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Examination Principle Issues	**Climate Change**

DEADLINE D2 SUBMISSION

I am a scientist with a background in computer modelling of complex phenomena, including climate change. Between 1995 and 2006, I ran the high-performance computer service at the University of East Anglia. I also have 17 years' experience working on planning and climate change issues as a councillor both on Norwich City Council and on Norfolk County Council, and as an environmental consultant. My current work at CEPP is to promote the necessary rapid response to the Climate and Ecological Emergencies in mainstream institutions, such as local authorities, planning inquiries and government, through the lenses of science, policy, and litigation. (Further resume in Appendix H).

In so far as the facts in this statement are within my knowledge, they are true. In so far as the facts in this statement are not within my direct knowledge, they are true to the best of my knowledge and belief.

SUMMARY

This Written Representation considers the legal and scientific implications of the land use, land-use change, and forestry ("**LULUCF**") greenhouse gas ("**GHG**") emissions of the scheme. These are indirect emissions of the project, but comprise a very significant, and centuries long climate change impact associated with the proposed Drax facility.

Consideration of these LULUCF emissions and their impacts shows that the biomass combustion process cannot be considered "carbon neutral" within the timescales of current national climate policy (ie until 2050). The biomass combustion might eventually be carbon neutral (for example after 2200), but the centuries long climate change impact remains from increased absolute carbon emissions in the atmosphere until carbon neutrality is reached.

Irrespective of the fact that carbon capture and storage ("**CCS**") is proposed, the severe carbon accounting error on the biomass combustion process itself means that all other subsequent assessment is flawed, and deeply incorrect in scientific terms. Without proper calculation, description and significance assessment of the LULUCF emissions of the project, the impact of the Drax BECCS project on the UK national legally binding targets and budgets is simply unquantified and unknown.

The science on this matter has been available since at least 2009. Three key papers are supplied in Appendices. Recent modelling is described from one of the papers. This shows, in terms of the effects of LULUCF emissions from the biomass fuel process associated with the project on global carbon cycles, that forest regrowth <u>might</u> eventually remove carbon dioxide generated by Drax from the atmosphere, but regrowth is uncertain and takes time, <u>decades to a century or more.</u>

The science appended shows, then, that the transboundary, long-term impacts on the global carbon cycle of the LULUCF emissions have a duration of centuries. The Environmental Impact Assessment regulations require that such indirect impacts (including transboundary, cumulative, short-term, long-term significant effects) are identified, described and assessed within the Environmental Statement. <u>They have not been on the Drax application which is a breach of the 2017 regulations.</u> Under section 104 (5) of the Planning Act 2008 such a breach overrides according with the applicable national policy statements, for decision making on the application.

I note the Office for Environmental Protection has recently intervened in the appeal of R (Finch) v Surrey County Council on the matter of the "*principles for determining the proper approach to the assessment of indirect effects under the EIA legislation*" and I explain the similar nature of the legal issues involved my main text.

The UK now has a legal and policy framework on Climate Change which contains several legal requirements, for example: the Net Zero target 2050, the Sixth Carbon Budget, the 2030 68% reduction target, the 2035 78% reduction target; and policy to deliver these legal requirements, for example, the Net Zero Strategy. Without proper calculation, description and significance assessment of the LULUCF emissions of the project, the impact of these legally binding targets and budgets is unknown. This is a short-term impact which just is not known or presented by the applicant in the Environmental Statement.

The key issue is then how the LULUCF emissions from upstream fuel production may be calculated, described, and assessed. This is <u>a necessary step</u> for the application to discharge the requirements under the 2017 regulations, and for the Secretary of State to be able to make a determination under section 104 of the 2008 Act.

I respectfully suggest to the Examining Authority ("ExA") that this matter needs urgent resolution. I request that the ExA give consideration to Reg 20 (1) of the 2017 Regulations which provides the Examining authority with the option to 'suspend consideration of the application' if it is necessary for the ES to contain further information.

Further, it is essential that the Secretary of Statement is fully briefed on the science of this issue, and the ramifications of it for delivery of international and national climate targets, and gives detailed and due consideration to it before making a determination on the proposal.

In any case, as a retired scientist who has read the science on this matter for years, I do not think that the Government has properly considered the totality of the environmental impacts from biomass with carbon capture and storage in developing its policy, and **I submit that the project should be recommended for refusal**.

Contents

1 INTRODUCTION

1.1 Deadline 2 (D2)

1 This is my Written Representation submission for Deadline D2. I previously submitted a Relevant Representation which is reproduced in clear format at Appendix G.

2 LEGAL AND POLICY FRAMEWORK

2.1 Planning Act 2008

2 As laid out at paragraphs 15.2.7 onwards of the Environmental Statement (ES) [APP-051], the applicable policy framework for the application includes:

- The Overarching National Policy Statement for Energy (EN-1)
- Draft Overarching National Policy Statement for Energy (EN1)
- National Policy Statement for Renewable Energy Infrastructure (EN-3)
- Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)

3 As the application has applicable national policy statements, section 104 of the Planning Act 2008 ("**the 2008 Act**") applies to the decision making. This states that the Secretary of State must decide an application for energy infrastructure in accordance with the relevant NPSs except to the extent s/he is satisfied that to do so would:

- lead to the UK being in breach of its international obligations (s104(4));
- be in breach of any statutory duty (s104(5));
- be unlawful (s104(6));
- result in adverse impacts from the development outweighing the benefits (s104(7)); or
- be contrary to regulations about how its decisions are to be taken (s104(8)).

2.2 The 2017 Regulations

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

5 The EIA process, including the preparation of an Environmental Statement (ES), must identify, describe and assess (those being separate statutory steps) in an appropriate manner, in light of each individual case, the direct and indirect significant effects of the proposed development on various prescribed factors, including <u>climate (for example the nature and magnitude of greenhouse gas emissions)</u>: see reg. 5(1), 5(2)(c) and Schedule 4, para. 5(f) of the 2017 Regulations. Further details are given in Appendix A.

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

> *"A description of the likely significant effects of the development on the environment resulting from, inter alia:*
>
> *[…]*
>
> *(e) the cumulation of effects with other existing and/or approved projects […]*
>
> *(f) the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.*
>
> *[…]*
>
> *The description of the likely significant effects on the factors specified in regulation 5(2) should cover the direct effects and <u>any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects</u> of the development …".*

7 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.

3 LULUCF GHG emissions

8 The United Nations[1] define "Land use, land-use change, and forestry" ("**LULUCF**"), also referred to as Forestry and other land use (FOLU), as a "*greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities.*"

9 LULUCF has impacts on the global carbon cycle and as such, these activities can add or remove carbon dioxide (or, more generally, carbon) from the atmosphere, influencing climate[2].

3.1 Treatment of LULUCF GHG emissions in the EIA scoping

10 The Scope of the assessment of GHG emissions from the project is presented at section 15.4 of the ES [APP-051].

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[1] "Glossary of climate change acronyms and terms", UNFCCC website, at: [redacted]

[2] "Land use, land-use change, and forestry", Wikipedia page at: [redacted]

11 I am concerned mainly with operational GHG emissions in this submission. However, I note under Table 15.3 of the ES [APP-051], that the Applicant identifies "Land use, land use change and forestry (LULUCF) at construction phase" as PAS 2080[3] module A5 construction phase GHG emissions, and as scoped in.

12 For operational emissions, under Table 15.4 of the ES [APP-051], the Applicant identifies "LULUCF during operation" as PAS 2080 module B8 operational phase GHG emissions is scoped in.

13 Paragraph 15.3.37 explains what LULUCF emissions are scoped in as "*for the Proposed Scheme, this relates to habitats that are reinstated, retained or improved*" This is essentially only LULUCF emissions from the proposed development site, or close to it, comprising the "East Construction Laydown Area, Woodyard, Habitat Provision Area, and the Off-site Habitat Provision Area".

14 Critically, this does not include process LULUCF emissions generated from biomass fuel production and their interaction with the global carbon cycle. A very narrow definition of LULUCF GHG has been used in the scoping; for example, it only covers direct effects at the site and the Off-site Habitat Provision Area. It does not cover "indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects" of LULUCF GHGs associated with the project as required by the 2017 regulations.

3.2 Treatment of LULUCF GHG emissions in the ES

15 Growing trees and felling them for biomass fuel production has a LULUCF carbon footprint. The science shows that this is a complex footprint which varies over time, on the timescales of centuries. The simplistic assumption that the carbon released from biomass combustion is immediately sequestered by new forest growth is false: the effects on the carbon cycle over time are critical as will be made clear in the later section on the "Scientific implications". Whilst a number on nations, including the United Kingdom, consider bioenergy to be carbon neutral and exclude the carbon dioxide generated from wood bioenergy combustion from GHG accounting, this is also false and incorrect scientifically.

16 Irrespective of the fact that carbon capture and storage ("**CCS**") is proposed, the severe carbon accounting error on the biomass combustion process itself resulting from omitting LULUCF emission from fuel processing means that all other subsequent assessment in the ES is flawed, and also deeply incorrect in scientific terms.

17 I am aware that it is because the UK consider "bioenergy to be carbon neutral" that **the LULUCF emissions for the fuel production of wood for Drax have not been accounted for in the ES.** As well as the extremely limited and misleading scoping of LULUCF emissions under PAS 2080, Plate 1.1 in "Appendix 15.2: Proposed Scheme GHG Emissions

[3] BSI. (2016). PAS 2080: Carbon Management in Infrastructure. BSI.

Calculation" [APP-169] also makes it clear that the LULUCF emissions accounted for under operational emissions are not from the fuel production supply chain.

18 Further confirmation of this comes from paragraph 15.5.27 which lists the stages of "biomass sourcing" supply chain emissions (a. to h.). The LULUCF emissions from fuel production are not included (and are not included under item "a. Processing at origin"). The very significant impact of LULUCF emissions on the global carbon cycle has been omitted from the fuel sourcing.

3.3 Legal implications of the exclusion of fuel production LULUCF GHG emissions

19 **The 2017 Regulations**: The main implication is that the LULUCF emissions associated with the scheme, not just for the next decade, or until 2050, but for centuries has been omitted, and this breaches the requirements under the 2017 regulations to describe "the likely significant effects on the factors specified in regulation 5(2)" including "any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the development".

20 The ES, therefore, does not comply with the 2017 Regulations as LULUCF emissions from fuel production around the world and their effects have not been accounted for, nor assessed, in the ES. I submit that this is unlawful and breaches the 2017 regulations.

21 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.

3.4 Other implications of the exclusion of fuel production LULUCF GHG emissions

22 **Study area:** Paragraph 15.6.1 states "the GHG assessment is not restricted by geographical area but instead includes any increase or decrease in GHG emissions as a result of the Proposed Scheme, wherever that may be". This is false as the LULUCF emissions from fuel production are not accounted for in the ES.

23 **BEIS Biomass Policy Statement ("BPS"):** This states:

"The Government is clear that any BECCS deployment must be genuinely and credibly 'net negative', meaning it must remove more GHG emissions from the atmosphere than it creates, and store them in long-term geological storage. This assessment would include all GHGs (including methane and nitrous oxide) from the whole BECCS supply chain, including carbon capture at the capture plant and eventual store."

24 The ES is not consistent with the BEIS BPS as the LULUCF emissions from fuel production which are part of the "whole BECCS supply chain" are not accounted for in the ES.

3.5 Further implications of breaching the 2017 regulations

25 I draw the ExA's attention to the recent intervention by the Office for Environmental Protection ("OEP") in the appeal of R (Finch) v Surrey County Council on February 9th 2023. The OEP Press Release is provided in Appendix F. This concerns a judicial review of the grant of planning permission for new oil wells on a site in Surrey. The Supreme Court will consider whether Surrey County Council (SCC) acted lawfully by not requiring the development's environmental impact assessment (EIA) to assess the impact of greenhouse gas emissions resulting from the future combustion of oil produced by the new oil wells. The specific issue in the Finch case is the indirect effects under the 2017 Regulations of downstream GHG emissions from the consumer combustion of the oil.

26 I submit that the indirect emissions from LULUCF emissions from the fuel production for the Drax proposal is arguably a similar legal issue. In the Finch case, the treatment of downstream emissions from fuel combustion under the EIA Regulations is under judicial review, and in the Drax examination the treatment of upstream emissions from LULUCF emissions from the fuel production under the 2017 regulations is of concern.

27 It should be noted that General Counsel for the OEP, Peter Ashford highlighted clarification of the principles involved as the reason for the OEP intervention in saying "*We hope that the Supreme Court will take this opportunity, and will develop principles for determining the proper approach to the assessment of indirect effects under the EIA legislation*", see Appendix F.

3.6 Errors in the ES

28 With reference to the very limited dealing of LULUCF emissions in the ES (not related to the fuel production LULUCF emissions), I report <u>two</u> errors.

29 The <u>first</u> is that Table 15.8 gives "Land use, land use change and forestry (LULUCF)" emissions as -10,863tC [tonnes of <u>carbon(C)</u>, not carbon dioxide (CO2)]. This is the same figure as in Table 1.1 of Appendix 15.1 [APP-168] for the <u>baseline</u> GHG calculation.

30 However in the final assessment table at Table 15.11, the "Baseline scenario potential carbon storage (tC)" is given as -8,760tC. This figure is not consistent with the figure of -10,863tC above.

31 The wrong net figure of 707tC is then put into the main table in Table 15.11 where the units are tCO2. The <u>second</u> error is that the sum of the table "Net total" is wrong as data in two different physical units (tC and tCO2) have been summed.

4 SCIENTIFIC IMPLICATIONS OF THE EXCLUSION OF LULUCF EMISSIONS FROM FUEL PRODUCTION

32 The issue that the impact of biomass energy lifecycle on the global carbon cycle on a centuries timescale was being incorrectly considered by governments is not new. Scientists have been warning of a critical climate accounting error that required "fixing" since 2009[4].

33 I consider this of such importance that I reproduce as appendices 3 key papers:

C. "*Does wood bioenergy help or harm the climate?*", Professor John Sherman, Massachusetts Institute of Technology (MIT) and colleagues, Appendix C

D. "*Correcting a fundamental error in greenhouse gas accounting related to bioenergy*", Professor Helmut Haberl, Alpen-Adria Universitaet, Vienna and colleagues, Appendix D

E. "*Serious mismatches continue between science and policy in forest bioenergy*", Dr Michael Norton, EASAC[5] Secretariat, German Academy of Sciences Leopoldina and colleagues, Appendix E

4.1 A short walk through the 2022 paper

34 I refer the ExA to the paper from Professor John Sherman from MIT and colleagues which is fully reproduced at Appendix C and is entitled "Does wood bioenergy help or harm the climate?". The relevance of the paper is clear from these sentences in the abstract:

> *"Therefore, the first impact of wood bioenergy is to increase the carbon dioxide in the atmosphere, worsening climate change. Forest regrowth might eventually remove that extra carbon dioxide from the atmosphere, but regrowth is uncertain and takes time – <u>decades to a century or more</u>, depending on forest composition and climatic zone – time we do not have to cut emissions enough to avoid the worst harms from climate change. More effective ways to cut greenhouse gas emissions are already available and affordable now, allowing forests to continue to serve as carbon sinks and moderate climate change."*

35 The key issue is the interaction of the carbon lifecycle of a biomass facility and its fuel production with the global carbon cycle, which poses questions such as "when wood biomass is combusted how long does it take to be genuinely become "carbon neutral" (also known as the "carbon debt payback time")?" and if there is delay, "what is the effect on the climate?". To answer this, the paper asks a series of questions:

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[4] Searchinger, T.D., Hamburg, S.P., Melillo, J., Chameides, W., Havlik, P., Kammen, D.M., Likens, G.E., Lubowski, R.N., Obersteiner, M., Oppenheimer, M., Philip Robertson, G., Schlesinger, W.H., David Tilman, G., 2009. Fixing a critical climate accounting error. Science 326, 527–528.

[5] European Academies' Science Advisory Council

(A) How much carbon dioxide does burning wood for energy add to the atmosphere?

(B) Will the forests harvested for bioenergy regrow? If so, how long will it take?

(C) Are the forests harvested for bioenergy growing and removing carbon dioxide now?

36 The authors then generate a "dynamic lifecycle assessment ("DLA") of wood bioenergy" examining these questions out to 2200 and beyond. Point (C) is crucial, and the DLA shows that:

> *"… the carbon sequestered by regrowth is initially less than the carbon the forest would have stored had it not been harvested"*

This means the biomass combustion emissions have been added to the atmosphere, have not been compensated, and therefore increase global levels of CO2.

37 The paper also notes that <u>regrowth is uncertain</u> (other uses may be made of the land in land use change), and <u>regrowth takes time</u>.

38 This is the crux of the issue about LULUCF emissions from the fuel production for the project. The carbon sunk in the trees which are processed for fuel <u>is not replaced by regrowth in zero time</u>. This leads to increases in atmospheric GHG emissions now. The harvesting also prevents additional growth in the forest and carbon sinking from that growth is lost over the next few decades.

39 For an example of a forest[6] harvested for biomass fuel in 2025, the impact is to increase (absolute levels of) GHG emissions until 2040. If genuinely zero-carbon energy was used instead of biomass, then the atmospheric CO2 from the combusted fuel in the biomass case remains above its initial level before 2025 (ie: zero) <u>until after 2200</u>. The paper explains that after centuries of carbon debt payback "eventual carbon neutrality" may be reached for the combusted biomass. **However "*eventual carbon neutrality*" is not "*climate neutrality*".**

40 It should be noted that the authors point out that their DLA modelling is optimistic as it does not include additional losses of CO2 due to soil disturbances in harvesting (eg: soil carbon oxidation), and it does not consider non-climate harms (ecological eg: habitat fragmentation and loss of biodiversity). I anticipate that some of these latter ecological harms may be dealt with by Biofuelwatch in their written representation.

41 All of these indirect climate and ecological impacts of the Drax project associated with the fuel production are not being accounted for in the ES in breach of the EIA Regulations.

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6 a 50-year-old oak-hickory forest in the south-central USA

42 The paper addresses these impacts are, and states:

> *"Even temporarily elevated levels of atmospheric carbon dioxide cause irreversible climate damage (IPCC 2022; Solomon et al. 2009). The excess carbon dioxide from wood bioenergy begins warming the climate immediately upon entering the atmosphere. The harms caused by that additional warming are not undone even if the carbon debt from wood energy is eventually repaid:"*

43 The seriousness of this cannot be underestimated. As the papers states:

> *"The excess warming from wood bioenergy increases the chances of going beyond various climate tipping points that could lead to runaway climate change: emissions "pathways that overshoot 1.5°C run a greater risk of passing through 'tipping points,' thresholds beyond which certain impacts can no longer be avoided even if temperatures are brought back down later on" (IPCC 2018, 283). Carbon neutrality is not climate neutrality."* {Emphasis in original}

44 It is on the basis of this very serious impact of the LULUCF emissions from the operation of the Drax scheme, via its fuel production, on international and national climate targets that **the breaching the 2017 regulations is extremely significant**. This is not a "minor breach": it is very serious and a response must be made by the applicant on the matter. **Further, it is essential that the Secretary of Statement is fully briefed on the science of this issue, and the ramifications of it for delivery of international and national climate targets, and gives detailed and due consideration to it before making a determination on the proposal.**

5 IMPLICATIONS OF THE EXCLUSION OF LULUCF EMISSIONS FROM FUEL PRODUCTION FOR THE EXAMINATION

45 The UK now has a legal and policy framework on Climate Change which contains several legal requirements, for example: the Net Zero target 2050, the Sixth Carbon Budget, the 2030 68% reduction target, the 2035 78% reduction target; and policy to deliver these legal requirements, for example, the Net Zero Strategy. Without proper calculation, description and significance assessment of the LULUCF emissions of the project, the impact on these legally binding targets and budgets is simply unquantified and unknown. This is a short-term impact which just is not known or presented by the applicant in the Environmental Statement.

46 The key issue is then how the LULUCF emissions from upstream fuel production may be calculated, described and assessed. This is a necessary step for the application to discharge the requirements under the 2017 regulations, and for the Secretary of State to be able to make a reasoned decision under section 104 of the 2008 Act.

47 I respectfully suggest to the Examining Authority ("ExA") that this matter needs urgent resolution. I request that the ExA give consideration to Reg 20 (1) of the 2017 Regulations which provides the Examining authority with the option to 'suspend consideration of the application' if it is necessary for the ES to contain further information.

6 CONCLUSIONS

48 Indirect LULUCF GHG emissions from the upstream fuel processing comprise a very significant, and centuries long climate change impact associated with the proposed Drax facility.

49 Consideration of these LULUCF emissions and their impact shows that the biomass combustion process cannot be considered “carbon neutral” within the timescales of current national climate policy (ie until 2050).

50 The Environmental Impact Assessment regulations require that such indirect impacts (including transboundary, cumulative, short-term, long-term significant effects) are identified, described and assessed within the Environmental Statement. <u>They have not been on the Drax application which is a breach of the 2017 regulations.</u>

51 The Secretary of State cannot make a legitimate decision under section 104 of the 2008 Act until the requirements under the 2017 regulations have been discharged.

52 I respectfully suggest to the Examining Authority (“ExA”) that the matter of the upstream LULUCF emissions from biomass fuel processing needs urgent resolution. I request that the ExA give consideration to Reg 20 (1) of the 2017 Regulations which provides the Examining authority with the option to ‘suspend consideration of the application’ if it is necessary for the ES to contain further information.

53 Further, it is essential that the Secretary of Statement is fully briefed on the science of this issue, and the ramifications of it for delivery of international and national climate targets, and gives detailed and due consideration to it before making a determination on the proposal.

54 In any case, as a retired scientist who has read the science on this matter for years, I do not think that the Government has properly considered the totality of the environmental impacts from biomass with carbon capture and storage in developing its policy, and I submit that the project should be recommended for refusal.

[redacted]

Dr Andrew Boswell,
Climate Emergency Policy and Planning, February 22nd 2023

7 APPENDIX A: LEGAL FRAMEWORK: ENVIRONMENTAL IMPACT ASSESSMENT

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

56 The EIA process, including the preparation of an ES, must identify, describe and assess (those being separate statutory steps) in an appropriate manner, in light of each individual case, the direct and indirect significant effects of the proposed development on various prescribed factors, including climate (for example the nature and magnitude of greenhouse gas emissions): see reg. 5(1), 5(2)(c) and Schedule 4, para. 5(f) of the 2017 Regulations.

57 By reg. 14(2) [CB/344-45], the ES must include, at least, the information set out in reg. 14(2)(a) to (f). This includes:

> "…
>
> *(b) a description of the likely significant effects of the proposed development on the environment [… and]*
>
> *(f) any additional information specified in Schedule 4 relevant to the specific characteristics of the particular development or type of development and to the environmental features likely to be significantly affected."*

58 By reg. 14(3)(b). an ES must:

> *"… include the information reasonably required for reaching a reasoned conclusion on the significant effects of the development on the environment, taking into account current knowledge and methods of assessment;"*

59 In turn, paragraph 5 of Schedule 4 to the 2017 Regulations requires the environmental statement to include:

> *"A description of the likely significant effects of the development on the environment resulting from, inter alia:*
>
> *[…]*
>
> *(e) the cumulation of effects with other existing and/or approved projects […]*
>
> *(f) the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.*

[…]

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 …".

60 When deciding whether to make an order granting development consent for relevant development the Secretary of State must, by reg. 21(1) [CB/346]:

"(a) examine the environmental information;

(b) reach a reasoned conclusion on the significant effects of the proposed development on the environment, taking into account the examination referred to in sub-paragraph (a) and, where appropriate, any supplementary examination considered necessary;

(c) integrate that conclusion into the decision as to whether an order is to be granted

[…]"

61 'Environmental information' is defined by reg.3(1) as:

"… the environmental statement […], including any further information and any other information, any representations made by any body required by these Regulations to be invited to make representations and any representations duly made by any other person about the environmental effects of the development and of any associated development…"

62 It follows that the conclusion on whether development consent is granted must be based on an assessment of the significant effects of the proposed development on the environment which must in turn take into account (among other things) *a description of the likely significant effects of the development on the environment resulting from the cumulation of effects with other existing and/or approved projects*. That involves three distinct stages: (1) identification and description of those cumulative effects, (2) assessment of their significance, and (3) integration of that into the decision on whether development consent should be granted.

7.1 Accepted application—effect of environmental statement being inadequate

63 Reg 20 (1) provides the Examining authority with the option to 'suspend consideration of the application' if it is necessary for the ES to contain further information. This situation would arise if the ES was found to be inadequate because it failed to make an adequate assessment of the significant effects of the proposed development on the environment, for example, because the ES did not include a description of the likely significant effects of the

development on the environment resulting from the cumulation of effects with other existing and/or approved projects, or a description of the likely significant effects of the development on the environment resulting from indirect impacts (including transboundary, cumulative, short-term, long-term significant effects).

64 The necessary steps are provided at Reg 20 as follows:

> *"(1) Where an Examining authority is examining an application for an order granting development consent and paragraph (2) applies, the Examining authority must—*
>
> > *(a)issue a written statement giving clearly and precisely the reasons for its conclusion;*
> >
> > *(b)send a copy of that written statement to the applicant; and*
> >
> > *(c)suspend consideration of the application until the requirements of paragraph (3) and, where appropriate, paragraph (4) are satisfied.*
>
> *(2) This paragraph applies if—*
>
> > *(a)the applicant has submitted a statement that the applicant refers to as an environmental statement; and*
> >
> > *(b)the Examining authority is of the view that it is necessary for the statement to contain further information.*
>
> *(3) The requirements mentioned in paragraph (1) are that the applicant must—*
>
> > *(a)provide the Examining authority with the further information;*
> >
> > *[…]"*

8 APPENDIX B: SCIENCE-BASED CARBON BUDGETS AND COMPLIANCE WITH THE PARIS AGREEMENT

65 This appendix is provided to give some overall context to carbon budgets, and the difference between policy-based carbon budgets, such as those in the UK carbon budgets, and science-based carbon budgets, such as the Tyndall Centre budgets.

8.1 What is a carbon budget and how is it produced?

66 A financial budget is defined as ‘a plan to show how much money a person or organisation will earn and how much they will need or be able to spend’[7]. A carbon budget is similar, but instead of money, it sets out “the cumulative amount of carbon dioxide (CO2) emissions permitted over a period of time to keep within a certain temperature threshold[8].” **Unlike money, for carbon budgets, there are no overdraft facilities, nor national deficits, not quantitative easing mechanisms from central banks.** Once a CO2 budget is spent, it cannot be recovered, and the laws of physics determine the consequences for the planet and for humanity[9]. Carbon budgets are a tool to help reveal the truth of this situation.

67 The “laws of physics” can now provide increasingly accurate modelling of the global and local carbon budgets. In the last five years the reports of the Intergovernmental Panel on Climate Change (IPCC) have highlighted that our political institutions, businesses, and society have not started to respond to the climate emergency with the urgency required. Simply put humanity is living outside of our budget.

68 Collectively, we now know that this decade is the most crucial decade for reversing 200 years of carbon polluting activities, reversing the rash, profligate spending of our collective carbon budget, and building a new future based on a non-polluting global society. It is crucial that we address this emergency using every tool possible, and this includes carbon budgets and their capacity to point to where we are not doing enough, as captured by IEMA[10] (in its best practice guidance of EIA assessment of GHGs from infrastructure projects) as “*doing enough to align with and contribute to the relevant transition scenario, keeping the UK on track towards net zero by 2050 with at least a 78% reduction by 2035 [footnote 37],and thereby potentially avoiding significant adverse effects.”*

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7 [redacted]

8 [redacted]

9 Greenhouse gas removals (GGR) and negative emissions technologies may provide extremely costly, speculative, and unproven at scale methods which proxy for an “overdraft facility”. Even if these work, they would be like paying back a loan at a huge interest rate. See, in core documents, Kevin Anderson , John F. Broderick & Isak Stoddard (2020): A factor of two: how the mitigation plans of ‘climate progressive’ nations fall far short of Paris-compliant pathways, Climate Policy, DOI: 10.1080/14693062.2020.1728209, Appendix A “*However, there is wide recognition that the efficacy and global rollout of such technologies are highly speculative, with a non-trivial risk of failing to deliver at, or even approaching, the scales typically assumed in the models. … Whilst the authors of this paper are supportive of funding further research, development and, potentially, deployment of NETs, the assumption that they will significantly extend the carbon budgets is a serious moral hazard (Anderson & Peters, 2016).*”

10 Institute of Environmental Management & Assessment (IEMA), “Assessing greenhouse gas emissions and evaluating their significance”, version 2, 2022

8.2 Relationship of a carbon budget and the 2015 Paris Agreement

69 The Paris Agreement 2015 is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016[11]. The UK is a signatory to the agreement. Its goal is to limit global heating to well below 2°C degrees, preferably to 1.5 °C, compared to pre-industrial levels.

70 Scientists have established models that calculate how much more carbon dioxide[12], at various statistical probabilities, may be emitted globally into the atmosphere before breaching various temperatures of global overheating – eg: how many billions of tonnes (or Gigatonnes, GtCO2) before breaching 1.5 degrees (at 66% chance), how many billions of tonnes before breaching 2.0 degrees etc (at 50% chance). These are referred to as carbon budgets, and I have previously explained them above as a bank account analogy but with no overdraft, deficit, or quantitative easing facilities available.

8.3 The difference between policy-based and science-based carbon budgets

71 It is important to understand the difference between science-based carbon budgets and political targets like the UK net-zero target. Net-zero by 2050 can be achieved by many different paths or trajectories of annual carbon emissions, and the carbon emitted is basically the area under the curve. Annual emissions cuts may be applied late (known as "backloaded") or early (known as "frontloaded") depending on policy decisions. Policy that delivers backloaded, or less steeply front-loaded, cuts will have a much greater quantum of carbon emissions emitted under the curve on the way to get to net-zero, and therefore also require larger carbon budgets (from the fixed global budget).

72 **Science-based carbon budgets by contrast** aim to define a curve or trajectory which meet the criterion of fitting within the global carbon budget. That is science-based carbon budgets follow the path necessary to meet a temperature target aligned to the Paris agreement.

73 The UK Committee on Climate Change publish paths and budgets, and Parliament has placed them in statute, but their ability to meet the criterion of the Paris temperature target has not been demonstrated scientifically – although CCC may genuinely endeavour to meet that criterion. In fact, the CCC budgets, and assumptions, and hence UK carbon budgets, are increasingly challenged by scientists, see below.

11 [redacted]

12 In fact, the models assess a variety of Greenhouse Gases, but for simplicity I restrict this document to CO2 (carbon dioxide) carbon budgets.

74 It is further worth noting that a recent report[13] from Climate Crisis Advisory Group (CCAG) has recently said that there is no remaining carbon budget for the 1.5°C Paris temperature target and policy should be directed towards net-negative carbon emissions as soon as possible. The report says:

> *"**The CCAG is clear that the current shift in global emissions is not sufficient to avoid global disaster, and there is no 'remaining Carbon Budget'**. If proper account is taken of all greenhouse gases, and their CO2 equivalence, the 450ppm threshold has already passed, contradicting the widespread notion of a 'carbon budget' that could still be spent whilst remaining below 1.5°C temperature rise."*

The CCAG was founded, and is chaired, by the eminent scientist Professor Sir David King, Fellow the Royal Society (FRS), and former UK Government's Chief Scientific Advisor from 2000 to 2007. CCAG comprises prominent climate scientists. It was created in response to the Climate Emergency in 2021, as a new advisory group to help inform the public, governments and financial institutions providing them with the most comprehensive science, and more crucially, guiding them towards action for climate repair. CCAG's important scientific commentary on the climate crisis can be made by their small group on a faster cycle than the IPCC.

8.4 Science-based carbon budget assessment of compliance against UK obligations under the Paris agreement

75 To understand what emission reductions should be made in UK local authority areas to make a 'fair' contribution[14] towards the Paris Climate Change Agreement, scientists at Manchester Tyndall Centre have taken IPCC global carbon budgets and produced the so-called SCATTER budgets for UK local authorities. SCATTER stands for Setting City Area Targets and Trajectories for Emissions Reduction project and was funded by the Department for Business Energy and Industrial Strategy (BEIS). It developed a methodology for Local Authorities to set carbon emissions targets that are consistent with United Nations Paris Climate Agreement[15].

76 These science-based budgets translate the "well below 2°C and pursuing 1.5°C" global temperature target, and the equity principles enshrined in the United Nations Paris Agreement, to a national UK carbon budget which is then split between sub-national areas using different allocation regimes.

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[13] CCAG report, August 2021, "The final warning bell", [redacted]

[14] 'fair' meaning equitable under the Paris Agreement equity principles between developing and developed nations, known as Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) [redacted]

[15] [redacted]

77 The assumptions for this transformation from global to local budgets in given in two sources:

a) a 2020 Climate Policy paper[16], widely referred to as the "Factor of Two" paper

b) the "full" reports from the Tyndall Carbon Budget Tool for UK Local Authorities, widely referred to SCATTER budgets

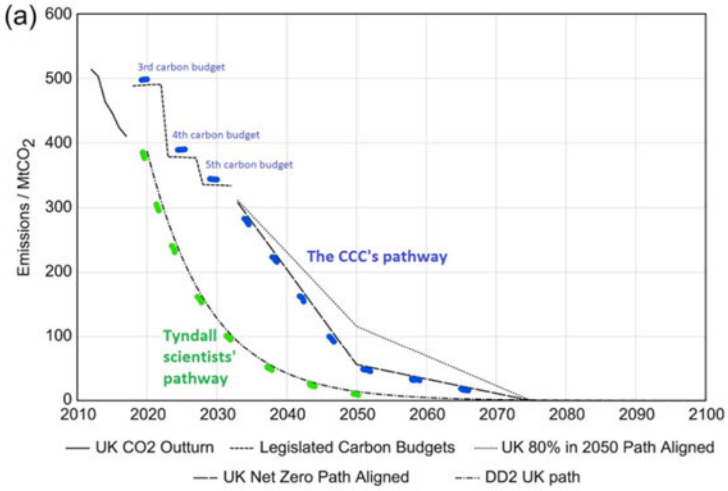
These two sources are authored by the same research group and are internally consistent. The "Factor of Two" paper is a landmark in 2020 in appraising national carbon budgets.

8.5 Comparison to carbon budgets/targets derivable from the Climate Change Committee

78 Following, the Climate Change Committee (CCC) sixth Carbon Budget (6CB) report, the UK has enshrined in law and policy its headline recommendation is for the UK to deliver a reduction in net annual emissions of 78%, against a 1990 baseline, by 2035. The previous UK ambition was targeting an 80% reduction against 1990 figures by 2050 under the original Climate Change Act, so this represents a halving of the time to get to around 80% emission cuts (against 1990 baseline) from 2020.

79 However, the CCC do not show anywhere how the 6th Carbon Budget (6CB) can be derived directly by a stepwise downscaling from a scientifically established global carbon budget (in contrast to the Manchester Tyndall research and references above which do demonstrate this). The derivation of the 6CB is focussed more on meeting the national, politically set, net zero-target of 2050 via an array of policy interventions rather than fitting to a specific carbon budget (relating to the back-loading and front-loading point above). The point here is that are many possible pathways to reach net-zero, and each will have different accumulated carbon emissions under the curve – so one can reach net-zero having added more or less emissions to the global atmosphere, some pathways may blow our carbon budgets. The science-based carbon budget approach is designed to specify a pathway which keeps within the carbon budgets.

[16] Kevin Anderson, John F. Broderick & Isak Stoddard (2020): A factor of two: how the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways, Climate Policy, DOI: 10.1080/14693062.2020.1728209



This graph is from the Factor of Two paper by climate scientists at the Tyndall centre. People & Nature added the highlights. The pathway for UK carbon emissions highlighted in green is one that, the scientists argue, is compatible with the Paris agreement. The pathway highlighted in blue is one they have plotted to reflect the CCC's emissions reductions proposals: it implies cutting emissions at about half the pace that the scientists' pathway implies

Figure CEPP.Drax.Fig-1: Comparison of science-based Tyndall Centre et and policy-based CCC carbon budgets, and Paris Agreement alignment (reproduced)

80 Generally, the difference between the Tyndall and CCC carbon budgets is that the Tyndall ones are 2 – 3 times smaller (and tighter). As shown above, the Tyndall budgets have rapid decarbonisation from 2020 in order to meet the overall budget (area under the curve). The Tyndall trajectory is derived from the IPCC budget for 1.7°C[17], supporting the point from CCAG that there is no remaining budget for 1.5°C (it is simply not possible to calculate the Tyndall budgets for 1.5 °C[18]). So the Tyndall budgets are consistent with IPCC global carbon budgets of 1.7°C degrees of global heating. This is not 1.5°C because, essentially, there are not enough degrees of freedom in the system to produce budgets consistent with 1.5°C, the lowest end of the Paris target[19].

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[17] at 50% chance in the IPCC SR1.5 report

[18] at a greater than a 17% chance

[19] see Tyndall's "Factor of Two" research paper, Kevin Anderson, John F. Broderick & Isak Stoddard (2020) A factor of two: how the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways, Climate Policy, 20:10, 1290-1304, DOI: 10.1080/14693062.2020.1728209

81 The graph above is taken from[20] and illustrates the difference between CCC and Tyndall carbon budgets. In simple terms, the carbon budget is the area under the annual emissions trajectory curve. Issues such the shape of the curve, front-loading or back-loading emissions reductions can produce vastly different curves and corresponding *areas under the curve*.

82 So it is possible for the UK to meet net-zero at 2050 via vastly different overall carbon budgets – the green line in the graph meets the global budget for 1.7 ^{o}C, the blue CCC pathway overshoots this temperature target. <u>Therefore "net-zero", in itself, is not a good measure of compliance with the Paris agreement temperature target whereas a science-based carbon budget is.</u>

83 Note, the details of the carbon accounting differ, so it is not easy to get a like-for-like comparison between the science-based carbon budget from Manchester Tyndall and the Climate Change Committee budgets. For further information, see footnotes[21].

84 Simply put the UK carbon budgets are based on the policy-driven target of net-zero by 2050. However, such a policy-driven target does not consider the overall emissions generated in how the UK gets to net-zero[22].

85 A key issue is the "area under the curve" in the emissions trajectories. Science-based carbon budgets such as those from the Tyndall Centre, research that the UK Department of Business, Energy and Industrial Strategy supported, demonstrate that the area under their curve of their emissions trajectories is consistent with the global carbon budgets from the Intergovernmental Panel on Climate Change (IPCC).

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[20] [redacted]

[21] "How the UK Climate Change Committee steals from the carbon budget", blog post by Professor Peter Somerville, 8th July 2021, [redacted]/ and "Calculating a fair carbon budget for the UK". blog post by Professor Peter Somerville, 8th July 2021, [redacted]

[22] This is clearly evidenced by the overarching UK Net Zero Strategy being found unlawful (London High Court judgment, July 18th 2022) and the UK Government accepting this by not appealing (October 13th 2022).

8.6 The risk in delivering Climate Change Committee budgets

86 Even on their own terms, these policy-based targets are far from guaranteed to be delivered with the state of current climate policy. This is evidenced by the recent legal case[23] on the UK Net Zero Strategy (NZS) where it was found that the policies had not been properly quantified, and that the UK Government had not considered several things, especially **the risk to delivery of the policies** in their strategy for meeting the sixth carbon budget. The UK Government have accepted the NZS is unlawful[24] and are not appealing.

87 Further on 29th June 2022, the Climate Change Committee (CCC) submitted its "Progress in reducing Emissions[25] - 2022 Report to Parliament" and found that "credible plans" existed for only 39% of the required emissions reduction to meet the UK Sixth Carbon Budget. This indicating a clear policy shortfall in policy on Climate Change across the UK, see Appendix D.

88 Over the period to 2050 in the UK, the Tyndall Centre found that at least two times as much carbon would be produced comparing the UK carbon budgets with their own science-based targets[26]. If the science-based budgets from Tyndall Centre can only deliver a UK contribution towards 1.7°C at best, then the CCC budgets for both the UK and Scotland are only consistent with a much-greater global heating temperature target with more than twice as many emissions being produced by 2050. Note the UK's obligation under the Paris Agreement is to "*keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius*".

89 In short, science-based targets give a far more accurate picture for assessment and risk analysis than nationally legislated carbon budgets. This especially applies to assessing whether infrastructure is consistent with the UK's commitments under the Paris Agreement. The best practice IEMA guidance also strongly encourages the use of science-based carbon budgets for local and regional contextualisation.

[23] See the judgment at [redacted] and the Court's Order at [redacted]

[24] "Government accepts its flagship climate strategy is unlawful"[redacted]

[25] [redacted]

[26] "Factor of two" paper as above

9 APPENDIX C: "Does wood bioenergy help or harm the climate?" PAPER, 2022

Does wood bioenergy help or harm the climate?

John Sterman, William Moomaw, Juliette N. Rooney-Varga & Lori Siegel
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Does wood bioenergy help or harm the climate?

John Sterman, William Moomaw, Juliette N. Rooney-Varga and Lori Siegel

ABSTRACT

The EU, UK, US, and other nations consider wood to be a carbon neutral fuel, ignoring the carbon dioxide emitted from wood combustion in their greenhouse gas accounting. Many countries subsidize wood energy – often by burning wood pellets in place of coal for electric power – to meet their renewable energy targets. But can wood bioenergy help cut greenhouse emissions in time to limit the worst damage from climate change? The argument in favor seems obvious: wood, a renewable resource, must be better than burning fossil fuels. But wood emits more carbon dioxide per kilowatt-hour than coal – and far more than other fossil fuels. Therefore, the first impact of wood bioenergy is to increase the carbon dioxide in the atmosphere, worsening climate change. Forest regrowth might eventually remove that extra carbon dioxide from the atmosphere, but regrowth is uncertain and takes time – decades to a century or more, depending on forest composition and climatic zone – time we do not have to cut emissions enough to avoid the worst harms from climate change. More effective ways to cut greenhouse gas emissions are already available and affordable now, allowing forests to continue to serve as carbon sinks and moderate climate change.

KEYWORDS

Biomass; bioenergy; carbon dioxide; climate change; forestry; greenhouse emissions; wood combustion

In the 2015 Paris climate accord, 197 countries agreed to limit warming to "well below 2 degrees Celsius," and to strive for 1.5 degrees Celsius. To have even a roughly 50 percent chance of achieving this goal, net global greenhouse gas emissions must be cut by nearly half from 2010 levels this decade and reach zero by mid-century (UNFCCC 2021). Consequently, at least 140 countries, accounting for about 90 percent of global greenhouse gas emissions, have pledged to reach net zero emissions around the middle of this century (Climate Action Tracker 2021). But few have specified how they will do so. A growing number, including the European Union, the United Kingdom, and the United States, have declared wood bioenergy to be carbon neutral, allowing them to exclude the carbon dioxide generated from wood bioenergy combustion in their greenhouse gas accounting. Many subsidize wood bioenergy to help meet their renewable energy targets (Norton et al. 2019). The appeal is intuitive: burning fossil fuels adds carbon that has been sequestered underground for millions of years to the atmosphere, while forests might regrow, eventually removing carbon dioxide from the atmosphere.

But can burning trees – including not just the trunk, but also the bark, branches, needles or leaves, roots, stumps, mill waste, sawdust, and all the other vegetative materials known as "biomass" that make up a forest – help cut carbon emissions in time to prevent climate catastrophe?

The bioenergy industry and many governments argue that wood bioenergy is carbon neutral. Table 1 lists some of the common claims the industry makes together with the science showing these claims to be incorrect. For example, the UN Food and Agriculture Organization claims that "While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plants grew" (Matthews and Robertson 2001). But the fact that the carbon in wood was previously removed from the atmosphere as the trees grew is irrelevant: A molecule of carbon dioxide added to the atmosphere today has the same impact on radiative forcing – its contribution to global warming – whether it comes from fossil fuels millions of years old or biomass grown last year. When burned, the carbon in those trees immediately increases atmospheric carbon dioxide above what it would have been had they not been burned.

To illustrate, consider a forest that was harvested for lumber, pulpwood, or energy 50 years ago, and has been regrowing since then. (Few forests in the United States and Europe are mature, "old growth" – most are "working forests" and go through cycles of harvest, regrowth, and reharvest [see US Forest Service 2014]). What happens if that forest is now cut and burned for energy? When the wood is burned, the carbon it contains is emitted as carbon dioxide into the atmosphere. If the forest regrows, after another 50 years it will have removed

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Table 1. Claims made about bioenergy and facts that counter those claims.

Claim: To stop climate change, it is necessary to replace fossil fuels with renewable energy, including wood bioenergy. "Well, that's the prime objective, to go to full renewables. But simply looking at how fast we need to do that, we just can't reach the levels of renewables we would need to have [to stop burning fossil fuels and meet European Union energy needs] to completely exclude biomass." Frans Timmermans, Vice President, European Commission, speaking at the 2021 UN Climate Summit, Glasgow (COP 26) (Catanoso 2021).	**Fact**: To stop climate change, greenhouse gas emissions including carbon dioxide must drop rapidly, reach net zero by approximately 2050 and be net negative after that. Burning wood for bioenergy emits carbon dioxide. Trees harvested for bioenergy may regrow, but regrowth is not certain and even if it occurs, would not remove the excess carbon dioxide from burning wood for many decades to a century or longer. In the meantime, the excess carbon dioxide remains in the atmosphere and worsens global warming. To meet our climate goals, steep carbon dioxide emission cuts from all sources are needed now (IPCC 2022; IPCC 2021).
Claim: Wood bioenergy only adds carbon that was recently taken up by trees back to the atmosphere. "While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plants grew." UN Food and Agriculture Organization (Matthews and Robertson 2001)	**Fact**: A molecule of carbon dioxide added to the atmosphere causes the same global warming whether it came from fossil fuels, trees, or other plants. "burning biomass for energy provision increases the amount of carbon in the air just like burning coal, oil or gas if harvesting the biomass decreases the amount of carbon stored in plants and soils, or reduces carbon sequestration." The result is a "fundamental accounting error" that "will likely have substantial adverse consequences" (Haberl et al. 2012).
Claim: Wood bioenergy is carbon neutral. Carbon that is emitted now and reabsorbed later has no impact on the climate. "Jen Jenkins, vice president at Enviva, the world's largest pellet producer, said her industry helped solve the climate crisis: The pellets displace coal, and even though their combustion releases carbon emissions, those would be sucked out of the atmosphere by replanted trees" (Ouzts 2019).	**Fact**: Eventual carbon neutrality is not climate neutrality. The climate damage caused by adding carbon dioxide to the atmosphere when wood is burned is not reversed even if forest regrowth eventually removes that carbon dioxide. Even if trees grow back, the additional warming creates irreversible changes: the Greenland and Antarctica ice sheets will not return, sea level will not drop, and thawing permafrost will have released more methane. These changes are not undone even if trees grow back (Solomon et al. 2009, Sterman, Siegel, and Rooney-Varga 2018b, IPCC 2022).
Claim: If trees are burned at the same rate that the forest grows, the amount of carbon stored in the forest remains constant. Therefore, wood bioenergy is carbon neutral. "In the Southeast U.S., privately owned and well managed forests produce one-fifth of the world's wood products. And even as they produce these harvested wood products, forests in the region are adding more carbon." (Enviva n.d.) "... the carbon neutrality of biomass harvested from sustainably managed forests has been recognized repeatedly by numerous studies, agencies, institutions, and rules around the world ...." US Senator Susan Collins (R, Maine) on the amendment to the Energy Policy Modernization Act, S. 2102 in 2016. "We are enormously grateful to ... all co-sponsors of this amendment, which accurately reflects the carbon beneficial impacts of power from forest biomass," Bob Cleaves, President and CEO of Biomass Power Association (Voegele 2016).	**Fact**: Growing use of wood bioenergy removes carbon from existing forests and emits it as carbon dioxide into the atmosphere. The stock of carbon on the land immediately falls. If wood for bioenergy is harvested at a constant rate and the land is replanted and allowed to regrow, regrowth may eventually equal the harvest. Until then, carbon removal exceeds carbon sequestration, causing the stock of carbon on the land to fall. If the carbon added from regrowth eventually equals the carbon removed by harvest and other losses, then the stock of carbon in the forests would stabilize and the harvest might be deemed "sustainable." But the total stock of carbon on the land stabilizes at a level lower than before wood bioenergy use began. The carbon lost from the land is added to the atmosphere, worsening climate change (Sterman, Siegel, and Rooney-Varga 2018a; Sterman, Siegel, and Rooney-Varga 2018b). When wood is taken from growing forests, the carbon that those growing trees would have removed from the atmosphere is also lost. And if bioenergy harvest grows over time, as projected, then emissions will exceed regrowth every year, even if replanting equals the harvest every year (Sterman, Siegel, and Rooney-Varga 2018a).
Claim: New trees will be planted that offset the carbon emitted from wood used for bioenergy. Dale Greene, dean of forestry at the University of Georgia, and an advisor to Drax (said) "If we harvest more (for bioenergy), we plant more and there is more carbon in the forest" (Pearce 2020).	**Fact**: Regrowth is uncertain. Land harvested for bioenergy may be converted to other uses (pasture, cropland, development). Newly planted trees may be reharvested as soon as it is economically worthwhile to do so (Newman 1988), releasing the carbon they accumulated back into the atmosphere. The result is lower stocks of carbon on the land and more in the atmosphere, worsening climate change. Newly planted trees have a high mortality rate, contain very little carbon and do not accumulate much carbon for decades (Besnard et al. 2018; Stephenson et al. 2014). Fire, drought, extreme weather, insects, and disease would cause the carbon accumulating in forests harvested for bioenergy to return to the atmosphere, worsening climate change. Climate change increases these risks (Brecka, Shahi, and Chen 2018; Xu et al. 2019), making it less likely that forests will fully recover carbon lost.
Claim: Wood bioenergy is carbon neutral when waste wood, thinnings, and wood that is not suitable for timber are burned. "Wood biomass is sourced from industrial wood waste (like sawdust), or low-grade wood, including 'thinnings,' limbs, tops or crooked and knotted trees that would otherwise not get used for lumber or other higher-value products." Seth Ginther, Executive Director, U.S. Industrial pellet Association (Booth 2018; Ginther 2018).	**Fact**: (i) Wood waste take years or decades to decompose, while burning it releases carbon immediately (Booth 2018). Allowing wood waste to decompose provides nutrients important for forest health. (ii) Much 'waste wood' unsuitable for lumber can be used in other long-lived wood-based products, like cellulose building insulation and oriented strand board keeping it out of the atmosphere for decades (Reuse Wood 2020).
Claim: Young trees grow faster than older trees. Therefore we should harvest older trees that are not accumulating much carbon, use them for bioenergy, and replace them with faster growing younger trees. "... young forests grow rapidly, removing much more CO_2 each year from the atmosphere than an older forest covering the same area" (NCASI 2021).	**Fact**: Harvesting and burning old trees releases large amounts of carbon immediately. The young trees that may grow if the land is reforested will not accumulate as much carbon as the existing forest emitted for a century or more. Older forests accumulate more carbon in trees and soils per year than do younger forests (Stephenson et al. 2014).

(Continued)

Table 1. (Continued).

Claim: Forests that are growing today are removing carbon dioxide from the atmosphere, which makes wood bioenergy carbon neutral and justifies omitting the carbon dioxide from burning wood from carbon accounting. "... since the state [North Carolina] has increasing overall timber volumes per acre and in total, we are sustainable, and we are carbon neutral or better" (Cubbage and Abt 2020). "The continued forest carbon gain across the landscape ... means that products from the Southeast U.S., including wood bioenergy, are not adding carbon emissions to the atmosphere. As a result, when wood pellets from this region are used to generate energy, we can set stack emissions to zero." (Enviva n.d.)	**Fact**: the carbon dioxide ("stack emissions") from burning wood for energy does not instantly increase forest growth on the harvested land or in forests miles away. Whether forests are growing now at landscape scale is irrelevant. What counts is the incremental impact of bioenergy on atmospheric carbon dioxide and climate change, i.e., how the amount of carbon dioxide in the atmosphere is changed by using wood bioenergy. Burning wood for energy emits carbon dioxide, increasing the amount of carbon dioxide in the atmosphere above what it would have been, even if the wood displaces coal or other fossil fuels (Sterman, Siegel, and Rooney-Varga 2018a). Harvesting wood from forests that are growing also prevents the growth of the forests that would have occurred but for harvesting and burning that wood. The faster the forests harvested for bioenergy are growing, the worse the climate impact of bioenergy (Sterman, Siegel, and Rooney-Varga 2018b).

about the same amount of carbon dioxide it emitted when it was cut and burned for energy. Until then, there's more carbon dioxide in the atmosphere than if it had not been burned, accelerating climate change.

But the situation is worse: If the forest had not been cut, it would have continued to grow, removing additional carbon from the atmosphere. Compared to allowing the forest to grow, cutting it for bioenergy would increase carbon dioxide emissions and worsen global warming for at least half a century – time we do not have to reach net-zero emissions and avoid the worst harms from climate change.

But what if the wood used to generate electricity reduces the use of fossil fuels? Wouldn't total carbon dioxide emissions then fall? That depends on how much carbon dioxide is emitted from wood relative to the fuel being displaced. To determine whether wood bioenergy can slow climate change, we therefore need to know the answers to a series of questions:

How much carbon dioxide does burning wood for energy add to the atmosphere?

Burning wood to generate electricity emits more carbon dioxide per kilowatt-hour generated than fossil fuels – even coal, the most carbon-intensive fossil fuel. Although wood and coal contain about the same amount of carbon per unit of primary energy – the raw energy in the fuel – (US EPA 2018), wood burns less efficiently, in part because it contains more water than coal. The higher the water content, the larger the fraction of the energy of combustion goes into vaporizing that water and up the flue instead of producing the heat needed to make the steam that powers the turbines and generators (Dzurenda and Banski 2017, 2019; Food and Agriculture Organization 2015). Carbon dioxide emissions from the wood supply chain also exceed those from coal. Wood must be harvested, transported to a mill, dried, processed into chips or pellets, and transported to a power plant (Figure 1). These activities emit carbon dioxide from fossil fuel-powered vehicles and machinery, plus emissions from burning wood or fossil fuels to reduce the water content of chips and pellets from approximately 50 percent for raw wood to about 10 percent for dried pellets. About 27 percent of the harvested biomass is lost in the wood pellet supply chain, of which the largest share – 18 percent – arises from burning some of the biomass to generate heat to dry pellets (Röder, Whittaker, and Thornley 2015). In contrast, coal processing adds only about 11 percent to emissions (Sterman, Siegel, and Rooney-Varga 2018a).

The situation is worse if wood displaces other fossil fuels: Wood releases about 25 percent more carbon dioxide per joule of primary energy than fuel oil, and about 75 percent more carbon dioxide than fossil (so-called "natural") gas (EPA 2018). Wood bioenergy therefore emits more carbon dioxide per kilowatt-hour of power generated than all fossil fuels, including coal (PFPI 2011), incurring a "carbon debt" – an immediate increase in carbon dioxide in the atmosphere, worsening climate change every year, unless and until that carbon debt is repaid later by forest regrowth.

Will the forests harvested for bioenergy regrow? If so, how long will it take?

The wood bioenergy industry claims to practice sustainable forestry and be carbon neutral (e.g., Drax 2021; Enviva 2021). The most important claim is that wood bioenergy is carbon neutral because the harvested forests will regrow, removing the carbon they add to the atmosphere when burned (Table 1). However, regrowth is uncertain, and regrowth takes time.

Regrowth is uncertain: Land harvested for bioenergy might be converted to pasture, cropland, or development, preventing regrowth. The carbon dioxide emitted

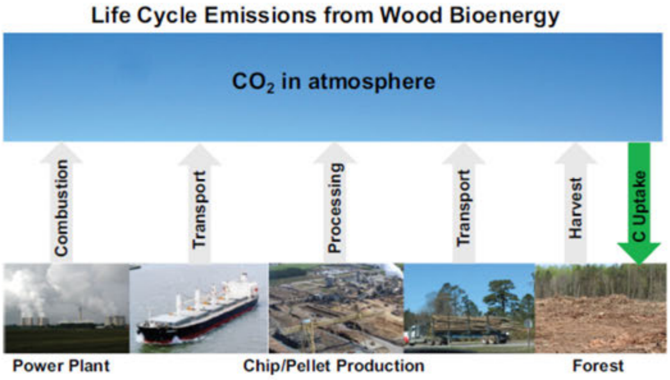

Figure 1. Life cycle emissions from wood bioenergy. Every stage of the supply chain adds carbon dioxide to the atmosphere, from cutting the trees through transport, processing the wood into chips or pellets, transporting them to a power plant, and combustion. Carbon dioxide is removed only later, and only if, the harvested land regrows. Photo credits, left to right: Power Plant, courtesy of Paul Glazzard, Creative Commons Attribution-ShareAlike 2.0 license. Transport: Handymax bulk carrier, courtesy of Nsandel/Wikimedia/Public Domain. Pellet mill, Truck Transport, and Forest images all courtesy of Dogwood Alliance, used with permission.

when the trees are burned is then never taken back up by forest regrowth on that land. Even if the harvested land is allowed to regrow, the trees may be harvested again, legally or illegally. The carbon dioxide released in each rotation returns to the atmosphere, where it worsens climate change.

Even if the recovering forest is somehow protected against all future harvest, the trees face risks from wildfire, insects, disease, extreme weather, and drought, all increasing as the climate warms (Brecka, Shahi, and Chen 2018; Xu et al. 2019; Boulton, Lenton, and Boers 2022). These factors slow or prevent carbon dioxide removal from the atmosphere by forests and may even convert forests from carbon sinks to carbon sources (Gatti et al. 2021). These growing risks to regrowth would limit the future removal of the carbon dioxide emitted by burning wood, permanently worsening climate change.

Regrowth takes time: Even if land conversion, repeated harvests, fire, drought, disease, and other adverse events never arise, regrowth takes time. The time required for regrowth to remove the carbon dioxide emitted when wood is burned for energy is known as the "carbon debt payback time."

Are the forests harvested for bioenergy growing and removing carbon dioxide now?

The US bioenergy industry uses the fact that many US forests are growing today to claim that wood bioenergy is carbon neutral. For example, Enviva, the largest US pellet producer, with multiple mills in the Southeast United States, falsely argues that " … continued forest carbon gain across the landscape … means that products from the Southeast U. S., including wood bioenergy, are not adding carbon emissions to the atmosphere. As a result, when wood pellets from this region are used to generate energy, we can set stack emissions to zero." (Enviva n.d.; see Table 1).

It is true that forests in the Southeast US are acting as carbon sinks today as the result of intensive management and recovery from prior harvests. But these and other forest carbon sinks are already accounted for in the national greenhouse gas emissions inventories required under the United Nations Framework Convention on Climate Change, which sets the rules for greenhouse gas accounting under international agreements (e.g. UNFCCC 2014). Therefore, what counts is what happens to emissions on the margin – that is, the incremental impact of harvesting forests for bioenergy compared to allowing those forests to continue to grow and serve as carbon sinks. Typical rotation periods for working forests are far shorter than the time required for them to reach maturity and maximum carbon storage (Moomaw, Masino, and Faison 2019; Sohngen and Brown 2011; US Forest Service 2014). The younger the forest and faster it is growing when harvested for bioenergy, the more future carbon sequestration is lost.

A dynamic lifecycle assessment of wood bioenergy

To determine the impact of wood bioenergy on carbon dioxide emissions we developed a model for dynamic lifecycle assessment of wood bioenergy (Sterman, Siegel, and Rooney-Varga 2018a, 2018b). The model includes carbon dioxide emissions from bioenergy, carbon dioxide uptake by regrowth, and carbon dioxide emissions avoided if wood displaces fossil fuels. Supply chain emissions for both wood and fossil fuels are included. Model parameters were estimated from data on forest regrowth in a wide range of forests in the southern and eastern USA, regions increasingly supplying wood for pellets, much of which is exported to Europe and the United Kingdom.

Figure 2 shows the impact of wood harvested for bioenergy from an oak-hickory forest, "perhaps the most extensive deciduous forest type of eastern North America" (Dick 2016). The simulation parameters are estimated for oak-hickory forests in the south central US, among the forests used to supply wood pellets for bioenergy, including exports to the United Kingdom (Buchholz and Gunn 2015; Sterman, Siegel, and Rooney-Varga 2018a, 2018b report results for other forests in the southern and eastern US). Most forests in the United States have been cut multiple times. We assume the last prior harvest was 50 years ago. To assess the dynamic impact of wood bioenergy use, Figure 2 traces the impact of a single harvest in 2025, showing the stocks of carbon in the biomass and soil and the resulting change in the concentration of carbon dioxide in the atmosphere. We consider two scenarios:

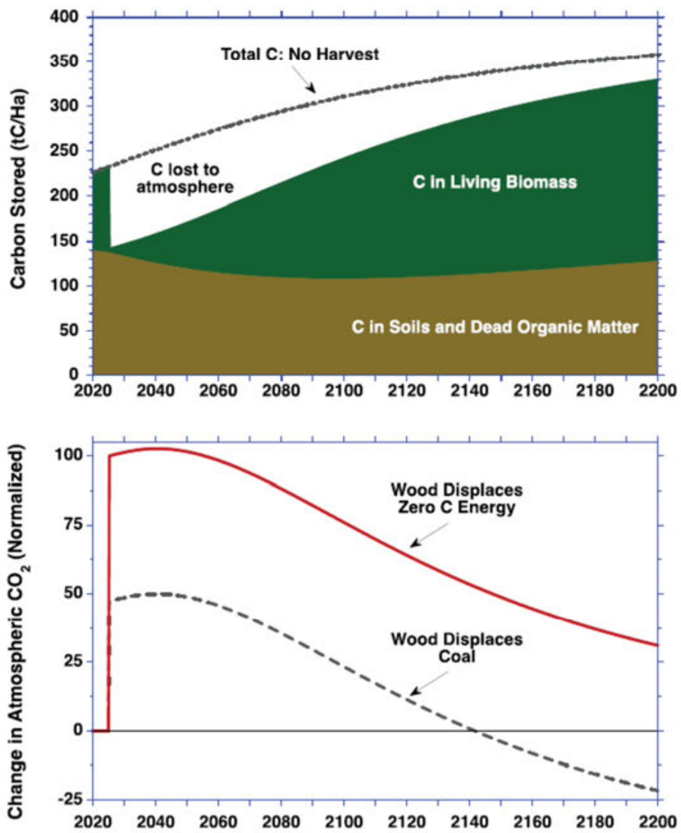

Figure 2. Impact of harvesting wood for bioenergy in 2025 from a 50-year-old oak-hickory forest in the south central USA. Top: Change in carbon on the harvested land (tons carbon per hectare). Brown: carbon in soils and dead organic matter; Green: carbon in living biomass. Dotted line: the total carbon stock (living biomass and soils) if the forest were not harvested in 2025. The forest would have continued to grow and remove carbon from the atmosphere but for being cut for bioenergy. The difference between the dotted no-harvest line and the top of the green band is the carbon emitted into the atmosphere by the harvest. Bottom: Change in atmospheric carbon dioxide resulting from the harvest and combustion of the wood. Solid line: wood displaces a zero-carbon energy source. Dotted line: wood displaces coal. Scale: the initial rise in atmospheric carbon dioxide when wood displaces zero-carbon energy is normalized to 100 percent. The initial rise in atmospheric carbon dioxide when wood displaces coal is about 50 percent less due to the emissions avoided by the reduction in coal use.

- The harvested wood is used to generate electric power that replaces an equivalent amount of energy generated from coal, the most carbon-intensive fossil fuel.
- The harvested wood is used to generate electric power that replaces an equivalent amount of energy produced by zero-carbon sources (e.g. wind and solar).

The top panel of Figure 2 shows the stock of carbon on the land harvested for bioenergy (metric tons of carbon per hectare), including the carbon in the living biomass and in soils and dead organic matter. The harvest and combustion of wood for energy immediately reduces the stock of carbon in living biomass on the land and increases atmospheric carbon dioxide. The stock of carbon in dead biomass and soil also begins to drop: the wood harvest reduces the flux of carbon from living biomass to soils, while heterotrophic respiration by bacteria, fungi, and other organisms continues to release the carbon in dead biomass and soils into the atmosphere. After the harvest, the forest begins to recover. Soil carbon continues to drop for some time, however, until the flux of carbon transferred to the soils from living biomass exceeds the flux of carbon emitted to the atmosphere from the soil by heterotrophic respiration.

The simulation assumes the land is harvested 50 years after the last rotation. The forest at that time is still recovering. The dotted line in the top panel of Figure 2 shows that the total stock of carbon on that land would have continued to grow through 2200 (and beyond), but for the harvest for bioenergy. The difference between the no-harvest and harvest cases is the quantity of carbon lost to the atmosphere due to the bioenergy harvest. The bioenergy harvest not only adds the carbon extracted and burned to the atmosphere, but prevents the additional growth that would have occurred had the forest not been harvested.

The bottom panel of Figure 2 shows the change in the concentration of carbon dioxide in the atmosphere for the two scenarios above. The figure shows the evolution of atmospheric carbon dioxide relative to the no-harvest case, scaled relative to the magnitude of the initial change in carbon dioxide when the wood displaces zero-carbon energy such as wind and solar (the absolute change in atmospheric carbon dioxide depends on the amount of wood harvested and burned). Cutting and burning trees for bioenergy immediately increases the concentration of carbon dioxide in the atmosphere. The jump in atmospheric carbon dioxide when wood displaces coal is approximately half as much as when the wood displaces zero-carbon energy. The impact of displacing other fossil fuels such as fuel oil or fossil ("natural") gas lies between the coal and zero-carbon scenarios because these fuels emit less carbon dioxide per kilowatt-hour than coal, but of course more than wind or solar.

Note that, in both cases atmospheric carbon dioxide continues to increase through approximately 2040, 15 years after the assumed harvest in 2025. Although the harvested land begins to regrow immediately, seedlings and saplings have much smaller leaf area for photosynthesis and accumulate carbon slower than older trees. Consequently, the carbon sequestered by regrowth is initially less than the carbon the forest would have stored had it not been harvested.

After approximately the year 2040, the excess carbon dioxide in the atmosphere from the harvest and combustion of the wood begins to fall as regrowth outpaces the growth in carbon in the no-harvest case. However, atmospheric carbon dioxide remains above the level it would have had but for the harvest well beyond the year 2100. Even when wood displaces coal, the excess carbon dioxide is not taken back up by forest regrowth until after the year 2140: The carbon debt payback time in this scenario is approximately 115 years. When the wood displaces zero-carbon energy, atmospheric carbon dioxide remains above its initial level well past the year 2200.

The simulation shows the impact of clearing a stand of forest and using the wood for bioenergy. The bioenergy industry claims that they practice what they call "sustainable" forestry – avoiding clearcutting, taking only residues from lumber and pulpwood harvests, or thinning forests by taking only small or diseased trees. Environmental groups, however, have documented the harvest of large trees and clear-cutting by the industry (Norton et al. 2019; Stashwick, Frost, and Carr 2019; Stashwick, Macon, and Carr 2017). To address this issue, we also simulated the impact of thinning, in which only 25 percent of the living biomass is removed from the harvested forest (Sterman, Siegel, and Rooney-Varga 2018a, 2018b). Across all the forests examined, thinning reduces the carbon debt payback times somewhat. For example, in the scenario shown in Figure 2, thinning reduces the carbon debt payback year from 2140 to 2115 – still too late.

The simulations favor wood bioenergy. We assume that the land remains forested, that the forest grows back without any subsequent harvest, and that it suffers no losses from wildfire, disease, insects, extreme weather or other threats to regrowth. We do not consider additional carbon loss from soils due to the disturbance caused by the harvest. We do not consider non-climate harms from wood harvest and bioenergy production, including habitat fragmentation, loss of biodiversity, and the health effects of exposure to particulates and other pollutants from wood processing and power plants.

To track the impact of wood bioenergy, the simulation shows the impact of harvesting and burning wood for energy in a single year. But the bioenergy industry is growing rapidly, stimulated by the false declaration that wood is carbon neutral and resulting subsidies in many nations. The International Energy Agency reports primary energy from biomass for electricity generation grew at an average rate of more than 6 percent per year between 1990 and 2018 (IEA 2020). The IEA's "Net-Zero by 2050" scenario projects modern bioenergy – which includes wood – will grow by more than a factor of four by 2050 (IEA 2021b).

What happens to atmospheric carbon dioxide in the realistic case of growing wood bioenergy use? Each year the carbon dioxide emissions from cutting and burning wood would exceed the removal of carbon dioxide by regrowth, continually increasing the concentration of carbon dioxide in the atmosphere, just as filling your bathtub faster than it drains will continually raise the level of water in the tub (until it overflows and damages your home).

The situation is analogous to a government that runs a continually growing fiscal deficit. The outstanding debt rises every year even if the government fully repays every bond it issues at maturity. In the same way, the growing use of wood bioenergy adds more carbon dioxide to the atmosphere every year, increasing the outstanding carbon debt, even if the forests are managed sustainably and all harvested lands eventually recover enough to fully repay the carbon debt incurred when the wood was extracted and burned.

Eventual carbon neutrality is not climate neutrality

Even under the best case where wood displaces coal, regrowth does not remove the excess carbon dioxide emitted by wood for many decades or more, and far longer if the harvested forests are growing today – as most are – and far more if wood displaces other fossil fuels. At that future time wood bioenergy could be said to have achieved carbon neutrality. Until then, wood bioenergy increases the level of carbon dioxide in the atmosphere above what it would have been, accelerating global warming.

But is the climate impact of that additional warming reversed if regrowth finally removes the excess carbon dioxide? Is eventual carbon neutrality the same as climate neutrality?

The answer is "No."

Even temporarily elevated levels of atmospheric carbon dioxide cause irreversible climate damage (IPCC 2022; Solomon et al. 2009). The excess carbon dioxide from wood bioenergy begins warming the climate immediately upon entering the atmosphere. The harms caused by that additional warming are not undone even if the carbon debt from wood energy is eventually repaid: The Greenland and Antarctic ice sheets melt faster, sea level rises higher, wildfires become more likely, permafrost thaws faster, and storms intensify more than if the wood had not been burned. Eventual full forest recovery will not replace lost ice, lower sea level, undo climate disasters, put carbon back into permafrost, or bring back homes lost to floods or wildfires. The excess warming from wood bioenergy increases the chances of going beyond various climate tipping points that could lead to runaway climate change: emissions "pathways that overshoot 1.5°C run a greater risk of passing through 'tipping points,' thresholds beyond which certain impacts can no longer be avoided even if temperatures are brought back down later on" (IPCC 2018, 283). *Carbon* neutrality is not *climate* neutrality.

Why does it matter? We have already raised global average surface temperatures about 1.1 degrees Celsius (2 degrees Fahrenheit) above preindustrial levels, and most of humanity already suffers from its effects (Callaghan et al. 2021; IPCC 2022). The consequences of warming beyond 2 degrees Celsius are expected to be devastating. Sea levels could rise by well over a meter by the end of this century, exposing millions of people to coastal flooding (Kulp and Strauss 2019). More than half the world's people would be exposed to deadly heat waves (Mora et al. 2017). The yields of crops including wheat, maize, rice, and soy would fall even as the United Nations projects that world population will grow by billions (Zhao et al. 2017; United Nations 2019). Droughts, wildfires, and intense storms will become more frequent and extreme (IPCC 2018). Warming could push the Earth beyond various tipping points that could lead to irreversible harm (IPCC 2018). These impacts would intensify hunger, economic disruption, mass migration, civil conflict, and war (Burke, Hsiang, and Miguel 2015; Hsiang and Burke 2014; Koubi 2019; Levy 2019). Scientists and nearly all nations on Earth therefore agree that global greenhouse gas emissions must fall as deeply and quickly as possible, reaching net zero by approximately midcentury.

Wood bioenergy moves the world in the wrong direction.

Policy implications

What can be done? First, policies that treat wood bioenergy as carbon neutral must end. These policies allow power plants and nations to ignore the carbon dioxide they emit by burning wood on the false assumption that those emissions are quickly offset by forest growth somewhere else, creating a "critical climate accounting error" (Searchinger et al. 2009). The carbon dioxide emitted from wood should be counted the same way emissions from other fuels are: fully, at the point of combustion.

Second, subsidies for wood bioenergy must end. Subsidizing wood bioenergy means taxpayers are paying pellet and power producers to make climate change worse.

Third, the fact that wood bioenergy is worse than coal in no way justifies the continued use of coal or any fossil fuel. To avoid the worst harms from climate change we must not only keep the vast majority of remaining fossil carbon in the ground, we must also keep the vast majority of the carbon in our forests on the land.

The good news is that existing technologies such as energy efficiency, solar, wind, and geothermal energy can meet people's needs for comfort, light, mobility, communication, and other purposes. The costs of these technologies are falling rapidly, and in many places are already lower than fossil fuels (IEA 2021a). Innovations in clean energy, energy storage, smart grids, and other technologies are expanding our ability to meet everyone's energy needs affordably. Unlike wood bioenergy, these technologies allow forests to continue growing and sequestering atmospheric carbon dioxide. Investments in energy efficiency and clean energy also generate multiple co-benefits including increased community resilience, jobs, and improved health and economic well-being, especially for low-income individuals and households (Belesova, Heymann, and Haines 2020; Burke, Davis, and Diffenbaugh 2018; IEA 2021a; IPCC 2018; Pollin et al. 2014; Shindell et al. 2018). In contrast, particulate emissions and other pollutants from wood bioenergy damage human health (Allergy & Asthma Network, American Academy of Pediatrics, American Lung Association, American Public Health Association, Asthma and Allergy Foundation of America, National Association of County & City Health Officials et al. 2016).

To keep global warming under 2 degrees Celsius, net greenhouse gas emissions must fall to net zero by approximately mid-century, less than 30 years from now. Wood bioenergy increases greenhouse gas emissions and makes climate change worse during these critical years and beyond, even if the wood displaces coal. More effective ways to cut greenhouse gas emissions and meet human needs are available and affordable now. Ending subsidies and policies that promote wood bioenergy will reduce emissions and allow forests to continue to grow, preserving their vital role as carbon sinks that moderate climate change.

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10 APPENDIX D: "Correcting a Fundamental Error in Greenhouse Gas Accounting Related to Bioenergy", PAPER, 2012

Haberl, H., D. Sprinz, M. Bonazountas, P. Cocco,
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Viewpoint

Correcting a fundamental error in greenhouse gas accounting related to bioenergy

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ABSTRACT

Many international policies encourage a switch from fossil fuels to bioenergy based on the premise that its use would not result in carbon accumulation in the atmosphere. Frequently cited bioenergy goals would at least double the present global human use of plant material, the production of which already requires the dedication of roughly 75% of vegetated lands and more than 70% of water withdrawals. However, burning biomass for energy provision increases the amount of carbon in the air just like burning coal, oil or gas if harvesting the biomass decreases the amount of carbon stored in plants and soils, or reduces carbon sequestration. Neglecting this fact results in an accounting error that could be corrected by considering that only the use of 'additional biomass' – biomass from additional plant growth or biomass that would decompose rapidly if not used for bioenergy – can reduce carbon emissions. Failure to correct this accounting flaw will likely have substantial adverse consequences. The article presents recommendations for correcting greenhouse gas accounts related to bioenergy.

1. Introduction

Governments worldwide have implemented policies to promote bioenergy as a means both of reducing dependency on fossil energy and of reducing greenhouse gas (GHG) emissions. In our opinion, several of these policies – some European examples are discussed below – inaccurately assess the GHG emission consequences of different forms of bioenergy and are likely to have serious adverse environmental consequences if not remedied (van Renssen, 2011).

This viewpoint article discusses the scientific background of an Opinion on bioenergy published in September 2011 by the Scientific Committee of the European Environment Agency (EEA).[1] In this article, 'bioenergy' refers to any energy produced by combusting

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biomass whether in solid form, such as wood chips or pellets burned for electricity; in liquid form, such as ethanol and biodiesel generated from crops or cellulose; or in gaseous form (biogas).

2. Bioenergy supply: Expectations and challenges

Correctly addressing the carbon implications of bioenergy is critical because a variety of studies and policies contemplate use of very large quantities of biomass in the belief that bioenergy is almost a GHG-neutral replacement for fossil fuels. Many projections imply at least doubling the total human harvest of world plant material. For example, the International Energy Agency has projected that bioenergy could supply over 20% of the world's primary energy by 2050 (IEA, 2008). A report by the Secretariat of the UNFCCC has claimed bioenergy can supply 800 EJ/yr (UNFCC Secretariat, 2008), which is far more than total world energy use today. The IPCC Special Report on Renewable Energy (SRREN) suggests that the global bioenergy potential could be as high as 500 EJ/yr (Chum et al., 2012), comparable to current fossil energy use. By contrast, the total global biomass harvest for food, feed, fibre, wood products, and traditional wood use for cooking and heat amounts to approximately 12 billion tonnes of dry matter of plant material per year (Krausmann et al., 2008) with a chemical energy value of 230 EJ.

An increase in the use of bioenergy of this magnitude could create substantial adverse impacts on natural ecosystems, compete with food production, and undermine other goals to reduce present impacts of agricultural production on the environment, and improve the well-being of farm animals (Erb et al., 2012; Haberl et al., 2011; Lambin and Meyfroidt, 2011; Smith et al., 2010). Ecosystems can be managed for satisfying human needs more or less sustainably, but all human uses of land and consumption of plants have environmental costs. Generating food, fiber and other biomass-based products that people currently consume utilizes roughly 75% of the world's vegetated land (Erb et al., 2007; UNEP, 2010). Agriculture, including livestock grazing, accounts for more than half of this area; in addition, a substantial fraction of the world's forests are managed for wood production. Moreover, over 70% of the water withdrawn from rivers and aquifers is used by agriculture (Comprehensive Assessment of Water Management in Agriculture, 2007). In addition, fertiliser use has doubled the amount of reactive nitrogen in the world, leading to large-scale pollution of aquatic ecosystems, extensive algal blooms and bodies of waters with low levels of oxygen (Erisman et al., 2008; Gruber and Galloway, 2008).

Even so, agricultural and forestry practices have not, on balance, increased the total quantity of biomass production: they have merely transformed natural ecosystems to produce goods and services for human consumption (Haberl et al., 2007). As human uses of land have already reached troubling levels (Foley et al., 2005, 2011; IAASTD, 2009; Millennium Ecosystem Assessment, 2005), and as large additional demands exist for food and timber (Smith et al., 2010), the challenges that would result from a doubling of global human biomass harvest for bioenergy (or even higher increases) should not be underestimated, and the full greenhouse gas emissions that would result from such an increase in bioenergy production are uncertain.

3. Correct greenhouse gas accounting

Many policies consider biomass combustion as 'carbon-neutral,' regardless of the source of the biomass. Although these policies may acknowledge the carbon emissions from using fossil fuels to produce and refine biomass, as well as trace-gases, they omit the carbon dioxide (CO_2) released by the burning of the biomass itself (Bird et al., 2011). They do so either by omitting these emissions when accounting for emissions from bioenergy or by simply endorsing all bioenergy on the assumption that it emits no net carbon dioxide (Searchinger et al., 2009). Such policies and regulations thus treat biomass as an inherently 'carbon neutral' energy source. This is not correct.

Replacement of fossil sources of energy with biomass does not reduce GHG emissions from combustion. For example, burning one metric tonne of bone-dry wood will release about 1.8 t of CO_2 into the atmosphere. While bioenergy reduces or eliminates carbon emissions from fossil fuels, the combustion of biomass results in its own carbon emissions (Bird et al., 2011; Searchinger, 2010).

The assumption of carbon neutrality is often justified on the grounds that burning biomass only returns the carbon absorbed by growing plants to the atmosphere. Plants do absorb carbon, but this line of thought makes a 'baseline' error because it fails to recognize that if bioenergy were not produced, plants not harvested would continue to absorb carbon and help to reduce carbon in the air. Because that carbon reduction would occur anyway and is counted in global projections of atmospheric carbon, counting bioenergy that uses this carbon as carbon-neutral results in double-counting.

An example shows why. Imagine a hectare of cropland just abandoned and allowed to reforest. These growing plants would absorb carbon from the atmosphere to form plant tissue, i.e., biomass. Some of that biomass would be consumed and the carbon released by animals, fungi or microorganisms and would go back into the atmosphere. Other carbon would be stored in vegetation and soils as the forest grows, and that carbon absorption would have the effect of offsetting some of the emissions of carbon by burning fossil fuels and holding down global warming (Baldocchi, 2008; Le Quere et al., 2009; Richter et al., 2011). If the land were used instead to grow energy crops to be burned in a power plant, fossil fuel emissions would decline but not the carbon emitted by the power plant chimneys. Per unit of energy, the CO_2 emissions would typically even be higher than those of a fossil fuel-burning power plant because (i) biomass contains less energy per unit of carbon than petroleum products or natural gas do and (ii) biomass is usually burned with a lower efficiency than fossil fuels (Bird et al., 2011). Although the growth of bioenergy crops absorbs carbon, using the land to grow bioenergy crops sacrifices the sequestration of carbon in the forest. This foregone carbon sequestration, which is not considered in current GHG accounting related to bioenergy, may be substantial. For example, in the western Ukraine forest growth following abandonment of farmland resulted in a net carbon sink of almost one ton of carbon per hectare forest and year (Kuemmerle et al., 2011).

Simplifying the steps in this story, the decision to use the land for bioenergy results in more carbon being stored underground in fossil fuels, but this benefit comes at the expense of less carbon being stored by plants and soils. Bioenergy reduces CO_2 emissions only to the extent the first effect outweighs the second.

The use of food crops for the production of transportation biofuels provides a comparable story as they also absorb carbon whether used for bioenergy or not. Their use for bioenergy does not by itself result in additional plant growth, offset the emissions from energy use, or justify failing to account for the carbon emitted from exhaust pipes. This use of crops can only reduce carbon emissions through a series of 'indirect' market responses:

- Food crops do not usually keep carbon away from the atmosphere for long periods of time because they are consumed by people and livestock, who nourish themselves and thereby return almost all carbon to the atmosphere as respiration and waste. If food crops used for bioenergy are not replaced, there is a reduction in carbon emissions because people and livestock will release less CO_2 to the atmosphere, but that is not a desirable way of reducing GHGs.

Table 1
Degree of likely accounting error when CO_2 emissions from biomass combustion are not properly considered.

Source of biomass	Degree of likely accounting error	Form of error
Converting forests currently sequestering carbon to bioenergy crops	Very high	Ignoring both immediate release of carbon and often continuing carbon sequestration of the forest if unharvested
Harvesting live trees for bioenergy and allowing forest to regrow	High	Same
Diverting crops or growing bioenergy crops on otherwise high-yielding agricultural land	High	Ignoring ongoing uptake of carbon on cropland and likely release of carbon in replacing the crops or reduced crop consumption
Using crop residues	Variable	Potentially ignores existing uses, need to replace nutrients, or potential effects on soil productivity (Blanco-Canqui and Lal, 2009)
Planting high-yielding energy crops on unused invasive grasslands	Low	Little or no error
Using post-harvest timber slash	Little or none	Could ignore temporal dimension of decomposition or existing uses
Using organic wastes otherwise deposited in landfill	Little or none	Little or no error

- If crops used for bioenergy are replaced by food production elsewhere, then the carbon emission consequences of bioenergy depend on how this is done. If more crops are grown on a unit of land, additional carbon is absorbed from the atmosphere.[2] If more land is converted to crops, then the calculation must include the lost carbon storage or sequestration due to changing land-use.

Only if, and to the extent to, these indirect effects are beneficial on balance could they justify ignoring some of the carbon emitted by the combustion of biomass such as biofuels.

It is important to be precise where and how physical changes occur in the absorption or emission of carbon in the use of bioenergy. Because bioenergy does not physically reduce emissions from exhausts, it must be true mathematically that bioenergy can reduce greenhouse gas emissions (except by reducing other human consumption of biomass, such as food) only if, and to the extent that:

1. land and plants are managed to grow additional biomass and take up additional CO_2 beyond what they would absorb without conversion into bioenergy, or
2. bioenergy production uses feedstocks, such as crop residues or wastes, that would otherwise decompose and release CO_2 to the atmosphere anyway.

To reiterate: only biomass grown in excess of that which would have grown anyway, or biomass that would otherwise have decomposed anyway, is ‘additional biomass’ containing ‘additional carbon,’ and has the potential to reduce carbon emissions when used for energy (Searchinger, 2010). The basic error in the carbon neutrality of biomass assumption is the failure to count the production and use of biomass that land would generate if not used for bioenergy (the counterfactual).

Correct GHG accounting needs to reflect not merely the loss of existing carbon stocks when biomass is produced and used for energy, but also any decline in carbon sequestration that would occur in the absence of bioenergy use. For example, forests particularly in the northern hemisphere are accumulating biomass for a variety of reasons (Erb et al., 2008; Pan et al., 2011; Richter et al., 2011) and this growth absorbs carbon from the atmosphere. Some estimates of bioenergy potential suggest that biomass reduces greenhouse gas emissions so long as harvest is ‘sustainable’: if harvesting is kept below the level of forest growth, carbon stocks are argued to remain constant. But this line of reasoning ignores the additional carbon sequestration that would occur without wood harvesting for bioenergy (the counterfactual), which does not make bioenergy carbon neutral (Haberl et al., 2003; Holtsmark, in press).

If a forest is allowed to re-grow after harvest, it achieves approximately the same carbon storage level as an unharvested forest when the build-up of carbon stocks slows down and eventually stops as the forest reaches maturity.[3] At that point, the use of the biomass becomes carbon-neutral. But achieving this parity may take decades or even centuries, which means that the CO_2 remains in the atmosphere for a long time before it is removed by plant growth, resulting in a ‘pulse’ of climate forcing that takes decades or centuries before being compensated by forest regrowth – thereby counteracting the goal of achieving GHG reductions in the next few decades (Cherubini et al., 2011a, 2011b). Increasing the harvest level in forests over longer time periods to achieve a sustained fuel wood flow permanently reduces the forest’s carbon stock and thereby creates a ‘carbon debt’ that may require centuries to be repaid, even if forest area is conserved (Holtsmark, in press). Thus, to assess the consequences on global warming alone, accounting must assess the rates of plant growth with and without bioenergy production, and the changes induced by bioenergy production in the total amount of carbon stored in terrestrial plants and soils.

The studies projecting large quantities of bioenergy potential discussed above do not rule out double-counting of biomass already used or sequestering carbon and mostly neglect the true counterfactual. For example, large bioenergy potential estimates assume the availability of abandoned or unused agricultural land in present and future, but such land is not a free resource as its reversion to forest and grassland is a major component of the global terrestrial carbon sink (Pan et al., 2011). Bioenergy potential studies also call for harvesting forest carbon growth in excess of timber harvest, but that would also reduce the carbon sink and therefore add carbon to the air (Holtsmark, 2011). Nevertheless, there are indeed potential biomass sources that can reduce greenhouse gas emissions and that could be generated sustainably. Realistic expectations of such truly ‘additional biomass’ should be the focus of climate change strategies.

Table 1 highlights the likely advantageous and disadvantageous forms of biomass and the likely potential error in the

[2] Increasing yields through agricultural intensification often requires more inputs such as fertilizer which often result in higher GHG emissions. This must of course also be considered.

[3] While this process is reasonably well understood for the aboveground component, uncertainties related to belowground carbon storage are larger.

existing directives of different forms of biomass highlights, showing that some bioenergy sources figuring prominently in current bioenergy policies are prone to be erroneously evaluated under current accounting rules.

4. Origins of the accounting error

The assumption that all biomass is carbon-neutral results from a misapplication of the original guidance provided for the national-level carbon accounting under the United Nations Framework Convention on Climate Change (UNFCC). Under the UNFCCC accounting rules, countries report their emissions from energy use and from land-use change separately. For example, if a hectare of forest is cleared and the wood used for bioenergy, the carbon lost from the forest is counted as a land-use emission. To avoid double-counting, the rules therefore allow countries to ignore the same carbon when it is released after combustion. This accounting principle does not assume that biomass is carbon-neutral, but rather that emissions can be reported in the land-use sector. This accounting system is complete and accurate because emissions are reported from both land and energy sectors worldwide.

The accounting rule under the Kyoto Protocol is different: it caps emissions from energy use but does not apply worldwide and it applies only incompletely to land use even in the Annex I countries. By excluding biogenic emissions from the energy system, the Protocol erred because this practice means that those emissions are in many cases never accounted for at all. Similarly, many national and European policies and, as well as many lifecycle and other analyses, mistakenly ignore biogenic emissions from energy use without including changes in land-based carbon as a result of that bioenergy use.

5. European policies affected by the accounting error

In order to show how important these considerations are in a policy context, we focus on the example of Europe.[4] European policies making this accounting error include at least:

- The European Union's Emissions Trading System[5] (which caps emissions from major factories and power plants) ignores CO_2 emissions from biomass combustion but does not apply to land use;
- The Renewable Energy Directive[6] (which requires that Member States increase their use of renewable energy to 20% by 2020) explicitly sets CO_2 emissions from biomass combustion to zero regardless of the source of the biomass.

The European Union has also adopted two Directives to promote transportation biofuels that at present fail to include proper GHG accounting:

- The renewable fuels portion of the Renewable Energy Directive,[7] which requires that the Member States use qualifying renewable energy, which is expected to be almost exclusively biofuels, for 10% of their transportation fuel.
- The Fuel Quality Directive,[8] which requires reductions in the carbon intensity of transportation fuels.

To measure GHG emissions related to bioenergy, these Directives use life-cycle analyses (LCA) that count emissions involved in growing crops and refining biofuels, as well as those from direct land use change, if a bioenergy crop is planted in a previously forested area or other high carbon ecosystems. But this accounting strategy still ignores the actual emissions of CO_2 by vehicles that use biofuels, without any assurance that the biomass is additional. If the bioenergy is supplied by crops grown on existing cropland, the analysis incorrectly assumes one of the following scenarios to be true: (i) this land would otherwise grow no plants, (ii) the crops it would generate are not replaced, or (iii) the crops are replaced entirely by intensifying planting and harvesting of existing cropland. If the crops are grown on grassland, the analysis counts the emissions from the conversion to cropland (i.e., carbon lost from soils and grass) but fails to assess the consequences of replacing the forage that this land would otherwise generate for livestock. Only a fully comprehensive accounting of indirect effects can fix this error. Even with proper accounting, care should be taken that biofuels are not credited with GHG reductions based on estimates that they will indirectly lead to reductions in food consumption.

Some people have suggested that as an alternative to accounting for indirect land use change, policymakers could use the same flawed accounting system but require that biofuels reduce greenhouse gas emissions by a higher percentage compared to fossil fuels, for example by 75% instead of the 50% that will be required in the EU Renewable Energy Directive. Doing so would not solve and could even exacerbate the problem. As long as the accounting ignores the CO_2 emissions from exhaust pipes without counting the indirect effects on land use, the accounting assumes that plant growth cancels out exhaust pipe emissions regardless of whether there is additional plant growth or reduced decomposition. Tighter thresholds will encourage making biofuels using more land, and more productive land (and perhaps even generate fewer litres of biofuels due to reduced yields), if doing so reduces GHG emissions from inputs (such as energy or fertiliser), even when the true consequences for greenhouse gases, hunger and biodiversity would be worse.

Although estimating the indirect consequences of biofuels is inherently uncertain, the proper alternative cannot be to assume that biomass is carbon free and emits no CO_2, which is the assumption in existing biofuels Directives. That approach is erroneous as the CO_2 emissions from the use of bioenergy are real and there may be no additional plant growth or reduced decomposition to compensate those emissions. We strongly recommend that any accounting system should fully quantify

[4] Europe was chosen as an example because most authors are Europeans. This choice should not interpreted as a judgement of accounting standards in European bioenergy policies compared to those of other regions.

[5] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, as subsequently amended. For full documentary history, see [redacted] for an overview see [redacted]

[6] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/E.

[7] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC ([redacted]

Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by [redacted] the greenhouse gas emissions attributable to the use of land, both direct and indirect, when evaluating the use of biofuels.

Recent developments in Europe indicate that political awareness of issues related to greenhouse gas accounting for bioenergy is rising. For instance, EU legislation such as the Renewable Energy Directive and the Fuel Quality Directive set out sustainability criteria for biofuels. More detailed provisions under the existing legislation are under discussion.[9] We hope that the issues raised in this viewpoint will be taken up in the on-going political process in order to strengthen the environmental integrity of EU policies.

6. Recommendations

Based on the above-discussed considerations the authors recommend that:

- Policies and their goals should be revised to encourage bioenergy use only from additional biomass that reduces greenhouse gas emissions, without displacing other ecosystems services such as the provision of food and the production of fibre.
- Accounting standards for GHGs should count all the carbon and other GHGs releases by the combustion of carbon (as emissions), and should count as an offset additional plant growth or reduced decomposition of biomass, which together make up additional sequestration. The balance reflects the net effect of the production and use of bioenergy.
- Bioenergy policies should encourage energy production from biomass by-products, wastes and residues (except if those are needed to sustain soil fertility). Bioenergy policies should also promote the integrated production of biomass that adds to, rather than displaces, food production.
- Decision makers and stakeholders worldwide should adjust global expectations of bioenergy use and potential to levels based on the planet's capacity to generate additional biomass, without jeopardizing natural ecosystems.

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[9] In 2010, for example, the European Commission adopted a report on sustainability requirements for the use of solid biomass and biogas in electricity, heating and cooling (EC, 2010). In the same year, the Joint Research Centre (JRC) published a study on indirect land-use change from biofuels (Edwards et al., 2010).

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11 APPENDIX E: "Serious Mismatches Continue between Science and Policy in Forest Bioenergy", PAPER, 2019

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"Serious Mismatches Continue between Science and Policy in Forest Bioenergy."

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Serious mismatches continue between science and policy in forest bioenergy

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Abstract

In recent years, the production of pellets derived from forestry biomass to replace coal for electricity generation has been increasing, with over 10 million tonnes traded internationally—primarily between United States and Europe but with an increasing trend to Asia. Critical to this trade is the classification of woody biomass as 'renewable energy' and thus eligible for public subsidies. However, much scientific study on the net effect of this trend suggests that it is having the opposite effect to that expected of renewable energy, by increasing atmospheric levels of carbon dioxide for substantial periods of time. This review, based on recent work by Europe's Academies of Science, finds that current policies are failing to recognize that removing forest carbon stocks for bioenergy leads to an initial increase in emissions. Moreover, the periods during which atmospheric CO_2 levels are raised before forest regrowth can reabsorb the excess emissions are incompatible with the urgency of reducing emissions to comply with the objectives enshrined in the Paris Agreement. We consider how current policy might be reformed to reduce negative impacts on climate and argue for a more realistic science-based assessment of the potential of forest bioenergy in substituting for fossil fuels. The length of time atmospheric concentrations of CO_2 increase is highly dependent on the feedstocks and we argue for regulations to explicitly require these to be sources with short payback periods. Furthermore, we describe the current United Nations Framework Convention on Climate Change accounting rules which allow imported biomass to be treated as zero emissions at the point of combustion and urge their revision to remove the risk of these providing incentives to import biomass with negative climate impacts. Reforms such as these would allow the industry to evolve to methods and scales which are more compatible with the basic purpose for which it was designed.

KEYWORDS

carbon accounting, carbon payback period, converting from coal to biomass, forest bioenergy, perverse incentives, policy, renewable energy, zero emissions

1 | INTRODUCTION

In recent years, the production of wood pellets using forest biomass as feedstock has increased, with industry consultants (Hawkins Wright, 2019) estimating that global industrial pellet production will reach 24 million metric tonnes (Mt) in 2019 (equivalent to a feedstock of ~50 million m^3 of wood). Most of the 'industrial' pellet production is for electricity generation which the International Renewable Energy Agency (IRENA, 2019) records under the 'solid biofuels and renewable waste' category. Here, global generating capacity has risen from 52,146 MW in 2009 to 95,687 MW in 2018, with the most rapid increases occurring (over the same period) in the EU (from 15,912 to 24,081 MW) and Asia (from 14,140 to 34,845 MW). Among the pellets produced globally, over 10 million tonnes are traded internationally—primarily between United States and United Kingdom and some other European countries but also to South Korea and Japan from sources such as Vietnam (IEABioenergy, 2017). This expanding biomass pellet business depends largely on its treatment in regulations that classify forest biomass as 'renewable', so that many countries have turned to biomass to meet their renewable energy targets—currently around half of the European Union (EU)'s 'renewable' energy comes from solid biomass (Berndes et al., 2016; Eurostat, 2019), with the amount of electricity generated from biomass increasing annually from 60.7 terawatt-hours (TWh) in 2009 to 94.7 TWh in 2017 (Eurostat, 2019).

The classification of forest biomass as 'renewable' is based on the reasoning that, since biomass carbon came from atmospheric CO_2 and regrowth absorbs CO_2 over time, it can be regarded as 'carbon neutral' with net emissions over the harvesting/regrowth cycle of zero. The 'carbon neutrality' concept is, however, a gross misrepresentation of the atmosphere's CO_2 balance since it ignores the slowness of the photosynthesis process which takes several decades for trees to reach maturity. This has been pointed out repeatedly (e.g. Agostini, Guiintoli, & Boulamanti, 2014; Berndes et al., 2016; Fisher, Jackson, & Biewald, 2012; Holtsmark, 2012, 2013; Mitchell, Harmon, & O'Connell, 2012; Ter-Mikaelian, Colombo, & Chen, 2015; Zanchi, Pena, & Bird, 2012). Nevertheless, its simplicity brought with it political and economic advantages and led to the inclusion of biomass in the European Commission's definition of renewable energy in its 2009 Renewable Energy Directive (RED; EC, 2009), being treated as 'part of the package of measures required to reduce greenhouse gas (GHG) emissions.'

The RED allowed governments to offer renewable energy subsidies to substitute coal in large power stations with biomass (without which the economics would be unfavourable; Walker, Lyddan, Perritt, & Pilla, 2015), creating the market incentive which has led to the rapid expansion in the demand for forest biomass pellets mentioned above. It is thus of considerable concern that scientific analyses indicate that, far from reducing GHG emissions, replacing coal by biomass for electricity generation is likely to initially increase emissions of CO_2 per kWh of electricity as a result of the lower energy density of wood, emissions along the supply chain, and/or less efficient conversion of combustion heat to electricity (see later). The resulting increase in atmospheric concentrations of CO_2 increases radiative forcing and thus contributes to global warming. This initial negative impact is only reversed later if and when the biomass regrows. Research has shown that the time needed to reabsorb the extra carbon released can be very long, so that current policies risk achieving the reverse of that intended—initially exacerbating rather than mitigating climate change. This issue has been pointed out by many authors (e.g. Booth, 2018; Laganière, Paré, Thiffault, & Bernier, 2017; Schlesinger, 2018; Ter-Mikaelian, Colombo, Lovekin, et al., 2015), and, in the specific context of the EU's policy (KNAW, 2017; Searchinger et al., 2018).

The European Academies Science Advisory Council (EASAC) has brought these issues to the attention of the European Commission in its recent reviews and statements (EASAC, 2017, 2018, 2019) and, during the debate on the revision of the EU's RED in 2018, many scientists (e.g. Beddington et al., 2018) argued against the simplistic assumptions of carbon neutrality and treating biomass as renewable. However, the revised directive (REDII) continues to classify biomass in the same way as solar, wind and other categories of renewable energy. Subsidies continue and other countries (including some of the 29 members of the 'Powering Beyond Coal Alliance') see substituting coal by biomass as a step towards mitigating climate change, thus leading to further expansion. In this commentary, we re-emphasize the reasons why current policy is achieving the opposite of that intended, and why the urgency of its revision has increased following the conclusion of the Paris Agreement.

Concern has also been expressed over the effects of increased forest biomass harvesting on ecosystem biodiversity and losing services such as the ecologic regulation of water and nutrient cycles or soil maintenance (e.g. Immerzeel, Verwuij, Hilst, & Faaij, 2014). However, in this overview, we concentrate on the central question of whether industrial use of forest biomass has a positive or negative impact on climate change mitigation and whether this is adequately recognized in renewable energy policy. Our analysis is specifically focused on forest biomass and does not apply to second-generation short rotation crops, perennial rhizomatous grasses and other feedstocks which have very short payback times (e.g. Heaton, Dohleman, & Long, 2008; Liu et al., 2016).

2 | HISTORICAL PERSPECTIVE

Forestry management has historically included bioenergy production along with construction timber, board manufacture, fibre for paper and other products. Branches, bark and other sawmill residues have produced the energy for driers, heating and in some cases local electricity generation. Within the framework of sustainable forest management, this can be seen as making the best use of available resources, where the fuel is from materials for which there is no higher value use (the 'cascade' principle; EC, 2014). Such a forest managed sustainably to maintain a stable or increasing carbon stock can be characterized as producing no net release of carbon and thus 'carbon neutral'.

Arguably, it was such a scenario which was influential when the EU first defined the renewable energies which should be included in the targets for the 2009 RED. Prior to this, another important decision had emerged from the United Nations Framework Convention on Climate Change (UNFCCC) where, following the Kyoto Protocol, rules for accounting for forestry emissions had to be developed. These started with the assumption that the carbon in a forest should be regarded as released when harvested (regardless of the subsequent use). Thus, when it came to accounting for emissions if forest biomass was burned, the carbon emitted should (for accounting purposes only) be regarded as zero because the forestry carbon had already been counted in the 'land use, land-use change, and forestry' (LULUCF) category. This means that accounting treats the emissions from forest biomass used in a power station as zero, so that when the power station, and the country in which it resides report emissions, these are not included. If the biomass is harvested and burned within the same country, accounting should reflect overall emission trends in that country. However, a consequence unforeseen at the time was that this rule creates an opportunity for a country to import biomass, use it for energy production and zero rate its emissions on the assumption that they are recorded in the exporting country's LULUCF statistics. The importing country can thus shift responsibility for reporting its own emissions from forest biomass to the exporting country (McKechnie, Colombo, & MacLean, 2014) and obtain a free ride on that proportion of its emissions originating from imported biomass.

Classifying biomass as renewable has had major consequences. Concerns over the intermittent nature of solar and wind have led governments to seek a 'renewable' supplier of baseload capacity which can be provided by existing infrastructure. This has led to the substitution of coal by imported wood pellets at a number of facilities across the EU (particularly the United Kingdom but also the Netherlands and Denmark). Renewable energy subsidies are considerable; a single UK power station (Drax) received £789 million in 2018 (https://www.drax.com/investors/—accessed May 10, 2019), while the Netherlands recently confirmed €3.6 billion over 8 years to subsidise biomass added to large energy/coal plants (https://www.rvo.nl/subsidies-regelingen/stimulering-duurzame-energieproductie/feiten-en-cijfers/volg-sde—accessed May 10, 2019). With the large investments already made in conversion and associated pellet mills and infrastructure (including bulk marine transport), substantial economic assets are dependent on this economic model continuing, and thus, stakeholder commitment to the climate neutrality argument is strong and likely to have been a factor in countering the scientific arguments presented to the European Parliament.

3 | CURRENT FOREST BIOENERGY AND CLIMATE CHANGE POLICY DEBATE

The EASAC applies the scientific expertise in Europe's 27 science academies to analysing topical issues where science interacts with European policy [redacted] One such issue was how best to manage sustainably Europe's forests when they were subject to multiple demands, and EASAC (2017) looked at the science underpinning sustainable forest management and the trade-offs between production, protection of biodiversity and responses to climate change. This and subsequent reports (EASAC, 2018, 2019) examined the issue of substituting fossil fuels by forest biomass, and pointed out that:

1. Woody biomass contains less energy than coal (biomass pellets 9.6–12.2 GJ/m^3; coal 18.4–23.8 GJ/m^3; IEABioenergy, 2017), so that CO_2 emissions for the same energy output are higher (110 kg CO_2/GJ for solid biomass, 94.6–96 kg CO_2/GJ for coals in IPCC, 2006). Combined with the energy needs to gather from diffuse sources and intermediate treatment (drying and pelleting), replacing fossil fuels in electricity generation results in significant increases in emissions of CO_2 per kWh. The net effect of switching to biomass is thus usually to increase emissions and thus increase atmospheric levels of CO_2. This is the reverse effect to the original objectives of the RED to 'decrease GHG emissions'.
2. Biomass is treated as renewable because it is assumed that the CO_2 emitted will be reabsorbed. However, burning forest biomass transmits the carbon from the forest stock to the atmosphere within minutes, and there is a carbon 'payback period' between this initial release and a return to forest carbon stocks through regrowth. This payback period may be of the order of years when forestry residues provide the feedstock. However, where additional trees are harvested the payback periods depends on the species and conditions of regrowth which range from decades to centuries (e.g. McKechnie, Colombo, Chen, Mabee, & MacLean, 2011; Nabuurs, Arets, & Schelhass, 2017; Sterman, Siegel, & Rooney-Varga, 2018; Ter-Mikaelian, Colombo, Lovekin, et al., 2015). In some scenarios, the carbon present in the original forest stock may never be recovered. This means that the concept of carbon neutrality is both uncertain and highly time and context dependent.
3. When climate mitigation policies were being developed, the delay in achieving net reductions in emissions was left out of the regulations. However, the Paris Agreement now commits 'to pursue efforts to limit the temperature increase even further to 1.5°C' [redacted] the-paris-agreement—accessed May 10, 2019). Given that the Intergovernmental Panel on Climate Change (IPCC, 2018) projects that average surface temperatures are likely to exceed 1.5°C between 2030 and 2052 on current trends, payback periods of decades increase the risk of overshooting Paris Agreement targets.
4. Assessing the net effects of switching from coal to forest biomass requires an integrated approach whereby carbon flows along the complete life cycle (including combustion emissions) in the bioenergy scenario are compared with carbon flows in the absence of increased harvesting for bioenergy (a reference or counterfactual scenario). Such analyses should include the reduction in the carbon stock of the forests harvested. Many such studies (e.g. Ricardo, 2016; Stephenson & Mackay, 2014; Sterman et al., 2018; Ter-Mikaelian, Colombo, Lovekin, et al., 2015) have shown that only residues from traditional forestry management (i.e. leftovers after use for timber, board, paper etc.) or naturally fast-decaying wood as a result of forest dieback from diseases or fire have payback periods of the order of years. In contrast, increasing forest stock harvesting of stemwood (whether thinnings or clear-cut) increases atmospheric CO_2 levels for decades to centuries depending on the counterfactual scenarios. The UK Department of Energy and Climate Change (DECC, 2014) developed the Biomass Emissions and Counterfactual (BEAC) model to estimate different feedstock payback times. Buchholz and Gunn (2015) applied the BEAC model to a scenario in which 80% of feedstock came from additional biomass harvests in US hardwoods and found emissions of 2,677 kg CO_2-eq/MWh-over double that of coal. Even scenarios with 65% residues and only 35% of additional harvests exceeded emissions from a coal reference scenario.
5. Even the shortest payback periods compare unfavourably with that of solar and wind which offer net CO_2 emission savings within months to a few years (Marimuthu & Kirubakaran, 2013). Biomass is thus relatively ineffective in reducing CO_2 emissions; yet it is treated equally in regulations and in some EU countries, comprises the largest proportion of renewable energy subsidies.
6. Sustainability criteria in the RED regulations include conditions that biomass should achieve a specified percentage of GHG emission savings relative to fossil fuel. This can be easily misinterpreted to mean that switching from coal to wood is immediately climate beneficial. This is found on industry publicity—for instance, Enviva's home page states 'We export our pellets primarily to power plants in the United Kingdom and Europe that previously were fuelled by coal, enabling them to reduce their lifetime carbon footprint by about 80%' [redacted] accessed April 24, 2019). It is seldom pointed out that this merely limits the emissions along the supply chain (from felling, transport, drying and pelleting,

shipping) to less than the emissions from burning coal, and ignores the carbon emissions when the wood is burned.

7. The UNFCCC accounting rules already mentioned allowing an importing country to count emissions from biomass as zero, are based on the assumption that reductions in forest biomass are accounted in the exporting country's LULUCF statistics. Since implementation and verification of the latter vary considerably between countries, the trade-off between reductions in carbon stock and emissions into the atmosphere at the point of combustion lacks transparency. Emissions reporting can thus be highly misleading since the importing country will record biomass emissions as zero and as reducing its national emissions inventory, even though the net effect of switching from coal to biomass pellets may be to increase atmospheric CO_2 levels for decades.

The above considerations led to EASAC recommending that forest biomass should not be regarded as a source of renewable energy under the EU's RED unless the replacement of fossil fuels by biomass leads to net reductions in atmospheric concentrations of CO_2 within a decade or so.

Counterarguments to the above include that the removal of carbon stock from one area of forest should be considered on the landscape scale where (at least in some regions) carbon stock may be increasing. The errors in this approach have already been analysed by Ter-Mikaelian, Colombo, and Chen (2015) and from a policy perspective, the key question is, what are the climate implications for policy options including bioenergy, and those without? As pointed out above (EASAC, 2017; Ricardo, 2016; Stephenson & Mackay, 2014), in the case of the import of pellets from the United States to the United Kingdom, scenarios are dominated by those exacerbating climate change. Moreover, even though some forest carbon stocks have been increasing in Europe and parts of the United States, the Global Forest Resources Assessment (FRA, 2015) estimated that forest carbon stocks globally decreased by 0.22 gigatonnes annually from 2011 to 2015.

4 | A WAY FORWARD

In the above, we have described how applying the simplistic concept of carbon neutrality has led to an expensive policy which is increasing atmospheric levels of CO_2 and worsening rather than mitigating climate change for indeterminate periods of time. The IPCC accounting rules aggregating all forestry-related emissions to the LULUCF category have created a reward for countries importing biomass since, even though overall emissions are likely to have increased as a result of switching from coal to imported biomass, the country can count them as zero and report a reduction. Considerable economic assets are now locked into the converted coal-fired power stations, the transport infrastructure and the forest biomass supply chain which could be stranded if the simplistic assumption of carbon neutrality was corrected. Moreover, energy security, ability to meet renewable energy targets and socio-economic benefits in some areas are key aspects which weigh, as much if not more, in the mind of policymakers than the nuances of the real impacts on climate change. How in this situation might the current policy be reformed to reduce perverse impacts on climate?

The starting point must be for policymakers to have a more realistic science-based assessment of the potential of bioenergy. The improved efficiency in photovoltaics has underlined the inherently low efficiency of exploiting photosynthesis for energy, since the amount of electricity that can be produced from a hectare of land using photovoltaics is at least 50–100 times that from biomass (Fthenakis & Kim, 2009; Geyer, Stoms, & Kallaos, 2013). Indeed, some EU member states have already recognized that biomass electricity has a much higher carbon footprint as a 'renewable' energy than solar and wind, and have set much more stringent standards for future renewable energy subsidies (e.g. OFGEM, 2018). This, however, only affects the conditions on future projects, not the facilities already established and operating. Nor do such trends in Europe appear to be reducing efforts by pellet manufacturers to expand their markets outside Europe; for example, recent market surveys forecast rapid growth in pellet demand in South Korea and Japan founded on the ability under UNFCCC accounting rules to rate the related emissions as zero (https://insights.risiinfo.com/bioenergy-pellet-global-outlook/index.html—accessed July 10, 2019).

The essential reform required for existing and new operators is to limit feedstocks to those that have payback periods compatible with the Paris Agreement targets. As already pointed out, these may include the residues of traditional forest management, or forests subject to dieback or high fire risk. This is a challenge for regulators since the EU's own analyses (Agostini et al., 2014; Strange Olesen, Bager, Kittler, Price, & Aguilar, 2015) found that the amounts of residues available are insufficient (or already used in the forestry supply chain) to support the increased demand from large pellet plants, and that stemwood from trees was the dominant source of biomass for US pellet plants. These conclusions on the limited amounts of residues available are consistent with monitoring by environmental groups which have tracked areas of clear-cut forests to pellet mills (e.g. [redacted] feedstock reporting acknowledges the limited contribution of residues (for instance, Enviva's track and trace system reports its sources as 17% residues, with softwoods and hardwoods providing 83% [redacted].

As noted by the UK Committee on Climate Change (CCC, 2018), avoiding biomass uses which are worse for the climate than fossil fuels requires new international governance systems to be established which regulate out high-risk feedstocks and ensure best practice (e.g. use of organic wastes and genuine agricultural or forestry residues, and certain perennial crops grown on marginal land). Applying stricter governance to limit feedstocks to those with short payback periods may thus have substantial implications for the industry and limit its scale, presenting governments and regulators with a major challenge. Nevertheless, the alternative is to see further expansion in a practice which is not only economically expensive but fails to achieve the core objective of renewable energy policy to reduce GHG emissions.

A key component of new governance systems would be to require operators to publish their assessments of the net effects on atmospheric levels of CO_2 over the full life cycle of their supply chain, including how their feedstock supplies are affecting present and future carbon stocks. Several methodologies for such calculations are available (the UK BEAC model and others recently assessed by Brandao, Kirschbaum, Cowie, & Hjuler, 2019). Some debate continues over the sensitivity of such assessments to the choice of reference (counterfactual) scenarios (e.g. Daigneault, Sohngen, & Sedjo, 2012; Koponen, Soimakallio, Kline, Cowie, & Brandao, 2018) and the role of external factors which might compensate for losses of forest carbon stock—for example, if a bioenergy demand leads to improved forest management and productivity reducing the payback period, or if a 'no bioenergy' scenario led to natural carbon loss through pests, fire or other disturbance. Where such mitigating arguments are used to justify increased harvesting of stemwood, policymakers concerned with ensuring the appropriate use of public subsidies for renewable energy have the means to place the burden of proof on the operator and to also ensure that management systems are in place to deliver any mitigating effects.

Finally, reporting requirements under the UNFCCC are urgently needed which reflect real emissions and their impact on climate, and to remove the current perverse incentives to import biomass arising from the ability to treat them as zero emissions at the point of combustion. In the meantime, the EU should reform its own reporting requirements under its Emission Trading Scheme to ensure that emissions from biomass are fully transparent and reflect real climate impacts. Possible alternative reporting criteria have been suggested (Booth, 2018), which would take into account the payback periods of a facility's feedstocks in determining the proportion of emissions which should be reported, with 'zero emission' limited to facilities which achieve a net reduction in atmospheric CO_2 concentrations in Paris Agreement-relevant timescales.

Reforms such as these would allow the industry to evolve to methods and scales which are more compatible with the basic purpose for which it was designed and supported—to achieve net reductions in GHG emissions. A climate-friendly biomass energy supply chain could still provide an additional income source to forest owners, by providing demand for the low-value intermediate removals from thinning and for other residues, providing incentives to landowners to keep their land as forests, and to keep them healthy and productive. Forestry and its products will continue to have a critical role to play in mitigating climate change, but from a climate change perspective, the optimum use of forests remains to maximize use in construction (lumber and panels), furnishings and other products which capture carbon for long periods (Chen, Ter-Mikaelian, Yang, & Colombo, 2018).

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12 APPENDIX F: OEP SEEKS PERMISSION TO INTERVENE IN SUPREME COURT APPEAL TO HIGHLIGHT IMPORTANCE OF CLARITY IN ENVIRONMENTAL LAW

Press Release, 09.02.2023, Reproduced from Office for Environmental Protection (OEP) website.

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OEP seeks permission to intervene in Supreme Court appeal to highlight importance of clarity in environmental law

09.02.2023

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The Office for Environmental Protection (OEP) has filed an application with the Supreme Court for permission to intervene in the appeal of R (Finch) v Surrey County Council highlighting the importance of clarity in the law to promote good environmental decision-making.

The appeal, which was filed yesterday (Wednesday, 8 February) concerns a judicial review of the grant of planning permission for new oil wells on a site in Surrey. The Supreme Court will consider whether Surrey County Council (SCC) acted lawfully by not requiring the development's environmental impact assessment (EIA) to assess the impact of greenhouse gas emissions resulting from the future combustion of oil produced by the new oil wells. The OEP's intervention is prompted by this failure or alleged failure of SCC to comply with environmental law.

OEP General Counsel, Peter Ashford, said: "Environmental impact assessment is so important for integrating the environment into planning decision-making. We are interested in this case because of the opportunity to clarify the law here to ensure proper decision-making that enhances environmental protection. We hope that the Supreme Court will take this opportunity, and will develop principles for determining the proper approach to the assessment of indirect effects under the EIA legislation."

We will now wait to hear whether the Supreme Court grants permission for the OEP to intervene."

Notes to Editors

1. Full reference for case: R (Finch) v Surrey County Council [2022] EWCA Civ 187
2. Under section 41 Environment Act 2021 the OEP must publish a statement where it applies to intervene in a case

13 APPENDIX G: Relevant Representation, Dr Andrew Boswell (as submitted 24 August 2022)

Dr Andrew Boswell, Climate Emergency Planning and Policy

I am an independent environmental consultant specialising in climate science, policy, and law. I object to Drax's application to add carbon capture technology to two of its wood-burning units:

(1) The Environmental Statement (ES) does not comply with the EIA Regulations on how the impacts of the greenhouse gas (GHG) emissions from the scheme should be assessed in these ways:

   (A) Upstream logging and transport emissions from feedstock production are not accounted.

   (B) Upstream Indirect Land-use Change (ILUC) emissions, which can be very significant, are not accounted.

   (C) For the power plant combustion emissions, only "scheme-only" estimates are given and assessed despite one of the requirements of the 2017 Regulations is that the applicant must provide an environmental statement ("**ES**") including the cumulative impacts of the project and other existing and/or approved projects.

(2) The EIA Regulation requirements can only be discharged by providing a whole life-cycle carbon appraisal including all the upstream and downstream emissions sources, and which provides a cumulative assessment on combustion emissions with other regional CO2 generating power plants.

(3) To provide such a cumulative, and regionally contextualised, assessment of GHGs, the scheme should be cumulative assessed across the overarching "East Coast Cluster" (ECC), across the Teesside and Humber areas of which the Drax project is a part. This includes the gas power stations currently undergoing their own DCO examinations: Keadby 3, [EN010114],and the Net Zero Teesside project [EN010103].

(4) This would be consistent with the Institute of Environmental Management & Assessment (IEMA) "Assessing greenhouse gas emissions and evaluating their significance" guidance (February 2022) which states that best EIA practice for GHGs uses multiple sources of evidence and contextualises GHG assessment against local and regional carbon budgets. The IEMA guidance says comparison against national budgets is only of "limited value". The ES does not follow this guidance, and instead makes a sole assessment of significance against the entire UK economy carbon budget.

(5) The potential harm to human health from the amine chemicals, and their by-products, used to separate the CO2 from the other flue gases including possible carcinogens nitrosamines and nitramines.

(6) Drax's Ecology Report for the project states that this development will lead to the degradation and destruction of a number of internationally, nationally and locally important habitats where ecological surveys found rare and protected species, including orchids, water voles, otters, Great Crested Newts and many species of birds.

14 APPENDIX H: RESUME, Dr Andrew Boswell

I am a retired scientist and environmental consultant, working at the intersection of science, policy, and law, particularly relating to ecology and climate change.

- Undergraduate degree, BSc 1977, 1st class honours, Chemistry, Imperial College London
- Postgraduate, DPhil 1981, Oxford University, supervisor Professor R J P Williams, FRS, in Structural Biology, protein binding sites and dynamics
- 1984-1993, software engineering, testing, simulation systems for high-level design and logic synthesis of Very Large Scale Integrated (VLSI) circuits
- MSc, 1994, Parallel Computing Systems, University of the West of England
- 1995-2006, Manager high-performance and computing service across science departments at the University of East Anglia (UEA). System management and scientific modelling including climate modelling.
- 2005-2017, Green Party Councillor and sometimes group leader, Norfolk County Council and Norwich City Council
- 2017-2022, Climate Emergency Policy and Planning. CEPP is my own consultancy to promote the necessary rapid response to the Climate Emergency in mainstream institutions, such as local authorities and government, through the lenses of science, policy, and litigation. Expert contributor to the proposed UK Climate and Ecology Bill[27]. Foundation for Integrated Transport[28]fellowship on "*Exposing the flaws in carbon assessment and transport modelling for road schemes*." Interested party and expert witness on many current UK infrastructure planning examinations[29]. Climate and science-based litigation on three schemes[30]: three judicial reviews launched in the London High Court in summer and autumn 2022.

27 [redacted]
28

29 including A38 Derby Junctions; A417 Missing Link; A57 Link Road; A303 Stonehenge; A47 Blofield to North Burlingham; A47 North Tuddenham to Easton; A47 -A11 Thickthorn Junction; A47 Wansford to Sutton; A66 Northern Trans-Pennine Project; A720 Sheriffhall Roundabout, Edinburgh; Net Zero Teesside; Drax Bioenergy with Carbon Capture and Storage Project

30 A47 Blofield to North Burlingham; A47 North Tuddenham to Easton; A47 -A11 Thickthorn Junction