the direct regulation of biofuel and bioliquid suppliers by means of GHG emissions calculations.

Overall, an important outcome of establishing a clear regulatory goal for the calculation methodology and applying the consequences rigorously is that each and every co-product which is sold from a biofuel or bioliquid production pathway should be subjected to a single, appropriate allocation procedure[2]. It should be noted that this outcome does not apply to any CO_2 capture and geological storage as this does not involve the sale of a co-product. Instead, as in the RED/FQD calculation methodology, this CO_2 should be subtracted from total emissions as it constitutes a removal of CO_2 from the atmosphere due to absorption by the original biomass feedstock.

In addition to the fundamental unsuitability of the RED/FQD calculation methodology to derive GHG emissions in a regulatory context, there are other important deficiencies which are related to its practical implementation. Most prominently, the calculation methodology specifies three different ways of determining the soil N_2O emissions associated with biomass feedstock cultivation by indicating the possible use of either the IPCC Tier 1, 2 or 3 methods in the communication on practical implementation. This means that there is a free choice of methods which, potentially, can generate different estimates of soil N_2O emissions. This is not a satisfactory basis for regulatory calculations especially as, for biofuels and bioliquids obtained from certain biomass feedstocks, the contribution from soil N_2O emissions to total GHG emissions can be very significant. It could be argued that, on the basis of subsidiarity, MS regulators could specify which method should be used although this could result in different outcomes across the EU.

Another consideration which has similar ramifications is the choice of emissions factors for all the inputs into biofuel and bioliquid production pathways. The RED/FQD methodology does not specify these nor does it recommend a particular source of these emissions factors. Again, individual MS regulators could rule on this but with the potential for generating diverse and potentially contradictory outcomes. In some respects, it could be argued that “official” sources of emissions factors have emerged through the development of software tools and their associated databases for the evaluation of GHG emissions for biofuels and bioliquids within individual MSs (see, for example, Refs. 13 to 15) and across the EU (Ref. 16). However, emissions factor database harmonisation[3] is only beginning to emerge and differences still exist over emissions factors for important inputs such as artificial N fertilisers.

Taking into account issues with practical implementation as well as problems of a fundamental nature that have been explored extensively, it is only possible to conclude that the RED/FQD calculation methodology is not suitable for biofuel and bioliquid regulation. The most basic and serious drawback is that it conflates regulatory and policy objectives which leads to considerable inherent

[2] It is noted, however, that this cannot be achieved with co-product allocation by energy content as required by the RED/FQD calculation methodology.
[3] It should also be noted that, as a matter of consistency, any database should contain emissions factors that are provided from attributional LCA since this is the appropriate form of LCA for regulatory purposes within the RED/FQD.

inconsistency. Since it does not apply necessary LCA principles rigorously, the RED/FQD calculation methodology has to include special rules, exceptions and qualifications which repeatedly rely on lists of examples to communicate their meaning. Consequently, the calculation methodology should be regarded as somewhat ostensive and yet prescriptive. However, if such an approach to formulating a methodology is adopted, it has to be completely comprehensive with wholly exhaustive lists and definitive rulings for all possible current and future circumstances. Unfortunately, the RED/FQD methodology does not achieve this and, as a result, many important aspects are unclear and, crucially, open to interpretation. This is not only an unsound basis for practical implementation in a regulatory context, it also undermines its consistent application to estimating actual values and derivation of existing and proposed default values.

3. METHODOLOGIES FOR DEFAULT VALUES

3.1 Existing Default Values

The methodology adopted to derive the existing default values that are presented in the RED and FQD was not originally documented and published by the EC. However, replication of RED/FQD default values in the BioGrace GHG Calculation Tool from the project on “Harmonised Calculations of Bioenergy Greenhouse Gas Emissions in Europe” (Ref. 16) enables this methodology to be deduced or inferred. This is also assisted by referring to documentation on the BioGrace calculation rules (Ref. 17).

It can be seen that the existing default values were obtained using the same elements for the calculation equation in the RED and FQD. However, for the default values, the emissions contributions from carbon stock changes caused by land-use change; e_l, soil accumulations via improved agricultural management, e_{sca}; carbon capture and geological storage, e_{ccs}; and carbon capture and replacement, e_{ccr}; are all set to zero. Presumably, it was assumed that such considerations would not be reflected in typical cases of biofuel and bioliquid production, from which default values were derived.

Although not included specifically in the EC list of inputs for which emissions must be calculated for extraction or cultivation of raw materials, e_{ec}, manure is incorporated in the BioGrace GHG Calculation Tool. However, based on the BioGrace interpretation of emissions associated with agricultural residues, it has been assumed that no emissions from the provision of manures should be taken into account. Furthermore, the input of manures is set at zero for derivation of default values and, consequently, they have no effect on “field” or soil N_2O emissions in this instance. The default value for sugar cane also includes methane (CH_4) emissions from trash burning, and emissions from the application of filter mud cake and vinasses, which are not specifically identified in emissions from the extraction or cultivation of raw materials in the RED, FQD or communication on practical implementation.

Explanation of the approach adopted for estimating soil N_2O emissions in existing default values is relatively complex. In terms of the relevant crops involved in biofuel and bioliquid production, a mix of methods has been used.

In particular, it is stated that soil N_2O emissions associated with EU crops have been obtained using the DeNitrification DeComposition (DNDC) model, whereas soil N_2O emissions related to non-EU crops have been derived with the IPCC Tier 1 method (Ref. 5; page 65). The reason for this dual approach is not documented explicitly. However, a possible explanation is provided in earlier JEC WTW studies, as likely sources of data and estimates for existing RED/FQD default values. Regarding application of the IPCC Tier 1 method to evaluating soil N_2O emissions associated with Brazilian sugar cane cultivation, it is noted that this specific crop was not then covered by the DNDC model (Ref. 12; Appendix 1, page 39). By extension, this would seem to have been applied to all non-EU crops.

An apparent further complication is that DNDC modelling of EU crops was based on statistics then available for the EU-15 which excluded Romania (Ref. 12; page 31). However, the existing default value for bioethanol production from maize was ostensibly based on Romania. Hence, it would seem that, in terms of DNDC modelling Romanian maize cultivation was regarded, effectively, as a non-EU crop. As a consequence of all this, it would appear that existing default values for EU sugar beet and wheat used estimates of soil N_2O emissions derived from the DNDC model whilst those for EU maize and Brazilian sugar cane were determined using the IPCC Tier 1 method.

However, even this explanation is not entirely clear and complete. This is because actual information on the derivation of these soil N_2O emissions is not available in sufficient detail. Default values for field or soil N_2O emissions are presented in the BioGrace GHG Calculation Tool (Ref. 16). For EU sugar beet and wheat, it is apparent that soil N_2O emissions were provided from JRC calculations on 25 June 2008. Although the nature of these calculations is unknown, these are assumed to be a consequence of DNDC modelling. In contrast, it appears that the estimate of soil N_2O emissions for EU maize was obtained from an earlier version of the GEMIS database (Ref. 18). Regardless of the actual source, it is clear that, given the default value of the N fertiliser application rate quoted in the BioGrace GHG Calculation Tool, the estimated soil N_2O emissions recorded in the same source cannot be replicated by application of the IPCC Tier 1 method[4]. No details of crop residues and their incorporation are provided in the BioGrace GHG Calculation Tool for Brazilian sugar cane cultivation to reproduce the default value documented for associated field or soil N_2O emissions.

[4] For "Community-produced" corn (maize), an N fertiliser application rate of 51.7 kg N/ha and field or soil N_2O emissions of 0.82 kg N_2O/ha are recorded as default values in the BioGrace GHG Calculation Tool. It is not indicated whether the 1996 or 2006 IPCC Tier 1 total emissions factor of soil N_2O emissions from N fertiliser of 0.0330 kg N_2O/kg N or 0.0208 kg N_2O/kg N, respectively, was applied. Depending on which was chosen, this would result in estimated soil N_2O emissions of 1.71 kg N_2O/ha or 1.08 kg N_2O/ha, respectively. Both these estimates are higher than the quoted default value. It should be noted that these are both under-estimates as they do not include soil N_2O emissions from crop residue incorporation (the implication in the BioGrace GHG Calculation Tool being that above as well as below ground residues are incorporated since no "co-product straw" is specified.

Existing default values for emissions from processing, e_p, include the consumption of fuels and electricity. However, whilst no chemical inputs are included for the production of bioethanol from corn/maize, sugar beet and wheat, they are incorporated in the production of bioethanol from sugar cane. Although subsequent contributions to GHG emissions are relatively small, this demonstrates the inconsistency that can be generated by deficiencies in the RED/FQD calculation methodology. It should be noted that, in the BioGrace GHG Calculation Tool, emissions savings due to excess electricity from cogeneration, e_{ee}, are addressed as credits within the calculation of emissions from processing, e_p. However, this is only a technical consideration which has no substantive consequences for derivation of existing default values.

More significantly, emissions associated with transport and distribution, e_{td}, consist of emissions from biomass feedstock handling and storage (including any drying), and the operation of filling stations, as well as transport of biofuels and bioliquids from processing to depot and from depot to filling station. This interpretation of this particular element of the calculation equation can be very significant for biofuel and bioliquid production pathways that involve biomass feedstock drying. Whilst being a sensible interpretation, given that these and other emissions contributions have to be taken into account, it is not immediately apparent that this is the meaning of this particular element in the RED/FQD calculation methodology.

3.2 Proposed Default Values

The calculation methodology adopted in deriving proposed default values can be discerned from the JRC proposal (Ref. 5). Although no reference is made to the specific elements of the calculation equation in the RED/FQD methodology, information for the derivation of proposed typical/default values are set out to reflect these elements. In general, the methodology follows that which can be deduced for the existing default values from the BioGrace GHG Calculation Tool.

In the JRC proposal, the information is organised into different steps which describe a biofuel or bioliquid production pathway. Hence, in relation to bioethanol production pathways specifically, there are steps for biomass feedstock crop cultivation (including harvesting); biomass feedstock drying (if necessary), handling and storage; biomass feedstock transportation; biomass feedstock conversion to bioethanol; bioethanol plant generation processes (including any excess electricity from cogeneration); transportation of bioethanol to a blending depot; bioethanol distribution (including blending depot and filling station operations but, apparently, excluding transportation from the blending depot to the filling station).

As with derivation of existing default values, emissions contributions from carbon stock changes caused by land-use change; e_l, soil accumulations via improved agricultural management, e_{sca}; carbon capture and geological storage, e_{ccs}; and carbon capture and replacement, e_{ccr}; are excluded from production of proposed default values. This is presumably for the same reason that such considerations are not part of typical biofuel and bioliquid production.

With the proposed default values, the inputs to cultivation have been expanded by adding CO_2 emissions from neutralisation of specifically-relevant forms of soil acidity by aglime ($CaCO_3$). It would appear that the exclusion of these CO_2 emissions from derivation of the existing default values was an oversight in earlier work. However, it could be argued that such oversights are always likely to arise when the coverage of sources of emissions in a methodology relies too much on prescriptive but incomplete lists of examples. As with the derivation of existing values, CH_4 emissions from trash burning in sugar cane cultivation, and emissions from the transportation and application of filter mud cake and vinasses are included in the proposed default values.

The RED/FQD calculation methodology clearly allows means of estimating soil N_2O emissions from biomass feedstock cultivation other than the IPCC Tier 1 method. Hence, there are no methodological objections to adopting a modelling approach, such as that represented by the Global crop- and site-specific Nitrous Oxide emission Calculator (GNOC), for deriving soil N_2O emissions in proposed default values (Ref. 5). It can be assumed that, according to the RED/FQD methodology, the use of GNOC would fit in with the IPCC Tier 3 method. However, in this instance, such effective reference to the IPCC Tier 3 method implies compliance with its methodological requirements. In particular, it is a requirement of the IPCC Tier 3 method that "models should only be used after validation by representative experimental measurements" (Ref. 6; Section 11.2.1.1, page 11.10). It is not apparent that GNOC has been validated in this manner for all the biomass crops to which it has been applied in deriving proposed default values.

In contrast to the approach adopted in the derivation of existing default values, the proposed default values include emissions associated with chemical inputs to the conversion of maize and wheat to bioethanol, as well as the production of bioethanol from sugar cane, but not for the conversion of sugar beet to bioethanol. As noted previously, these emissions are comparatively small. However, such an erratic approach to the inclusion or exclusion of sources of GHG emissions again demonstrates the fundamental deficiencies of the RED/FQD calculation methodology that have the potential to generate differences between the estimation of actual values and derivation of existing and proposed default values.

There are similar concerns over formulation of emissions from transport and distribution. As with derivation of existing default values, the handling and storage of biomass feedstocks, including any drying, is taken into account in the proposed default values. Similarly, emissions associated with filling station operations are included. However, emissions for blending depot operations are also incorporated into the proposed default values. These emissions were not identified specifically in the RED/FQD methodology and do not appear in derivation of existing default values, as represented in the BioGrace GHG Calculation Tool. Strangely, emissions from transportation from the blending depot to the filling station, which are included in the existing default values, appear to be missing from the documentation on the proposed default values.

4. COMPARISON OF METHODOLOGIES

A summary of the comparisons between the main features of the RED/FQD methodology for calculating actual values, and of the methodologies for deriving existing and proposed default values, with particular reference to current bioethanol production, is provided in Table 1. It can be seen that the main differences are associated with the composition of the sources of emissions from the cultivation of current bioethanol crops, from processing and from transport and distribution, and the chosen methods for estimating soil N_2O emissions in cultivation.

Most of the sources of emissions from cultivation are the same between the methodologies for actual values, existing default and proposed default values. However, emissions from trash burning as well as filter mud cake and vinasses application are included to sugar cane cultivation in the existing default value. As well as these emissions, filter mud cake and vinasses transportation are explicitly incorporated in the proposed default value for sugar cane. Additionally, CO_2 emissions from neutralisation of some forms of soil acidity are included in proposed default values for all crops.

It is possible to use either the IPCC Tier 1, 2 or 3 methods for estimating soil N_2O emissions in the actual value methodology. Depending on the biofuel crop and its country of origin, either the IPCC Tier 1 method or the IPCC Tier 3 method, in the form of the DNDC model, is adopted in the methodology for deriving existing default values. The proposed default values adopt the IPCC Tier 3 method by apply modelling in the form of GNOC, although the compliance of this model to IPCC requirements for validation is unknown.

In general, the actual value methodology specifies the inclusion of emissions from fuels, electricity and the production of chemicals in bioethanol processing. However, chemicals are only taken into account for bioethanol production from sugar cane in derivation of existing default values. In contrast, the proposed default value methodology incorporates emissions from the production of chemical inputs to the processing of bioethanol from all crops except sugar beet.

There are notable differences in the composition of sources of emissions associated with transport and distribution between the actual value, existing default value and proposed default value methodologies. Both the existing and proposed default value methodologies include emissions from biomass feedstock handling, drying and storage as well as filling station operations. Although these sources of emissions are not explicitly mentioned in the actual value methodology, this must be an oversight as it is clear that these should be included. This would be the consequence of undertaking GHG emissions with a clearly stated regulatory goal which would automatically establish the starting point (extraction or cultivation of raw materials) and the end point (biofuel or bioliquid delivered to a final user) of the production pathway. More significantly, there are discrepancies between the existing and proposed default value methodologies over the inclusion of emissions from transportation between the depot and the filling station, and emissions from blending station operations. Again, it is apparent that such emissions should always be included.

Table 1 Comparison of Main Features of Methodologies for Derivation of Actual Values, Existing Default Values and Proposed Default Values

Feature of Methodology	Actual Value Methodology	Existing Default Value Methodology	Proposed Default Value Methodology
Sources of emissions from cultivation of biomass feedstock crops	Typically, seeds, fuel fertiliser, pesticides and soil N_2O emissions	Seeds, fuel fertiliser, pesticides, soil N_2O emissions **and trash burning, and filter mud cake and vinasses application for sugar cane**	Seeds, fuel fertiliser, pesticides, soil N_2O emissions **and CO_2 from neutralisation of some forms soil acidity, and trash burning, and filter mud cake and vinasses transportation and application for sugar cane**
Estimation of soil N_2O emissions	Based on IPCC Tier 1, 2 or 3 methods	**Based on IPCC Tier 3 (DNDC model) for sugar beet and wheat, and IPCC Tier 1 for maize and sugar cane**	**Based on GNOC but unknown compliance with IPCC Tier 3 method requirements**
Sources of emissions from processing	Processing itself, waste and leakages, and production of chemicals or products used in processing	Fuels and electricity **but only chemicals for bioethanol production from sugar cane**	Fuels, electricity and chemicals **but not for bioethanol from sugar beet**
Sources of emissions from transport and distribution	Transportation of biomass feedstocks, and storage and distribution of finished materials	Transportation of biomass feedstocks, transportation of bioethanol from processing plant to deport and from depot to filling station, **and handling and storage of biomass feedstocks (including drying), and operation of filling station**	Transportation of biomass feedstocks, transportation of bioethanol from processing plant to deport **and handling and storage of biomass feedstocks (including drying) operation of filling station but not transportation of bioethanol from blending depot to filling station**

5. CONCLUSIONS

It is apparent that, within the RED/FQD, the same methodological framework provides the basis for estimating actual values for GHG emissions associated with the production of biofuels and bioliquids and for deriving existing and proposed default values. This framework is set out as a calculation methodology in the RED, FQD and subsequent communication on practical implementation. However, due to fundamental deficiencies in the formulation and presentation of the RED/FQD methodology, it is open to interpretation. This is the basic cause of differences that have been identified in its application to estimating actual values and to deriving existing and proposed default values. The main differences consist of the composition of sources of emissions that are included in GHG emissions calculations and, with respect to soil N_2O emissions, how these are calculated. The seemingly arbitrary and subjective choice of what is covered by the calculations affects all the methodologies equally so that no one in particular can be considered as superior. Ultimately, this can only be properly resolved by adopting a methodology which is firmly based on LCA principles including, crucially, a clearly-stated regulatory goal.

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