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Preface

The analysis presented in this report was financially supported by the 'Helpdesk Agroketens en Visserij' on request of Mr. J.W.J. van Esch of the Dutch Ministry of Economic Affairs, Agriculture and Innovation ('kennisvraag' AKV-114, dated 30-08-2010).

Summary

The EC Renewable Energy Directive (RED; EC, 2009) involves national reports on the average greenhouse gas (GHG) emissions caused by the production of energy crops on NUTS-2 regional level. These emissions should not exceed the RED default value, expressed in g CO_2-eq emitted per MJ biofuel produced, for the production to be considered accountable to the EU biofuel targets. The default values are based on the CONCAWE/EUCAR/JRC-IES 'Well to Wheels' study (WtW, Edwards *et al.*, 2006). Calculation methods for the reporting are not prescribed and hence, differences in emissions reported are not only caused by differences in production systems and conditions, but also by differences in calculation methodology. Differences in reported emissions, caused by different methods, could lead to improper judgement of the acceptability of the energy crop production. To clarify this uncertainty, and to judge whether a reshape of the calculations could be justified, a number of NUTS-2 reports were analysed.

The report of the Netherlands was compared with the reports of Germany, Denmark, Sweden, United Kingdom, Belgium (Flanders) and France. The analysis included all four crops reported by the Netherlands: winter wheat, winter rapeseed, grain maize and sugar beet. Purpose was to review the methods and data used by individual countries and to evaluate the reported differences in emissions. This evaluation should provide insight in to what extent differences in used methodology are responsible for the differences in emissions and how the use of a 'level playing field' methodology would alter the reported differences in emissions.

Although the methodology to be used for the calculation of GHG emissions from energy crop production is not prescribed in detail in the RED, the basis of the calculations is clear. All relevant inputs, N, P, K and Ca fertilisers, diesel, seeds, plant protection agents and energy for drying, must be quantified in units per hectare and multiplied with an emission factor expressed in kg CO_2-eq per unit applied. Methods for data sampling and establishing emission factors, however, are not prescribed. For the calculation of the field emissions of N_2O no single general accepted method is available and largely different methods are used. The sum of emissions results in a total emission per hectare and this is converted into a net emission allocated per unit biofuel.

Reported GHG emissions

The total GHG emission resulting from the production of energy crops shows significant differences between countries (Figure 2.1). Differences between countries are generally larger than the differences between regions within countries. Regional differences are large in the United Kingdom and France and remarkably small in Germany. The average value for wheat from the Netherlands is the only one exceeding the RED default value. Furthermore the default value is exceeded in a few regions for wheat in France and for wheat and rapeseed in the United Kingdom. The Netherlands reports the highest value for corn and more or less average values for rapeseed and sugar beet.

In the analysis the total emissions have been divided into four main components: i.e. N_2O field emissions, nitrogen fertiliser application, diesel use and 'other' sources (Figure 2.2). Obviously, differences between countries here are much larger in comparison to the total emissions as high values for one component are often compensated by low values for another. In most countries and crops the order from high to low contribution to total GHG emission is: (1) N_2O, (2) fertilizer N, (3) diesel and (4) other, with as average contributions respectively 46, 30, 15 and 9%. For the Netherlands the values for N_2O emission and diesel use are relatively high and values for fertiliser nitrogen are low.

- *National average GHG emissions from the cultivation of biofuel crops are lower than the RED default values, except for wheat in the Netherlands. Emissions from the production of wheat or rapeseed are also higher for some minor production regions in the United Kingdom and France.*
- *The GHG emissions related to N_2O field emissions and fertilizer nitrogen on average explain 76% of the total reported emissions.*

N_2O

The N_2O emissions show very large differences between countries (Figure 2.3), primarily caused by large differences in the methodology of calculating N_2O emissions in the NUTS-2 reports. Three types of calculation method were used: the 'IPCC-2006' method (IPCC, 2006), the model of Stehfest & Bouwman (2006) and methods based on the WtW European average values, as used in the BioGrace tool (version 2; BioGrace, 2010).

Besides principally different methods, the different countries used different approaches within the same method. Every country has added or omitted aspects to arrive at a 'local' version of the original methodology. Important differences within IPCC based methods are a 20% decrease of the N_2O emission in order to be more comparable with the WtW values by the Netherlands and using lower N inputs with crop residues, accounting for advised fertiliser rather than statistical N levels and using a correction for a reference vegetation by Denmark and Sweden. The United Kingdom is the only country using the Stehfest & Bouwman model which considers the total N input from fertilisers and manure, while the report only takes fertiliser N input into account. Regarding the WtW values based methods, Belgium uses emission factors per kg fertiliser N neglecting the effects of manure N applications and Germany has estimated its fertiliser N application only with crop nitrogen removal by harvest. France used the average European emission per ha while yields and N inputs in France can be higher than the average European yields that comply with the average emissons.

To provide a 'level playing field' for all countries it seems useful to follow the recommendation in the report of the Netherlands for the EC to decide on the use of one common method to determine N_2O field emissions. For the short term, an IPCC-2006 based method is preferred, because it can be more easily applied and other reporting activities also use IPCC methodologies (national reporting on total GHG emissions). A number of reports concluded that using detailed process models that include effects of soil and weather conditions was not yet possible in a reliable way, but regarded it as a promising future option.

- *The large variation in field emissions of N_2O is mainly caused by the use and interpretation of calculation methods. This causes a different 'playing field' for farmers of (neighbouring) EU countries. Differences in the level of nitrogen inputs are another cause of variation.*
- *None of the countries of this report have used a methodology to assess the actual N_2O emissions per unit biofuel: methods were adapted, resulting in lower values in comparison with standard methodologies.*
- *An EC decision on the use of one common method to determine N_2O field emissions is recommended. Given the current science with respect to detailed process models, the more simple approach of emission factors of the IPCC-2006 guidelines is preferred.*

Fertiliser N

The emission from the production and distribution of chemical fertiliser N applied per crop depends on the efficiency of nitrogen use (expressed as kg fertiliser N applied per ton dry matter production harvested, Figure 2.5) and on the emission factor (expressed as kg CO_2-eq per kg fertiliser N, Figure 2.4). Both values show a large variation and can be explained by (i) different fertiliser needs per crop, (ii) different amounts of manure applied by which chemical fertiliser can be substituted, (iii) used data source for estimating the fertilizer use (e.g. statistical data, advised levels or (under)estimated by harvested crop nitrogen values) and (iv) different efficiencies of the fertiliser plants from which farmers purchase their fertilizers.

The emission factor can be very different, depending on the individual production plants. The BioGrace reference value is 5.92 kg CO_2-eq kg^{-1} N, Jensssen & Kongshaug (2003) estimated the average European value on 5.29 and the minimum value, using 'best available techniques', on 2.45 kg CO_2-eq kg^{-1} N. Germany, Belgium and France used values close to the reference while the Netherlands, Sweden and UK used values close to 'BAT', referring to specific production plants. Denmark used an intermediate value. The very low value reported for the Netherlands is valid for major production plants in the Netherlands, however, it was not reported to what extent fertilisers from other production plants are used in the Netherlands.

The effect of the emission factor on the total emission is large: for wheat the difference in emission calculated with the standard factor and the 'BAT' factor is on average for the reports analysed 5.5 kg CO_2-eq MJ^{-1} biofuel on a default value of 23. Differences for other crops are in the same order.

- *GHG emissions from production of fertiliser nitrogen show a large variation with respect to level of application and to the emission factor used.*
- *The level of application should be taken from agricultural statistics and not taken from advised application levels or estimated by nitrogen removal with harvested crop products. The choice of the emission factor should be motivated with supporting data on the origin of the fertilisers used.*
- *Differences in the emission factor of fertiliser nitrogen have a large impact on the total emission.*

Diesel use

The emission from the use of diesel for tractors and farm machines depends on the efficiency of diesel use (expressed as litres diesel used per ton dry matter production harvested, Figure 2.7) and on the emission factor (expressed as kg CO_2-eq per liter diesel used). Diesel use shows a large variation, contrary to the emission factor which varies only little. The diesel use for the seed crops in the Netherlands is remarkably high with no explanation, whereas Denmark and Sweden generally have low levels of diesel use, probably due to less intensive soil tillage.

Generally the figures for diesel use are lower than the BioGrace reference values; the main reason for this difference is a higher yield level compared with the European average, resulting in a lower diesel use per ton of harvested product because the major part of diesel use is related to the cultivated area rather than to crop harvesting activities.

- *The emission from diesel use is variable, but only with respect to input volumes and not to the emission factor. Different crop yields are an important cause of differences in diesel use per unit harvested product.*
- *The quantity of diesel used per ha in the Netherlands for the production of wheat, rapeseed and corn is remarkably high.*

Other sources

GHG emission from other sources includes a number of minor items causing GHG emission: non-nitrogen fertilisers, seeds, plant protection agents and drying of rapeseed. Differences between countries exist but are generally of minor importance.

- *Emissions from 'other' inputs show minor variations. Application of nutrients (P, K, Ca) to a crop rotation rather than to individual crops is an important cause of variation.*

Conversion and allocation

After the production of the agricultural feedstock for biofuel production two more factors can have an effect on the GHG emission per unit biofuel energy: the conversion factor and the allocation factor (Figure 2.9). The conversion factor is a measure of the amount of biofuel energy that is produced per unit agricultural product and the allocation factor depicts the division of the GHG emission over the biofuel and its co-products (DDGS, beet pulp, rape meal) produced. The conversion factor and allocation factor are related: a higher production of biofuel from a unit agricultural product will result in less co-product and hence, a higher conversion factor should coincide with a higher allocation factor, with a compensating effect on the GHG emission per unit biofuel as a result.

The differences in reported conversion and allocation factors are small but can be significant in relation with the RED default values. Most reports do use standard factors as presented in BioGrace but sometimes higher or lower conversion and allocation factors are reported. In some cases high values for both factors could compensate each other but in others they do not. Underestimation of the GHG emission per unit biofuel energy is to be expected for wheat (Belgium) and rapeseed (Denmark, Sweden, Belgium and France), overestimation for wheat (France) and corn

(France). The probable overestimation of the GHG emission from wheat production in France even seems to be the cause of the regional exceeding of the default value: using the standard values for conversion and allocation would result in a decrease of the maximum regional value of 24 g CO_2-eq MJ^{-1} to a value lower than the default.

- *The differences in reported conversion and allocation factors are small but can be significant in relation to the RED default values. Using standard values would decrease the maximum regional value of wheat from France to below the RED default value.*

Additional calculations

In an additional calculation the values for yields and inputs from the NUTS-2 reports were used as input for the BioGrace tool (version 2 ; BioGrace, 2010). When compared with the total emissions from the NUTS-2 reports it is obvious that an appreciable number of figures is higher (Figure 3.1). As a result, more values exceed the RED default values. Besides the average emission for wheat in the Netherlands also the average values for wheat in Germany and for rapeseed in the Netherlands, Denmark, Sweden, the United Kingdom and France now exceed the default values. The Dutch value for corn is not longer the highest but much more average. When the total emissions of the additional calculations are divided into the four main components mentioned before and are compared with the figures from the NUTS-2 reports, large differences can be seen in N_2O emission and in emission from fertiliser nitrogen, emission from diesel use and from other sources are comparable (Figure 3.2).

In the calculation of the RED default value, for each crop an average N_2O emission, based on detailed calculations from the WtW study, is used. In the BioGrace tool (version 2) the average N_2O emission is given as proportional to the crop yield[1]. This was used in our calculations and results in a constant emission per unit biofuel produced, irrespective of differences in production management or conditions. This approach can yield very different results in comparison to methods where the emission is proportional to nitrogen inputs, like the IPCC-2006 methodology. Scientifically, the processes that cause N_2O field emissions can best be related to the nitrogen inputs rather than crop yield, a.o. due to the curvi-linear response of crops to fertilization.

The increase of the emission from fertiliser N for most countries is a result of using the standard BioGrace emission factor instead of a 'national' factor. Due to the use of a standard emission factor, the differences found here are proportional to the differences in fertiliser nitrogen use as shown in Figure 2.5.

- *If the BioGrace tool (version 2) would be used in the calculations, the RED default emission values would be exceeded in much more regions than presently is reported.*

- *An approach to determine N_2O as proportional to crop yields is not adequate to assess the actual variation of N_2O emissions in Europe related to crop cultivation.*

Note 1: In the more recent version of BioGrace (version 3) the field N_2O emission is given in kg ha^{-1} y^{-1}.
In version 4 a calculation tool will be included to determine the emission of N_2O by using the IPCC-2006 tier 1 methodology (pers. comm. John Neeft, AgentschapNL).

Samenvatting

De EC 'Hernieuwbare Energie Directive' (RED; EC, 2009) vraagt nationale rapportages over de gemiddelde broeikasgas (BKG) emissies van de teelt van energiegewassen op NUTS-2 regionaal niveau. Deze emissies mogen de RED default waarden, uitgedrukt in g CO_2-eq emissie per MJ geproduceerde biobrandstof niet overschrijden om mee te kunnen tellen voor de EU biobrandstof doelstellingen. De default waarden zijn gebaseerd op de CONCAWE/EUCAR/JRC-IES 'Well to Wheels' studie (WtW, Edwards *et al.*, 2006). Berekeningsmethoden voor de rapportage zijn niet voorgeschreven en daarom kunnen verschillen in gerapporteerde emissies niet alleen veroorzaakt worden door verschillen in productie systemen en omstandigheden, maar ook door verschillen in berekeningsmethoden. Verschillen in gerapporteerde emissies, veroorzaakt door verschil in gehanteerde methodiek, kunnen leiden tot een onjuist oordeel over de aanvaardbaarheid van de productie van energiegewassen. Om deze onzekerheid op te helderen, en te kunnen beoordelen of de berekeningen goed vergelijkbaar zijn, is een aantal NUTS-2 rapportages geanalyseerd.

De rapportage van Nederland is vergeleken met de rapportages van Duitsland, Denemarken, Zweden, Groot Brittannië, België (Vlaanderen) en Frankrijk. De analyse omvatte alle vier gewassen waarvoor Nederland gerapporteerd heeft: wintertarwe, winterkoolzaad, korrelmaïs en suikerbiet. Doel van de analyse was een overzicht te geven van de door individuele landen gebruikte methoden en data en de gerapporteerde verschillen in emissies te evalueren. Deze evaluatie moet inzichtelijk maken in hoeverre verschillen in gebruikte methodologie verantwoordelijk zijn voor de verschillen in gerapporteerde emissies en hoe het toepassen van een 'level playing field' methodologie de gerapporteerde verschillen in emissie zou veranderen.

Hoewel de te gebruiken methodologie voor het berekenen van de BKG emissies van de teelt van energiegewassen niet in detail voorgeschreven is in de RED, is de basis van de berekeningen duidelijk. Alle relevante inputs, N, P, K and Ca kunstmeststoffen, diesel, zaden, gewasbeschermingsmiddelen en energie voor drogen, worden gekwantificeerd in eenheden per hectare en vermenigvuldigd met een emissiefactor uitgedrukt in kg CO_2-eq per eenheid. Methoden voor het verzamelen van gegevens en het vaststellen van emissiefactoren zijn echter niet voorgeschreven. Voor het berekenen van de emissie van N_2O uit de bodem is niet een eenduidige algemeen geaccepteerde methode beschikbaar en worden sterk verschillende methoden gebruikt. Optellen van de verschillende emissies resulteert in een totale emissie per hectare en deze wordt omgerekend naar een netto gealloceerde emissie per eenheid geproduceerde biobrandstof.

Gerapporteerde BKG emissies

De gerapporteerde totale BKG emissies zijn significant verschillend tussen landen (Figuur 2.1). Verschillen tussen landen zijn in het algemeen groter dan de verschillen tussen regio's binnen landen. Regionale verschillen zijn groot in Groot Brittannië en Frankrijk en opvallend klein in Duitsland. De gemiddelde waarde voor tarwe uit Nederland is de enige gemiddelde waarde die de RED default waarde overschrijdt. Verder wordt de default waarde overschreden in enkele regio's voor tarwe in Frankrijk en voor tarwe en koolzaad in Groot Brittannië. Nederland rapporteert de hoogste waarde voor korrelmaïs en gemiddelde waarden voor koolzaad en suikerbiet.

In de analyse is de totale emissie verdeeld in vier componenten: N_2O, kunstmest N, diesel en 'andere' bronnen (Figuur 2.2). De verschillen tussen landen zijn hier duidelijk veel groter vergeleken met de totale waarden omdat een hoge waarde voor één component vaak gecompenseerd wordt door een lage waarde voor een andere. Voor de meeste landen en gewassen is de volgorde in de totale emissie: (1) N_2O, (2) kunstmest N, (3) diesel and (4) 'andere' met als gemiddelde aandelen respectievelijk 46, 30, 15 en 9%. Voor Nederland zijn de waarden vergeleken met andere landen voor N_2O emissie en verbruik van diesel hoog en de waarden voor kunstmest N laag.

- *Nationaal gemiddelde waarden van BKG emissies veroorzaakt door de teelt van energiegewassen zijn lager dan de default waarden, behalve voor tarwe in Nederland. Emissies voor tarwe of koolzaad zijn ook hoger voor enkele minder belangrijke productiegebieden in Groot Brittannië en Frankrijk.*
- *De BKG emissies van N_2O uit de bodem en kunstmest N samen verklaren gemiddeld 76% van de totale gerapporteerde emissies.*

N_2O

De N_2O emissies vertonen zeer grote verschillen tussen landen (Figuur 2.3), deze zijn in de eerste plaats veroorzaakt door grote verschillen in de gebruikte methodologie voor het berekenen van de N_2O emissies in de NUTS-2 rapporten. Drie typen berekeningsmethoden zijn gebruikt: de 'IPCC-2006' methodiek (IPCC, 2006), het model van Stehfest & Bouwman (2006) en methoden gebaseerd op de WtW Europese gemiddelde waarden zoals gebruikt in het BioGrace rekenprogramma (BioGrace, 2010).

Behalve principieel verschillende methoden hebben verschillende landen ook verschillende benaderingen binnen die methoden gevolgd. Ieder land heeft aspecten toegevoegd of weggelaten om te komen tot een 'locale' versie van de originele methodologie. Belangrijke verschillen binnen de op IPCC-2006 gebaseerde methoden zijn een 20% reductie van de N_2O emissie met als doel een betere vergelijkbaarheid met de WtW waarden te krijgen door Nederland en het gebruiken van lagere N inputs met gewasresten, het gebruiken van adviesniveaus van N bemesting in plaats van statistische gegevens en het toepassen van een correctie voor een referentie vegetatie door Denemarken en Zweden. Groot Brittannië is het enige land dat het model van Stehfest & Bouwman gebruikt. Dit model gebruikt de totale N aanvoer uit kunstmest en dierlijke mest als input terwijl het NUTS-2 rapport alleen rekening houdt met kunstmest N. Wat betreft de op de WtW waarden gebaseerde methoden gebruikt België emissiefactoren per kg kunstmest N en negeert daarmee de toepassing van dierlijke mest en heeft Duitsland het gebruik van kunstmest N geschat met alleen de afvoer van N met het gewas. Frankrijk gebruikt de gemiddelde Europese emissie per hectare terwijl de opbrengsten en N niveaus in Frankrijk hoger kunnen zijn dan de gemiddelde Europese niveaus die horen bij die gemiddelde emissies.

Om een 'level playing field' voor alle landen te garanderen lijkt het nuttig de aanbeveling in het NUTS-2 rapport van Nederland aan de EC het gebruiken van één gezamenlijke methode voor de bepaling van de N_2O emissies uit de bodem voor te schrijven te volgen. Voor de korte termijn is dat bij voorkeur een op de IPCC-2006 systematiek gebaseerde methode, omdat deze eenvoudig overal toegepast kan worden en andere rapportages, zoals de nationale rapportage van totale BKG emissies, ook gebruik maken van de IPCC-2006 methodologie. Een aantal NUTS-2 rapporten concludeert dat het gebruiken van gedetailleerde procesmodellen die rekening houden met de effecten van bodem en weersomstandigheden nog niet op een betrouwbare manier mogelijk was, maar dat dit wel mogelijkheden voor de toekomst biedt.

- *De grote variatie in emissies van N_2O uit de bodem wordt in de eerste plaats veroorzaakt door het gebruiken van verschillende berekeningsmethoden en verschillende interpretaties van deze methoden. Gevolg is het ontbreken van een 'level playing field' voor boeren in EU (buur)landen. Verschillen in het N bemestingsniveau zijn een andere oorzaak van variatie*
- *Geen van de landen uit dit rapport heeft een methodologie gebruikt gericht op het bepalen van de werkelijke emissie van N_2O: alle methoden zijn aangepast met als resultaat lagere emissies.*
- *Een EC besluit over het gebruiken van één gezamenlijke methode voor de bepaling van de N_2O emissies uit de bodem is aanbevolen. Bij de huidige stand van de kennis over gedetailleerde procesmodellen is een simpeler benadering met de standaard emissiefactoren van de IPCC-2006 richtlijnen aan te bevelen.*

Kunstmest N

De emissie van de productie en distributie van kunstmest N toegediend per gewas is afhankelijk van de efficiency waarmee N wordt gebruikt door het gewas (uitgedrukt als kg kunstmest N toegediend per ton droge stof geoogst product, Figuur 2.5) en van de emissiefactor (uitgedrukt als kg CO_2-eq per kg kunstmest N, Figuur 2.4). Beide getallen hebben een grote spreiding die kan worden verklaard door (i) verschillende bemestingsbehoefte per gewas, (ii) verschillende niveaus van dierlijke mest die kunstmest kan vervangen, (iii) gebruikte bronnen voor schatting van het niveau van kunstmest N gebruik (bv. statistisch gegevens, advies niveaus of afgeleid van de gehalten in geoogste producten) en (iv) verschil in efficiency van kunstmestfabrieken die landen bevoorraden.

De emissiefactor kan sterk verschillen per individuele kunstmestfabriek. De BioGrace referentie waarde is 5.92 kg CO_2-eq kg^{-1} N, Jensssen & Kongshaug (2003) schatten de gemiddelde waarde voor de Europese productie op 5.29 en de minimum waarde, bij gebruik van de 'beste beschikbare techniek, BAT', op 2.45 kg CO_2-eq kg^{-1} N. Duitsland, België en Frankrijk gebruiken waarden dicht bij de referentie, terwijl Nederland, Zweden and Groot Brittannië waarden dicht bij 'BAT' gebruiken, daarbij refererend aan specifieke fabrieken. Denemarken gebruikt een tussenliggende waarde. De zeer lage waarde die Nederland gebruikt geldt voor de belangrijkste fabrieken in Nederland maar het is niet duidelijk in hoeverre ook nog kunstmest N van andere fabrieken gebruikt wordt in Nederland.

Het effect van de emissiefactor op de totale emissie is groot: voor tarwe is het verschil in emissie berekend met de standaard emissiefactor en met de 'BAT' factor gemiddeld voor de geanalyseerde NUTS-2 rapporten 5.5 kg CO_2-eq MJ^{-1} biobrandstof op een default waarde van 23. Verschillen voor andere gewassen liggen in dezelfde orde.

- *BKG emissies van productie van kunstmest N tonen een grote spreiding, zowel wat betreft bemestingsniveau als wat betreft emissiefactor.*
- *Het bemestingsniveau kan het best bepaald worden uit landbouwstatistieken en niet afgeleid worden van adviesniveaus of van de afvoer van N met de geoogste producten. De gehanteerde waarde van de emissiefactor dient ondersteund te worden met gegevens over de herkomst van de gebruikte kunstmest N.*
- *Verschillen in emissiefactor hebben een groot effect op de totale emissie.*

Diesel

De emissie uit verbruik van diesel voor tractoren and machines is afhankelijk van de efficiency van dieselverbruik (uitgedrukt als liters diesel verbruikt per ton droge stof geoogst product, Figuur 2.7) en van de emissiefactor (uitgedrukt als kg CO_2-eq per liter diesel). Het verbruik van diesel heeft een grote spreiding, in tegenstelling tot de emissiefactor die maar weinig varieert. Het verbruik van diesel is voor alle drie de zaadgewassen in Nederland is opmerkelijk hoog, Denemarken en Zweden hebben in het algemeen een laag verbruik, waarschijnlijk door een minder intensieve grondbewerking.

In het algemeen zijn de cijfers voor verbruik van diesel lager dan de BioGrace referentiewaarden; de belangrijkste redden voor dit verschil is een hoger opbrengstniveau in vergelijking met het Europees gemiddelde met als resultaat een lager verbruik per ton geoogst product omdat een groot deel van het verbruik meer afhankelijk is van het bewerkte oppervlak dan van het opbrengstniveau.

- *De BKG emissie uit verbruik van diesel is variabel, maar alleen wat betreft hoeveelheid en niet wat betreft de emissiefactor. Verschillen in opbrengstniveau zijn een belangrijke oorzaak van verschillen in dieselverbruik per ton geoogst product.*
- *Het verbruik van diesel per hectare voor de teelt van zaadgewassen is in Nederland opmerkelijk hoog.*

Overige bronnen

BKG emissie uit overige bronnen omvat een aantal kleinere bronnen van emissie: niet-stikstof kunstmeststoffen, zaaizaad, gewasbeschermingsmiddelen en drogen van koolzaad. Verschillen tussen landen zijn aanwezig maar zijn in het algemeen kwantitatief van weinig belang.

- *BKG emissies uit 'overige' bronnen zijn variabel maar meestal van weinig belang. Gebruik van meststoffen (P, K, Ca) in een rotatie in plaats van voor individuele gewassen is een belangrijke oorzaak van variatie.*

Conversie en allocatie

Na de teelt van een landbouwgewas voor de productie van biobrandstof kunnen nog twee factoren effect hebben op de BKG emissie per eenheid biobrandstof energie: de conversiefactor en de allocatiefactor (Figuur 2.9). De conversiefactor is een maat voor de hoeveelheid biobrandstof energie die geproduceerd kan worden per eenheid landbouwproduct en de allocatiefactor is een maat voor de verdeling van de BKG emissie over de biobrandstof en de geproduceerde bijproducten (DDGS, bietenpulp, koolzaadschroot). De conversiefactor en de allocatiefactor zijn aan elkaar gerelateerd: een hogere productie van biobrandstof uit een eenheid landbouwproduct resulteert in de productie van minder bijproduct en zo zal een hogere conversiefactor samen gaan met een hogere allocatiefactor, met een compenserend effect op de BKG emissie per eenheid biobrandstof energie als gevolg.

De gerapporteerde verschillen in conversie- en allocatiefactoren zijn klein maar soms wel significant in relatie tot de RED default waarden. In de meeste gevallen zijn de standaard factoren uit Edwards *et al.* (2006) gebruikt, soms zijn echter hogere of lagere waarden gerapporteerd. In een aantal gevallen compenseren hogere warden voor beide factoren elkaar, in andere gevallen is dat niet zo. Onderschatting van de BKG emissie per eenheid biobrandstof energie komt waarschijnlijk voor bij tarwe (België) en koolzaad (Denemarken, Zweden, België en Frankrijk), overschatting bij tarwe (Frankrijk) en korrelmaïs (Frankrijk). De waarschijnlijke overschatting van de BKG emissie bij de productie van tarwe in Frankrijk lijkt zelfs de oorzaak van de regionale overschrijding van de RED default waarde te zijn: gebruik van de standaard factoren voor conversie and allocatie resulteert in een daling van de maximale regionale waarde van 24 g CO_2-eq MJ^{-1} naar een waarde lager dan de default van 23.

- *Verschillen in gerapporteerde conversie- en allocatiefactoren zijn klein maar kunnen ten opzichte van de RED default waarden wel significant zijn. Bij gebruik van standaard waarden zou de maximum regionale emissie van tarwe voor Frankrijk tot onder de RED default waarde dalen.*

Aanvullende berekeningen

In een aanvullende berekening zijn de waarden voor opbrengsten en inputs uit de NUTS-2 rapporten gebruikt als input voor het BioGrace rekentool (versie 2; BioGrace, 2010). Bij vergelijking met de totale emissies uit de NUTS-2 rapporten blijkt een groot aantal uitkomsten hoger uit te komen (Figuur 3.1). Als gevolg worden de RED default waarden vaker overschreden. Naast de gemiddelde emissie voor tarwe in Nederland overschrijden nu ook de gemiddelde waarden voor tarwe in Duitsland en voor koolzaad in Nederland, Denemarken, Zweden, Groot Brittannië en Frankrijk de default waarden. De Nederlandse emissie voor korrelmaïs is niet langer de hoogste maar vrijwel gemiddeld. Wanneer de totale emissies van de aanvullende berekeningen worden verdeeld over de vier eerder genoemde componenten en worden vergeleken met de getallen uit de NUTS-2 rapporten, zien we grote verschillen in N_2O emissie en in emissie uit kunstmest N, de emissie uit dieselverbruik en uit andere bronnen blijft vergelijkbaar (Figuur 3.2).

In de berekening van de RED default waarde is voor ieder gewas een gemiddelde N_2O emissie gebruikt die is gebaseerd op gedetailleerde berekeningen WtW studie. In het BioGrace rekentool (versie 2) wordt de gemiddelde N_2O emissie gegeven als proportioneel met de gewasopbrengst[1]. Dit hebben we gebruikt in de berekeningen en resulteert in een vaste emissie per eenheid geproduceerde biobrandstof, onafhankelijk van verschillen in teeltsystemen of omstandigheden. Deze berekeningswijze kan grote verschillen geven met methoden waarbij de emissie is proportioneel is met de N inputs, zoals de IPCC-2006 methodologie. Wetenschappelijk gezien is het beter de processen die verantwoordelijk zijn voor N_2O emissie uit de bodem te relateren aan de N inputs in plaats van aan de gewasopbrengst, o.a. door de curvi-lineaire response van de gewasopbrengst aan de N bemesting.

De toename van de emissie uit kunstmest N bij de meeste landen is een gevolg van het gebruiken van de standaard BioGrace emissiefactor in plaats van een 'nationale' factor. Door het gebruik van een standaard emissiefactor worden de hier gevonden verschillen proportioneel met de verschillen in kunstmest N niveau die zijn weergegeven in Figuur 2.5. Gemiddeld is het kunstmest N niveau vergelijkbaar met de gemiddelde waarde in BioGrace voor alle vier gewassen. De verschillen tussen landen kunnen echter aanzienlijk zijn.

- *Bij gebruiken van de BioGrace tool (versie 2) als een gezamenlijke rekenmethode worden de RED default waarden in meer gevallen overschreden.*
- *Een benadering die de emissie van N_2O beschouwt als proportioneel met de gewasopbrengst is niet geschikt voor het bepalen van de werkelijke variatie in emissie.*

Noot 1: In een recente versie van BioGrace (versie 3), is de bodem N_2O emission gegeven in kg ha^{-1} j^{-1}. In versie 4 zal een rekentool worden opgenomen om de emissie van N_2O te bepalen aan de hand van de IPCC-2006 tier 1 methodologie (pers. comm. John Neeft, AgentschapNL).

1. Introduction

The EC Renewable Energy Directive (in short: RED; EC, 2009) involves national reports on the average greenhouse gas (GHG) emissions caused by the production of energy crops. These emissions should not exceed the RED default values, expressed in g CO_2-eq emitted per MJ biofuel produced, for the production to be considered acceptable in order to count to obligations or to be eligible for financial support. Emissions must be reported at the so-called NUTS-2 regional level within each country. Calculation methods are not prescribed and hence, differences in emissions reported may not only be caused by differences in production systems and conditions, but also by differences in calculation methodology. Differences in reported emissions, caused by different methods of calculation, could lead to improper judgement of the acceptability of the energy crop production in countries of the EU and raise questions whether high emissions (e.g. from winter wheat production in the Netherlands) are due to real differences in production conditions or crop management or to the absence of a methodological 'level playing field'. In order to answer these questions, and to judge whether a reshape of the calculations could be justified, a number of NUTS-2 reports were analysed.

Purpose of the analysis was to review calculation methods and data used by individual countries and to evaluate the reported differences in emissions. This evaluation should provide insight in to what extent differences in used methodology are responsible for the differences in emissions and how the use of a 'level playing field' methodology would alter the reported differences in emissions. This could provide a basis for an eventual request for reshaping of the GHG emissions calculations.

The report of the Netherlands was compared with the reports of Germany, Denmark, Sweden, United Kingdom, Belgium-Flanders and France. These countries were selected for reasons of comparability with the Netherlands with respect to production systems and conditions. For Belgium, separate reports exist for the Flanders and the Wallonia region. Both reports followed exactly the same methodology and only the Flanders report was analysed, this will be further referred to as 'Belgium'. The analysis included all four crops reported by the Netherlands: winter wheat, winter rapeseed, grain maize and sugar beet; in the analysis abbreviated to wheat, rapeseed, corn and sugar beet. Primary sources of information were the NUTS-2 reports and a German background report (Fehrenbach, 2009). The NUTS-2 reports are available on http://ec.europa.eu/energy/renewables/transparency_platform/emissions_en.htm.

The results of the analysis are described in chapter 2 and the results of additional calculations of the emissions using a standard methodology (BioGrace, 2010) are described in chapter 3.

2. Data analysis

The general methodology for the calculation of GHG emissions from the cultivation of biofuel crops is described in paragraph 2.1 and the total GHG emission resulting from the production of energy crops as published in the NUTS-2 reports is presented in paragraph 2.2. This total emission is divided in four main components: (i) field emission of nitrous oxide and GHG emissions from (ii) fertiliser nitrogen use, (iii) diesel use and (iv) a remaining part, referred to as 'other'. This was done to get a better insight in the relative contribution of different aspects of energy crop cultivation in (differences of) total GHG emission. These components are described in the paragraphs 2.3 to 2.6.
In paragraph 2.7 conversion and allocation factors are discussed. These two parameters have no effect on the total emissions from crop cultivation but since the emissions are expressed as emission per unit of biofuel produced, the emissions are affected by the conversion of the agricultural product to biofuel and by the allocation of the total emission to biofuel and eventual co-products.

2.1 Methodology

Although the methodology to be used for the calculation of GHG emissions from energy crop production is not prescribed in detail in the RED, the basis of the calculations is clear. All relevant inputs, (N, P, K and Ca fertilisers, diesel, seeds, plant protection agents and energy for drying), are quantified in units per hectare and multiplied with an emission factor expressed in kg CO_2-eq per unit applied. Methods for data sampling and establishing emission factors, however, are not prescribed. For the calculation of the field emissions of N_2O no single general accepted method is available and different methods are used, as described in paragraph 2.3. The sum of emissions results in a total emission per hectare. This total is divided by the crop yield (emission per kg agricultural crop), divided by a conversion factor (emission per unit biofuel) and multiplied with an allocation factor to result finally in a net emission per unit biofuel produced. The allocation factor divides the total emission over biofuel and co-products on the basis of energy content. Co-products to be accounted for in the RED are DDGS from wheat and corn, rape meal from rapeseed and pulp from sugar beets. It is not allowed to allocate emission to the co-products straw and beet leaves and to glycerine from biodiesel production (EC, 2009).

2.2 Total GHG emissions

The total GHG emission resulting from the production of energy crops are shown in Figure 2.1. Differences between countries can be significant and are generally larger than the differences between regions within countries. Regional differences are large in the United Kingdom and France and remarkably small in Germany (see the difference in minimum and maximum values in Figure 2.1).

The average value for wheat from the Netherlands is the only average crop value exceeding the RED default. This value is exceeded in 11 of the 12 regions in the Netherlands. Furthermore, regional crop values exceeded the default for wheat in France in 3 of 18 regions and in UK in 1 of 11 regions and for rapeseed in UK in 3 of 11 regions. The Netherlands reported the highest values for corn and more or less average values for rapeseed and sugar beet.

In Figure 2.2 the average total emissions are divided into four components: (i) field emission of N_2O and GHG emissions from (ii) fertiliser nitrogen use, (iii) diesel use and (iv) 'other' sources. Obviously, here the differences between countries are much larger compared to the total values and high values for one component are often compensated by low values for another. In most countries and crops the order from high to low contribution to total GHG emission is: (1) N_2O, (2) fertilizer N, (3) diesel and (4) other with as average contributions respectively 46, 30, 15 and 9%. For the Netherlands, values for N_2O emission and diesel use are high and values for fertiliser nitrogen are low. The background of these differences will be discussed in paragraph 2.3 to 2.6. In order to have a reference value, in all Figures the European average calculated with the BioGrace tool (version 2; BioGrace, 2010) is shown. These values comply with the basic values used for the calculations of the RED default values. The RED default values and the average European inputs as used in BioGrace are summarized for the four crops analysed in Appendix I.

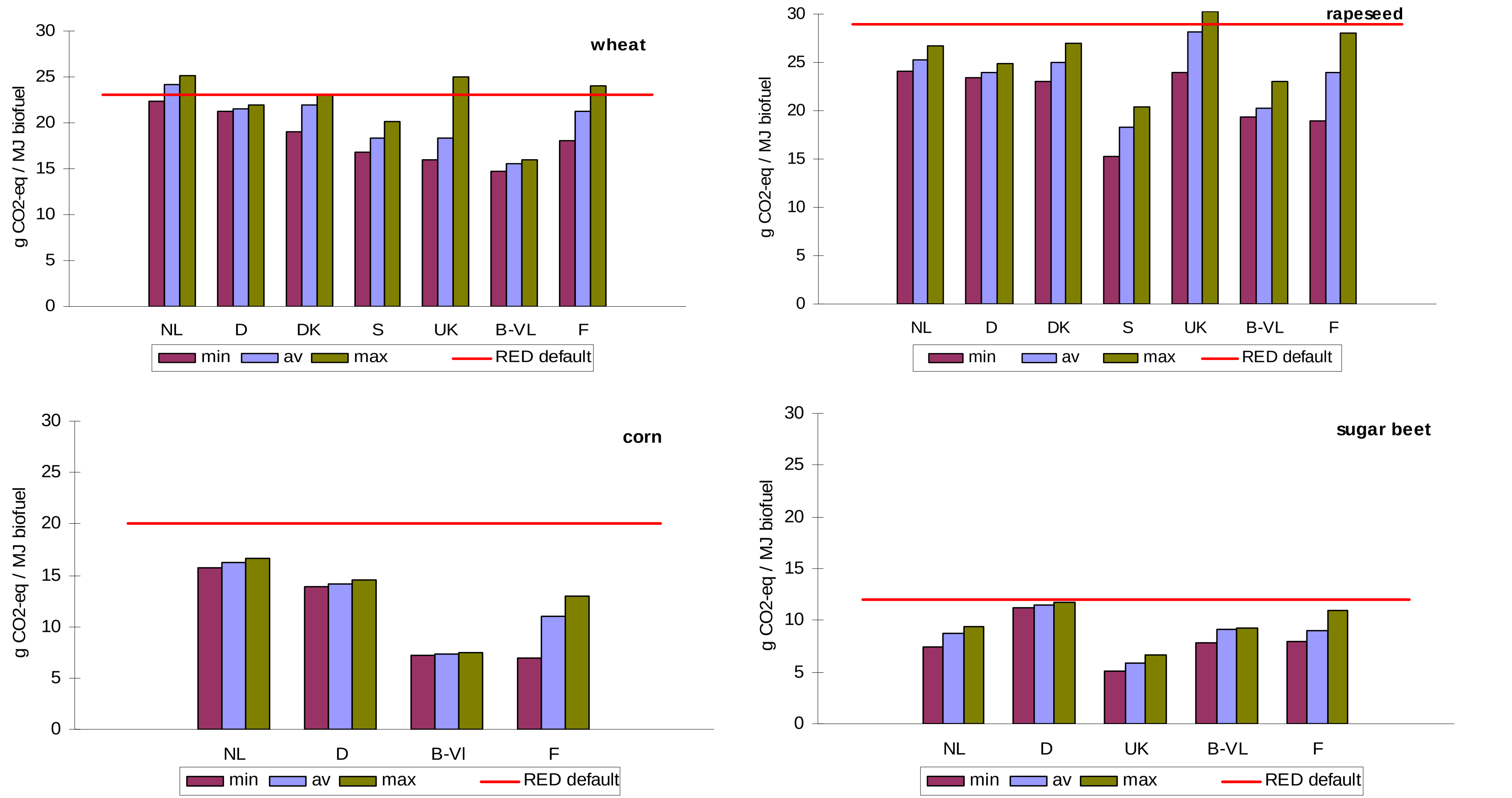

Figure 2.1. GHG emissions from agricultural production of energy crops after national reports (minimum, average and maximum NUTS2 regional values) compared with RED default values.

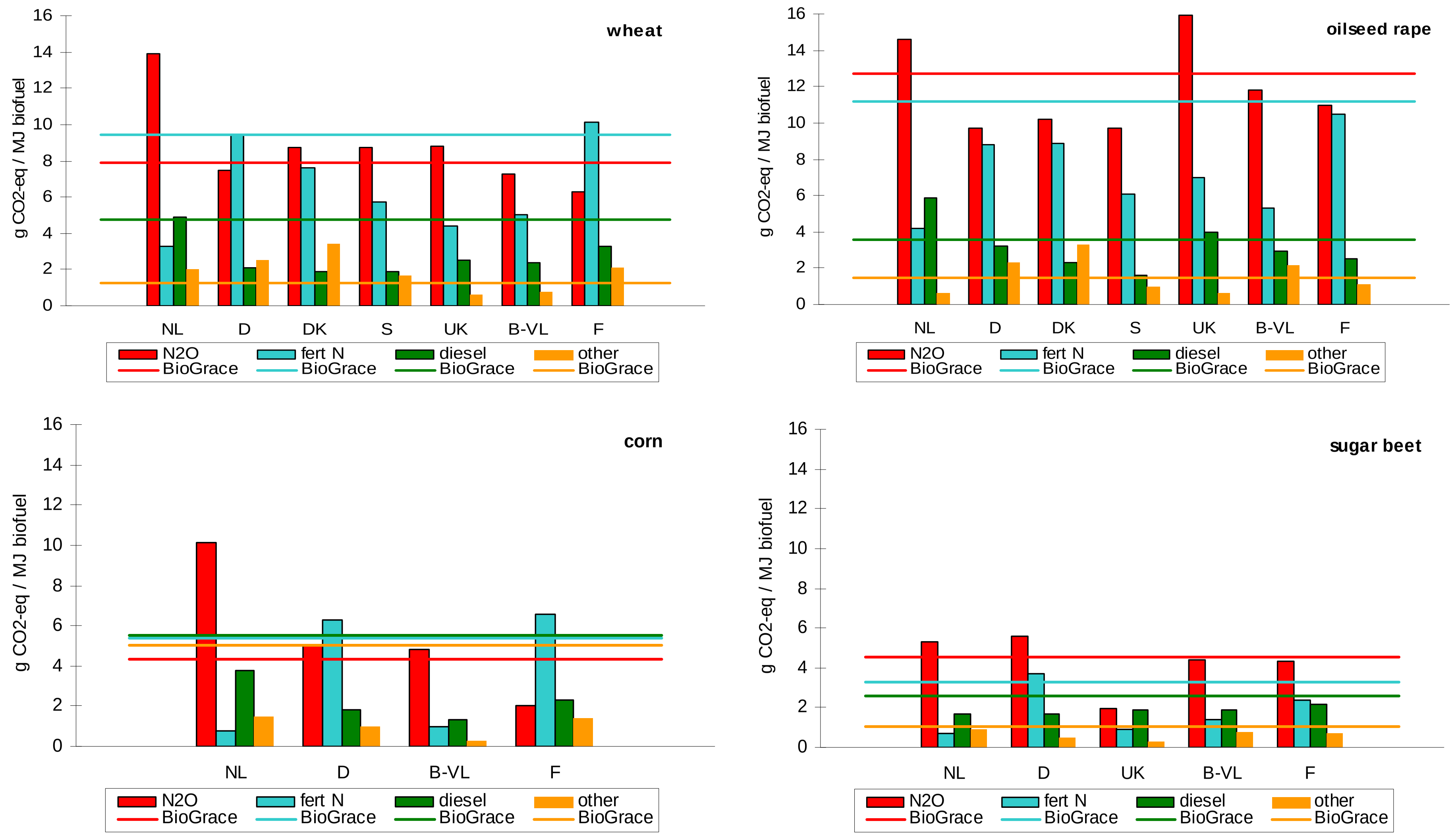

Figure 2.2. *Average GHG emissions from agricultural production of energy crops after NUTS-2 reports; divided into different components, compared with average European values calculated with BioGrace.*

2.3 Nitrous oxide emissions

Field emissions of N_2O, expressed as total direct and indirect N_2O emission per ha divided by crop dry matter yield per ha, show very large differences (Figure 2.3). Estimations vary from less than half of the average European value (corn in France and sugar beet in the United Kingdom) to almost two times the average European value (corn in the Netherlands). Since the N_2O emission is not simply calculated by an input and an emission factor, like the other sources of GHG emissions, first the calculation methods used in the different countries will be discussed.

Large differences exist in the way N_2O emissions are calculated. Three calculation methods can be distinguished. The Netherlands, Denmark and Sweden used the 'IPCC-2006' method (IPCC, 2006), the United Kingdom used the IPCC based model of Stehfest and Bouwman (2006) and Germany, Belgium and France used methods based on average European values, obtained from the CONCAWE/EUCAR/JRC-IES 'Well to Wheels' study (WtW, Edwards *et al.*, 2006), which are also used in the BioGrace tool (version 2; BioGrace, 2010). All methods can consider the effects of regional differences in soil and climate conditions, but in practice only general emission factors or average emissions were used. Appendix II contains a more detailed description of the calculation methods for N_2O emission that were applied.

Differences in N_2O emissions, as shown in Figure 2.3, do not only depend on the principle choice between IPCC or model based methods, also within these methods the variation in reported emissions is large. A large part of this variation seems to be due to different ways nitrogen inputs are treated. The Netherlands stayed most close to the IPCC-2006 methodology, taking N inputs in fertilisers and manure from statistical data into account and using the IPCC-2006 parameters for the calculation of N inputs in crop residues. Country specific lower emission factors, based on measurements, were used for the calculation of the emission of NH_3 from fertiliser and manure application. Furthermore, a 20% decrease was applied to the total emission, in order to decrease the gap between calculated emissions and the European average values from the WtW study.

Denmark considered as fertiliser N input the advised levels of 'effective' N (mineral fertiliser N plus N in manure multiplied with an efficiency factor). As a consequence, the calculated emission for this country is only valid for a system without input of manure and with an average fertiliser N input conform the advised level while it is not clear how representative this system is. Sweden considered only mineral N applied without mentioning eventual use of organic N Furthermore, based on local literature Denmark and Sweden account for appreciably lower N inputs with crop residues as compared to IPCC-2006, while Denmark completely neglects the N input with belowground crop residues. Both countries introduce a reduction as compensation for the emission of a reference vegetation, which seems not right, because with the IPCC-2006 emission factors a correction is already made for the background emission (IPCC only calculates anthropogenic emissions).

The United Kingdom is the only country using the Stehfest & Bouwman model; its calculated emissions can therefore not directly be compared with other countries. It is remarkable that the model considers the total N input from fertilisers and manure as N input, while the report only discusses fertiliser N input from statistical data, not mentioning manure at all.

Regarding the WtW European average based methods, Belgium and Germany use emission factors per kg fertiliser N while the calculation is supposed to depend on this N input in an indirect way only. Fertiliser N input in Belgium is low and manure N input is high, with a clear underestimation of the N_2O emission as a result. For Germany the fertiliser N input accounted for is determined by the yield and the N content of the crop in a way that the input is equal to the export of N from the field with the crop. In this way, the emission is proportional to the yield and not to the real N input. France has simply taken the average European emission per ha. For wheat and corn, crops where French yields exceed the European average, this results in a low emission per ton dry matter and per unit biofuel produced. The reliability of these low emissions is doubtful; the higher yields probably result from a higher availability of water and/or a more intensive cultivation and this can be presumed an indication for a higher emission than average following the WtW analysis.

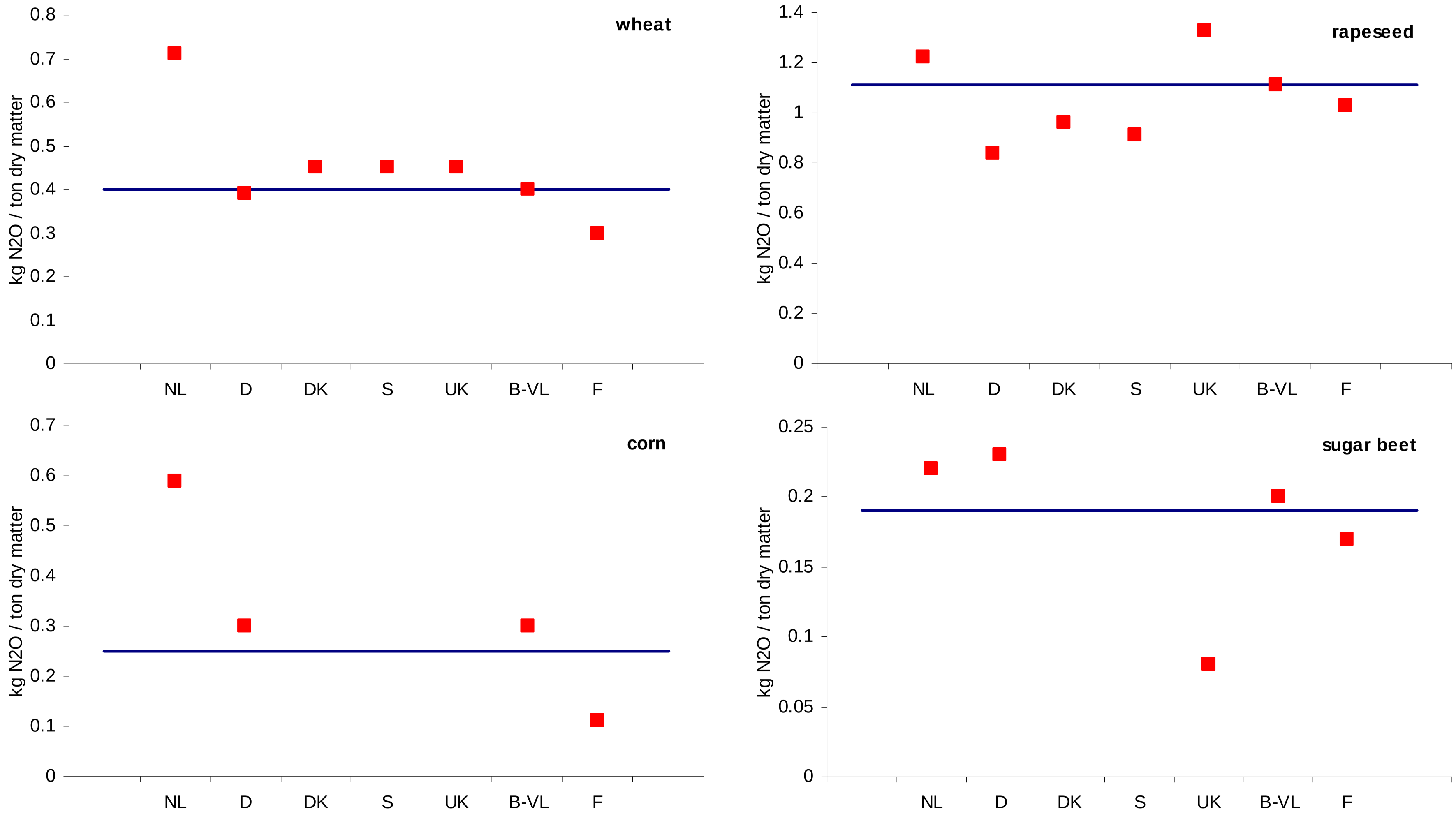

Figure 2.3. Intensity of field N_2O emission from the production of energy crops; values calculated from NUTS-2 reports, compared with average European values calculated with BioGrace (solid lines).

It is clear that large differences exist with respect to emission calculation methods applied and to sources of nitrogen taken into account. What method would best reflect the actual emissions can not yet be decided due to the complicated nature of the N_2O field emission. However, it seems preferable to calculate N_2O emissions as function of (all) N inputs rather than crop yields, because soil processes causing N_2O emission are driven by the availability of nitrogen in combination with local soil and weather conditions.

To provide a 'level playing field' for all countries it seems useful to follow the recommendation in the report of the Netherlands for the EC to decide on the use of one common method to determine N_2O field emissions. For the short term, an IPCC-2006 based method is preferred, because it can be more easily applied and other reporting activities also use IPCC methodologies (national reporting on total GHG emissions). A number of reports concluded that using detailed process models that include effects of soil and weather conditions was not yet possible in a reliable way, but regarded it as a promising future option.

2.4 Fertiliser nitrogen

Production and distribution of fertiliser nitrogen is one of the two most important sources of GHG emission in agriculture. This emission is partly N_2O from nitrate production and partly CO_2 (and for a very small part CH_4) from energy use related to the production and distribution of fertiliser nitrogen. In this report these emissions are not distinguished, but shown as integrated GHG values (CO_2-eq.). The emission per unit of agricultural product depends on the efficiency of nitrogen use (expressed as 'nitrogen use': kg fertiliser N applied per ton dry matter production harvested) as shown in Figure 2.5 for the four crops, and on the emission factor (expressed as kg CO_2-eq per kg fertiliser N) as shown in Figure 2.4. Both values show a large variation and refer to chemical fertilizer only.

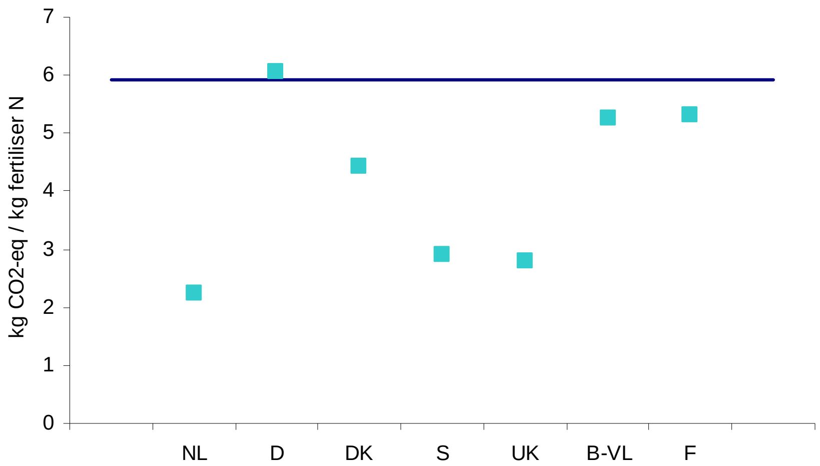

Figure 2.4. Emission factors for the production of fertiliser nitrogen compared with the average European value from BioGrace.

On average, the use of fertiliser nitrogen is comparable with the average value used in BioGrace for all four crops, if expressed per kg of crop yield. The differences between countries, however, can be appreciable. These differences in nitrogen use values can be caused by several factors.

- Different crops are produced with different quantities of fertiliser nitrogen per ton dry matter: the reference values from BioGrace increase in the order sugar beet (6.9), corn (15.7), wheat (24.3), rapeseed (49).
- Use of animal manure: application of animal manure provides crops with nitrogen and hence, animal manure can partly substitute fertiliser nitrogen. Only the reports of the Netherlands and Denmark are clear on the use of animal manure: for the Netherlands it is quantified while Denmark describes production systems where no animal manure is used. For the other countries possible use of animal manure remains unclear, but it is obvious that the combination of low fertiliser nitrogen levels and high yields in Belgium is only possible because of ample use of animal manure. It is assumed that the GHG emission related to the production of animal manure is not attributed to the crops that receive this manure.
- Data sampling: in most reports statistical data were used, Denmark used advised levels of fertiliser nitrogen and Germany used the export of nitrogen in the crop from the field as an (under)estimate of the nitrogen fertiliser level.

The emission from the production of fertiliser nitrogen is showing a large variation, depending on the plant where the fertiliser is produced. The BioGrace reference value is 5.92 kg CO_2-eq kg^{-1} N, whereas Jensssen & Kongshaug (2003) estimated the average European value on 5.29 and the minimum value, using best available techniques (BAT), on 2.45 kg CO_2-eq kg^{-1} N. Germany, Belgium and France used values close to the reference while the Netherlands, Sweden and UK used values close to BAT, referring to specific production plants. Denmark used an intermediate value, referring to partly import from a specific low emission production plant and partly import from unidentified other production plants. The very low value reported for the Netherlands is valid for major production plants in the Netherlands, however, it is not known to what extent fertilisers from other production plants are used in the Netherlands. This information is considered confidential, while Denmark and Sweden do actually use comparable information on market shares.

The effect of the emission factor on the total emission is large: for wheat the difference in emission calculated with the standard factor and the 'BAT' factor is on average for the reports analysed 5.5 kg CO_2-eq MJ^{-1} biofuel on a default value of 23. Differences for other crops are in the same order.

While the possibilities of decreasing the nitrogen use are limited because decreased input will lead to decreased yields, a major improvement can be made by replacing or improving older nitrogen fertiliser production plants.

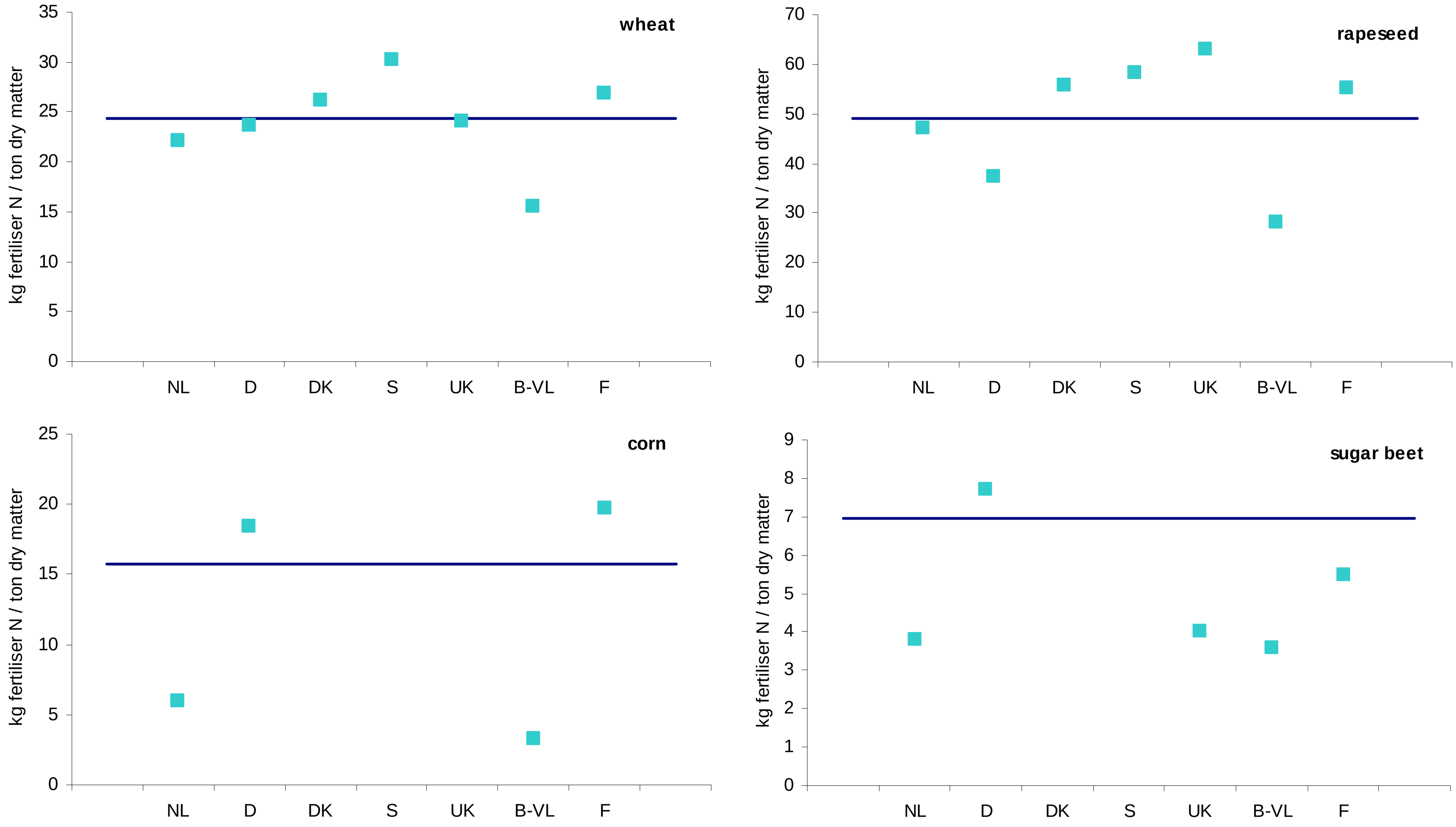

Figure 2.5. Efficiency of fertilizer N used to produce energy crops; values calculated from NUTS-2 reports, compared with average European values calculated with BioGrace (solid lines).

2.5 Diesel use

A third important source of GHG emission in agricultural production is diesel use by tractors and farm machinery. In analogy with fertiliser nitrogen, also here the emission per unit agricultural product depends on the efficiency of diesel use (expressed as liter diesel used per ton dry matter production harvested) as shown in Figure 2.7 for the four crops, and on the emission factor (expressed as kg CO_2-eq per liter diesel used) as shown in Figure 2.6.

The large differences observed in diesel use can have several reasons:

- Different crop types ask for different use of machinery.
- The yield level has a large effect on the diesel use per ton of product since the diesel use of most activities does not depend on the yield level but on the area cultivated.
- Country specific differences do exist. Most differences as shown in Figure 2.7 can be explained by the two foregoing factors but the high diesel use for seed crops in the Netherlands is remarkable, even more so as diesel use in the production of sugar beets is comparable with other countries. Denmark and Sweden have generally low levels of diesel use, probably due to a less intensive soil tillage.

Generally the figures for diesel use are lower than the BioGrace reference values; the main reason for this difference is a higher yield level compared to the European average, resulting in a lower diesel use per ton of harvested product.

The emission factor shows only a very small variation which is not surprising since the major part of the GHG emission from diesel use comes directly from the combustion of the diesel and can not show more than a minimal variation. Some variation can result from differences in the indirect emission, i.e. the emission caused by energy use during production and distribution of the diesel.

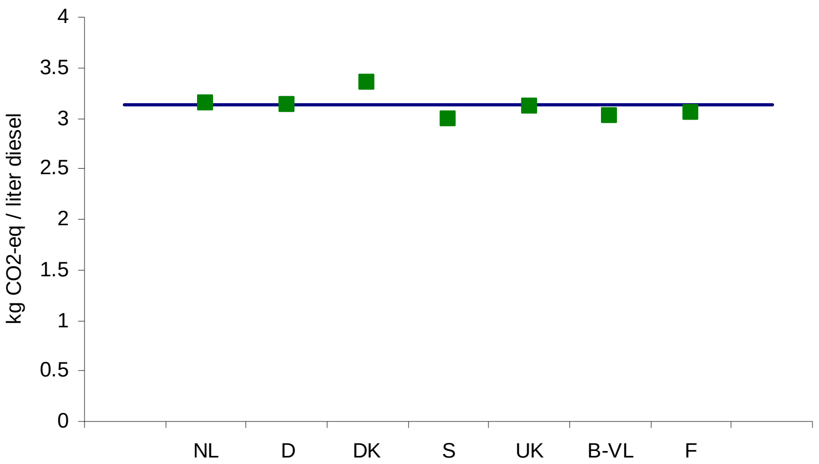

Figure 2.6. Emission factors for diesel use, compared with the average European value from BioGrace.

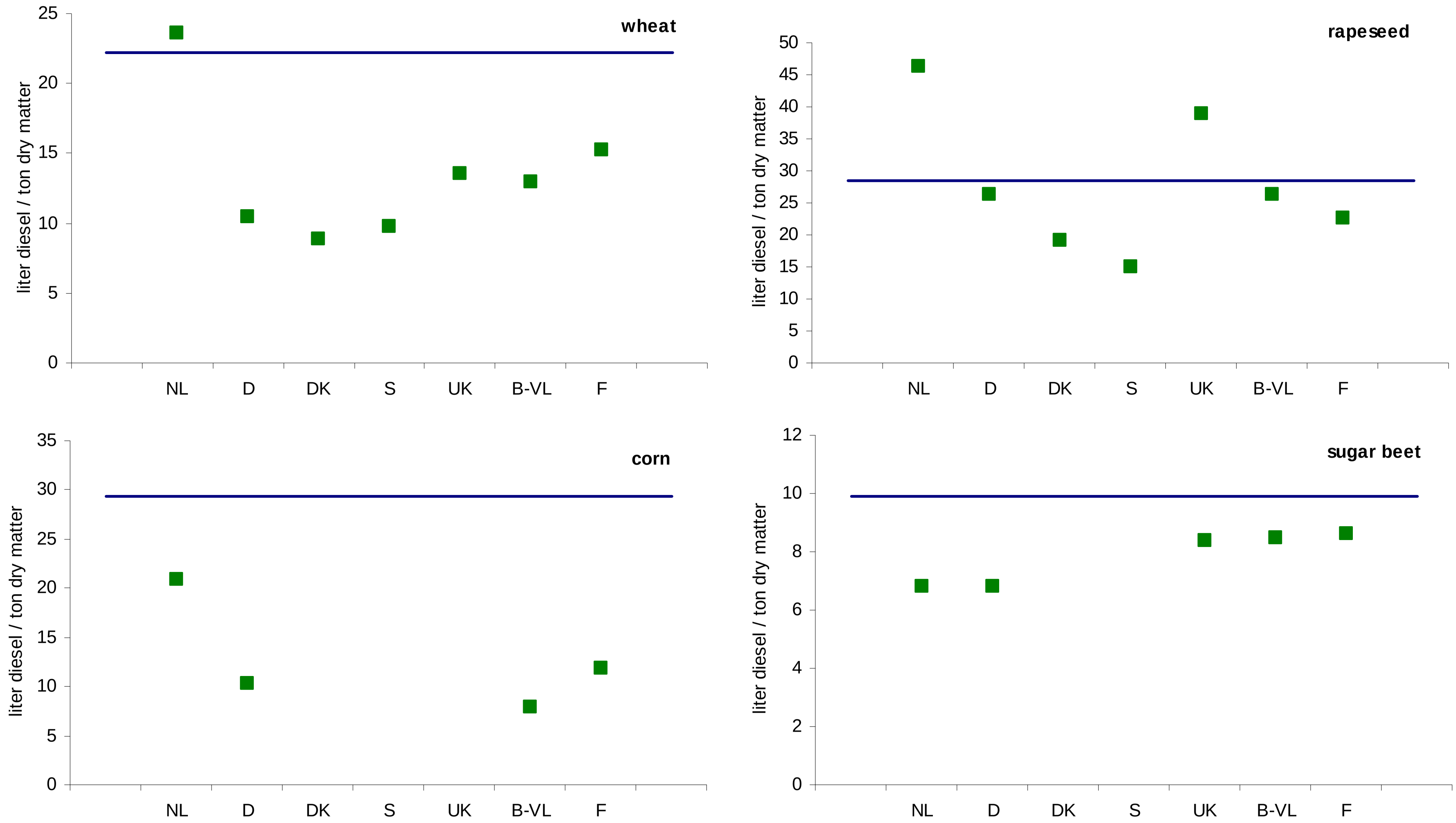

Figure 2.7. Efficiency of diesel fuel used to produce energy crops; values calculated from NUTS-2 reports, compared with average European values calculated with BioGrace (solid lines).

2.6 Emissions from ‘other’ inputs in agriculture

The remaining GHG emission, introduced in this report as ‘other’, includes a number of minor items: non-nitrogen fertilisers (P, K and Ca), seeds, plant protection agents and (conform to the RED only for rapeseed) drying. Results are shown in Figure 2.8. Diesel use involved in application of these items is already included in section 2.5. Because of the variety of emission sources, it is mostly hard to explain differences and at the same time these differences are of minor importance for the total emission. Therefore, only a few clear differing values will be evaluated.

The average European value calculated with BioGrace for corn is very high due to a heavy lime application (1600 kg CaO ha^{-1}) to the production of corn. The NUTS-2 report studied, however, do not report any lime application to corn. Furthermore, BioGrace accounts 400 kg ha^{-1} CaO to sugar beet and no lime to wheat and rapeseed (conform inputs to calculate the RED default values). The Netherlands, Germany, the United Kingdom and France report lime application to sugar beet, Denmark, Germany and the United kingdom to rapeseed and Denmark also to wheat. Mostly, lime is applied only once in a number of years and this application is not attributed to individual crops. Accounting for lime application and inclusion of emission from drying while the RED asks to include drying only for rapeseed cause a particularly high emission from ‘other’ sources for wheat in Denmark. Other variations in this category are often caused by differences in P and K fertiliser application, mostly based on statistics. P and K fertiliser application to individual crops is highly variable: P and K can be preferably applied to some crops in a rotation and much less to others and furthermore P and K can be applied with animal manure.

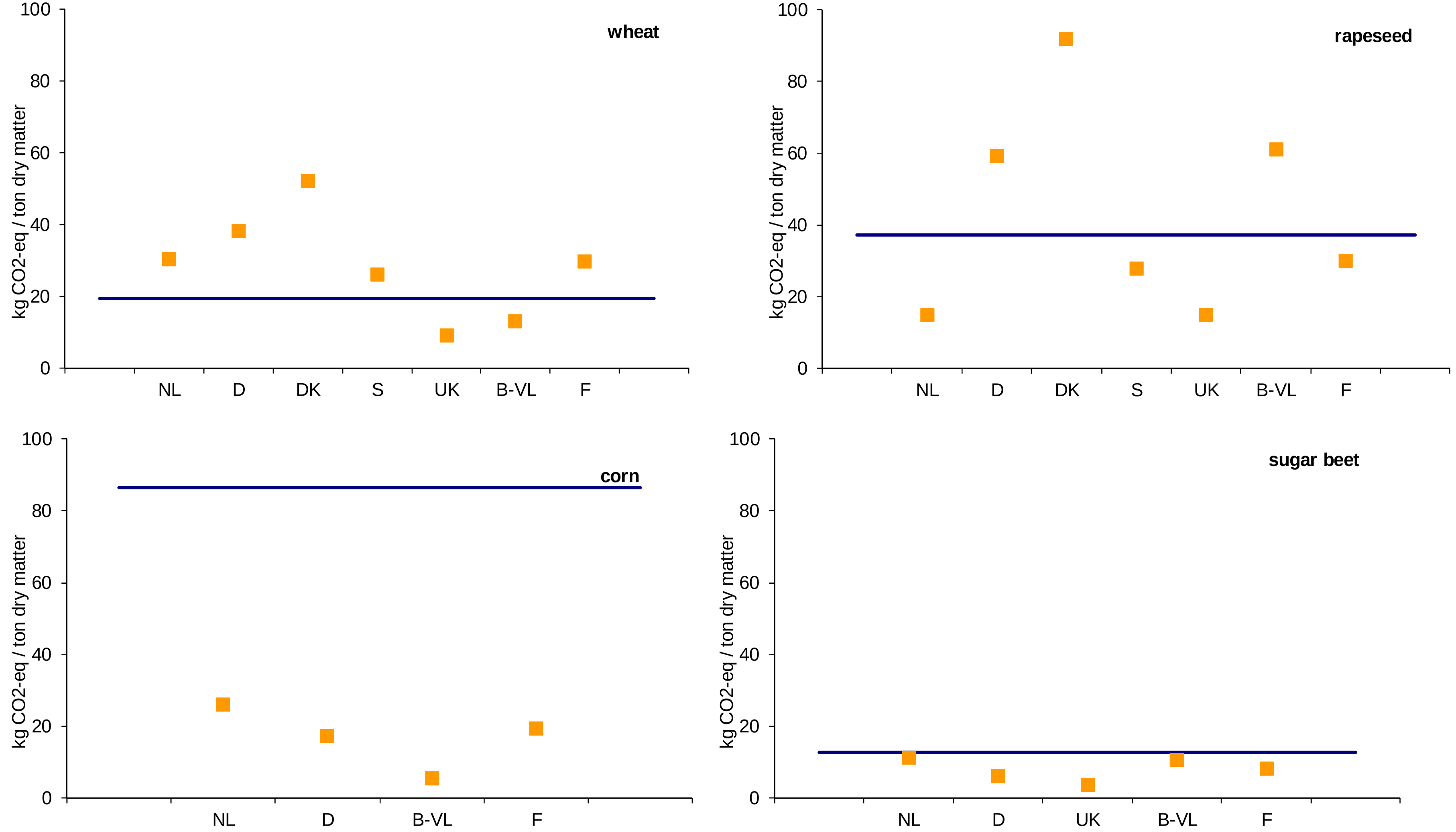

Figure 2.8. *GHG emissions from 'other' sources in production of energy crops; values calculated from NUTS-2 reports, compared with average European values calculated with BioGrace (solid lines).*

2.7 Conversion and allocation factors

After the production of the agricultural feedstock for biofuel production two more factors can have an effect on the GHG emission per unit biofuel energy: the conversion factor and the allocation factor. Reported values are shown in Figure 2.9.

The conversion factor is a measure of the amount of biofuel energy produced per unit of agricultural product. A higher conversion factor, resulting from a more efficient process or a higher content of the relevant compound (starch, sugar or oil) in the agricultural product, results in a lower GHG emission per unit biofuel energy, given a certain GHG emission per unit agricultural product.

The allocation factor depicts division of the total GHG emission over the biofuel and its co-products (DDGS, beet pulp, rape meal) produced. A higher allocation factor, resulting from a higher ratio of energy in biofuel compared to energy in co-product, results in a higher GHG emission per unit biofuel energy.

The conversion and allocation factors are not independent: a higher biofuel production per unit of agricultural product will result in relatively low amounts of co-product. Consequentially, a higher conversion factor coincides with a higher allocation factor, with a compensating effect on the GHG emission per unit biofuel as a result.

Differences in reported conversion and allocation factors are small but can be significant in relation to the RED default values. Most reports use standard conversion and allocation factors as presented in Biograce. However, substantially higher and lower values are also applied. Mostly high values for both factors compensate each other (partly), but this is not always the case. Underestimation of the GHG emission per unit biofuel energy is expected for wheat (Belgium) and rapeseed (Denmark, Sweden, Belgium and France), overestimation for wheat (France) and corn (France). The impact of the probable overestimation of the GHG emission from wheat production in France is highly significant: using the standard values for conversion and allocation results in a decrease in GHG emission of nearly 2 g CO_2-eq MJ^{-1}. This would decrease the maximum regional value (24 g CO_2-eq MJ^{-1}) below the RED default value of 23 g CO_2-eq MJ^{-1}.

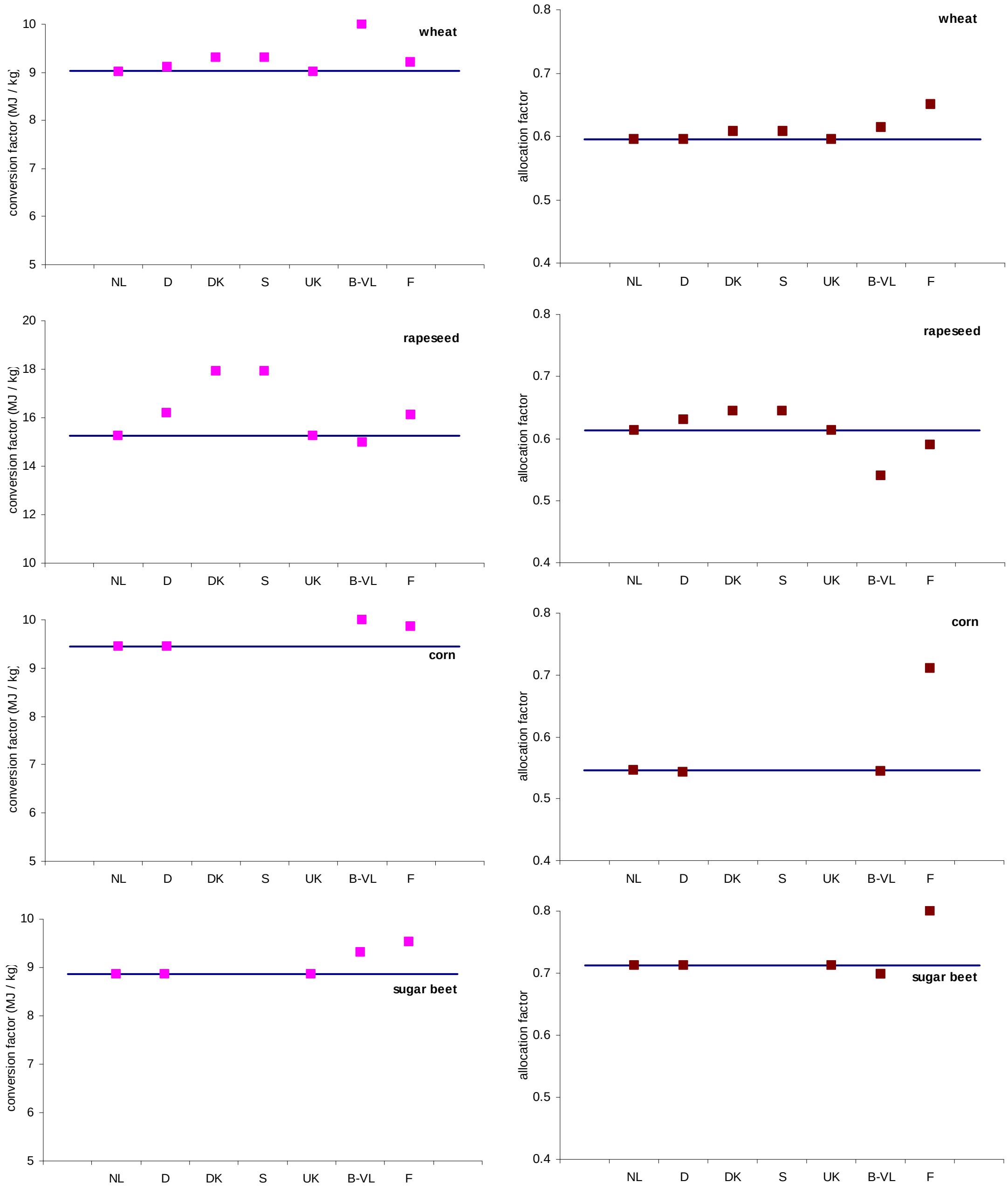

Figure 2.9. Conversion and allocation factors, compared with average European values calculated with BioGrace (solid lines).

3. Additional calculations

A formal comparison of the GHG emission in the different countries requires a common methodology which can be applied to all countries included in this study. For this purpose, the BioGrace tool has been selected (version 2; BioGrace, 2010). Figure 3.1 presents results of calculations with the BioGrace tool, using the average values for yields and inputs for each country from the NUTS-2 reports as input. When compared with the total average emissions from the NUTS-2 reports it is obvious that an appreciable number of values is higher. As a result, more values exceed the RED defaults when the BioGrace tool is used. The average emissions for wheat in the Netherlands still exceed the default value a little but not longer as an exception. Average values for wheat in Germany and for rapeseed in the Netherlands, Denmark, Sweden, UK and France now also exceed the default values. Furthermore, the Dutch value for corn is no longer the highest but rather an average value.

In Figure 3.2 the total emissions of the additional calculations are divided into the four main components. When compared with reported values in Figure 2.2, large differences can be seen in N_2O emission and in emission from fertiliser nitrogen. Emissions from diesel use and from other sources are more or less similar.

N_2O

In the calculation of the RED default value, for each crop an average European N_2O emission, based on detailed calculations from the WtW study is used. The inevitable variation around these average N_2O emissions, due to differences in soil and climate conditions and in nitrogen inputs, is not documented. In the BioGrace tool (version 2) the average N_2O emission is given as proportional to the crop yield. This was used in our calculations and results in a constant emission per unit biofuel produced, irrespective of differences in production systems or conditions. This approach can yield large differences in comparison to methods where the emission is proportional to nitrogen inputs, like the IPCC-2006 methodology that was used by the Netherlands, Denmark and Sweden. Since nitrogen inputs directly affect N_2O emission, in contrast to crop yields, relating N_2O emission to the nitrogen inputs is scientifically more sound. Using a relation with crop yields neglects the well-known curve-linear response of crop yields to nitrogen input.

According to IPCC (2006), anthropogenic N_2O emission depends on fertiliser nitrogen input as well as on other nitrogen inputs like animal manure and crop residues. As long as it is not feasible to use models considering regional differences in soil and climate conditions, it is to be recommended to use the IPCC-2006 methodology. Besides regional statistical data on fertiliser nitrogen use, data on animal manure use are needed. Crop residue production can be calculated from the crop yields. Although the IPCC-2006 methodology is clear with respect to the inputs to be accounted for and to the way how this has to be done, Denmark and Sweden did not completely follow these guidelines for unknown reasons with lower emissions as a result. The Netherlands motivated its choice for a different calculation by pointing at the situation that the RED default values were determined with the generally lower WtW values, concluding that for reasons of comparability the original values from Dutch energy crops calculated with IPCC-2006 should be reduced with 20%. Using IPCC-2006 for GHG emission of energy crops also has the advantage of similar methodology compared with national reporting on total national GHG emissions by using IPCC guidelines.

Fertiliser N

The increase of the emission from fertiliser N for most countries is a result of using the standard BioGrace emission factor in stead of a ‘national’ factor. Due to the use of a standard emission factor, the differences found here are proportional to the differences in fertiliser nitrogen use as shown in Figure 2.5.

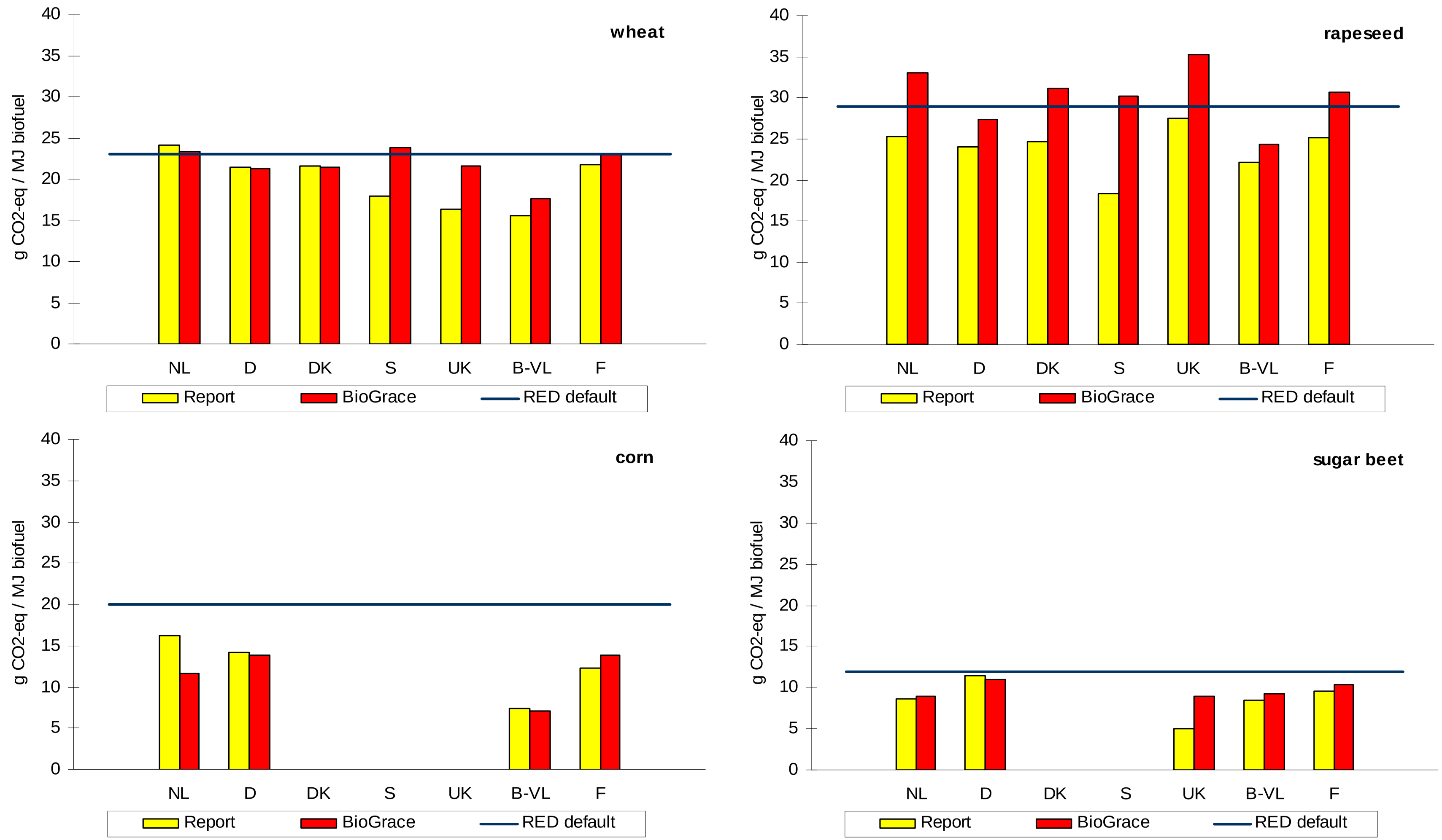

Figure 3.1. *GHG emissions from agricultural production of energy crops; comparison between values from NUTS-2 reports and calculations with inputs from the NUTS-2 reports using the BioGrace tool (version 2) and comparison with EC default values.*

Diesel use

Since the variation in emission factor from diesel use is small, the results from using a standard factor do hardly differ from the results using 'national' emission factors as shown in Figure 2.7.

'Other'

The emissions from other sources differ only slightly from the NUTS-2 reports. The high value for wheat of Denmark has disappeared by using the standard methodology where drying of wheat is not part of the BioGrace calculation.

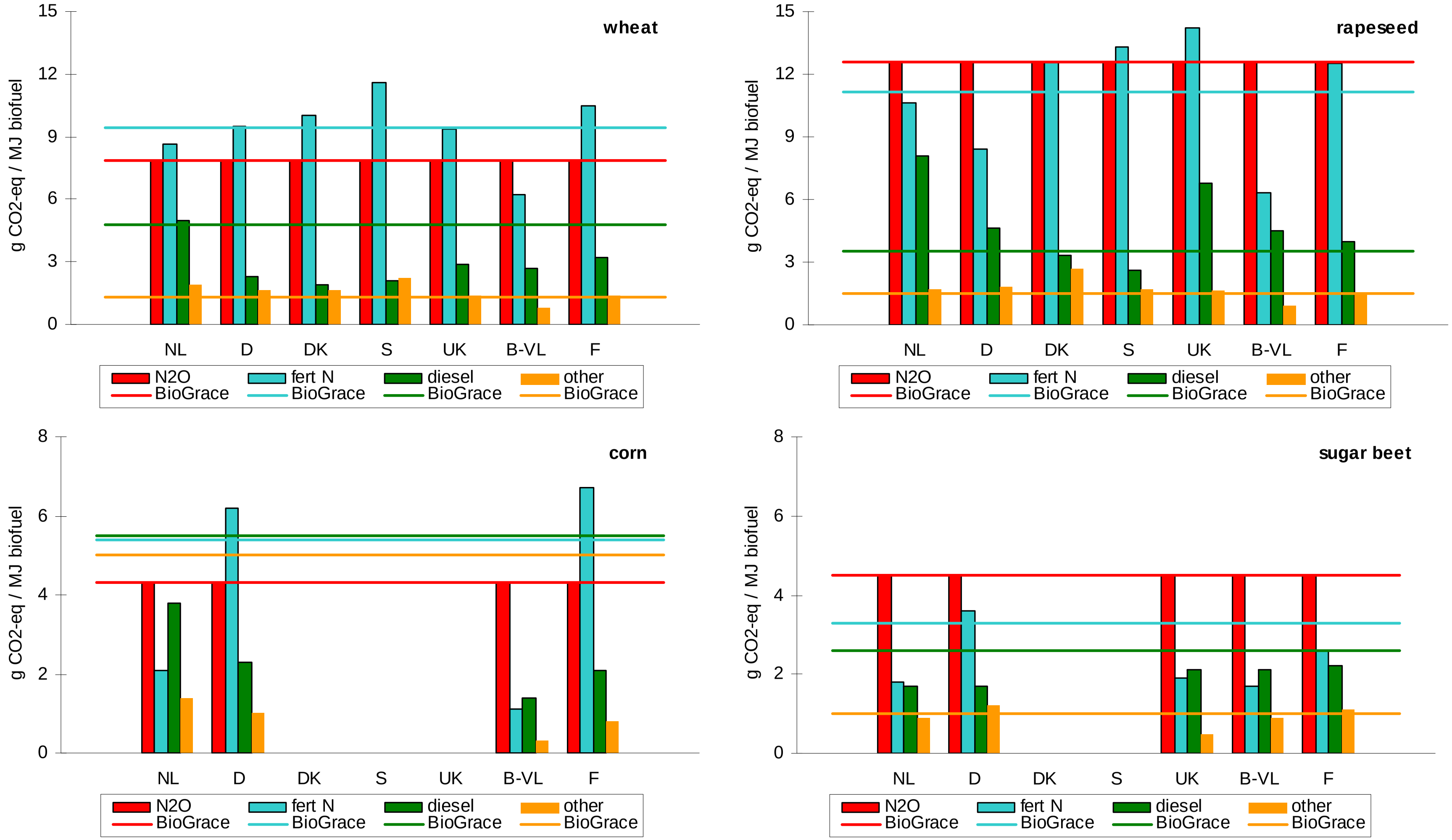

Figure 3.2. GHG emissions from agricultural production of energy crops calculated with inputs from the NUTS-2 reports using the BioGrace tool (version 2); divided into different components, compared with average European values calculated with BioGrace.

4. Conclusions

- National average GHG emissions from the cultivation of biofuel crops are lower than the RED default values, except for wheat in the Netherlands. Emissions from the production of wheat or rapeseed are also higher for some minor production regions in the United Kingdom and France.
- The GHG emissions related to N_2O field emission and fertiliser nitrogen on average explain 76% of the total reported emissions.
- The large variation in field emissions of N_2O is mainly caused by the use and interpretation of calculation methods. This causes a different ‘playing field’ for farmers of (neighbouring) EU countries. Differences in the level of nitrogen inputs are another cause of variation.
- None of the countries of this report have used a methodology to assess the actual N_2O emissions per unit biofuel: methods were adapted, resulting in lower values in comparison with standard methodologies.
- An EC decision on the use of one common method to determine N_2O field emissions is recommended. Given the current science with respect to detailed process models, the more simple approach of emission factors of the IPCC-2006 guidelines is preferred.
- GHG emissions from fertiliser nitrogen show a large variation with respect to level of application and to the emission factor used.
- The application level should be taken from agricultural statistics and not taken from advised application levels or estimated by nitrogen removal with harvested crop products. The choice of the emission factor should be motivated with supporting data on the origin of the fertilisers used.
- Differences in the emission factor of fertiliser nitrogen have a large impact on the total emission.
- The emission from diesel use is variable, but only with respect to input volumes and not to the emission factor. Different crop yields are an important cause of differences in diesel use per unit harvested product.
- The quantity of diesel used per ha in the Netherlands for the production of wheat, rapeseed and corn is remarkably high.
- Emissions from ‘other’ inputs show minor variations. Application of nutrients (P, K, Ca) to a crop rotation rather than to individual crops is an important cause of variation.
- Differences in reported conversion and allocation factors are small but can be significant in relation to the RED default values. Using standard values would decrease the maximum regional value of wheat from France to below the RED default value.
- If the BioGrace tool (version 2)would be used in the calculations, the RED default emission values would be exceeded in much more regions than presently is reported.
- An approach to determine N_2O as proportional to crop yields is not adequate to assess the actual variation of N_2O emissions in Europe related to crop cultivation.

5. References

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Appendix I.
Default and standard values

RED default values for the total GHG emission from the cultivation of biofuel crops and European average values for emissions and inputs from the 'Well to Wheels' study as used in the BioGrace tool (version 2).

	unit	Winter wheat	Rapeseed	Grain maize	Sugar beet
RED default	g CO_2-eq MJ^{-1}	23	29	20	12
- N_2O field emission	g CO_2-eq MJ^{-1}	7.88	12.69	4.3	4.56
- fertiliser N	g CO_2-eq MJ^{-1}	9.46	11.15	5.4	3.31
- diesel use	g CO_2-eq MJ^{-1}	4.77	3.56	5.5	2.60
- 'other' sources	g CO_2-eq MJ^{-1}	1.29	1.50	5.0	1.03
yield	kg ha^{-1}	5208	3113	3863	68860
- moisture content	%	13.5	10	15	75
N input	kg ha^{-1}	109.3	137.4	51.7	119.7
P input	kg ha^{-1}	16.4	49.5	25.8	134.9
K input	kg ha^{-1}	21.6	33.7	34.5	59.7
lime input	kg ha^{-1}	0	0	1600	400
diesel use	liter ha^{-1}	103.7	82.6	100.4	176.5
pesticides use	kg ha^{-1} act. ag.	2.3	1.2	2.4	1.3
seeds	kg ha^{-1}	120	6	?	6
N_2O field emission	kg ha^{-1}	1.81	3.10	0.82	3.27
conversion factor	MJ kg^{-1} d.m.	9.03	15.27	9.45	8.86
allocation factor	-	0.595	0.613	0.546	0.713

Appendix II.
Calculation methods for N_2O emission

IPCC-2006 approved methods (IPCC, 2006) distinguish three options for calculation of N_2O emissions. Under the so-called Tier 1, *direct* emissions of nitrous oxide are calculated following a relatively simple equation with nitrogen inputs (including crop residues) and emission factors provided in the IPCC report. If more detailed emission factors and crop and soil management data are available, direct emission calculations can be further specified representing local conditions by accommodating country specific emission factors to the application of synthetic fertilisers and organic N (Tier 2). The specific emission factors need to be rigorously documented (peer reviewed). Tier 3 refers to modelling or direct emission measurements, where models can relate soil and environmental variables affecting N_2O emissions to the size of those emissions after which these relationships can be used to predict emissions from larger areas in combination with N inputs. IPCC warns that models should only be used after validation by representative experimental measurements. A similar approach is defined for *indirect* nitrous oxide emissions, occurring outside the field after volatilisation or leaching of part of the nitrogen inputs from that field. Generic emission factors to be used under Tier 1 and country specific factors under Tier 2 calculations. Tier 3, again, refers to modelling or measurement programs. All countries that used IPCC-2006 based methods in the reports did use a Tier 1 approach.

The Stehfest and Bouwman (2006) model was set up to take regional differences in soil and climate conditions into account, by specifying emission factors for N input from chemical fertilisers and animal manure to soil types and climate zones. This model is an example of the Tier-3 approach. However, when only average emission factors are used (as in the UK report), irrespective of differences in soil and climate conditions, the approach is not different from a Tier 1.

The average European values for N_2O emissions as used in the BioGrace tool (version 2; BioGrace, 2010) are crop specific averages for Europe, resulting from model calculations in the CONCAWE/EUCAR/JRC-IES 'Well to Wheels' study (WtW, Edwards *et al.*, 2006). In this study the DNDC model was used to assess the effects of soil and climate conditions. This analysis is an example of a Tier 3 approach, as it considers regional differences. However, since only average European values were used, the approach here is qualified as a Tier 1 method.