Methodology and Evidence Base on the Indirect Greenhouse Gas Effects of Using Wastes, Residues, and By-products for Biofuels and Bioenergy

Report to the Renewable Fuels Agency and the Department for Energy and Climate Change

Report Control

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Executive Summary

Background to the project

As part of its climate change programme the UK Government has introduced market based regulatory measures to encourage the provision of renewable energy. At the European level the Renewable Energy Directive (RED) is expected to result in significant new demand for energy from biomass, particularly in the transport sector where other options are limited. Furthermore, the contribution of biofuels made from “wastes” and “residues” towards compliance with national renewable energy obligations will be considered twice that of other biofuels (Article 21, 2, RED).

Recent research and other reports, including the Gallagher Review, have drawn attention to the possible indirect effects of redirecting biomass resources to energy end uses. These effects are not captured in the current life-cycle carbon reporting methodologies for the Renewable Transport Fuel Obligation or the Renewable Energy Directive, as the system boundaries are drawn too narrowly. The current methodologies do not consider what would have happened to the resource if it were not used in energy applications, and the subsequent effects of its availability being withdrawn from alternative uses or disposal systems.

The research presented in this report has been commissioned by the Renewable Fuels Agency and the Department for Energy and Climate Change in order to develop a methodology for quantifying the indirect greenhouse gas impacts of using “wastes”, “residues” and “by-products” for biofuels or bioenergy, and to provide an evidence base on these effects.

Aims of the project

The aims of the project are to:

1. Develop a methodology for quantifying the indirect greenhouse gas impacts of using “wastes”, “residues” and “by-products” for biofuels or bioenergy

2. Provide four case studies, applying the methodology to the following materials:

    a. Molasses
    b. Municipal Solid Waste (MSW)
    c. Straw
    d. Tallow

The report also provides discussion on existing legislative definitions of “wastes”, “residues” and “by-products”; an assessment of the applicability of the methodology to the heat and power sectors; the practical implications of incorporating the methodology into regulatory mechanisms; and the compatibility of the methodology with the Renewable Energy Directive.

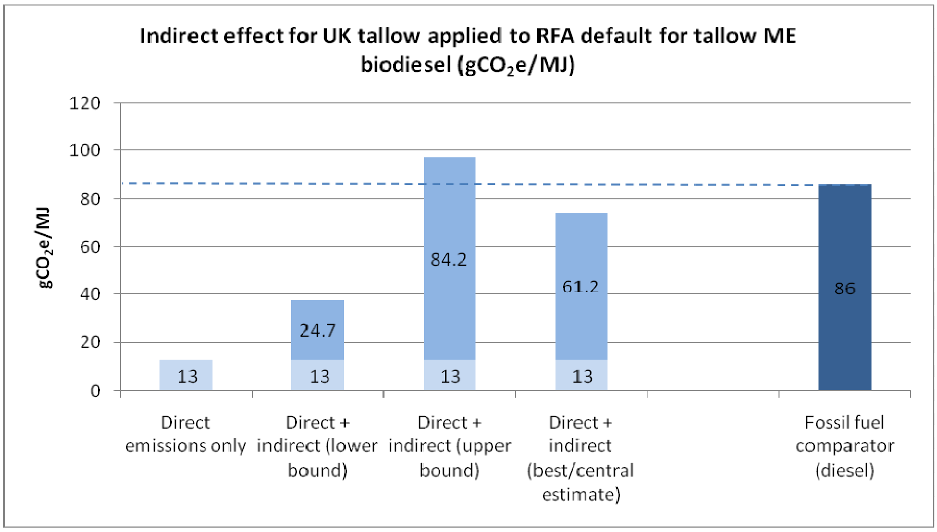
Key findings

- The use of materials which have existing uses (in the absence of biofuels/bioenergy usage) is likely to create negative indirect greenhouse gas effects (i.e. create additional emissions which are not currently accounted for in the carbon reporting methodologies for the RTFO or the RED). Alternatively, the use of materials which are disposed of (in the absence of biofuel/bioenergy usage) can create large positive greenhouse gas effects (i.e. create a reduction in emissions which is not accounted for in current carbon reporting approaches).

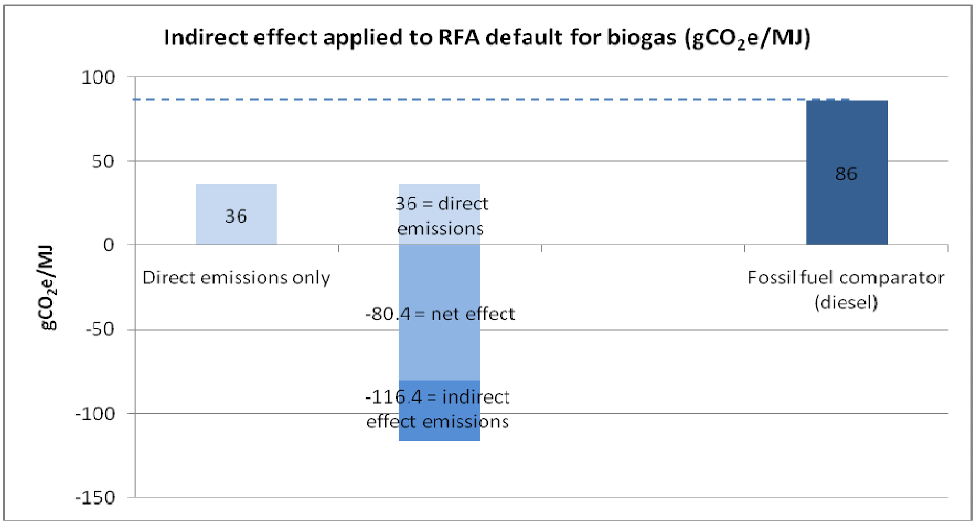
- Different levels of certainty will be achieved in quantifying the indirect GHG effect for different feedstock materials. The certainty of the assessment will depend on a number of factors: the number of existing uses/disposal pathways, the complexity of the markets in which the material is traded, the number of possible substitutes/alternative production systems for the material, the range of possible emissions factors for the substitutes/alternative products/existing disposal pathways, and the availability of data for these factors. The assessment for some materials may therefore be highly uncertain, while for other materials a higher level of certainty can be achieved.

- Understanding the uncertainty in the assessment of indirect GHG effects is important for interpreting and using the output results. Although there may be low certainty for any point estimate, the findings from an assessment may still allow a clear conclusion if all the outcomes from the assessment show the same directional result (e.g. all outcomes show a negative and significant indirect effect, although the range of possible outcomes is large).

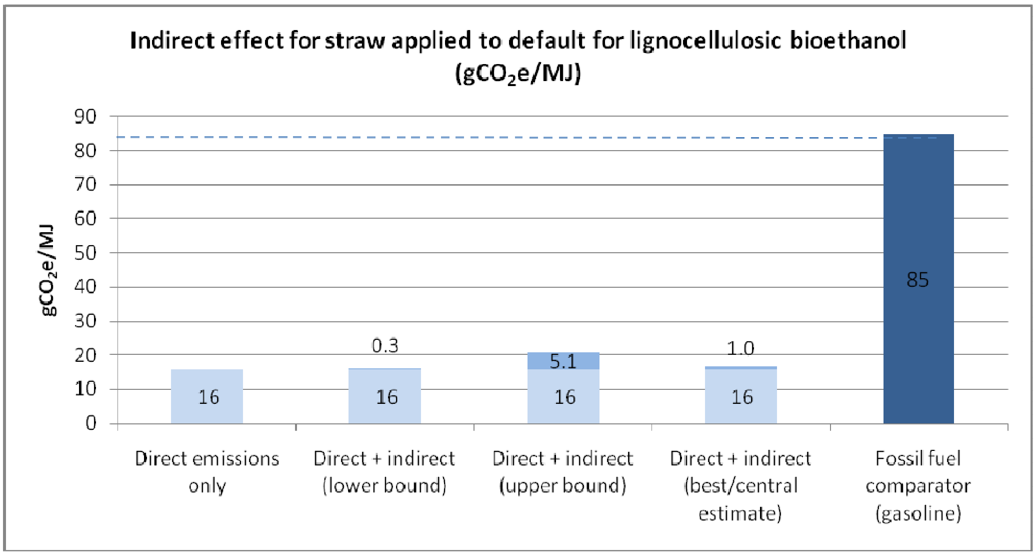
- The findings for UK tallow show a large range of possible indirect effects (between 0.89 tCO_2e/tonne of tallow used to 3.03 tCO_2e/tonne of tallow used), however all the outcomes are negative. The graph below shows the lower, upper and central estimate figures for the indirect effects for using tallow for biodiesel production, applied to the Renewable Fuels Agency's default value for tallow methyl ester biodiesel. In the lower bound case, the net (direct and indirect) emissions show a carbon savings of 56% relative to fossil diesel; in the upper bound case there is a net increase in emissions of 13%.



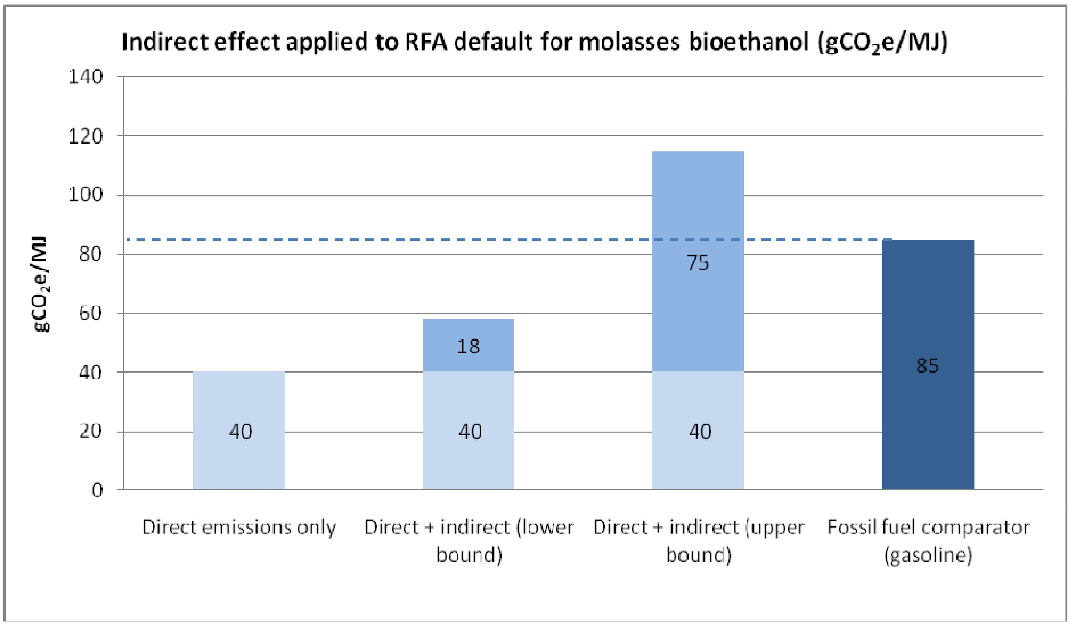
- The indirect GHG effect from the use of MSW is relatively certain, and also positive, in comparison with the other materials studied. The indirect impact of switching 1 tonne of residual MSW away from landfill is calculated as 0.5 tCO_2e. For other forms of MSW the figures are 0.78 tCO_2e for garden waste, 0.97 tCO_2e for paper and 0.5 tCO_2e for food waste. The graph below shows the indirect effect for residual MSW switching away from landfill applied to the Renewable Fuels Agency's default value for biogas from UK MSW. The fossil fuel comparator used is fossil diesel. The net emissions show a carbon savings of 193% relative to fossil diesel.



- The UK wheat straw case study shows a range of possible indirect effects (between 0.002 tCO_2e/tonne to 0.038 tCO_2e/tonne of wheat straw used for biofuels/bioenergy), dependent on the substitutions and data used. It should be noted that none of the possible outcomes show a large indirect effect. Applying a "most likely" scenario, the indirect effect is estimated to be 0.0074 tCO_2e/tonne of wheat straw used. Applying this indirect effect value to a direct emissions figure for lignocellulosic bioethanol reduces the net greenhouse gas savings from 81% to an 80% saving (relative to gasoline).



- The case study for European sugar beet molasses also shows a range of possible indirect effects (from 0.1 to 0.4 tCO_2e per tonne of molasses used for biofuels/bioenergy), dependent on the substitutions and assumptions used. These figures equate to an indirect effect of 18 to 75 gCO_2e/MJ ethanol. Applying these values to the Renewable Fuels Agency default fuel chain for UK beet molasses results in a net change in greenhouse gas emissions of -32% to +35% (relative to gasoline).



- Indirect GHG effects are determined by the existing uses (or disposal pathways) for the material, the possible substitutes/alternative products switched to, and the emissions resulting from the production of those substitutes/alternative products (or change in emissions from waste disposal). Therefore the indirect GHG effect may be different in different localities, regions and countries, depending on these determining characteristics. For example, the current use of tallow in the US is significantly different from current tallow use in the UK, and therefore the indirect effects of using US tallow for biofuel/bioenergy may be significantly different from the use of UK tallow.

- There are a number of practical and methodological challenges with using indirect GHG effect factors within life-cycle carbon reporting requirements:

    1. Temporal changes: indirect effects will change over time if any of the determining factors change (e.g. the existing uses/disposal pathways for the material, the substitute materials used, changes in substitution costs due to changes in other policy mechanisms, such as the introduction of the Renewable Heat Incentive etc). If indirect effect factors are included within carbon reporting requirements the factors may need to be updated regularly to account for changes over time. This changeability raises issues for investor confidence.

    2. Locational variation: as noted above, indirect effects may be different in different localities, regions and countries. If indirect effect factors are included within life-cycle carbon reporting requirements then geographically specific factors would be required. For materials which have different existing uses or disposal pathways in different localities, facility or locality specific indirect effect factors may be required. This raises cost and practicality issues for implementing indirect effect factors within fuel chain-level carbon reporting.

    3. Uncertainty: the magnitude of indirect effects, and any point estimate, may be highly uncertain. This presents difficulties for selecting single indirect effect figures to include within life-cycle carbon reporting requirements.

    4. Circular effects in the analysis: circular effects may arise when the alternative uses of the material studied are themselves biofuel/bioenergy applications which may also be assessed for their indirect effects. This problem may be addressed by identifying a baseline non-energy alternative use, or by undertaking a net calculation for the indirect effects of the different competing energy applications. However, such methodological steps add to the complexity and uncertainty of quantifying indirect effects.

- Although there are a number of difficulties in operationalising indirect GHG effect factors within life-cycle carbon reporting this does not entail that indirect GHG effects are insignificant or should not be taken into consideration in biofuel/bioenergy support mechanisms.

- The Renewable Energy Directive will create double incentives for biofuels made from “wastes” and “residues”. This is understood to have been included on the assumption that such fuels would lead to additional environmental benefits compared with crop based feedstocks. If this policy objective is to be realised, this study illustrates that it is important that the definitions of “wastes” and “residues” are qualified to ensure only materials which can be expected to create a significant net positive GHG saving receive double incentives. There are a number of possible options for ensuring only "appropriate" wastes and residues receive double incentives:

1. A case-by-case assessment of feedstock materials, with a positive list of "appropriate" materials provided in ordinance.
2. A "rule-of-thumb" approach: all materials which are disposed of in the absence of biofuel/bioenergy usage may be considered "appropriate". However, it should be noted that this simplified approach may be subject to exceptions, and may incentivise the use of materials which will create negative indirect effects (e.g. if using recyclable materials, which would otherwise displace primary production processes).

- The methodology for quantifying indirect GHG effects is equally applicable to materials used for biofuels, bioheat, or biopower. However, in order to fully utilise an indirect GHG effects factor it is necessary have a broader carbon reporting framework in which to use the figure. The Renewable Energy Directive requires carbon life-cycle reporting for biofuels and bioliquids, but not for bioheat and biopower.
- There may be a number of possible positive actions which biofuel/bioenergy producers can undertake to limit or mitigate their negative indirect GHG effects, e.g. sourcing materials from countries/regions where the material has low levels of utilisation or has low-carbon substitutes; increasing the efficient use of the material to free a proportion for biofuel/bioenergy applications; entering into agreements with existing users of the material to promote the use of low-carbon substitutes/alternatives. Comparable mitigation measures are currently being explored for indirect land use change.

Contents

1. Introduction

1.1. Background to the research

As part of its climate change programme the UK Government has introduced market based regulatory measures to encourage the provision of renewable energy. At the European level the Renewable Energy Directive (RED) is expected to result in significant new demand for energy from biomass, particularly in the transport sector where other options are limited. Furthermore, the contribution of biofuels made from "wastes" and "residues" towards compliance with national renewable energy obligations will be considered twice that of other biofuels (Article 21, 2, RED).

Recent research and other reports, including the Gallagher Review, have drawn attention to the possible indirect effects of redirecting biomass resources to energy end uses. These effects are not captured in the current life-cycle carbon reporting methodologies for the Renewable Transport Fuel Obligation or the Renewable Energy Directive, as the system boundaries are drawn too narrowly. The current methodologies do not consider what would have happened to the resource if it were not used in energy applications, and the subsequent effects of its availability being withdrawn from alternative uses or disposal systems.

The need to account for the indirect GHG effects of using wastes and residues has been recognised by other regulatory agencies. In the US similar research to that commissioned in this research project is currently being undertaken for the Californian Air Resources Board, using the global economic general equilibrium model GTAP.

In response to the need to distinguish between "wastes", "residues" and "by-products" that are effective in achieving net greenhouse gas savings when used for bioenergy, and those that are not the RFA and DECC commissioned the development of a practical methodological approach for quantifying the indirect effects of using these materials for biofuels and other forms of bioenergy.

This report presents a general methodology for quantifying the indirect greenhouse gas effects of using materials which have inelastic supply for biofuel or other bioenergy purposes. The report also presents the findings from four case studies which apply the methodology. The feedstock materials assessed in the case studies are:

- Molasses
- Municipal solid waste
- Straw
- Tallow

1.2. Indirect effects from wastes, residues, and by-products

Indirect effects may arise from the use of any material for bioenergy applications if an increase in demand for the feedstock material increases its price, and existing users subsequently switch to alternatives which have higher or lower greenhouse gas impacts. The indirect effects from using "wastes", "residues" or "by-products" are expected to be particularly significant as these materials tend to have the characteristic of inelastic supply, i.e. their supply is not responsive to an increase in demand. This is because the quantity produced is determined by other factors, such as demand for the main product (e.g. meat in the case of tallow) or for a precursor product (e.g. food in the case of organic MSW).

If a quantity of material which has inelastic supply is diverted to a bioenergy application, there will be a corresponding reduction in the availability of that material for existing users or existing disposal systems. In the case of materials which are currently used, indirect effects will occur if the existing users of the material then use substitute materials, the production of which may cause additional emissions. In the case of materials which are disposed of, there will be a reduction in the quantity of material going into waste management systems, and this too may cause a change in emissions (e.g. a reduction in landfill gas emissions).

The methodology developed in this project is aimed primarily at quantifying the effects of using materials which have inelastic supply, however provision is included for cases where supply is not perfectly inelastic (and there is some increase in supply as a result of increases in demand).

2. General Methodology

2.1. Review and revision of 3-step method for wastes and by-products methodology

An outline "3-step" methodology for quantifying indirect greenhouse gas effects was developed by E4-tech, and was consulted on by the Renewable Fuels Agency in December 2008. The 3-step methodology has been taken as the starting point for the methodology developed in this project, and the responses to the 2008 consultation have been taken into consideration in developing the methodology. A copy of the 3-step methodology is provided in Appendix 1.

The main developments to the 3-step methodology are as follows:

- The 3-steps have been broken-down into a more detailed set of 10 steps. This is in order to provide more explicit guidance to practitioners following the methodology, and to ensure that there is consistency in the way the methodology is applied by different practitioners, or to different materials.

- The 10-step methodology includes an estimation of the level of demand from biofuels/bioenergy, and the estimation of an "order of dispatch" - the order in which existing users of the feedstock material will switch to substitute materials or alternative production systems. The order of dispatch is preferable to a simple weighted average of indirect effects as it better represents the changes in emissions at different levels of demand for the feedstock material. E.g. if the biofuel/bioenergy sector only use a small quantity of the feedstock material then it is only the substitution effect from the first existing use in the order of dispatch which should be quantified.

- The 3-step methodology provides one methodology for materials which have an existing use, and one for materials which do not have an existing use. If a material is partly used and partly disposed of then a weighted average would need to be derived based on the results from each sub-methodology.

  The two developed sub-methodologies in the 10-step methodology are for: materials which are fully used in alternative applications (in the absence of biofuel/bioenergy demand), and; materials which are disposed of or which are partly used and partly disposed of (in the absence of biofuel/bioenergy demand). The second methodology deals with materials which are partly used and partly disposed within a single methodology in order to avoid the need for a weighted average. This is preferable as a weighted average approach may not reflect the order in which a material switches from its existing uses/disposal pathways. E.g. the quantity of the material which is disposed of may switch from its disposal pathway first, and none of the material may be displaced from its existing uses. The weighted average approach will not reflect this situation, and may consequently overestimate the indirect GHG effect.

- The 10-step methodology allows for the possibility that the existing use of the feedstock material may reduce production, and the displaced supply will be met by alternative production systems (the effect of which is then calculated).

- The 10-step methodology includes a sensitivity analysis, in order to show the range of possible outcomes given alternative input values.

2.2. Assessment of the definition of wastes, by-products and residues

The Renewable Energy Directive (RED) will introduce additional incentives for using wastes and residues by awarding double compliance credits for biofuels made from these feedstocks[1]. "Wastes" and "residues" are not defined in the Renewable Energy Directive but it appears likely that the terms will be defined in accordance with the Waste Framework Directive 2008 (WFD).

It should be noted that the definitions in the WFD do not match with definitions commonly used in life-cycle assessment. There may be confusion if the same terms are used with different meanings when considering the RED legislation or when considering the life-cycle assessment of feedstock materials. In order to resolve this issue, and also because it is not necessary to define "wastes" and "residues" etc for the purpose of quantifying their indirect effects, the 10-step methodology does not make reference to these terms.

A review of existing legislative and non-legislative definitions of "wastes", "residues" and "by-products" was carried out as background research to this project. A summary and detailed inventory of these definitions is provided in Appendix 2.

Although it is not yet decided how the terms "wastes" and "residues" will be defined for the purposes of the RED, there is a clear need for the definitions to discriminate between materials which are likely to involve negative indirect greenhouse gas effects, and those which will not. If "wastes" and "residues" are not appropriately defined, it is possible that the Directive will create double-incentives for biofuels which may have limited or even negative greenhouse gas benefits (assuming indirect effect emissions factors are not included within the life-cycle carbon reporting requirements under the RED).

One solution is to define "wastes" and "residues" in line with existing waste legislation, e.g. the WFD, and to also include an additional "screen" of those materials which qualify as "waste" or "residues", to ensure that only those which create significant GHG reductions receive double incentives. There are a number of possible options for this screening test:

[1] Directive 2009/28/EC

1. A case-by-case assessment using the methodology for quantifying the indirect GHG effects of using the material, with a positive list of "appropriate" materials provided in ordinance.
2. A "rule-of-thumb" approach: all materials which are disposed of in the absence of biofuel/bioenergy usage may be considered "appropriate", again with a positive list provided in ordinance However, it should be noted that this simplified approach may be subject to exceptions, and may incentivise the use of materials which will create negative indirect effects (e.g. if using recyclable materials, which would otherwise displace primary production processes).

An advantage of this approach is that the determination of which materials are "wastes" or "residues" can be done using existing legislative definitions (e.g. the WFD definition of wastes), but the additional screening test can be used to ensure that only "wastes" and "residues" which are unlikely to involve negative indirect greenhouse gas effects will receive double-incentives.

2.3. Methodology for quantifying the indirect effects of using materials with inelastic supply

The purpose of the methodology is to calculate a value for the indirect greenhouse gas effects of using materials with inelastic supply. This value can then be used as an input into a consequential life-cycle assessment of biofuels or bioenergy, or in broader policy appraisal.

The use of wastes, residues, and by-products are expected to give rise to indirect effects as the supply of these materials tends to be inelastic, i.e. supply is not responsive to a change in demand or price[2]. In the case of materials which have existing uses in the absence of biofuel/bioenergy demand, if the material is diverted to biofuel/bioenergy production and there is no increase in supply, existing users will have to find alternative materials, the production of which may create additional GHG emissions. In the case of materials which do not have an existing use, if the material is used for biofuel/bioenergy production and there is no increase in supply, the quantity of material going to existing disposal systems will be reduced, which may result in changes in GHG emissions[3].

The methodology is intended for materials which have inelastic or relatively inelastic supply (provision is made in the methodology for materials which do not have perfectly inelasticity supply).

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[2] It should be noted that any material, including those that may commonly be termed co-products or primary products, may have similar indirect effects if their supply is inelastic. It should also be noted that other market-driven indirect effects can occur for materials which do not have inelastic supply, i.e. where an increase in demand causes an increase in price, and existing users of the material switch to lower-cost substitutes. This methodology is primarily focused on materials which have inelastic supply, however provision is made for cases where the material studied does not have perfectly inelastic supply.

[3] This is a simplified account of the possible indirect GHG effects of using materials with inelastic supply– for introductory purposes. A greater range and complexity of indirect effects is allowed for in the methodology.

Separate sub-methodologies are developed for:

1. Material type 1 (sub-methodology 1): materials which are fully used in alternative applications (in the absence of demand for the feedstock material)
2. Material type 2 (sub-methodology 2): materials which are disposed of, or which are partly disposed of and partly used in alternative applications (in the absence of demand for the feedstock material)

The full methodology is provided in Appendix 3.

2.4. Temporal changes in the indirect GHG effect

The indirect greenhouse gas effects of using a material for biofuels/bioenergy will change over time if any of the determining factors change. These include:

- The quantity of material used by the biofuel/bioenergy sector.
- The alternative uses/disposal pathways of the material (in the absence of biofuel/bioenergy demand) and the quantity in each alternative use/disposal pathway.
- The conversion ratios between the material studied and any substitute materials/alternative products.
- The costs of switching to substitute materials/alternative products.
- Changes in the technical, consumer preference, or regulatory constraints on the use the substitute materials.
- The carbon intensity of substitutes/alternative products or the emissions associated with different disposal pathways.

In addition to the parameters used in the methodology the following may also change the indirect effect of using a by-product or waste for biofuels/bioenergy:

- The total quantity of the feedstock material available.

If indirect GHG effects are accounted for in biofuel/bioenergy support mechanism, e.g. within life-cycle carbon reporting or for determining which "wastes" and "residues" are appropriate for double-incentives, it will be necessary to update the assessment of the indirect effects over time.

One issue with updating factors over time is impact on investor confidence. Compliance with the RED requires that biofuels achieve a 35% reduction in emissions against a fossil fuel comparator, rising to 50% in 2017 (Article 17, RED). If the indirect GHG effects of using wastes and residues were included within the carbon reporting requirements for the RED (as is currently under consideration for indirect land use change[4]), and if the indirect GHG effect increases over time, then biofuels which currently meet the reduction threshold may fail to meet the threshold once the factor is updated.

[4] It should be noted that the RED requires the Commission to report on the impact of indirect land use change and ways of minimising that impact (Article 19 (6)), but no requirement is stipulated in the directive for addressing the indirect GHG effects of using wastes and residues for biofuels or bioenergy.

Similarly, the Fuel Quality Directive proposes incentives based on GHG reductions, and therefore returns on investment will be affected by changes in the indirect effects factors. It should be noted that the indirect effects factor may go up or down, depending on the determining factors and how they change over time. A key point for investor confidence is that it will be difficult to predict how the indirect effects will change in the future, and therefore how to manage this risk.

One possible approach to safeguarding investment in biofuels produced from wastes, residues etc is to apply a derogation or "grandfathering" approach for any upward increase in the indirect effect factor for existing production facilities. This approach is already used in the RED with regard to any additional sustainability measures adopted in relation to indirect land use change (Article 19 (6)).

2.5. Assessment of the methodology for its application to the renewable heat and electricity sectors.

The 10-step methodology is equally applicable to biofuels, bioheat, and biopower. If the material studied is not currently used for any bioenergy applications then there will be a single indirect GHG effect factor which can be applied to any biofuel or bioenergy application which subsequently uses the material. If one or more of the existing uses of the material are themselves biofuel or bioenergy applications then separate factors need to be calculated. For example, if one of the existing uses of tallow is for bioheat, and this use switches to alternative fuels due to increased demand for tallow from the biofuel sector, then the emissions from the heating fuel substitutes should be calculated and included in the indirect effects factor for the biofuel. Alternatively, if there is an increase in the use of tallow for bioheat then existing tallow use for bioheat is not being displaced, and the heating fuel substitutes for tallow should not be included in the calculation of the indirect GHG effects. Different indirect effect factors will be appropriate in each case.

One important point to note in terms of applicability to renewable heat and power is that at present there is no life-cycle carbon reporting requirement for these bioenergy sectors, in which an indirect GHG effect factor could be used. Indirect effect factors could still be used in broader policy appraisal - this is discussed in Section 4.1 below.

Circular Effects when Assessing Competing Biofuel and Bioenergy Applications
What may be called "circular effects" occur where one of the existing uses of the material studied is another form of biofuel or bioenergy. The analysis of the indirect effects of biofuel/bioenergy A will include the displacement of the feedstock material from biofuel/bioenergy B, and therefore may incur a penalty for the emissions from the substitute which biofuel/bioenergy B switches to. Similarly, the analysis of the effects of biofuel/bioenergy B will include the displacement of the feedstock from biofuel/bioenergy A, and therefore will incur a penalty for the emissions from the substitute which biofuel/bioenergy A switches to.

It is possible that the inclusion of the indirect effect factor for both applications will show that neither achieves the GHG reduction threshold required by the relevant biofuel/bioenergy support mechanism, e.g. 35% under the RED. This is a problematic outcome as the use of the material in one or more of the alternative applications may achieve a sufficient emissions reduction.

There are two possible solutions to this problem:

1. The first is to identify a baseline non-energy application which would have used the feedstock material if the competing biofuel/bioenergy applications were not using it. The indirect effect of displacing this use of the material should be assessed. This approach has the advantage of providing a single indirect effect factor which can be applied to all biofuel/bioenergy applications.

2. There may be circumstances in which it is not possible to identify a baseline non-energy use for the feedstock material, either through lack of evidence, or because there is not a realistic baseline non-energy use for economic or regulatory reasons. For example, animal by-products in the EU which are not intended for human consumption are categorised according to their risk of transmitting TSEs. A proportion of animal by-product material will be Category 1, and therefore can only be used as a fuel. In this case there will not be a non-energy alternative use of the feedstock material.

   A proposed solution is to undertake a net calculation using the displacement effects for each competing biofuel/bioenergy application. The biofuel/bioenergy application with the lowest displacement effect should be allocated an indirect emissions value of zero, and the application(s) with higher indirect emissions should be allocated their corresponding net values (i.e. the additional emissions they cause above the lowest indirect effect value)[5].

   Figure 1 below illustrates the net calculation approach. The area above the dashed line indicates the net increase in emissions if the feedstock material is switched between the two competing biofuel/bioenergy applications.

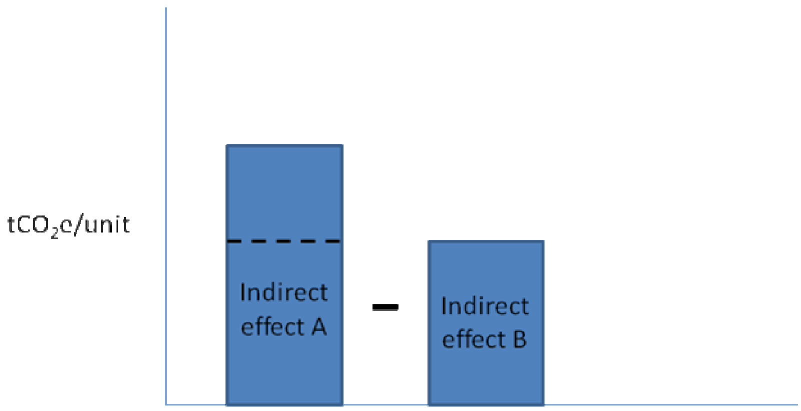

Figure 1. Net calculation approach

[5] Please note that the net values are only for the indirect effects related to the use of substitutes in other biofuel/bioenergy applications, and not for the indirect effects related to the use of substitutes in non-energy applications, which should be calculated as normal.

The following is a worked example for the net calculation approach (all figures are for illustration only):

Information for assessing tallow based biodiesel:

a) Alternative use which is displaced = tallow combusted for heat in rendering plants
b) Emissions factor for fuel oil (substitute used in rendering plants) = 3.5 tCO_2e/tonne of fuel oil
c) Indirect emissions from tallow based biodiesel = 3.5 tCO_2e/tonne of feedstock material (based on 1:1 substitution ratio)

Information for assessing tallow combustion for heat in rendering plants:

a) Alternative use which is displaced = tallow based biodiesel
b) Emissions factor for palm oil (substitute used for biodiesel) = 2 tCO_2e/tonne of substitute
c) Indirect emissions from tallow combustion in rendering plants = 2 tCO_2e/tonne of feedstock material (based on 1:1 substitution ratio)

Net calculation:

3.5 tCO_2e - 2 tCO_2e = 1.5 tCO_2e

Indirect effect emissions from tallow based biodiesel = 1.5 tCO_2e
Indirect effect emissions from tallow combustion in rendering plants = 0 tCO_2e

3. Case Studies

This section presents summaries of the case studies undertaken. The full case study texts are provided as accompanying appendices. Further details of the calculations and data used for the case studies are provided in additional appendices in order to manage the size of each document.

3.1. Molasses

Summary

The material studied is molasses produced in Europe. Molasses production is assumed to have an inelastic supply, as it may constitute zero or close to zero of the farm gate value of sugarcane and sugar beet production. Within certain bounds, a change in the price of molasses is unlikely to influence the total quantity sugar beet or cane supplied, and therefore will not influence the total amount of molasses produced. All current uses of molasses in Europe are included within the scope of the assessment. These are as: an animal feed component, as a growth medium for yeast, in lactic and citric acid production, and in niche applications including dust suppression, food flavouring and colouring. However, the largest current use of molasses in Europe is as a component of animal feed and it is reported that for compound animal feed in particular, a wide range of components are used in its production and that there is some flexibility to switch between individual feedstocks whilst maintaining energy and nutritional quality. It therefore seems likely that the order in which existing uses of molasses will switch directly or indirectly to supplying an increasing demand for biofuels or bioenergy will be from animal feed first and then as medium for yeast growth. The other uses are assumed to be niche applications and so unlikely to materially affect greenhouse gas emissions as a result of a switch of use of molasses to biofuel production.

A number of possible scenarios have been tested based on the use of different substitutes replacing molasses in animal feed. The calculated range in emissions resulting from the displacement effects of using molasses is from 0.1 to 0.4 tCO_2e per tonne of molasses. Where molasses is used as a feedstock for bioethanol production, the indirect emissions are equivalent to 18 to 75 gCO_2e/MJ ethanol. Applying these figures to the Renewable Fuels Agency default fuel chain for molasses results in net greenhouse gas emissions of -32% to +35% from molasses ethanol. It should be noted that a number of assumptions underpinning this calculation are considered to be uncertain, particularly the origin of new supplies for molasses as a result of increased demand/prices.

3.2. Municipal solid waste

Summary

The material studied is municipal solid waste (MSW) generated in the UK. The generation of MSW in the UK is considered to have an inelastic supply. This is because any change in the price paid or gate fee received, for onward management of any material within the MSW stream, is unlikely to influence the total quantity goods or services consumed by households and therefore will not influence the total amount of MSW generated.[6]

Driven by the EU Landfill Directive, both the Landfill Allowance (Trading) Schemes (LAS) and the Landfill Tax Escalator are rapidly changing the approach to management of MSW in the UK. The structure and longevity of most contracts for the treatment of MSW (usually 20-25 years for the 'residual' stream) is such that currently, it is likely that MSW will only be switched away from landfill, for which contracts are far shorter in duration. As a default value, therefore, emissions from landfill should be assumed as being the indirect impact (or benefit) of using MSW as a feedstock for biofuels or bioenergy. If considering indirect emissions associated with conversion of MSW to biofuel at the plant level, i.e. for the development of specific facility, however, it would most likely be possible to trace the displaced management route. To illustrate the differing indirect GHG impacts associated with alternative treatment methods, we have therefore considered a number of alternative scenarios.

Under our central case, the indirect impact of switching 1 tonne of residual MSW away from landfill is 0.5 tCO_2e, rising to 0.78 tCO_2e for garden waste, 0.97 tCO_2e for paper and 0.5 tCO_2e for food waste. In contrast, for the other treatment methods considered, for example, anaerobic digestion and mechanical-biological treatment (MBT), the majority result in a negative emissions balance, ranging from -0.02 tCO_2e to -1.24 tCO_2e per tonne of MSW. This is the result of the offset of CO_2 emissions which occur either as a result of renewable energy generation, or from reprocessing of recovered materials in place of primary production processes. Importantly, therefore, in the future, switching of MSW away from non-landfill methods to biofuel or bioheat applications could result in greater overall emissions, which reflects the need for analysis at the facility-level.

There are a range of assumptions relating to the calculation of the default value for landfill. The most important of these relates to the efficiency of landfill gas capture, about which there is currently little consensus in the literature. Our central case assumes 75% of landfill gas is

[6] Municipal solid waste includes household waste and any other wastes collected by waste collection authorities (or their agents) such as municipal parks and gardens waste, beach cleansing waste, commercial or industrial waste and waste resulting from the clearance of fly-tipped materials. In 2007, around 89% of municipal waste was from households

captured, but if this is reduced to 50%, the indirect impact of switching 1 tonne of residual MSW away from landfill rises from 0.5 to 1.15 tCO_2e.

In terms of total emissions, as an example, if the central case of 0.5t CO_2e/ tonne MSW is applied as a credit to the RFA default value for the direct impacts of the generation of biogas from MSW via anaerobic digestion (1,630kgCO_2e/tonne of biogas), the total impact of switching MSW away from landfill represents a benefit of 3,618 kgCO_2e/tonne of biogas. In terms of carbon saving per MJ, applying these figures to the RFA's default fuel chain for biogas from MSW results in a net saving from biogas used as a transport fuel, if compared with fossil diesel, of 193% (or a carbon intensity of -80.4 gCO_2e/MJ of biogas).

3.3. Tallow

Summary

The material studied is tallow produced in the UK. Total UK tallow production is considered to have an inelastic supply, as it constitutes zero or close to zero of the farm gate value of livestock. A change in the price of tallow is unlikely to influence the total quantity of livestock supplied, and therefore will not influence the total amount of tallow produced.

All the current uses of tallow in the UK are included within the scope of the assessment, these are: oleochemicals, soap, animal feed, biodiesel, heat, food, and pet food. It was not possible to establish the order in which existing uses of tallow will switch from tallow as a result of increasing demand for biofuels or bioenergy, and therefore a range of weighted average indirect greenhouse gas effects were calculated. A number of possible scenarios were tested, representing different existing uses of tallow switching to substitutes or being replaced by alternative production systems. Possible substitutes and alternative emissions factors were identified, and possible outcomes examined. The range of lower and upper bound output values was large (0.89 tCO_2e/tonne of tallow used to 3.03 tCO_2e/tonne of tallow used for biodiesel), but every combination of input values tested showed an indirect greenhouse gas effect from the use of tallow.

Separate indirect effect figures are calculated for biofuel and bioheat, as biofuel and bioheat are already existing users of tallow, and therefore are not included in the calculation of their own displacement effects. Based on a weighted mean across all other existing uses of tallow[7], the central estimate for the indirect effect of using an additional tonne of UK tallow for biodiesel was 2.2 tCO_2e/tonne of tallow. Applying this figure to the Renewable Fuels Agency default fuel chain for tallow methyl ester biodiesel results in a net saving from tallow biodiesel of 14% (or a carbon intensity of 74gCO_2e/MJ of tallow ME biodiesel). The central estimate for bioheat is 0.95

7 Excluding tallow used in food, which is high value and therefore assumed to be unlikely to switch.

tCO_2e/tonne of tallow. Assuming that fuel oil is the fossil fuel comparator, and that there are zero direct emissions from the use of tallow for bioheat, using tallow for bioheat represents a net saving of 71%. These central estimates depend on the data and assumptions used, and should be interpreted in the context of their lower and upper bound ranges. It should also be noted that these figures are for the indirect effects of using additional units of UK tallow for biofuels/bioenergy applications (i.e. the effects at the margin). The average indirect effects from current levels of biofuel/bioenergy usage are estimated as: between 1.86 to 2.22 tCO_2e/tonne of tallow used for biofuels, and 0.22 and 0.9 tCO_2e/tonne of tallow for bioheat.

3.4. Straw

Summary

The material studied is wheat straw (WS) (Triticum aestivum L.) produced in the UK. WS comprises approximately 55% by mass of all the straw produced in the UK (barley 20%, oilseed rape 20%, oats 4% and others 1%). The production of WS and other cereal or oilseed straws in the UK has an inelastic supply – at least largely. The primary economic purpose of cultivation for all UK cereal and oilseed crops is to obtain the seeds or grains and straw is unavoidably co-produced as part of this activity. These straws are managed by the farmer in various ways ranging from incorporation into soil to baling and removal from the field for use both on- and off-farm. This range of straw management options offers several potential benefits to farmers including contributions to soil quality and fertility, material for animal bedding and feed needs, energy use on-farm and direct economic benefit through sales. It is important to note that straws do not enter typical waste management systems such as landfilling or waste incineration, though some of the on-farm management options do have parallels in the waste management sector e.g. 'Deposit into or onto land' (D1 of the Waste Framework Directive). The decisions by farmers as to which management options to adopt for their straws are affected by a many factors such as planned crop rotations, contractual arrangements for straw supply off-farm, spot price for straw, weather conditions at harvest time, equipment availability, labour availability and many others. Because of their essential nature as co-products of cereal grain/oilseed production and the variety of management options which can affect availability as a traded material on the market, straws can be regarded as having an inelastic supply at the gross scale (quantity produced in-field derives from the level of crop planting controlled by demand and market for cereals/oilseeds, not straws) but with aspects of elasticity (flexibility in straw harvesting and on-farm use meaning that actual supply to the straw market can respond to pricing signals within the gross production 'limit'). Significant quantities of WS are produced[8] each year in the UK – something in the order of 10 million tonnes (85% dry matter) - alongside

[8] In this sense 'produced' means developed by the wheat plant during its growth in the field – it is not the same as 'recoverable' or 'harvestable' which most estimates indicate is approx. 60% of the produced value.

approximately 16 million tonnes of wheat grain on approximately 2 million ha of UK arable land. Estimates of harvestable wheat straw vary – values between 3 and 5 tonnes per hectare (85% dry matter) are common and an estimate of approximately 6 million tonnes of WS in current uses or in management is applied in this case study. It should be noted that there is a considerable volume of straw potentially available through higher 'off take' and harvesting to meet increased demand.

This case study considers all the major classes of use for WS in the UK. These are: incorporation back into soil, animal bedding, combustion for power (and heat), mushroom compost and specialist uses e.g. in packaging. This case study does not establish a definitive order in which WS will be switched out of existing uses in response to an increased demand from biofuel/bioenergy uses and instead a range weighted average indirect greenhouse gas effects have been calculated for various scenarios based on different existing uses and management of WS, including soil incorporation. Possible substitutes and alternative emission factors were identified, and applied in the scenarios. Across the scenarios a range of low levels of indirect GHG emissions was found (0.007 – 0.023 tCO_2e/tonne of WS used in weighted average scenarios; 0.002 – 0.025 tCO_2e/tonne of WS used dependent upon fertiliser replacement assumptions; 0.015 – 0.038 tCO_2e/tonne WS used for worst case 'pure' substitution extremes). The majority of cases showed an indirect greenhouse gas effect from the use of WS but, overall, these were small in relation to direct emissions and especially, in relation to GHG emissions from a gasoline comparison. Examination of a 'most likely' scenario for the indirect effect of using an additional tonne of UK WS for bioethanol using the methodology generated a result of 0.0074 tCO_2e/tonne of WS. Applying this figure to the default fuel chain parameters for lignocellulosic ethanol used in the Gallagher Review work gives a value for WS ethanol of 80% (or 17gCO_2e/MJ). This and other values from the scenarios are dependent on the data and assumptions used herein, and should be interpreted in the context of the substantial uncertainties over possible future developments in WS biofuel, bioenergy and farm level production responses.

4. Issues for Implementation

4.1. Options and practical implications for incorporating the methodology into regulatory based mechanisms

Carbon reporting framework

The output from the methodology is an emissions factor, or range of emissions factors, for the feedstock material studied, e.g. -0.5 tonnes of CO_2e/tonne of MSW. This figure can then be included as an additional emissions source in life-cycle carbon accounting for fuels or bioenergy applications which use the feedstock material. The outputs of the methodology therefore require a carbon reporting framework in which the emissions factor can be used, i.e. a carbon reporting framework such as that in the RED or RFA reporting guidance.

At present there are carbon reporting rules in the RED for biofuels and bioliquids, but not for bioheat or biopower. In order to fully incorporate the methodology into regulatory based mechanisms for other bioenergy applications, carbon reporting requirements would need to be established for these sectors, as for biofuels. The Commission is committed to reporting on the requirements for a sustainability scheme for energy uses of biomass, other than biofuels and bioliquids, by 31 December 2009 (Article 17 RED).

In the absence of a carbon reporting requirement, the outputs from applying the methodology can also be used to inform higher-level reviews or assessments of biofuel or bioenergy support mechanisms. The Commission is committed to monitoring and reporting on the impacts of the RED, including the impact of increased demand for biomass on biomass using sectors (Article 23, 5b, RED).

Uncertainty in the methodology outputs

There will be varying degrees of certainty for the indirect effects calculated using the methodology, depending on the availability of data, the number of existing disposal pathways/uses of the material studied, market and regulatory complexities, and the need to estimate how the material would have been used (in cases where the material is already used in biofuel/bioenergy applications, and the displacement effects which are already occurring need to be quantified).

For some feedstock materials there will be a clear and quantifiable displacement effect, and for others there may be a high level of uncertainty. The sensitivity analysis in the methodology should be used to test the range of possible outcomes from the assessment, given alternative input values or assumptions. Where there is a wide range of possible figures for the indirect effect it may not be possible to identify a single figure which should be used for life-cycle carbon reporting.

Political rather than scientific judgement may be required to decide whether to include an uncertain indirect figure within the carbon reporting framework. If the range of available figures all show the same directional effect, i.e. either all positive or all negative indirect effects, then the inclusion of a central estimate value may be preferable to not accounting for the effect at all.

Methodology is not intended for use by individual reporting companies

The carbon reporting rules for biofuels in the RED and RFA guidance allow reporting companies to either use default values or to provide information for their specific fuel chain. If indirect GHG effects are included with life-cycle carbon reporting requirements it is not envisaged that the indirect effects methodology is appropriate for use by individual reporting companies. Rather the methodology is intended for use by a regulatory agency or practitioner working on behalf of a regulatory agency. Indirect effect values could be provided by the agency, which can then be used by reporting companies.

One reason that the use of the methodology itself is not appropriate for individual company reporting is that indirect effects tend to occur as broad market-level effects, i.e. the increased demand for a feedstock material will have a general effect on the price of that material, which in turn will drive existing users to switch to substitutes. It is not relevant to trace the physical source of the feedstock material used for individual batches of biofuels/bioenergy, or where the physical quantity of feedstock material would have been used in the absence of biofuel/bioenergy usage. In addition, the data required for using the methodology will tend to be general market information, and not information from the fuel chain which a reporting company as influence over.

It should be noted that for some materials which have a highly localised market, covering a small geographic area, the indirect GHG effect may be specific to that locality or even to a biofuel/bioenergy installation. However, it remains the case that the information requirements for the methodology will tend to relate to the broader effects of an increase in demand within the local market, and not necessarily to the supply chain which the reporting company has influence over (and is able to request information from).

Mean and Marginal Values

One issue for using the outputs of the methodology is whether to use an average indirect effects figure or a marginal indirect effects figure. This issue is particularly relevant when the marginal indirect effect of additional units of feedstock material used are very high, but the average indirect effect figure is low. This situation will arise when there is a large difference in the indirect GHG effect at different levels of utilisation for biofuels or bioenergy. E.g. if a feedstock material is partially disposed of and partly used, utilising the material which is disposed of may have zero indirect GHG effects, or may even reduce emissions. However, if the quantity of material used for biofuels/bioenergy increases, and is taken from an existing use (which then uses a substitute material), the indirect effect could be very large for those marginal units.

Using a low average indirect effect factor may allow the continued use of the feedstock material (i.e. the inclusion of the indirect factor in life-cycle carbon reporting for the fuel may not stop the fuel meeting its GHG reduction threshold), even though the indirect effects at the margin are large and negative. However, using the marginal indirect effect factor for all biofuel/bioenergy use of the feedstock material will penalise the proportion of usage which has zero or even beneficial indirect effects. Figure 2 below illustrates the potential difference between marginal and average figures.

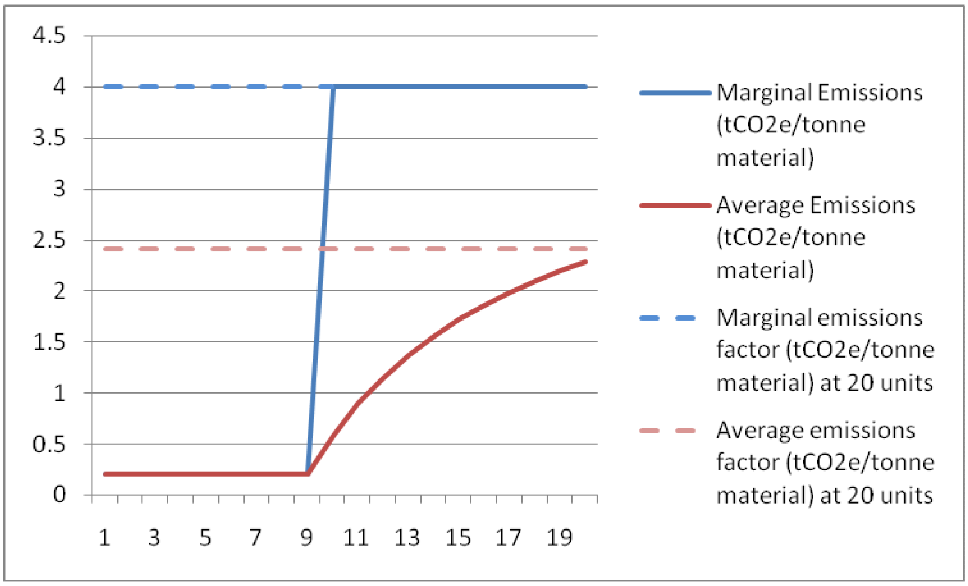

Figure 2. Marginal and average indirect effects

One possible solution to this issue is to apply a derogation from the indirect factor for existing facilities which use feedstock material. This would discourage the development of new production capacity for feedstock materials which have a high marginal indirect effect, but not penalise the existing facilities which use the material.

Alternatively, a quota system could be introduced so that the feedstock material can only be used up to the point where it starts to create large indirect effects. E.g. up to 9 tonnes in the simplified example shown in Figure 2.

Positive actions and derogations

One of the purposes of requiring life-cycle carbon reporting for biofuels is to drive behaviour which reduces emissions in the supply chain. It is therefore important that there are practical measures that fuel or energy suppliers can take to mitigate the indirect effects of using wastes, residues and by-products. A derogation from the indirect effect factor could be applied if suppliers are able to demonstrate that they have successfully reduced the risk of indirect effects. The following is an initial list of measures which could be undertaken to mitigate indirect effects.

- Sourcing material from regions or countries where the material does not have existing uses, or is under-utilised.
- Entering into arrangements with existing users of the material to increase efficiency in the use of the material, and thereby freeing a proportion of the resource for biofuel/bioenergy applications.
- Entering into arrangements with existing users of the material to ensure that low-emission substitutes are used in place of the feedstock material.
- Identifying opportunities to increase the supply of the material.

There will be issues with proving the additionality of these measures, and further research is required on the practicality of this approach. It should be noted that the Renewable Fuels Agency has commissioned research into similar approaches which can be undertaken to avoid the risk of indirect land use change.

4.2. Consistency with the Renewable Energy Directive

The carbon reporting methodology in Annex V of the RED is largely consistent with attributional life-cycle assessment (ALCA), whereas the inclusion of indirect effects is a feature of consequential life -cycle assessment (CLCA).

ALCA aims to quantify all the greenhouse gas emissions associated with the processes directly used in producing (and consuming and disposing of) a product. In contrast, CLCA aims to quantify the total change in greenhouse gas emissions that result as a consequence of a change in the level of production (consumption and disposal) of a product, including any indirect effects. There is therefore a methodological tension with including indirect effect figures with attributional LCA figures. Although combining elements of consequential and attributional analysis within a single life-cycle assessment is not methodologically correct, it is a practical solution for carbon reporting within a regulatory framework. It combines the relatively straightforward attributional methods for reporting direct emissions (and therefore lessens the administrative burden for reporting companies), but also allows the inclusion of indirect effects, which is necessary in order to quantify the total greenhouse gas impact from biofuels or bioenergy.

The European Commission is considering the possibility of including an indirect land use change factor in the carbon reporting methodology for biofuels and bioliquids. The inclusion of an iLUC factor would involve the same methodological compromise as the inclusion of an indirect effects factor for materials with inelastic supply.

4.3. Wider sustainability issues associated with diverting wastes and by-products

There may be other environmental, social and economic impacts from the diversion of wastes and residues to biofuels or bioenergy uses. These may be positive or negative, depending on the materials diverted and what their existing uses or disposal pathways are. In would be necessary to undertake a wider sustainability assessment on a case-by-case basis in order to identify these effects.