Author Details	
Name	**Dr Andrew Boswell**
Position	**Scientist and Consultant**
A66 Northern Trans-Pennine Project Link Roads Registration	**20032289**
Organisation	**Climate Emergency Policy and Planning (CEPP)**
Examination Principle Issues	**Climate Change**

DEADLINE D4 SUBMISSION
SUMMARY

The key principle area of difference between Climate Emergency Planning and Policy (CEPP), and the Applicant, is the zero rating of the biomass combustion GHG emissions from the scheme **<u>in the Environmental Impact Assessment</u>**.

The IPCC guidance cannot be applied under the Planning Act 2008 regime. It is not within the required statutory framework, and is not in any case a statutory document for any jurisdiction.

Under the IPCC guidance, CO2 from biomass combustion is treated as part of the AFOLU[1] carbon stock for a country, for national greenhouse gas inventory purposes. That does not mean that there is not a real quantity of GHG emissions that is generated into the atmosphere when biomass is combusted. Carbon payback issues mean that these emissions not sequestered "instantly" (as the Applicant's approach suggests) but over centuries timescales by forest regrowth.

For Environmental Impact Assessment, biomass combustion emissions are a <u>direct effect</u> generated by the development itself. Under the 2017 regulations, as a direct effect, they should be calculated and assessed as part of the GHG assessment. The relevance of the Finch case on the scope of EIA assessment is stronger given this is a direct effect (not an upstream or downstream effect).

I provide such a calculation finding that the power plant with the proposed scheme will emit an additional 331,983,143 tCO2e over 25 years (at 90% CCS rate). As the power plant is only financially viable with the proposed scheme much of these emissions would not occur without the scheme being implemented. These emissions are approximately 1/1000th of the entire remaining global carbon from 2020 for a 50% likelihood of limiting global heating to 1.5°C, the Paris temperature target.

The Secretary of State must consider the information in this submission, including these additional emissions from the scheme, as part of his/her process in reaching a reasoned conclusion on the significant effects of the development on the environment under the 2017 regulations.

I have provided new material to the examination on the emissions in a science-based presentation. This must form part of the material before the Secretary of State in any reasoned decision making on the proposed scheme.

[1] Agriculture, Forestry and Other Land Use

The Applicant should reply to the full submission, not this summary.

Contents

1 INTRODUCTION

1 This submission responds to:

- REP3-020 “Applicant’s responses to issues raised at Deadline 2” which responded to my Deadline 2 written representation at section 11;
- REP{1}-028 “Summary of oral case at issue specific hearing 1 and open floor hearing 1” and Appendix 1 “Summary of the GHG assessment process for the scheme.

2 Please note:

(1) The applicant has responded very superficially to my written submission. In REP3-020, they only responded to paragraphs 1 to 4 of my Summary. The applicant has not responded at all to my main Written Representation. The applicant has misunderstood the matters being raised as they have not considered the detail. So the matters are re-presented, with some further analysis, in this document.

(2) I waited until I received the Applicant’s response to my written representation before responding to REP-028 so I could respond in consideration of both documents.

2 ZERO-RATING OF BIOMASS COMBUSTION

3 A key principle area of difference between Climate Emergency Planning and Policy (CEPP), and the Applicant, is the zero rating of the biomass combustion emissions from the scheme **in the Environmental Impact Assessment**.

2.1 Can the IPCC guidance be applied under the Planning Act 2008 regime

4 The Scheme is a Nationally Significant Infrastructure Project ("NSIP") within the meaning of section 14 and section 22 of the Planning Act 2008 and is an EIA development. EIA of NSIPs is governed by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 ("the 2017 Regulations").

5 The applicant justifies zero rating of biomass combustion emissions on the basis of IPCC guidance and UK Environmental Reporting guidelines [REP3-020/page 61 in response to CEPP]. I show below that this is not guidance on how to comply with the requirements of EIA Assessment and the 2017 regulations, and the Applicant misapplies it in attempting to use it for EIA purposes.

6 In brief, at this stage, the IPCC guidance relates to how national inventories of GHG gas emissions are required to be prepared at the international level, and the UK Environmental Reporting guidelines relates to how inventories of GHG gas emissions are prepared at the UK national level.

7 Neither of these guidance's purport to show how to meet the statutory requirements of the EIA regulations.

8 The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change[2]. It does not provide guidance intended for planning decisions on individual schemes under national jurisdictions.

9 The UK Environmental Reporting Guidelines (March 2019) make clear in the introduction that they are guidance for Limited Liability Partnerships (Energy and Carbon Report) Regulations 2018 ('the 2018 Regulations'). The document does not mention the 2017 (EIA) regulations. It clearly does not relate to Environmental Impact Assessment.

10 Therefore, the answer to "can the IPCC guidance be applied under the Planning Act 2008 regime" is no.

[2] IPCC website top page

2.2 Applicant's response to the ExA's ISH Action Point

11 Even though, the IPCC guidance has no statutory relevance anyway, I now explain how the Applicant misinterprets it in its response to the ExA.

12 In [EV-018], the ExA requested at ISH1-AP2 clarification on the IPCC guidance on calculation of CO2 at point of combustion of biomass. In its response, in REP-028, the Applicant provided two selected paragraphs from the original 2006 guidance ["2006-GUIDE"] and the 2019 amendments ["2019-AMEND"] to it. I provide the relevant sections on the treatment of biomass in full in the Appendices A and B. I also provide the relevant section from the IPCC FAQ in Appendix C which the Applicant has not supplied.

13 The 2006 IPCC guidance which the Applicant quotes is entitled "2006 IPCC Guidelines for National Greenhouse Gas Inventories". It is, therefore, clear from the outset that the guidance relates to how the IPCC and the UN calculate and report national GHG emissions.

14 It does not pertain to address how to calculate, report and assess GHG emissions from individual installations for the purposes of planning under individual national regimes. Nor is the guidance in any sense regulatory guidance that is statutory applicable in the UK.

15 The IPCC guidance quotes selected by the Applicant do not explain how CO2 at the point of combustion is calculated as requested by the ExA The quotes, instead, are concerned how the calculated figure is accounted for, at a national level, once it has been derived.

2.3 What the IPCC guidance is concerned with

16 The first page of Appendix A shows the overall volume structure of the guidance. It is based on reporting of emissions and emissions removals at the national level in five main sectors (as described in Volume 1, Chapter 8 of the 2006 guidance):

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other

17 This breakdown of sectors was first established in 1995. With respect to biomass, the first two paragraphs of section 2.3.3.4 "Treatment of Biomass" of the guidance (as reproduced in Appendix A) explains:

> *"**Emissions of CO2 from biomass fuels are estimated and reported in the AFOLU sector as part of the AFOLU methodology.** In the reporting tables, emissions from combustion of biofuels are reported as information items but not included in the sectoral or national totals to avoid double counting. In the emission factor tables*

presented in this chapter, default CO2 emission factors are presented to enable the user to estimate these information items.

For biomass, only that part of the biomass that is combusted for energy purposes should be estimated for inclusion as an information item in the Energy sector."

18 Effectively CO2 from combustion is treated as part of the AFOLU carbon stock for a country, for accounting purposes. That does not mean that there is not a real quantity of emissions that is generated when biomass is combusted. Indeed, the guidance states that it should be included an information item in the Energy sector inventory. It is not accounted for under Energy so as not to double count as it has already been accounted for under AFOLU.

2.4 Applicant's conflicting position on carbon neutrality

19 The Applicant claims that the combustion of biomass is carbon neutral in Environmental Statement, chapter 15 [APP-051] at Table 15.12 for PAS2080 B6 CO2 data type – "*the process is carbon neutral*".

20 Subsequently, the Applicant has subsequently retracted that position:

A. [REP-028] / 2.4.26; and

B. [REP3-020/11.1] that its position is "*that biomass is zero rated at the point of combustion, <u>not that it is carbon neutral</u>*".

3 ENVIRONMENTAL IMPACT ASSESSMENT

21 This section examines further the Applicant's presentation and extends it to calculate full life-cycle emissions for the scheme without zero rating combustion emissions as zero rating distorts the assessment by not properly considering the carbon payback time required for forest regrowth.

3.1 GHG data

22 The Applicant has presented GHG data across a number of documents in tables with a confusing array of data. In order to see the data more clearly, I have aggregated the key GHG data from the various documents and tables into a single table at Table CEPP.Drax.Tab-1. This has also allowed extension of the calculation to consider two further aspects:

(1) including the biomass combustion emissions at the source of production (ie not zero-rating the combustion emissions);

(2) including a more realistic 90% CCS rate. This is consistent with cautious scientific warnings about the possible delivery of a greater than 90% CO2 capture rate[3].

23 This gives enables GHG calculations to be made for five scenarios:

① The Applicant's presentation for the scheme, as at Table 15.12 [APP-051] and Table 1.1 [APP-169].

② = ① with combustion emissions included

③ The Applicant's presentation for the "whole plant", as at the table under ISH1-AP1 in [REP-028].

④ = ③ with combustion emissions included

⑤ = ④ with no CCS – this corresponds to the current situation

24 These five scenarios are calculated in the table on the next page.

[3] See December 2020 report by the Tyndall Centre for Climate Change research at Manchester University provided at *Appendix E* "A Review of the Role of Fossil Fuel Based Carbon Capture and Storage in the Energy System" which states: "*However, the lack of sufficient data on natural gas CCS power station capture rates, CCS hydrogen production operations, or any CCS energy application with >90% capture rate, means that it is prudent to await these results before applying high capture rates to these emissions factors*."

tCO2e/yr			Scheme: Units 1 and 2		Units 1 and 2, and 3 and 4		
			①	②	③	④	⑤
	Emissions generated	**PAS 2080**	**Zero-rated**	**Not zero-rated**	**Zero rated**	**Not zero-rated**	**Not zero-rated /No CCS**
A	CH4 and N2O combustion emissions (not included)		24,474	24,474	48,948	48,948	48,948
B	Additional Scope 1 and 2 emissions from operation				160,000	160,000	160,000
C	104,700 tCO2e annualised over 25 years: Construction	A1-A5	4,188	4,188	4,188	4,188	4,188
D	Replacement and Refurbishment Emissions	B2-5	0	0	0	0	0
E	Combustion = Operation energy use	B6	0	9,691,567	0	19,383,135	19,383,135
F	Solvent used for the Carbon Capture process	B8	6,939	6,939	6,939	6,939	6,939
G	707 tC annualised over 25 years LULUCF (tC)*[4]	B8	28	28	28	28	28
H	Biomass supply chain GHG Emissions (Operational)	D	1,223,723	1,223,723	2,447,446	2,447,446	2,447,446
	Emissions captured						
Z	Forest regrowth in harvested forest**[5]		(assumed instant***[6])	0	(assumed instant***)	0	0
I	95% CO2 captured through the Carbon Capture process	B1	-9,206,989	-9,206,989	-9,206,989	-9,206,989	0
J= B+C+D+E+F+G+H+I+Z	**Net total tCO2 @95%CCS**		**-7,972,111**	**1,719,456**	**-6,588,388**	**12,794,747**	**22,001,736 [0%CCS]**
K=J/P	Carbon intensity @95% CCS		-978	211	-340	660	1,135
L	*90% CO2 captured through the Carbon Capture process*		*-8,722,410*	*-8,722,410*	*-8,722,410*	*-8,722,410*	
M= B+C+D+E+F+G+H+L+Z	***Net total tCO2 @90%CCS***		***-7,487,532***	***2,204,035***	***-6,103,809***	***13,279,326***	
N=M/P	Carbon intensity @90% CCS	gCO2/kWh	-918	270	-315	685	
	25-year net emissions generated (not zero-rated, power plant)					331,983,143	
P	Total Proposed Scheme electricity generated (net)	kWh	8,153,523,609		19,380,339,609		

Table CEPP.Drax.Tab-1 – Aggregated GHG table

[4] * LULUCF emissions are expressed as tC whereas all other figures are tCO2e. As noted on the next page, this is an error by the Applicant. I have reproduced the error as it provides consistency in the data presentations.

[5] **See next page, next section – zero over 25 years

[6] *Forest regrowth assumed instant by Applicant in its "zero rated" scenarios

3.2 Treatment of combustion emissions and forest regrowth

25 The Applicant's approach is to assume that loss of forest carbon stock for fuel stock and combustion is instantly replaced with forest carbon stock elsewhere in the global carbon cycle. This is the "carbon neutral" principle which the Applicant agrees is not true ("The Applicant's position is that biomass is zero rated at the point of combustion, not carbon neutral", [REP3-020/PDF page 61]).

26 Scientists are concerned that the net carbon impacts of increased forest harvests for bioenergy are rising. There is a reduction in forest carbon stocks associated with increased use of forest biomass relative to the counterfactual scenario with lower harvests, as it often takes considerable periods of time until forest bioenergy actually provides net carbon savings in comparison to fossil-based reference systems (see extract from source paper at Appendix 4).

The problem is that the forest carbon stock for fuel stock and combustion is **not** instantly replaced with forest carbon stock elsewhere in the global AFOLU system.

27 For this reason, I have separated out forest regrowth from the combustion emissions in scenarios ②, ④ and ⑤. The analysis of Sterman et all (2022) reproduced in my written submission [REP2-075/Appendix C] provides evidence that the impact of harvesting biomass fuel in 2025 is to increase forest emissions until around 2040 [REP2-075/paras 37-39] "the carbon sequestered by regrowth is initially less than the carbon the forest would have stored had it not been harvested". Examining Figure 2 in the Sherman paper would suggest that there is no net carbon payback until 2050 (starting from 2025). Given the project lifetime of 25 years, I have therefore applied zero sequestration from forest regrowth (row Z in Table CEPP.Drax.Tab-1) for scenarios ②, ④ and ⑤.

28 Treatment of combustion emissions is considered next.

3.3 Treatment of combustion emissions

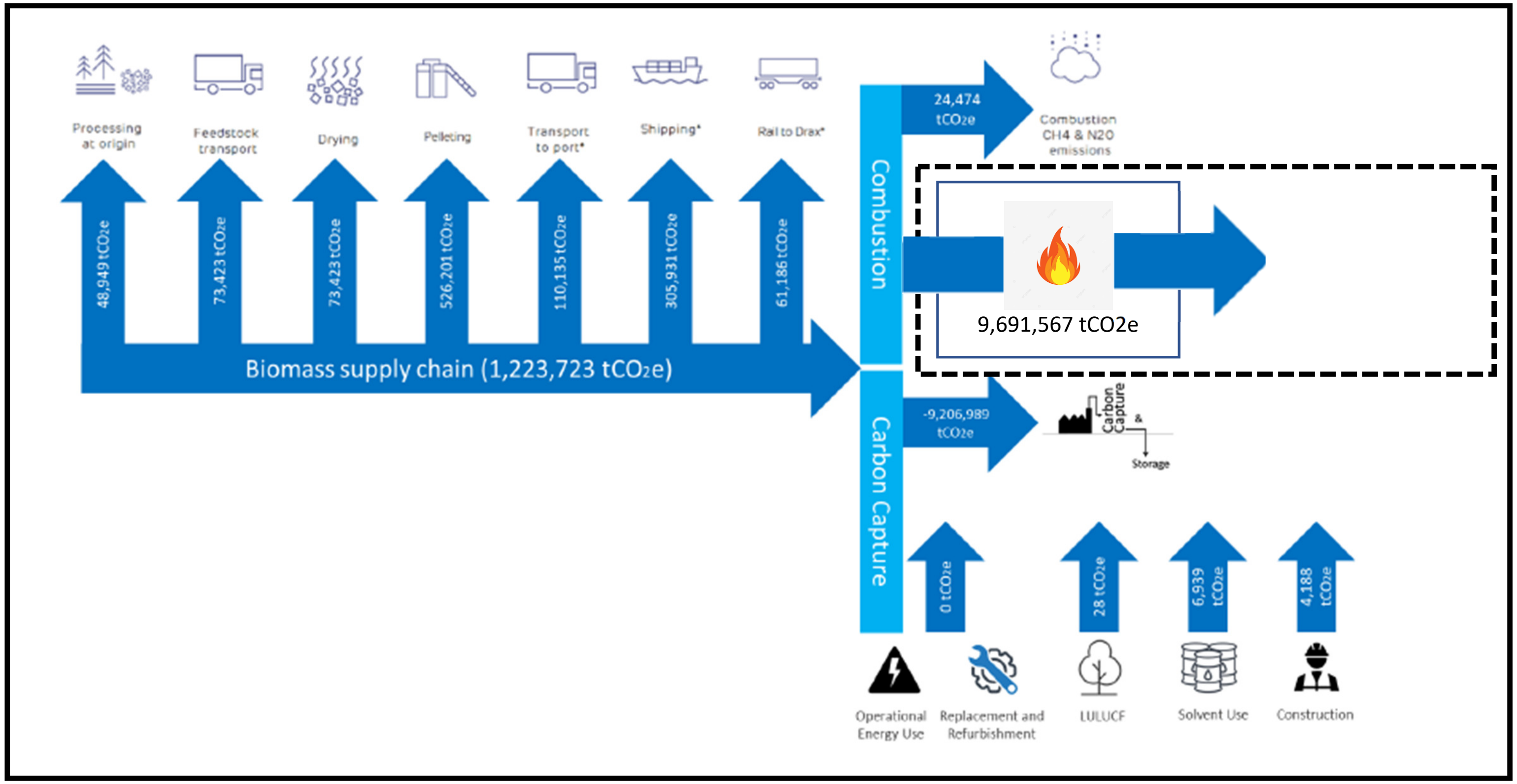

Figure CEPP.Drax.Fig-1 – Treatment of combustion emission (Proposed scheme)

29 Figure CEPP.Drax.Fig-1 adapts Plate 1.1 [APP-169] to show the combustion emissions.

30 Paragraph 5 of Schedule 4 to the 2017 Regulations requires the environmental statement to include:

> *The description of the likely significant effects on the factors specified in regulation 5(2) should cover the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the development …".*

Where this includes "*the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions)*" and climate is a factor.

31 For the purposes of environmental assessment (as opposed to reporting national carbon inventories under the UN regime), the combustion emissions at the proposed scheme are a **direct effect** of the development. Therefore, the question is whether the combustion emissions may be treated as an internality or an externality of the EIA assessment.

This question is clearly shown in Figure CEPP.Drax.Fig-1 – are the combustion emissions represented by the dashed box included inside (internality) of the overall assessment represented by the outer non-dashed box, or are they treated outside (externality, or "zero rated")? This may also be expressed as the decision on where the "line is drawn" to which the Applicant has referred.

32 I submit, as above, that the IPCC guidelines (and UK Environmental Reporting guidelines) for the construction of national accounting and international inventories in the UN climate regime have no implications, nor statutory binding, on how the EIA assessment for an individual assessment is done. **Methods agreed a long time ago (in 1995) for the national-level reporting and accounting of GHG emissions were never intended to provide methodologies for sound environmental assessment and decision-making for individual schemes.**

33 The EIA regulations need to be read in their own context, their own time and with their own guidance.

34 In REP3-020, the Applicant responds to my written representation:

> *"The Applicant notes that it has been clear that it has defined the scope of its assessment, including of appropriate upstream considerations, with reference to relevant and appropriate Guidance. By contrast, the Interested Party has stated that this is necessary, but not set out on what basis it considers the 'line' should be drawn for such an assessment in this regard. The Finch judgement (noting that the Supreme Court judgement in that case is awaited) that is referenced by the Interested Party made clear that the question of where and how that line should be drawn can be a matter of planning judgement, which can only be challengeable on*

public grounds of unreasonableness and irrationality. In the Applicant's submission, it would be unreasonable and irrational for the Secretary of State to depart from clear guidance on this matter, particularly in light of the lack of any alternative."

35 The first point to note is that the combustion emissions from the plant are <u>direct</u> emissions, and not upstream, or downstream, emissions. There is therefore <u>a stronger case</u> that the direct combustion emissions are included in the EIA Assessment than the downstream emissions being considered in the Finch case. The Finch case is relevant for these reasons:

(A) It explores the scope of the EIA regulations. This is relevant to the Drax schemes, first on where the line is drawn relating to the direct emissions from the scheme. Given the emerging science in this area, it is entirely reasonable and rational to expect that very large scale combustion emissions <u>directly</u> from operation of the plant should be included in the environmental assessment.

(B) Second, there are downstream (and significantly later ie on a long cycle) emissions in terms so the forest regrowth and carbon payback: the science papers appended to my Written Representation showed the carbon payback for biomass systems takes place on a centuries timescale. As in Table CEPP.Drax.Tab-1, these can realistically treated as zero for at least the first 25 years, but when considered over a longer cycle can provide negative sequestration emissions.

Where is the EIA line drawn on these downstream emissions? The rational and scientifically reasonable approach is to include these (negative) emissions in EIA but to properly represent their timescale of their creation. This is what I have done in scenarios ②, ④ and ⑤ in Table CEPP.Drax.Tab-1.

36 The IPCC guidance, as quoted by the Applicant, is not "*relevant and appropriate Guidance"* to the Planning Act 2008 and DCO regime.

3.4 The context of the combustion emissions in the scheme

37 The applicant submits that the "*existence of the Proposed Scheme, by itself, will not change the nature of extent of that biomass supply to the Power Station*". However, this is not true. The unabated power station is unlikely to continue to operate for the same time into the future as the proposed abated power station, including the proposed scheme, as the generated electricity will no longer accrue subsidies, and without subsidies Drax's operating financial model collapses. Even if this does not happen in 2027, it will inevitably happen as energy decarbonisation progresses in the UK.

This means that the power station with the proposed scheme will have a longer lifetime and will lock-in combustion emissions over a longer time that the existing unabated power station would.

38 Scenario ④ in Table CEPP.Drax.Tab-1 calculates the carbon figures when the combustion emissions are not zero rated. With the more realistic 90% CCS rate, the power station emits 13,279,326 tCO2e/yr at a carbon intensity of 685 gCO2/kWh. Over the 25 years life-time of the project, this equates to an additional 331,983,143 tCO2e. (It should be noted that the long period of carbon payback associated with each year's combustion starts at that year's combustion. So assuming no net carbon payback for 25 years (Sherman paper graph as above), combustion in 2050 will not start to payback until around 2075.

39 331 MtCO2e (million tonnes) is additional emissions on a very large scale. It is approximately 1/1000th of the entire remaining global carbon from 2020 for a 50% likelihood of limiting global heating to 1.5°C, the Paris temperature target[7].

40 1/1000th of the entire remaining global carbon on one power station is a hugely disproportionate, and inequitable, expenditure of the carbon budgets when the UN and IPCC are shouting that emissions need to be rapidly reduced this decade, and that the "choices and actions implemented in this decade will have impacts now and for thousands of years" [8].

41 This argues strongly against the scheme.

3.5 Obligations on the Secretary of State

42 I discussed this at para 19 – 21 of my WR [REP2-075]. I now expand this.

43 The starting places is that the Secretary of State is obliged to make a decision which complies with the 2017 Regulations and section 104 (4), (5) and (8) require that this obligation is discharged before accordance with the relevant NPSs is considered.

44 As already discussed, the IPCC guidance was written for a different purpose to that of environmental assessment and planning decision making for a particular scheme. Apart from not been written with DCO decision making in mind, the IPCC guidance (and the UK Environmental Report guidance) has no statutory role in the DCO regime.

45 Therefore, it is for the Secretary of State to ensure that the EIA Regulations have been legitimately applied. The 2017 regulations require that the Environmental Statement describes "the likely significant effects on the factors specified in regulation 5(2)" including "*<u>the direct effects</u> and any indirect, secondary, cumulative, transboundary, short-term,*

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[7] The recent SYNTHESIS REPORT OF THE IPCC SIXTH ASSESSMENT REPORT (AR6), release March 20th 2023, presents "remaining carbon budgets could be 300 or 600 GtCO2 for 1.5°C (50%), respectively for high and low non-CO2 emissions, compared to 500 GtCO2 in the central case" (Summary for Policymakers, footnote 41) from beginning of 2020. By beginning of 2023, around an additional 100 – 150 GtCO2 had been emitted, leaving around 350 GtCO2.

[8] The recent SYNTHESIS REPORT OF THE IPCC SIXTH ASSESSMENT REPORT (AR6), release March 20th 2023, presents "remaining carbon budgets could be 300 or 600 GtCO2 for 1.5°C (50%), respectively for high and low non-CO2 emissions, compared to 500 GtCO2 in the central case" (Summary for Policymakers, footnote 41) from beginning of 2020. By beginning of 2023, around an additional 100 – 150 GtCO2 had been emitted, leaving around 350 GtCO2.

medium-term and long-term, permanent and temporary, positive and negative effects of the development …".

46 Should the scheme go ahead, it will extend the life-time of the power plant for at least 25 years from now (whereas it might be forced to close due to failure of the Drax financial model based on subsidies if the scheme does not go ahead). As argued above, this will be a longer life-time than if the scheme does not go ahead and the power plant remains unabated. The regrowth of the forest harvested for the scheme itself is unlikely to provide carbon payback over the 25 year period meaning that approximately 331 MtCO2e will be emitted over the first 25 year operating period. The Secretary of State must be sure that the scheme complies with section 104 of the Planning Act 2008 ("**the 2008 Act**"); for example, that the scheme will not lead to the UK being in breach of its international obligations, nor that it is unlawful.

47 I submit that with a carbon footprint of 331MtCO2e over 25 years that the scheme would lead to the UK being in breach of its international obligations as the footprint is approximately 1/1000th of the remaining global carbon budget for the Paris agreement. The scheme would also certainly breach most, if not all, of the remaining carbon budgets until 2050 (ie the 5th to 9th carbon budgets).

48 I submit that the Secretary of State must also consider the information in this submission as part of his/her process in reaching a reasoned conclusion on the significant effects of the development on the environment under the 2017 regulations.

49 I have provided new material to the examination on the emissions in a science-based presentation. This must form part of the material before the Secretary of State in any reasoned decision making on the proposed scheme.

3.6 Probable errors in Applicant's data

50 In compiling the aggregate table, these probable errors were noted in the Applicant's presentation:

(A) Table 15.12 [APP-051] and Table 1.1 [APP-169] give the "Operational Supply chain GHG Emissions – D" as **1,223,723** tCO2e/yr. Plate 1.1 [APP-169] provides numbers for the elements of the supply chain which sum to this value.

- However, Table 15.8 "GHG Emissions Generated <u>Per Annum</u> in the Baseline Scenario" [APP-051] gives "Biomass supply chain GHG Emissions (baseline) D" as **558,778** tCO2e with the associated Plate 15.1. These figures do not tally at all. I note that the Applicant expresses one value as tCO2e/yr and the other as tCO2e, but do see that this explains the very marked difference as the table is "per annum".

(B) LULUCF B8 emissions are given as -10,863 tC "per annum" in Table 15.8 [APP-051] for "existing baseline". LULUCF "Baseline scenario potential carbon storage (tC)" are given as -8,760 tC in Table 15.12 [APP-051]. These figures do not tally at all.

- Table 1.2 [APP-169] gives construction LULUCF emissions as -2,102 tC and operation LULUCF emissions as -8,760 tC for the baseline scenario which does sum to -10,862 tC. There appear to be two errors here. First, it is not clear how construction phase emissions apply to the plant running in the baseline scenario (where construction is not taking place). Second, the Applicant appears to have added construction emissions (one-off) to operation emissions (annual).

(C) LULUCF emissions are expressed as tC but included in the calculations with tCO2e data in Table 15.8 [APP-051], Table 15.11 [APP-051], Table 15.12 [APP-051], Table 1.1 [APP-169], and the table under ISH1-AP1 in [REP-028]. Checking the numbers in the these table shows that tC units have been added tCO2e with being converted first to generate the totals. This introduces a small error (as the LULUCF emissions are relatively small by comparison to other figures). As noted in my Table above, <u>I have reproduced this error but only so that there is consistency in the data presentations</u>. I have tried to clarify the data in the aggregated data and correcting this error would make my table harder for the reader to compare with the Applicant's tables. .

(D) Construction emissions are referred to PAS Modules "**A1-A5**" in Table 15.12 [APP-051], Table 1.1 [APP-169] and the table under ISH1-AP1 in [REP-028]. However, the annual construction figures are <u>incorrectly</u> referred to PAS Modules "**C1-C5**" in the table under ISH1-AP1 in [REP-028]. PAS Modules "C1-C5" are for "Boundary of end of life stage" emissions in the PAS 2080 guidance.

51 The applicant should respond and correct the Environmental Statement where necessary.

4 CONCLUSIONS

52 I have provided a calculation finding that the power plant with the proposed scheme will emit an additional 331,983,143 tCO_2e over 25 years (at 90% CCS rate). As the power plant is only financially viable with the proposed scheme much of these emissions would not occur without the scheme being implemented. These emissions are approximately 1/1000th of the entire remaining global carbon from 2020 for a 50% likelihood of limiting global heating to 1.5°C, the Paris temperature target.

53 The scheme would also certainly breach most, if not all, of the remaining carbon budgets until 2050 (ie the 5th to 9th carbon budgets).

54 The Secretary of State must consider the information in this submission, including these additional emissions from the scheme, as part of his/her process in reaching a reasoned conclusion on the significant effects of the development on the environment under the 2017 regulations.

55 I have provided new material to the examination on the emissions in a science-based presentation. This must form part of the material before the Secretary of State in any reasoned decision making on the proposed scheme.

56 When the very large emissions from the scheme are considered under the scope of the 2017 regulations, I submit that the project should be recommended for refusal.

[redacted]

Dr Andrew Boswell,
Climate Emergency Policy and Planning, March 28th 2023

5 APPENDIX A: 2006 IPCC GUIDELINES

5.1 (Website) Index page of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"

Publications

2006 IPCC Guidelines for National Greenhouse Gas Inventories

- 2006 IPCC Guidelines Top
  - Vol.1 GGR
  - Vol.2 Energy
  - Vol.3 IPPU
  - Vol.4 AFOLU
  - Vol.5 Waste
- Other Language Versions:
  - Arabic
  - Chinese
  - French
  - Russian
  - Spanish

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2006 IPCC Guidelines for National Greenhouse Gas Inventories

Cover, Foreword and Preface PDF

Overview PDF

Glossary PDF

List of Contributors PDF *1

*1: Corrected chapter(s) as of April 2007.

The series consists of five volumes:

Volume 1 General Guidance and Reporting

Volume 2 Energy

Volume 3 Industrial Processes and Product Use

Volume 4 Agriculture, Forestry and Other Land Use

Volume 5 Waste

5.2 (Website) Index page of "Volume 2: Energy"

2006 IPCC Guidelines for National Greenhouse Gas Inventories

- 2006 IPCC Guidelines Top
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2006 IPCC Guidelines for National Greenhouse Gas Inventories
Volume 2
Energy

Chapter	Chapter Name
-	Cover Page of Volume 2
1	Introduction
2	Stationary Combustion *1
3	Mobile Combustion *4 *11
4	Fugitive Emissions *2 *10 *11
5	Carbon Dioxide Transport, Injection and Geological Storage
6	Reference Approach
Annex 1	Worksheets *6

*1 : Corrected chapter(s) as of April 2007.
*2 : Corrected chapter(s) as of November 2008.
*4 : Corrected chapter(s) as of June 2010.
*6 : Corrected chapter(s) as of August 2011.
*10 : Corrected chapter(s) as of April 2018.
*11 : Corrected chapter(s) as of June 2019.

In addition the worksheets are provided here in MS Excel spreadsheet format as supporting material to assist users of the guidelines. They are simply the worksheets above translated into spreadsheets without any additional formulae.

All Worksheets in Vol.2

All Worksheets of 2006GLs (all in one file. zipped. 201KB)

5.3 Front page of Chapter 2 "Stationary Combustion"

Chapter 2: Stationary Combustion

CHAPTER 2

STATIONARY COMBUSTION

5.4 Treatment of biomass section

2.3.3.4 TREATMENT OF BIOMASS

Biomass is a special case:

- Emissions of CO_2 from biomass fuels are estimated and reported in the AFOLU sector as part of the AFOLU methodology. In the reporting tables, emissions from combustion of biofuels are reported as information items but not included in the sectoral or national totals to avoid double counting. In the emission factor tables presented in this chapter, default CO_2 emission factors are presented to enable the user to estimate these information items.
- For biomass, only that part of the biomass that is combusted for energy purposes should be estimated for inclusion as an information item in the Energy sector.
- The emissions of CH_4 and N_2O, however, are estimated and included in the sector and national totals because their effect is in addition to the stock changes estimated in the AFOLU sector.
- For fuel wood, activity data are available from the IEA or the FAO (Food and Agriculture Organisation of the United Nations). These data originate from national sources and inventory compilers can obtain a better understanding of national circumstances by contacting national statistical agencies to find the organisations involved.
- For agricultural crop residues (part of other primary solid biomass) and also for fuel wood, estimation methods for activity data are available in Chapter 5 of the AFOLU volume.

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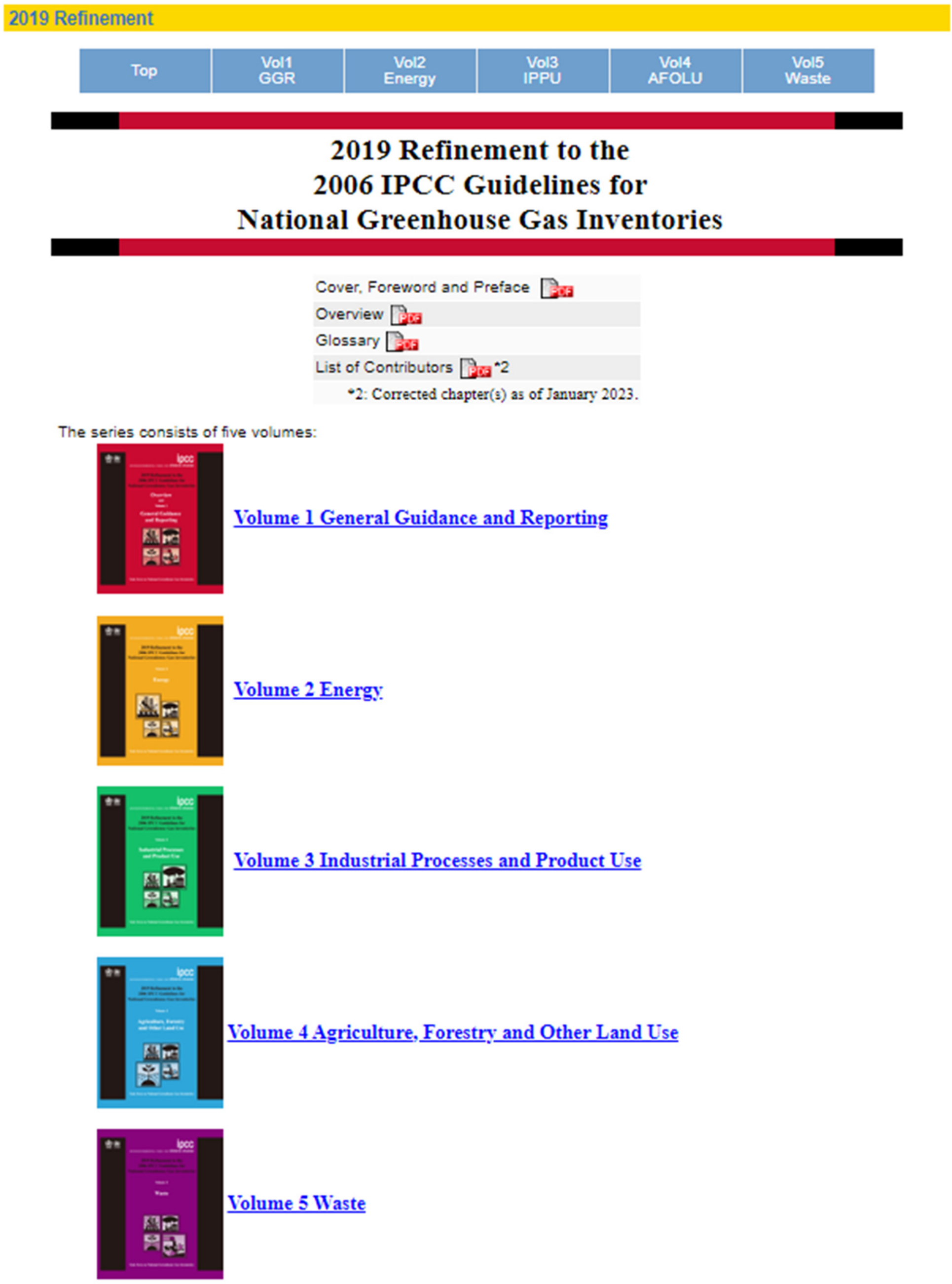
- In some instances, biofuels will be combusted jointly with fossil fuels. In this case, the split between the fossil and non-fossil fraction of the fuel should be established and the emission factors applied to the appropriate fractions.

6 APPENDIX B: 2019 IPCC GUIDELINES REVISION

6.1 (Website) Index page of "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories"



2019 Refinement

Top	Vol1 GGR	Vol2 Energy	Vol3 IPPU	Vol4 AFOLU	Vol5 Waste

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Cover, Foreword and Preface

Overview

Glossary

List of Contributors *2

*2: Corrected chapter(s) as of January 2023.

The series consists of five volumes:

Volume 1 General Guidance and Reporting

Volume 2 Energy

Volume 3 Industrial Processes and Product Use

Volume 4 Agriculture, Forestry and Other Land Use

Volume 5 Waste

6.2 (Website) Index page of "Volume 2: Energy"

2019 Refinement

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2019 Refinement to the
2006 IPCC Guidelines for
National Greenhouse Gas Inventories
Volume 2
Energy

Chapter	Chapter Name
-	Cover Page of Volume 2
1	Introduction
2	Stationary Combustion
3	(No Refinement)
4	Fugitive Emissions *3
5	(No Refinement)
6	(No Refinement)
Annex 1	Worksheets
Annex 2	Mapping Tables

*3 : Corrected chapter(s) as of February 2023.

6.3 Front page of Chapter 2 “Stationary Combustion”

Chapter 2: Stationary Combustion

CHAPTER 2

STATIONARY COMBUSTION

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories 2.1

6.4 Treatment of biomass section

2.3.3.4 TREATMENT OF BIOMASS

Biomass is a special case:

- The overall IPCC approach to greenhouse gas emissions from combustion of biomass or biomass-based products (e.g., ethanol) at the national level allows for complete coverage of emissions and sinks, and involves all IPCC sectors, including in particular, Energy, Agriculture, Forestry and Other Land-Use (AFOLU), and Waste.
- Carbon dioxide (CO_2) emissions from the combustion of biomass or biomass-based products are captured within the CO_2 emissions in the AFOLU sector through the estimated changes in carbon stocks from biomass harvest, even in cases where the emissions physically take place in other sectors (e.g., energy). This approach to estimate and report all CO_2 emissions from biomass or biomass-based products in the AFOLU sector was introduced in the first IPCC guidelines for national greenhouse gas emissions (IPCC 1995), reflecting close linkages with data on biomass harvesting, and for the pragmatic reason to avoid double counting.

2.4 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Chapter 2: Stationary Combustion

- In the Energy sector, CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions from combustion of biomass or biomass-based products for energy are estimated, but the CO_2 emissions are recorded as an information item that is not included in the sectoral total emissions for the Energy sector, as they are already included in AFOLU. The CH_4 and N_2O emissions from the combustion of biomass for energy are included in the sectoral total emissions in the Energy sector, as emission rates depend on combustion and transformation conditions and cannot be estimated using AFOLU carbon stock change methodologies. This provides a complete picture of a country's energy system and avoids double counting of emissions with those reported in the AFOLU sector.
- For biomass, only that part of the biomass that is combusted for energy purposes should be estimated for inclusion as an information item in the Energy sector.
- For fuel wood, activity data are available from the International Energy Agency (IEA) or the Food and Agriculture Organization of the United Nations, (FAO). These data originate from national sources and inventory compilers can obtain a better understanding of national circumstances by contacting national statistical agencies to find the organisations involved.
- For agricultural crop residues (part of other primary solid biomass) and also for fuel wood, estimation methods for activity data are available in Chapter 5 of the AFOLU volume.
- In some instances, biofuels will be combusted jointly with fossil fuels. In this case, the split between the fossil and non-fossil fraction of the fuel should be established and the emission factors applied to the appropriate fractions.
- Further clarification on the approach for biomass energy emissions can be found in Section 1.1, "Concepts" in Volume 1, Chapter 1. Further clarification on the reporting of emissions from burning woody biomass for energy is provided in Section 12.5, Chapter 12 of the AFOLU volume of *the 2019 Refinement*.

7 APPENDIX C: IPCC NATIONAL GREENHOUSE GAS INVENTORIES (TFI) FAQ

7.1 First page

FAQs

Frequently Asked Questions

1. IPCC Task Force on National Greenhouse Gas Inventories (TFI), general guidance and other inventory issues

1.1. Questions about IPCC National Greenhouse Gas Inventories Programme

Q1-1-1. What is the role of the IPCC in Greenhouse Gas Inventories and reporting to the UNFCCC?

A: The IPCC has generated a number of methodology reports on national greenhouse gas inventories with a view to providing internationally acceptable inventory methodologies. These methodology reports are available on the following website [redacted] The IPCC accepts the responsibility to provide scientific and technical advice on specific questions related to those inventory methods and practices that are contained in these reports, or at the request of the UNFCCC in accordance with established IPCC procedures. The IPCC has set up the Task Force on National Greenhouse Gas Inventories (TFI) to run the National Greenhouse Gas Inventory Programme (NGGIP) to produce this methodological advice. Parties to the UNFCCC have agreed to use the *IPCC Guidelines* in reporting to the Convention. Annex I Parties shall use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (*2006 IPCC Guidelines*) and are encouraged to use the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (*Wetlands Supplement*).

For the purpose of providing information on anthropogenic greenhouse gas emissions and removals from LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol, Annex I Parties shall apply, as appropriate, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (*KP Supplement*). The *Wetlands Supplement* shall apply for providing information on wetland drainage and rewetting elected activity under Article 3.4 of the Kyoto Protocol and is encouraged but not mandatory for any other activities under Article 3.3 and 3.4 of the Kyoto Protocol.

Non-Annex I Parties should use the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (*Revised 1996 IPCC Guidelines*), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*), and the Good Practice Guidance for Land Use, Land-Use Change and Forestry (*GPG-LULUCF*). Some non-Annex I Parties have started using also the 2006 IPCC Guidelines in their reporting to the UNFCCC.

In addition, Paris Agreement (Article 13 paragraph 7(a)) states that Each Party shall regularly provide a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the IPCC and agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

7.2 Q2-10 & Q2-11

Q2-10. According to the IPCC Guidelines CO_2 Emissions from the combustion of biomass are reported as zero in the Energy sector. Do the IPCC Guidelines consider biomass used for energy to be carbon neutral?

A: The overall IPCC approach to estimating and reporting bioenergy greenhouse gas emissions at the national level requires complete coverage of all IPCC sectors, including the AFOLU and Energy sectors. All CO_2 emissions and removals associated with biomass are reported in the AFOLU sector. Therefore, CO_2 emissions from biomass combustion used for energy are only recorded as a memo item in the Energy sector; these emissions are not included in the Energy sector total to avoid double counting. The approach of not including these emissions in the Energy Sector total should not be interpreted as a conclusion about the sustainability, or carbon neutrality of bioenergy.

While individual methodologies and emission factors provided in the IPCC Guidelines may be relevant for estimating CO_2 emissions from the use of bioenergy at an individual facility or industry, the IPCC Guidelines as an overall framework for a national GHG inventory do not provide an analytical approach for assessing the full bioenergy emissions at sub-national entities such as industry sectors. A complete coverage of bioenergy emissions at the sub-national level – for example for an industry sector – may require additional analytical work and assumptions beyond the scope of the 2006 IPCC Guidelines to attribute all relevant bioenergy emissions (e.g. those associated with growing bioenergy crop, land-use change, fertilization, transportation, etc.) to the sub-national entities of interest.

Thus, the IPCC Guidelines do not automatically consider or assume biomass used for energy as "carbon neutral", even in cases where the biomass is thought to be produced sustainably. The methodological framework used within the IPCC Guidelines reflect the following:

1. CO_2 emissions and removals due to the harvesting, combustion and growth of biomass are included in the carbon stock changes of the relevant land use category of the AFOLU sector where the biomass originates.

2. The IPCC guidelines provide the simplifying assumption (Tier 1 method) regarding CO_2 emissions and removals associated with annual biomass (e.g., corn, colza) that over the course of a year, the CO_2 emissions from the combustion/oxidation/decay of annual biomass are balanced by carbon uptake prior to harvest, within the uncertainties of the estimates, so the net emission is zero.

3. CO_2, CH_4 and N_2O emissions and removals related to biomass production associated with land-use practices and management as well as changes in these e.g., deforestation or fertilisation and lime use, are also captured in the overall estimates provided in the AFOLU sector.

4. There may also be additional emissions that are estimated and reported in other sectors, the sector is chosen based on where the emissions occur, e.g.:
    a. from the processing and transportation of the biomass, in the Energy sector;
    b. CH_4 and N_2O emissions from the biomass combustion, in the Energy sector;
    c. CH_4 and N_2O emissions from the biogenic part of waste burned without energy recovery, in the Waste sector.

For more information, see Volume 1, Chapter 1 as well as section 2.3.3.4 "Treatment of biomass", in volume 2 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [redacted]

Q2-11. How to report CCS of Biogenic CO_2?

A: In the context of national GHG inventories, carbon dioxide capture and storage (CCS) means geological carbon sequestration. Per the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines), geologic sequestration can be incorporated into GHG inventories using a Tier 3, site-specific methodology. This includes geologic sequestration of biogenic CO_2. The 2006 IPCC Guidelines note that "Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon: emissions and storage of both will be estimated and reported." (Volume 2, Chapter 5, Table 5.4), and that "Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such." (Volume 2, Chapter 5, Section 5.3). Information on Tier 3 methodologies for geologic sequestration can be found in the 2006 IPCC Guidelines, Volume 2, Chapter 5, Section 5.7, Methodological Issues.

In the case of biogenic CO_2, the negative emissions are to be reported in the IPCC sector in which capture takes place, at the most disaggregated level possible. For example, in the case of capture of fugitive emissions of biogenic CO_2 at ethanol plants that produce ethanol for fuel use, the negative emissions could be reported as capture under 1.B.3.

Relevant text
2006 IPCC Guidelines, Volume 2, Chapter 5, Table 5.1 (UNCHANGED in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement))
"Carbon dioxide (CO_2) capture and storage (CCS) involves the capture of CO_2, its transport to a storage location and its long-term isolation from the atmosphere. Emissions associated with CO_2 transport, injection and storage are covered under category 1C. Emissions (and reductions) associated with CO_2 capture should be reported under the IPCC sector in which capture takes place (e.g. Stationary Combustion or Industrial Activities)."

2006 IPCC Guidelines, Volume 2, Chapter 5, Table 5.4 (UNCHANGED in 2019 Refinement)
"Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon: emissions and storage of both will be estimated and reported."

2006 IPCC Guidelines, Volume 2, Chapter 5, Section 5.3 (UNCHANGED in 2019 Refinement)
Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such.

2019 Refinement, Volume 1, Chapter 8, Section 8.2.1
"CO_2 emissions from biomass combustion for energy are reported in the energy sector as memo item and estimated and reported in the AFOLU Sector as part of net changes in carbon stocks. (NEW text) The capture of biogenic CO_2 emissions from biomass combustion, or other processes, should be treated consistently with CO_2 capture from fossil fuel combustion and reported in the Energy and/or IPPU Sectors. Once captured, and added to the carbon capture and storage process there is no differentiated treatment between biogenic carbon and fossil carbon. Both captured biogenic and fossil CO_2 should not be added to the total emissions, i.e. net emissions should be reported (also see section 5.3 of Chapter 5 in Volume 2 of the *2006 IPCC Guidelines*). Non-CO_2 emissions from biomass combustion are reported in the Energy Sector. Non-CO_2 fugitive emissions from production of fuels (e.g. charcoal or biochar) are reported in the Energy Sector (see Table 4.3.1 in Chapter 4, Volume 2 for the correct allocation of non-CO_2 fugitive emissions from fuel transformation)."

8 APPENDIX D: "Natural climate solutions versus bioenergy: Can carbon benefits of natural succession compete with bioenergy from short rotation coppice?"

Kalt G, Mayer A, Theurl MC, Lauk C, Erb K-H, Haberl H. Natural climate solutions versus bioenergy: Can carbon benefits of natural succession compete with bioenergy from short rotation coppice? GCB Bioenergy. 2019;11:1283– 1297. https ://doi.org/10.1111/gcbb.12626

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ORIGINAL RESEARCH

GLOBAL CHANGE BIOLOGY BIOENERGY WILEY

Natural climate solutions versus bioenergy: Can carbon benefits of natural succession compete with bioenergy from short rotation coppice?

Gerald Kalt | **Andreas Mayer** | **Michaela C. Theurl** | **Christian Lauk** | **Karl-Heinz Erb** | **Helmut Haberl**

Institute of Social Ecology (SEC), Department of Economics and Social Sciences, University of Natural Resources & Life Sciences, Vienna (BOKU), Austria

Correspondence
Gerald Kalt, Institute of Social Ecology (SEC), Department of Economics and Social Sciences, University of Natural Resources & Life Sciences, Vienna (BOKU), 1070 Vienna, Schottenfeldgasse 29, Austria.
Email: gerald.kalt@boku.ac.at

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Abstract

Short rotation plantations are often considered as holding vast potentials for future global bioenergy supply. In contrast to raising biomass harvests in forests, purpose-grown biomass does not interfere with forest carbon (C) stocks. Provided that agricultural land can be diverted from food and feed production without impairing food security, energy plantations on current agricultural land appear as a beneficial option in terms of renewable, climate-friendly energy supply. However, instead of supporting energy plantations, land could also be devoted to natural succession. It then acts as a long-term C sink which also results in C benefits. We here compare the sink strength of natural succession on arable land with the C saving effects of bioenergy from plantations. Using geographically explicit data on global cropland distribution among climate and ecological zones, regionally specific C accumulation rates are calculated with IPCC default methods and values. C savings from bioenergy are given for a range of displacement factors (DFs), acknowledging the varying efficiency of bioenergy routes and technologies in fossil fuel displacement. A uniform spatial pattern is assumed for succession and bioenergy plantations, and the considered timeframes range from 20 to 100 years. For many parameter settings—in particular, longer timeframes and high DFs—bioenergy yields higher cumulative C savings than natural succession. Still, if woody biomass displaces liquid transport fuels or natural gas-based electricity generation, natural succession is competitive or even superior for timeframes of 20–50 years. This finding has strong implications with climate and environmental policies: Freeing land for natural succession is a worthwhile low-cost natural climate solution that has many co-benefits for biodiversity and other ecosystem services. A considerable risk, however, is C stock losses (i.e., emissions) due to disturbances or land conversion at a later time.

KEYWORDS

bioenergy, carbon accounting, carbon sequestration, carbon stock change, climate change mitigation, CO_2, energy plantations, land use, land-use change, natural climate solution, natural succession, reforestation, short rotation coppice

1 | INTRODUCTION

On a global level, bioenergy currently holds the largest share of all renewable energy sources (REN21, 2018). Although its size is intensively discussed, the sustainable potential of biomass for energy is mostly considered to be substantial (e.g., Coelho et al., 2012; Creutzig et al., 2015; Dornburg et al., 2010; Haberl, Beringer, Bhattacharya, Erb, & Hoogwijk, 2010; Searle & Malins, 2015; WBGU, 2009), and global long-term energy scenarios often show considerable increase in bioenergy production (Azar et al., 2010; Calvin et al., 2013; Creutzig et al., 2012; Daioglou, Doelman, Wicke, Faaij, & van Vuuren, 2019; Kitous et al., 2017; Krey, Luderer, Clarke, & Kriegler, 2014; Loftus, Cohen, Long, & Jenkins, 2015; OECD/IEA & IRENA, 2017; Riahi et al., 2017; Rogelj et al., 2016, 2018). It is generally assumed that large quantities of solid biomass could be sourced through intensified forest management and the conversion of unmanaged to managed forests (e.g., Fricko et al., 2017; Kraxner et al., 2013). Yet, concerns regarding the net carbon (C) impacts of increased forest harvests are rising. Due to the reduction in forest C stocks associated with increased use of forest biomass relative to a counterfactual scenario with lower harvests, it often takes considerable periods of time until forest bioenergy actually provides net C savings in comparison to fossil-based reference systems ("fossil fuel parity time," see Cherubini, Bright, & Strømman, 2012; Cintas et al., 2017; Gustavsson, Haus, Ortiz, Sathre, & Truong, 2015, 2016; Holtsmark, 2012; Hudiburg, Law, Wirth, & Luyssaert, 2011; Jonker, Junginger, & Faaij, 2014; Lamers & Junginger, 2013; McKechnie, Colombo, Chen, Mabee, & MacLean, 2011; Sterman, Siegel, & Rooney-Varga, 2018; Vanhala, Repo, & Liski, 2013; Zanchi, Pena, & Bird, 2010, 2012). Depending on different influencing factors (management practices, tree species, types of fossil fuels being displaced, which parts of trees are used for energy and other uses, etc.), parity times vary from less than a year to several decades or even centuries (e.g., Agostini, Giuntoli, & Boulamanti, 2013; Bentsen, 2017; Buchholz, Hurteau, Gunn, & Saah, 2016; Mitchell, Harmon, & O'Connell, 2012).

An option for providing possibly large quantities of biomass without interfering with forest C stocks are purpose-grown biomass plantations managed in short rotation (short rotation coppice; SRC). If established on current agricultural land, such plantations usually result in the buildup of C stocks in biota and soils rather than their reduction (e.g., Arevalo, Bhatti, Chang, & Sidders, 2011; Rytter, 2012; Verlinden et al., 2013) and usually provide higher energy yields per unit area and year than conventional energy crops like cereals or oilseeds (Boehmel, Lewandowski, & Claupein, 2008; Ericsson, Rosenqvist, & Nilsson, 2009; WBGU, 2009). Hence, provided that agricultural land can be diverted from food and feed production without impairing food security (Haberl et al., 2011), SRC appears as an attractive climate change mitigation measure. Scenario results of integrated assessment models also often show large-scale deployment of energy plantations (e.g., Daioglou et al., 2019; Fricko et al., 2017; Kraxner et al., 2013).

However, land used for SRC could also be left to natural succession, that is, revert to natural ecosystems (usually natural forests), thereby acting as a potentially significant long-term C sink. The world's croplands are mostly located in ecological zones that would revert to forests if left undisturbed, but there are also cropland areas located in regions characterized as shrublands, desert, or steppe (see Table S1). We therefore use the term "natural succession" (rather than "reforestation"), meaning any kind of regrowth of natural vegetation. Following the IPCC (Intergovernmental Panel on Climate Change) definition, we use the term "natural forest" for forest composed of indigenous trees as contrasted with plantations. We are aware that such forests would, for a long time, differ strongly from natural old-growth forests without human use for centennial timeframes, which is the meaning usually attached to the notion of "natural forests" among conservation ecologists.

Contributions of bioenergy based on SRC (SRC-based bioenergy) and natural succession to the reduction in atmospheric C are here referred to as "carbon benefits" (C benefits). This definition of C benefits differs from the C benefit index recently proposed by Searchinger, Wirsenius, Beringer, and Dumas (2018), which relates greenhouse gas emissions to a standardized land-based product index allowing comparisons across products. In contrast, we here quantify reductions in atmospheric C resulting from two different land uses.

Depending on site-specific conditions (climate, ecological zone), the considered timeframe, and the efficiency of the respective bioenergy pathways, natural succession might represent a worthwhile alternative to fossil fuel substitution with biomass from energy plantations. Erb et al. (2018) have recently highlighted the high relevance of natural vegetation as C storage and the massive effects of land use on C stocks, including land management without land-cover conversion (e.g., forestry). Numerous studies have investigated C trade-offs between forest management aiming at fossil fuel displacement and setting aside forests to maximize C sequestration (e.g., Cintas et al., 2017; Mitchell et al., 2012; Taeroe, Mustapha, Stupak, & Raulund-Rasmussen, 2017; Vanhala et al., 2013), but few studies have compared C benefits of natural succession with those of SRC for energy. Albanito et al. (2016) have shown that for a timeframe of 20 years, reforestation of cropland would be superior to bioenergy from SRC in terms of their C balance on 17% of all global cropland areas. However, their assumptions regarding the average amount of fossil C being displaced per unit of biomass-derived C are quite optimistic, as they assumed a high displacement factor (DF) of 0.878 (see below). In contrast,

9 APPENDIX E: "A REVIEW OF THE ROLE OF FOSSIL FUEL BASED CARBON CAPTURE AND STORAGE IN THE ENERGY SYSTEM", DECEMBER 2020, TYNDALL CENTRE FOR CLIMATE CHANGE RESEARCH AT MANCHESTER UNIVERSITY

Supplied as separate document