Regional emissions from biofuels cultivation - Revised report: June 2021

Report for the Department for Transport

Authors:
Harley Stoddart
Jim Dimmock

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Executive Summary

European Union Member States are required by Directive 2009/28/EC (the Renewable Energy Directive (RED)) to assess the typical emissions at regional level arising from the cultivation step of biofuel supply chains. Where possible this assessment should be carried out at the NUTS2[1] level of spatial disaggregation and cover the most common biofuel crops grown in those regions.

The original purpose of this requirement was to identify those areas of the EU where typical GHG emissions from the cultivation of crops can be expected to be less than or equal to the disaggregated default values for cultivation[2] in the Directive. In regions where this is the case – known as 'NUTS2 compliant' regions – those reporting on biofuel supply chain GHG emissions using crops from that region are permitted to use the disaggregated default value for the cultivation step from the RED. Alternatively, it is also permitted to use such regional cultivation data in the place of actual crop production data for calculation of actual fuel chain GHG emissions. Provision of NUTS2 regional values therefore reduces the administrative burden for farmers and the agricultural trade to produce farm-level emission data. When reporting on biofuel supply chain GHG emissions, this figure can then be combined with GHG data for downstream emissions (i.e. the processing and transport steps of the supply chain).

This report represents the UK's fulfilment of the RED requirements[3] by setting out the approach and results of calculations undertaken to determine the typical GHG emissions arising from the cultivation of the most common biofuel feedstocks in the UK at a regional level. This is the second revision that has been made of the original UK report[4]. The original version of this report was completed in December 2010 and updated in December 2012. The rationale behind this latest revision is to ensure that the most up-to-date data and assumptions reflecting UK agricultural practices and processes are used, to ensure the most accurate possible representation of UK cultivation emissions. The main updates made to the analysis in this revised report are:

- Average Emission Factor (EF) for N_2O-N from applied fertiliser N updated to reflect latest evidence for UK soils, drawing on the National Greenhouse Gas Inventories
- Regional crop yields revised using most relevant data
- Fertiliser and pesticide application rates revised using most relevant data
- Organic fertiliser application rates and emission factors
- Emission factors for other energy and material inputs updated

Three crops with RED default values are assessed (winter feed wheat, oilseed rape and sugar beet) as well as four crops which do not have default values (winter barley, spring barley, oats and triticale). The analysis adheres to the calculation methodology set out in

[1] Nomenclature of Territorial Units for Statistics or "NUTS" is a method of defining regions within European countries employed by the European Commission. NUTS2 refers to the second level on the scale and divides the EU into 276 regions. Figure 1 and Table 1 below show the location and names of each UK NUTS2 region for reference.

[2] These disaggregated defaults for cultivation can be found in Annex V.D of Directive 2009/28/EC

[3] Although the requirement to demonstrate 'NUTS2 compliance' in order to use the appropriate default values has now been removed from the RED as a result of Directive 2015/1513 (the "Indirect Land Use Change (ILUC) Directive").

[4] *Emissions from Biofuels Cultivation: A report prepared for the Department for Transport,* December 2010

Annex V.C of Directive 2009/28/EC, capturing all of the relevant emissions from the cultivation steps of biofuel supply chains. The most recent and credible data on UK agricultural practices and processes was collated, reviewed and applied in the analysis where appropriate.

The largest emissions from crop cultivation arise from direct N_2O emissions, manufacture of fertiliser and machinery diesel. The greater the amount of dry matter (DM) yield per kg of fertiliser-N applied, the smaller were the GHG emissions per MJ of biofuel. Crops such as oats, which produced the most feedstock per kg N fertiliser applied, produce smaller emissions, expressed as gCO_2-eqv/MJ of biofuel

The results of the assessment for each crop are set out in Summary Tables 1 and 2 below. Table 1 presents the results for the three UK biofuel crops for which RED default values exist. The analysis indicates that the cultivation of winter wheat will result in GHG emissions equal to or lower than the disaggregated default value of 23 gCO_2e/MJ[biofuel] in all regions except for North West England. For oilseed rape, all regions demonstrate values equal to or lower than the default of 29 gCO_2e/MJ[biofuel]. All of the regions for which sugar beet is assessed also demonstrate emissions values equal to or lower than the default of 12 gCO_2e/MJ[biofuel].

The other cereal crops show a very similar regional distribution in emissions to winter wheat, with highest emissions typically occurring for the crops grown in the North West, due to the lower yields in these NUTS2 regions.

Summary Table 1: GHG emissions arising from cultivation of feed wheat, oilseed rape and sugar beet for biofuel in the UK NUTS2 regions. Results are in units of [gCO_2-eqv./MJ biofuel] and [$kgCO_2$-eqv/tonne dry feedstock]. Figures in bold indicate that they are below the disaggregated default value for that crop

	Feed Wheat		OSR		Sugar beet	
Region	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]
N East						
UKC1	**19**	290	**23**	631	NA	NA
UKC2	**19**	290	**23**	631	NA	NA
N West						
UKD1	25	388	**25**	670	NA	NA
UKD2	25	388	**25**	670	NA	NA
UKD3	25	388	**25**	670	NA	NA
UKD4	25	388	**25**	670	NA	NA
UKD5	25	388	**25**	670	NA	NA
Yorks						
UKE1	**18**	276	**23**	614	**9**	117
UKE2	**18**	276	**23**	614	**9**	117
UKE3	**18**	276	**23**	614	**9**	117
UKE4	**18**	276	**23**	614	**9**	117
E Mids						
UKF1	**18**	269	**23**	615	**9**	115
UKF2	**18**	269	**23**	615	**9**	115
UKF3	**18**	269	**23**	615	**9**	115
W Mids						
UKG1	**20**	300	**24**	658	**9**	121
UKG2	**20**	300	**24**	658	NA	NA
UKG3	**20**	300	**24**	658	NA	NA
Eastern						
UKH1	**17**	261	**23**	615	**9**	115
UKH2	**17**	261	**23**	615	**9**	115
UKH3	**17**	261	**23**	615	**9**	115
S East						
UKJ1	**18**	271	**25**	664	NA	NA
UKJ2	**18**	271	**25**	664	NA	NA
UKJ3	**18**	271	**25**	664	NA	NA
UKJ4	**18**	271	**25**	664	NA	NA
S West						
UKK1	**20**	310	**26**	697	NA	NA
UKK2	**20**	309	**26**	697	NA	NA
UKK3	**20**	309	**26**	697	NA	NA
UKK4	**20**	309	**26**	697	NA	NA
Wales						
UKL1	**21**	322	**25**	675	NA	NA
UKL2	**21**	322	**25**	675	NA	NA
Scotland						
UKM2	**17**	265	**22**	585	NA	NA
UKM3	**17**	265	**22**	585	NA	NA
UKM5	**17**	265	**22**	585	NA	NA
UKM6	**17**	265	**22**	585	NA	NA
N Ireland						
N Ireland	**19**	290	**25**	687	NA	NA
RED default	23		29		12	

NA = not applicable (sugar beet is not currently grown in these regions)

Summary Table 2: GHG emissions arising from cultivation of winter barley, spring barley, oats and triticale for biofuel in the UK NUTS2 regions. Results are in units of [gCO_2-eqv./MJ biofuel] and [$kgCO_2$-eqv/tonne dry feedstock].

	Winter Barley		Spring Barley		Oats		Triticale	
Region	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]
N East								
UKC1	18	289	18	281	17	264	18	277
UKC2	18	289	18	281	17	264	18	277
N West								
UKD1	21	336	21	332	21	324	19	288
UKD2	21	336	21	332	21	324	19	288
UKD3	21	336	21	332	21	324	19	288
UKD4	21	336	21	332	21	324	19	288
UKD5	21	336	21	332	21	324	19	288
Yorks								
UKE1	16	254	16	250	16	252	18	276
UKE2	16	254	16	250	16	252	18	276
UKE3	16	254	16	250	16	252	18	276
UKE4	16	254	16	250	16	252	18	276
E Mids								
UKF1	18	281	16	249	18	278	17	255
UKF2	18	281	16	249	18	278	17	255
UKF3	18	281	16	249	18	278	17	255
W Mids								
UKG1	19	304	18	288	17	264	19	289
UKG2	19	304	18	288	17	264	19	289
UKG3	19	304	18	288	17	264	19	289
Eastern								
UKH1	17	273	16	248	16	249	18	268
UKH2	17	273	16	248	16	249	18	268
UKH3	17	273	16	248	16	249	18	268
S East								
UKJ1	18	286	16	253	18	272	18	280
UKJ2	18	286	16	253	18	272	18	280
UKJ3	18	286	16	253	18	272	18	280
UKJ4	18	286	16	253	18	272	18	280
S West								
UKK1	19	304	19	299	19	298	20	305
UKK2	19	305	19	299	19	298	20	299
UKK3	19	305	19	299	19	298	20	299
UKK4	19	305	19	299	19	298	20	299
Wales								
UKL1	20	318	20	314	20	304	19	296
UKL2	20	318	20	314	20	304	19	296
Scotland								
UKM2	16	260	16	255	16	242	18	276
UKM3	16	260	16	255	16	242	18	276
UKM5	16	260	16	255	16	242	18	276
UKM6	16	260	16	255	16	242	18	276
N Ireland								
N Ireland	13	205	18	281	17	268	17	264

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Abbreviations

AFBI	Agri-Food & Biosciences Institute
AN	Ammonium nitrate fertiliser
BSFP	British Survey of Fertiliser Practice
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eqv.	The global warming potential of a GHG expressed as the warming equivalent to that produced by a kg of CO_2 over 100 years
DA	Devolved Authority
DARDNI	Department for Agriculture and Rural Development Northern Ireland
Defra	Department for Environment, Food and Rural Affairs
DM	Dry matter
EF	Emission factor
FERA	Food and Environment Research Agency
GHG	Greenhouse gas
IPCC	Inter-Governmental Panel on Climate Change
K	Potassium
K_2O	Potash
LANDIS	Land Information System
LCA	Life cycle analysis
MJ	Megajoules
MLURI	Macaulay Land Use Research Institute
N	Nitrogen
N_2	Nitrogen gas
N_2O	Nitrous oxide
NO_3^-	Nitrate
NUTS	Nomenclature of Territorial Units for Statistics
O_2	Oxygen
OC	Organic carbon
OSR	Oilseed rape
P	Phosphorus
P_2O_5	Phosphate
RED	Renewable Energy Directive
SD	Standard deviation
SE	Standard error of the mean

1 Introduction

On 23 April 2009, the European Commission adopted a Directive on the promotion of the use of energy from renewable sources (Directive 2009/28/EC). The Renewable Energy Directive (RED) includes a methodology to ensure that biofuels and bioliquids secure reductions in greenhouse gas (GHG) emissions. Article 19 of the RED sets out how GHG emissions savings for biofuels and bioliquids are to be calculated, with specific requirements on the estimation of GHG emissions from the cultivation of agricultural crops for biofuels set out in Article 19(2). The article seeks to identify those areas of the EU where typical GHG emissions from the cultivation of raw materials can be expected to be less than or equal to the disaggregated default for cultivation values[5] in the Directive. Each Member State was required to identify these areas and report to the Commission by 31 March 2010

For feedstocks grown in the EU the use of default values (or the disaggregated default for cultivation) to calculate GHG emissions is only permitted if the emissions arising from cultivation in the region the crop was grown have been shown to be typically less than, or equal to, the disaggregated default value for cultivation for that crop, known as 'NUTS2 compliant' regions. Alternatively, it is also permitted to use such regional cultivation data in the place of actual crop production data for calculation of actual fuel chain GHG emissions. Provision of NUTS2 regional values therefore reduces the bureaucratic burden for farmers and the agricultural trade to produce farm-level emission data. For areas with production in excess of these values, either average values for the region or actual values for cultivation must be used in GHG emissions assessments.

The requirement to demonstrate 'NUTS2 compliance' in order to use the appropriate default values has now been removed from the RED as a result of Directive 2015/1513, known as the 'Indirect Land Use Change (ILUC) Directive', coming into force. However, the amended RED still provides for such reports to be submitted to the Commission and, subject to the necessary assessment and examination procedures, to be recognised as containing accurate data for the purposes of measuring the GHG emissions associated with the cultivation of biofuel feedstocks. EU Member States had until 10 September 2017 to transpose the requirements of Directive 2015/1513 into national law.

This report represents the UK's fulfilment of these requirements by setting out the results of calculations undertaken to determine the typical GHG emissions arising from the cultivation of the most common biofuel feedstocks in the UK at NUTS2[6] regional level. The report thus identifies the UK crops and regions for which it is permissible to use the disaggregated default value for cultivation emissions.

[5] These disaggregated defaults for cultivation can be found in Annex V.D of Directive 2009/28/EC

[6] Nomenclature of Territorial Units for Statistics or "NUTS" is a method of defining regions within European countries employed by the European Commission. **NUTS2** refers to the second level on the scale and divides the EU into 276 regions. Figure 1 and Table 1 below show the location and names of each UK NUTS2 region for reference.

1.1 Updates made in this report

This report represents the second revision since the original UK report[7] was submitted. The original version of this report was completed in December 2010 and updated again in December 2012. The rationale behind this latest revision is to ensure that the most relevant data and assumptions reflecting UK agricultural practices and processes are used to ensure the most accurate representation of UK emissions from cultivation. The main updates made to the analysis in this revised report are:

- Average Emission Factors (EF) for N_2O-N from applied urea and N fertiliser updated to reflect latest evidence for UK soils consistent with UK National Atmospheric Emissions Inventory (NAEI)
- Regional crop yields updated
- Fertiliser and pesticide application rates updated
- Organic fertiliser application rates and emission factors updated

These changes are explained in more detail in sections 2.3 and 3. A full overview of changes to data and assumptions in this version can be found in Appendix 2.

1.2 How to use this report

This report is designed to be of use to those responsible for reporting on the GHG intensity of biofuel produced from UK-grown crops. The report is structured as follows:

- Section 2 sets out the approach taken in calculating the GHG emissions
- Section 3 presents the data and assumptions used in the calculation
- Section 4 sets out the high-level results of the calculation
- Appendix 1 presents the data used and a detailed breakdown of the results for each crop.

The most relevant parts of the report for those reporting on GHG emissions are:

- **Cultivation GHG emission results for Winter Wheat, Oilseed Rape and Sugar Beet:** Table 4.1 in section 4 presents the calculated GHG emissions for each crop in each region in units of both gCO_2e/MJ[biofuel] and gCO_2e/MJ[feedstock]. The table also identifies which regions qualify as 'compliant' (i.e. it is permissible to report the disaggregated default value for cultivation). Note that once the provisions of the ILUC Directive are transposed into UK legislation reporters can report these typical values for their relevant NUTS2 region. These cultivation emission figures can then be combined with downstream emissions in the fuel chain (i.e. processing and transport steps) to give the full fuel chain GHG emissions.
- **Detailed breakdown of contributions to cultivation emissions:** Tables 5 to 18 in Appendix 1 show how the emissions from cultivation are comprised for each crop
- **Assumptions used in calculations:** Tables 1 to 4 in Appendix 1 present the data used in the calculations. Sources and discussion on this data can be found in section 3.

[7] *Emissions from Biofuels Cultivation: A report prepared for the Department for Transport*, December 2010

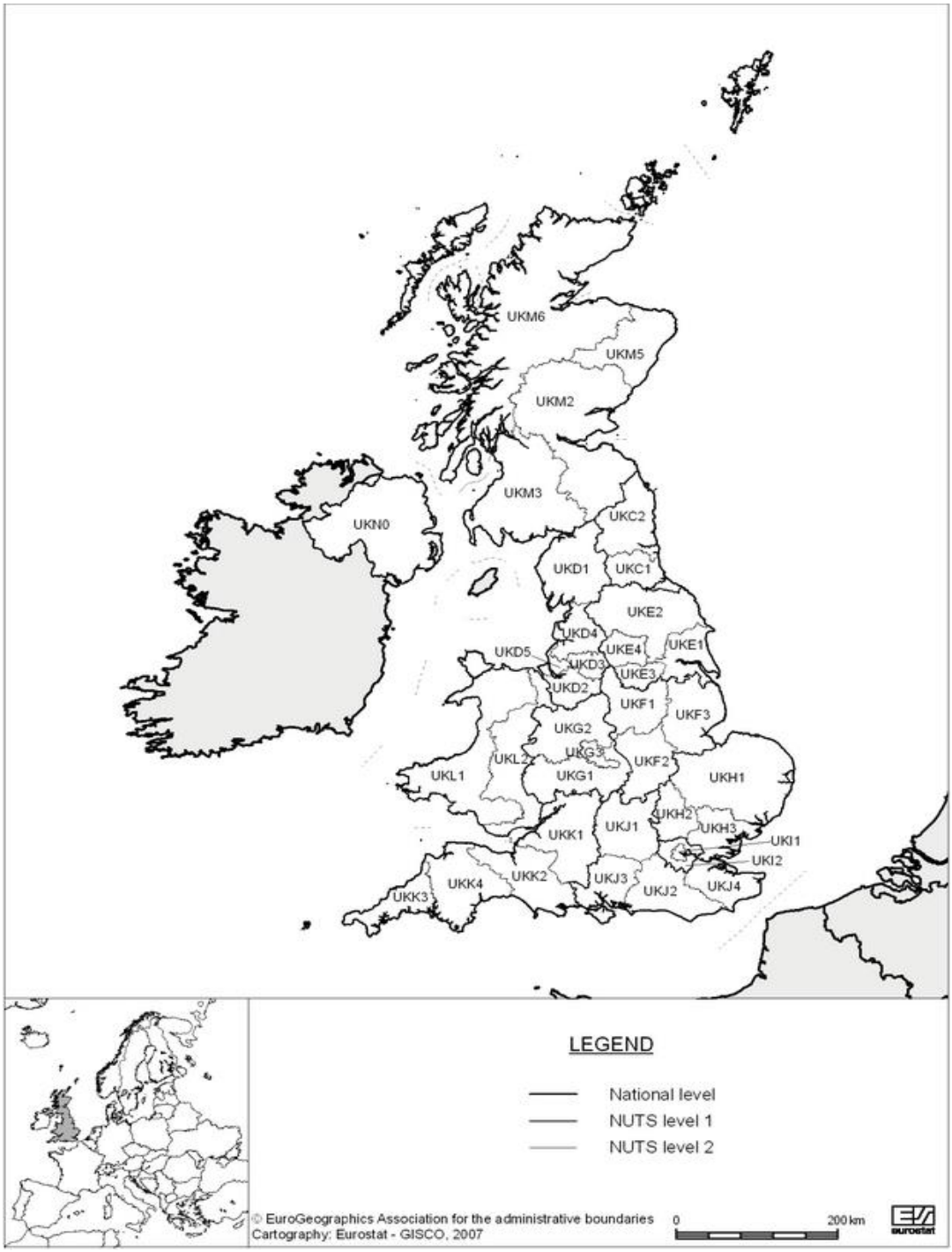

Figure 1: Map illustrating the NUTS2 regions of the UK. Note that the two London region codes UKI1 and UKI2 have been replaced by UKI3 and UKI4, but since no crops have been assessed for these regions they are omitted from this report.

Table 1-1: Key to counties and districts comprising the NUTS1 and NUTS2 regions in ** above.

NUTS1 regions	NUTS2 regions	Counties and districts comprising the NUTS2 regions
North East	UKC1	Tees Valley and Durham
	UKC2	Northumberland and Tyne and Wear
North West	UKD1	Cumbria
	UKD2	Cheshire
	UKD3	Greater Manchester
	UKD4	Lancashire
	UKD5	Merseyside
Yorkshire and Humberside	UKE1	East Yorkshire and Northern Lincolnshire
	UKE2	North Yorkshire
	UKE3	South Yorkshire
	UKE4	West Yorkshire
East Midlands	UKF1	Derbyshire and Nottinghamshire
	UKF2	Leicestershire, Rutland and Northamptonshire
	UKF3	Lincolnshire
West Midlands	UKG1	Herefordshire, Worcestershire and Warwickshire
	UKG2	Shropshire and Staffordshire
	UKG3	West Midlands
East	UKH1	East Anglia
	UKH2	Bedfordshire and Hertfordshire
	UKH3	Essex
London	UKI1[8]	Inner London
	UKI2	Outer London
South East	UKJ1	Berkshire, Buckinghamshire and Oxfordshire
	UKJ2	Surrey, East and West Sussex
	UKJ3	Hampshire and Isle of Wight
	UKJ4	Kent
South West	UKK1	Gloucestershire, Wiltshire and Bristol/Bath area
	UKK2	Dorset and Somerset
	UKK3	Cornwall and Isles of Scilly
	UKK4	Devon
Wales	UKL1	West Wales and The Valleys
	UKL2	East Wales
Scotland	UKM2	Eastern Scotland
	UKM3	South Western Scotland
	UKM5	North Eastern Scotland
	UKM6	The Highlands and islands of Scotland
Northern Ireland	UKN0	Northern Ireland

[8] The two London region codes UKI1 and UKI2 have now been replaced by UKI3 and UKI4. In this report no crops are assessed in these regions so they have been omitted.

2 Approach

2.1 Scope of calculation

The following crops are assessed in the analysis:

- Winter feed wheat
- Winter barley
- Spring barley
- Oats
- Triticale
- Oilseed rape (OSR)
- Sugar beet

Three of these crops have default values in the RED: wheat, OSR and sugar beet. The GHG calculation includes the following sources of emissions for each crop:

- Emissions from the manufacture of fertilisers (ammonium nitrate, urea, phosphorus, potassium, lime), pesticides and seeding materials
- Emissions from on-farm diesel use for cultivation, harvesting and other operations
- Direct soil N_2O emissions from nitrogen fertiliser use, organic fertiliser use and crop residue returns
- Indirect soil N_2O emissions from denitrification of fertiliser-N lost from the soil by leaching, and nitrification/denitrification following deposition to land of fertiliser-N emitted as NH_3

Details on the assumptions taken when determining the impact of each of the above sources are set out in section 3.

2.2 Calculation Methodology

The methodology used in the analysis for calculating GHG emissions from feedstock cultivation adheres to the approach set out in Annex V.C of Directive 2009/28/EC. In particular, this methodology states that both emissions arising from the cultivation and emissions due to the production of chemicals or other products used during the cultivation should be accounted for.

Further details of the methodology, in particular the inputs which should be considered, have been interpreted from information the European Commission has released on the derivation of the default values in Annex V of the RED. Where necessary this guidance has been supplemented using the approach or data as specified in the “Well to wheels” report published by the EC’s Joint Research Centre, CONCAWE and EUCAR (JEC, 2014), as the authors of that study were responsible for the calculation of the default values, and informal advice from the Commission.

The calculation is executed in an Excel workbook which replicates the above methodology, factoring in all of the emission sources summarised in section 2.1.

2.3 Methodology for determining nitrous oxide emissions

Article 19(2) of the RED, which sets out the requirements regarding the NUTS2 calculations, states that '*That method shall take into account soil characteristic, climate and expected raw material yield*.' We interpret this as referring to soil and climate effects on crop yields, GHG emissions from soils, and also differences in crop husbandry, which will depend on soils and climate.

Soil characteristics will vary greatly at national and regional levels, affecting the level of nitrous oxide (N_2O) emissions arising from the use of fertilisers and presence of crop residues. Therefore, where national or regional data on soil dynamics is available, this should be applied.

The Inter-Governmental Panel on Climate Change (IPCC) Guidelines provide three Tiers, or levels of complexity, for the methodologies which may be employed to compile inventories of N_2O emissions arising from agriculture. These capture direct emissions from managed soils as well as indirect N_2O emissions from additions of N to land due to deposition and leaching, and CO_2 due to application of urea fertilisers. The three tiers set out are:

- Tier 1 is the basic method, designed to use readily-available national statistics (also known as activity data) in combination with default EFs and additional parameters that are provided. This approach is straightforward and transparent. The default EFs are derived from very large datasets and hence give an accurate representation of 'average' emissions at the global scale. However, a Tier 1 methodology is less accurate in representing the effects that regional or local variations in management and/or environment within a given source category may have on GHG emissions from soils and on the effects of implementing GHG mitigation methods.

- Tier 2 represents an intermediate level of complexity, where source categories are broken down into more detail (e.g. sub-categories for livestock types and/or management stages) and country-specific data are used instead of default parameters.

- Tier 3 represents the greatest complexity; for example, the use of mechanistic or process-based models to derive EFs.

With the increasing level of detail, Tier 2 and Tier 3 methodologies have the potential to yield more accurate estimates, especially for discrete locations/situations, and the ability to reflect changing practices and the implementation of mitigation methods. However, the requirement for input parameters (e.g. characterisation of soils and climate and the interactions among them as well as activity data) is greater for these methodologies and, in many cases, their application at larger scale, such as NUTS2 regions, becomes less accurate due to the need to average or approximate key inputs.

The complexity of Tier 3 models means robust validation is essential prior to their use. The complexities of scaling up from field-scale models to regional or national scale are not to be underestimated, particularly with respect to relating regional soil properties and climate to emissions of N_2O. While much work has been done on this topic, and large programmes of model development are in place or being commissioned, much remains to be done in finalising and validating the approaches. In particular, the outputs of modelled estimates need validation against actual field measurements. These do not currently exist in sufficient detail for the UK to enable the validation of the emissions estimated by models. Although a robust and reliable approach is likely to be agreed in the future, it is not currently available.

In view of the foregoing considerations we concluded that, at present, it is not justified to derive Tier 2 or Tier 3 EFs to estimate default soil emissions of N_2O in UK NUTS2 regions as they cannot be validated. We concluded that the most justifiable approach is to use a Tier 1 approach while applying UK-specific EFs (where available), applied to more local fertiliser-N use data.

The primary update in this version of the report is the use in the analysis of a UK-specific average EF for N_2O-N from applied fertiliser N. In the IPPC guidelines on accounting for N_2O emissions from managed soils (IPPC, 2006) it refers to this factor as the *EF for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O-N (kg N)$^{-1}$]*. The default value given is 1% with an uncertainty range of 0.3%–3%. The generic figure of 1% has been updated for the latest emissions factors used in the UK's NAEI (2020). The inventory uses separate emission factors for Urea or UAN fertilisers and for Other N fertilisers applied to arable land with values of 0.429% and 0.649% respectively.

The emissions due to the application of organic fertilisers have been accounted for in the Tier 1 calculation. Again values from the UK NAEI were used, applying separate EF's for fertilisers from slurry and bedding origins with values of 0.601% and 0.364% respectively. Consistent with artificial fertiliser use, application rates of organic fertilisers have been taken from the British Survey of Fertiliser Practice.

Given the stipulation in the RED that the method should take into account soil characteristics, applying a UK-specific EF is appropriate. The UK NAEI utilises the most comprehensive assessment of nitrous oxide emissions from arable crops in the UK and thus this constitutes the best available data. A full list of EFs used in the N_2O emission calculation are summarised in section 3.6.

The UK NAEI (2020) uses Tier 3 methodology to account for regional differences in soils and climate.

3 Data & Assumptions

This section summarises the key assumptions and data inputs to the calculation workbook. UK-specific information was used where practices in the UK were considered likely to vary significantly from those modelled in the RED default values. Information specific to NUTS1 or NUTS2 regions was used when such information was agreed to be sufficiently robust. The key data discussed in this section can be reviewed in Appendix 1 of the report.

3.1 Crop yields

Data on yields of cereals and OSR crops was obtained from Defra (Defra, 2015), while sugar beet yield data was provided by British Sugar (Carter, 2015). Regional yield data for OSR and cereals in the UK is collected at NUTS1 level so it was not possible to specify yields at a higher spatial resolution. The variations in yields within each NUTS1 region are not significant so these yields are good representative averages for each NUTS2 region. For sugar beet, only a national average yield is recorded by British Sugar but the varying farm machinery energy demands based on variations in soil types and average field sizes will capture the regional variation in emissions (see section 3.3). Only NUTS2 regions in which a significant amount of sugar beet is cultivated were included in the assessment.

The yields were averaged over three years, as is standard practice for agricultural life-cycle analysis (LCA) studies. In this updated report, estimates are based on average yields reported for 2013–2015. The yield assumptions applied can be found in Appendix Table 1 in Appendix 1.

3.1.1 Winter feed wheat

The wheat yields reported by Defra are an average of milling and feed wheats. Since bioethanol is made from feed wheat rather than milling wheat[9], yield estimates need to be adjusted to reflect this. Since milling wheats typically yield around 8% lower than feed wheats (Nix, 2015), yields in each NUTS1 region have been adjusted based on the proportion of Group 4 wheat grown in that region using AHDB Planting Survey data (AHDB, 2015).

3.2 Fertiliser & Pesticides

3.2.1 Fertiliser and pesticide application

Information on fertiliser use was obtained from the British Survey of Fertiliser Practice and was used to calculate the 3 year average application rates for the years 2013, 2014 and 2015 (BSFP 2015, 2016).

[9] Nabim Group 4 varieties, see p.4 of AHDB (2016)

Average annual applications of the following fertilisers (synthetic and organic) were collated from the BSFP Annual Reports:

- Nitrogen (N) fertiliser input (kg N per ha) – Table GB1.1
- Phosphorus (P) fertiliser input (kg P_2O_5 per ha) – Table GB1.1
- Potassium (K) fertiliser input (kg K_2O per ha) – Table GB1.1
- Lime (L) fertiliser input (kg K_2O per ha) – Table GB1.4

The average share of fertiliser-N applied that is urea for each crop was also used (Table GB3.1), and the remaining share was assumed to be ammonium nitrate. The type of N fertiliser applied to each crop is given in Appendix Table 2 in Appendix 1.

The BSFP sample sizes, which provides data from approximately 1,360 farms in 2013, 1,363 in 2014 and 1,343 in 2015, were not large enough to discriminate differences in average fertiliser applications among either NUTS1 or NUTS2 regions. We have therefore used national average results (expressed as kg nutrient/ha) to calculate direct soil emissions arising from N fertiliser application. Those for Wales, Northern Ireland and Scotland use the same figure as England. The N application rates for feed wheat and milling wheat are given separately in the BSFP and the data for feed wheat were used.

Annual pesticide usage for each of the crops was taken from the applicable Pesticide Usage Survey for Great Britain and Northern Ireland (2014) (Garthwaite *et al*., 2014). It was not possible to refine the pesticide usage below national level as the information is not sufficiently robust, but pesticide application is not expected to vary significantly with region. The most recent data available for arable crops was for 2014.

All of the application rate assumptions can be found in Appendix Table 2 in Appendix 1.

3.2.2 Fertiliser and pesticide manufacture emission factors

Indirect GHG emissions arising from the manufacture of equipment and machinery are not included in the RED methodology. However, manufacture of fertilisers is a significant source of GHG emissions, and is therefore included. GHG emissions are expressed in terms of kg of carbon dioxide equivalent (CO_2-eqv), and include emissions of the GHGs CO_2, CH_4 and N_2O.

RED default values were calculated using only one EF for N fertiliser manufacture (representing ammonium nitrate (AN) production). This manufacture of AN generates N_2O, whereas the manufacture of some other N fertilisers, such as urea, does not. Hence GHG emissions from the manufacture of urea are much less than from the manufacture of AN. Between 2%–14% of fertiliser-N applied to combinable crops in the UK is in the form of urea. Hence we considered that the type of N fertiliser applied to crops and its respective emission factor should be taken into account.

Emission Factors for the manufacture of fertiliser were taken from the Fertilizers Europe report *Energy Efficiency and Greenhouse Gas Emissions in European Nitrogen Fertilizer Production and Use* (Brentrup, F. & Palliere, C., 2011). The values given for ammonium nitrate and urea are 1.18 kgCO_2e/kg product and 0.91 kgCO_2e/kg product, respectively, or 3.52 kgCO_2e/kg[N] and 1.98 kgCO_2e/kg[N]. More recent sources indicate that these emissions are likely to be lower – a report by GrowHow (GrowHow, 2013) give a value of

3.4 $kgCO_2e/kg[N]$ (for Nitram fertiliser). This is partly due to the adoption of N_2O abatement technology in AN production. However the more conservative 2011 data is used since this also gives the EF for urea which couldn't be found in more recent sources.

Emission factors for phosphorus, potassium and lime fertiliser manufacture, as well as pesticide manufacture were taken from the BioGrace II (BioGrace, 2015) GHG calculation spreadsheet. These are the most up to date estimates from the JRC's E3 database of the EFs for these inputs.

3.3 Diesel fuel consumption during cultivation, harvest and other operations

Some features like soil type and field size vary among regions and affect how much fuel power units have to use to complete a given amount of work. The calculation of fuel usage for the different regions of the UK was based on the following assumptions:

1. The principal fuel-consuming field operations are listed for the crops considered and standard hours/hectare values allocated to each task (Nix, 2012).

2. An average suite of machinery was assumed to be used across the UK with large tractor units typically used for ploughing and cultivation, and medium-sized units for non-tillage field operations. The total power and the number of units reported by the Agricultural Engineers Association website (AEA, 2012) shows an average tractor engine power output of about 107 kW. Mindful that the national tractor fleet is a mix of new and older units, the figures in Table 4.1 have been used in this study. The pressure for future increases in the fuel efficiency of new machinery should enable these unit sizes to remain representative for the near future. There is considerable variation in engine efficiencies but a value of 2.40 kWh energy output per litre of fuel consumed (kWh/L) for tractors fitted with engines up to 170 kW power output has been used (NTTL, 2010).

Table 3-1: Average power use, actual power use and fuel efficiency for agricultural machinery

Size	Average power (kW)	Actual power use (kW)	Fuel Efficiency (kWh/L)
Tractors			
Large	104	78 (75%)	2.40
Medium	57	43 (75%)	2.40
Combines			
	167	125 (75%)	2.40

3. Cereal harvesting is done by large-to-average size combines. Fuel consumption for these different size combines has been taken to be the same. The larger combines are usually newer and more efficient than the smaller ones, hence the differences in power requirement are balanced by the differences in fuel efficiency. Sugar beet is harvested by trailed harvester powered by a large tractor.

4. Data on regional soil types (the mix of heavy, medium and light within each region) have been used to produce a relative draught energy factor for each NUTS1 region (derived from Culpin, 1992).

5. Data on regional differences in field size were used to derive a field efficiency factor to account for the more efficient fuel usage in larger fields where less turning and unproductive running time are involved (derived from Butterworth and Nix, 1983).

6. Both regional factors were used to adjust the standard running time for each task such that heavier soils and smaller fields increase the time required for ploughing and cultivation. Only the field size adjustment was used to adjust field operations that are not affected by soil type.

7. Assuming a uniform machinery suite with variable running times avoids the problems arising from larger or smaller machinery working at different rates, and allows the regional physical soil and field differences to be expressed through the single variable of variation in the duration of fuel use. Since the same suite of machines has been taken to be used in all regions, differences in fuel use have been estimated based on regional differences in factors such as field size and soil type.

8. In the absence of specific datasets, Scotland has been assumed to be like NE England, its arable operations tending to be in larger well-run farms with a mixed range of soils. Northern Ireland has been taken as having similar soils to Scotland but with field sizes similar to Wales and SW England. South East England field sizes have been taken as average for the UK.

9. Minimum tillage and direct drilling operations are widely used on a range of soil types across all regions for the establishment of cereals. The exact set of operations varies with soil type and equipment and the prevailing weather. Ploughing energy requirements are adjusted based on the proportion of the crop for which minimum tillage practices are applied in each region. Data sets for areas cultivated using minimum tillage were derived from information provided by Defra and Scottish Government.

Estimates of diesel use for each crop in each region are summarised in Appendix Table 4 in Appendix 1.

3.4 Crop residue returns

Emissions arising from crop residues are also included in line with the methodology used in the BioGrace default value calculations. Data specific to the UK were collated on the fraction of above-ground crop residues that are removed and how much N is left in above-ground residues. This research made use of published papers and reports from ADAS as well as wider literature.

Published literature was reviewed to quantify the amount of N residues in plant roots, making use of a model of root distribution developed by ADAS. Due to the paucity of literature on the amount of root N per hectare, information was used on the concentration of N in root dry

matter (DM) together with DM information to help to quantify the amount of root N per hectare. The data used were as follows:

- **Fresh yield (t/ha)** used the same 2013–2015 average yields set out in section 3.1.

- **Percentage Dry Matter (DM) of fresh yield** was used to calculate the DM content of a crop yield from the marketable fresh weight of the yield.

- **Harvest index (HI)** is the ratio between DM grain yield and the total above ground crop dry weight at harvest. Data from Stoddart & Watts (2012) was used for harvest Index, apart from for sugar beet for which the HI was calculated based on data from British Sugar.

- **Total dry straw yield (t/ha)** was calculated as the product of the inverse HI and the total crop dry weight. This includes the chaff and pod walls for cereals and OSR, respectively, and represents the leaf and stalks of sugar beet.

- **Ratio of baled straw to total straw yield.** In practice straw is harvested 10 to 20 cm above ground level and it is impossible to collect all of the straw and chaff in the baling process. Only a proportion of the above-ground non-grain material would equate to a farmer's straw yield. The best estimate available for the proportion of farmer's straw yield to above-ground non-grain material for modern cereal varieties is 0.6, and 0.5 for OSR (Stoddart & Watts, 2012).

- **Dry straw remaining after baling (t/ha)** accounts for the likely inefficiencies of the baling process and was calculated as a product of the total dry straw yield and the ratio of baled straw to total straw yield.

- **Percentage N in non-yield above ground residues** was taken as the mean of several values from different sources of UK data (specific to the different crops). IPCC figures have been used where appropriate, OSR and Sugar Beet values have come from BioGrace and British Sugar, respectively.

- **Total N in straw (kg/ha)** was calculated as the product of the straw yield and the percentage N in unharvested above-ground residues.

- **Total N in straw after baling (kg/ha)** was calculated as the product of dry straw remaining after baling (t/ha) and the percentage N in non-yield above ground residues.

- **Below ground biomass (t/ha)** is the total weight of below-ground biomass at harvest. IPCC figures have been used where appropriate, OSR and SBt values have come from BioGrace and British Sugar, respectively.

- **% N in root biomass**. Values were not available for any of the crops except wheat, which was used as the default value for all crops.

- **N in roots (kg/ha)** was calculated as the product of % N in root biomass and the below ground biomass.

- **Proportion of root biomass to dry yield** was calculated as the fraction of below-ground biomass over the DM yield. Only the yields that corresponded with the below-ground biomass or root length data were used.

Table 3-2: Values used to calculate the N content in crop residues

	Harvest Index	Ratio of baled straw to total straw yield	N content of above ground residues	Ratio of below-ground residues to above-ground biomass	%N in root biomass
Winter feed wheat	0.51	0.6	0.58%	0.23	1.00%
Winter barley	0.51	0.6	0.58%	0.22	1.00%
Spring barley	0.51	0.6	0.50%	0.22	1.00%
Oats	0.47	0.6	0.70%	0.25	1.00%
Triticale	0.51	0.6	0.50%	0.22	1.00%
Oilseed rape	0.35	0.5	1.02%	0.19	1.00%
Sugar beet	0.74		2.33%	0	

The data gathered were used to calculate the Nitrogen content of crop residues left on the field (kg[N]/ha.yr). Applying the IPCC default N_2O emission factor of 0.01 kg N_2O -N / (kg N), the resulting direct N_2O emissions from crop residue returns were calculated. The impacts of this component can be noted in Appendix Tables 5 to 18.

3.5 Organic fertiliser application

The application of organic fertiliser to UK crops has been included in the updated calculation. Organic fertiliser usage varies by region based on the local agricultural industry and the presence of livestock. Further to this, the type and scale of local animal production also affect application rates and nutrient content of the fertiliser. Data from the British Survey of Fertiliser Practices annual reports of 2013, 2014 and 2015 were used to calculate the three year average application rates of organic fertilisers to UK crops. The table references are consistent across the reports.

The BSFP provide data on the nutrient content (N, P and K) of different manure types in Table D2.2. Table D3.2a provides data on the application rates of the different manure types which has been grouped by winter sown and spring sown crop categories. The average nutrient application rate for each manure type was calculated using the manure nutrient content and the manure average application rate.

The UK NAEI (2020) provides emission factors for both liquid (slurry) and deep bedding (farm yard manure) manure groupings and so the average nutrient application was calculated for these. These average nutrient application rates were weighted by the total volume of manure as it was spread over both winter and spring sown crop types.

To calculate the overall nutrient application rates of organic fertilisers to each crop type, the average nutrient rate was multiplied by the farm yard manure (FYM) "Crop area dressing cover" as provided in Table GB1.1.

Regional variations for organic fertiliser usage are not provided by the BSFP, so an average national organic fertiliser application rate is assumed and incorporated pro-rata into overall nitrogen application rates.

3.6 N_2O Emission Factors

As outlined in section 2.3, the analysis should take into account soil properties and thus where possible UK-specific data should be used. Therefore data from the UK National Atmoshpheric Emissions Inventory (NAEI, 2018) has been applied within a Tier 1 approach to calculating emissions from soils, including the split for urea and AN usage. The UK-specific average EF for N_2O-N from applied urea fertiliser of 0.604% and from Other N fertiliser of 0.791% have been used. The default value given by the IPCC is 1% with an uncertainty range of 0.3%–3% so this figure still lies within the uncertainty range.

The Tier 1 approach also considers indirect N_2O emissions arising from the following processes:

- Denitrification of fertiliser-N lost from the soil by leaching to ground and surface waters as nitrate (NO_3^-);
- Nitrification and denitrification following deposition to land of fertiliser-N emitted as NH_3 after application

Indirect losses arising from NO_3^- leaching were calculated using the IPCC default EFs for the fraction fertiliser-N lost by leaching (0.30), which is supported for arable UK soils by a modelling study by Cardenas *et al*. (2013), and for the fraction of leached N subsequently denitrified to N_2O-N (0.0075).

The EFs for the proportion of fertiliser-N lost as NH_3 and NO_X through volatilisation were taken as the average EFs for tillage land for AN and urea as reported in the UK Ammonia Emissions Inventory (Misselbrook *et al.,* 2009). These were 1.5% of N applied as AN and 17% of N applied as urea[10]. Emissions following deposition of NH_3-N to land were calculated as 1.0% of the N deposited (IPCC, 2006).

Otherwise the IPCC default EFs have been used. All of the EFs used are summarised below in

[10] While these values are not explicitly referenced in Misselbrook *et al.,* (2009), the author confirmed, per comms, their input for the calculations of the Inventory of Ammonia Emissions from UK Agriculture,.

Table 3-3.

Table 3-3: Summary of Emission Factors used in N_2O emission analysis

Emission factor	Unit	Value used in analysis	IPCC Default value	IPCC Uncertainty range	Reference
EF for N additions from urea mineral fertilisers, and N mineralised form mineral soil as a result of loss of soil carbon	[kg N_2O-N / (kg N)]	0.00429	0.01	0.003 - 0.03	*UK NAEI (2018) – more detail can be found in Appendix 3*
EF for N additions from Other N mineral fertilisers	[kg N_2O-N / (kg N)]	0.00649	0.01	0.003 - 0.03	*UK NAEI (2018) – more detail can be found in Appendix 3*
EF for N additions from crop residues	[kg N_2O-N / (kg N)]	0.01	0.01	0.003 - 0.03	*Brown, P. et al (2016) UK Greenhouse Gas Inventory*
EF for N additions from liquid organic carbon	[kg N_2O-N / (kg N)]	0.00601	0.01	0.003 - 0.03	*Brown, P. et al (2016) UK Greenhouse Gas Inventory Annexes*
EF for N additions from bedding organic amendments	[kg N_2O-N / (kg N)]	0.00364	0.01	0.003 - 0.03	*Brown, P. et al (2016) UK Greenhouse Gas Inventory Annexes*
Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	[kg N_2O-N / (kg NH_3-N + NO_x-N volatilised)]	0.01	0.01	0.002 - 0.05	De Klein *et al.* (2006) *Chapter 11 - N_2O emissions from managed soils and CO_2 emissions from lime and urea application,* in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
Fraction of AN fertiliser that volatilises as NH_3 and NO_x	[(kg NH_3-N + NO_x-N) / kg N applied]	0.015	0.1	0.03 - 0.3	Misselbrook *et al*. (2009) UK Ammonia Emissions Inventory
Fraction of urea that volatilises an NH_3 and NO_x	[(kg NH_3-N + NO_x-N) / kg N applied]	0.17	0.2	0.05 - 0.5	Misselbrook *et al*. (2009) UK Ammonia Emissions Inventory
Emission factor for N_2O emissions from N leaching and runoff	[kg N_2O-N / (kg N leached and runoff)]	0.0075	0.0075	0.0005 - 0.025	De Klein *et al*. (2006) *Chapter 11 - N_2O emissions from managed soils and CO_2 emissions from lime and urea application,* in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
Fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff	[kg N / kg N additions]	0.3	0.3	0.1 - 0.8	De Klein *et al.* (2006) *Chapter 11 - N_2O emissions from managed soils and CO_2 emissions from lime and urea application,* in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*

3.7 Other Assumptions

3.7.1 Seeding material

The rate of application of seeding materials and the GHG emissions due to their production are included in the RED default values for the crops included in this study with the exception of sugar beet. The emission factors for the seeding material were taken from the BioGrace II spreadsheet (BioGrace, 2015) and whilst an emission factor was not provided for oats and it was assumed oats had the same seeding material emissions factor as wheat. The seeding material emissions for sugar beet were not included in the calculation as there was no suitable data for the seeding application rate. However, seeding materials have a very small contribution to the total emissions from feedstock cultivation (*c*. 1% or less) and the omission from the calculations for sugar beet is not likely to significantly affect the results.

3.7.2 Energy content of oilseed rape

The lower heating values (LHV) for biofuel feedstocks were all taken from the BioGrace II spreadsheet (BioGrace, 2015) except for OSR. This was updated as the oil content of UK OSR has been increasing annually as cultivation practices have improved, and the standard value in BioGrace does not reflect the UK situation. A UK figure of 27.3 MJ/kg was calculated based on the 2013–2015 UK average OSR oil content (44.6%) provided by SCOPA (SCOPA, 2016). By comparison the BioGrace figure is 26.5 MJ/kg for an oil content of 40.5%.

4 Results – Regional GHG emissions from cultivation of UK biofuel crops

4.1 Results tables

The results of the GHG calculation based on the data and assumption set out above are summarised in the tables below. The tables are split between crops for which a disaggregated default value exists (wheat, oilseed rape, sugar beet) and those for which there is no default value. Results are expressed in units of gCO_2-eqv/MJ[biofuel] as well as gCO_2-eqv/tonne[dry feedstock] in order to assist reporters. Results for each crop are set out in more detail in the tables in Appendix 1, presented to two decimal places.

Table 4-1 indicates that the cultivation of winter wheat will result in GHG emissions equal to or lower than the disaggregated default value of 23 gCO_2e/MJ[biofuel] in all regions except for North West England. For oilseed rape, all regions achieve typical values equal to or lower than the default of 29 gCO_2e/MJ[biofuel]. All of the regions for which sugar beet is assessed also deliver typical values equal to or lower than the default of 12 gCO_2e/MJ[biofuel].

The other cereal crops show a very similar regional distribution in emissions to winter wheat, with highest emissions typically occurring in the crops grown in the North West England, primarily due to lower yields in this region.

Table 4-1: GHG emissions arising from biofuel cultivation of feed wheat, oilseed rape and sugar beet in the UK NUTS2 regions by [gCO_2-eqv./MJ biofuel] and [$kgCO_2$-eqv/tonne dry feedstock].

	Feed Wheat		OSR		Sugar beet	
Region	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]
N East						
UKC1	**19**	290	**23**	631	NA	NA
UKC2	**19**	290	**23**	631	NA	NA
N West						
UKD1	25	388	**25**	670	NA	NA
UKD2	25	388	**25**	670	NA	NA
UKD3	25	388	**25**	670	NA	NA
UKD4	25	388	**25**	670	NA	NA
UKD5	25	388	**25**	670	NA	NA
Yorks						
UKE1	**18**	276	**23**	614	**9**	117
UKE2	**18**	276	**23**	614	**9**	117
UKE3	**18**	276	**23**	614	**9**	117
UKE4	**18**	276	**23**	614	**9**	117
E Mids						
UKF1	**18**	269	**23**	615	**9**	115
UKF2	**18**	269	**23**	615	**9**	115
UKF3	**18**	269	**23**	615	**9**	115
W Mids						
UKG1	**20**	300	**24**	658	**9**	121
UKG2	**20**	300	**24**	658	NA	NA
UKG3	**20**	300	**24**	658	NA	NA
Eastern						
UKH1	**17**	261	**23**	615	**9**	115
UKH2	**17**	261	**23**	615	**9**	115
UKH3	**17**	261	**23**	615	**9**	115
S East						
UKJ1	**18**	271	**25**	664	NA	NA
UKJ2	**18**	271	**25**	664	NA	NA
UKJ3	**18**	271	**25**	664	NA	NA
UKJ4	**18**	271	**25**	664	NA	NA
S West						
UKK1	**20**	310	**26**	697	NA	NA
UKK2	**20**	309	**26**	697	NA	NA
UKK3	**20**	309	**26**	697	NA	NA
UKK4	**20**	309	**26**	697	NA	NA
Wales						
UKL1	**21**	322	**25**	675	NA	NA
UKL2	**21**	322	**25**	675	NA	NA
Scotland						
UKM2	**17**	265	**22**	585	NA	NA
UKM3	**17**	265	**22**	585	NA	NA
UKM5	**17**	265	**22**	585	NA	NA
UKM6	**17**	265	**22**	585	NA	NA
N Ireland						
N Ireland	**19**	290	**25**	687	NA	NA
RED default	23		29		12	

NA = not applicable (sugar beet is not currently grown in these regions)

Table 4-2: GHG emissions arising from biofuel cultivation of winter barley, spring barley, oats and triticale in the UK NUTS2 regions by [gCO_2-eqv./MJ biofuel] and [$kgCO_2$-eqv/tonne dry feedstock].

	Winter Barley		Spring Barley		Oats		Triticale	
Region	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]	gCO_2-eqv/MJ biofuel	$kgCO_2$-eqv/tonne [dry feedstock]
N East								
UKC1	18	289	18	281	17	264	18	277
UKC2	18	289	18	281	17	264	18	277
N West								
UKD1	21	336	21	332	21	324	19	288
UKD2	21	336	21	332	21	324	19	288
UKD3	21	336	21	332	21	324	19	288
UKD4	21	336	21	332	21	324	19	288
UKD5	21	336	21	332	21	324	19	288
Yorks								
UKE1	16	254	16	250	16	252	18	276
UKE2	16	254	16	250	16	252	18	276
UKE3	16	254	16	250	16	252	18	276
UKE4	16	254	16	250	16	252	18	276
E Mids								
UKF1	18	281	16	249	18	278	17	255
UKF2	18	281	16	249	18	278	17	255
UKF3	18	281	16	249	18	278	17	255
W Mids								
UKG1	19	304	18	288	17	264	19	289
UKG2	19	304	18	288	17	264	19	289
UKG3	19	304	18	288	17	264	19	289
Eastern								
UKH1	17	273	16	248	16	249	18	268
UKH2	17	273	16	248	16	249	18	268
UKH3	17	273	16	248	16	249	18	268
S East								
UKJ1	18	286	16	253	18	272	18	280
UKJ2	18	286	16	253	18	272	18	280
UKJ3	18	286	16	253	18	272	18	280
UKJ4	18	286	16	253	18	272	18	280
S West								
UKK1	19	304	19	299	19	298	20	305
UKK2	19	305	19	299	19	298	20	299
UKK3	19	305	19	299	19	298	20	299
UKK4	19	305	19	299	19	298	20	299
Wales								
UKL1	20	318	20	314	20	304	19	296
UKL2	20	318	20	314	20	304	19	296
Scotland								
UKM2	16	260	16	255	16	242	18	276
UKM3	16	260	16	255	16	242	18	276
UKM5	16	260	16	255	16	242	18	276
UKM6	16	260	16	255	16	242	18	276
N Ireland								
N Ireland	13	205	18	281	17	268	17	264

4.2 Interpretation and Uncertainty

The GHG assessment has used the best available data and evidence to give a UK-specific estimate of typical regional emissions from cultivation. This includes regional UK data for yields, fertiliser use, machinery diesel use, crop residue returns, and national data for pesticide application and N_2O EFs. As with all GHG analyses, the assessment contains some uncertainty. As can be seen from the detailed results in Appendix 2, the biggest contributing components of the final GHG emissions are 1) emissions from manufacture of fertiliser, 2) direct N_2O emissions, and 3) machinery diesel emissions. An appraisal of these components and the parameters which affect them is presented below.

The greater the amount of dry matter (DM) yield per kg of fertiliser-N applied, the smaller were the GHG emissions per MJ of biofuel. Crops such as oats, which produced the most feedstock per kg N fertiliser applied, produce smaller emissions, expressed as gCO_2-eqv/MJ of biofuel.

4.2.1 Emissions from fertiliser manufacture

Emissions from fertiliser manufacture depend primarily on the amount of fertiliser applied and the fertiliser manufacture Emissions Factors. According to the sampling variation analysis in the BSFP (BSFP, 2014) the standard errors for fertiliser application are around 1–3%, therefore the uncertainty associated with this parameter is relatively small. No significant regional variations in fertiliser application are known of so the use of national averages is considered to be a robust assumption.

As outlined in section 3.2.2, conservative assumptions for Emission Factors for the manufacture of fertiliser have been used so as not to underestimate emissions from fertiliser manufacture. The fertiliser which contributes most is ammonium nitrate, where an EF of 3.52 $kgCO_2e/kg[N]$ has been used (Brentrup, F. & Palliere, C., 2011). Even using the most conservative figure available (a value of 4.57 $kgCO_2e/kg[N]$ from BioGrace II) does not change the compliance status of any crops, thus there is some tolerance in the results to variations to this parameter.

4.2.2 Emissions from direct N_2O emissions

There is considerable uncertainty over estimates of N_2O emissions from soil. This study concluded that applying the IPCC Tier 1 methodology with the UK-specific N_2O EF provides the most robust estimate of GHG emissions from UK soils based on current evidence. The uncertainty range of the IPCC Tier 1 EF for N_2O emissions of 1.0% is considered to be between 0.3 and 3.0% (Table 11.1, IPCC, 2006). No estimate of standard deviation (SD) or SE is provided by IPCC.

The UK average values of 0.429% for Urea or UAN fertilisers and 0.649% for Other N fertilisers as applied lie within this uncertainty range. The UK NAEI (2020) consulted a wide range of evidence and represents the most robust assessment of N_2O emissions from agricultural land in the UK and thus this constitutes the best available data.

4.2.3 Machinery fuel use

The estimates of actual fuel use were based on a combination of reported data of machinery purchased, working rates and fuel consumption, combined with expert judgement on the way in which machines are used on farms. It is difficult to quantify the uncertainty in these estimates, but a conservative approach has been taken to ensure that emissions from this step are not underestimated (e.g. ensuring all machinery activities are included, assuming quite a high average tractor power). Diesel use from ploughing, cultivation, drilling, fertiliser application and harvesting operations have all been included. Even with 50% higher diesel consumption than assumed, the compliance status of all crops remains unchanged.

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Appendices

Appendix 1: Results of Data Collation and revised results reported per MJ of feedstock to enable comparison with the report submitted in March.

Appendix 2: Overview of changes made to UK NUTS2 reports.

Appendix 3: Emission Factor for nitrogen additions from mineral fertilisers

Appendix 1

Results of data collation

Appendix Table 1. Crop yields, t/ha DM. Values are the arithmetic mean of harvests over the 4-year period 2012–2015 – inclusive

Region	Winter wheat	Winter barley	Spring barley	Oats	Triticale	Oilseed rape	Sugar beet*
	Yield	Yield	Yield	Yield	Yield	Yield	Yield
N East	6.9	5.7	4.7	5.0	3.8	3.1	15.8
N West	5.2	5.1	4.0	4.1	3.8	3.1	15.8
Yorks	7.3	6.6	5.3	5.1	3.8	3.3	15.8
E Mids	7.3	5.8	5.2	4.5	3.8	3.2	15.8
W Mids	6.8	5.6	4.7	5.1	3.8	3.1	15.8
Eastern	7.6	6.0	5.2	5.0	3.8	3.1	15.8
S East	7.5	5.8	5.3	4.9	3.8	3.0	15.8
S West	6.8	5.8	4.7	4.7	3.8	3.0	15.8
Wales	6.5	5.6	4.5	4.5	3.8	3.1	15.8
Scotland	7.7	6.5	5.1	5.4	3.8	3.5	15.8
N Ireland	7.0	6.3	4.6	4.8	3.8	3.1	15.8

*British Sugar measure sugar yield per hectare, and not biomass/ha. The above DM yields per ha were calculated by converting to yields at a fixed sugar content.

Appendix Table 2a. UK average overall fertiliser applications, kg nutrient per ha, from BSFP 2013-2015. N is nitrogen, P_2O_5 is phosphate, K_2O is potash

	Winter wheat	Winter barley	Spring barley	Oats	Triticale	Oilseed rape	Sugar beet
N	188	146	104	96	65	180	97
P_2O_5	27	29	33	30	0	28	23
K_2O	34	42	45	42	28	29	69
Lime	227	263	445	276	0	392	1390

Appendix Table 2b. Average shares of fertiliser-N applied that is urea and ammonium nitrate differ as a result of manufacture and indirect emissions from soils. BSFP, 2013-2015.

	Winter wheat	Winter barley	Spring barley	Oats	Triticale	Oilseed rape	Sugar beet
Urea	9.6%	9.6%	5.1%	9.6%	9.6%	12.8%	5.1%
Other Nitrogen Fertilisers	90.4%	90.4%	94.9%	90.4%	90.4%	87.2%	94.9%

Appendix Table 3. UK average pesticide use, kg active ingredient per ha, for relevant crops

Region	Winter wheat	Winter barley	Spring barley	Oats	Triticale	Oilseed rape	Sugar beet
UK ave.	4.29	3.07	1.58	1.65	2.52	3.25	4.02

Appendix Table 4. Machinery use: litres of diesel per hectare

Region	Winter wheat	Winter barley	Spring barley	Oats	Triticale	Oilseed rape	Sugar beet
N East	99	103	103	103	103	94	
N West	121	118	113	114	114	115	
Yorks	100	103	103	95	104	97	
E Mids	88	95	96	92	82	85	
W Mids	113	120	116	114	116	107	
Eastern	87	93	92	87	95	80	
S East	100	102	106	109	108	90	
S West	124	128	126	133	133	116	
Wales	124	131	127	124	127	118	
Scotland	103	101	100	97	102	103	
N Ireland	101	100	99	100	90	131	
UK ave.	105	109	107	106	107	103	

Appendix Table 5. GHG emissions arising from the cultivation of winter wheat in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	4.87	1.89	2.05	5.26	0.56	3.48	0.47	18.95
UKC2	4.87	1.89	2.05	5.26	0.56	3.48	0.47	18.95
N West								
UKD1	6.42	2.49	2.05	6.95	0.74	5.60	0.63	25.35
UKD2	6.42	2.49	2.05	6.95	0.74	5.60	0.63	25.35
UKD3	6.42	2.49	2.05	6.95	0.74	5.60	0.63	25.35
UKD4	6.42	2.49	2.05	6.95	0.74	5.60	0.63	25.35
UKD5	6.42	2.49	2.05	6.95	0.74	5.60	0.63	25.35
Yorks								
UKE1	4.60	1.78	2.05	4.97	0.53	3.32	0.41	17.99
UKE2	4.60	1.78	2.05	4.97	0.53	3.32	0.41	17.99
UKE3	4.60	1.78	2.05	4.97	0.53	3.32	0.41	17.99
UKE4	4.60	1.78	2.05	4.97	0.53	3.32	0.41	17.99
E Mids								
UKF1	4.59	1.78	2.05	4.96	0.53	2.93	0.41	17.58
UKF2	4.59	1.78	2.05	4.96	0.53	2.93	0.41	17.58
UKF3	4.59	1.78	2.05	4.96	0.53	2.93	0.41	17.58
W Mids								
UKG1	4.92	1.91	2.05	5.32	0.57	4.00	0.44	19.57
UKG2	4.92	1.91	2.05	5.32	0.57	4.00	0.44	19.57
UKG3	4.92	1.91	2.05	5.32	0.57	4.00	0.44	19.57
Eastern								
UKH1	4.44	1.72	2.05	4.80	0.51	2.79	0.39	17.02
UKH2	4.44	1.72	2.05	4.80	0.51	2.79	0.39	17.02
UKH3	4.44	1.72	2.05	4.80	0.51	2.79	0.39	17.02
S East								
UKJ1	4.52	1.75	2.05	4.89	0.52	3.25	0.40	17.71
UKJ2	4.52	1.75	2.05	4.89	0.52	3.25	0.40	17.71
UKJ3	4.52	1.75	2.05	4.89	0.52	3.25	0.40	17.71
UKJ4	4.52	1.75	2.05	4.89	0.52	3.25	0.40	17.71
S West								
UKK1	4.99	1.94	2.05	5.39	0.58	4.47	0.46	20.25
UKK2	4.99	1.94	2.05	5.38	0.51	4.47	0.46	20.17
UKK3	4.99	1.94	2.05	5.38	0.51	4.47	0.46	20.17
UKK4	4.99	1.94	2.05	5.38	0.51	4.47	0.46	20.17
Wales								
UKL1	5.21	2.02	2.05	5.62	0.60	4.64	0.51	21.04
UKL2	5.21	2.02	2.05	5.62	0.60	4.64	0.51	21.04
Scotland								
UKM2	4.36	1.69	2.05	4.72	0.50	3.23	0.43	17.31
UKM3	4.36	1.69	2.05	4.72	0.50	3.23	0.43	17.31
UKM5	4.36	1.69	2.05	4.72	0.50	3.23	0.43	17.31
UKM6	4.36	1.69	2.05	4.72	0.50	3.23	0.43	17.31
N Ireland								
N Ireland	4.84	1.88	2.05	5.24	0.56	3.51	0.47	18.91
***UK typical**	4.44	1.72	2.05	4.80	0.51	2.79	0.39	**17.02**
% of total	26%	10%	12%	28%	3%	16%	2%	

Appendix Table 6. GHG emissions arising from the cultivation of winter barley in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	4.36	1.60	1.93	4.70	0.47	4.23	NA	18.37
UKC2	4.36	1.60	1.93	4.70	0.47	4.23	NA	18.37
N West								
UKD1	4.96	1.81	1.93	5.34	0.54	5.51	NA	21.32
UKD2	4.96	1.81	1.93	5.34	0.54	5.51	NA	21.32
UKD3	4.96	1.81	1.93	5.34	0.54	5.51	NA	21.32
UKD4	4.96	1.81	1.93	5.34	0.54	5.51	NA	21.32
UKD5	4.96	1.81	1.93	5.34	0.54	5.51	NA	21.32
Yorks								
UKE1	3.77	1.38	1.93	4.06	0.41	3.67	NA	16.12
UKE2	3.77	1.38	1.93	4.06	0.41	3.67	NA	16.12
UKE3	3.77	1.38	1.93	4.06	0.41	3.67	NA	16.12
UKE4	3.77	1.38	1.93	4.06	0.41	3.67	NA	16.12
E Mids								
UKF1	4.31	1.58	1.93	4.64	0.47	3.88	NA	17.81
UKF2	4.31	1.58	1.93	4.64	0.47	3.88	NA	17.81
UKF3	4.31	1.58	1.93	4.64	0.47	3.88	NA	17.81
W Mids								
UKG1	4.44	1.62	1.93	4.78	0.48	5.01	NA	19.32
UKG2	4.44	1.62	1.93	4.78	0.48	5.01	NA	19.32
UKG3	4.44	1.62	1.93	4.78	0.48	5.01	NA	19.32
Eastern								
UKH1	4.21	1.54	1.93	4.54	0.45	3.69	NA	17.36
UKH2	4.21	1.54	1.93	4.54	0.45	3.69	NA	17.36
UKH3	4.21	1.54	1.93	4.54	0.45	3.69	NA	17.36
S East								
UKJ1	4.33	1.58	1.93	4.66	0.47	4.18	NA	18.19
UKJ2	4.33	1.58	1.93	4.66	0.47	4.18	NA	18.19
UKJ3	4.33	1.58	1.93	4.66	0.47	4.18	NA	18.19
UKJ4	4.33	1.58	1.93	4.66	0.47	4.18	NA	18.19
S West								
UKK1	4.35	1.59	1.93	4.68	0.47	5.24	NA	19.31
UKK2	4.35	1.59	1.93	4.74	0.46	5.24	NA	19.36
UKK3	4.35	1.59	1.93	4.74	0.46	5.24	NA	19.36
UKK4	4.35	1.59	1.93	4.74	0.46	5.24	NA	19.36
Wales								
UKL1	4.51	1.65	1.93	4.87	0.49	5.58	NA	20.18
UKL2	4.51	1.65	1.93	4.87	0.49	5.58	NA	20.18
Scotland								
UKM2	3.88	1.42	1.93	4.17	0.42	3.70	NA	16.48
UKM3	3.88	1.42	1.93	4.17	0.42	3.70	NA	16.48
UKM5	3.88	1.42	1.93	4.17	0.42	3.70	NA	16.48
UKM6	3.88	1.42	1.93	4.17	0.42	3.70	NA	16.48
N Ireland								
N Ireland	3.96	1.45	1.93	4.26	0.43		NA	13.01
*UK typical	4.21	1.54	1.93	4.54	0.45	3.69	NA	**17.36**
% of total	24%	9%	11%	26%	3%	21%	NA	

Appendix Table 7. GHG emissions arising from the cultivation of spring barley in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	3.85	1.07	1.84	3.90	0.30	5.23	NA	17.84
UKC2	3.85	1.07	1.84	3.90	0.30	5.23	NA	17.84
N West								
UKD1	4.48	1.25	1.84	4.55	0.35	6.68	NA	21.07
UKD2	4.48	1.25	1.84	4.55	0.35	6.68	NA	21.07
UKD3	4.48	1.25	1.84	4.55	0.35	6.68	NA	21.07
UKD4	4.48	1.25	1.84	4.55	0.35	6.68	NA	21.07
UKD5	4.48	1.25	1.84	4.55	0.35	6.68	NA	21.07
Yorks								
UKE1	3.39	0.94	1.84	3.44	0.26	4.61	NA	15.89
UKE2	3.39	0.94	1.84	3.44	0.26	4.61	NA	15.89
UKE3	3.39	0.94	1.84	3.44	0.26	4.61	NA	15.89
UKE4	3.39	0.94	1.84	3.44	0.26	4.61	NA	15.89
E Mids								
UKF1	3.45	0.96	1.84	3.50	0.27	4.36	NA	15.80
UKF2	3.45	0.96	1.84	3.50	0.27	4.36	NA	15.80
UKF3	3.45	0.96	1.84	3.50	0.27	4.36	NA	15.80
W Mids								
UKG1	3.80	1.06	1.84	3.85	0.30	5.83	NA	18.25
UKG2	3.80	1.06	1.84	3.85	0.30	5.83	NA	18.25
UKG3	3.80	1.06	1.84	3.85	0.30	5.83	NA	18.25
Eastern								
UKH1	3.47	0.97	1.84	3.52	0.27	4.20	NA	15.70
UKH2	3.47	0.97	1.84	3.52	0.27	4.20	NA	15.70
UKH3	3.47	0.97	1.84	3.52	0.27	4.20	NA	15.70
S East								
UKJ1	3.40	0.95	1.84	3.45	0.27	4.77	NA	16.07
UKJ2	3.40	0.95	1.84	3.45	0.27	4.77	NA	16.07
UKJ3	3.40	0.95	1.84	3.45	0.27	4.77	NA	16.07
UKJ4	3.40	0.95	1.84	3.45	0.27	4.77	NA	16.07
S West								
UKK1	3.84	1.07	1.84	3.90	0.30	6.40	NA	18.96
UKK2	3.84	1.07	1.84	3.92	0.27	6.40	NA	18.96
UKK3	3.84	1.07	1.84	3.92	0.27	6.40	NA	18.96
UKK4	3.84	1.07	1.84	3.92	0.27	6.40	NA	18.96
Wales								
UKL1	3.98	1.15	1.84	4.15	0.31	6.70	NA	19.91
UKL2	3.98	1.15	1.84	4.15	0.31	6.70	NA	19.91
Scotland								
UKM2	3.49	0.97	1.84	3.54	0.27	4.60	NA	16.21
UKM3	3.49	0.97	1.84	3.54	0.27	4.60	NA	16.21
UKM5	3.49	0.97	1.84	3.54	0.27	4.60	NA	16.21
UKM6	3.49	0.97	1.84	3.54	0.27	4.60	NA	16.21
N Ireland								
N Ireland	3.89	1.08	1.84	3.94	0.30	5.09	NA	17.82
*UK typical	3.84	1.07	1.84	3.90	0.30	4.20	NA	18.96
% of total	20%	6%	10%	21%	2%	22%	NA	

Appendix Table 8. GHG emissions arising from the cultivation of oats in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	3.38	1.09	2.58	3.57	0.30	5.04	NA	17.23
UKC2	3.38	1.09	2.58	3.57	0.30	5.04	NA	17.23
N West								
UKD1	4.12	1.33	2.58	4.35	0.37	6.83	NA	21.13
UKD2	4.12	1.33	2.58	4.35	0.37	6.83	NA	21.13
UKD3	4.12	1.33	2.58	4.35	0.37	6.83	NA	21.13
UKD4	4.12	1.33	2.58	4.35	0.37	6.83	NA	21.13
UKD5	4.12	1.33	2.58	4.35	0.37	6.83	NA	21.13
Yorks								
UKE1	3.29	1.06	2.58	3.47	0.29	4.53	NA	16.46
UKE2	3.29	1.06	2.58	3.47	0.29	4.53	NA	16.46
UKE3	3.29	1.06	2.58	3.47	0.29	4.53	NA	16.46
UKE4	3.29	1.06	2.58	3.47	0.29	4.53	NA	16.46
E Mids								
UKF1	3.73	1.20	2.58	3.94	0.33	4.95	NA	18.14
UKF2	3.73	1.20	2.58	3.94	0.33	4.95	NA	18.14
UKF3	3.73	1.20	2.58	3.94	0.33	4.95	NA	18.14
W Mids								
UKG1	3.26	1.05	2.58	3.44	0.29	5.36	NA	17.20
UKG2	3.26	1.05	2.58	3.44	0.29	5.36	NA	17.20
UKG3	3.26	1.05	2.58	3.44	0.29	5.36	NA	17.20
Eastern								
UKH1	3.33	1.07	2.58	3.51	0.30	4.19	NA	16.23
UKH2	3.33	1.07	2.58	3.51	0.30	4.19	NA	16.23
UKH3	3.33	1.07	2.58	3.51	0.30	4.19	NA	16.23
S East								
UKJ1	3.43	1.10	2.58	3.62	0.31	5.41	NA	17.74
UKJ2	3.43	1.10	2.58	3.62	0.31	5.41	NA	17.74
UKJ3	3.43	1.10	2.58	3.62	0.31	5.41	NA	17.74
UKJ4	3.43	1.10	2.58	3.62	0.31	5.41	NA	17.74
S West								
UKK1	3.54	1.14	2.58	3.73	0.32	6.80	NA	19.45
UKK2	3.54	1.14	2.58	3.73	0.32	6.80	NA	19.45
UKK3	3.54	1.14	2.58	3.73	0.32	6.80	NA	19.45
UKK4	3.54	1.14	2.58	3.73	0.32	6.80	NA	19.45
Wales								
UKL1	3.71	1.19	2.58	3.89	0.33	6.68	NA	19.82
UKL2	3.71	1.19	2.58	3.89	0.33	6.68	NA	19.82
Scotland								
UKM2	3.10	1.00	2.58	3.27	0.28	4.35	NA	15.76
UKM3	3.10	1.00	2.58	3.27	0.28	4.35	NA	15.76
UKM5	3.10	1.00	2.58	3.27	0.28	4.35	NA	15.76
UKM6	3.10	1.00	2.58	3.27	0.28	4.35	NA	15.76
N Ireland								
N Ireland	3.47	1.12	2.58	3.66	0.31	5.01	NA	17.46
*UK typical	3.43	1.10	2.58	3.62	0.31	5.41	NA	17.74
% of total	19%	6%	15%	20%	2%	31%	NA	

Appendix Table 9. GHG emissions arising from the cultivation of triticale in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	3.24	1.17	1.90	3.27	0.61	6.68	NA	18.08
UKC2	3.24	1.17	1.90	3.27	0.61	6.68	NA	18.08
N West								
UKD1	3.24	1.17	1.90	3.27	0.61	7.43	NA	18.83
UKD2	3.24	1.17	1.90	3.27	0.61	7.43	NA	18.83
UKD3	3.24	1.17	1.90	3.27	0.61	7.43	NA	18.83
UKD4	3.24	1.17	1.90	3.27	0.61	7.43	NA	18.83
UKD5	3.24	1.17	1.90	3.27	0.61	7.43	NA	18.83
Yorks								
UKE1	3.24	1.17	1.90	3.27	0.61	6.75	NA	18.07
UKE2	3.24	1.17	1.90	3.27	0.61	6.75	NA	18.07
UKE3	3.24	1.17	1.90	3.27	0.61	6.75	NA	18.07
UKE4	3.24	1.17	1.90	3.27	0.61	6.75	NA	18.07
E Mids								
UKF1	3.24	1.17	1.90	3.27	0.61	5.33	NA	16.65
UKF2	3.24	1.17	1.90	3.27	0.61	5.33	NA	16.65
UKF3	3.24	1.17	1.90	3.27	0.61	5.33	NA	16.65
W Mids								
UKG1	3.24	1.17	1.90	3.27	0.61	7.55	NA	18.86
UKG2	3.24	1.17	1.90	3.27	0.61	7.55	NA	18.86
UKG3	3.24	1.17	1.90	3.27	0.61	7.55	NA	18.86
Eastern								
UKH1	3.24	1.17	1.90	3.27	0.61	6.20	NA	17.52
UKH2	3.24	1.17	1.90	3.27	0.61	6.20	NA	17.52
UKH3	3.24	1.17	1.90	3.27	0.61	6.20	NA	17.52
S East								
UKJ1	3.24	1.17	1.90	3.27	0.61	7.01	NA	18.33
UKJ2	3.24	1.17	1.90	3.27	0.61	7.01	NA	18.33
UKJ3	3.24	1.17	1.90	3.27	0.61	7.01	NA	18.33
UKJ4	3.24	1.17	1.90	3.27	0.61	7.01	NA	18.33
S West								
UKK1	3.24	1.17	1.90	3.27	0.61	8.61	NA	19.97
UKK2	3.24	1.17	1.90	3.34	0.10	8.61	NA	19.52
UKK3	3.24	1.17	1.90	3.34	0.10	8.61	NA	19.52
UKK4	3.24	1.17	1.90	3.34	0.10	8.61	NA	19.52
Wales								
UKL1	3.27	1.06	1.90	2.99	0.61	8.27	NA	19.34
UKL2	3.27	1.06	1.90	2.99	0.61	8.27	NA	19.34
Scotland								
UKM2	3.24	1.17	1.90	3.27	0.61	6.61	NA	18.01
UKM3	3.24	1.17	1.90	3.27	0.61	6.61	NA	18.01
UKM5	3.24	1.17	1.90	3.27	0.61	6.61	NA	18.01
UKM6	3.24	1.17	1.90	3.27	0.61	6.61	NA	18.01
N Ireland								
N Ireland	3.24	1.17	1.90	3.27	0.61	5.85	NA	17.25
*UK typical	3.24	1.17	1.90	3.27	0.61	5.33	NA	16.65
% of total	19%	7%	11%	20%	4%	32%	NA	

Appendix Table 10. GHG emissions arising from the cultivation of oilseed rape in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	6.16	2.97	2.55	6.61	0.53	4.09	0.05	**23.29**
UKC2	6.16	2.97	2.55	6.61	0.53	4.09	0.05	**23.29**
N West								
UKD1	6.30	3.04	2.55	6.76	0.54	5.13	0.05	**24.72**
UKD2	6.30	3.04	2.55	6.76	0.54	5.13	0.05	**24.72**
UKD3	6.30	3.04	2.55	6.76	0.54	5.13	0.05	**24.72**
UKD4	6.30	3.04	2.55	6.76	0.54	5.13	0.05	**24.72**
UKD5	6.30	3.04	2.55	6.76	0.54	5.13	0.05	**24.72**
Yorks								
UKE1	5.93	2.86	2.55	6.36	0.51	4.06	0.05	**22.63**
UKE2	5.93	2.86	2.55	6.36	0.51	4.06	0.05	**22.63**
UKE3	5.93	2.86	2.55	6.36	0.51	4.06	0.05	**22.63**
UKE4	5.93	2.86	2.55	6.36	0.51	4.06	0.05	**22.63**
E Mids								
UKF1	6.10	2.94	2.55	6.55	0.52	3.66	0.05	**22.70**
UKF2	6.10	2.94	2.55	6.55	0.52	3.66	0.05	**22.70**
UKF3	6.10	2.94	2.55	6.55	0.52	3.66	0.05	**22.70**
W Mids								
UKG1	6.26	3.02	2.55	6.72	0.54	4.77	0.05	**24.26**
UKG2	6.26	3.02	2.55	6.72	0.54	4.77	0.05	**24.26**
UKG3	6.26	3.02	2.55	6.72	0.54	4.77	0.05	**24.26**
Eastern								
UKH1	6.15	2.97	2.55	6.61	0.53	3.49	0.05	**22.68**
UKH2	6.15	2.97	2.55	6.61	0.53	3.49	0.05	**22.68**
UKH3	6.15	2.97	2.55	6.61	0.53	3.49	0.05	**22.68**
S East								
UKJ1	6.56	3.16	2.55	7.04	0.56	4.21	0.05	**24.50**
UKJ2	6.56	3.16	2.55	7.04	0.56	4.21	0.05	**24.50**
UKJ3	6.56	3.16	2.55	7.04	0.56	4.21	0.05	**24.50**
UKJ4	6.56	3.16	2.55	7.04	0.56	4.21	0.05	**24.50**
S West								
UKK1	6.56	3.16	2.55	7.04	0.56	5.40	0.05	**25.70**
UKK2	6.56	3.16	2.55	7.05	0.56	5.40	0.05	**25.70**
UKK3	6.56	3.16	2.55	7.05	0.56	5.40	0.05	**25.70**
UKK4	6.56	3.16	2.55	7.05	0.56	5.40	0.05	**25.70**
Wales								
UKL1	6.29	3.06	2.55	6.81	0.54	5.24	0.05	**24.92**
UKL2	6.29	3.06	2.55	6.81	0.54	5.24	0.05	**24.92**
Scotland								
UKM2	5.54	2.67	2.55	5.94	0.48	4.04	0.04	**21.56**
UKM3	5.54	2.67	2.55	5.94	0.48	4.04	0.04	**21.56**
UKM5	5.54	2.67	2.55	5.94	0.48	4.04	0.04	**21.56**
UKM6	5.54	2.67	2.55	5.94	0.48	4.04	0.04	**21.56**
N Ireland								
N Ireland	6.27	3.02	2.55	6.73	0.54	5.84	0.05	**25.35**
*__UK typical__	6.10	2.94	2.55	6.55	0.52	3.66	0.05	**22.70**
% of total	27%	13%	11%	29%	2%	16%	0%	

Appendix Table 11. GHG emissions arising from the cultivation of sugar beet in the UK regions [g CO_2-eqv./MJ biofuel]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	NA	NA	NA	NA	NA	NA	NA	NA
UKC2	NA	NA	NA	NA	NA	NA	NA	NA
N West								
UKD1	NA	NA	NA	NA	NA	NA	NA	NA
UKD2	NA	NA	NA	NA	NA	NA	NA	NA
UKD3	NA	NA	NA	NA	NA	NA	NA	NA
UKD4	NA	NA	NA	NA	NA	NA	NA	NA
UKD5	NA	NA	NA	NA	NA	NA	NA	NA
Yorks								
UKE1	1.21	0.90	3.03	1.11	0.28	2.61	NA	**9.35**
UKE2	1.21	0.90	3.03	1.11	0.28	2.61	NA	**9.35**
UKE3	1.21	0.90	3.03	1.11	0.28	2.61	NA	**9.35**
UKE4	1.21	0.90	3.03	1.11	0.28	2.61	NA	**9.35**
E Mids								
UKF1	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.16**
UKF2	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.16**
UKF3	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.16**
W Mids								
UKG1	1.21	0.90	3.03	1.11	0.28	2.93	NA	**9.68**
UKG2	NA	NA	NA	NA	NA	NA	NA	NA
UKG3	NA	NA	NA	NA	NA	NA	NA	NA
Eastern								
UKH1	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.15**
UKH2	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.15**
UKH3	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.15**
S East								
UKJ1	NA	NA	NA	NA	NA	NA	NA	NA
UKJ2	NA	NA	NA	NA	NA	NA	NA	NA
UKJ3	NA	NA	NA	NA	NA	NA	NA	NA
UKJ4	NA	NA	NA	NA	NA	NA	NA	NA
S West								
UKK1	NA	NA	NA	NA	NA	NA	NA	NA
UKK2	NA	NA	NA	NA	NA	NA	NA	NA
UKK3	NA	NA	NA	NA	NA	NA	NA	NA
UKK4	NA	NA	NA	NA	NA	NA	NA	NA
Wales								
UKL1	NA	NA	NA	NA	NA	NA	NA	NA
UKL2	NA	NA	NA	NA	NA	NA	NA	NA
Scotland								
UKM2	NA	NA	NA	NA	NA	NA	NA	NA
UKM3	NA	NA	NA	NA	NA	NA	NA	NA
UKM5	NA	NA	NA	NA	NA	NA	NA	NA
UKM6	NA	NA	NA	NA	NA	NA	NA	NA
N Ireland								
N Ireland	NA	NA	NA	NA	NA	NA	NA	NA
***UK typical**	1.21	0.90	3.03	1.11	0.28	2.41	NA	**9.15**
% of total	13%	10%	33%	12%	3%	26%	NA	

Appendix Table 12. GHG emissions arising from the cultivation of winter wheat in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	74.54	28.92	31.35	80.59	8.61	53.29	7.26	290.34
UKC2	74.54	28.92	31.35	80.59	8.61	53.29	7.26	290.34
N West								
UKD1	98.34	38.16	31.35	106.33	11.36	85.75	9.58	388.49
UKD2	98.34	38.16	31.35	106.33	11.36	85.75	9.58	388.49
UKD3	98.34	38.16	31.35	106.33	11.36	85.75	9.58	388.49
UKD4	98.34	38.16	31.35	106.33	11.36	85.75	9.58	388.49
UKD5	98.34	38.16	31.35	106.33	11.36	85.75	9.58	388.49
Yorks								
UKE1	70.39	27.31	31.35	76.10	8.13	50.76	6.25	275.74
UKE2	70.39	27.31	31.35	76.10	8.13	50.76	6.25	275.74
UKE3	70.39	27.31	31.35	76.10	8.13	50.76	6.25	275.74
UKE4	70.39	27.31	31.35	76.10	8.13	50.76	6.25	275.74
E Mids								
UKF1	70.26	27.26	31.35	75.96	8.11	44.81	6.24	269.44
UKF2	70.26	27.26	31.35	75.96	8.11	44.81	6.24	269.44
UKF3	70.26	27.26	31.35	75.96	8.11	44.81	6.24	269.44
W Mids								
UKG1	75.32	29.23	31.35	81.44	8.70	61.30	6.69	299.86
UKG2	75.32	29.23	31.35	81.44	8.70	61.30	6.69	299.86
UKG3	75.32	29.23	31.35	81.44	8.70	61.30	6.69	299.86
Eastern								
UKH1	67.91	26.35	31.35	73.42	7.84	42.71	6.03	260.87
UKH2	67.91	26.35	31.35	73.42	7.84	42.71	6.03	260.87
UKH3	67.91	26.35	31.35	73.42	7.84	42.71	6.03	260.87
S East								
UKJ1	69.19	26.85	31.35	74.81	7.99	49.69	6.15	271.39
UKJ2	69.19	26.85	31.35	74.81	7.99	49.69	6.15	271.39
UKJ3	69.19	26.85	31.35	74.81	7.99	49.69	6.15	271.39
UKJ4	69.19	26.85	31.35	74.81	7.99	49.69	6.15	271.39
S West								
UKK1	76.39	29.64	31.35	82.59	8.82	68.48	7.11	310.29
UKK2	76.39	29.64	31.35	82.33	7.88	68.48	7.11	309.09
UKK3	76.39	29.64	31.35	82.33	7.88	68.48	7.11	309.09
UKK4	76.39	29.64	31.35	82.33	7.88	68.48	7.11	309.09
Wales								
UKL1	79.72	30.86	31.35	86.00	9.21	71.05	7.77	322.39
UKL2	79.72	30.86	31.35	86.00	9.21	71.05	7.77	322.39
Scotland								
UKM2	66.82	25.93	31.35	72.25	7.72	49.51	6.51	265.26
UKM3	66.82	25.93	31.35	72.25	7.72	49.51	6.51	265.26
UKM5	66.82	25.93	31.35	72.25	7.72	49.51	6.51	265.26
UKM6	66.82	25.93	31.35	72.25	7.72	49.51	6.51	265.26
N Ireland								
N Ireland	74.14	28.77	31.35	80.16	8.56	53.76	7.22	289.71
***UK typical**	67.91	26.35	31.35	73.42	7.84	42.71	6.03	260.87
% of total	26%	10%	12%	28%	3%	16%	2%	

Appendix Table 13. GHG emissions arising from the cultivation of winter barley in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	68.65	25.11	30.43	73.93	7.41	66.56	NA	289.40
UKC2	68.65	25.11	30.43	73.93	7.41	66.56	NA	289.40
N West								
UKD1	78.03	28.54	30.43	84.03	8.43	86.69	NA	335.81
UKD2	78.03	28.54	30.43	84.03	8.43	86.69	NA	335.81
UKD3	78.03	28.54	30.43	84.03	8.43	86.69	NA	335.81
UKD4	78.03	28.54	30.43	84.03	8.43	86.69	NA	335.81
UKD5	78.03	28.54	30.43	84.03	8.43	86.69	NA	335.81
Yorks								
UKE1	59.36	21.71	30.43	63.93	6.41	57.77	NA	253.85
UKE2	59.36	21.71	30.43	63.93	6.41	57.77	NA	253.85
UKE3	59.36	21.71	30.43	63.93	6.41	57.77	NA	253.85
UKE4	59.36	21.71	30.43	63.93	6.41	57.77	NA	253.85
E Mids								
UKF1	67.80	24.80	30.43	73.02	7.32	61.01	NA	280.63
UKF2	67.80	24.80	30.43	73.02	7.32	61.01	NA	280.63
UKF3	67.80	24.80	30.43	73.02	7.32	61.01	NA	280.63
W Mids								
UKG1	69.90	25.56	30.43	75.28	7.55	78.84	NA	304.31
UKG2	69.90	25.56	30.43	75.28	7.55	78.84	NA	304.31
UKG3	69.90	25.56	30.43	75.28	7.55	78.84	NA	304.31
Eastern								
UKH1	66.28	24.24	30.43	71.38	7.16	58.09	NA	273.45
UKH2	66.28	24.24	30.43	71.38	7.16	58.09	NA	273.45
UKH3	66.28	24.24	30.43	71.38	7.16	58.09	NA	273.45
S East								
UKJ1	68.17	24.93	30.43	73.42	7.36	65.83	NA	286.49
UKJ2	68.17	24.93	30.43	73.42	7.36	65.83	NA	286.49
UKJ3	68.17	24.93	30.43	73.42	7.36	65.83	NA	286.49
UKJ4	68.17	24.93	30.43	73.42	7.36	65.83	NA	286.49
S West								
UKK1	68.40	25.01	30.43	73.66	7.39	82.44	NA	304.14
UKK2	68.40	25.01	30.43	74.60	7.25	82.44	NA	304.94
UKK3	68.40	25.01	30.43	74.60	7.25	82.44	NA	304.94
UKK4	68.40	25.01	30.43	74.60	7.25	82.44	NA	304.94
Wales								
UKL1	71.06	26.04	30.43	76.66	7.68	87.79	NA	317.90
UKL2	71.06	26.04	30.43	76.66	7.68	87.79	NA	317.90
Scotland								
UKM2	61.00	22.31	30.43	65.69	6.59	58.23	NA	259.62
UKM3	61.00	22.31	30.43	65.69	6.59	58.23	NA	259.62
UKM5	61.00	22.31	30.43	65.69	6.59	58.23	NA	259.62
UKM6	61.00	22.31	30.43	65.69	6.59	58.23	NA	259.62
N Ireland								
N Ireland	62.28	22.78	30.43	67.07	6.73	65.02	NA	204.99
***UK typical**	66.28	24.24	30.43	71.38	7.16	58.09	NA	273.45
% of total	24%	9%	11%	26%	3%	21%	NA	

Appendix Table 14. GHG emissions arising from the cultivation of spring barley in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	60.55	16.85	29.00	61.41	4.73	82.28	NA	281.28
UKC2	60.55	16.85	29.00	61.41	4.73	82.28	NA	281.28
N West								
UKD1	70.54	19.63	29.00	71.54	5.51	105.07	NA	332.12
UKD2	70.54	19.63	29.00	71.54	5.51	105.07	NA	332.12
UKD3	70.54	19.63	29.00	71.54	5.51	105.07	NA	332.12
UKD4	70.54	19.63	29.00	71.54	5.51	105.07	NA	332.12
UKD5	70.54	19.63	29.00	71.54	5.51	105.07	NA	332.12
Yorks								
UKE1	53.36	14.85	29.00	54.12	4.16	72.60	NA	250.48
UKE2	53.36	14.85	29.00	54.12	4.16	72.60	NA	250.48
UKE3	53.36	14.85	29.00	54.12	4.16	72.60	NA	250.48
UKE4	53.36	14.85	29.00	54.12	4.16	72.60	NA	250.48
E Mids								
UKF1	54.30	15.11	29.00	55.07	4.24	68.59	NA	249.11
UKF2	54.30	15.11	29.00	55.07	4.24	68.59	NA	249.11
UKF3	54.30	15.11	29.00	55.07	4.24	68.59	NA	249.11
W Mids								
UKG1	59.81	16.64	29.00	60.66	4.67	91.81	NA	287.71
UKG2	59.81	16.64	29.00	60.66	4.67	91.81	NA	287.71
UKG3	59.81	16.64	29.00	60.66	4.67	91.81	NA	287.71
Eastern								
UKH1	54.62	15.20	29.00	55.40	4.26	66.14	NA	247.54
UKH2	54.62	15.20	29.00	55.40	4.26	66.14	NA	247.54
UKH3	54.62	15.20	29.00	55.40	4.26	66.14	NA	247.54
S East								
UKJ1	53.49	14.88	29.00	54.25	4.17	75.06	NA	253.32
UKJ2	53.49	14.88	29.00	54.25	4.17	75.06	NA	253.32
UKJ3	53.49	14.88	29.00	54.25	4.17	75.06	NA	253.32
UKJ4	53.49	14.88	29.00	54.25	4.17	75.06	NA	253.32
S West								
UKK1	60.45	16.82	29.00	61.31	4.72	100.69	NA	298.88
UKK2	60.45	16.82	29.00	61.66	4.23	100.69	NA	298.75
UKK3	60.45	16.82	29.00	61.66	4.23	100.69	NA	298.75
UKK4	60.45	16.82	29.00	61.66	4.23	100.69	NA	298.75
Wales								
UKL1	62.63	18.07	29.00	65.35	4.90	105.49	NA	313.92
UKL2	62.63	18.07	29.00	65.35	4.90	105.49	NA	313.92
Scotland								
UKM2	54.91	15.28	29.00	55.69	4.29	72.34	NA	255.49
UKM3	54.91	15.28	29.00	55.69	4.29	72.34	NA	255.49
UKM5	54.91	15.28	29.00	55.69	4.29	72.34	NA	255.49
UKM6	54.91	15.28	29.00	55.69	4.29	72.34	NA	255.49
N Ireland								
N Ireland	61.22	17.03	29.00	62.09	4.78	80.08	NA	280.95
***UK typical**	60.45	16.82	29.00	61.31	4.72	100.69	NA	298.88
% of total	344%	96%	165%	349%	27%	573%	NA	

Appendix Table 15. GHG emissions arising from the cultivation of oats in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	51.76	16.67	39.43	54.58	4.63	77.15	NA	264.28
UKC2	51.76	16.67	39.43	54.58	4.63	77.15	NA	264.28
N West								
UKD1	63.08	20.31	39.43	66.52	5.64	104.57	NA	324.00
UKD2	63.08	20.31	39.43	66.52	5.64	104.57	NA	324.00
UKD3	63.08	20.31	39.43	66.52	5.64	104.57	NA	324.00
UKD4	63.08	20.31	39.43	66.52	5.64	104.57	NA	324.00
UKD5	63.08	20.31	39.43	66.52	5.64	104.57	NA	324.00
Yorks								
UKE1	50.37	16.22	39.43	53.12	4.51	69.30	NA	252.46
UKE2	50.37	16.22	39.43	53.12	4.51	69.30	NA	252.46
UKE3	50.37	16.22	39.43	53.12	4.51	69.30	NA	252.46
UKE4	50.37	16.22	39.43	53.12	4.51	69.30	NA	252.46
E Mids								
UKF1	57.13	18.40	39.43	60.25	5.11	75.77	NA	278.22
UKF2	57.13	18.40	39.43	60.25	5.11	75.77	NA	278.22
UKF3	57.13	18.40	39.43	60.25	5.11	75.77	NA	278.22
W Mids								
UKG1	49.89	16.07	39.43	52.61	4.46	82.05	NA	263.83
UKG2	49.89	16.07	39.43	52.61	4.46	82.05	NA	263.83
UKG3	49.89	16.07	39.43	52.61	4.46	82.05	NA	263.83
Eastern								
UKH1	50.92	16.40	39.43	53.71	4.56	64.21	NA	248.95
UKH2	50.92	16.40	39.43	53.71	4.56	64.21	NA	248.95
UKH3	50.92	16.40	39.43	53.71	4.56	64.21	NA	248.95
S East								
UKJ1	52.49	16.90	39.43	55.36	4.70	82.85	NA	272.06
UKJ2	52.49	16.90	39.43	55.36	4.70	82.85	NA	272.06
UKJ3	52.49	16.90	39.43	55.36	4.70	82.85	NA	272.06
UKJ4	52.49	16.90	39.43	55.36	4.70	82.85	NA	272.06
S West								
UKK1	54.21	17.46	39.43	57.17	4.85	104.12	NA	298.25
UKK2	54.21	17.46	39.43	57.17	4.85	104.12	NA	298.25
UKK3	54.21	17.46	39.43	57.17	4.85	104.12	NA	298.25
UKK4	54.21	17.46	39.43	57.17	4.85	104.12	NA	298.25
Wales								
UKL1	56.82	18.18	39.43	59.62	5.08	102.31	NA	303.91
UKL2	56.82	18.18	39.43	59.62	5.08	102.31	NA	303.91
Scotland								
UKM2	47.52	15.30	39.43	50.11	4.25	66.63	NA	241.66
UKM3	47.52	15.30	39.43	50.11	4.25	66.63	NA	241.66
UKM5	47.52	15.30	39.43	50.11	4.25	66.63	NA	241.66
UKM6	47.52	15.30	39.43	50.11	4.25	66.63	NA	241.66
N Ireland								
N Ireland	53.10	17.10	39.43	56.00	4.75	76.77	NA	267.73
***UK typical**	52.49	16.90	39.43	55.36	4.70	82.85	NA	272.06
% of total	19%	6%	14%	20%	2%	30%	NA	

Appendix Table 16. GHG emissions arising from the cultivation of triticale in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	49.56	17.95	29.00	49.99	9.33	102.10	NA	276.63
UKC2	49.56	17.95	29.00	49.99	9.33	102.10	NA	276.63
N West								
UKD1	49.56	17.95	29.00	49.99	9.33	113.54	NA	288.07
UKD2	49.56	17.95	29.00	49.99	9.33	113.54	NA	288.07
UKD3	49.56	17.95	29.00	49.99	9.33	113.54	NA	288.07
UKD4	49.56	17.95	29.00	49.99	9.33	113.54	NA	288.07
UKD5	49.56	17.95	29.00	49.99	9.33	113.54	NA	288.07
Yorks								
UKE1	49.56	17.95	29.00	49.99	9.33	103.14	NA	276.42
UKE2	49.56	17.95	29.00	49.99	9.33	103.14	NA	276.42
UKE3	49.56	17.95	29.00	49.99	9.33	103.14	NA	276.42
UKE4	49.56	17.95	29.00	49.99	9.33	103.14	NA	276.42
E Mids								
UKF1	49.56	17.95	29.00	49.99	9.33	81.49	NA	254.76
UKF2	49.56	17.95	29.00	49.99	9.33	81.49	NA	254.76
UKF3	49.56	17.95	29.00	49.99	9.33	81.49	NA	254.76
W Mids								
UKG1	49.56	17.95	29.00	49.99	9.33	115.33	NA	288.61
UKG2	49.56	17.95	29.00	49.99	9.33	115.33	NA	288.61
UKG3	49.56	17.95	29.00	49.99	9.33	115.33	NA	288.61
Eastern								
UKH1	49.56	17.95	29.00	49.99	9.33	94.74	NA	268.01
UKH2	49.56	17.95	29.00	49.99	9.33	94.74	NA	268.01
UKH3	49.56	17.95	29.00	49.99	9.33	94.74	NA	268.01
S East								
UKJ1	49.56	17.95	29.00	49.99	9.33	107.10	NA	280.38
UKJ2	49.56	17.95	29.00	49.99	9.33	107.10	NA	280.38
UKJ3	49.56	17.95	29.00	49.99	9.33	107.10	NA	280.38
UKJ4	49.56	17.95	29.00	49.99	9.33	107.10	NA	280.38
S West								
UKK1	49.56	17.95	29.00	49.99	9.33	131.54	NA	305.43
UKK2	49.56	17.95	29.00	50.98	1.52	131.54	NA	298.60
UKK3	49.56	17.95	29.00	50.98	1.52	131.54	NA	298.60
UKK4	49.56	17.95	29.00	50.98	1.52	131.54	NA	298.60
Wales								
UKL1	49.88	16.24	29.00	45.69	9.33	126.32	NA	295.92
UKL2	49.88	16.24	29.00	45.69	9.33	126.32	NA	295.92
Scotland								
UKM2	49.56	17.95	29.00	49.99	9.33	101.05	NA	275.58
UKM3	49.56	17.95	29.00	49.99	9.33	101.05	NA	275.58
UKM5	49.56	17.95	29.00	49.99	9.33	101.05	NA	275.58
UKM6	49.56	17.95	29.00	49.99	9.33	101.05	NA	275.58
N Ireland								
N Ireland	49.56	17.95	29.00	49.99	9.33	89.44	NA	263.97
*__UK typical__	49.56	17.95	29.00	49.99	9.33	81.49	NA	254.76
% of total	19%	7%	11%	20%	4%	32%	NA	

Appendix Table 17. GHG emissions arising from the cultivation of oilseed rape in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	166.85	80.48	69.09	179.12	14.34	110.75	1.29	631.21
UKC2	166.85	80.48	69.09	179.12	14.34	110.75	1.29	631.21
N West								
UKD1	170.75	82.37	69.09	183.31	14.68	139.13	1.32	670.15
UKD2	170.75	82.37	69.09	183.31	14.68	139.13	1.32	670.15
UKD3	170.75	82.37	69.09	183.31	14.68	139.13	1.32	670.15
UKD4	170.75	82.37	69.09	183.31	14.68	139.13	1.32	670.15
UKD5	170.75	82.37	69.09	183.31	14.68	139.13	1.32	670.15
Yorks								
UKE1	160.62	77.48	69.09	172.43	13.81	109.93	1.24	613.53
UKE2	160.62	77.48	69.09	172.43	13.81	109.93	1.24	613.53
UKE3	160.62	77.48	69.09	172.43	13.81	109.93	1.24	613.53
UKE4	160.62	77.48	69.09	172.43	13.81	109.93	1.24	613.53
E Mids								
UKF1	165.28	79.73	69.09	177.43	14.21	99.11	1.28	615.31
UKF2	165.28	79.73	69.09	177.43	14.21	99.11	1.28	615.31
UKF3	165.28	79.73	69.09	177.43	14.21	99.11	1.28	615.31
W Mids								
UKG1	169.76	81.89	69.09	182.25	14.59	129.22	1.31	657.56
UKG2	169.76	81.89	69.09	182.25	14.59	129.22	1.31	657.56
UKG3	169.76	81.89	69.09	182.25	14.59	129.22	1.31	657.56
Eastern								
UKH1	166.80	80.46	69.09	179.07	14.34	94.49	1.29	614.82
UKH2	166.80	80.46	69.09	179.07	14.34	94.49	1.29	614.82
UKH3	166.80	80.46	69.09	179.07	14.34	94.49	1.29	614.82
S East								
UKJ1	177.83	85.78	69.09	190.91	15.29	114.04	1.37	664.21
UKJ2	177.83	85.78	69.09	190.91	15.29	114.04	1.37	664.21
UKJ3	177.83	85.78	69.09	190.91	15.29	114.04	1.37	664.21
UKJ4	177.83	85.78	69.09	190.91	15.29	114.04	1.37	664.21
S West								
UKK1	177.82	85.78	69.09	190.90	15.29	146.49	1.37	696.64
UKK2	177.82	85.78	69.09	191.01	15.29	146.49	1.37	696.75
UKK3	177.82	85.78	69.09	191.01	15.29	146.49	1.37	696.75
UKK4	177.82	85.78	69.09	191.01	15.29	146.49	1.37	696.75
Wales								
UKL1	170.51	82.87	69.09	184.50	14.66	142.17	1.32	675.44
UKL2	170.51	82.87	69.09	184.50	14.66	142.17	1.32	675.44
Scotland								
UKM2	150.04	72.37	69.09	161.07	12.90	109.55	1.16	584.53
UKM3	150.04	72.37	69.09	161.07	12.90	109.55	1.16	584.53
UKM5	150.04	72.37	69.09	161.07	12.90	109.55	1.16	584.53
UKM6	150.04	72.37	69.09	161.07	12.90	109.55	1.16	584.53
N Ireland								
N Ireland	169.98	81.99	69.09	182.48	14.61	158.28	1.31	687.20
UK typical**	165.28	79.73	69.09	177.43	14.21	99.11	1.28	615.31
% of total	27%	13%	11%	29%	2%	16%	0%	

Appendix Table 18. GHG emissions arising from the cultivation of sugar beet in the UK regions [kg CO_2-eqv./tonne dry feedstock]

	Soil N_2O emissions		Crop Residues	Manufacturing emissions		Machinery fuel use	Seed	Total
Region	Direct	Indirect		Fertiliser	Pesticide			
N East								
UKC1	NA	NA	NA	NA	NA	NA	NA	NA
UKC2	NA	NA	NA	NA	NA	NA	NA	NA
N West								
UKD1	NA	NA	NA	NA	NA	NA	NA	NA
UKD2	NA	NA	NA	NA	NA	NA	NA	NA
UKD3	NA	NA	NA	NA	NA	NA	NA	NA
UKD4	NA	NA	NA	NA	NA	NA	NA	NA
UKD5	NA	NA	NA	NA	NA	NA	NA	NA
Yorks								
UKE1	15.06	11.25	37.67	13.81	3.54	32.38	NA	117.00
UKE2	15.06	11.25	37.67	13.81	3.54	32.38	NA	117.00
UKE3	15.06	11.25	37.67	13.81	3.54	32.38	NA	117.00
UKE4	15.06	11.25	37.67	13.81	3.54	32.38	NA	117.00
E Mids								
UKF1	15.06	11.25	37.67	13.81	3.54	30.01	NA	114.63
UKF2	15.06	11.25	37.67	13.81	3.54	30.01	NA	114.63
UKF3	15.06	11.25	37.67	13.81	3.54	30.01	NA	114.63
W Mids								
UKG1	15.06	11.25	37.67	13.81	3.54	36.40	NA	121.02
UKG2	NA	NA	NA	NA	NA	NA	NA	NA
UKG3	NA	NA	NA	NA	NA	NA	NA	NA
Eastern								
UKH1	15.06	11.25	37.67	13.81	3.54	29.90	NA	114.52
UKH2	15.06	11.25	37.67	13.81	3.54	29.90	NA	114.52
UKH3	15.06	11.25	37.67	13.81	3.54	29.90	NA	114.52
S East								
UKJ1	NA	NA	NA	NA	NA	NA	NA	NA
UKJ2	NA	NA	NA	NA	NA	NA	NA	NA
UKJ3	NA	NA	NA	NA	NA	NA	NA	NA
UKJ4	NA	NA	NA	NA	NA	NA	NA	NA
S West								
UKK1	NA	NA	NA	NA	NA	NA	NA	NA
UKK2	NA	NA	NA	NA	NA	NA	NA	NA
UKK3	NA	NA	NA	NA	NA	NA	NA	NA
UKK4	NA	NA	NA	NA	NA	NA	NA	NA
Wales								
UKL1	NA	NA	NA	NA	NA	NA	NA	NA
UKL2	NA	NA	NA	NA	NA	NA	NA	NA
Scotland								
UKM2	NA	NA	NA	NA	NA	NA	NA	NA
UKM3	NA	NA	NA	NA	NA	NA	NA	NA
UKM5	NA	NA	NA	NA	NA	NA	NA	NA
UKM6	NA	NA	NA	NA	NA	NA	NA	NA
N Ireland								
N Ireland	NA	NA	NA	NA	NA	NA	NA	NA
***UK typical**	15.06	11.25	37.67	13.81	3.54	29.90	NA	114.52
% of total	13%	10%	33%	12%	3%	26%	NA	

Appendix 2

Overview of changes made to UK NUTS2 report

The report *Emissions from Biofuels Cultivation: A report prepared for the Department for Transport* was originally completed on 12 March 2010 and submitted to the European Commission to satisfy the requirements of Article 19(2). It was revised following feedback received from the European Commission, and re-submitted on 15 December 2010. The revised version was accepted by the Commission in March 2011.

This report was subsequently updated in 2012, to make the following revisions:

- Updated the 5-year average yield data for all crops. Updated to 2007–2011, from Government national statistics, including the proportion of whole crop wheat; and sugar beet yields from British Sugar.
- Updated the oil content of oilseed rape in line with 5-year average. Updated to 2007–2011 average, from UK oilseed industry data; adjusted the lower heating value/net calorific value of rapeseed accordingly.
- Updated nitrogen, phosphorus, potassium and lime fertiliser use and pesticide use data to 3-year average. Updated to 2007-2011 average, to align with 5-year average yields and 5-year average oil content; previous report used a single year's data.
- Update of fuel consumption figures from Nix Pocket Handbook (2011) and including adjustment for the proportion applied between ploughing and min-till systems using data collated from Defra and Scottish Government surveys.
- Adjusted methodological approach to align with the IPCC guidelines for soil organic content, such that soils should have an organic carbon content of 20% or more by weight before applying the RED default emission factor for cultivation. The previously used threshold of 12% organic carbon content applies only to soils that are either less than 10 cm in horizon depth, or subject to water saturation episodes (FAO (1998) World Reference Base for Soil Resources. World Soil Resources Reports 84. FAO, Rome. 88pp).
- Updated the nitrogen content of residues returned/incorporated in to soils. Information from published literature used in line with JRC methodology.
- Update of transport losses for oilseed rape and wheat, with data from industry.

In this current version of the report the following updates have been made:

- Updated the Emission Factor for nitrogen additions from mineral fertilisers, organic amendments and crop residues, and nitrogen mineralised from mineral soil as a result of loss of soil carbon. The UK averages for Urea and Other N fertilisers taken from the National Atmospheric Emissions Inventory have been applied.
- The application of organic fertilisers to UK crops and the associated emissions have now been taken into account using 3 year average data from the BSFP 2013, 2014 & 2015 and incorporated pro-rata within reported overall nitrogen use.

- 3 year average UK data for urea / AN shares of Nitrogen fertiliser for each crop used.
- Most recent fertiliser emission factors used (AN, urea, P, K and L)
- Other emission factors updated – pesticides, seeding materials, and diesel
- Average oil content of oilseed rape updated – Average UK oil content was previously 43.9%, now 44.62%
- Crop yield data (2013–2015 averages) applied for wheat, winter barley, spring barley, oats, triticale, OSR, sugar beet
- 3 year average N fertiliser application rates used (BSFP, 2013, 2014 & 2015)
- Updated the most recent data on phosphorus, potassium, lime and pesticide application rates. In previous editions the lime fertiliser use was not input for several crops, now included for all crops where it is used (BSFP, 2013, 2014 & 2015)

Appendix 3

Emission factor for nitrogen additions from mineral fertilisers

Appendix Table 19 derivation of emission factor for nitrogen additions from mineral fertilisers

Fertiliser Type	Direct Nitrous Oxide [kg N_2O-N]	Total N in Fertiliser Applied [kg]	EF on "as N" basis	EF on "as N_2O" basis
Urea	624295.3784	145115699.3904	0.004302053	0.006760368
Urea Ammonium Nitrate	390018.1619	91157880.9800	0.004278491	0.006723343
Ammonium Nitrate	2286787.891	357300063.8401	0.006400189	0.01005744
Ammonium Sulphate - Diammonium Phosphate	92549.71996	14388196.5711	0.006432336	0.010107957
Calcium Ammonium Nitrate	94708.36838	13320261.5858	0.007110098	0.011173012
Other Nitrogen including Compound Blends	444393.8805	65009910.1149	0.006835787	0.010741951

Fertiliser Group	Direct Nitrous Oxide (kg N_2O-N)	Total N in Fertiliser Applied [kg]	EF on "as N" basis
U/UAN	1014313.54	236273580.3705	**0.004292962**
Other	2918439.86	450018432.1119	**0.006485156**

Reference: UK NAEI (2018) *UK National Atmospheric Emissions Inventory, 1990 to 2018*