DISPROOF OF THE ACP BIOFUEL PAPER

N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels
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ABSTRACT:

The fundamental approach of the ACP biofuel paper is that the N content of a crop or crop part determines the amount of N_2O emissions ascribable to its production, and the paper compares the warming effect Meq of the N_2O emissions related to liquid biofuels to the cooling effect M of the CO_2 savings resulting from their replacing fossil fuels, expressed in the ratio Meq/M. Although this N contents approach is sound, a set of assumptions and simplifications far from reality, including an overestimation of the N_2O emissions from agriculture as a whole, result in completely misleading values of Meq/M, so the sensational unconditional conclusion, that liquid biofuels cause warming rather than cooling, is simply a fallacy.

As demonstrated in this disproof with its available sources and comprehensive calculations based upon the conditions in the real world outside the cities, liquid biofuels produced as part of responsible and competent agriculture cause no or only small N_2O emissions in themselves, which leads to Meq/M values that are either 0 or rather low, in other words no, or only a limited, warming effect to counteract the cooling effect of using liquid biofuels; even for an agriculture as incredibly wasteful as assumed in ACP biofuel paper, unthinkable in responsible and competent agriculture, the real Meq/M values are far below the paper values. Apart from reducing GHG emissions, the production of liquid biofuels may contribute to significant environmental improvements in agriculture as a whole, especially if it is regulated by simple and reasonable environmental requirements on a worldwide scale.

CONTENTS:

RECOGNITION:

The present disproof, and the comprehensive spreadsheet used throughout it, could never have been written without the kind and invaluable help from many experts and a few neighbouring farmers and friends, some of whom appear in the sources, and none of whom are responsible for possible errors.

1. INTRODUCTION:

Basically, all the objections to the ACP biofuel paper may be summarized in an objection to its apparently being based upon City Thinking and to the fallacies resulting from it. *There is a world outside the cities* at *www.ppo.bugge.com* presents a description of the concept.

This disproof is written in defence of responsible and competent farmers all over the world, especially farmers that grow oil plants as a sound part of sustainable agriculture and utilize the crop for purposes of their own choice, which may include the use of PPO (pure plant oil) as engine fuel or for other purposes such as medicine, cosmetics, lubrication, and food, if applicable, and which may include the use of press cakes/pellets as fodder, as green manure, as renewable fuel, or for other purposes, and which may include the use of sediments/filter residues in soapmaking and for other purposes, and which may include the use of various parts of oil plants such as leaves, flowers, whole pods, sap, bark, roots, and straw/stems/trunks/branches, for a great variety of purposes which may include medicine, cosmetics, dyes, food, and solid fuel.

This disproof is not written in defence of non sustainable farming, especially at a large scale, without crop rotation, with GMO and/or unnecessary amounts of synthetic fertilizers, pesticides, and artificial growth regulation means, all resulting in soil exhaustion, extinction of invaluable plants and animals, extreme suppression of nature, and poorer food. Actually, such agriculture is created and maintained by unjust and harmful trade conditions, shameless trade profits, and subsidies to lower prices, all governed by City Thinking.

Nor is this disproof written in defence of non sustainable biofuel production, generally caused by City Thinking.

Nor is this disproof written in defence of biofuel production causing actual food shortage, generally caused by City Thinking.

Nor is this disproof written in defence of biofuel production causing destruction of nature or its diversity, including wildlife, generally caused by City Thinking.

Nor is this disproof written in defence of unrestrained use of fuels, whether renewable or fossil, generally caused by City Thinking.

All in all, responsible farmers round the world seem to have been caught as innocent victims and taken hostages, or sacrificed as pawns, in a fight between concerned City Thinkers and ruthless City Thinkers.

Apart from a fairy tale and a number of other completely different activities, the author of this disproof, written during half a year without earnings, has worked non profit with renewable energy for more than thirty years, has switched from normal farming to farming with reduced use of N, further to organic farming with the use of green manure only, and further to the Danish MVJ scheme which is an even stricter form of cultivating grass without any fertilization, is Vice President of EPPOA, the European Pure Plant Oil Association, and is member of the independent association Frie Bønder – Levende Land (Free Farmers – Living Land).

2. OVERALL PRESENTATION WITH GENERAL CONCLUSIONS:

The authors have published their paper within Atmospheric Chemistry and Physics Discussions, starting with a Discussion Paper, supplementing it by Author Comments during the following Interactive Discussion, and finalizing it with the final paper, all of which are openly available, so they might have foreseen their attracting great attention, especially counting a winner of the Nobel Prize for related work, and they might have presented reservations to the validity of their identical handling of all liquid biofuels produced anywhere in the world.

However, apart from one single sentence hidden away in one Author Comment, no reservations at all have been made, neither in answer to objections and suggestions raised in the Interactive Discussion, nor as a result of the foreseeable great attention and impact of the paper; on the contrary, all objections and suggestions that might have led to a moderation of the paper or to clear and express reservations preventing overinterpretation, have been rejected.

Therefore, the apparent claim to unconditional worldwide validity of the ACP Biofuel paper, in other words its applicability to each and every one of the liquid biofuels in question, produced from agricultural crops anywhere in the world, has been taken at face value in this disproof, as indeed it has among scientists, politicians, other decision makers, and everyone communicating news and knowledge.

The fundamental approach of the ACP Biofuel paper is that the N (nitrogen) content of a crop, or of a crop part, determines the amounts of N_2O (laughing gas) emissions resulting from its production, and the paper compares the warming effect Meq of these N_2O emissions to the cooling effect M of the CO_2 savings resulting from the replacement of the corresponding fossil fuel, expressed in the ratio Meq/M:

- *Here we concentrated on the climate effects due only to required N fertilization in biofuel production and we have shown that, depending on N content, the current use of several agricultural crops for energy production, at current total nitrogen use efficiencies, can lead to N_2O emissions large enough to cause climate warming instead of cooling by "saved fossil CO_2". Conclusions, page 393*
- *These equations are valid for all above-ground harvested lant material, and separately also for the products and residues which are removed from the agricultural fields. If Meq>M, there will be net climate warming, the greenhouse warming by increased N_2O release to the atmosphere then being larger than the quasi-cooling effect from "saved fossil CO_2".*
  3. N_2O release versus CO_2 saved in biofuels, page391

In other words: the fundamental approach of the ACP Biofuel paper is to follow the N content in order to calculate the separate contributions of N_2O to the GHG emissions.

Actually, without this fundamental N contents approach the ACP Biofuel paper would not really offer anything new as compared to other attempts to determine the environmental impacts related to the production and use of biofuels.

It should be noted that the amounts of N_2O emissions are measured by their N contents, sometimes expressly denoted N_2O-N, throughout the ACP Biofuel paper and this disproof.

The N contents approach is sound, and it has neither been questioned in the closed Interactive Discussion nor in general.

It should be noted that any objection to the use of the N contents approach in this disproof, and in future calculations of the environmental impact of liquid biofuels, would also be an objection to, and a rejection of, any validity of the entire ACP Biofuel paper.

Therefore the very same N contents approach is followed throughout this disproof, ultimately leading to calculations of N chains to determine the N_2O emissions from liquid biofuel production in the real world.

And it is suggested that the N contents approach is extended into a universal contents approach to a complete determination of the total environmental effects in the real world, including GHG emissions such as N_2O and CO_2, based upon the actual uses of the contents and the extent that each use of each parts constitutes a genuine replacement of something otherwise needed.

The authors of the ACP Biofuel paper specifically mention the crops rapeseed, wheat, barley, oat, maize, and sugar cane, used for liquid biofuels in the form of biodiesel and bioethanol; PPO (pure plant oil) is omitted entirely.

And for each combination of liquid biofuel and crop, the authors calculate a required amount of fresh synthetic (commercial) N fertilizer that is in direct proportion to the N content in the whole crop, leading to a specific range of N_2O emissions, further leading to a specific range of warming effect, which is then compared to the cooling effect resulting from replacing fossil fuel by the liquid biofuel, as calculated from the C (carbon) content in the liquid biofuel alone, each and every step of the calculations being based upon simplified assumptions and estimates entirely determined by the authors themselves.

In other words: according to the authors of the ACP Biofuel paper, the relative N_2O emissions caused by a liquid biofuel can be calculated simply from the ratio of the N content in the whole crop to the C content in the biofuel alone, using their very own extremely simplified calculation basis. The simplifications chiefly reflect assumed worst cases, many of which are worse than worst cases in the real world; the combination of them presented as generally valid is far worse than worst case.

Referring to the introduction, apparently this calculation basis is so deeply rooted in City Thinking that it inadvertently presents a number of express or implied claims that might otherwise be seen as rather grave insults to the farmers of the world.

Referring to the separate objections in sections 3.1 - 3.7, the structure and use of which is explained in the initial part of chapter 3, the most important parts of the calculation basis reflect what appears to be a somewhat strange and not entirely coherent interpretation of reality in the world outside the cities:

3.1. The use of a common N uptake efficiency NUE/e = 0.4:

- All crops for liquid biofuels are grown 100% on synthetic N fertilizers at the world average N uptake efficiency e = 0.4 or 40%, no more, no less.

The effect of this is a significant overestimation of the N consumption and thereby N_2O emissions in environmentally concerned parts of the world and in responsible and competent agriculture, and an underestimation of the N consumption and thereby N_2O emissions in less environmentally concerned regions and in less responsible and less competent agriculture.

3.2. The values of N content r_N for biofuel crops:
– The N content in protein is 17.7%, not 16% as everyone else thinks.
The effect of this, along with a few unusually high values of protein/N contents, is an overestimation of the N content in the crop, and thereby the N_2O emissions, for rapeseed and wheat.

3.3. The disregarding of energy consumption and of other crop parts:
– Fossil fuels simply emerge at the pumps at the fuelling stations, ready for use, with no energy consumption or emissions related to their production and transport;
– The energy consumption to produce any liquid biofuel is outbalanced by the value of other crop parts, and the energy content of any other crop part is outbalanced by the additional energy consumption required to produce it, even if no energy consumption is needed at all;
– The other crop parts are not used at all.
The effect of this is a corruption of any comparison between liquid biofuels and fossil fuels, and between different liquid biofuels, leading to an overestimation of the GHG emissions, including the N_2O emissions, especially from the production of the environmentally best of liquid biofuels.

3.4. The use of the C content r_C instead of the effective energy content:
– The energy content of a fuel is determined by its C content alone.
The effect of this is an overestimation of the effective energy content, and thereby an underestimation of the N_2O emissions for biodiesel, and an underestimation of the effective energy content, and thereby an overestimation of the N_2O emissions, for bioethanol; used in connexion with methane (biogas), the effect would be a significant underestimation of the effective energy content and thereby a significant overestimation of the N_2O emissions.

3.5. The ascription of all N in the crop to the liquid biofuels:
– All farmers in the world producing liquid biofuels dump 100% of the other crop parts with all the N content and up to half the energy content of the crop, in a way so that 100% of their N contents are removed from the agricultural circulation but still produce 100% of the N_2O emissions ascribed to agriculture in general, and so that 100% of their energy content is lost.
The effect of this is that N contents and N_2O emissions, that should be ascribed entirely or partially to the other crop parts according to the fundamental N contents approach, are falsely ascribed to the liquid biofuels, thus corrupting the calculation of the GHG emissions, including N_2O emissions, especially for the production of the environmentally best liquid biofuels.

A remarkable special effect is that all the N_2O emissions related to concentrates imported into countries such as Denmark, where they cause more than half the real amounts of N_2O emissions, are thereby transferred to the countries where the crops are grown, thus reducing the N_2O emissions ascribed to agriculture in countries such as Denmark to the amounts caused by the crop cultivation alone.

3.6. The ascription of N_2O emissions to agriculture/fertilizer use, leading to the range y = 3 - 5%, expressing the proportion of N in synthetic fertilizer that ends as N_2O-N as a result of any kind of agriculture, including liquid biofuel production:

- 100% of the agricultural N_2O emissions in the world are caused by application of new synthetic N fertilizers to the fields, the major part being socalled background N_2O emissions emitted elsewhere but still entirely caused by new N fertilization, with no contribution from animal manure, green manure, or any other kind of manure;
- 100% of the N_2O emissions from agricultural soils, including the additional background field emission of 1 kgN_2O-N/ha not ascribable to recent fertilizer use according to the paper itself, are caused by fertilizer use;
- 100% of all anthropogenic N_2O emissions in the world not expressly ascribed to specific non agricultural sources are caused by agriculture;
- 100% of all N_2O emissions in the world not expressly ascribed to specific natural sources are anthropogenic;
- The annulment of any claim to worldwide validity and applicability, presented in the paper itself in the form of the reservation made in the Author Comments, but omitted in both the Discussion Paper and the final paper, namely that the approach of the paper cannot be used for actual ascriptions of N_2O emissions, neither to specific countries nor to specific sources, is disregarded and thus annulled;
- The N_2O emissions values in the 2006 IPCC Guidelines should not be used because they are insufficient to explain the range of N_2O emissions related to liquid biofuel production; and at the same time the very same 2006 IPCC Guidelines support the paper.

The effect of this is that uncertain but significant amounts of N_2O emissions are falsely ascribed to agriculture, more specifically to fertilizer use, which means that the range y = 3 - 5% is clearly an overestimation; the dependence on a correct assessment of natural N_2O emissions, generally considered to have a considerable uncertainty, and of other anthropogenic N_2O emissions add to the uncertainty; and the obvious contradictions related to the reservation and to the contrasting claims about the 2006 IPCC Guidelines underline the uncertainty.

3.7. The ascription of N_2O emissions to liquid biofuels, leading to the values of Meq/M for the different biofuel crops based upon the values of e, r_N, r_C, and y:

- For each biofuel crop, the range of the Meq/M values can be calculated simply from the crop specific values of r_N and r_C, the general value of e, and the general range of values y, regardless of any differences in the use of other crop parts, and regardless of any differences in the entire N chains of uses and losses.

The effect of this, which includes all the effects mentioned above, is a completely misleading presentation of the N_2O emissions related to biofuel crops, including a false ascription of all the N_2O emissions to the very first use of fertilizer.

With this remarkable calculation basis, the authors of the ACP biofuel paper end up calculating the N_2O emissions related to the production of a liquid biofuel from the ratio of the N content in the other crop parts to the C content in the biofuel.

In other words: with this calculation basis, the authors of the ACP biofuel paper end up calculating the N_2O emissions for a liquid biofuel from the ratio of the N content that is not in the biofuel to the C content that is in the biofuel.

Quite foreseeable on this basis, the authors of the ACP biofuel paper draw the final conclusion that liquid biofuels cause large amounts N_2O emissions, “large enough to cause climate warming instead of cooling”.

More specifically, the authors present the following rather discouraging values of Meq/M, expressing the ratio between the warming effect Meq of the N_2O emissions resulting from liquid biofuel production and the cooling effect M obtained by replacing the corresponding fossil fuels, only considering the CO_2 emissions from the actual use of the fuels:

Liquid biofuel	Biodiesel	Bioethanol			
Crop	Rapeseed	Wheat	Barley/oat	Maize	Sugar cane
Paper value of Meq/M	1.0 - 1.7	1.3 - 2.1	1.1 - 1.9	0.9 - 1.5	0.5 - 0.9

Furthermore, instead of presenting reservations to their Meq/M values, the authors have underlined the claim to unconditional worldwide validity of the ACP biofuel paper to the liquid biofuels in question by adding a sensitivity analysis where the effects of a higher N uptake efficiency, of a certain limited use of animal manure, and of a certain use of other crop parts, have been presented separately.

However, as it appears from section 3.7 in this disproof and in accordance with the fundamental N contents approach of the ACP biofuel paper, the possible amounts of N_2O emissions ascribable to a liquid biofuel depend upon the liquid biofuel, upon the crop, upon the use of other crop parts, and upon the agricultural responsibility and competence, all resulting in a specific agricultural N chain and a corresponding N_2O emission chain related to, and thus ascribable to, specific parts of the N chain.

Based upon available sources, section 3.7 in this disproof presents verifiable chains of N consumption and N_2O emissions leading to N_2O emissions and Meq/M values really ascribable to a number of different liquid biofuels produced from a number of biofuel crops.

Similarly, in accordance with the suggested universal contents approach, the amount of fossil fuel used/saved, and thus the CO_2 emissions/savings ascribable to a liquid biofuel depend upon the liquid biofuel and its use, upon the crop, upon the use of other crop parts, and upon the agricultural responsibility and competence, all resulting in a specific agricultural energy chain and a corresponding CO_2 emission chain, along with the corresponding fossil energy and CO_2 emission chain, all resulting in a specific ratio of CO_2 emissions to CO_2 savings.

CO_2 emission chains and CO_2 savings are not specifically dealt with in this disproof.

The fallacy of ascribing all N_2O emissions to the first use of fertilizer seems to arise from a failure to understand how the agricultural circulation works: N leads to N_2O emissions, not only once, but starting even before the first application to the field and continuing through every transformtion until it is eventually lost from the circulation.

This fallacy leads to far greater errors than a corresponding wellknown fallacy in the world inside the city: failing to understand the concept of compound interest leads to the erroneous claim that it takes 11.1% and not 8% interest to double the amount on an account in 9 years.

The final comprehensive calculations of the ratios N_2O-N to N in the first crop and total N_2O-N emissions to N in original synthetic fertilizers according to the 2006 IPCC Guidelines, summarized in tables in section 3,7, show that the values of Meq/M presented in the ACP biofuel paper are useless to describe the real N_2O emissions and the real GHG impacts related to the production of liquid biofuels.

The calculations include PPO and biodiesel produced from rapeseed and bioethanol produced from the cereals wheat, barley, and maize, all crops grown with Danish and world average N uptake efficiencies, with and without use of straw, except for maize where the straw is always left in field, and with a number of different more or less likely uses of the other crop parts in the form of rapeseed cakes/pellets and distillers grain.

The more likely uses of the other crop parts include the natural use as fodder, the possible use as green manure, especially of distillers grain, if the amounts should exceed the demand for fodder, and the possible use as fuel, especially of rapeseed cakes/pellets.

The less likely uses of the other crop parts, at least in environmentally concerned parts of the world with responsible and competent agriculture, include waste removed and disposed of by biofuel companies outside agriculture, and the least responsible and also extremely unfavourable: the dumping of the other crop parts in the field without their having any fertilizing effect.

It should be noted that only the very last use, as waste left in field, unthinkable except in less responsible and less competent agriculture, corresponds to the ACP biofuel paper.

And it should be noted that the calculation of Meq/M values are based upon lower relative yields of liquid biofuels than those presented in the paper, and that the 5% higher effective energy in PPO reported by PPO drivers is disregarded, thus leading to higher Meq/M values than would otherwise result from the calculations.

And it should be noted that the use of the straw does not necessitate additional N fertilization; on the contrary, it reduces leaching.

In accordance with the fundamental N contents approach of the ACP biofuel paper to follow the N content in order to calculate the separate contributions of N_2O to the GHG emissions, the ascription of N and N_2O emissions to the liquid biofuel, and thus its Meq/M value, depends upon the use of the other crop part which holds the total amount of N:

When the other crop part is used as fodder, in the form of a concentrate replacing other fodders otherwise needed, which would be grown on at least the same amounts of fertilizer N, the Meq/M value is 0.

When the other crop part is used as fuel, the Meq/M value is 0 for the liquid biofuel, whereas the full value of Meq/M relative to the N_2O emissions applies to the other crop part which is dealt with separately.

When the other crop part is used as green manure, replacing a certain amount of fertilizer N otherwise needed, and thus reducing the amount of other fertilizer N that is required for the next crop, the value of Meq/M is reduced correspondingly relative to the total N_2O emissions.

When the other crop parts are dumped as waste, replacing nothing otherwise needed, the full value of Meq/M relative to the N_2O emissions applies.

The following summaries of Meq/M values for different combinations of liquid biofuels and crops, calculated according to the 2006 IPCC Guidelines, apply to Danish N uptake efficiencies and to the world average, depending on the use of other crop parts.

Values with straw used are shown to the left, and values with straw left in the field are shown to the right.

Meq/M values calculated according to the 2006 IPCC Guidelines					
Danish values, Straw used/left in field, Use of other crop part	PPO produced from Rapeseed	Biodiesel produced from Rapeseed	Bioethanol produced from Wheat	Bioethanol produced from Barley	Bioethanol produced from Maize
Fodder	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00
Fuel	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00
Green manure	0.13 0.19	0.12 0.18	0.15 0.20	0.16 0.22	0.17
Waste removed	0.19 0.30	0.18 0.28	0.22 0.31	0.24 0.34	0.25
Waste left in field	0.28 0.40	0.26 0.37	0.31 0.40	0.33 0.44	0.32
Paper values	(1.0 - 1.7)	1.00 - 1.70	1.30 - 2.10	1.10 - 1.90	0.90 - 1.50

Meq/M values calculated according to the 2006 IPCC Guidelines					
<NUE/e> = 0.4, Straw used/left in field, Use of other crop part	PPO produced from Rapeseed	Biodiesel produced from Rapeseed	Bioethanol produced from Wheat	Bioethanol produced from Barley	Bioethanol produced from Maize
Fodder	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00
Fuel	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00
Green manure	0.33 0.46	0.31 0.42	0.31 0.41	0.31 0.41	0.32
Waste removed	0.42 0.58	0.39 0.54	0.40 0.51	0.40 0.53	0.40
Waste left in field	0.51 0.70	0.47 0.65	0.49 0.61	0.49 0.62	0.48
Paper values	(1.0 - 1.7)	1.00 - 1.70	1.30 - 2.10	1.10 - 1.90	0.90 - 1.50

Evidently, the ranges of Meq/M values in the ACP biofuel paper are completely useless to describe the environmental effects of N_2O emissions from the cultivation of biofuel crops for liquid biofuels, because all the real Meq/M values are either 0 or far below the minimum values of the ranges in the paper.

As it appears, the Meq/M values chiefly depend upon the use of other crop parts, not upon the crops as do the values in the ACP biofuel paper.

And it appears, the Meq/M values in the ACP biofuel paper would have been far too high even if they had been presented as worst case in less responsible and less competent agriculture at world average N uptake efficiencies, because the middle values of the ranges are about 2 - 2.8 times higher than worst case.

Values of total N_2O-N to N in original synthetic fertilizers have been calculated for a large number of normal agricultural crops in normal crop rotations, with and without the additional background field emission of 1 kgN_2O-N/ha not ascribable to recent fertilizer use.

In connexion with chiefly cereal crop rotations, the N_2O-N to fertilizer N values in themselves are clearly below the value range y = 3 - 5% in the ACP paper, but more or less within it when the background emission is added.

In connexion with crop rotations starting with N fixating crops, the N_2O-N to fertilizer N values are much higher than the value range y = 3 - 5% in the ACP paper.

This shows that the 2006 IPCC Guidelines may indeed reflect the generally assumed amounts of N_2O emissions from agriculture, in contrast to the ACP biofuel paper.

The following approximations may apply to the real Meq/M values for Danish N uptake efficiencies and for the world average N uptake efficiency of 40%, covering all combinations of the liquid biofuels PPO, biodiesel, and bioethanol, and the biofuel crops rapeseed, wheat, barley, and maize, consisting of common basic values and possible adjustments depending on the use of straw for rapeseed, wheat, and barley:

<table>
<tr><th colspan="5">Meq/M values calculated according to the 2006 IPCC Guidelines</th></tr>
<tr><th>Use of other crop part</th><th colspan="2">Danish values</th><th colspan="2"><NUE/e> = 0.4</th></tr>
<tr><td>Fodder</td><td>0.00</td><td rowspan="5">Rapeseed: x 0.75 if straw is used, x 1.15 if straw is left in field; Wheat: x 1.25 if straw is left in field; Barley: x 1.40 if straw is left in field.</td><td>0.00</td><td rowspan="5">Rapeseed: x 1.35 if straw is left in field; Wheat and barley: x 1.28 if straw is left in field.</td></tr>
<tr><td>Fuel</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Green manure</td><td>0.16</td><td>0.32</td></tr>
<tr><td>Waste removed</td><td>0.24</td><td>0.40</td></tr>
<tr><td>Waste left in field</td><td>0.32</td><td>0.48</td></tr>
<tr><td>Paper values</td><td colspan="2">0.90 - 2.10</td><td colspan="2">0.90 - 2.10</td></tr>
</table>

It should be noted that the use of other crop parts as fuel, and the resulting removal of N from the agricultural circulation may be questionable, but this use should be judged separately and independently of the liquid biofuels, and their Meq/M values should form part of the calculation of their total GHG impacts, as is the case with the liquid biofuels; this is dealt with in section 3.7 where separate Meq/M values based upon the replacement of coal are stated.

With this, all the paper values and the paper conclusions have been disproved, and this disproof may form the basis of a universal contents approach to a complete determination of the total environmental effects of liquid biofuels and other biofuels, including GHG emissions such as N_2O and CO_2, in the real world outside the cities.

Evidently, the immense differences in Meq/M values, from 0 to about 0.7, shows that the N_2O emissions related to liquid biofuels depend entirely upon responsibility and competence in agriculture, and that it is indeed possible to produce liquid biofuels without N_2O emissions at all.

Therefore, every possible effort should be made to ensure that liquid biofuels are produced with a minimum of environmental impacts, including no or very low N_2O emissions, as a natural part of agriculture everywhere in the world.

With such an effort, a reasonable amount of liquid biofuels may strengthen responsible and competent agriculture in general.

However, instead of bringing about more attention to the total use of crops, and to the environmental impacts of each crop part, and thereby supporting more responsible and competent management of all crop parts, thus contributing to significant worldwide reductions of N_2O emissions and other environmental impacts of agriculture in general and of liquid biofuel production in particular, the ACP paper removes attention from the use of other crop parts and thereby actually supports less responsible and less competent management of all crop parts, and thus counteracts such reductions.

Adding to this effect, the lack of attention to differences in management of other crop parts will prevent pressure on less responsible farmers and/or regions in the world, thus further counteracting improvements in agriculture as a whole and contributing to a development where liquid biofuels are chiefly produced in less environmentally concerned regions of the world with much greater N_2O emissions and other environmental impacts.

All in all, the ACP biofuel paper, obviously written out of a genuine concern, does not present actual contributions to solutions within the environmental issues of biofuels and agriculture; rather, it has helped rounding up the usual suspects in City Thinking: the farmers.

Therefore, others will have to make the effort of ensuring that liquid biofuels are produced in the best possible way, thereby fulfilling their part in a transition into a sustainable future.

And others will have to seize the golden opportunity, created by the great attention to liquid biofuels, to obtain decisive and lasting improvements in agriculture as a whole, leading to crucial reductions in the N_2O emissions and other environmental impacts, and hopefully also to improved food, food supply, and welfare.

This disproof, with its general information, specific values, and conclusions, with the calculation tools that it refers to, and with its recommendations and suggestions, has grown beyond its original purpose to constitute an attempt to contribute to this double effort.

3. SEPARATE OBJECTIONS WITH CONSEQUENCES AND CONCLUSIONS:

The objections disproving the ACP biofuel paper are rather comprehensive and detailed, for four mutually intensifying reasons:

Firstly, the paper has a very high apparent credibility owing to its being written by highly esteemed scientists including a Nobel Prize winner within a related area; therefore a disproof must have a considerable evidential weight, presented thoroughly and detailed.

Secondly, the paper as it is known consists of the original Discussion Paper totalling 15 pages, the Author Comments during the following Interactive Discussion totalling 20 pages, and the final paper totalling 7 pages, all in all 42 pages, six times the length of the final paper, all of which form part of the paper as it has been presented by the authors and had its impact through its wide circle of readers and the great attention it has created, and each of which are needed to get the full picture of what actually is put forth and which changes and modification have been made in statements, values, and general figures, throughout the time the paper has been generally known and referred to; therefore a disproof must address each of the separate versions of what is put forth, referring to the relevant constituent part(s) in question; it is quite possible that the original Discussion Paper, with some of the most conspicuous statements which have later been moderated, and with certain values and general figures which have later been changed, is still the part that has had the greatest impact and received the greatest attention.

Thirdly, the curtness of the paper, and especially its condensed derivations based upon numerous implicit prerequisites and assumptions, necessitates an exposition of what is actually being derived and what the actual basis is; unfortunately, the extent of the exposition must be in inverse ratio to the explicitness of the paper.

Fourthly, many prerequisites and assumptions leading to fallacies seem to be based upon City Thinking, and upon a corresponding lack of insight and understanding concerning agriculture, which few readers can be expected to discover; therefore, to be useful for all readers, a disproof must correct basic misconceptions and provide the proper understanding; occasionally, reference to the real world outside the cities is used in answer to what might seem plainly insulting to the farmers of the world if not simply viewed as manifestations of City Thinking.

The sheer length of the objections may appear discouraging.

However, the objections are structured in a way that enables reading of selected parts only, as it appears from the following.

In addition, the information, explanations, and calculation tools, presented in this disproof may be used as a basis for further understanding of agriculture in general and liquid biofuel production in particular, and as a basis for further development.

Each of the sections 3.1 to 3.6 forms a disproof of one aspect of the paper assumptions, paper simplifications, and paper values, and put together they lead to section 3.7 which forms the explicit final disproof of the claimed N_2O emissions from cultivation of crops ascribable to liquid biofuels, and of the comparison between the warming effect of N_2O emissions and the cooling effect of CO_2 savings which is the final claim of the paper.

Sections 3.1 to 3.7 deal with the N chain, thus together following the N all the way from the original fertilization to the final uses and losses, corresponding to the fundamental and sound paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions. Sections 3.1, 3.5, and 3.6, deal with individual links and values in the N chain, and section 3.7 deals with the entire N chain referring to the previous sections. Sections 3.2, 3.3, and 3.4, deal with different aspects of the comparison between the warming effect of N_2O emissions and the cooling effect of CO_2 savings.

This means that section 3.7 may be read as the main section with the actual and explicit disproof, possibly supplemented by one or more of the other sections, or all sections may be read to present the full picture, or each section may be read in its own right.

Each section consists of four parts which may be read in full or in part according to need:

1) A presentation of the essence in the assumptions, simplifications, and claims, made on the subject in question in the original Discussion Paper, in the Author Comments during the following Interactive Discussion whenever relevant, and in the final paper, all of which form part of the paper as it has been presented by the authors and had its impact through its wide circle of readers and the great attention it has created.

   All quotes are shown in ***dark grey bold italics with underlining of key parts*** and are supplied with page numbers:
   - The Discussion Paper page numbers range from 11191 to 11205,
   - The Author Comments page numbers range from S3829 to S6601,
   - The final paper page numbers range from 389 to 395;
2) An exposition of the objections, revealing fallacies, errors, and inaccuracies, in the paper, based upon common knowledge and sense along with specific knowledge based upon easily available and verifiable sources;
3) A presentation of the consequences and conclusions of the objections which apply to the subject in question;
4) A listing of the available sources of specific knowledge with live links, each of which may be used as an extension of the section; all sources are named by website publishers; in the full list in chapter 5, the sources are named by authors, if any are stated.

This means that the third part of each section may be read as the main part, possibly supplemented by one or more of the other parts, or all parts may be read.

Sections 3.1, 3.2, 3.5, 3.6, and 3.7, refer to a common source in the form of a comprehensive spreadsheet [1]; Sheet A contains notes and sources, Sheet B contains Danish N uptake efficiencies and N contents of crops, and Sheets C and D contain complete N chain calculations following the N all the way from original fertilization, through crop rotation, over fodder crops and animal husbandry and/or over crops for food, fuel, or other purposes, to final uses and losses, until all the N is spent, Sheet C being entirely based upon Danish values, Sheet D having values chosen by the user; Sheet E holds information about Danish fodder amounts.

And sections 3.4, 3.5, and 3.7, refer to a common source in the form of a spreadsheet [11] with energy contents of fuels, coefficients for comparison of the opposite GHG effects of N_2O and CO_2 emissions based upon the energy contents of the fuels, and other values.

3.1. THE USE OF A COMMON N UPTAKE EFFICIENCY NUE/e = 0.4:

3.1.1. PAPER ASSUMPTIONS:

Two crucial paper assumptions are the assumption that all crops for liquid biofuels are grown on new synthetic N fertilizer and the assumption that all calculations of N_2O emissions related to liquid biofuel production can be based upon a common value of 0.4, or 40%, for the N uptake efficiency, denoted e here, elsewhere known as NUE, expressing the efficiency of the uptake by plants of N from new synthetic fertilizers, as stated in the Discussion Paper and repeated in the final paper with slight additions:

- *We start this study by deriving the yield of N_2O from fresh N input, based largely on data compiled by Prather et al. (2001) and Galloway et al. (2004).* 11193
- *e is the uptake efficiency of the fertilizer by the plants;* 11195

- *We start this study by deriving the yield of N2O from fresh N input, based on data compiled by Prather et al. (2001) and Galloway et al. (2004) with some analysis of our own.* 389
- *e is a surrogate for the uptake efficiency of the fertilizer by the plants;* 391

The assumption that all crops for liquid biofuels are grown on new synthetic N fertilizer is expressly and repeatedly stated in the Author Comments and stated again in the final paper:

- *We (in Crutzen et al., 2007) assume that biofuel production is performed in addition to current agriculture, and therefore will be based on freshly formed reactive nitrogen.* S5152
- *a) We assume that biofuel production requires fresh reactive nitrogen, i.e. mineral fertilizer only. Leip (2007) argues that, under current agricultural practice and probably also under a future extension of biofuels, sufficient manure will be available to provide approximately 20% of N needed for all crop production from livestock manure. This could potentially decrease mineral fertilizer requirement by 20%. While it may be useful to account for manure for current systems and possibly also in the future, at the same time we observe a spatial and organizational separation of animal production and biofuel production in many places where industrial livestock production is practiced. Even if there is a flow of manure nitrogen back into fields to replace mineral fertilizer, mineral fertilizer will remain clearly the largest fertilizer source – as may also be seen by fertilizer industry's prospect of increased production due to biofuel production. For that reason we have – for the main line of argument – remained with our original figures.* S6597

- *Furthermore, we assume that biofuel production is based on mineral fertilizer only (substitution of manure for synthetic fertilizer would offset our result by the percentage of synthetic fertilizer that is not used).* 391

The paper does state the fact that the value NUE/e = 0.4 = 40% is a worldwide average value under 'current agricultural practices', however without presenting any reservations to prevent the most natural implication of the term, which seems to express a worldwide homogeneity rather than a great diversity, namely that the value NUE/e = 0.4 is applicable as the common value for any crop anywhere in the world, as stated in the Discussion Paper, unyieldingly defended in the Author Comments, and even more expressly stated in the final paper, clearly stating that higher values only apply on a research basis, only as a possibility which may be generally realized in the agriculture of the future and therefore included in the sensitivity analysis in Table 2 in the final paper:

- *Under current agricultural practices, worldwide, the average value for e ≈ 0.4 (Cassman et al., 2002; Galloway et al., 2003; Balasubramanian et al., 2004).* 11196
- *Although there are possibilities for improvements by increasing the efficiency, e.g. for the uptake of N fertilizer by plants (Cassman et al., 2002) – which is much needed in regular agriculture as well – on a globally averaged basis the use of agricultural crops for energy production can readily be detrimental for climate due to the accompanying N2O emissions, as indicated here for the common biofuels: rapeseed/bio-diesel, and corn/ethanol.* 11197 - 11198

- **) In our paper the factor we called "e", with a value of 0.4, is exactly the same as the "RE_N" of Balasubramanian et al. (2004). These authors, in an authoritative review, have values of RE_N for different arable crops under current farming practice, ranging from <20% to 50% (<0.2 to 0.5, in our terms), with the value for irrigated maize given as 37% (or 0.37). Our use of 0.4 is thus well towards the upper end of the range, deliberately to make our estimates of N_2O more conservative. In the same SCOPE volume, Krupnik et al (2004) estimate RE_N to be 0.35-0.38 for all crops and regions.* S5146 - S5147
- *d) We assume that we need to add 2.5 times the amount of N to soil as is contained in the crops (e = 0.4). This has been challenged by Rauh and Berenz (2007) based on data from Europe. They suggest using the ratio between N-content of plants and fertilizer N-input to soils which they have demonstrated to be as high as 0.7. We recognise that test plots in some systems may give such N recoveries, and we are aware of other studies that provide nitrogen use efficiencies of 0.5-0.6 for rape seed (Nyikako, 2006), but the global average N efficiency in agricultural practice is lower (Balasubramanian et al. 2004), hence our factor of 0.4. Increase in nitrogen use efficiencies is needed in general (see Hirel et al., 2007). We now (in the revised manuscript) attempt to quantify what an improvement of 50% over the current global average could mean in terms of N2O emissions.* S6598

- *Under current agricultural practices, worldwide, the average value for e ≈ 0.4 (or 40%) (Cassman et al., 2002; Galloway et al., 2003; Balasubramanian et al., 2004). This value reflects the considerable amounts of N lost to the atmosphere via ammonia volatilization and denitrification (N2) and by leaching and runoff to aquatic systems. Fertilizer N use efficiency much higher than this (e.g. Rauh and Berenz, 2007) is certainly possible when fertilizer N is made available according to plant uptake requirements, but this does not reflect the agricultural practice in many countries of the world. Nonetheless, we recognise the possibility of better efficiencies in future, as has been possible in special circumstances on a research basis. Below we derive values for rN based on both e=0.4 and e=0.6.* 391
- *Here we concentrated on the climate effects due only to required N fertilization in biofuel production and we have shown that, depending on N content, the current use of several agricultural crops for energy production, at current total nitrogen use efficiencies, can lead to N2O emissions large enough to cause climate warming instead of cooling by "saved fossil CO2".* 393
- *Table 2. Sensitivity analysis, showing the impact on relative warming (Meq/M) resulting from changes to parameters used for Table 1. The calculations depend on assumptions made about the global agricultural practice of biofuel production. In each column, values differ from those presented in Table 1 by one parameter only as indicated in the relevant column heading.*

Crop	*Increased N-efficiency (e=0.6)*	*High share of manure (20%) in fertilizer for biofuels*	*Efficient use of by-products: Considerable fraction (50%) of N harvested for biofuel production replaces crops that would need N fertilizer*	
Rapeseed	*0.7–1.2*	*0.8–1.4*	*0.5–0.9*	
Maize	*0.6–1.0*	*0.7–1.2*	*0.4–0.7*	
Sugar cane	*0.4–0.6*	*0.4–0.7*	*0.3–0.4*	*392*

And, apparently based upon the claimed general applicability of the value NUE/e = 0.4, the paper presents no reservations concerning the general validity of the specific warming effects presented in its Table 1 and of its Conclusions, all of which therefore appear as valid for all crops used for liquid biofuel production anywhere in the world, as stated in the Discussion Paper and repeated in the final paper with slight additions:

- *Data on r_N for several agricultural products, in g(N)/kg dry matter (Velthof and Kuikman, 2004; Biewinga and van der Bijl, 1996), are presented in Table 1. They show net climate warming, or considerably reduced climate cooling, by fossil fuel "CO_2 savings", due to N_2O emissions.* *11197*
- *Here we concentrated on the climate effects due only to required N fertilization in biomass production and we have shown that, depending on N content, the use of several agricultural crops for energy production can readily lead to N2O emissions large enough to cause climate warming instead of cooling by "saved fossil CO2".* *11199*

- *Data on rN for several agricultural products, in g (N)/kg dry matter (Velthof and Kuikman, 2004; Biewinga and van der Bijl, 1996), are presented in Table 1, together with results on "relative warming". They show net climate warming, or considerably reduced climate cooling, by fossil fuel "CO2 savings", due to N2O emissions.* *391 - 392*
- *Here we concentrated on the climate effects due only to required N fertilization in biofuel production and we have shown that, depending on N content, the current use of several agricultural crops for energy production, at current total nitrogen use efficiencies, can lead to N2O emissions large enough to cause climate warming instead of cooling by "saved fossil CO2".* *393*

And, apparently the paper presents the statements in its Abstract as having general validity and applicability to all crops used for liquid biofuel production anywhere in the world, except for grass, this too apparently anywhere in the world, as stated in the Discussion Paper and repeated in the final paper with slight additions:

- *When the extra N_2O emission from biofuel production is calculated in "CO_2-equivalent" global warming terms, and compared with the quasi-cooling effect of "saving" emissions of fossil fuel derived CO_2, the outcome is that the production of commonly used biofuels, such as biodiesel from rapeseed and bioethanol from corn (maize), can contribute as much or more to global warming by N_2O emissions than cooling by fossil fuel savings. Crops with less N demand, such as grasses and woody coppice species have more favourable climate impacts.* *11192*

- *When the extra N2O emission from biofuel production is calculated in "CO2-equivalent" global warming terms, and compared with the quasi-cooling effect of "saving" emissions of fossil fuel derived*

CO2, the outcome is that the production of commonly used biofuels, such as biodiesel from rapeseed and bioethanol from corn (maize), depending on N fertilizer uptake efficiency by the plants, can contribute as much or more to global warming by N2O emissions than cooling by fossil fuel savings. Crops with less N demand, such as grasses and woody coppice species, have more favourable climate impacts. *389*

3.1.2. OBJECTION:

In the world outside the cities, the paper assumption that all crops for liquid biofuels are grown on new synthetic N fertilizer is obviously wrong; this is dealt with in sections 3.6 and 3.7.

And even with a worldwide average value of NUE/e = 0.4 or 40%, expressing the efficiency of the uptake by plants of N from new synthetic fertilizers, the paper assumption of its general validity is completely misleading: there are significant differences in N uptake efficiency, between different crops, between different kinds of agriculture, and between different countries, not just in research fields but in the real fields, and not sometime in the future but now.

This may be demonstrated by the following two cases:

Case 3.1.2.1: Cultivation of crops with the strictly regulated use of fertilizers in Danish agriculture:

As part of environmental impacts regulations, Danish farmers are obliged to follow specific harmony rules based upon crops and soil types, with limited total use of fertilizer N, including all sources including synthetic fertilizers, organic fertilizers such as animal manure, and precrop values, all calculated as equivalent amounts of N from synthetic fertilizers and reported in annual fertilizer accounts since 1993, resulting in a verifiable and consistent range of N uptake efficiencies according to [2]. For each crop, the total allowed amounts of N are chosen so that they are low enough to ensure a high N uptake efficiency and a moderate environmental impact, and they are below the amounts that would create the highest earnings; this has reduced the total Danish N fertilizer use by more than 1/3 in the first decade after 1993.

The following values of NUE/e = N uptake efficiency, calculated for Danish soil types according to Sheet B in [1], apply to a number of food/fodder crops suited for liquid biofuels and normal yield permanent hay/grass when the N content of straw/stems is excluded and the precrop value is assigned to the contributing crop as it obviously should, the values of <NUE>/<e> being weighed averages of all Danish soil types, and the values of $NUE_{2/3}/e_{2/3}$ being weighed averages of the best 2/3 of Danish soils where high value crops such as rapeseed, bread wheat, and maize for cobs, are mostly grown:

Crop without straw/stems	Winter rapeseed	Winter wheat	Winter wheat, bread	Winter barley	Maize, cobs	Grass hay, permanent	Grass, permanent,
<NUE>/<e>	0.71	0.64	0.54	0.60	0.62	0.44	0.81
<NUE>/<e>:0.4	1.78	1.60	1.35	1.50	1.55	1.10	2.03
$NUE_{2/3}/e_{2/3}$	0.77	0.70	0.58	0.64	0.66	0.44	0.81
$NUE_{2/3}/e_{2/3}$:0.4	1.93	1.75	1.45	1.60	1.65	1.10	2.03
% above 0.4	78-93%	60-75%	35-45%	50-60%	50-63%	10%	103%

As it appears, all Danish crops suitable for liquid biofuel production have an N uptake efficiency <NUE>/<e> for all Danish soils that is at least 50% above the worldwide average, even when the N content of straw/stems is excluded, thus presenting the biofuel crops less favourably than permanent grass and energy plants where all plant parts above ground are used. This is consistent with the reduction in fertilizer use after 1993 of more than 1/3.

And as it appears, rapeseed has the highest N uptake efficiency of all these crops, except for fresh permanent grass, <NUE>/<e> being 78% above the worldwide average, and the corresponding value $NUE_{2/3}/e_{2/3}$ for the best 2/3 of Danish soils being 93% above the worldwide average.

And as it appears, grass hay from normal yield permanent grass has a significantly lower N uptake efficiency than any of the crops suited for liquid biofuel, both <NUE>/<e> and $NUE_{2/3}/e_{2/3}$ being only 10% above the worldwide average. This means that grass has a high N uptake efficiency only when grazed or used fresh: when turned into a durable and easily storable crop comparable to those suitable for liquid biofuel production, it has a significantly inferior N uptake efficiency.

And as it appears, bread wheat has a somewhat lower N uptake efficiency than have any of the other crops shown here, apart from grass hay; probably, the same applies to wheats with special properties grown in other countries. This shows the importance of choosing types of crops with the highest N uptake efficiencies for liquid biofuels whenever possible.

The following corresponding values of <NUE/e> and $NUE_{2/3}/e_{2/3}$ according to Sheet B in [1] apply when the N content of straw/stems that may be gathered is included:

Crop with straw/stems	Winter rape-seed	Winter wheat	Winter wheat, bread	Winter barley	Maize, cobs	Grass hay, per-manent	Grass, perma-nent,
<NUE>/<e>	0.84	0.75	0.62	0.72	0.62	0.44	0.81
<NUE>/<e>:0.4	2.10	1.88	1.55	1.80	1.55	1.10	2.03
$NUE_{2/3}/e_{2/3}$	0.89	0.81	0.67	0.77	0.66	0.44	0.81
$NUE_{2/3}/e_{2/3}$:0.4	2.23	2.03	1.68	1.93	1.65	1.10	2.03
% above 0.4	110 - 123%	88 - 103%	55 - 68%	80 - 93%	55 - 65%	10%	103%

As it appears, all Danish crops suitable for liquid biofuel production except for maize, where the stems cannot be not gathered with present equipment, have an N uptake efficiency <NUE>/<e> for all Danish soils that is at least 80% above the worldwide average when the N content of straw/stems is included, thus making the biofuel crops actually comparable to permanent grass and energy plants.

And as it appears, rapeseed has the highest N uptake efficiency of all these crops, even higher than fresh permanent grass, <NUE>/<e> being 110% above the worldwide average, while the corresponding value $NUE_{2/3}/e_{2/3}$ for the best 2/3 of Danish soils is 123% above the worldwide average.

The following corresponding values of <NUE/e> according to Sheet B in [1] apply when the N content of crop residues on the field in the form of stubble, and chaff/siliquas and the like, and possibly roots in the field, is also included:

Crop with straw/ stems/crop residues/± roots	Winter rapeseed	Winter wheat	Winter wheat, bread	Winter barley	Maize, cobs	Grass hay, permanent	Grass, permanent,
<NUE>/<e>:+roots	1.45	1.27	1.04	1.23	1.07	1.04	1.41
<NUE>/<e>:–roots	0.89	0.86	0.71	0.79	0.86	0.59	0.96

According to Sheet B in [1], the corresponding values for especially hardy cereals such as rye and oat are 1.46 and 1.38 including roots and 0.90 and 0.97 excluding roots.

As it appears, the total N uptake efficiency is more than 100% when the N content of crop residues on the field and roots in the field is also included, towards 150% for rapeseed, permanent grass, and hardy cereals such as rye and oat; this shows that large amounts of N are recirculated in the field. Even excluding the roots, and only including crop residues on the field, the N uptake efficiency is towards 100% for the most efficient crops.

As it appears, the Danish environmental impacts regulations do indeed ensure high N uptake efficiencies and moderate environmental impacts, so close to what is obtainable that further reductions of fertilizer N would probably only lead to meaningless loss of yields and earnings.

As it appears, a worldwide implementation of the Danish environmental impacts regulations could very well lead to an increase in the worldwide average N uptake efficiency of more than 50%.

Case 3.1.2.2: Cultivation and use of Jatropha without N fertilizers in Tabakoro, Sikasso, Mali:

As it appears from [3], the inedible seeds of the sturdy shrub Jatropha, originating in Central America, supply the inhabitants of the village Tabakoro, Sikasso Region, Mali, with PPO in the form of Jatropha oil to run their Multitask Energy Platforms and supply fuel for vehicles, along with Jatropha oil sediment to form the basis of soapmaking, and along with press cakes to supply green manure, all without any external supply of fertilizer and energy, thus producing N fertilizer instead of using it.

And as it appears, this use of Jatropha is spreading to other villages of Mali, and further to other West African countries.

And as it appears, Jatropha is planted on non arable land, either as plantations or as hedges protecting fields from animals, and is also used as protection against desertification and for soil fertility improvement.

3.1.3. CONSEQUENCES AND CONCLUSIONS:

In the world outside the cities, a worldwide average value of NUE/e, expressing the efficiency of the uptake by plants of N from new synthetic fertilizers, being equal to 0.4 or 40%, is completely useless as a basis for assessing the environmental impact of agriculture at any specific place and for assessing the environmental impact of any specific crop, whether used for liquid biofuel production or not.

As it appears from case 3.1.2.1, any crop grown in Denmark will have an N uptake efficiency significantly above the worldwide average; the figure is at least 50% higher for biofuel crops in general and at least 78% higher for rapeseed.

And as it appears from case 3.1.2.1, the total N uptake efficiency is even higher, towards 150% for rapeseed, the hardiest cereals, and permanent grass; so high that there is hardly room for further improvements; and if the Danish environmental impacts regulations were used worldwide, similar N uptake efficiencies could possibly be obtained in any country.

As it appears from case 3.1.2.2, the very concept is completely useless in connexion with the use of Jatropha in Mali because N fertilizers are not used but created by the crop; the same applies to the use of Jatropha and several other similar oil plants grown in many countries round the world, such as the Moringa tree which is exceptionally versatile and serves a great number of different purposes.

The paper assumptions will lead to a considerable overestimation of the N consumption in environmentally concerned parts of the world and in responsible and competent agriculture, and it may very well lead to an underestimation of the N consumption in less environmentally concerned regions and in less responsible and less competent agriculture, and it will lead to an overestimation of the N consumption for liquid biofuels from rapeseed and fodder wheat as compared to those from other crops suitable for liquid biofuel production.

And, instead of bringing more attention to the significant differences in farming round the world and thereby supporting responsible and competent agriculture, thus contributing to worldwide reductions of N_2O emissions and other environmental impacts of agriculture, the paper assumptions remove attention from the differences in farming and thereby actually supports less responsible and less competent agriculture, and thus counteracts worldwide reductions of N_2O emissions and other environmental impacts from agriculture.

Adding to this effect, the lack of attention to differences in farming will prevent pressure on less responsible agriculture and/or parts of the world, thus further counteracting improvements in agriculture as a whole and contributing to a development where liquid biofuels are chiefly produced in less environmentally concerned regions of the world resulting in greater N_2O emissions and other environmental impacts.

3.1.4. SOURCES:

[1] Cecilie & Jacob Bugge: N chain calculations, 2007.
Available at: *www.ppo.bugge.com*

[2] Plantedirektoratet: Vejledning om gødsknings- og harmoniregler, 2007.
(The Danish Plant Directorate: Guide to fertilizing and harmony rules)
Available at: *www.plantedir.dk/Default.aspx?ID=2268*
A general explanation is available at: *www.plantedir.dk/Default.aspx?ID=6633*

[3] Mali-Folkecenter: MFC Jatropha activities, 2007.
Link under African Centre for Plant Oil Technology Jatropha at:
www.malifolkecenter.org

3.2. THE VALUES OF N CONTENT r_N FOR BIOFUEL CROPS:

3.2.1. PAPER VALUES:

The paper term r_N is defined as the N content in g/kg, in other words in ‰:

– *rN is the mass ratio of N to dry matter in g N/kg;* 11195/390

The paper values of r_N are taken from two sources:

– *Data on rN for several agricultural products, in g(N)/kg dry matter (Velthof and Kuikman, 2004; Biewinga and van der Bijl, 1996), are presented in Table 1.* 11197

– *Data on rN for several agricultural products, in g (N)/kg dry matter (Velthof and Kuikman, 2004; Biewinga and van der Bijl, 1996), are presented in Table 1, together with results on "relative warming".* 391-392

The paper amount of protein in rapeseed is taken from a third, unrelated source:

– *Oil content of original rapeseed=45 % (450 kg/tonne), and non-oil components = 550 kg/tonne, of which*
– protein is 40 % (~220 kg/tonne original rapeseed), with a C content of 510 g/kg;
– the remainder (60 %,~330 kg/tonne original rapeseed) is dominantly carbohydrate,
(Colin Morgan, SAC Edinburgh, personal communication) 11201/394

The paper values of r_N for five main biofuel crops and certain crop residues, including sugar beet leaves but not sugar beets themselves although the latter are comparable to sugar cane in many ways, are as follows, presented along with the corresponding relative warming effects and types of liquid biofuels according to Table 1 in the Discussion Paper, and the same paper values of r_N for three of the liquid biofuel crops are shown in Table 1 in the final paper:

– *Table 1. Relative warming derived from N_2O production for crops, crop residues, and forages used in the production of biofuel.*

Crop	*r_N (gN/kg dry matter)*	*relative warming Meq/M*	*type of fuel produced*	
Rapeseed	*39*	*1.0 - 1.7*	*Biodiesel*	
Wheat	*22*	*1.3 - 2.1*	*Bio-ethanol*	
Barley, Oat	*19*	*1.1 - 1.9*	*Bio-ethanol*	
Maize	*15*	*0.9 - 1.5*	*Bio-ethanol*	
Sugar cane	*7.3*	*0.5 - 0.9*	*Bio-ethanol*	
Residue				
Sugar beet leaves	*25*	*1.5 - 2.4*	*Bio-ethanol*	
Root crops	*16*	*0.9 - 1.6*	*Bio-ethanol*	
Forages, low N	*15*	*0.9 - 1.5*	*Bio-ethanol*	
Forages, high N	*27*	*1.6 - 2.6*	*Bio-ethanol*	*11205*

– *Table 1. Relative warming derived from N_2O production against cooling by "saved fossil CO_2" by crops as a function of the actual nitrogen content r_N(actual). Uncertainty ranges presented derive from the uncertainty of the yield factor y (see text).*

Crop	*r_N(actual) (g N/kg dry matter)*	*Relative warming (Meq/M) (N-efficiency e=0.4)*	*Type of fuel produced*	
Rapeseed	*39*	*1.0–1.7*	*Bio-diesel*	
Maize	*15*	*0.9–1.5*	*Bio-ethanol*	
Sugar cane	*7.3*	*0.5–0.9*	*Bio-ethanol*	*391*

The paper values of r_N for a number of other crops are as follows, as presented in the Discussion Paper and in the final paper:

– *More favourable conditions for bio-energy production, with much lower nitrogen to dry matter ratios, resulting in smaller N_2O emissions, exist for special "energy plants", for instance perennial grasses (Christian et al., 2006) such as switch grass (Panicum virgatum) and elephant grass (Miscanthus×giganteus hybrid), with a r_N of 7.3 g N/kg dry matter. The production of biofuel from oil palm (Wahid et al., 2005), with a r_N of 6.4 g N/kg dry matter, may also have moderately positive effects on climate. Other favourable examples are ligno-cellulosic plants, e.g. eucalyptus, poplar and willow.* *11198*

– *More favourable conditions for bio-energy production, with much lower nitrogen to dry matter ratios (Tillman et al., 2006), resulting in smaller N_2O emissions, exist for special "energy plants", for instance perennial grasses (Christian et al., 2006) such as switch grass (Panicum virgatum) and elephant grass (Miscanthus × giganteus hybrid), with a r_N of 7.3 g N/kg dry matter. The production of biofuel from palm oil, with a r_N of 6.4 g N/kg dry matter (Wahid et al., 2005), may also have moderately positive effects on climate, viewed solely from the perspective of N2O emissions. Other favourable examples are ligno-cellulosic plants, e.g. eucalyptus, poplar and willow.* *392*

3.2.2. OBJECTION:

The paper values of r_N for rapeseed and wheat are clearly wrong, whereas the paper values of r_N for barley and maize are relatively close to the real values. The many other paper values of r_N for other crops and crop residues may be right or wrong, but a comparison of r_N values for different plants without considering differences in the crops may be misleading, as it appears from Sheet B in [1] which shows that two crops from the same plants grown on the same amount of N fertilizer may have significant differences in r_N values: grass hay has r_N = 17.9 g/kg, and fresh grass has r_N = 33.1 g/kg, in other words a ratio close to 1:2. It would have been suitable to include sugar beets in the paper because it is a crop corresponding to sugarcane.

A simple comparison between the paper values of protein content and N content in rapeseed should have revealed a fundamental inconsistency to the authors: an N content r_N = 39 g/kg which is 39‰, so a protein content of 22% corresponds to an N content in protein of 17.7%. However, it is well known that the general N content in protein is 1/6.25 = 16%, as it appears from [4]. In other words, the paper value of r_N is 11% too high as compared to the paper value of protein content.

Evidently, the values of r_N in the world outside the cities depend on the actual protein contents in the crops in question. For four crops in Denmark suitable for liquid biofuel production and for bread wheat, the following values apply, based upon real values of protein contents as listed in Sheet B in [1]:

Crop	Rapeseed, oil/fodder	Wheat, food/ fodder	Wheat, bread	Barley, fodder	Maize, cobs
Protein content in crop, %	21.0	11.5	12.0	11.1	9.5
Real r_N,‰	33.6	18.4	19.2	17.8	15.2
Paper r_N, ‰	39	22	22	19	15
Real r_N/Paper r_N	0.86	0.84	0.87	0.94	1.01
Overestimation of r_N, %	16%	19%	15%	6%	-1%

As it appears, the real values of r_N for rapeseed and wheat are significantly lower than the paper values, the value for barley is slightly lower, and the value for maize is practically the same; the overestimation is 16% for rapeseed and 19% for food/fodder wheat.

3.2.3. CONSEQUENCES AND CONCLUSIONS:

In the world outside the cities, some of the paper values of r_N are clearly wrong, and any use as a basis for assessing the environmental impacts of agriculture at any given place and for assessing the environmental impact of any given crop, whether used for liquid biofuel production or not, is misleading.

As it appears, the paper values of protein content and N content r_N for the only crop where both values are stated, namely rapeseed, do not even match; in itself, this leads to an overestimation of r_N by 11%.

And as it appears, at least for two of the most important crops suitable for liquid biofuel production and grown in Denmark, the paper values of r_N are clearly too high and will lead to a considerable overestimation of the N consumption, the figure being 16% for rapeseed and 19% for fodder wheat; the corresponding figure is 6% for fodder barley, in other words a moderate overestimation, and -1% for maize, in other words no overestimation.

The many other paper paper values of r_N for other crops and residues may be right or wrong, but a comparison of r_N values related to different plants without considering differences in the crops may be misleading: two crops produced from the same plants grown on the same amount of N fertilizer may have significantly different r_N values.

It would have been suitable to include sugar beets in the paper because it is a crop corresponding to sugarcane.

3.2.4. SOURCES:

[1] Cecilie & Jacob Bugge: N chain calculations, 2007.
Available at: *www.ppo.bugge.com*

[4] DOE: Documentation for Emissions of Greenhouse Gases in the United States 2005.
Available at: *www.eia.doe.gov/oiaf/1605/ggrpt/fnote3.html*

3.3. THE DISREGARDING OF ENERGY CONSUMPTION AND OF OTHER CROP PARTS:

The paper simplifications dealt with here are closely linked to the paper simplifications dealt with in the following sections 3.4 and 3.5.

3.3.1. PAPER SIMPLIFICATIONS AND PAPER ASSUMPTION:

Two crucial paper simplifications are the expressly stated disregarding of the energy consumption for production of liquid biofuels and the expressly stated disregarding of other crop parts; the latter leads to ascription of the total amount of N in the crops to the liquid biofuel in the calculation of N_2O emissions resulting from liquid biofuel production, although the total amount of N is actually found in the other crop parts, as dealt with in section 3.5.

The paper simplifications are based upon the crucial paper assumption that the combined effect of the energy consumption for liquid biofuel production and the use of other crop parts (coproducts), can be disregarded because the two effects partially compensate each other:

- *This analysis only considers the conversion of biomass to biofuel. It does not take into account the use of fossil fuel on the farms and for fertilizer and pesticide production, but it also neglects the production of useful co-products. Both factors partially compensate each other. This needs to be analyzed in a full life cycle assessment.* 11192/389
- *Here we will only consider the climatic effects of conversion of biomass to biofuel and not a full life-cycle, leaving out for instance the input of fossil fuels for biomass production, on the one hand, and the use of co-products on the other hand.* 11195/390

At the same time, the paper seems to acknowledge the importance of energy consumption for liquid biofuel production and the use of other crop parts (coproducts), however without recognizing the significance of the protein/N content of other crop parts (coproducts) and without ascribing any N_2O emissions to other crop parts (coproducts), as stated in the Discussion Paper:

- *What we have discussed is one important step in a life cycle analysis, i.e. the emissions of N_2O, which must be considered in addition to the fossil fuel input and co-production of useful chemicals in biofuel production.* 11199 - 11200

And at the same time, the paper seems to acknowledge the fact that the equations, and thereby the values, consequences, and conclusions, apply separately to each of the crop parts including residues, however without recognizing the implications with regard to other crop parts (coproducts) used independently of the liquid biofuels:

- *These equations are valid for all above-ground harvested plant material, and separately also for the products and residues, which are removed from the agricultural fields.* 11196/391

The paper holds the implied unconditional claim that the comparison between the cooling effect of the CO_2 savings by replacement of fossil fuels and the warming effect of the N_2O emissions can be made by simply dividing the amount of N in the whole crop by the amount of C in the liquid biofuel alone, using their very own calculation basis, in other words disregarding the CO_2 emissions from fuel production, the actual effective energy content of the fuel, the energy content contribution from chemical bonds/other elements which is being dealt with in section 3.4, and the N content and the energy content in other crop parts which is being dealt with in section 3.5:

– *In these formulae r_C is in g carbon per g dry matter in the feedstock; r_N is the mass ratio of N to dry matter in g N/kg; cv is the mass of carbon in the biofuel per mass of carbon in feedstock biomass (corn, rapeseed, sugar cane);* 11195/390 - 391
– *Inserting these values in Eqs. 1 and 2 we thus obtain, with expressions in parentheses representing ranges,*
  $M=3.667.cv.r_C$ (3)
  $Meq=(14\text{-}23.2)r_N/e$ (4)
  $Meq/M=(3.8\text{-}6.3)r_N/(e.cv.r_C)$ (5)
  The latter term is the ratio between the climate warming effect of N_2O emissions and the cooling effect due to the displacement of fossil fuels by biofuels. 11196/391

– *An abridged analysis as presented above, yielding N/C ratios to indicate whether biofuels are GHG-positive or GHG-negative, can not replace a full life cycle assessment.* 392

And, the claim to general validity of the disregarding of other crop parts (coproducts) is confirmed in the Author Comments:

– *3) Co-products cannot be ignored*
  Certainly the N content of biofuels is low; however, this is not relevant. What is relevant is the fact that a large amount of reactive nitrogen is used in the production of the biofuel crop. If biofuels are grown we should not assume, without any other knowledge, that N-rich byproducts such as oilseed cake will substitute for similar materials currently produced elsewhere. Only such a replacement would allow accounting for the N_2O emissions elsewhere than in the biofuel production. The revised text attempts to accommodate that issue. S6593

And, the fact that the paper value of the cooling effect of the CO_2 savings by replacement of fossil fuels, is based solely upon the C content in the liquid biofuel, in other words disregarding the CO_2 emissions from fuel production and the actual effective energy content, is expressly stated in the Author Comments:

– *b) We assume that CO_2 from combustion of biofuels is the same as "CO_2 saved", i.e. the emissions from fossil fuels that have been replaced. Both Leip (2007) and Anonymous (2007) note that this should be done in comparison to the fossil fuels replaced, in order to estimate the fossil CO_2 avoided. Using JRC (2007) – well-to-tank report – it is easy to show that the energy content of the fuels concerned per mass of C are almost identical (Ethanol 51.3, RME 48.6, Gasoline and Diesel 50 MJ/kg C). In the revised version of the manuscript we make this conversion explicit.* S6597

And, the fact that the disregarding of other crop parts (coproducts) leads to ascription of the total amount of N in biofuel crops to the liquid biofuels in the calculation of N_2O emissions resulting from liquid biofuel production which is being dealt with in section 3.5, is expressly confirmed in the Author Comments:

- *c) We assume that biofuel production is responsible for N_2O emissions from fixed N specifically converted from atmospheric N for its production, even if emissions happen in subsequent stages far from the production site. Until proven otherwise we do not account for benefits and/or replacement of other crops due to biofuel production residues (as e.g. in cattle farms using ethanol distillation residues as feed). This is in stark contrast to the point made by referee #2, that biofuels should not be blamed for fertilizer N as the N is used elsewhere and is not contained in the biofuel.* *S6597 - S6598*

The unconditional concluding statement of the paper section 3. N_2O release versus CO_2 saved by liquid biofuels, as presented in the Discussion Paper,

- *Note that our analysis only considers the conversion of biomass to biofuels, emphasizing the role of N2O emissions. It does not take into account the supply of fossil fuel for farm machinery or fertilizer production; on the other hand it also neglects the production of useful co-products, which partially compensate for each other (see for instance Hill et al., 2006, for corn ethanol).* *11197*

is further elaborated and emphasized in the final paper by additional unconditional claims, namely that the energy content of the other crop parts (coproducts) are outbalanced by the additional energy consumption to produce them, and that it cannot be taken for granted that other crop parts (coproducts) are used at all:

- *Note that our analysis only considers the conversion of biomass to biofuels, emphasizing the role of N2O emissions. It does not take into account the supply of fossil fuel for fertilizer production, farm machinery and biofuel process facility, which require a considerable fraction of the energy gained (Hill et al., 2006). Furthermore, we assume that biofuel production is based on mineral fertilizer only (substitution of manure for synthetic fertilizer would offset our result by the percentage of synthetic fertilizer that is not used). The energy content gained from by-products will largely be offset from additional energy needed to produce it (Hill et al., 2006), here we also neglect its potential to replace other animal feed crops (and the associated N2O emissions). We are aware that integrated processes exist which better connect biofuel production with animal husbandry, but we believe this cannot be taken for granted on a global scale.* *391*

Nowhere in the Discussion Paper, in the Author Comments, or in the final paper, is there any mentioning of the environmental impacts related to the production of fossil fuels.

3.3.2. OBJECTION:
The failure to include, or at least mention, the energy consumption and the environmental impacts related to the production of fossil fuels is an obvious and crucial oversight, even when the corresponding energy consumption and environmental impacts of production of liquid biofuels is only considered through the paper assumption that the combined effect of the energy consumption for liquid biofuel production and the use of other crop parts can be disregarded because the two effects partially compensate each other.

The fossil fuels do not emerge at the pumps of the filling stations: somewhere in the world outside the cities, they are pumped up from deep wells and often preprocessed on site, transported long distances by ship and/or pipes, processed at refineries, transported by ship, train, or truck, stored, and transported by truck to the filling stations, often considerable distances. All these steps involve energy consumption and environmental impacts.

And the crucial assumption, that the combined effect of the energy consumption for liquid biofuel production and the use of other crop parts can be disregarded because the two effects partially compensate each other, is an obvious fallacy, as are the additional unconditional claims and the implied claim.

The fallacy of the assumption is evident: rapeseed PPO is produced along with rapeseed cakes/pellets from rapeseeds through a simple cold pressing which requires a very modest energy consumption, as it appears from Annex VII Part D in [5].

The fallacy of the additional unconditional claim, that the energy content of the other crop parts are outbalanced by the additional energy consumption to produce them, is also evident: the rapeseed cakes/pellets produced along with PPO/biodiesel are ready for use as fodder or fuel without any kind of further processing and thus without any additional energy consumption at all; similarly, the energy consumption for pressing is insignificant in comparison with the energy content in rapeseed straw. According to [6], which is referred to in the paper, harvesting the straw does not increase the need for N fertilization, and it is even feasible to use dried distillers grain as fuel, although this use necessitates energy consumption for its drying.

The fallacy of the additional unconditional claim, that it cannot be taken for granted that other crop parts are used at all, is also evident: in Denmark, rapeseed cakes/pellets form a recognized and valuable concentrate which can never meet the demand but only reduce the amounts of imported concentrates, especially soy meal, and as fuel for stoker stoves they can replace wood pellets; similarly, in Denmark, straw is increasingly recognized as an important renewable energy source, presently as a solid biofuel only but seen as a possible future source of liquid biofuels. This fallacy is further dealt with in section 3.5.

The fallacy of the implied unconditional claim, that the comparison between the cooling effect of the CO_2 savings by replacement of fossil fuels and the warming effect of the N_2O emissions can be made by simply dividing the amount of N in the whole crop by the amount of C in the liquid biofuel alone, is obvious considering the oversight and fallacies mentioned above.

Any proper attempt to calculate the environmental impacts of biofuels, which may be in the form of an energy/GHG balance, a life cycle analysis, or an economic comparison such as shadow prices of greenhouse gas savings, must comprise an initial calculation where the total environmental impacts related to the whole crop are divided between the biofuel in question and all the other available crop parts which may include one or more other biofuels, and a final calculation with a full comparison of the demonstrably ascribable environmental impacts to each biofuel and to the corresponding fossil fuel.

There may be significant differences in the resulting environmental impacts of different biofuels regardless of crops, depending on the use of other crop parts, depending on the production methods and equipment, and depending on where and how the biofuel is used.

And there may be significant differences in the resulting environmental impacts of the same biofuels from different crops.

And there may be significant differences in the environmental impacts of fossil fuels, depending on the production methods and equipment, and depending on how and where the fossil fuel is used.

Unfortunately, at least some attempts to calculate the environmental impacts of liquid biofuels have led to an overestimation of the impacts and costs related to liquid biofuels, at least in connexion with certain liquid biofuels, and generally to an underestimation of the corresponding impacts and costs related to fossil fuels.

In all cases, the calculations concerning liquid biofuels have been based upon the energy content, in the form of lower heating value, not upon the effective energy, thus disregarding the often reported experience mentioned in [7] made by PPO drivers with the best engine conversions, namely that they obtain the same mileage and even a greater torque at low speeds of rotation when comparing PPO and diesel, so that each litre of PPO has the same amount of effective energy as has a litre of diesel despite a lower energy content; according to this, PPO has about 5% higher efficiency than has diesel when used in vehicle engines.

And at least in some cases, the calculations concerning liquid biofuels have been performed on an incomplete basis, leaving out or underestimating the value and/or energy content of other usable crop parts including straw/stems, leaving out some of the most environmentally friendly solutions, and overestimating costs, energy consumptions, and environmental impacts, of cultivating crops, among other things by assuming wasteful management of the farms, thus underestimating the ability of the farmers to integrate biofuels, and by using uncultivated land as a basis for comparison, sometimes when it is not even an option.

And at least in some cases, the calculations concerning fossil fuels have been performed on an incomplete basis, only considering the most obvious short term impacts and costs, thus failing to incorporate growing impacts and costs caused by depletion of fossil fuel sources, less obvious short term impacts such as pollution and other immediate environmental impacts, and all the long term impacts caused by the consuming of the carbon stock of the past, including the increase of CO_2, the general warming, and all the more violent changes.

And at least in some cases, economic calculations have been based upon assumptions favouring the continued use of fossil fuels, such as artificially low projected fossil fuel prices and artificially high projected interests.

However, no matter how the impacts of liquid biofuels are assessed, it is obvious that the impact differs between different liquid biofuels and between different production methods.

This may be demonstrated by the following cases:

Case 3.3.2.1: PPO, fodder cakes, and straw, produced in connexion with farm plants in Denmark: For PPO produced along with fodder cakes from rapeseed and along with straw in connexion with one of the existing farm plants in Denmark, all crop parts being used locally for fuelling, feeding, and CHP/heating, the only energy consumption and environmental impacts, apart from that related to cultivating and harvesting the seeds and the straw, comes from the modest power needed for the simple cold pressing, and that power can be produced by the PPO itself; there is no need for transport, neither of the PPO nor of the fodder cakes, which may be used on the farm or sold to neighbours, and PPO is harmless to groundwater according to [8]; the straw is used separately as a solid biofuel, either on the farm replacing fossil fuel oil, or in a

CHP plant replacing coal, in the latter case requiring transport. Obviously, the total amount of energy consumption and environmental impacts should be divided between the PPO, the fodder cakes, and the straw; the division could be based upon energy content, upon the values of the crop parts, or upon a combination of both.

Any comparison to liquid biofuels from energy plants would confirm that the calculations should include all plant parts above ground since everything is harvested and usable in both cases; and the rapeseed straw can be used in exactly the same way as can the energy plants, in addition to the PPO and the fodder cakes.

Any comparison to liquid biofuels such as biodiesel and bioethanol would reveal that these liquid biofuels result in greater environmental impacts because their production require much more energy, equipment, and transport, and because both fuels, and the chemicals involved in biodiesel production, present a certain hazard to groundwater according to [8]; the great difference in energy consumption and environmental impacts are evident from Annex VII Part D in [5]; it should be noted that some of the higher oil amount obtainable by hot pressing or extracting rapeseed oil for biodiesel is lost in the esterification, reducing the possible difference in the final amounts of PPO and biodiesel.

Any comparison with diesel to replace the PPO, and fuel oil to replace the straw, should include transport to the farm, not only of the fossil fuel(s) but also of the fodder.

Case 3.3.2.2: PPO and fodder cakes produced by feedstuffs companies in Denmark:
The main difference from case 3.3.2.1 consists of the fact that the rapeseeds are cold pressed at feedstuffs companies such as [9], adding transport of seeds from and fodder cakes to the farms along with short distance transport of the PPO not used by the feedstuffs companies.

Case 3.3.2.3: PPO and fuel pellets produced from rapeseed in Denmark:
For PPO produced along with fuel pellets from rapeseed, the conditions and comparisons are basically the same as in cases 3.3.2.1 or 3.3.2.2, apart from the fact that the other crop part is a solid biofuel, that on the one hand replaces a fossil fuel with comparable energy content and price and on the other hand removes N from the agricultural circulation; the use of straw occurs in connexion with harvesting the rapeseeds at the farms.

For such production taking place on one of the existing small independent plants in Denmark where PPO is cold pressed in connexion with a stoker stove and where the production is simply governed by the current need for pellets to meet the heat requirement as described in [10], there is no transport of fuel pellets at all, and the PPO may be used or sold in connexion with the plant.

Case 3.3.2.4: PPO and press cakes produced from Jatropha in Tabakoro, Sikasso, Mali:
For PPO produced along with press cakes from Jatropha in Tabakoro, no external energy is used at all.

Any comparison with fossil diesel to replace the PPO, should include a costly transport by smaller vehicles to Tabakoro, not only of fossil diesel, which has a very high price in rural areas far from the cities, but also of N fertilizer to replace the press cakes.

3.3.3. CONSEQUENCES AND CONCLUSIONS:

The failure to consider the energy consumption and other impacts related to the production of fossil fuels in the paper is a crucial oversight.

The fossil fuels do not emerge at the pumps of the filling stations: somewhere in the world outside the cities, they are pumped up from deep wells and often preprocessed on site, transported long distances by ship and/or pipes, processed at refineries, transported by ship, train, or truck, stored, and transported by truck to the filling stations, often considerable distances. All these steps involve energy consumption and environmental impacts.

And the crucial assumption that the combined effect of the energy consumption for liquid biofuel production and the use of other crop parts (coproducts), can be disregarded because the two effects partially compensate each other is an obvious fallacy, as are the additional unconditional claims and the implied claim.

The fallacy of the crucial assumption may be seen from the following: rapeseed PPO is produced along with rapeseed cakes/pellets from rapeseeds through a simple cold pressing which requires a very modest energy consumption.

The fallacy of the additional unconditional claim that the energy content of the other crop parts (coproducts) are outbalanced by the additional energy consumption to produce them may be seen from the following: the rapeseed cakes/pellets produced along with PPO are ready for use as fodder or fuel without any kind of further processing and thus without any additional processing energy at all; similarly, the energy consumption for pressing is insignificant in comparison with the energy content in straw.

The fallacy of the additional unconditional claim that it cannot be taken for granted that other crop parts (coproducts) are used at all may be seen from the following: in Denmark, rapeseed fodder cakes form a recognized and valuable concentrate which can never exceed the demand but only reduce the amounts of corresponding imported concentrates, especially soy meal; similarly, in Denmark, straw is recognized as an important renewable energy source, presently used as a solid biofuel only but seen as a prospective source of liquid biofuels.

The fallacy of the implied unconditional claim that the comparison between the cooling effect of the CO_2 savings by replacement of fossil fuels and the warming effect of the N_2O emissions can be made by simply dividing the amount of N in the whole crop by the amount of C in the liquid biofuel alone, is obvious considering the oversight and fallacies mentioned above.

With these oversights and fallacies, the paper simplifications corrupt any comparison between liquid biofuels and fossil fuels, leading to an overestimation of the environmental impacts of liquid biofuels as compared to fossil fuels.

And, the paper simplifications corrupt any comparison between different liquid biofuels, leading to an overestimation of the environmental impacts of PPO as compared to biodiesel and bioethanol.

And, instead of attracting more attention to differences in the environmental impacts of liquid biofuels and thereby supporting attempts of improvements and the best solutions, thus contributing to a reduction of environmental impacts from liquid biofuels, the paper assumptions removes attention from the differences and thereby actually supports inferior solutions, and thus counteracts reductions of environmental impacts from liquid biofuels.

Any proper attempt to perform a complete assessment of the environmental impacts of liquid biofuels should be based upon an initial division of the total amount of energy consumption and other impacts related to the crop between the liquid biofuel in question and the other crop parts, followed by a complete comparison of the energy consumption and other impacts demonstrably ascribable to the liquid biofuel and to the corresponding fossil fuel, the liquid biofuel being treated on a more fair and equal basis than is often seen; this may be in the form of energy/GHG balances, life cycle analyses, or economic comparisons such as shadow prices of GHG savings.

Any proper attempt to provide useful separate information on the impacts of N_2O emissions, applicable to such proper assessments of the environmental impacts of liquid biofuels, should therefore provide an accurate division of N_2O emissions between the liquid biofuel in question and the other crop parts and nothing more, so that the N_2O emission demonstrably ascribable to the liquid biofuel in question, if any, can be correctly added to the other environmental impacts related to the replacement of fossil fuels by liquid biofuels.

Consequently, as an attempt to provide useful information on the impacts of N_2O emissions, leaving out other environmental impacts, the paper should have included a proper calculation, or at least a proper assessment, of the amounts of N and thus N_2O emissions demonstrably ascribable to the liquid biofuels in question, depending on the use of other crop parts. This is dealt with in the following section 3.5.

And consequently, the paper should not include calculation or assessment of other impacts.

3.3.4. SOURCES:

[5] COMMISSION OF THE EUROPEAN COMMUNITIES: COM(2008) 19 final, 2008/0016 (COD): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources.
Available at: *eur-lex.europa.eu/COMIndex.do?ihmlang=en,* search for 0019 in 2008

[6] EU Joint Research Centre: Well To Tank Reports, 2007.
Available at: *ies.jrc.ec.europa.eu/wtw.html*

[7] DAJOLKA: Informations: PPO concept.
Available at: *www.dajolka.dk/index_en.htm*

[8] Umweltbundesamt (The German Federal Environment Agency): Water, Drinking Water, and Water Protection, Substances Hazardous to Water, at:
www.umweltbundesamt.de/wgs-e/vwvws.htm

[9] Hedegaard Agro, *www.hedegaard-agro.dk*

[10] Hybren: Individual solutions for large and small needs, 2005.
Available at: *www.hybren.dk/cms/filarkiv/messebrochure_2008d.pdf*

3.4. THE USE OF THE C CONTENT r_C INSTEAD OF THE EFFECTIVE ENERGY CONTENT:

As mentioned in the previous section 3.3, the paper uses the C content r_C in the liquid biofuel as the calculation basis for the cooling effect of the CO_2 savings by replacement of fossil fuels.

3.4.1. PAPER VALUES:

The values expressing the cooling effect of the CO_2 savings by replacement of fossil fuels are among the crucial paper values.

The paper value M of the cooling effect of the CO_2 savings by replacement of fossil fuels, which is compared to the warming effect of N_2O emissions, is not based upon useful energy or energy content, but solely upon the C content r_C, in other words disregarding the contents of other elements in the fuels and the chemical energy contained in the compounds, corresponding to all fuels being treated as if the only effective part were carbon, as stated in the Discussion Paper, unyieldingly defended in the Author Comments, and even more expressly stated in the final paper, referring to [6] designated (JRC, 2007):

- *We also obtain the fossil CO_2 emissions avoided from the carbon processed in the harvested biomass to yield the biofuel. With these assumptions, we can compare the climatic gain of fossil fuel-derived CO_2 "savings", or net avoided fossil CO_2 emissions, with the counteracting effect of enhanced N_2O release resulting from fixed N input. Our assumptions lead to expressions per unit mass of dry matter harvested in biofuel production to avoid fossil CO_2 emissions, "saved CO_2",(M), and for "equivalent CO_2", (Meq), the latter term accounting for the global warming potential (GWP) of the N_2O emissions: 11195*

- *5) Equation 1 is incomplete*
  The referee correctly states that a comparison needs to be done on the basis of energy content per carbon content of fuels. In the revised version we acknowledge that and state that this ratio is virtually identical for the fuels under consideration. S6593
- *b) We assume that CO_2 from combustion of biofuels is the same as "CO_2 saved", i.e. the emissions from fossil fuels that have been replaced. Both Leip (2007) and Anonymous (2007) note that this should be done in comparison to the fossil fuels replaced, in order to estimate the fossil CO2 avoided. Using JRC (2007) – well-to-tank report – it is easy to show that the energy content of the fuels concerned per mass of C are almost identical (Ethanol 51.3, RME 48.6, Gasoline and Diesel 50 MJ/kg C). In the revised version of the manuscript we make this conversion explicit. S6597*

- *We also obtain the fossil CO_2 emissions avoided from the carbon processed in the harvested biomass to yield the biofuel. With these assumptions, we can compare the climatic gain of fossil fuel-derived CO_2 "savings", or net avoided fossil CO_2 emissions, with the counteracting effect of enhanced N_2O release resulting from fixed N input. Our assumptions lead to expressions per unit mass of dry matter harvested in biofuel production to avoid fossil CO_2 emissions, "saved CO_2",(M), and for "equivalent CO_2", (Meq), the latter term accounting for the global warming potential (GWP) of the N_2O emissions. We derive M from carbon contained in biomass as the lower heat value per carbon, and consequently the CO2 emissions per energy unit, are almost identical for the fossil fuels and biofuels discussed here (JRC, 2007): 390*

– *An abridged analysis as presented above, yielding N/C ratios to indicate whether biofuels are GHG-positive or GHG-negative, can not replace a full life cycle assessment.* *392*

At the same time, the following independent paper values of C content in biodiesel and bio-ethanol, as calculated by the authors, are stated:

– *the average composition of the oil is adequately represented by the triglyceride of the dominant fatty acid, erucic acid, i.e.* $(C_{22}H_{41}O_2)_3(C_3H_5)$*, mol. wt. 1052, then*
C content of the oil by weight = 828/1052=0.787 kg/kg. *11200/394*
– *C content of ethanol (*C_2H_5OH*, mol. wt. 46) by weight=24/46=522 g/kg.* *11201/394*

Nowhere in the Discussion Paper, in the Author Comments, or in the final paper, is there any mentioning of reservations to the approach in connexion with other biofuels which may be used for vehicles.

3.4.2. OBJECTION:
Using the amount of CO_2 savings in connexion with the actual use of fuels, in other words useful energy and CO_2 emission, as a general calculation basis is quite appropriate.

However, any proper attempt to calculate the CO_2 savings should be based upon the real effective energy contained in the liquid biofuel in question and in the fossil fuel to be replaced, using the real efficiencies: replacing 1 litre of fossil fuel results in savings equalling the CO_2 emission from 1 litre of fossil fuel; no more, no less.

As mentioned in section 3.3, the usual approach, which fails to incorporate possible differences in efficiencies, is based upon energy contents, in the form of lower heating values.

The paper approach leading to the paper values of CO_2 savings is based upon the C content in the liquid biofuel alone, as expressed in the relative C content r_C, thus disregarding not only possible differences in efficiencies and thereby effective energy contents, but also the contents of other elements and the chemical energy contained in the compounds, corresponding to all fuels being treated as if the only effective part were carbon.

And the paper presents no reservations to the approach in connexion with other biofuels which may be used for vehicles.

As it appears from [6] and [11], the former of which is the actual paper reference, the ratios of energy content to C content stated in the Author Comments actually reveal an inaccuracy: the energy content of bioethanol should be 2.6% higher and the energy content of biodiesel should be 2.9% lower to be consistent with the corresponding fossil fuels.

Further, the paper value of the C content of biodiesel, based upon the paper assumption that biodiesel produced from rapeseed can be described as esters of erucic acid which has 22 C atoms corresponding to the paper composition $(C_{22}H_{41}O_2)_3(C_3H_5)$, is 2.9% too high, namely 78.7%, as it appears from [11]: the average length of the fatty acids constituting rapeseed oil is about 18 C atoms, corresponding to the average composition $(C_{18}H_{33}O_2)_3(C_3H_5)$, and a C content of 77.0%, which is consistent with [6] and other sources such as [12] and [13].

All in all, this means that the paper energy content is about 2.5% too low for bioethanol and about 5% too high for biodiesel. According to [7], PPO drivers report the same mileage as fossil diesel; this corresponds to a 5% higher effective energy content, thus matching the energy content according to the paper. The paper yields of biodiesel and bioethanol from the crops seem rather high, as it appears from [11]; this is further dealt with in section 3.7.

These inaccuracies may seem insignificant, but as it appears from [11], the paper approach may lead to a significant underestimation of the energy content if used in connexion with other biofuels used for vehicles; the energy content of methane should be set about 30% higher to be consistent with the corresponding fossil fuel, petrol.

It should be noted that the paper assumption about the general composition of rapeseed oil is outdated: erucic acid is only predominant in older rapeseed strains, and most rapeseeds grown the last 30 years contain very low levels of erucic acid.

3.4.3. CONSEQUENCES AND CONCLUSIONS:

Using the amount of CO_2 savings in connexion with the actual use of fuels, in other words actual useful energy and CO_2 emission, as a calculation basis is quite useful.

However, any proper attempt to calculate the CO_2 savings should be based upon the actual effective energy contained in the liquid biofuel in question and in the fossil fuel to be replaced, thus incorporating the actual efficiencies: replacing 1 litre of fossil fuel results in savings equalling the amount of CO_2 released from that 1 litre of fossil fuel; no more, no less.

The paper approach leading to the paper values of CO_2 savings is based upon the C content r_C, thus not only disregarding possible differences in efficiencies and thereby effective energy contents, but also disregarding the contents of other elements in the fuels and the chemical energy contained in the compounds, corresponding to all fuels being treated as if the only effective part were carbon.

The paper energy content is about 2.5% too low for bioethanol, and about 5% too high for biodiesel. According to widespread driving experience, PPO may have the same mileage as fossil diesel; this corresponds to a 5% higher effective energy content, thus matching the energy content according to the paper. The paper yields of biodiesel and bioethanol from the crops seem rather high.

The paper presents no reservations to the approach in connexion with other biofuels which may be used for vehicles. Used in connexion with methane, the paper approach would lead to an underestimation of the energy content of about 30%.

The paper assumption about the composition of rapeseed oil is outdated by about 30 years.

3.4.4. SOURCES:

[6] EU Joint Research Centre: Well To Tank Reports, 2007.
Available at: *ies.jrc.ec.europa.eu/wtw.html*

[7] DAJOLKA: Informations: PPO concept.
Available at: *www.dajolka.dk/index_en.htm*

[11] Cecilie & Jacob Bugge: Effective energy contents of different fuels, 2007.
Available at: *www.ppo.bugge.com*

[12] ETA Renewable Energies: Stationary Applications of Liquid Biofuels, 2004.
Available at: *ec.europa.eu/energy/res/sectors/bioenergy_publications_en.htm*

[13] U.S. Department of Energy: Properties of Fuels, 2006.
Available at: *www.eere.energy.gov/afdc/*, search for fueltable

3.5. THE ASCRIPTION OF ALL N IN THE CROPS TO THE LIQUID BIOFUELS:

The paper simplification dealt with here is closely linked to the paper simplification dealt with in the previous section 3.3.

3.5.1. PAPER SIMPLIFICATION AND PAPER ASSUMPTION:

A crucial paper simplification is the ascription of the total amount of N in biofuel crops to the liquid biofuels in the calculation of N_2O emissions from liquid biofuel production of any kind anywhere in the world, thus disregarding all other crop parts. This forms a crucial limitation to the basically sound fundamental paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions.

The paper simplification is based upon the crucial paper simplifications and the underlying paper assumption dealt with more comprehensively in section 3.3, and especially upon the expressly stated disregarding of other crop parts:

- *This analysis only considers the conversion of biomass to biofuel. It does not take into account the use of fossil fuel on the farms and for fertilizer and pesticide production, but it also neglects the production of useful co-products. Both factors partially compensate each other. This needs to be analyzed in a full life cycle assessment.* *11192/389*
- *Here we will only consider the climatic effects of conversion of biomass to biofuel and not a full life-cycle, leaving out for instance the input of fossil fuels for biomass production, on the one hand, and the use of co-products on the other hand.* *11195/390*

And at the same time, the paper seems to acknowledge the fact that the equations, and thereby the values, consequences, and conclusions, apply separately to each of the crop parts including residues, however without recognizing the implications with regard to other crop parts (coproducts) used independently of the liquid biofuels:

- *These equations are valid for all above-ground harvested plant material, and separately also for the products and residues, which are removed from the agricultural fields.* *11196/391*

And at the same time, the paper expressly states the fact that the total amount of N in rapeseed is found in the other crop part (coproduct), namely the rapeseed fodder cakes, whereas there is basically no N at all in PPO/biodiesel:

- *the average composition of the oil is adequately represented by the triglyceride of the dominant fatty acid, erucic acid, i.e.* $(C_{22}H_{41}O_2)_3(C_3H_5)$, *mol. wt. 1052, then*
  C content of the oil by weight = 828/1052=0.787 kg/kg. *11200/394*
- *Oil content of original rapeseed = 45% (450 kg/tonne),*
  and non-oil components = 550 kg/tonne, of which
  – protein is 40% (220 kg/tonne original rapeseed), with a C content of 510 g/kg;
  – the remainder (60%, 330 kg/tonne original rapeseed) is dominantly carbohydrate,
  (Colin Morgan, SAC Edinburgh, personal communication) *11201/394*

And the paper expressly states the fact that there is no N at all in bioethanol either:

– *C content of ethanol (C_2H_5OH, mol. wt. 46) by weight=24/46=522 g/kg.* *11201/394*

And, the claim to general validity of the disregarding of other crop parts (coproducts) is confirmed in the Author Comments, openly claiming that the cultivation of biofuel crops forms a separate branch of agriculture, generally without use of other crop parts and performed in addition to current agriculture which is obviously impossible without cultivating new land to grow them:

– *We (in Crutzen et al., 2007) assume that biofuel production is performed in addition to current agriculture, and therefore will be based on freshly formed reactive nitrogen. We are aware that the integration and optimization of processes is possible, including use of nitrogen in crops for further agricultural production (animal husbandry, manure application to replace further application of mineral fertilizer). But we assume biofuel production to occur under current agricultural practices, worldwide, and consider the subsequent fate of nitrogen a direct consequence of its first application. There may be delays, after the fertiliser N application, before further indirect emissions take place (Bakken & Bleken, 1998; Mosier & Kroeze, 2000), but nonetheless there is a link, and we think it desirable to include these later emissions in our overall calculation.* *S5153*
– *3) Co-products cannot be ignored*
  Certainly the N content of biofuels is low; however, this is not relevant. What is relevant is the fact that a large amount of reactive nitrogen is used in the production of the biofuel crop. If biofuels are grown we should not assume, without any other knowledge, that N-rich byproducts such as oilseed cake will substitute for similar materials currently produced elsewhere. Only such a replacement would allow accounting for the N_2O emissions elsewhere than in the biofuel production. The revised text attempts to accommodate that issue. *S6593*
– *a) We assume that biofuel production requires fresh reactive nitrogen, i.e. mineral fertilizer only. Leip (2007) argues that, under current agricultural practice and probably also under a future extension of biofuels, sufficient manure will be available to provide approximately 20% of N needed for all crop production from livestock manure. This could potentially decrease mineral fertilizer requirement by 20%.*
  While it may be useful to account for manure for current systems and possibly also in the future, at the same time we observe a spatial and organizational separation of animal production and biofuel production in many places where industrial livestock production is practiced. Even if there is a flow of manure nitrogen back into fields to replace mineral fertilizer, mineral fertilizer will remain clearly the largest fertilizer source – as may also be seen by fertilizer industry's prospect of increased production due to biofuel production. For that reason we have – for the main line of argument – remained with our original figures. *S6597*

The paper further presents rapeseed as an especially questionable biofuel crop because of its high N content, and its promotion in Europe is specifically mentioned:

– *The effect of the high nitrogen content of rapeseed is particularly striking; it offsets the advantages of a high carbon content and energy density for biodiesel production. World-wide, rapeseed is the source of >80% of bio-diesel for transportation, and has been particularly promoted for this purpose in Europe. For bio-diesel derived from rapeseed, this analysis indicates that the global warming by N_2O is* *on average about 1.0–1.7 times larger than the quasi-cooling effect due to "saved fossil CO_2" emissions.* *11197/392*

The paper further expressly presents energy plants and oil palm as more favourable owing to their lower N content, without any reservations concerning the cultivation of new land to grow them:

– *More favourable conditions for bio-energy production, with much lower nitrogen to dry matter ratios, resulting in smaller N_2O emissions, exist for special "energy plants", for instance perennial grasses (Christian et al., 2006) such as switch grass (Panicum virgatum) and elephant grass (Miscanthus×giganteus hybrid), with a r_N of 7.3 g N/kg dry matter. The production of biofuel from oil palm (Wahid et al., 2005), with a r_N of 6.4 g N/kg dry matter, may also have moderately positive effects on climate. Other favourable examples are ligno-cellulosic plants, e.g. eucalyptus, poplar and willow.* *11198*

– *More favourable conditions for bio-energy production, with much lower nitrogen to dry matter ratios (Tillman et al., 2006), resulting in smaller N_2O emissions, exist for special "energy plants", for instance perennial grasses (Christian et al., 2006) such as switch grass (Panicum virgatum) and elephant grass (Miscanthus × giganteus hybrid), with a r_N of 7.3 g N/kg dry matter. The production of biofuel from palm oil, with a r_N of 6.4 g N/kg dry matter (Wahid et al., 2005), may also have moderately positive effects on climate, viewed solely from the perspective of N2O emissions. Other favourable examples are ligno-cellulosic plants, e.g. eucalyptus, poplar and willow.* *392*

And the disregarding of other crop parts (coproducts), leading to ascription of all N in biofuel crops to the liquid biofuels in the calculation of N_2O emissions resulting from liquid biofuel production, is expressly confirmed in the Author Comments, rejecting each and every objection raised and claiming that the allocation of N_2O emissions is a legal issue, based upon the unconditional claim that the other crop parts (byproducts) should be neglected because it cannot be taken for granted that they will replace other fodder crops, so that is just an option that may be realized in the agriculture of the future and therefore included in the sensitivity analysis in Table 2 in the final paper, as is the use of animal manure:

c) We assume that biofuel production is responsible for N2O emissions from fixed N specifically converted from atmospheric N for its production, even if emissions happen in subsequent stages far from the production site. Until proven otherwise we do not account for benefits and/or replacement of other crops due to biofuel production residues (as e.g. in cattle farms using ethanol distillation residues as feed). This is in stark contrast to the point made by referee #2, that biofuels should not be blamed for fertilizer N as the N is used elsewhere and is not contained in the biofuel.
The issue of appropriate accounting of N2O emissions to the "polluter" has also been brought up by Smeets et al. (2007). These correspondents refer to the use of byproducts of biofuel production by animal husbandry, and claim that N2O related to such by-products should not be attributed to biofuel, but to animal production. Eventually here we are moving into legal issues rather than scientific. Who is responsible for the release of a trace gas? Can we safely assume – without prior knowledge – that biofuel by-products will indeed replace agricultural crops previously produced for animal feeds? Ammann et al. (2007) argue on the same issue, just accounting N2O emissions separately for the subsequent

cycles reactive nitrogen takes in the environment. We have covered this in the specific response to these authors.
Additionally the discussion is reflected in the revised manuscript, where we note that we neglect the potential of byproducts to replace other animal feed crops (and the associated N2O emissions), as they cannot be taken for granted on the global scale. *S6597-S6598*

The unconditional concluding statement of the paper section 3, N_2O release versus CO_2 saved by liquid biofuels, as presented in the Discussion Paper,

– *Note that our analysis only considers the conversion of biomass to biofuels, emphasizing the role of N2O emissions. It does not take into account the supply of fossil fuel for farm machinery or fertilizer production; on the other hand it also neglects the production of useful co-products, which partially compensate for each other (see for instance Hill et al., 2006, for corn ethanol).* *11197*

is further elaborated and emphasized in the final paper by additional unconditional claims, namely that the energy content of the other crop parts (coproducts) are outbalanced by an additional energy consumption to produce them, and that it cannot be taken for granted that other crop parts (coproducts) are used at all:

– *Note that our analysis only considers the conversion of biomass to biofuels, emphasizing the role of N2O emissions. It does not take into account the supply of fossil fuel for fertilizer production, farm machinery and biofuel process facility, which require a considerable fraction of the energy gained (Hill et al., 2006). Furthermore, we assume that biofuel production is based on mineral fertilizer only (substitution of manure for synthetic fertilizer would offset our result by the percentage of synthetic fertilizer that is not used). The energy content gained from by-products will largely be offset from additional energy needed to produce it (Hill et al., 2006), here we also neglect its potential to replace other animal feed crops (and the associated N2O emissions). We are aware that integrated processes exist which better connect biofuel production with animal husbandry, but we believe this cannot be taken for granted on a global scale.* *391*

3.5.2. OBJECTION:

The paper simplification, ascribing the total amount of N in biofuel crops to the liquid biofuels in the calculation of N_2O emissions, would only be valid if all other crop parts in connexion with all liquid biofuels produced anywhere in the world were simply dumped as waste and lost in a way that would result in the same N_2O emissions as assumed in the paper; the paper simplification forms a crucial limitation to the fundamental and sound paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions.

Obviously, the paper simplification implies the corresponding general fallacy of ascribing the total amount of N in crops used for production of oil and ethanol (alcohol) to the oil/ethanol in connexion with calculation of N_2O emissions from agriculture.

In the world outside the cities, other crop parts are certainly used in responsible and competent agriculture, contrary to the paper assumption.

The use of other crop parts may differ between different biofuel crops, between different kinds of farming, and between different countries; and each and every use of other crop parts leads to an ascription of N that is fundamentally different from the paper values; and the use of other crop parts from rapeseed, which is presented in the paper as the most questionable biofuel crop, presents the strongest contrast to the paper simplification.

The express and unconditional paper claim that the use of other crop parts, in the form of rapeseed cakes/pellets and distillers grain, the latter also known as draff, cannot be taken for granted is actually turned into a much stronger implied paper claim that it can be taken for granted that other crop parts are not used: that is the actual basis for the paper calculations.

Contrary to the paper claim, there is a widespread use of these crop parts as concentrates to increase the N content in the concentrate part of the fodder above that of cereals, including maize; such concentrates form an important part of high yield animal husbandry in many countries, and with a growing worldwide demand for meat, the use and efficiency of animal husbandry will increase, and so will the use of concentrates other than cereals, including maize; and already, concentrates such as soy meal forms an important article in the worldwide feedstuffs trade.

In addition to their use as concentrates, rapeseed cakes/pellets and distillers grain may be used as green manure, and especially rapeseed cakes/pellets may be used as fuel, independently of the use of the crops for liquid biofuels.

Straw may be used for agricultural purposes such as litter/fodder, or as fuel, independently of the use of the main crop; certain amounts should be ploughed down to improve the soil.

In contrast, in the world outside the cities, there is no generally recognized use of other crop parts in connexion with energy plants, which are presented in the paper as more favourable along with oil palm, in contrast to the biofuel crops which are presented as questionable.

And, as it appears from [14], in the world outside the cities, the unconditional paper presentation of oil palm as more favourable, without any reservations concerning the cultivation of new land to grow it, is especially unfortunate and unfounded.

The significance of the use of other crop parts may be demonstrated by the following cases:

Case 3.5.2.1: PPO and fodder cakes produced from rapeseed in Denmark:
In Denmark, rapeseed is always forming part of crop rotation where it constitutes a valuable break crop, generally grown every five years, and the cold pressing of PPO yields about 1 part PPO and 2 parts fodder cakes ready for use without any further processing, and the fodder cakes comprise a recognized valuable fodder crop, in the form of a concentrate, in its own right, rich in easily digested protein and fat and containing about thrice as much protein as does wheat; and the crop rotation limits the supply so it will never exceed the demand for such fodders: the use of concentrates with high N contents is crucial to the high yields which are obtained in Danish animal husbandry.

According to Sheet E in [1], as based upon [15], almost 2/3 of the total amount of N in concentrates used in Danish animal husbandry come from concentrates other than cereals, in other words almost twice the amounts of N in fodder cereals, which constitute about 80% of the total amounts of cereals grown in Denmark. And even after a 44% increase of rapeseed cultivation from 2006 to 2007 according to [16], the current amounts of rapeseed cakes only covers about 10% of the total N content in such concentrates used in Denmark; more than 70% is being imported, and imported soy meal alone contributes about 60%.

And the cold pressing of oil as food or PPO along with rapeseed cakes as fodder is a natural part of Danish agriculture, occurring at farms and forming a natural part of the production activities at feedstuffs companies such as [9].

And all the N in the rapeseeds is found in the rapeseed fodder cakes, which is ready for use without any further processing, whereas the PPO basically contains no N at all. This means that, no matter how much the cultivation of rapeseed is increased, the total amount of N harvested with the rapeseeds can be used in the Danish animal husbandry as fodder cakes, directly comparable to any whole fodder crop, and completely independently of the use of the rapeseed oil, whether as food oil or as PPO.

And in Denmark, straw is increasingly recognized as an important renewable energy source, as a present source of solid biofuel, and as a potential future source of liquid biofuels.

The following values of digestibility of N as measured in %, and the corresponding derived values of NUE_D/e_D = digestible N uptake efficiency, calculated for averages of Danish soil types as described in Sheet B in [1], apply to a number of food/fodder crops suited for liquid biofuels and normal yield permanent hay/grass, which are excepted from the paper value of the worldwide average, when the N content in straw/stems is excluded and the precrop value is ascribed to the contributing crop as it obviously should, the values $<NUE_D>/<e_D>$ being weighed averages of all Danish soil types, the values of $NUE_{2/3D}/e_{2/3D}$ being the averages of the best 2/3 of Danish soils where high value crops such as rapeseed, bread wheat, and maize, are mostly grown:

Crop without straw/stems	Winter rapeseed, Oil/fodder		Winter wheat, food/fodder	Winter wheat, bread	Winter barley, fodder	Maize, cobs, food/fodder	Grass hay, permanent	Grass, permanent
Part of crop	Oil	Fodder cake	Whole crop	Whole crop	Whole crop	Whole crop	Whole crop	Whole crop
Digestibility of N in %	—	84	67	68.3	65.8	61.5	66.1	78.4
$<NUE/e>$	—	0.71	0.64	0.54	0.60	0.60	0.44	0.81
$<NUE_D/e_D>$	—	0.60	0.43	0.37	0.39	0.37	0.29	0.64
in % of food/fodder wheat	—	140%	100%	86%	91%	86%	67%	149%
$NUE_{2/3}/e_{2/3}$	—	0.77	0.70	0.58	0.64	0.65	0.44	0.81
$NUE_{2/3D}/e_{2/3D}$	—	0.65	0.47	0.40	0.42	0.40	0.29	0.64
in % of food/fodder wheat	—	138%	100%	85%	89%	85%	62%	136%

As it appears, along with fresh permanent grass, fodder cakes from rapeseed have a higher digestibility of N than any of the other fodder crops, and the highest digestible N uptake efficiency along with fresh permanent grass, 138 - 140% of the value of food/fodder wheat, 154 - 162% of the values of the other cereals, and 207 - 224% of the value of hay. This means that each unit of fertilizer N yields 23 - 100% more digestible N in rapeseed fodder cakes than in whole fodder crops apart from permanent grass, regardless of the PPO being used for non agricultural purposes.

And as it appears, grass hay has a significantly lower digestibility of N than any of the crops suited for liquid biofuels. This means that grass has a high digestibility of N only when grazed or used fresh: when turned into a durable and easily storable crop comparable to those suitable for liquid biofuel production, it has a significantly inferior digestibility of N.

In the world outside the cities, the ascription of the total amount of N in crops used for oil and ehanol (alcohol) to the oil/ethanol in the calculation of N_2O emissions, which is implied by the paper simplification, would lead to the obvious fallacy of ascribing the total amount of N in imported concentrates used in Danish animal husbandry to crops in other countries, thus ascribing most of the N_2O emissions from Danish agriculture, most of which is caused by animal manure, to the cultivation of plants in other countries, thus reducing the N_2O emissions ascribed to Danish agriculture to the amounts caused by the cultivation of plants alone.

Case 3.5.2.2: PPO and press cakes produced from Jatropha in Tabakoro, Sikasso, Mali:
The Jatropha shrubs are grown without any external supply of fertilizer and energy in the village Tabakoro, Sikasso Region, Mali, thus creating N fertilizer instead of using it. Further, the total amount of N in the seeds is found in the press cakes/pellets, which are used as green manure to improve soil fertility, and in the sediment, which is used for soapmaking.

Case 3.5.2.3: Biodiesel and fodder produced from rapeseed in Denmark:
The main differences from case 3.5.2.1 consists of the facts that the energy consumption, from soil to wheel, is significantly larger for biodiesel than for PPO, that the production is less suited for small units such as farms, and that the rapeseed oil may be hot pressed/extracted, thus yielding higher amounts of oil and smaller amounts of less valuable rapeseed cakes/meal with less oil, although with a limited difference between the final amounts of PPO and biodiesel as it appears from[11]. Still, all the N is found in the rapeseed fodder cakes whereas the biodiesel basically contains no N at all. And still, the straw is an independent crop part.

This means that the total amount of N harvested with the rapeseeds can be put to use in animal husbandry just as any other fodder crop, without any further processing, completely independently of the use of the rapeseed oil as biodiesel.

Case 3.5.2.4: PPO/biodiesel produced from rapeseed with other uses for rapeseed cakes/pellets:
With their high protein and energy content, rapeseed cakes/pellets may be used for a number of other purposes than fodder, without any further processing, completely independently of the use of the rapeseed oil as PPO or biodiesel, with straw as an independent additional crop.

Used as green manure, the N content of the rapeseed cakes/pellets, which comprises the total amount of N in the crop, will be returned to the soil in a manner similar to that of other organic manures, thus reducing the need for new synthetic N fertilizer, and they may be spread in a way similar to that of solid synthetic N fertilizer.

The amount of synthetic N fertilizer which may be saved depends on the N uptake efficiency of the green manure N as compared to synthetic fertilizer N. So far, only few specific N uptake efficiency values for green manure have been included in [2], namely potato juice with 50% and green pellet juice with 40%, the latter of also being the general value applying to other organic manure; the values for different kinds of animal manure range from 45% to 85%.

Obviously, the N uptake efficiency depends upon the time of spreading the green manure. Normal green manure, which consists of plant residues and catch crops with a low to moderate N content, and which are generally spread or ploughed down in connexion with harvesting or sowing, is often spread far too early for the following crop to benefit fully. As is the case with N fertilizers, rapeseed cakes/pellets may be spread at the time where the following crop will obtain maximum benefit.

As it appears from [17], the N uptake efficiency of plant residues also seems to depend upon their composition and/or N content: according to [17], the measured N uptake efficiency of rice straw with low N content, which may be comparable to straw from rapeseed and cereals and, is 33%, whereas the measured N uptake efficiency of rice bran with high N content, which may be comparable to rapeseed cakes/pellets, is 73%.

Therefore it is possible that the N uptake efficiency of rapeseed cakes/pellets may be much higher than the general N uptake efficiency of plant residues of 40%, maybe as high as 70%.

Used for non agricultural purposes, including energy purposes such as solid biofuel for stoker stoves, the N content of the rapeseed cakes/pellets, which comprises the total amount of N in the crop, will be lost from the agricultural circulation, thus corresponding to the paper assumption, but the loss of N to be replaced will be caused entirely by the end use of the rapeseed cakes/pellets, thus being completely independent of the use of the rapeseed oil as PPO/biodiesel or for other purposes; rapeseed cakes/pellets are already being used in stoker stoves in Denmark, and there are even combined plants, where the cold pressing of PPO for other purposes is governed by the heat requirement as described in [10].

As it appears from [11], rapeseed cakes/pellets have a slightly higher energy content and a lower water content than has wood, and the price level of wood pellets in Denmark has become so high that there would be a huge viable market for any surplus rapeseed cakes/pellets.

Case 3.5.2.5: Bioethanol and distillers grain produced from cereals:

Unlike rapeseed, cereals such as wheat, barley, and maize, may be grown without crop rotation, in some cases several years in a row; and even with crop rotation, different cereals can be grown for bioethanol production several years in a row.

This means that the amounts of the other crop part in the form of distillers grain, either in its raw form as wet distillers grain WDG, or in its dried form as dried distillers grain with/without solubles DDGS/DDG, all of which constitute recognized fodders with higher digestibility than the corresponding whole crops, may exceed the demand for such fodder in some countries; in Denmark, brewers grain and distillers grain together supply less than 2%of the N content in concentrates used in Danish animal husbandry, so there is room for a considerable production of bioethanol along with distillers grain as fodder, even along with a significant increase in the production of PPO/biodiesel along with rapeseed fodder cakes.

All the N is found in the distillers grain whereas the bioethanol basically contains no N at all. This means that the total amount of N harvested with the cereal may be used independently of the bioethanol, as fodder in animal husbandry, as green manure, or for other purposes. The drying of DDGS and DDG requires an energy consumption, whereas WDG is ready for use without any further processing.

Used as fodder, WDG, DDG, and especially DDGS, are recognized concentrates, especially in countries with a considerable production of bioethanol, as it appears from [18] and [19]. And all the N is found in the distillers grain whereas the bioethanol basically contains no N at all.

This means that the total amount of N harvested with the cereals will be put to use in animal husbandry just as any other whole crop, completely independent of the use of bioethanol, up to the limit set by the demand for such concentrates.

Used as green manure, the N content of the distillers grain, which comprises the total amount of N in the crop, will be returned to the soil in a manner similar to that of other organic manures, thus reducing the need for new synthetic N fertilizer; WDG may be spread like liquid manure, whereas DDGS and DDG may be spread like solid synthetic N fertilizer.

The amount of synthetic N fertilizer which may be saved depends on the N uptake efficiency of the green manure N as compared to fertilizer N.

As with rapeseed cakes/pellets, it is conceivable that the N uptake efficiency of distillers grain is 70% as opposed to a general N uptake efficiency of plant residues of 40%.

Used for non agricultural purposes, including energy purposes such as fuel for stoker stoves, the N content of the distillers grain, which comprises the total amount of N in the crop, will be lost from the agricultural circulation, thus corresponding to the paper assumption, but the loss of N to be replenished will be caused entirely by the end use of the distillers grain, thus being completely independent of the use of bioethanol.

Obviously, the use for energy purposes such as fuel for stoker stoves may be questionable because is limited to dried distillers grain which require energy consumption for its drying; however, it should be noted that this use is considered viable in [6], which is referred to in the paper: according to [6], DDGS even has a higher Energy Credit as fuel than as fodder.

Case 3.5.2.6: Liquid biofuels with no use of other crop parts/residues:
If there is no use of other crop parts, in other words if the residue from liquid biofuel production is simply dumped as waste, its N content, which comprises the total amount of N in the crop, will indeed be completely lost from the agricultural circulation without finding use elsewhere.

Obviously, in connexion with biofuel companies outside agriculture, it may occur to a certain extent that the residues are disposed of as industrial waste instead of being returned to agriculture, especially in less environmentally concerned parts of the world, and especially in connexion with less useful residues such as those from energy plants.

Simply dumping residues, and even useful crop parts, as waste in the field instead of using them as green manure is unthinkable in connexion with responsible and competent agriculture, especially in the most environmentally concerned parts of the world; it may occur to a certain extent in connexion with less responsible and less competent agriculture, especially in less environmentally concerned parts of the world, and especially in connexion with less useful residues such as those from energy plants. This, and only this, rather extraordinary management of crop residues will result in the full effect of the paper simplification.

3.5.3. CONSEQUENCES AND CONCLUSIONS:

The express paper claim that the use of other crop parts cannot be taken for granted is actually turned into a much stronger implied paper claim that it can be taken for granted that other crop parts are not used: that is the actual basis for the paper calculations.

In the real world outside the cities, the total N content in the crops used for liquid biofuels is found in the other crop parts, and depending on the value and use of those other crop parts, all or some of the N content and the corresponding N_2O emissions should be ascribed to those other crop parts instead of to the liquid biofuels, in accordance with the fundamental paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions; this also applies to straw which may be used as litter/fodder or as fuel, apart from a certain amount which should be ploughed down to improve the soil.

As it appears from case 3.5.2.1, fodder cakes produced along with PPO from rapeseed in Denmark forms a recognized and valuable fodder crop in itself, a concentrate with a higher yield of digestible N than any cereal used as a whole crop for fodder, and a concentrate that can never meet the demand but only reduce the amounts of corresponding imported concentrates. Consequently, in this case, the total amount of N in the crop and thus the total N_2O emission from rapeseed cultivation should be ascribed to the fodder cakes.

This means that no part of the N_2O emission from rapeseed cultivation should be ascribed to PPO produced along with fodder cakes in Denmark.

Obviously, the same applies to PPO produced along with fodder cakes in other countries, to the extent that the amounts of fodder cakes meet demands for concentrates.

In the world outside the cities, the ascription of the total amount of N in crops used for oil and ethanol (alcohol) to the oil/ethanol in the calculation of N_2O emissions, which is implied by the paper simplification, would lead to the obvious fallacy of ascribing the total amount of N in imported concentrates used in Danish animal husbandry to crops in other countries, thus ascribing most of the N_2O emissions from Danish agriculture, of which most is caused by animal manure, to the cultivation of plants in other countries, thus reducing the N_2O emissions ascribed to Danish agriculture to the amounts caused by the crop cultivation alone.

As it appears from case 3.5.2.2, no fertilizer N is used to cultivate Jatropha in the village Tabakoro, Sikasso Region, Mali. Consequently, the cultivation of Jatropha and its uses for PPO and other purposes result in a reduction of the amount of N to be added to the soil, which again leads to a reduction of the total N_2O emission from the soil as compared to any other agricultural use.

This means that an N_2O saving should be ascribed to PPO produced from Jatropha in Tabakoro.

Obviously, the same applies to PPO produced from Jatropha and several other oil plants grown in a similar way in many countries round the world.

As it appears from case 3.5.2.3, fodder cakes produced along with biodiesel from rapeseed in Denmark form a fodder crop in themselves. Consequently, the total amount of N in the crop and the total N_2O emission from rapeseed cultivation should be ascribed to the fodder cakes.

This means that no part of the N_2O emission from rapeseed cultivation should be ascribed to biodiesel produced along with fodder cakes in Denmark.

Obviously, the same applies to biodiesel produced along with fodder cakes in other countries, to the extent that the amounts of fodder cakes meet demands for concentrates.

As it appears from case 3.5.2.4, rapeseed cakes/pellets for other purposes produced along with PPO/biodiesel from rapeseed in Denmark are either returned to the soil as green manure or used for other purposes such as solid biofuel. In the former case, the effective amount of N in the green manure and the corresponding N_2O emission should be omitted from the amounts ascribed to the PPO/biodiesel; in the latter case, the total amount of N in the crop and thus the total N_2O emission should be ascribed to the use for other purposes.

This means that only a certain part of the N_2O emission from rapeseed cultivation should be ascribed to PPO/biodiesel produced along with rapeseed cakes/pellets used as green manure in Denmark.

Obviously, the same applies to PPO/biodiesel produced along with rapeseed cakes/pellets used as green manure in other countries.

This means that, according to the fundamental paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions, no part of the N_2O emissions from rapeseed cultivation should be ascribed to PPO/biodiesel produced along with rapeseed cakes/pellets used for other purposes such as solid biofuel in Denmark; instead, the N_2O emissions should be ascribed to those other and judged independently.

Obviously, the same applies to PPO/biodiesel produced along with rapeseed cakes/pellets used for other purposes such as solid biofuel in other countries.

As it appears from case 3.5.2.5, distillers grain produced along with bioethanol from cereals may be used as fodder with higher digestibility than the corresponding whole crop, at least up to the amounts that meet the demand for such concentrates, or it may be returned to the soil as green manure, or it may be used for other purposes such as solid biofuel. In the first case, all the N in the crop and thus the total N_2O emission from cereal cultivation should be ascribed to the distillers grain; in the second case, the effective amount of N returned to the soil and the corresponding N_2O emission should be omitted from the amounts ascribed to the bioethanol; in the third case, the total amount of N in the crop and thus the total N_2O emission from the cereal cultivation in question should be ascribed to the use for other purposes.

This means that no part of the N_2O emission from cereal cultivation should be ascribed to bioethanol produced along with distillers grain used as fodder.

This means that only a certain part of the N_2O emission from cereal cultivation should be ascribed to bioethanol produced along with distillers grain used as green manure.

This means that, according to the fundamental paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions, no part of the N_2O emission from cereal cultivation should be ascribed to bioethanol produced along with distillers grain used for other purposes such as solid biofuel; instead, the N_2O emissions should be ascribed to those other purposes and judged independently.

In contrast, as it appears from case 3.5.2.6, if there is no use of other crop parts, the total N content in the crop may indeed be completely lost from the agricultural circulation without finding use elsewhere, either as industrial waste disposed of by biofuel companies outside agriculture or dumped in the field without being used as green manure.

Obviously, in connexion with biofuel companies outside agriculture, it may occur to a certain extent that the residues are disposed of as industrial waste instead of being returned to agriculture, especially in less environmentally concerned parts of the world, and especially in connexion with less useful residues such as those from energy plants.

Simply dumping residues, and even useful crop parts, as waste in the field instead of using them as green manure is unthinkable in connexion with responsible and competent agriculture, especially in the most environmentally concerned parts of the world; it may occur to a certain extent in connexion with less responsible and less competent agriculture, especially in less environmentally concerned parts of the world, and especially in connexion with less useful residues such as those from energy plants. This, and only this, rather extraordinary management of crop residues will result in the full effect of the paper simplification.

Consequently, the paper simplification, ascribing the total amount of N in biofuel crops and the total amount of corresponding N_2O emissions to the liquid biofuels, is an obvious fallacy.

Instead, the ascription of N_2O emissions should depend upon the value and use, if any, of the other crop parts/residues.

In all cases of responsible and competent agriculture, no part or only a certain part of the N_2O emissions from cultivating the crops should be ascribed to liquid biofuels.

Further, N_2O savings should be ascribed to liquid biofuels produced from crops cultivated with no external fertilizers.

The paper simplification is only justified when other crop parts/residues are dumped as waste, which is most likely to occur in connexion with less responsible and less competent agriculture and in connexion with energy plants.

And the full effect of the paper simplification only occurs if the other crop parts/residues are dumped as waste in the field without having any effect as green manure.

As it appears, in the real world outside the cities, it is more likely that energy plants, which are presented in the paper as more favourable along with oil palm, contribute N_2O emissions corresponding to their N content, in other words an ascription of N and N_2O emissions according to the paper simplification, in contrast to the biofuel crops which are presented as questionable in the paper.

And, as it appears from [14], in the real world outside the cities, the unconditional paper presentation of oil palm as more favourable is especially unfortunate and unfounded because the increased plantation of oil palm, of all plants, is now one of the main causes of rainforest and wildlife destruction.

Instead of bringing about more attention to the total use of crops and to the environmental impacts of each crop part and thereby supporting more responsible and competent management of all crop parts, thus contributing to worldwide reductions of N_2O emissions and other environmental impacts of agriculture in general and of liquid biofuels in particular, the paper assumptions removes attention from the use of other crop parts and thereby actually supports less responsible and less competent management of all crop parts, and thus counteracts worldwide reductions of N_2O emissions and other environmental impacts of agriculture in general and of liquid biofuels in particular.

Adding to this effect, the lack of attention to differences in management of other crop parts will prevent pressure on less responsible farmers and/or regions in the world, thus further counteracting improvements in agriculture as a whole and contributing to a development where liquid biofuels are chiefly produced in the less environmentally concerned regions of the world with greater N_2O emissions and other environmental impacts.

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3.6. THE ASCRIPTION OF N_2O EMISSIONS TO AGRICULTURE/FERTILIZER USE:

3.6.1. PAPER VALUE RANGE, PAPER ASSUMPTIONS, AND PAPER SIMPLIFICATIONS:

A crucial paper value range is the range y = 0.03 - 0.05 expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production.

This range of values is based upon the paper assumptions leading to the ascription of N_2O emissions to agriculture, and upon the crucial paper simplifications, dealt with in the previous sections 3.1, 3.3, and 3.5, and it is expressly presented as being in contrast to the values obtained by using the 2006 IPCC Guidelines, as stated rather bluntly in the Discussion Paper, which also expressly mentions an additional annual emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer use:

- *The relationship, in both the pre-industrial period and in recent times, after taking into account the large-scale changes in synthetic N fertiliser production and deforestation, is consistent, showing an overall conversion factor of 3–5 %. This factor is covered only in part by the 1 % of "direct" emissions from agricultural crop lands estimated by IPCC (2006), or the "indirect" emissions cited therein. This means that the extra N_2O entering the atmosphere as a result of using N to produce crops for biofuels will also be correspondingly greater than that estimated just on the basis of IPCC (2006).* 11192
- *An evaluation of hundreds of field measurements has shown that N fertilization causes a release of N_2O in agricultural fields that is highly variable but averages close to 1 % of the fixed nitrogen input from mineral fertilizer or biologically fixed N (Bouwman et al., 2002; Stehfest and Bouwman, 2006), and a value of 1 % for such direct emissions has recently been adopted by IPCC (2006). There is an additional emission from agricultural soils of 1 kgN_2O-N/ha/year, which does not appear to be directly related to recent fixed N-input. The in-situ fertilizer-related contribution from agricultural fields to the N_2O flux is thus 3-5 times smaller than our adopted global average N_2O yield of 4±1 % of the fixed N input. The large difference between the low yield of 25 N_2O in agricultural fields, compared to the much larger average value derived from the global N_2O budget, implies considerable "background" N_2O production occurring beyond agricultural fields, but, nevertheless, related to fertilizer use, from sources such as rivers, estuaries and coastal zones, animal husbandry and the atmospheric deposition 11194 of ammonia and NO_x (Kroeze et al., 1999).* 11194

The blunt rejection of the 2006 IPCC values is expressed more politely in the Author Comments, but apart from the reservation that the paper approach cannot be used for the ascription of emissions to specific countries and sources and is therefore not useful for IPCC, the rejection of the 2006 IPCC values is still unyieldingly defended with the additional claims that there is no inconsistency between the IPCC values and the paper values, that the IPCC approach actually supports the paper approach, and that the paper, with its range of values, provides an approach that allows a higher precision in the assessment of N_2O emissions than does the IPCC approach, however omitting the additional annual emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer use:

- **) We do not argue at all that the measurements of emissions directly from agricultural fields are incorrect. We do, however, argue that those emissions are only part (one third to one fifth) of the total N_2O emitted to the atmosphere annually due to new input of reactive nitrogen into global terrestrial systems. As we state in the manuscript, much of the N input into biofuel crop production, as well as* *other crops, is released to the global atmosphere, and to aquatic and terrestrial systems distinct from agricultural fields, where immobilization/mineralization/nitrification/denitrification occurs to produce N_2O. This N_2O is virtually unquantifiable, except through a global mass balance approach, such as that we present in this paper. As only part of the N_2O emissions over the lifetime of Nr is accounted for in the 1% N_2O yield on the plot scale, it is regrettable that this number is still being referred to in life cycle assessments.* S5147

- *The IPCC plot scale direct emission factor is presented as 0.003 - 0.03 kgN_2O-N per kgN fertilizer applied (IPCC, 2006). The upper end of the range is consistent with the lower end of our range (0.03-0.05), while we consider indirect emissions in addition. Furthermore, Seitzinger et al. (2000) estimate indirect emissions from rivers, estuaries and continental shelves between 0.9 and 9.0 Tg N per year (best estimate 1.9), with a large share (more than two thirds, at least in the best estimate case) due to anthropogenic nitrogen. All of the anthropogenic N_2O source we assume in our paper (5.6-6.5 Tg N) can be explained by the indirect emissions alone, if using the upper end estimate. We could add that indirect emissions are not necessarily limited to aquatic regimes.*
  The point is that due to extreme variability in emission patterns, both temporally and spatially, it is extremely difficult to obtain consistent and reliable measurement results. Despite considerable efforts, emission factors of N2O are still highly uncertain. This problem calls for an alternate approach that allows assessing such emissions at higher precision. We claim to be able, at least on a global scale, to provide such an approach. We also claim that this is not in discrepancy with the set of measurements available. But we reject the expectation that our result should fit the best estimate of a very uncertain set of data.
  There is reason to believe that uncertainty margins applicable for plot scale are largely overestimated on the global scale (see the agreement observed by Mosier et al., 1998). In that case, additional indirect N2O formation needs to be assumed, as from re-use of reactive nitrogen and subsequent N2O formation during animal husbandry and in form of manure fertilizer (see Ammann et al., 2007, and our response). Note that, according to IPCC (2006), manure application will be regarded a cause of additional N2O, while it is no additional reactive nitrogen. This supports rather than alters our argument.
  A global approach as presented by Crutzen et al. (2007) will not allow a direct attribution of emissions to a specific country and a specific source. This will be needed to be useful for IPCC. Also for this purpose - here we fully agree with Donner (2007) - a better understanding of soil processes, especially of the nitrogen mobilization, is required. S5149 - S5150
- *It has not been the intention of our manuscript (Crutzen et al., 2007) to criticize the IPCC methodology to underestimate N_2O emissions from agriculture. Instead, we wish to point out that a direct application of this methodology to assess emissions due to biofuel production may lead to serious underestimation of the consequences of the reactive nitrogen released.* S5152
- *8) Discrepancy between global analysis and field studies*
  In the revised version we specifically explain that the emissions estimated by our global analysis are much larger than the default value of 1% of applied N used by IPCC (2006) for direct emissions from agricultural fields. But we point out that the default value has a wide uncertainty range, and furthermore, that in addition to the direct emissions there are background emissions from diverse environments impacted by N fertiliser use; in total these background emissions appear to exceed the amount indicated by their default values. S6594

Thus, the range of values y = 0.03 - 0.05 expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production, is maintained in the final paper, rejecting the 2006 IPCC values and at the same time claiming that they may not be inconsistent with the paper values, and omitting the additional annual emission of 1 kg N_2O-N/ha from agricultural soils not ascribable to recent fertilizer use mentioned in the Discussion Paper:

– *For both the pre-industrial period and in recent times, after taking into account the large-scale changes in synthetic N fertiliser production, we find an overall conversion factor of 3–5 % from newly fixed N to N_2O-N. We assume the same factor to be valid for biofuel production systems. It is covered only in part by the default conversion factor for "direct" emissions from agricultural crop lands (1 %) estimated by IPCC (2006), and the default factors for the "indirect" emissions (following volatilization/deposition and leaching/runoff of N: 0.35 – 0.45 %) cited therein. However, as we show in the paper, when additional emissions included in the IPCC methodology, e.g. those from livestock production, are included, the total may not be inconsistent with that given by our "topdown" method.* 389

The paper rejection of the IPCC values is linked to a rejection of current life cycle analyses, with the claim that they underestimate the N_2O emissions, most bluntly expressed in the Discusion Paper, and maintained in the Author Comments and the final paper:

– *In these life cycle studies, release rates typically are based on the rates recommended by IPCC (2006) for "direct" emissions which were derived from plot-scale measurements (1 % of the fertilizer N applied, or, in a previous version, 1.25 %). Only a few studies (Adler et al., 2007) fully account for the "indirect" emissions also specified by IPCC (which, together with the direct emissions, add up to almost 2 % of fertilizer N), whereas our global analysis indicates a value of 3–5 %. Clearly, all past studies have severely underestimated the release rates of N_2O to the atmosphere, with great potential impact on climate warming.* 11199
– *As only part of the N_2O emissions over the lifetime of Nr is accounted for in the 1 % N_2O yield on the plot scale, it is regrettable that this number is still being referred to in life cycle assessments.* S5147

– *In these life cycle studies, release rates typically are based on the default values estimated by IPCC (2006) for "direct" emissions which were derived from plot-scale measurements (1 % of the fertilizer N applied, or, in a previous version, 1.25 %). Only a few studies (Adler et al., 2007) also incorporate the corresponding default values for "indirect" emissions also specified by IPCC (totalling less than 0.5 % and which, together with the direct emissions, add up to c. 1.5 % of fertilizer N), whereas our global analysis indicates a value of 3–5 %. Past studies seem to have underestimated the release rates of N_2O to the atmosphere, with great potential impact on climate warming.* 392 - 393
– *Here we have shown that the yield of N_2O-N from fixed nitrogen application in agro-biofuel production can be in the range of 3–5 %, 3–5 times larger than assumed in current life cycle analyses, with great importance for climate.* 393

The reservation to the usefulness for IPCC of the paper approach, mentioned and quoted above, deserves great attention in its own right, because it expressly states that the paper approach cannot be used for actual ascriptions of N_2O emissions, neither to specific countries nor to specific sources; however this crucial reservation is omitted in both the Discussion Paper and the final paper and thus only appears once in the Author Comments:

– *A global approach as presented by Crutzen et al. (2007) will not allow a direct attribution of emissions to a specific country and a specific source. This will be needed to be useful for IPCC. Also for this purpose - here we fully agree with Donner (2007) - a better understanding of soil processes, especially of the nitrogen mobilization, is required.* S5150

The derivation of the paper ascription of N_2O to agriculture, and specifically to synthetic N fertilizers, leading to the crucial paper value range y = 0.03 - 0.05, also deserves attention in its own right: the paper expressly calculates the anthropogenic N_2O emissions as the difference between the total N_2O emissions and the natural N_2O emissions from everything else but agricultural soils, and it further expressly calculates the N_2O emissions from agiculture as the difference between the total anthropogenic N_2O emissions and the N_2O emissions from industrial sources, as presented in the final paper:

– *We start this study by deriving the yield of N2O from fresh N input, based on data compiled by Prather et al. (2001) and Galloway et al. (2004) with some analysis of our own. Fresh fixed N input includes N, which is produced by chemical, biological and atmospheric processes. The pre-industrial, natural N2O sink and source at an atmospheric mixing ratio of 270 nmol/mol is calculated to be equal to 10.2 TgN2ON/yr (Prather et al., 2001), which includes marine emissions. By the start of the present century, at an atmospheric volume mixing ratio of 315 nmol/mol, the stratospheric photochemical sink of N2O was about 11.9 TgN2O-N/yr. The total N2O source at that time was equal to the photochemical sink (11.9 TgN2O-N/yr) plus the atmospheric growth rate (3.9 TgN2O-N/yr), together totalling 15.8 TgN2O-N/yr (Prather et al., 2001). The anthropogenic N2O source is the difference between the total source strength, 15.8 TgN2ON/yr, and the current natural source, which is equal to the preindustrial source of 10.2 TgN2O-N/yr minus an uncertain 0–0.9 TgN2O-N, with the latter number taking into account a decreased natural N2O source due to 30% global deforestation (Klein Goldewijk, 2001). Thus we derive an anthropogenic N2O source of 5.6–6.5 TgN2O-N/yr. To obtain the agricultural contribution, we subtract the estimated industrial source of 0.7–1.3 TgN2O-N/yr (Prather et al., 2001), giving a range of 4.3–5.8 TgN2O-N/yr. This is 3.8–5.1% of the anthropogenic "new" fixed nitrogen input of 114 Tg N/yr for the early 1990s; the input value is derived from the 100 Tg of N fixed by the Haber-Bosch process, plus 24.2 Tg of N fixed due to fossil fuel combustion and 3.5 Tg difference from biological N fixation, BNF, between current and pre-industrial times (Galloway et al., 2004), reduced by the 14 Tg of Haber-Bosch N not used as fertilizer (Smeets et al, 2007).* 389 - 390

Nowhere in the paper is there any reservation to the ascription of N_2O emissions to non agricultural sources, although it forms the very basis of the paper ascription of N_2O to agriculture, ultimately leading to the neat conclusion:

– *Here we concentrated on the climate effects due only to required N fertilization in biofuel production and we have shown that, depending on N content, the current use of several agricultural crops for energy production, at current total nitrogen use efficiencies, can lead to N2O emissions large enough to cause climate warming instead of cooling by "saved fossil CO2".* 393

3.6.2. OBJECTIONS:

The crucial reservation stated in the Author Comments, that the paper approach cannot be used for actual ascriptions of N_2O emissions, neither to specific countries nor to specific sources, is actually an annulment of all the express and implied claims to worldwide validity and applicability occurring throughout the paper, and it is also a contradiction of the repeated rejection of current life cycle analyses.

Thus, the omission in both the Discussion Paper and the final paper of this crucial statement, which is only presented once in the Author Comments, specifically related to a comparison between paper values and IPCC values, renders the whole paper misleading.

And, far from being an approach that allows assessing N_2O emissions at higher precision, as expressly claimed, the paper only consists of extremely simplified conclusions and calculations based upon the simple observation that the total worldwide amount of N_2O emissions ascribed to agricultural soils according to the paper is about 0.03 - 0.05 times, or about 3 - 5% of, the total worldwide amount of N in synthetic N fertilizer applied to fields.

Furthermore, the fundamental paper conclusion based upon the paper ascription of N_2O emissions to agriculture, namely that all these emissions are caused by the current use of fertilizers, more specifically by the current use of synthetic N fertilizers, is an obvious fallacy, which is actually revealed in the paper itself:

The derivation of the paper ascription of 4.3–5.8 Tg N_2O-N/year to agriculture and the corresponding paper value range of 3.8–5.1% N_2O-N ascribed to synthetic N fertilizers, includes a specific paper reduction in the natural emissions of 0–0.9 Tg N_2O-N/year caused by deforestation; however, these natural N_2O background emissions caused by the naturally developed soil conditions prior to the agricultural use, and at least lasting for some time afterwards, are thereby transferred from natural sources to anthropogenic sources and are further specifically ascribed to current synthetic N fertilizers which has had no part in their formation.

And, even more importantly, the additional annual background emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer as expressly mentioned the Discussion Paper but omitted in the final paper, reveals that significant contributions to the N_2O emissions from agricultural soils cannot be related to the current use of fertilizers. This emission does not form part of the 2006 and 1996 IPCC Guidelines, [20] and [21], because it is not caused by recent agricultural use but is considered natural emissions, as explained in [22]:

– *IPCC's metod att beräkna N_2O emission från jordbruksmark baseras på Bouwman's arbete 1996, tabell 1, där emissionen är 1,25 % (0,25 - 2,5 %) av tillfört kväve. En bakgrundsemission (1 kgN_2O-N ha^{-1} $år^{-1}$) räknas inte med i IPCC's metodik utan man antar att marken har en naturlig emission.* *IPCCs emissionsfaktorer för dikväveoxid från jordbruksmark, side 5*

(IPCC's method of calculating N_2O emissions from agricultural fields are based upon Bouwman's work 1996, table 1, where the emission is 1.25% (0.25 - 2.5%) of applied nitrogen. A background emission (1 kgN_2O-N ha^{-1} $year^{-1}$) is not included in IPCC's methodology in that it is presumed that the field has a natural emission.

IPCCs emission factors for nitrous oxide from agricultural fields, page 5)

Based upon [22], half the background emission, namely 0.5 kgN_2O-N/ha, is included in the Swedish National Inventories such as [23] in connexion with a reduction of the national emission value from 1.25% to 0.8% for synthetic fertilizers, leaving out the other half.

Most countries, including Denmark, do not include the background emissions at all in their National Inventories, consistent with the IPCC approach of assessing anthropogenic N_2O emissions and not natural N_2O emissions.

Evidently, in any proper assessment of anthropogenic N_2O emissions, including those caused by agriculture, the natural background emissions from fields should be left out.

According to [24], the total worldwide land use for agriculture amounts to about 5 milliard ha, about 1.4 milliard ha being arable land, about 0.15 milliard ha holding permanent crops, and about 3.45 milliard ha being pastures, all of which would otherwise have been covered with natural vegetation causing corresponding natural N_2O emissions. A natural background emission of 1 kgN_2O-N/ha from the 1.4 milliard ha arable land alone corresponds to 1.4 TG N_2O-N/year which is one fourth to one third of the paper value of the total N_2O emissions from agricultural soils. The natural background emissions from the remaining 3.6 milliard ha with pastures and permanent crop also contribute to the natural N_2O emissions from agricultural soils, thus further reducing the amount actually ascribable to agriculture.

As it appears, it is evident that large amounts of N_2O emissions from agricultural soils are not ascribable to current fertilizer use.

Furthermore, a number of crucial observations have been stated in [25], which forms part of the IPCC Third Assessment Report which forms part of the scientific basis for the 2006 IPCC Guidelines, including the following, with underlining of key parts:

– *Substantial, pre-industrial abundances for CH4 and N2O are found in the tiny bubbles of ancient air trapped in ice cores. Both gases have large, natural emission rates, which have varied over past climatic changes but have sustained a stable atmospheric abundance for the centuries prior to the Industrial Revolution (see Figures 4.1 and 4.2). Emissions of CH4 and N2O due to human activities are also substantial and have caused large relative increases in their respective burdens over the last century. The atmospheric burdens of CH4 and N2O over the next century will likely be driven by changes in both anthropogenic and natural sources.* *4.1.1. Sources of Greenhouse Gases 243*
– *The biosphere's response to global change will impact the atmospheric composition of the 21st century. The anticipated changes in climate (e.g., temperature, precipitation) and in chemistry will alter ecosystems and thus the "natural", background emissions of trace gases. There is accumulating evidence that increased N deposition (the result of NOx and ammonia (NH3) emissions) and elevated surface O3 abundances have opposite influences on plant CO2 uptake: O3 (>40 ppb) inhibits CO2 uptake; while N deposition enhances it up to a threshold, above which the effects are detrimental. In addition, the increased N availability from atmospheric deposition and direct fertilisation accelerates the emission of N-containing trace gases (NO, N2O and NH3) and CH4, as well as altering species diversity and biospheric functioning. These complex interactions represent a chemistry-biosphere feedback that may alter greenhouse forcing.* *4.1.2. Atmospheric Chemistry and Feedbacks, page 246*
– *The source strength (Tg/yr) for most greenhouse gases is comprised of surface emissions. For synthetic gases where industrial production and emissions are well documented, the source strengths may be*

accurately known. For CH_4 and N_2O, however, there are large, not well-quantified, natural emissions. Further, the anthropogenic emissions of these gases are primarily associated with agricultural sources that are difficult to quantify accurately. Considerable research has gone into identifying and quantifying the emissions from individual sources for CH_4 and N_2O, as discussed below.

4.1.3. Trace Gas Budgets and Trends, page 246

- *The enhanced N_2O emissions from agricultural and natural ecosystems are believed to be caused by increasing soil N availability driven by increased fertilizer use, agricultural nitrogen (N_2) fixation, and N deposition; and this model can explain the increase in atmospheric N_2O abundances over the last 150 years (Nevison and Holland, 1997). Recent discovery of a faster-than-linear feedback in the emission of N_2O and NO from soils in response to external N inputs is important, given the projected increases of N fertilisation and deposition increases in tropical countries (Matson et al., 1999). Tropical ecosystems, currently an important source of N_2O (and NO) are often phosphorus-limited rather than being N-limited like the Northern Hemispheric terrestrial ecosystems. Nitrogen fertiliser inputs into these phosphorus-limited ecosystems generate NO and N_2O fluxes that are 10 to 100 times greater than the same fertiliser addition to nearby N-limited ecosystems (Hall and Matson, 1999). In addition to N availability, soil N_2O emissions are regulated by temperature and soil moisture and so are likely to respond to climate changes (Frolking et al., 1998; Parton et al., 1998). The magnitude of this response will be affected by feedbacks operating through the biospheric carbon cycle (Li et al., 1992, 1996).* *4.2.1.2. Nitrous oxide (N_2O), page 257*
- *Most tropospheric NO_x are emitted as NO, which photochemically equilibrates with nitrogen dioxide (NO_2) within a few minutes. Significant sources, summarised in Table 4.8, include both surface and in situ emissions, and only a small amount is transported down from the stratosphere. NO_x emitted within polluted regions are more rapidly removed than those in remote regions. Emissions directly into the free troposphere have a disproportionately large impact on global greenhouse gases. The major source of NO_x is fossil fuel combustion, with 40% coming from the transportation sector.*

  4.2.3.3.Nitrogen oxides (NO_x), page 259
- *The dominant sink of NO_x is atmospheric oxidation of NO_2 by OH to form nitric acid (HNO_3), which then collects on aerosols or dissolves in precipitation and is subsequently scavenged by rainfall. Other pathways for direct NO_x removal occur through canopy scavenging of NO_x and direct, dry deposition of NO_x, HNO_3, and particulate nitrates to the land surface and the ocean. Dry deposition can influence the surface exchanges and can thus alter the release of NO_x and N_2O to the atmosphere.* *4.2.3.3.Nitrogen oxides (NO_x), page 260*
- *Natural emissions of N_2O and CH_4 are currently the dominant contributors to their respective atmospheric burdens, with terrestrial emissions greatest in the tropics. Emissions of both of these gases are clearly driven by changes in physical climate as seen in the ice-core record (Figure 4.1e). Soil N_2O emissions are sensitive to temperature and soil moisture and changes in rates of carbon and nitrogen cycling (Prinn et al., 1999).* *4.5.3. Feedbacks through Natural Emissions, page 278*

Furthermore, a number of crucial observations have been stated in various sources such as [6], including the following, with underlining of key parts:

- *The most sensitive parameter influencing agricultural N_2O emissions is the soil organic content (usually described by the soil organic carbon (SOC) concentration), as indicated in Figure 3.4.1. Much of the emissions, especially from high-organic fields, would occur even if the field was not ploughed, and this effect is taken into account through the "grass" reference case. However, the extra N_2O emissions from arable farming also increase with SOC, and very rapidly when the SOC is over*

10% (the scale is logarithmic). In fact this effect is so strong that the results from a few fields with over 10% SOC significantly affect the whole average.

3.4.1. Common issues, Nitrous oxide emissions, page 32

As it appears, there is a considerable uncertainty about the amounts of N_2O emissions from natural sources, evidently leading to an uncertainty about the amounts of N_2O emissions from anthropogenic sources.

And, there are significant differences in the amount of N_2O emissions resulting from a given amount of synthetic fertilizer N.

The N_2O-N/N emissions may be many times greater for soils where growth is limited by P than for soils where growth is limited by N, as is the case for Denmark and other countries where the management of fertilizer use is aided by field measurements and research.

And the N_2O-N/N emissions are far greater for high SOC soils, also known as organogenic soils, than for low SOC soils, also known as mineral soils; the latter form most of the agricultural soils. In both the 1996 and 2006 IPCC Guidelines, a fixed emission of 8 kgN_2O-N/ha is used for organogenic soils, in addition to the amounts caused by the agricultural use, reflecting the fact that a large part of the N_2O emissions are independent of agricultural use; 8 kg N_2O-N/ha corresponds to the emissions from 640 and 800 kg/ha of synthetic fertilizer N according to the 1996 and 2006 IPCC Guidelines respectively.

And, the amounts of N_2O emissions from all soils, including agricultural soils, are also influenced by general changes caused by the combined effect of all GHG emissions.

And, deposition of NO_x emissions, chiefly from industrial sources in the form of combustion of fossil fuels including considerable amounts from vehicles, also influence the amounts of N_2O emissions from all soils, including agricultural soils.

Furthermore, as dealt with in the following section 3.7, it is evident that the amount of N_2O emissions resulting from a given amount of fertilizer N is determined by the entire N chain from the original fertilizer use to the final uses and losses, thus not only being dependent upon N uptake efficiencies but also upon choice of crops and uses; and the amount of N_2O emissions related to a given amount of animal/green manure N is greater than the amount of N_2O emissions related to the same amount of synthetic fertilizer N.

Based upon the paper ascription of N_2O emissions to agriculture mentioned above, the range of values y = 0.03 - 0.05, expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production, is maintained throughout paper, regardless of the additional annual emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer use according to the Discussion Paper.

And this paper ascription is used to present a double paper claim of opposites: the N_2O emissions values in the 2006 IPCC Guidelines are rejected as insufficient to explain the N_2O emissions from agriculture and thus from the production of liquid biofuels, along with just about the opposite claim that the very same N_2O emissions values in the 2006 IPCC Guidelines may not be inconsistent with the paper values. The paper rejection of the IPCC values is followed up by a paper rejection of current life cycle analyses, with the claim that they underestimate the N_2O emissions because they use the IPCC values, also most bluntly expressed in the Discussion Paper.

The first part of the double paper claim of opposites about the 2006 IPCC Guidelines N_2O emissions values, namely that they are insufficient to explain the N_2O emissions from agriculture and thus from the production of liquid biofuels, is further dealt with in the following section 3.7.

Evidently, the IPCC Guidelines are based upon a continuously increasing knowledge basis, and each set of Guidelines reflects the knowledge developed so far; this means that the 2006 IPCC Guidelines [20] represent a further development based upon added knowledge obtained after the publication of the 1996 IPCC Guidelines [21].

The most important changes concerning N_2O emissions from the 1996 IPCC Guidelines to the 2006 IPCC Guidelines are reductions in a number of N_2O-N to N values.

Probably, the most crucial change is the 70% reduction of the N_2O-N to N value for leaching, from 0.025 to 0.0075, the uncertainty range being changed and significantly reduced from 0.0002-0.12 to 0.0005-0.025; as it appears, the 1996 value corresponds to the maximum value in the 2006 uncertainty range; it should be noted that in [22] a reduction of 90% to 0.0025 was suggested for Sweden, based upon Swedish measurements.

The N_2O-N to N value for field application of synthetic N fertilizer and animal manure is reduced by 20%, from 0.0125 to 0.01, the uncertainty range being changed and slightly increased from 0.0025-0.0225 to 0.003-0.03; as it appears, the 1996 value was midway between the minimum and maximum values of the uncertainty range.

The N_2O-N to N value for crop residues is also reduced by 20%, from 0.0125 to 0.01, the 2006 uncertainty range also being 0.003-0.03 here.

The N_2O-N to N value for N fixing crops is reduced by 100%, from 0.0125 to 0, and the value for manure deposited on grass is halved for animals other than cattle, pigs, and poultry, from 0.02 to 0.01, the value for cattle, pigs, and poultry, still being 0.02.

This means that N_2O emissions calculated according to the 2006 IPCC Guidelines, which are based upon the current further developed knowledge basis, are generally somewhat lower than N_2O emissions calculated according to the 1996 IPCC Guidelines, which are based upon the older and thus outdated knowledge basis.

It should be noted that all current National Inventories are based upon the 1996 IPCC Guidelines [21], in other words upon the older and outdated knowledge basis, whereas the paper rightly refers to the 2006 IPCC Guidelines [20], in other words to the current further developed knowledge basis.

And it should be noted that according to [26], after subtraction of the natural N_2O emissions corresponding to unfertilized fields, the world average fertilizer induced N_2O emissions amount to 0.8%, or 0.008, of fertilizer N; this is the same value as in [22] and [23], less than the 2006 IPCC Guidelines N_2O-N to N value for field application of synthetic N fertilizer which was reduced from 0.0125 to 0.01 as compared to the 1996 IPCC Guidelines value.

The total N_2O emissions from Danish agriculture presented in [27] and [28] are based upon the outdated 1996 IPCC Guidelines [21] and upon [29]; all these sources form part of the basis for Sheets C and D in [1].

As it appears from [27] and [28], the N_2O emissions from Danish agriculture calculated according to the 1996 IPCC Guidelines values have been reduced by about 1/3 between 1985 and 2005, consistent with the reduction in fertilizer use of more than 1/3 since the fertilizer accounts according to [2] were introduced in 1993, as it appears from section 3.1.

And as it appears from [28], the N_2O emissions ascribed to the application of synthetic N fertilizers to the fields, calculated according to the 1996 IPCC Guidelines values, amount to about 20% of the total N_2O emissions from Danish agriculture.

In other words: the total N_2O emissions from agriculture are 5 times greater than the emissions from the application of synthetic N fertilizers.

This might lead to the false assumption that the Danish National Inventories imply a value $y = 0.05$, corresponding to the paper claim that the IPCC values support the paper values.

However, as it appears from Sheet E in [1], the Danish agricultural soils receive more N from animal manure than from synthetic N fertilizer so the Danish N_2O emissions would correspond to $y < 0.025$, below the minimum value of the paper range.

And as stated above, and as it appears from Sheets C and D in [1], the values in the further developed 2006 IPCC Guidelines referred to in the paper are lower than the outdated 1996 IPCC Guidelines values used in the current National Inventories.

Therefore, the second part of the paper claim, that the 2006 IPCC Guidelines values actually support the paper range of values, is clearly contradicted by the values in the Danish National Inventories such as [27].

As it appears, there is a considerable uncertainty in determining the total natural N_2O emissions which form the paper basis of the total anthropogenic N_2O emissions, and there are also evident errors in the paper calculations of the latter as the difference between the total N_2O emissions and the total natural N_2O emissions.

There may be a number of ways to determine or assess the natural N_2O emissions that come from agricultural soils, thereby narrowing down the N_2O emissions from agricultural soils actually ascribable to agriculture.

One way is by comparison to corresponding unfertilized fields as in [26]; another way might be by comparison to corresponding land with natural undisturbed vegetation, in other words the N_2O emissions that would occur if the soils had remained in their original state with the original natural vegetation, without anthropogenic effects of cultivation such as increased amounts of N, drainage, and soil exhaustion.

All in all, the crucial paper value range $y = 0.03 - 0.05$ expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production is not consistent with the real world outside the cities.

And evidently, even with a correct determination of the total natural N_2O emissions and thereby of the total anthropogenic N_2O emissions, the derivation of the N_2O emissions from agriculture, calculated as the difference between the total anthropogenic N_2O emissions and the

N_2O emissions from industrial sources, can only be done correctly if the N_2O emissions from industrial sources are determined correctly.

It should be noted that in the paper, the term industrial sources cover all non agricultural anthropogenic sources, thus including not only the production of goods and energy, seemingly including biomass burning, but also all kinds of traffic, on land, at sea, and in the air, and all kinds of waste, thus also including all household wastes including human wastes; in [25], biomass burning is presented as a separate source, not included in the industrial sources.

This means that any added knowledge changing the estimated amounts of the N_2O emissions from industrial sources should change the derived total paper amounts of N_2O emissions from agriculture, all of which are ascribed to synthetic N fertilizers.

Since the paper expressly claims to establish specific N_2O emissions from agriculture, and since the paper has its own derivation of the total anthropogenic N_2O emissions, the absence of any kind of consideration or reservation related to the crucial paper ascription of N_2O emissions to industrial sources is conspicuous, especially in the light of the rather extraordinary and sensational conclusions drawn in the paper.

3.6.3. CONSEQUENCES AND CONCLUSIONS:

The crucial reservation stated in the Author Comments, that the paper approach cannot be used for actual ascriptions of N_2O emissions, neither to specific countries nor to specific sources, is actually an annulment of all the express and implied claims to worldwide validity and applicability occurring throughout the paper, and it is also a contradiction of the repeated rejection of current life cycle analyses.

Thus, the omission in both the Discussion Paper and the final paper of this crucial statement, which is only presented once in the Author Comments, specifically related to a comparison between paper values and IPCC values, renders the whole paper misleading.

And, far from being an approach that allows assessing N_2O emissions at higher precision, as expressly claimed, the paper only consists of extremely simplified conclusions and calculations based upon the simple observation that the total worldwide amount of N_2O emissions ascribed to agricultural soils according to the paper is about 0.03 - 0.05 times, or about 3 - 5% of, the total worldwide amount of N in synthetic N fertilizer applied to fields.

Furthermore, the fundamental paper conclusion based upon the paper ascription of N_2O emissions to agriculture, namely that all these emissions are caused by the current use of fertilizers, more specifically by the current use of synthetic N fertilizers, is an obvious fallacy, which is actually revealed in the paper itself.

Most importantly, the additional annual background emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer use, expressly mentioned in the Discussion Paper but omitted in the final paper, reveals that significant contributions to the N_2O emissions from agricultural soils cannot be related to the current use of fertilizers; this emission does not form part of the IPCC Guidelines because it is not caused by recent agricultural use but is considered natural emissions.

Evidently, in any proper assessment of anthropogenic N_2O emissions including those caused by agriculture, the natural background emissions from fields should be left out.

The total worldwide land use for agriculture amounts to about 5 milliard ha, about 1.4 milliard ha being arable land, about 0.15 milliard ha holding permanent crops, and about 3.45 milliard ha being pastures, all of which would otherwise have been covered with natural vegetation causing corresponding natural N2O emissions. A natural background emission of 1 kgN2O-N/ha from the 1.4 milliard ha arable land alone corresponds to 1.4 TG N2O-N/year which is one fourth to one third of the paper value of the total N2O emissions from agricultural soils. The natural background emissions from the remaining 3.6 milliard ha with pastures and permanent crop also add to the natural N2O emissions from agricultural soils, thus further reducing the amount ascribable to agriculture.

As it appears, based upon information in the paper itself, it is evident that large amounts of N_2O emissions from agricultural soils are clearly not ascribable to current fertilizer use.

Furthermore, a number of crucial observations stated in the IPCC Third Assessment Report, which forms part of the scientific basis for the 2006 IPCC Guidelines, and in various other sources, demonstrate that there is a considerable uncertainty about the amounts of N_2O emissions from natural sources, evidently leading to an uncertainty about the amounts from anthropogenic sources.

They also demonstrate that there are significant differences in the amount of N_2O emissions that may result from a given amount of synthetic fertilizer N.

The N_2O-N/N emissions may be many times greater for soils where growth is limited by P than for soils where growth is limited by N, as is the case for most countries, including Denmark where the management of fertilizers is aided by field measurements and research and unnecessary use of N fertilizers is avoided.

And the N_2O-N/N emissions are far greater for high SOC soils, also known as organogenic soils, than for low SOC soils, also known as mineral soils; the latter form most of the agricultural soils. In both the 1996 and 2006 IPCC Guidelines, a fixed emission of 8 kgN_2O-N/ha is used for organogenic soils, in addition to the amounts caused by the agricultural use, reflecting the fact that a large part of the N_2O emissions are independent of agricultural use; 8 kgN_2O-N/ha corresponds to the emissions from 640 and 800 kg/ha of synthetic N fertilizer according to the 1996 and 2006 IPCC Guidelines respectively.

And, the amounts of N_2O emissions from soils are also influenced by general changes caused by the combined effect of all GHG emissions.

And, deposition of NO_x emissions, mostly from industrial sources including considerable amounts from transportation, also have an influence on the amounts of N_2O emissions from soils.

Furthermore, the amount of N_2O emissions resulting from a given amount of fertilizer N is evidently determined by the entire N chain from the original fertilizer use to the final uses and losses, thus not only dependent upon N uptake efficiencies but also upon choice of crops and uses; and the amount of N_2O emissions resulting from a given amount of animal/green manure N is greater than the amount of N_2O emissions resulting from the same amount of synthetic fertilizer N.

Based upon the paper ascription of N_2O emissions to agriculture mentioned above, the range of values y = 0.03 - 0.05, expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production, is maintained throughout paper, regardless of the additional annual emission of 1 kgN_2O-N/ha from agricultural soils not ascribable to recent fertilizer use according to the Discussion Paper.

And this paper ascription is used to present a double paper claim of opposites: the 2006 IPCC Guidelines N_2O emissions values are rejected as insufficient to explain the N_2O emissions from agriculture, and more specifically from the production of liquid biofuels, most bluntly expressed in the Discussion Paper and maintained more politely in the Author Comments and in the final paper; at the same time just about the opposite claim is put forward, namely that the very same 2006 IPCC Guidelines N_2O emissions values may not be inconsistent with the paper values. The paper rejection of the IPCC values is followed up by a paper rejection of current life cycle analyses, with the claim that they underestimate the N_2O emissions because they use the IPCC values, also most bluntly expressed in the Discussion Paper and maintained in the Author Comments and the final paper.

The first part of the double paper claim about the 2006 IPCC Guidelines N_2O emissions values, namely that they are insufficient to explain the N_2O emissions from agriculture, and specifically from the production of liquid biofuels, is further dealt with in the following section 3.7.

Evidently, the IPCC Guidelines are based upon a continuously increasing knowledge basis, and each set of Guidelines reflects the knowledge developed so far; this means that the 2006 IPCC Guidelines represent a further development based upon added knowledge obtained after the publication of the 1996 IPCC Guidelines.

The most important changes concerning N_2O emissions from the 1996 IPCC Guidelines to the 2006 IPCC Guidelines are reductions in a number of N_2O-N to N values.

Probably, the most crucial change is the 70% reduction of the N_2O-N to N value for leaching, from 0.025 to 0.0075, the uncertainty range being changed and significantly reduced from 0.0002-0.12 to 0.0005-0.025; as it appears, the 1996 value corresponds to the maximum value in the 2006 uncertainty range; it should be noted that a reduction of 90% to 0.0025 has been suggested for Sweden, based upon Swedish measurements.

The N_2O-N to N value for field application of synthetic N fertilizer and animal manure is reduced by 20%, from 0.0125 to 0.01; the N_2O-N to N value for crop residues is also reduced by 20%, from 0.0125 to 0.01, the N_2O-N to N value for N fixing crops is reduced by 100%, from 0.0125 to 0, and the value for manure deposited on grass is halved for animals other than cattle, pigs, and poultry, from 0.02 to 0.01.

It should be noted that in the estimates of worldwide N_2O emissions from agricultural land by FAO, after subtraction of the corresponding natural N_2O emissions from unfertilized fields, the world average fertilizer induced N_2O emissions amount to 0.8%, or 0.008, in other words less than the 2006 IPCC Guidelines N_2O-N to N value for field application of synthetic N fertilizer.

This means that N_2O emissions calculated according to the 2006 IPCC Guidelines, which are based upon the current further developed knowledge basis, are generally somewhat lower than N_2O emissions calculated according to the 1996 IPCC Guidelines, which are based upon the older and thus outdated knowledge basis.

It should be noted that all current National Inventories are based upon the 1996 IPCC Guidelines, in other words upon the older outdated knowledge basis, whereas the paper rightly refers to the current further developed knowledge basis: the 2006 IPCC Guidelines.

The total agricultural N_2O emissions in the Danish National Inventories would correspond to $y < 0.025$, which is below the minimum value of the paper range, even though they are based upon the higher emission values in the 1996 IPCC Guidelines.

Therefore, the second part of the paper claim, namely that the 2006 IPCC Guidelines values actually support the paper range of values, is clearly contradicted by the Danish National Inventories.

As it appears, there is a considerable uncertainty in determining the total natural N_2O emissions which form the paper basis of the total anthropogenic N_2O emissions, and there are also evident errors in the paper calculations of the latter as the difference between the total N_2O emissions and the total natural N_2O emissions.

There may be a number of ways to determine or assess the part of the natural N_2O emissions that come from agricultural soils, thereby narrowing down the N_2O emissions from agricultural soils actually ascribable to agriculture.

One way is by comparison to corresponding unfertilized fields; another way might be by comparison to corresponding land with natural undisturbed vegetation, in other words the N_2O emissions that would occur if the soils had remained in their original state with the original natural vegetation, obviously without anthropogenic effects of cultivation such as increased levels of N, drainage, and soil exhaustion.

All in all, the crucial paper value range $y = 0.03 - 0.05$ expressing the proportion of N in synthetic N fertilizer that ends as N in N_2O emissions as a result of liquid biofuel production is not consistent with the real world outside the cities.

And evidently, even with a correct determination of the total natural N_2O emissions and thereby of the total anthropogenic N_2O emissions, the derivation of the agricultural N_2O emissions, calculated as the difference between the total anthropogenic N_2O emissions and the N_2O emissions from industrial sources, can only be done correctly if the N_2O emissions from industrial sources are determined correctly.

It should be noted that in the paper, the term industrial sources cover all non agricultural anthropogenic sources, thus including not only the production of goods and energy, seemingly including biomass burning, but also all kinds of traffic, on land, at sea, and in the air, and all kinds of waste, thus also including all household wastes.

This means that any added knowledge changing the estimated amounts of the N_2O emissions from industrial sources will change the derived total N_2O emissions from agriculture, all of which are ascribed to synthetic N fertilizers in the paper.

Since the paper expressly claims to establish specific N_2O emissions from agriculture, and since the paper has its own derivation of total anthropogenic N_2O emissions, the absence of any kind of consideration or reservation related to the crucial paper ascription of N_2O emissions to industrial sources is conspicuous, especially in the light of the rather extraordinary and sensational conclusions drawn in the paper.

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3.7. THE ASCRIPTION OF N_2O EMISSIONS TO LIQUID BIOFUELS:

3.7.1. PAPER VALUE RANGES:

Based upon the paper expressions of the cooling effect of replacing fossil fuels and the warming effect of producing liquid biofuels, most concisely presented in the Discussion Paper,

– *Our assumptions lead to expressions per unit mass of dry matter harvested in biofuel production to avoid fossil CO2 emissions, "saved CO2",(M), and for "equivalent CO2", (Meq), the latter term accounting for the global warming potential (GWP) of the N2O emissions:*
$M=rC\times\mu CO2/\mu C\times cv$ (1)
$Meq=rN\times y\times\mu N2O/\mu N2\times GWP/e$ (2) 11195

and upon the paper values, simplifications and assumptions, further dealt with in sections 3.1 to 3.6, the following final paper value ranges expressing the ratio Meq/M between the warming effect of producing liquid biofuels and the cooling effect of replacing fossil fuels apply, most comprehensively presented in the Discussion Paper:

– *Table 1. Relative warming derived from N_2O production for crops, crop residues, and forages used in the production of biofuel.*

Crop	*r_N (gN/kg dry matter)*	*relative warming Meq/M*	*type of fuel produced*
Rapeseed	*39*	*1.0 - 1.7*	*Biodiesel*
Wheat	*22*	*1.3 - 2.1*	*Bio-ethanol*
Barley, Oat	*19*	*1.1 - 1.9*	*Bio-ethanol*
Maize	*15*	*0.9 - 1.5*	*Bio-ethanol*
Sugar cane	*7.3*	*0.5 - 0.9*	*Bio-ethanol*

In these formulae r_C is in g carbon per g dry matter in the feedstock; r_N is the mass ratio of N to dry matter in g N/kg; cv is the mass of carbon in the biofuel per mass of carbon in feedstock biomass (corn, rapeseed, sugar cane); e is the uptake efficiency of the fertilizer by the plants; y=0.03–0.05, the range of yields of N_2O-N from fixed N application; GWP=296;$\mu CO_2/\mu C=44/12$, $\mu N_2O/\mu N_2=44/28$, where the μ terms are the molar weights of N_2O, N_2, CO_2, and C. 11205

3.7.2. OBJECTIONS:

Based upon the paper values of N content in biofuel crops r_N, the paper values of C content in liquid biofuels r_C, the general paper value of N uptake efficiency e = 0.4, and the general paper range of ratios between N_2O-N emissions and amount of original fertilizer N y = 0.03 - 0.05, or 3 - 5%, all of which have been disproved in the previous sections, the paper presents the following paper ranges Meq/M, expressing the ratio of the warming effect Meq of N_2O emissions resulting from liquid biofuel production to the cooling effect M obtained by replacing the corresponding fossil fuels, only considering the CO_2 emission from the actual use of the fuels, in all cases using the same values for each crop, regardless of possible differences in the use of other crop parts and in the entire N chains of uses and losses.

The fallacy of using general values and value ranges, such as e = 40% and y = 3 - 5%, for the calculation of the N_2O emissions from a given amount of synthetic N fertilizer seems obvious, because the actual emissions depend upon the entire N chain of uses and losses, including possible recycling of N in subsequent crops and possible multiplication of N from fertilization, or even procurement of N without the use of fertilizer, by N fixation.

This may be seen from the following values of N_2O-N to first crop N, expressing the emissions related to a given amount of N harvested with the first crop, and of N_2O-N to food N, expressing the emissions related to a given amount of N available in the final use as food, and of the total N_2O-N emissions to original fertilizer N, expressing the total emissions from the entire N chain to a given amount of original fertilizer N (with values including an assumed natural background emission of 1 kgN_2O-N/ha shown in brackets), according to the 2006 IPCC Guidelines [20].

All values are calculated with the use of an extended version of Sheets C and D in [1] for a number of normal agricultural uses of crops in normal chiefly cereal crop rotations, along with the corresponding paper values of N_2O-N to first crop N, the paper values e = 0.4 and y = 3 - 5% implying N_2O-N to first crop N values of y/e = 7.5 - 12.5%, and total N_2O-N emissions to original fertilizer N, the paper value being y = 3 - 5%; for N fixation, the efficiencies relative to synthetic fertilizer N are set to 0.4 - 0.7, or 40% - 70%.

The fertilizer uses, agricultural uses, and crop rotations are as follows:

- Synthetic N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops:
  Crop rotation: winter rapeseed, winter wheat, winter wheat, spring barley, winter barley;
  The uses are formed by a large number of combinations of end uses as food from animal husbandry and relevant kinds of manure management: the end uses as food are cattle dairy and meat, pig pork, poultry meat and eggs, sheep milk/mutton, and goat milk/meat; the kinds of manure management are liquid manure, separated manure, and deep litter, with or without storage before application in the field, and manure dropped in the field;
- Synthetic N fertilizer for winter wheat for food:
  All the N taken up by the wheat as first crop is removed from the agricultural circulation which means that the following crops in the crop rotation are actually irrelevant;
- Synthetic N fertilizer for winter wheat for fuel, included to demonstrate that this use results in the same N_2O emissions a does winter wheat for food:
  All the N taken up by the wheat as first crop is removed from the agricultural circulation which means that the following crops in the crop rotation are actually irrelevant;
- Synthetic N fertilizer for clover grass for fodder followed by winter wheat for fodder:
  Crop rotation: clover grass, clover grass, winter wheat, winter wheat, winter wheat;
  The original fertilizer N is multiplied twice by N fixation in the clover grass;
  The end use as food is cattle dairy;
- Synthetic N fertilizer for clover grass for fodder followed by winter wheat for food:
  Crop rotation: clover grass, clover grass, winter wheat, winter wheat, winter wheat;
  The original fertilizer N is multiplied twice by N fixation in the clover grass;
  The end use is food in the form of cattle dairy and from the wheat itself;
- Unfertilized clover grass for green manure followed by cereal fodder crops:
  Crop rotation: clover grass, winter wheat, winter wheat, spring barley, winter barley;
  The N for the cereal crops is created by N fixation in the clover grass;
  The end use as food is cattle dairy;

All calculations are performed for both Danish conditions and for corresponding conditions based upon the world average N uptake efficiency, <NUE/e> = 0.4 or 40%.

And the calculations are performed both with and without use of straw whenever relevant.

The values are as follows when the straw is used:

Agricultural use and crop rotation, Danish values, straw used, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	1.31 - 2.58	2.97 - 10.18	1.69 - 3.57 (2.53 - 4.55)
N fertilizer for winter wheat for food	1.74	1.74	1.30 (1.94)
N fertilizer for winter wheat for fuel	1.74	1.74	1.30 (1.94)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.86	4.91 - 4.93	2113 - 2371 (3120 - 3509)
N fertilizer for clover grass for fodder followed by wheat for food	1.86	2.75 - 2.78	395 - 404 (603 - 619)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.36	9.05 - 11.81	97 - 111 (151 - 183)
Paper value ranges	7.5 - 12.5		3 - 5

Agricultural use and crop rotation, <NUE/e> = 0.4, straw used, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	2.83 - 4.07	5.40 - 15.30	1.70 - 2.65 (2.44 - 3.45)
N fertilizer for winter wheat for food	3.14	3.14	1.47 (2.10)
N fertilizer for winter wheat for fuel	3.14	3.14	1.47 (2.10)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.44	5.18	783 - 847 (1184 - 1282)
N fertilizer for clover grass for fodder followed by wheat for food	1.44	3.32 - 3.34	378 - 387 (586 - 601)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.25	14.38 - 18.85	82 - 88 (132 - 151)
Paper value ranges	7.5 - 12.5		3 - 5

The values are as follows when the straw is left in the field:

Agricultural use and crop rotation, Danish values, straw left in field, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	1.99 - 3.51	4.95 - 41.06	2.01 - 4.00 (2.86 - 4.99)
N fertilizer for winter wheat for food	2.36	2.36	1.52 (2.16)
N fertilizer for winter wheat for fuel	2.36	2.36	1.52 (2.16)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.86	6.28 - 6.29	2252 - 2531 (3260 - 3669)
N fertilizer for clover grass for fodder followed by wheat for food	1.86	3.19 - 3.22	419 - 429 (627 - 644)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.36	17.81 - 28.43	106 - 122 (160 - 194)
Paper value ranges	7.5 - 12.5		3 - 5

Agricultural use and crop rotation, <NUE/e> = 0.4, straw left in field, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	3.92 - 5.44	8.63 - 59.85	1.90 - 2.88 (2.63 - 3.68)
N fertilizer for winter wheat for food	4.00	4.00	1.60 (2.24)
N fertilizer for winter wheat for fuel	4.00	4.00	1.60 (2.24)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.44	6.04 - 6.06	816 - 882 (1216 - 1318)
N fertilizer for clover grass for fodder followed by wheat for food	1.44	3.70 - 3.72	393 - 403 (601 - 617)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.25	27.27 - 45.13	87 - 93 (137 - 157)
Paper value ranges	7.5 - 12.5		3 - 5

As it appears, there are significant differences between the two sets of values: using the straw reduces the N_2O emissions, most decisively when the crops are used as fodder.

The following full ranges of values apply:

Agricultural use and crop rotation, Danish values, straw used/left, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	1.31 - 3.51	2.97 - 41.06	1.69 - 4.00 (2.53 - 4.99)
N fertilizer for winter wheat for food	1.74 - 2.36	1.74 - 2.36	1.30 - 1.52 (1.94 - 2.16)
N fertilizer for winter wheat for fuel	1.74 - 2.36	1.74 - 2.36	1.30 - 1.52 (1.94 - 2.16)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.86	4.91 - 6.29	2113 - 2531 (3120 - 3669)
N fertilizer for clover grass for fodder followed by wheat for food	1.86	2.75 - 3.22	395 - 429 (603 - 644)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.36	9.05 - 28.43	97 - 122 (151 - 194)
Paper value ranges	7.5 - 12.5		3 - 5

Agricultural use and crop rotation, <NUE/e> = 0.4, straw used/left, according to the 2006 IPCC Guidelines	N_2O-N/N in first crop, %	N_2O-N/N in food, %	N_2O-N/N total, %
N fertilizer for rapeseed for oil and fodder followed by cereal fodder crops	2.83 - 5.44	5.40 - 59.85	1.70 - 2.88 (2.44 - 3.68)
N fertilizer for winter wheat for food	3.14 - 4.00	3.14 - 4.00	1.47 - 1.60 (2.10 - 2.24)
N fertilizer for winter wheat for fuel	3.14 - 4.00	3.14 - 4.00	1.47 - 1.60 (2.10 - 2.24)
N fertilizer for clover grass for fodder followed by wheat for fodder	1.44	5.18 - 6.06	783 - 882 (1184 - 1318)
N fertilizer for clover grass for fodder followed by wheat for food	1.44	3.32 - 3.72	378 - 403 (586 - 617)
Unfertilized clover gras for green manure followed by cereal fodder crops	0.25	14.38 - 45.13	82 - 93 (132 - 157)
Paper value ranges	7.5 - 12.5		3 - 5

Obviously, identical fodder and food crops have the same N_2O-N to first crop N values, but as it appears, fodder crops have much higher N_2O-N to food N values than have food crops, and the same applies to the total N_2O emissions. This is consistent with the fact that some of the crop N is lost in animal husbandry yielding less food N and that no N is recycled after food crops, and it is reflected in the corresponding differences between the N_2O-N to first crop N values and the N_2O-N to food N values for fodder crops.

And as it appears, the N_2O-N to food N values are lower with the Danish N uptake efficiencies than with the world average, but the total N_2O emissions are higher. This is consistent with the fact that Danish N uptake efficiencies are higher, and that the total N_2O emissions to a great extent reflect the amounts of N that are recycled. Most of the N_2O-N to first crop N values are also lower with the Danish N uptake efficiencies than with the world average, the exception being the values for clover grass owing to the far greater amounts of first year N being recycled under Danish conditions.

It should be noted that the immense differences in N_2O-N to food N values for fodder crops, from about 3% to about 60%, are not only caused by the difference between the Danish N uptake efficiencies and the world average, and by the significance of the straw use.

A great deal of the differences are caused by differences in the fodder to food efficiencies of the different domestic animals and, to a lesser extent, by differences in the N_2O emissions and N efficiencies related to different kinds of manure management; to some extent, animal welfare and limitation of N_2O emissions are contrasting goals.

As it appears, all Danish N_2O-N to first crop N values are less than half the minimum value of the paper range, and all world average N_2O-N to first crop N values are less than three fourths the minimum value of the paper range.

And as it appears, the Danish total N_2O-N emission values for fodder crops in chiefly cereal crop rotations range from about half the minimum value of the paper range to the middle of the paper range, but almost correspond to the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And as it appears, the world average total N_2O-N emission values for fodder crops in chiefly cereal crop rotations are well below the minimum value of the paper range, but partly within the lower end of the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And as it appears, the highest total N_2O emissions for food crops in cereal crop rotations are about half the minimum value of the paper range, about three quarters if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And as it appears, two years of clover grass followed by three years of wheat for dairy cattle yields N_2O-N to first crop N values and N_2O-N to food N values comparable to those of fodder cereal crop rotations, but the range of total N_2O emissions are about 150 - 500 times the maximum value of the paper range, about 240 - 720 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And as it appears, two years of clover grass followed by three years of wheat for food yields N_2O-N to first crop N values and N_2O-N to food N values between the values for fodder cereal crop rotations and for cereals for food, but the range of total N_2O emissions are about 80 times the maximum value of the paper range, about 120 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And as it appears, a single year of unfertilized clover grass used as green manure and followed by fodder cereals yields N_2O-N to first crop N values far below the values for fodder cereal crop rotations, and N_2O-N to food N values comparable to those of fodder cereal crop rotations, but the range of total N_2O emissions are about 15 - 25 times the maximum value of the paper range, about 25 - 40 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included. This shows that significant amounts of total N_2O emissions can be created in sustainable agriculture without the use of any synthetic N fertilizer at all.

In other words: in the world outside the cities, the paper values of e and y are useless to describe the actual N_2O emissions from agriculture in general; and it is evident that high N_2O emissions are caused by animal husbandry, not production of food or fuel.

In contrast, the fact that the total N_2O-N emission values for fodder crops in chiefly cereal crop rotations more or less correspond to the paper range, when an assumed natural background emission of 1 kgN_2O-N/ha is included, show that the 2006 IPCC Guidelines [20] may indeed reflect the generally assumed amounts of N_2O emissions from agriculture.

The same applies to the production of liquid biofuels in particular, as it may seen from the following values calculated according to the 2006 IPCC Guidelines [20] of N_2O-N to first crop N values, Meq/M values, and total N_2O emissions (with values including an assumed natural background emission of 1 kgN_2O-N/ha shown in brackets), calculated with extended versions of Sheets C and D in [1] along with [11]. Referring to section 3.3, it should be noted that all the Meq/M values are based upon lower heating values in [11]; according to [7], a 5% higher effective energy content is reported for PPO which would lead to 5% lower Meq/M values for PPO.

The values and value ranges are calculated for PPO and biodiesel produced from rapeseed, and for bioethanol produced from the cereals wheat, barley, and maize, all crops grown with Danish and world average N uptake efficiencies, with and without use of straw except for maize where the straw is always left in field, and with the following uses of other crop parts, referring to sections 3.3.2 and 3.5.2:

- Fodder: the natural use as part of normal agriculture with animal husbandry;

  Rapeseed cakes produced along with PPO at the farms or at feedstuff companies such as [9] is a natural part of the feedstuffs trade in many countries such as Denmark; the amounts of rapeseed cakes produced along with PPO or biodiesel will never exceed the demand in countries with a significant animal husbandry such as Denmark because rapeseed is only grown as a break crop in crop rotation, chiefly every five years, and they may become an important article in the worldwide feedstuffs trade just like soy meal;

  Distillers grain produced along with bioethanol, in the form of wet distillers grain, WDG, or dry distillers grain with or without solubles, DDGS or DDG, is a natural part of normal agriculture in many countries; the amounts may exceed the demand because it can be produced from crops that are grown several years in a row;
- Green manure: a possible use, especially for distillers grain, if the amounts should exceed the demand for fodder; wet distillers grain may be spread like liquid manure, whereas rapeseed cakes/pellets and dry distillers grain may be spread like dry synthetic N fertilizers;
- Fuel: a possible use, most obvious for rapeseed cakes/pellets;

  Rapeseed cakes/pellets, especially when produced along with PPO, need no further processing, and they can replace wood pellets; small independent plants, such as those described in [10], where PPO is cold pressed in connexion with a stoker stove already exist in Denmark; distillers grain must be dried in order to be used as solid fuel;

  The removal of N from the agricultural circulation and the burning of crop parts with high N content may be questionable, but this use should be judged independently of the production of liquid biofuls; it should also be noted that according to [6], which the paper refers to, DDGS even has a higher Energy Credit as fuel than as fodder;

In the calculations, specific Meq/M values for the replacement of coal by rapeseed cakes/pellets and dried distillers grain have been stated;

- Waste removed and disposed of by biofuel companies outside agriculture: an unlikely option, except in less environmentally concerned parts of the world;

  Dumping crop parts when they may be used as fodder, green manure, or fuel, as industrial waste is not only less responsible but also unfavourable because they constitute possible, mostly valuable, articles and/or fuels for the liquid biofuel production;
- Waste left in field: an unthinkable concept, except in less responsible and less competent agriculture;

  Dumping crop parts in the field when they may be used as fodder, green manure, or fuel, is not only less responsible but also extremely unfavourable because they may constitute mostly valuable articles within agriculture and/or fuels, or green manure; normally, it even requires a certain effort to completely avoid any fertilizing effect as green manure.

Only the very last use, as waste left in field, unthinkable except in less responsible and less competent agriculture, corresponds to the paper simplifications and paper assumptions.

It should be noted that the crop uses here, described by the uses of other crop parts, correspond to some of the normal agricultural crop uses mentioned above, with the following differences: the fodder and green manure uses here are in addition to the production of liquid biofuel, the fuel use here is in addition to liquid biofuel, and the dumping of other crop parts here reduces the use to the crop part that contains no N but forms the basis of the liquid biofuel prodution.

And it should be noted that not only the use of other crop parts as fuel, but also the wasting of other crop parts, remove all the N from the agricultural circulation as do the uses as food and fuel mentioned above.

And it should be noted that according to [6], the use of straw does not necessitate additional N fertilization; on the contrary, it reduces leaching.

And referring to section 3.4, it should be noted that except for bioethanol from maize, the relative yields of liquid biofuels from the crops in question according to [11] are up to 15% lower than the paper values; this means that the values of Meq/M are up to 15% higher than they would have been if they had been based upon the paper values of relative liquid biofuel yields.

The differences in liquid biofuel share of crop in %, as measured in kg/kg, are as follows:

- PPO from rapeseed: 35.5%, no paper value;
- Biodiesel from rapeseed: 38.4%, paper value 45.0%
- Bioethanol from wheat: 28.9%, paper value 31.3%;
- Bioethanol from barley: 27.0%, paper value 31.3%;
- Bioethanol from maize: 31.3%, paper value 31.3%.

It should be noted that the use of Danish fodder to food efficiencies throughout the calculations only effects the N_2O emissions in connexion with fodder crops and fodder use, not the Meq/M values.

PPO from winter rapeseed, straw used/left, Danish values		Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any		First crop PPO	other	Total, %	First crop PPO	other	Total %
Fodder	N_2O-N/N:	0	0.013 - 0.026	1.59 - 3.57	0	0.020 - 0.036	2.01 - 4.00
	Meq/M:	0	—	(2.53 - 4.55)	0	—	(2.86 - 4.99)
Green manure	N_2O-N/N:	0.007 - 0.010	0.006 - 0.003	2.48 - 2.65 (3.60 - 4.04)	0.011 - 0.015	0.009 - 0.005	2.92 - 3.11 (4.04 - 4.51)
	Meq/M:	0.10 - 0.15	—		0.16 - 0.22	—	
Fuel	N_2O-N/N:	0	0.013	1.13	0	0.020	2.92 - 3.11
	Meq/M:	0	0.15	(1.90)	0	0.23	(4.04 - 4.51)
Waste removed	N_2O-N/N:	0.013	0	1.13	0.020	0	1.42
	Meq/M:	0.19	—	(1.90)	0.30	—	(2.19)
Waste left	N_2O-N/N:	0.019	0	1.66	0.027	0	1.95
	Meq/M:	0.28	—	(2.43)	0.40	—	(2.72)
Paper	Meq/M:	(1.00 - 1.70)	0	3 - 5	(1.00 - 1.70)	0	3 - 5

PPO from winter rapeseed, straw used/left, <NUE/e> = 0.4		Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any		First crop PPO	other	Total	First crop PPO	other	Total
Fodder	N_2O-N/N:	0	0.028 - 0.042	1.70 - 2.65	0	0.039 - 0.055	1.90 - 2.88
	Meq/M:	0	—	(2.44 - 3.45)	0	—	(2.63 - 3.68)
Green manure	N_2O-N/N:	0.020 - 0.024	0.008 - 0.005	2.09 - 2.14 (2.95 - 3.12)	0.028 - 0.033	0.011 - 0.006	2.31 - 2.37 (3.17 - 3.36)
	Meq/M:	0.30 - 0.36	—		0.42 - 0.49	—	
Fuel	N_2O-N/N:	0	0.028	1.39	0	0.039	1.57
	Meq/M:	0	0.32	(2.08)	0	0.44	(2.26)
Waste removed	N_2O-N/N:	0.028	0	1.39	0.039	0	1.57
	Meq/M:	0.42	—	(2.08)	0.58	—	(2.26)
Waste left	N_2O-N/N:	0.034	0	1.69	0.047	0	1.87
	Meq/M:	0.51	—	(2.38)	0.70	—	(2.56)
Paper	Meq/M:	(1.00 - 1.70)	0	3 - 5	(1.00 - 1.70)	0	3 - 5

Biodiesel from winter rapeseed, straw used/left, Danish values	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Biodiesel	First crop other	Total	First crop Biodiesel	First crop other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.013 - 0.026 —	1.59 - 3.57 (2.53 - 4.55)	0 0	0.020 - 0.036 —	2.01 - 4.00 (2.86 - 4.99)
Green manure N_2O-N/N: Meq/M:	0.007 - 0.010 0.10 - 0.14	0.006 - 0.003 —	2.48 - 2.65 (3.60 - 4.04)	0.011 - 0.015 0.15 - 0.21	0.009 - 0.005 —	2.92 - 3.11 (4.04 - 4.51)
Fuel N_2O-N/N: Meq/M:	0 0	0.013 0.15	1.13 (1.90)	0 0	0.020 0.23	1.42 (2.19)
Waste removed N_2O-N/N: Meq/M:	0.013 0.18	0 —	1.13 (1.90)	0.020 0.28	0 —	1.42 (2.19)
Waste left N_2O-N/N: Meq/M:	0.019 0.26	0 —	1.66 (2.43)	0.027 0.37	0 —	1.95 (2.72)
Paper Meq/M:	1.00 - 1.70	0	3 - 5	1.00 - 1.70	0	3 - 5

Biodiesel from winter rapeseed, straw used/left, <NUE/e> = 0.4	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Biodiesel	First crop other	Total	First crop Biodiesel	First crop other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.028 - 0.042 —	1.70 - 2.65 (2.44 - 3.45)	0 0	0.039 - 0.055 —	1.90 - 2.88 (2.63 - 3.68)
Green manure N_2O-N/N: Meq/M:	0.020 - 0.024 0.28 - 0.33	0.008 - 0.005 —	2.09 - 2.14 (2.95 - 3.12)	0.028 - 0.033 0.39 - 0.45	0.011 - 0.006 —	2.31 - 2.37 (3.17 - 3.36)
Fuel N_2O-N/N: Meq/M:	0 0	0.028 0.32	1.39 (2.08)	0 0	0.039 0.44	1.57 (2.26)
Waste removed N_2O-N/N: Meq/M:	0.028 0.39	0 —	1.39 (2.08)	0.039 0.54	0 —	1.57 (2.26)
Waste left N_2O-N/N: Meq/M:	0.034 0.47	0 —	1.69 (2.38)	0.047 0.65	0 —	1.87 (2.56)
Paper Meq/M:	1.00 - 1.70	0	3 - 5	1.00 - 1.70	0	3 - 5

Bioethanol from winter wheat, straw used/left, Danish values	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Bioethanol	other	Total	First crop Bioethanol	other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.017 - 0.031 —	1.81 - 3.51 (2.51 - 4.33)	0 0	0.024 - 0.040 —	2.06 - 3.85 (2.76 - 4.68)
Green manure N_2O-N/N: Meq/M:	0.010 - 0.013 0.13 - 0.17	0.008 - 0.004 —	2.52 - 2.66 (3.48 - 3.87)	0.013 - 0.018 0.17 - 0.23	0.011 - 0.006 —	2.87 - 3.05 (3.83 - 4.24)
Fuel N_2O-N/N: Meq/M:	0 0	0.017 0.22	1.30 (1.94)	0 0	0.024 0.28	1.52 (2.16)
Waste removed N_2O-N/N: Meq/M:	0.017 0.22	0 —	1.30 (1.94)	0.024 0.31	0 —	1.52 (2.16)
Waste left N_2O-N/N: Meq/M:	0.024 0.31	0 —	1.78 (2.42)	0.031 0.40	0 —	2.00 (2.64)
Paper Meq/M:	1.30 - 2.10	0	3 - 5	1.30 - 2.10	0	3 - 5

Bioethanol from winter wheat, straw used/left, <NUE/e> = 0.4	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Bioethanol	other	Total	First crop Bioethanol	other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.031 - 0.045 —	1.78 - 2.73 (2.45 - 3.47)	0 0	0.040 - 0.056 —	1.93 - 2.91 (2.60 - 3.65)
Green manure N_2O-N/N: Meq/M:	0.023 - 0.026 0.29 - 0.33	0.009 - 0.005 —	2.16 - 2.21 (2.97 - 3.14)	0.029 - 0.034 0.37 - 0.44	0.011 - 0.006 —	2.34 - 2.40 (3.15 - 3.33)
Fuel N_2O-N/N: Meq/M:	0 0	0.031 0.36	1.47 (2.10)	0 0	0.040 0.46	1.60 (2.24)
Waste removed N_2O-N/N: Meq/M:	0.031 0.40	0 —	1.47 (2.10)	0.040 0.51	0 —	1.60 (2.24)
Waste left N_2O-N/N: Meq/M:	0.038 0.49	0 —	1.77 (2.40)	0.048 0.61	0 —	1.90 (2.54)
Paper Meq/M:	1.30 - 2.10	0	3 - 5	1.30 - 2.10	0	3 - 5

Bioethanol from winter barley, straw used/left, Danish values	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Bioethanol	other	Total	First crop Bioethanol	other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.018 - 0.032 —	1.77 - 3.34 (2.51 - 4.20)	0 0	0.026 - 0.042 —	2.02 - 3.69 (2.76 - 4.54)
Green manure N_2O-N/N: Meq/M:	0.010 - 0.014 0.13 - 0.19	0.008 - 0.005 —	2.43 - 2.57 (3.40 - 3.76)	0.014 - 0.019 0.19 - 0.25	0.011 - 0.007 —	2.78 - 2.94 (3.75 - 4.14)
Fuel N_2O-N/N: Meq/M:	0 0	0.018 0.22	1.30 (1.98)	0 0	0.026 0.31	1.52 (2.20)
Waste removed N_2O-N/N: Meq/M:	0.018 0.24	0 —	1.30 (1.98)	0.026 0.34	0 —	1.52 (2.20)
Waste left N_2O-N/N: Meq/M:	0.025 0.33	0 —	1.74 (2.42)	0.033 0.44	0 —	1.97 (2.65)
Paper Meq/M:	1.10 - 1.90	0	3 - 5	1.10 - 1.90	0	3 - 5

Bioethanol from winter barley, straw used/left, <NUE/e> = 0.4	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field		
Use of other crop part, if any	First crop Bioethanol	other	Total	First crop Bioethanol	other	Total
Fodder N_2O-N/N: Meq/M:	0 0	0.030 - 0.044 —	1.75 - 2.70 (2.47 - 3.49)	0 0	0.040 - 0.056 —	1.92 - 2.90 (2.64 - 3.69)
Green manure N_2O-N/N: Meq/M:	0.022 - 0.025 0.29 - 0.33	0.008 - 0.005 —	2.14 - 2.19 (2.98 - 3.16)	0.029 - 0.033 0.38 - 0.44	0.011 - 0.006 —	2.34 - 2.39 (3.18 - 3.36)
Fuel N_2O-N/N: Meq/M:	0 0	0.030 0.36	1.44	0 0	0.040 0.48	1.59 (2.27)
Waste removed N_2O-N/N: Meq/M:	0.030 0.40	0 —	1.44 (2.12)	0.040 0.53	0 —	1.59 (2.27)
Waste left N_2O-N/N: Meq/M:	0.037 0.49	0 —	1.74 (2.42)	0.047 0.62	0 —	1.89 (2.57)
Paper Meq/M:	1.10 - 1.90	0	3 - 5	1.10 - 1.90	0	3 - 5

Bioethanol from maize cobs, straw used/left, Danish values	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used		Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field	
Use of other crop part, if any	First crop Bioethanolother	Total	First crop Bioethanolother	Total
Fodder N_2O-N/N: Meq/M:			0 0.025 - 0.041 0 —	2.05 - 3.77 (2.82 - 4.67)
Green manure N_2O-N/N: Meq/M:			0.014 - 0.019 0.011 - 0.006 0.14 - 0.19 —	2.83 - 3.00 (3.84 - 4.25)
Fuel N_2O-N/N: Meq/M:			0 0.025 0 0.31	1.53 (2.25)
Waste removed N_2O-N/N: Meq/M:			0.025 0 0.25 —	1.53 (2.25)
Waste left N_2O-N/N: Meq/M:			0.032 0 0.32 —	1.99 (2.71)
Paper Meq/M:			0.90 - 1.50 0	3 - 5

Bioethanol from maize cobs, straw used/left, <NUE/e> = 0.4	Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw used		Values according to the 2006 IPCC Guidelines, crop rotation with cereals, straw left in field	
Use of other crop part, if any	First crop Bioethanolother	Total	First crop Bioethanolother	Total
Fodder N_2O-N/N: Meq/M:			0 0.040 - 0.56 0 —	1.93 - 2.91 (2.68 - 3.73)
Green manure N_2O-N/N: Meq/M:			0.029 - 0.034 0.011 - 0.006 0.29 - 0.34 —	2.35 - 2.40 (3.23 - 3.41)
Fuel N_2O-N/N: Meq/M:			0 0.040 0 0.50	1.60 (2.32)
Waste removed N_2O-N/N: Meq/M:			0.040 0 0.40 —	1.60 (2.32)
Waste left N_2O-N/N: Meq/M:			0.048 0 0.48 —	1.90 (2.62)
Paper Meq/M:			0.90 - 1.50 0	3 - 5

As for the normal agricultural uses of crops, the N_2O-N to first crop N values are obviously lower with the higher Danish N uptake efficiencies than with the world average, and the total N_2O emissions are higher in most cases because greater amounts of N are recycled at the higher Danish N uptake efficiencies.

And, corresponding to the normal agricultural use of chiefly cereal crops as fodder, the total N_2O emissions for crop parts used as fodder range from about half the minimum value of the paper range to the middle of the paper range, but almost correspond to the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that in this case no part of the N_2O emissions should be ascribed to the liquid biofuel so the value of Meq/M is 0.

And, the total N_2O emissions with other crop parts used as green manure range from about two thirds the minimum value of the paper range to the minimum value of the paper range, but more or less correspond to the lower half of the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that in this case only a certain part of the N_2O emissions should be ascribed to the liquid biofuel so the values of Meq/M relative to the N_2O emissions are reduced.

And as for the normal agricultural uses of crops, the total N_2O emissions are significantly lower than the minimum value of the paper range when N is not recirculated.

When the other crop parts are used as fuel or disposed of as waste outside agriculture, the total N_2O emissions are only up to about half the minimum paper value, up to about three fourths if an assumed natural background emission of 1 kgN_2O-N/ha is included.

When the other crop parts are dumped as waste in the field without being used as green manure, the total N_2O emissions are only up to about two thirds the minimum paper value, and slightly below it if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that when the other crop parts are used as fuel, no part of the N_2O emissions should be ascribed to the liquid biofuel so the value of Meq/M is 0. Instead the N_2O emissions should be ascribed to the solid biofuel; the values of Meq/M for other crop parts used as fuel are based upon the replacement of coal.

It should be noted that when the other crop parts are dumped as waste, all the N_2O emissions should be ascribed to the liquid biofuel so in these cases the full values of Meq/M relative to the N_2O emissions apply.

The following summaries of Meq/M values for different combinations of liquid biofuels and crops, calculated according to the 2006 IPCC Guidelines [20], apply to Danish N uptake efficiencies and to the world average, depending on the use of other crop parts.

Values with straw used are shown to the left, and values with straw left in the field are shown to the right. For other crop parts being used as green manure, and thus depending on the use of fodder, each value range is rather limited so only the middle value is stated.

Meq/M values calculated according to the 2006 IPCC Guidelines									
Danish values, Straw used/left in field, Use of other crop part	PPO produced from Rapeseed		Biodiesel produced from Rapeseed		Bioethanol produced from Wheat		Barley		Maize
Fodder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green manure	0.13	0.19	0.12	0.18	0.15	0.20	0.16	0.22	0.17
Waste removed	0.19	0.30	0.18	0.28	0.22	0.31	0.24	0.34	0.25
Waste left in field	0.28	0.40	0.26	0.37	0.31	0.40	0.33	0.44	0.32
Paper values	(1.0 - 1.7)		1.00 - 1.70		1.30 - 2.10		1.10 - 1.90		0.90 - 1.50

Meq/M values calculated according to the 2006 IPCC Guidelines									
<NUE/e> = 0.4, Straw used/left in field, Use of other crop part	PPO produced from Rapeseed		Biodiesel produced from Rapeseed		Bioethanol produced from Wheat		Barley		Maize
Fodder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green manure	0.33	0.46	0.31	0.42	0.31	0.41	0.31	0.41	0.32
Waste removed	0.42	0.58	0.39	0.54	0.40	0.51	0.40	0.53	0.40
Waste left in field	0.51	0.70	0.47	0.65	0.49	0.61	0.49	0.62	0.48
Paper values	(1.0 - 1.7)		1.00 - 1.70		1.30 - 2.10		1.10 - 1.90		0.90 - 1.50

Evidently, the paper value ranges of Meq/M are useless to describe the actual effects of N_2O emissions from the cultivation of biofuel crops for liquid biofuels, in terms of the warming effect of N_2O emissions compared to the cooling effect of CO_2 savings by the actual replacement of fossil fuels, because all Meq/M values are either 0 or far below the minimum values of the paper ranges.

As it appears, the differences in Meq/M values between the different liquid biofuels and biofuel crops are quite limited for each use of other crop parts, and completely unrelated to the corresponding paper value ranges; it should be noted that the Meq/M values for PPO would be 5% lower if based upon the effective energy content reported by PPO drivers, leading to almost the same values as for biodiesel.

This means that under identical conditions, the production of PPO, biodiesel, and bioethanol, result in almost identical N_2O emissions, if any, so the differences in their total environmental impacts, including their total GHG emissions, depends almost entirely upon other aspects such as integration in normal agriculture including use of other crop parts, energy consumption for the actual liquid biofuel production, and the degree of hazard each of them presents to groundwater.

Referring to section 3.5, the production of PPO is, or may easily become, fully integrated in normal agriculture, at feedstuffs companies or at the farms themselves; and rapeseed as the basis for PPO/biodiesel forms a valuable break crop in a chiefly cereal crop rotation, only grown about once every five years, thus limiting the amounts of other crop parts to more or less meet the demand for concentrates with high N content. With the option of growing crops for bioethanol several years in a row, ethanol production may be more or less well integrated in normal agriculture.

And referring to section 3.3, the energy consumption for the actual production of PPO is negligible, as opposed to that for biodiesel and biothanol.

And, referring to section 3.3, only PPO is completely harmless to groundwater.

Evidently, the occurrence of N uptake efficiencies above the world average in some countries such as Denmark implies the occurrence of N uptake efficiencies below the world average in other countries.

The effect of N uptake efficiencies below the world average may be illustrated by the following comparison of N_2O-N to first crop N values, Meq/M values, and total N_2O emissions, between the world average N uptake efficiency <NUE/e> = 0.4 and half the world average, namely NUE/e = 0.2, for bioethanol produced from maize:

Bioethanol from maize cobs, <NUE/e> = 0.4 and NUE/e = 0.2		Values according to the 2006 IPCC Guidelines, crop rotation with cereals, <NUE/e> = 0.4			Values according to the 2006 IPCC Guidelines, crop rotation with cereals, NUE/e = 0.2		
Use of other crop part, if any		First crop Bioethanol	other	Total	First crop Bioethanol	other	Total
Fodder	N_2O-N/N:	0	0.040 - 0.56	1.93 - 2.91	0	0.083 - 0.99	1.83 - 2.27
	Meq/M:	0	—	(2.68 - 3.73)	0	—	(2.56 - 3.04)
Green manure	N_2O-N/N:	0.029 - 0.034	0.011 - 0.006	2.35 - 2.40	0.072 - 0.077	0.012 - 0.007	2.01 - 2.02
	Meq/M:	0.29 - 0.34	—	(3.23 - 3.41)	0.72 - 0.77	—	(2.80 - 2.86)
Fuel	N_2O-N/N:	0	0.040	1.60	0	0.083	1.67
	Meq/M:	0	0.50	(2.32)	0	1.03	(2.38)
Waste removed	N_2O-N/N:	0.040	0	1.60	0.083	0	1.67
	Meq/M:	0.40	—	(2.32)	0.83	—	(2.38)
Waste left in field	N_2O-N/N:	0.048	0	1.90	0.091	0	1.82
	Meq/M:	0.48	—	(2.62)	0.92	—	(2.53)
Paper value	Meq/M:	0.90 - 1.50	0	3 - 5	0.90 - 1.50	0	3 - 5

As it appears, the Meq/M values for the world average N uptake efficiency are about 1.5 to 2.5 times as high as those for Danish N uptake efficiencies; the lower value corresponds more or less to the ratio between the N uptake efficiencies.

And as it appears, the Meq/M values for bioethanol from maize for NUE/e = 0.2 are about 2 to 2.5 times those for <NUE/e> = 0.4; the lower value corresponds more or less to the ratio of N uptake efficiencies which is 2; the corresponding ratio for Meq/M values for distillers grain used as fuel is also 2 times higher.

In other words: it seems that the Meq/M decrease at least proportionally to an increase in the N uptake efficiency.

And it seems that the minimum value of the paper range of Meq/M values can only be reached for bioethanol from maize if the distillers grain is dumped in the field and if the N uptake efficiency is no more than half the world average.

For bioethanol from other cereals and for PPO/biodiesel from rapeseed, the minimum values of the paper range of Meq/M values are higher, so they can probably only be reached if the N uptake efficiency is even lower than half the world average.

This means that the paper values of Meq/M can only be reached in the real world outside the cities if all farmers in the world make sure that all their biofuel crops are grown at N uptake efficiencies lower than half the world average, lower than one third the Danish values, and if they carefully dump the total amounts of other crop parts with all the N content as waste in the fields without any fertilizing effect.

The following approximations may apply to Meq/M values for Danish N uptake efficiencies and for the world average, covering all combinations of the liquid biofuels and biofuel crops in question, consisting of common basic values and possible adjustments depending on the use of straw for rapeseed, wheat, and barley:

<table>
<tr><th colspan="5">Meq/M values calculated according to the 2006 IPCC Guidelines</th></tr>
<tr><td>Use of other crop part</td><td colspan="2">Danish values</td><td colspan="2"><NUE/e> = 0.4</td></tr>
<tr><td>Fodder</td><td>0.00</td><td rowspan="5">Rapeseed: x 0.75 if straw is used, x 1.15 if straw is left in field; Wheat: x 1.25 if straw is left in field; Barley: x 1.40 if straw is left in field.</td><td>0.00</td><td rowspan="5">Rapeseed: x 1.35 if straw is left in field; Wheat and barley: x 1.28 if straw is left in field.</td></tr>
<tr><td>Fuel</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Green manure</td><td>0.16</td><td>0.32</td></tr>
<tr><td>Waste removed</td><td>0.24</td><td>0.40</td></tr>
<tr><td>Waste left in field</td><td>0.32</td><td>0.48</td></tr>
<tr><td>Paper values</td><td colspan="2">0.90 - 2.10</td><td colspan="2">0.90 - 2.10</td></tr>
</table>

The following Meq/M values calculated according to the 2006 IPCC Guidelines [20] for the use of other crop parts as solid biofuel apply to Danish N uptake efficiencies and to the world average, values with straw used shown to the left and values with straw left in the field shown to the right:

Meq/M values for other crop parts calculated according to the 2006 IPCC Guidelines				
Solid biofuel and crop, straw used or left in field	Danish values		<NUE/e> = 0.4	
PPO/biodiesel from rapeseed	0.15	0.23	0.32	0.44
Bioethanol from wheat	0.22	0.28	0.36	0.46
Bioethanol from barley	0.22	0.31	0.36	0.48
Bioethanol from maize		0.31		0.50

As it appears, the use of other crop parts as fuel is least questionable for rapeseed cakes/pellets from rapeseed cultivated at high N uptake efficiencies when the straw is also used.

And as it appears, the use of other crop parts as fuel is most questionable for distillers grain from maize and other cereals without use of straw, especially at low N uptake efficiency.

And as it appears, the Meq/M values for rapeseed cakes/pellets from rapeseed and distillers grain from wheat and barley used as fuel more or less correspond to the values applying to PPO/biodiesel and bioethanol when the rapeseed cakes/pellets and the distillers grain are used as green manure or disposed of as waste outside agriculture.

And as it appears, the Meq/M values for distillers grain from maize used as fuel more or less correspond to the values applying to bioethanol when the distillers grain is dumped as waste in the field.

It should be noted that except for rapeseed cakes/pellets produced along with PPO, the other crop parts have a slightly lower energy share of the crop than have the corresponding liquid biofuels, so in most cases the Meq/M values apply to slightly lower amounts of biofuel.

Evidently, in connexion with the environmental assessment of liquid biofuels, in each and every case the Meq/M values for liquid biofuels should reflect the real conditions in the real world outside the cities.

As mentioned above, some uses of other crop parts are unlikely, or even unthinkable, in connexion with responsible and competent agriculture.

Obviously, a crucial effect of responsible and competent agriculture is the endeavour of obtaining or upholding high N uptake efficiencies.

Therefore, referring to section 3.5, the credible ranges of Meq/M in the real world outside the cities are as follows, based upon the likely uses of other crop parts and based upon the approximate values stated above:

In Denmark where animal husbandry is predominant and where more than 70% of the greatly demanded concentrates with high N content must be imported, the total amount of other crop parts from liquid biofuel production are likely to be used as fodder to reduce the import of concentrates from abroad; a limited amount, especially of rapeseed cakes/pellets, may be used as solid biofuel, in which case it should be judged independently.

For the total amounts of liquid biofuels produced in Denmark, the credible value is therefore Meq/M = 0.

In other countries with responsible and competent agriculture and where animal husbandry forms a significant part of agriculture and/or from where significant amounts of concentrates can be exported, most or all of the total amount of other crop parts from liquid biofuel production are likely to be used or sold as fodder; again, a limited amount, especially of rapeseed cakes/pellets, may be used as solid biofuel, in which case it should be judged independently.

For most or all of the amounts of liquid biofuels produced in such countries, the credible value is therefore Meq/M = 0.

In other countries with responsible and competent agriculture, the other crop parts exceeding the demand for fodder and fuel are likely to be used as green manure.

For liquid biofuels produced in such countries with N uptake efficiencies as in Denmark, the credible values for liquid biofuels therefore range from Meq/M = 0 when produced along with fodder or fuel to Meq/M = 0.12 - 0.20 when produced along with green manure, the range depending upon crop and use of straw.

And for liquid biofuels produced in such countries with world average N uptake efficiencies, the credible values for liquid biofuels therefore range from Meq/M = 0 when produced along with fodder or fuel to Meq/M = 0.32 - 0.40 when produced along with green manure, the range depending upon crop and use of straw.

In countries with less responsible and less competent agriculture, the other crop parts exceeding the demand for fodder and fuel are may be used as green manure, dumped as waste outside agriculture, or to a limited extent even dumped as waste in the field with no fertilizing effect.

For liquid biofuels produced in such countries with N uptake efficiencies as in Denmark, the credible values therefore range from Meq/M = 0 when produced along with fodder or fuel, over Meq/M = 0.12 - 0.20 when produced along with green manure, to Meq/M = 0.24 - 0.30 when produced along with crop parts that are disposed of outside agriculture, or to a limited extent even to Meq/M = 0.32 - 0.40 when produced along with crop parts that are dumped in the field without any fertilizing effect as green manure, the ranges depending upon crop and use of straw.

And for liquid biofuels produced in such countries with world average N uptake efficiencies, the credible values therefore range from Meq/M = 0 when produced along with fodder or fuel, over Meq/M = 0.32 - 0.40 when produced along with green manure, to Meq/M = 0.40 - 0.50 when produced along with crop parts that are disposed of outside agriculture, or to a limited extent even to Meq/M = 0.48 - 0.60 when produced along with crop parts dumped in the field without any fertilizing effect as green manure, the ranges depending upon crop and use of straw.

Referring to sections 3.1 and 3.5, it should be remembered that the production of PPO from Jatropha and similar plants in a number of countries generally results in the actual creation of fertilizer N.

The credible value for PPO produced from such plants is therefore Meq/M < 0.

It should also be remembered that rapeseed in general and the production of PPO in particular are fully, or most easily, integrated in normal agriculture with the use of rapeseed cakes as fodder, and that the possible use of rapeseed cakes/pellets as fuel does not necessitate any further processing such as drying.

It should also be remembered that the use of other crop parts as fuel should be judged separately by including the N_2O emissions in the form of Meq/M values in the calculation of their own total GHG effects; this would ensure a full calculation of GHG effects from plants using other crop parts as fuel, including prodution plants for liquid biofuels, and it would also ensure a full calculation of GHG effects from combined plants using both liquid biofuels and other crop parts as fuels; obviously, the latter case corresponds to lower Meq/M values for the entire amount of fuels.

Evidently, for each possible use of other crop parts, the environmental impacts in the form of N_2O emissions and Meq/M values decrease with increasing N uptake efficiencies which are generally obtained by more responsible and competent agriculture.

And the likelihood of the more inferior uses of other crop parts decreases with more responsible and competent agriculture

The combined effect is that there may be immense differences in the environmental impacts in the form of N_2O emissions and Meq/M values for liquid biofuel production, especially between environmentally concerned parts of the world with responsible and competent agriculture at high N uptake efficiencies and environmentally less concerned parts of the world with less responsible and less competent agriculture at low N uptake efficiencies.

However, even with such immense differences, the paper value ranges of Meq/M are completely useless to describe the impacts of liquid biofuel production in the real world outside the cities:

As it appears, liquid biofuels produced as a natural part of responsible and competent agriculture have the Meq/M value 0, according to the fundamental and sound paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions.

And as it appears, the Meq/M values for liquid biofuels are far below the minimum values of the paper ranges, even in less responsible and competent agriculture at world average N uptake efficiencies and with the most wasteful and unfavourable use of other biofuel crop parts.

And as it appears, the biofuel crops must be grown at N uptake efficiencies below half the world average, below one third of the Danish values, with the most wasteful and unfavourable use other crop parts, namely simply dumping them in the field without using their N content as green manure, in order to reach as high Meq/M values for liquid biofuels as the paper ranges.

With the immense differences in possible N_2O emissions and Meq/M values for liquid biofuels, it is evident that the greatest possible effort must made to promote the production of liquid biofuels without or with only small amounts of N_2O emissions and to prevent production with greater, unnecessary N_2O emissions.

If such an effort is made, the production of liquid biofuels under close environmental supervision may actually help reducing N_2O emissions and other environmental impacts of agriculture as a whole.

In this connexion, it should be noted that the highest total N_2O emissions and the highest N_2O-N to end use N values occur in connexion with the use of crops/crop parts as fodder in animal husbandry, regardless of the production of liquid biofuels.

This means that in the world outside the cities, significantly higher amounts of N_2O emissions from agriculture are foreseeable, not caused by a reasonable amount of liquid biofuels, but first and foremost caused by a large scale conversion from food crops to fodder crops to meet the increasing demand for meat and dairy wares, obviously along with the population growth, unless the N_2O-N to food N values are reduced considerably by more responsible and competent agriculture on a worldwide scale, including higher world average N uptake efficiencies by the crops along with high fodder to food efficiencies of domestic animals and avoidance of any unnecessary waste of N in all its forms.

In this connexion, a reasonable amount of liquid biofuels, produced in an environmentally responsible way, especially along with concentrates meeting the growing demand, may actually form part of the basis of such improvements, by increasing the attention to environmental effects and extending it to include agriculture as a whole.

3.7.3. CONSEQUENCES AND CONCLUSIONS:

Based upon the paper values of N content in biofuel crops r_N, the paper values of C content in liquid biofuels r_C, the general paper value of N uptake efficiency e = 0.4, and the general paper range of ratios between N_2O-N emissions and amount of original fertilizer N y = 0.03 - 0.05, or 3 - 5%, all of which have been disproved in the previous sections, the paper presents the following paper ranges Meq/M, expressing the ratio of the warming effect Meq of N_2O emissions resulting from liquid biofuel production to the cooling effect M obtained by replacing the corresponding fossil fuels, only considering the CO_2 emission from the actual use of the fuels:

Liquid biofuel	Biodiesel	Bioethanol			
Crop	Rapeseed	Wheat	Barley/oat	Maize	Sugar cane
Paper value of Meq/M	1.0 - 1.7	1.3 - 2.1	1.1 - 1.9	0.9 - 1.5	0.5 - 0.9

Together, the values e = 0.4 and y = 3 - 5% imply a paper range of ratios of N_2O-N to first crop N values of y/e = 7.5 - 12.5% for all biofuel crops grown everywhere in the world, along with total N_2O-N emissions to original synthetic fertilizer N values of y = 3 - 5% for all biofuel crops grown everywhere in the world.

However, calculations of these ratios according to the 2006 IPCC Guidelines, based upon real values in normal agriculture in the real world outside the cities, using Danish N uptake efficiencies and the world average, demonstrate the following:

The Danish N_2O-N to first crop N values are less than half the minimum value of the paper range, and all world average N_2O-N to first crop N values are less than three fourths the minimum value of the paper range.

And the Danish total N_2O-N emission values for fodder crops in chiefly cereal crop rotations range from about half the minimum value of the paper range to the middle of the paper range, but almost correspond to the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And the world average total N_2O-N emission values for fodder crops in chiefly cereal crop rotations are well below the minimum value of the paper range, but partly within the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

And the range of total N_2O emissions for food crops in cereal crop rotations are about half the minimum value of the paper range, about three quarters if an assumed natural background emission of 1 kgN_2O-N/ha is included.

In comparison, two years of clover grass followed by three years of wheat for dairy cattle yields N_2O-N to first crop N values and N_2O-N to food N values comparable to those of fodder crop rotations based upon cereals, but the range of total N_2O emissions are about 150 - 500 times the maximum value of the paper range, about 240 - 720 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included. And two years of clover grass followed by three years of wheat for food yields N_2O-N to first crop N values and N_2O-N to food N values between those of fodder crops rotations and food crops chiefly based upon cereals, but the range of total N_2O emissions are about 80 times the maximum value of the paper range, about 120 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included. And a single year of unfertilized clover grass used as green manure and followed by cereal fodder crops yields N_2O-N to first crop N values far below those of fodder crop rotations based upon cereals, and N_2O-N to food N values comparable to those of fodder crop rotations based upon cereals, but the range of total N_2O emissions are about 15 - 25 times the maximum value of the paper range, about 25 - 40 times the maximum value if an assumed natural background emission of 1 kgN_2O-N/ha is included.

This shows that significant amounts of total N_2O emissions can be created in sustainable agriculture with or without the use of any synthetic N fertilizer.

It should be noted that the immense differences in N_2O-N to food N values for fodder crops demonstrated by the calculations, from about 3% to about 60%, are not only caused by the obvious differences between Danish values and values based upon the world average N uptake efficiency, and by the significance of the use of straw.

A great deal of the difference is caused by differences in the fodder to food efficiencies of the different domestic animals and, to a lesser extent, by differences in the N_2O emissions and N efficiencies related to different kinds of manure management

To a certain extent, animal welfare and limitation of N_2O emissions are contrasting goals.

As it appears, all N_2O-N to first crop N values and all total N_2O-N emissions to original synthetic fertilizer N values in chiefly cereal crop rotations are well below the paper ranges in normal agriculture.

However, when an assumed natural background emission of 1 kgN_2O-N/ha, expressly mentioned in the paper itself although only once, is included, the total N_2O emissions in connexion with fodder crops in chiefly cereal crop rotation may correspond more or less to the paper range.

And in connexion with multiplication of fertilizer N by N fixation, the total N_2O emissions may amount to many times the paper range. And the same applies to the total N_2O emissions resulting from N created entirely by N fixation, without synthetic fertilizer.

In other words: in the world outside the cities, the paper values of e and y are useless to describe the real N_2O emissions from agriculture in general; and it is evident that high N_2O emissions are caused by animal husbandry, not production of food or fuel.

In contrast, the fact that the total N_2O-N emission values for fodder crops in chiefly cereal crop rotations more or less correspond to the paper range, when the assumed natural background emission of 1 kgN_2O-N/ha mentioned in the paper itself is included, shows that the 2006 IPCC Guidelines may indeed reflect the generally assumed amounts of N_2O emissions from agriculture as a whole.

The same applies to the production of liquid biofuels from biofuel crops in particular.

This is demonstrated by comprehensive calculations according to the 2006 IPCC Guidelines, leading to N_2O-N to first crop N values, Meq/M values, and total N_2O emissions, all based upon real values in normal agriculture in the real world outside the cities, using both Danish N uptake efficiencies and the world average.

The values and value ranges are calculated for PPO and biodiesel produced from rapeseed, and for bioethanol produced from the cereals wheat, barley, and maize, all crops grown with Danish and world average N uptake efficiencies, with and without use of straw except for maize where the straw is always left in field, and with a number of different more or less likely uses of the other crop parts in the form of rapeseed cakes/pellets and distillers grain.

The more likely uses of other crop parts include the natural use as fodder, the possible use as green manure, especially relevant for distillers grain, if the amounts should exceed the demand for fodder, and the possible use as fuel, especially relevant for rapeseed cakes/pellets.

The less likely uses of other crop parts, at least in environmentally concerned parts of the world with responsible and competent agriculture, include waste removed and disposed of by biofuel companies outside agriculture and the least responsible and also extremely unfavourable: the dumping of other crop parts in the field without their having any fertilizing effect.

It should be noted that only the very last use, as waste left in field, unthinkable except in less responsible and less competent agriculture, corresponds to the paper simplifications and paper assumptions.

It should also be noted that the calculation of Meq/M values are based upon lower relative yields of liquid biofuels than those presented in the paper, and that the 5% higher effective energy in PPO reported by PPO drivers is disregarded, thus yielding higher Meq/M values than would otherwise result from the calculations.

It should also be noted that the crop uses in connexion with the production of liquid biofuels, described by the uses of other crop parts, correspond to some of the normal agricultural crop uses. And not only their use as fuel, but also as waste, remove all the N from the agricultural circulation as does the use as food.

And it should also be noted that the use of straw does not necessitate additional N fertilization; on the contrary, it reduces leaching.

The comprehensive calculations according to the 2006 IPCC Guidelines show that, as for the normal agricultural uses of crops, the N_2O-N to first crop N values are obviously lower with the higher Danish N uptake efficiencies than with the world average, and the total N_2O emissions are higher in most cases because greater amounts of N are recycled at the higher Danish N uptake efficiencies.

And the total N_2O emissions with other crop parts used as fodder range from about half the minimum value of the paper range to the middle of the paper range, but almost correspond to the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that in this case no part of the N_2O emissions should be ascribed to the liquid biofuel so the value of Meq/M is 0.

And, the total N_2O emissions with other crop parts used as green manure range from about two thirds the minimum value of the paper range to the minimum value of the paper range, but more or less correspond to the lower half of the paper range if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that in this case only a certain part of the N_2O emissions should be ascribed to the liquid biofuel so the values of Meq/M relative to the N_2O emissions are reduced.

And as for the normal agricultural uses of crops, the total N_2O emissions are significantly lower than the minimum value of the paper range when N is not recirculated.

When the other crop parts are used as fuel or disposed of as waste outside agriculture, the total N_2O emissions are only up to about half the minimum paper value, up to about three fourths if an assumed natural background emission of 1 kgN_2O-N/ha is included.

When the other crop parts are dumped as waste in the field without being used as green manure, the total N_2O emissions are only up to about two thirds the minimum paper value, and slightly below it if an assumed natural background emission of 1 kgN_2O-N/ha is included.

It should be noted that when the other crop parts are used as fuel, no part of the N_2O emissions should be ascribed to the liquid biofuel so the value of Meq/M is 0. Instead the N_2O emissions should be ascribed to the solid biofuel; the values of Meq/M for other crop parts used as fuel should be based upon the replacement of coal.

It should be noted that when the other crop parts are dumped as waste, all the N_2O emissions should be ascribed to the liquid biofuel so in these cases the full values of Meq/M relative to the N_2O emissions apply.

The following summaries of Meq/M values for different combinations of liquid biofuels and crops, calculated according to the 2006 IPCC Guidelines, apply to Danish N uptake efficiencies and to the world average, depending on the use of other crop parts.

Values with straw used are shown to the left, and values with straw left in the field are shown to the right; for other crop parts being used as green manure, and thus depending on the use of fodder, each value range is rather limited so only the middle value is stated.

Meq/M values calculated according to the 2006 IPCC Guidelines					
Danish values, Straw used or left in field, Use of other crop part	PPO (produced from Rapeseed)	Biodiesel (produced from Rapeseed)	Bioethanol produced from: Wheat	Barley	Maize
Fodder	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0
Fuel	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0
Green manure	0.13 0.19	0.12 0.18	0.15 0.20	0.16 0.22	0.17
Waste removed	0.19 0.30	0.18 0.28	0.22 0.31	0.24 0.34	0.25
Waste left in field	0.28 0.40	0.26 0.37	0.31 0.40	0.33 0.44	0.32
Paper values	(1.0 - 1.7)	1.00 - 1.70	1.30 - 2.10	1.10 - 1.90	0.90 - 1.50

Meq/M values calculated according to the 2006 IPCC Guidelines					
<NUE/e> = 0.4, Straw used or left in field, Use of other crop part	PPO (produced from Rapeseed)	Biodiesel (produced from Rapeseed)	Bioethanol produced from: Wheat	Barley	Maize
Fodder	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0
Fuel	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0
Green manure	0.33 0.46	0.31 0.42	0.31 0.41	0.31 0.41	0.32
Waste removed	0.42 0.58	0.39 0.54	0.40 0.51	0.40 0.53	0.4
Waste left in field	0.51 0.70	0.47 0.65	0.49 0.61	0.49 0.62	0.48
Paper values	(1.0 - 1.7)	1.00 - 1.70	1.30 - 2.10	1.10 - 1.90	0.90 - 1.50

Evidently, the paper value ranges of Meq/M are useless to describe the actual effects of N_2O emissions from the cultivation of biofuel crops for liquid biofuels, in terms of the warming effect of N_2O emissions compared to the cooling effect of CO_2 savings by the actual replacement of fossil fuels, because all Meq/M values are either 0 or far below the minimum values of the paper ranges.

As it appears, for each use of other crop parts, the differences in Meq/M values between the different liquid biofuels and biofuel crops are quite limited and completely unrelated to the corresponding paper value ranges; it should be noted that the Meq/M values for PPO would be 5% lower if based upon the effective energy content reported by PPO drivers, leading to almost the same values as for biodiesel.

This means that under identical conditions, the production of PPO, biodiesel, and bioethanol, result in almost identical N_2O emissions, if any, so the differences in their total environmental impacts, including their total GHG emissions, depends almost entirely upon other aspects such as integration in normal agriculture including use of other crop parts, energy consumption for the actual liquid biofuel production, and the degree of hazard each of them presents to groundwater.

The production of PPO is, or may easily become, fully integrated in normal agriculture, at feedstuffs companies or at the farms themselves; and rapeseed as the basis for PPO/biodiesel forms a valuable break crop in a chiefly cereal crop rotation, only grown about once every five years, thus limiting the amounts of other crop parts to more or less meet the demand for concentrates with high N content. With the option of growing crops for bioethanol several years in a row, ethanol production may be more or less well integrated in normal agriculture.

And the energy consumption for the actual production of PPO is negligible, as opposed to that for biodiesel and biothanol; and rapeseed cakes/pellets may be used as fuel without any further processing.

And only PPO is completely harmless to groundwater.

Evidently, the occurrence of N uptake efficiencies above the world average in some countries such as Denmark implies the occurrence of N uptake efficiencies below the world average in other countries, so comparative calculations for bioethanol produced from maize at the world average N uptake efficiency <NUE/e> = 0.4 and half the value, namely NUE/e = 0.2 have been performed.

According to the calculations, the values of Meq/M seem to decrease at least proportionally to an increase in the N uptake efficiency.

And according to the calculations, the paper values of Meq/M can only be reached in the real world outside the cities if all farmers in the world make sure that all their biofuel crops are grown at N uptake efficiencies lower than half the world average, lower than one third the Danish values, and if they carefully dump the total amounts of other crop parts with all the N content as waste in the fields without any fertilizing effect.

The following approximations may apply to Meq/M values for Danish N uptake efficiencies and for the world average, covering all combinations of the liquid biofuels and biofuel crops in question, consisting of common basic values and possible adjustments depending on the use of straw for rapeseed, wheat, and barley:

<table>
<tr><th colspan="5">Meq/M values calculated according to the 2006 IPCC Guidelines</th></tr>
<tr><td>Use of other crop part</td><td colspan="2">Danish values</td><td colspan="2"><NUE/e> = 0.4</td></tr>
<tr><td>Fodder</td><td>0.00</td><td rowspan="5">Rapeseed: x 0.75 if straw is used, x 1.15 if straw is left in field;
Wheat: x 1.25 if straw is left in field;
Barley: x 1.40 if straw is left in field.</td><td>0.00</td><td rowspan="5">Rapeseed: x 1.35 if straw is left in field;

Wheat and barley: x 1.28 if straw is left in field.</td></tr>
<tr><td>Fuel</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Green manure</td><td>0.16</td><td>0.32</td></tr>
<tr><td>Waste removed</td><td>0.24</td><td>0.40</td></tr>
<tr><td>Waste left in field</td><td>0.32</td><td>0.48</td></tr>
<tr><td>Paper values</td><td colspan="2">0.90 - 2.10</td><td colspan="2">0.90 - 2.10</td></tr>
</table>

The use of other crop parts as fuel, and the resulting removal of N from the agricultural circulation may be questionable, but this use should be judged separately and independently of the liquid biofuels, and their Meq/M values should form part of the calculation of their own total GHG impacts, as is the case with liquid biofuels.

It should also be noted that according to the Well to Tank calculations in one of the sources referred to in the paper, DDGS even has a higher Energy Credit as fuel than as fodder.

Specific Meq/M calculations performed according to the 2006 IPCC Guidelines for the use of other crop parts as fuel, replacing coal by rapeseed cakes/pellets and dried distillers grain, show that this use is least questionable for rapeseed cakes/pellets from rapeseed cultivated at high N uptake efficiencies when the straw is also used, and most questionable for distillers grain from maize and other cereals without use of straw, especially at low N uptake efficiencies.

It should be noted that in most cases the other crop parts have a slightly lower energy share of the crop than have the corresponding liquid biofuels, and therefore the Meq/M values apply to slightly lower amounts of biofuel here.

Evidently, in connexion with the environmental assessment of liquid biofuels, in each and every case the Meq/M values for liquid biofuels should reflect the actual conditions in the real world outside the cities.

As mentioned above, some uses of other crop parts are unlikely, or even unthinkable, in connexion with responsible and competent agriculture.

Obviously, a crucial effect of responsible and competent agriculture is the endeavour of obtaining or upholding high N uptake efficiencies.

Therefore, the credible ranges of Meq/M in the real world outside the cities are as follows, based upon the likely uses of other crop parts and based upon the approximate values stated above:

In Denmark where animal husbandry is predominant and where more than 70% of the greatly demanded concentrates with high N content must be imported, the total amount of other crop parts from liquid biofuel production are likely to be used as fodder to reduce the import of concentrates from abroad; a limited amount, especially of rapeseed cakes/pellets, may be used as solid biofuel, in which case it should be judged independently.

For the total amounts of liquid biofuels produced in Denmark, the credible value is therefore Meq/M = 0.

In other countries with responsible and competent agriculture and where animal husbandry forms a significant part of agriculture and/or from where significant amounts of concentrates can be exported, most or all of the total amount of other crop parts from liquid biofuel production are likely to be used or sold as fodder; again, a limited amount, especially of rapeseed cakes/pellets, may be used as solid biofuel, in which case it should be judged independently.

For most or all of the amounts of liquid biofuels produced in such countries, the credible value is therefore Meq/M = 0.

In other countries with responsible and competent agriculture, the other crop parts exceeding the demand for fodder and fuel are likely to be used as green manure.

For liquid biofuels produced in such countries with N uptake efficiencies as in Denmark, the credible values for liquid biofuels therefore range from Meq/M = 0 when produced along with fodder or fuel to Meq/M = 0.12 - 0.20 when produced along with green manure, the range depending upon crop and use of straw.

And for liquid biofuels produced in such countries with world average N uptake efficiencies, the credible values for liquid biofuels therefore range from Meq/M = 0 when produced along with fodder or fuel to Meq/M = 0.32 - 0.40 when produced along with green manure, the range depending upon crop and use of straw.

In countries with less responsible and less competent agriculture, the other crop parts exceeding the demand for fodder and fuel are may be used as green manure, dumped as waste outside agriculture, or to a limited extent even dumped as waste in the field with no fertilizing effect.

For liquid biofuels produced in such countries with N uptake efficiencies as in Denmark, the credible values therefore range from Meq/M = 0 when produced along with fodder or fuel, over Meq/M = 0.12 - 0.20 when produced along with green manure, to Meq/M = 0.24 - 0.30 when produced along with crop parts that are disposed of outside agriculture, or to a limited extent even to Meq/M = 0.32 - 0.40 when produced along with crop parts that are dumped in the field without any fertilizing effect as green manure, the ranges depending upon crop and use of straw.

And for liquid biofuels produced in such countries with world average N uptake efficiencies, the credible values therefore range from Meq/M = 0 when produced along with fodder or fuel, over Meq/M = 0.32 - 0.40 when produced along with green manure, to Meq/M = 0.40 - 0.50 when produced along with crop parts that are disposed of outside agriculture, or to a limited extent even to Meq/M = 0.48 - 0.60 when produced along with crop parts dumped in the field without any fertilizing effect as green manure, the ranges depending upon crop and use of straw.

It should be remembered that the production of PPO from Jatropha and similar plants in a number of countries generally results in the actual creation of fertilizer N.

The credible value for PPO produced from such plants is therefore Meq/M < 0.

It should also be remembered that rapeseed in general and the production of PPO in particular are fully, or most easily, integrated in normal agriculture with the use of rapeseed cakes as fodder, and that the possible use of rapeseed cakes/pellets as fuel does not necessitate any further processing such as drying.

It should also be remembered that the use of other crop parts as fuel should be judged separately by including the N_2O emissions in the form of Meq/M values in the calculation of their own total GHG effects; this would ensure a full calculation of GHG effects from plants using other crop parts as fuel, including prodution plants for liquid biofuels, and it would also ensure a full calculation of GHG effects from combined plants using both liquid biofuels and other crop parts as fuels; obviously, the latter case corresponds to lower Meq/M values for the entire amount of fuels.

Evidently, for each possible use of other crop parts, the environmental impacts in the form of N_2O emissions and Meq/M values decrease with increasing N uptake efficiencies which are generally obtained by more responsible and competent agriculture.

And the likelihood of the more inferior uses of other crop parts decreases with more responsible and competent agriculture.

The combined effect is that there may be immense differences in the environmental impacts in the form of N_2O emissions and Meq/M values from liquid biofuel production, especially between environmentally concerned parts of the world with responsible and competent agriculture at high N uptake efficiencies and environmentally less concerned parts of the world with less responsible and less competent agriculture at low N uptake efficiencies.

However, even with such immense differences, the paper value ranges of Meq/M are completely useless to describe the impacts of liquid biofuel production in the real world outside the cities:

As it appears, liquid biofuels produced as a natural part of responsible and competent agriculture have the Meq/M value 0 according to the fundamental and sound paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions.

And as it appears, in all cases, the Meq/M values for liquid biofuels are far below the minimum values of the paper ranges, even with the most wasteful and unfavourable use of other crop parts in less responsible and competent agriculture at the world average N uptake efficiency.

And as it appears, in order to reach as high Meq/M values for liquid biofuels as the paper ranges, the biofuel crops must be grown at N uptake efficiencies below half the world average, below one third of the Danish values, with the most wasteful and unfavourable use of other crop parts, namely simply dumping them in the field without using their N content as green manure.

With the immense differences in possible N_2O emissions and Meq/M values for liquid biofuels, it is evident that the greatest possible effort must made to promote the production of liquid biofuels without or with only small amounts of N_2O emissions and to prevent production with greater, unnecessary N_2O emissions.

If such an effort is made, the production of liquid biofuels under close environmental supervision may actually help reducing N_2O emissions and other environmental impacts of agriculture as a whole.

In this connexion, it should be noted that the highest total N_2O emissions and the highest N_2O-N to end use N values occur in connexion with the use of crops/crop parts as fodder in animal husbandry, regardless of the production of liquid biofuels.

This means that in the world outside the cities, significantly higher amounts of N_2O emissions from agriculture are foreseeable, not caused by a reasonable amount of liquid biofuels, but first and foremost caused by a large scale conversion from food crops to fodder crops to meet the increasing demand for meat and dairy wares, obviously along with the population growth, unless the N_2O-N to food N values are reduced considerably by more responsible and competent agriculture on a worldwide scale, including higher world average N uptake efficiencies by the crops along with high fodder to food efficiencies of domestic animals and avoidance of any unnecessary waste of N in all its forms.

In this connexion, a reasonable amount of liquid biofuels, produced in an environmentally responsible way, especially along with concentrates meeting the growing demand, may actually form part of the basis of such improvements, by increasing the attention to environmental effects and extending it to include agriculture as a whole.

Hereby, the great attention to liquid biofuels may be a golden opportunity to obtain decisive and lasting improvements which may lead to significant reductions in the N_2O emissions from agriculture as a whole.

However, instead of bringing about more attention to the total use of crops and to the environmental impacts of each crop part and thereby supporting more responsible and competent management of all crop parts, thus contributing to worldwide reductions of N_2O emissions and other environmental impacts of agriculture in general and of liquid biofuels in particular, the paper value ranges remove attention from the use of other crop parts and thereby actually support less responsible and less competent management of all crop parts, and thus counteracts worldwide reductions of N_2O emissions and other environmental impacts of agriculture in general and of liquid biofuels in particular.

Adding to this effect, the lack of attention to differences in management of other crop parts will prevent pressure on less responsible farmers and/or regions in the world, thus further counteracting improvements in agriculture as a whole and contributing to a development where liquid biofuels are chiefly produced in the less environmentally concerned regions of the world with far greater environmental impacts, including N_2O emissions.

On the other hand, the fundamental and sound paper approach of following the N content in order to calculate the separate contribution of N_2O to the GHG emissions could form part of a universal contents approach to a complete determination of the total environmental effects in the real world, including GHG emissions such as N_2O and CO_2, based upon the actual uses of the contents and the extent that each use of each parts constitutes a genuine replacement of something otherwise needed.

In connexion with liquid biofuels, the universal contents approach can be used to follow the protein/N content and the energy content separately in order to ascribe the correct amounts of N_2O and CO_2 emissions to the different parts of the biofuel crops, using the Meq/M value as a common unit, ultimately leading to a total Meq/M value covering all N_2O and CO_2 emissions.

Using the universal contents approach to follow the protein/N content in order to correctly ascribe the N_2O emissions related to the biofuel crop cultivation confirms the derivation of values of Meq/M for liquid biofuels stated above:

In connexion with the use of the other crop part as a fodder in its own right, where its protein/N content replaces at least the same amount of protein/N in other fodders, its use constitutes a genuine full replacement of other fodders which would otherwise be needed and which would cause at least the same N_2O emissions; therefore the total amount of N_2O emissions is ascribed to the other crop part, and no N_2O emissions are ascribed to the liquid biofuel, leading to the value Meq/M = 0 for the liquid biofuel.

And in connexion with the use of the other crop part as a solid biofuel in its own right, where its total content, including its N content, replaces a certain amount of coal, its use constitutes a genuine full replacement of fossil fuels otherwise needed; therefore the total amount of N_2O emissions is ascribed to the other crop part, and no N_2O emissions are ascribed to the liquid biofuel, leading to the value Meq/M = 0 for the liquid biofuel; in this case the other crop part has its own full value of Meq/M.

And in connexion with the use of the other crop part as green manure, where its N content replaces a smaller amount of other fertilizers such as synthetic N fertilizers, its use constitutes a genuine but only partial replacement of other fertilizers which would otherwise be needed and which would therefore cause smaller amounts of N_2O emissions; therefore the corresponding share of the N_2O emissions are ascribed to the other crop part, and the remaining N_2O emissions are ascribed to the liquid biofuel, leading to a corresponding reduced value of Meq/M for the liquid biofuel.

And in connexion with no use of the other crop part which is simply dumped as waste, where its total content, including its N content, replaces nothing else, its use does not constitute a genuine replacement of anything which would otherwise be needed; therefore the total amount of N_2O emissions is ascribed to the liquid biofuel, leading to a corresponding full value of Meq/M for the liquid biofuel.

Using the universal contents approach, the energy content can be followed in a similar way in order to correctly ascribe the contribution fra CO_2 emissions related to the cultivation of the biofuel crops, leading to the value of Meq/M for the liquid biofuel, to be added to the other values from the CO_2 emissions related to the subsequent steps leading to the final use, such as the actual production, possible further processing, handling, and transport, if any:

In connexion with the use of the other crop part as a fodder in its own right, where its energy content replaces the same amount of energy in other fodders, its use constitutes a genuine full replacement of other fodders which would otherwise be needed and which would cause corresponding CO_2 emissions; therefore the total amount of CO_2 emissions related to the cultivation of the crop should be divided between the liquid biofuel and the other crop part in the same proportions as their shares of the total energy content in the crop, leading to the corresponding contribution from the cultivation of the crop to the value of Meq/M for the liquid biofuel.

And similarly, in connexion with the use of the other crop part as a solid biofuel in its own right, where its energy content replaces the same amount of energy in coal, its use constitutes a genuine full replacement of a fossil fuel which would otherwise be needed and which would cause specific amounts of CO_2 emissions; therefore the total amount of CO_2 emissions related to the cultivation of the crop should be divided between the liquid biofuel and the other crop part in the same proportions as their shares of the total energy content in the crop, leading to the corresponding contributions from the cultivation of the biofuel crop to the value of

Meq/M for the liquid biofuel, and to the value of Meq/M for the other crop part; obviously, the corresponding total Meq/M value should be based upon the total CO_2 emissions related to the corresponding amount of energy contained in petrol or diesel for the liquid biofuel, and the corresponding total Meq/M value should be based upon the total CO_2 emissions related to the corresponding amount of energy contained in coal for the other crop part.

And similarly, in connexion with the use of the other crop part as green manure, where its N content replaces a smaller amount of other fertilizers such as synthetic N fertilizers, its use constitutes a genuine but only partial replacement of other fertilizers which would otherwise be needed and which would therefore cause smaller amounts of CO_2 emissions; therefore the said amounts of CO_2 emissions are ascribed to the other crop part, and the remaining part of the total amount of CO_2 emissions related to the cultivation of the biofuel crop is ascribed to the liquid biofuel, leading to a corresponding reduced value of Meq/M for the liquid biofuel.

And similarly, in connexion with no use of the other crop part which is simply dumped as waste, where its total energy content replaces nothing else, its use does not constitute a genuine of anything which would otherwise be needed; therefore the total amounts of CO_2 emissions related to the cultivation of the biofuel crop are ascribed to the liquid biofuel, leading to the corresponding full value of Meq/M for the liquid biofuel.

As it appears, in each case the contributions from the N_2O and CO_2 emissions put together constitute the total Meq/M value related to the crop cultivation and ascribable to the liquid biofuel, to be combined with the other Meq/M values from the CO_2 emissions related to the subsequent steps leading to the final use, and to be compared with the corresponding total Meq/M values related to the corresponding fossil fuel.

And as it appears, the same applies to the other crop part used as a solid biofuel.

And, in each case the contributions from the N_2O and CO_2 emissions related to both crop parts put together constitute the total N_2O and CO_2 emissions related to the entire biofuel crop.

With this, all the paper values and the paper conclusions have been disproved, and this disproof may form the basis of a universal contents approach to a complete determination of the total environmental effects of liquid biofuels and other biofuels, including GHG emissions such as N_2O and CO_2, in the real world outside the cities.

3.7.4. SOURCES:

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4. RECOMMENDATIONS AND SUGGESTIONS:

It is recommended to use a universal contents approach to a complete determination of the total environmental effects of liquid biofuels and other biofuels, including GHG emissions such as N_2O and CO_2, as described in section 3.7 in this disproof.

It is suggested that all ascriptions of N_2O emissions to liquid biofuels are performed on the basis of this disproof and the underlying sources, especially [1] and [11], possibly in further developed versions.

Further, it is recommended to promote liquid biofuels with the smallest possible GHG emissions and other environmental impacts, including production without or with only little N_2O emissions, and to counteract greater and thus unnecessary GHG emissions, rather than laying down minimum requirements as suggested in [5].

It is suggested that all production of liquid biofuels is kept under close environmental supervision and that every possible means, including subsidies, tax reduction/exemption, and possibly prohibitions, based upon an GHG/environmental rating of liquid biofuels, is used to encourage the use of the best solutions and to discourage the use of the poorest; a few suggestions to this effect are included in the consultation responses in [30].

Further, in each and every assessment of the environmental impacts of any kind of biofuels, such as energy/GHG balances, life cycle analyses, and economic comparisons such as shadow prices of greenhouse gas savings, it is recommended to include experts within agriculture and biofuels, and especially within the crops and biofuels in question.

It is suggested that all assessments performed without the inclusion of such experts are reconsidered; the consultation responses in [30] and [31] reveal some of the possible errors and oversights.

Further, it is recommended to flexibly adapt the production of all biofuels to the need for fodder and food, to strengthen the integration in normal agriculture as well as rural selfsufficiency and at the same time avoid its causing actual food shortage and overpricing, which are most likely to occur with fixed amounts of biofuels.

It is suggested that a full integration of liquid biofuel production in normal agriculture is encouraged, preferably adapted to the need for concentrates and other appropriate uses of other crop parts, and that the production of liquid biofuels as a separate branch of agriculture is discouraged.

Further, it is recommended to seize the golden opportunity created by the current great attention to liquid biofuels to obtain decisive and lasting improvements leading to significant reductions in the N_2O emissions from agriculture as a whole.

It is suggested that every possible effort is made to disseminate the knowledge and insight gained in connexion with the cultivation of crops for liquid biofuels as widely as possible to help reducing N_2O emissions and other environmental impacts.

Further, it is recommended to make every possible effort to improve the N uptake efficiencies by all crops in agriculture throughout the world.

It is suggested that invaluable knowledge and experience, obtained in responsible and competent agriculture, and in agricultural research, in countries with high N uptake efficiencies such as Denmark, are disseminated to all countries in the world; [1] may contribute to this.

Further, it is recommended to make the greatest possible effort to ensure sound and diverse agriculture.

It is suggested that sustainable farming, including organic farming, at reasonable farm sizes with sound crop rotations, without GMO and/or unnecessary amounts of synthetic fertilizers, pesticides, and artificial growth regulation means, is promoted to preserve and improve soil fertility and nutrient content, preferably with the addition of specific measures to uphold smaller farms and diversified crop cultivation and animal husbandry; this forms part of the basis for NGOs such as [32] and independent farmer associations such as [33].

Further, it is recommended to make an additional effort to ensure sound, ripe, and truly fresh, food.

It is suggested that specific measures are taken to abolish artificial ripening, prolonged keeping, and overprocessing, resulting in even poorer nutrient contents.

Further, it is recommended to ensure that the farmers obtain the real price for real food and that the rural areas with their population, diversity of crops and domestic animals, and diversity of nature, including wildlife, are kept alive.

It is suggested that every possible effort is made to replace the current circulation of poverty involving low food prices, poverty, and depopulation, in the rural areas and poverty and overpopulation in the cities, with a circulation of prosperity involving real food prices, prosperity, and new life in the rural areas and prosperity and new opportunities in the cities, and to counteract unjust and harmful trade conditions, shameless trade profits, and subsidies to lower prices, the last named possibly being replaced by subsidies to uphold diversity of plants and animals and undisturbed nature; this also forms part of the basis for NGOs such as [32] and independent farmer associations such as [33].

Further, it is recommended to continuously publish and disseminate disproofs of fallacies concerning biofuels that are based upon unfounded claims, such as the ACP paper and exaggerated reports about the influence on food prices/supply, and to maintain that any judgment of biofuels, with their prospects and limitations, should be based upon real conditions; obviously, this also applies to matters of genuine concern.

It is suggested that information about all available knowledge is made generally known and explained in an easily accessible manner in order to improve the general understanding and insight concerning biofuels, including liquid biofuels produced from biofuel crops as one of the means to reduce GHG emissions, now and possibly far into the future, and concerning the real reasons for food shortage and related issues and the obvious limitations to the role in this played by biofuels; important contributions to such information may is found in [34].

Further, it is recommended to make the greatest possible effort to promote a complete replacement of fossil fuels by liquid biofuels and other sustainable propellants, and at the same time enable a flexible adaptation of the production of liquid biofuels.

It is suggested that the grey solutions of mixing fuels in fixed proportions, and of adapting the fuels to the engines are replaced by the green solution of adapting the engines to the fuels, with engine conversion subsidies and with the requirement that the design of all new engines must enable their running entirely on any of the corresponding liquid biofuels or other sustainable propellants, as mentioned in the consultation responses in [30].

Further, it is recommended to make the greatest possible effort to reduce the consumption of fuels, including liquid fuels, whether sustainable or fossil, as part of a common responsible approach where environmental considerations take precedence over trade conditions.

It is suggested that the current unrestrained increase in the consumption of fuels, especially of liquid fuels, including the consumption related to all kinds of traffic, on land, at sea, and in the air, is counteracted in every possible way, including limitation of traffic in itself; the consequences of failing to meet the present challenge are described in [35].

Further, it is recommended to continuously scrutinize the assessment of N_2O emissions from all other anthropogenic sources, including industrial sources, in order to reduce the uncertainty of the actual N_2O emissions from agriculture and to ensure that the efforts are directed at the real N_2O emissions in the real world, inside or outside the cities, thus hopefully preventing or reducing false ascription of N_2O emissions to agriculture.

It is suggested that all such assessments are reconsidered, including the effects of instant measurement of N_2O emissions from fossil combustion, including vehicles, introduced after the discovery of the Artifact reported in [36] in 1988, resulting in an immense downsizing of the N_2O emissions ascribed to fossil combustion, by about 3 TG N_2O-N, corresponding to about 50% of the N_2O emissions generally ascribed to agriculture, as it appears from [37], [38], and [25]; if the Artifact, in the form of subsequent formation of N_2O from the mixture of combustion gases in sampling containers, actually reflects what happens or may happen, especially in moist/heavily polluted air which may to some extent correspond to the conditions in the sampling containers, this may comprise an undetected, possibly considerable, anthropogenic N_2O emission, ascribable to fossil fuel combustion, maybe especially vehicles, along with other recently, or still not, detected anthropogenic N_2O emissions such as the formation of N_2O from N_2 and O_3 during thunderstorms and near powerlines described in [39].

Such scrutinizing might be more useful than just rounding up the usual suspects in City Thinking: the farmers.

Finally, it is recommended to lift the curse of City Thinking by continuously revealing its shortcomings and openly discuss the real conditions, prospects, and issues, related to responsible and competent agriculture.

It is suggested that all parties involved, including farmers and their associations and related experts, consumers and their associations, and everyone caring about issues such as environment, welfare/animal welfare, and healthy food, make a genuine joint effort.

These last words were written far from the cities at a very special time in 2008:

– *The cherry flowers seemed to float in the air; soon they would sink into the grass, and vanish.*

The Land, All The Way, page 494

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