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DEADLINE D2 SUBMISSION

I am an independent researcher and environmental consultant, working at the intersection of science, policy, and law, particularly relating to ecology and climate change. I work at a consultancy called Climate Emergency Policy and Planning (CEPP). A brief resume is given at Appendix A2.

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 (WR) addresses whether Environmental Statement (ES) for the H2Teesside project realistically describes the Greenhouse Gas (GHG) emissions that the project would produce against the relevant latest science and knowledge of the natural gas supply market.

The main submission is intended to be read sequentially as it builds up material in a logical flow. However, for this summary, I start at section 8 which sets outs the principles of Environmental Impact Assessment (EIA) from recent case law, and identifies related issues for the ExA and SoS pertaining to the H2Teesside Environmental Statement (ES). In essence, EIA is a process of identifying, describing and assessing environmental effects from a development for their environmental impact, in this case on the global climate. For any assessment to be meaningful, it must be preceded by the first two steps of adequately identifying and describing the effects. What does "adequately" mean? I suggest these tests for the ExA and SoS to consider:

(i) whether the full knowledge of the environmental cost of the project has been described in the ES;

(ii) does the ES contain as much knowledge as can reasonably be obtained, given the nature of the project, about its likely significant effects on the environment;

(iii) have the possible future effects on the environment been adequately described;

(iv) has the EIA inquiry been "forward looking", and has it tested whether effects are likely (in the future), and then fully included and described them in the ES.

I find that none of the above tests have been met in the ES, and therefore no meaningful assessment can be made.

In particular, this is because the Greenhouse Gas (GHG) emissions from the project are severely underestimated. The underestimates are compounded from three significant factors, each of which carries its own substantial underestimate. These are:

(i) The project claims a 95% carbon capture rate when no similar project has achieved more than 80% carbon capture;

(ii) Emission factors for upstream fugitive emissions from the natural gas supply are based on out-of-date data, and do not reflect the potential changes to the natural gas supply market in the UK;

(iii) The climate impact of methane is inadequately modelled for its short-term but extremely damaging effect to the atmosphere.

To assist the ExA to follow some very complex background material, I provide at section 3 "Key Issues Raised in This Submission" which outlines the key technical issues drawn from around 15 Appendix documents. I would draw the ExA's attention to section 2.4 "Background reading"

which respectfully suggests some carefully selected reading from key background information from the Appendices, which especially relates the above three significant factors. My intention by suggesting this "background reading" is to give the ExA a quick dive into the issues where they have already been well explained by others, and also to avoid long narratives in my own submissions to "wade through". It is intended to save time for readers, and I hope it achieves this.

In section 7, I provide eight sensitivity tests (ST) of these three significant factors where the climate impact is underestimated in the ES. These STs are conservative compared to the recent literature and provide a reasonable worst-case (but not the worst-case) estimate for the 25-year Phase 2 operation emissions of **99.71 MtCO2e** (millions of tonnes of carbon dioxide equivalents) compared to the Applicant's estimate of **19.13 MtCO2e**: in other words over 5 times greater. The conclusion from this is that the Applicant's EIA has failed at the first two steps of identification and description of the effects, and no meaningful assessment can be made on the current data in the ES. Despite, this section 9 does provide some comments on the Applicant's assessment.

A number of key points are made along the way. In summary, these are:

(i) I respectfully request that the ExA extend the examination to cover the implications of the nearby Teesside Flexible Regas Port project.

(ii) I request that the ExA extend the examination to cover the implications of the nearby Net Zero Teesside project.

(iii) The Applicant claims to have adopted the principles of the "Rochdale envelope" approach but has not actually applied it to its EIA assessment in Chapter 19.

(iv) The full knowledge[1] of the environmental cost, which can reasonably be obtained for H2Teesside, has not been identified, nor described in the Applicant's ES.

(v) The GHG gas emissions from H2Teesside are much greater than those described in the ES by the Applicant (as the numbers above show).

(vi) In order to minimise the full scale and quantum of GHGs taken forward to the assessment stage, the Applicant hides behind various assumptions in the ES description.

(vii) The Well to Tank (WTT) emissions from H2Teesside are equivalent to 34% (reasonable worst-case) of the fuel supply sector residual emissions in the 6th carbon budget (although not all of these account to the UK carbon budget because they are a mixture of territorial and consumption emissions).

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[1] The legal significance of the underlined terms will be explained in section 8

(viii) The uncaptured Autothermal Reformer (ATR) process emissions consume 8.61% (reasonable worst-case) of the Power sector residual emissions in the 6th carbon budget (all being UK territorial emissions).

(ix) There is no reasoned explanation of how the project is "*fully in line with measures necessary to achieve the UK's trajectory towards net zero*" although the Applicant's significance assessment claims that it is by virtue of a Minor Adverse significance via the IEMA guidance[2].

(x) I request that the ExA requests that the Applicant provides an explanation of how it reaches the conclusion that the project is Minor Adverse.

(xi) I request that the ExA requires a cumulative assessment to be made across the UK gas-CCS and blue hydrogen sector, based on current projections of planned roll-out to 2035.

(xii) The notion that an additional EIA significance assessment can be made by including the use of the hydrogen product to offset the emissions estimated for the project is not legitimate. There is no "full knowledge"[3] assessment of how this offsetting would work for EIA purposes (just as there is no "full knowledge" assessment the H2Teesside project itself).

(xiii) I request that the ExA considers if a DCO provision can be drafted in the H2Teesside DCO so that a minimum carbon capture rate is secured in the DCO itself similar to similar provisions already extant in the Net Zero Teesside and Keadby 3 DCOs. The capture rate should be 95% reflecting the assumptions in Applicant's ES.

(xiv) I request that the ExA also considers if a similar provision to be drafted in the H2Teesside DCO so that the natural gas supply to the H2Teesside plant must be compliant with the LCHS standard.

(xv) In a few cases my own calculations cannot reproduce the Applicants, and in each case[4] I lay out the difference and request the Applicant to explain it.

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

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[2] Institute of Environmental Management and Assessment (IEMA) for Assessing Greenhouse Gas (GHG) Emissions and Evaluating their Significance (IEMA, 2022)

[3] The legal significance of this term will be explained in section 8

[4] These are:

(i) Clarify how the Scope 2 "Imported electricity" decline, and provide the annual values which it has calculated for the Scope 2 emissions between 2027 and 2055 (section 6.1)

(ii) Low Carbon Hydrogen Standard (LCHS) estimates (section 6.2)

(iii) Shortfall in estimating fuel supply emissions (section 9.1)

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1 PROCEDURAL ISSUES

1.1 Rule 8 letter, 30th August 2024

2 I want to thank the ExA and the Applicant for accommodating my request to delay the Written Representation deadline, and I appreciate the considerable discussion of this at the Preliminary Hearing leading to the deadline change for all parties. I accept this as the most satisfactory decision and fair to all parties. I just want to clarify on a small point, no longer relevant but for the record, that I was also away during August although my original email hadn't made that clear to parties.

1.2 Rule 17 letter, 10th September 2024

3 In response to the ExA's letter on the recent guidance on AI, I confirm that I have not used AI to create or alter any part of my documents, information or data, submitted to this Examination to date. I note the requirement to clearly identify the use of AI in any subsequent submissions.

2 INTRODUCTION

2.1 Deadline 2 (D2)

4 This is my submission for Deadline 2. It comprises my Written Representation (WR).

2.2 ExQ1

5 I note the ExA's first written questions (ExQ1), and in particular ExQ1/Q1.5.6 on the assumptions in the applicant's EIA assessment of Greenhouse Gas (GHG) emissions in ES Chapter 19. This submission is <u>not</u> a response to the ExQ1 or ExQ1/Q1.5.6 specifically: however, the thrust of this submission is on the unjustified and unevidenced assumptions in the EIA, so the material here relates to ExQ1/Q1.5.6.

6 I make some small comments on other ExQ1 questions where they relate, but again <u>not</u> as a formal response.

2.3 ES Chapter 19

7 My submission largely relates to Chapter 19 of the Environmental Statement, "Climate Change" [**APP-072**] and the Environmental Impact Assessment (EIA) of GHG emissions from the development.

8 Chapter 19 is an Environmental Statement ("**ES**") under the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the "**2017 regulations**"). This document will be simply referred to "**ES**" below.

2.4 Background reading

9 I have appended various appendices to this WR, and I will refer to specific pages from them during my narrative.

10 A comprehensive set of appendix information provides a basis, and background, for my own submission, and I advise that it would be helpful for ExA and parties to read the reports from Carbon Tracker[5] "Kind of Blue" and Institute of Energy Economics and Financial Analysis (IEEFA[6]) "Blue Hydrogen: Not Clean, Not Low Carbon, Not a Solution" in full as these are very recent and well researched reports into the issues raised in this document.

11 The purpose of this request for "background reading" is to save time for all by providing relevant sources of background information, and not repeating background information of this complex matter unnecessarily within this document itself, and thereby focussing this submission as much as possible on my own work. I try to relate these other sources to the planning and EIA issues of the planning examination, and the H2Teesside development.

12 Bearing in mind the demand on the ExA's time, I suggest these sections of each report in particular are given attention as they either contain vital background information to my submission or they will be referred to in later sections of this document.

13 Carbon Tracker "Kind of Blue" report (Appendix B):

(i) Key findings. 1 page (Page1, PDF Page 4)

(ii) Executive Summary. 4 pages (Pages 2-5, PDF Pages 5-8)

(iii) Policy recommendations. 2 pages (Pages 6-7, PDF Pages 9-10). Especially "reporting standards" which directly relates to the emissions factors used in the ES, and "Environmental Impact Assessments (EIA)" which directly relates.

(iv) Section 2 "Upstream Emissions of Natural Gas". 2 pages (Pages 13-14, PDF Pages 16-17). This section provides vital information on the underestimation of emission factors for upstream emissions by UK bodies such as North Sea Transition Authority (NTSA) and provides references (footnotes 21-26) which formed the basis of a review of emissions factors by Carbon Tracker.

(v) Section 2.1 "UK's Natural Gas Outlook". 3 pages (Pages 14-16, PDF pages 17-19). This section describes likely variation in natural gas supply, especially of Liquified Natural Gas (LNG) imports. The emission factor table of scenarios,

[5] About Carbon Tracker: The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's capital markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system in the transition to a low carbon economy. https://carbontracker.org/ (from Appendix B)

[6] About IEEFA: The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org (from Appendix D)

derived to adjust for UK underestimates and natural gas variation, and which is used as a basis for sensitivity testing in this submission is given at Table 1 on page 16.

(vi) Section 5. “Considerations for Environmental Impact Assessments”. (Pages 21-27, PDF Pages 24-30), especially section 5.1 directly relating to the ES for H2Teesside. The wider impacts of the UK CCUS programme under the Net Zero Strategy, and its impact in creating an increased demand for LNG is covered in section 5.3.

IEEFA “Blue Hydrogen: Not Clean, Not Low Carbon, not a Solution” report. Please note that this report is written for the US market, but the technical points apply:

(i) Section “Not Considering 20-year GWPs Means the Effects of Methane Emissions and Hydrogen Leakage Are Underestimated” (Pages10-12)

(ii) Section “A 1% Methane Emission Rate Is Not Consistent with Recent Scientific Surveys and Analyses” (Pages 12-15).

(iii) Section “There Is No Evidence That Existing Commercial-scale Carbon Capture Projects Have Captured Anywhere Close to 95% of the CO2 They Create” (Pages 17-23)

14 I am grateful to Carbon Tracker and IEEFA for the use of their reports, and for checking my usage of their material.

3 KEY ISSUES RAISED IN THIS SUBMISSION

15 The key issue in this submission is whether the H2Teesside project will increase or reduce the GHG emissions causing climate change. Then how this is reflected in the ES and EIA assessment. This will be considered, both for the project itself and the project in the wider context of the project with other related developments in Teesside and the use of the hydrogen product itself.

16 So overall this submission will address the GHG emissions of both H2Teesside itself, and in the wider context.

17 The 2107 Regulations require that the likely significant effects on the environment, including GHGs, are identified, described and assessed. The receptor for these effects is the global climate[7]. In this submission, I will use “climate impacts” as a shorthand for “impacts on the global climate”.

[7] As stated by the Applicant at ES 19.5.2

18 The emissions from H2Teesside itself come from construction, direct and indirect operational emissions, and decommissioning. I will focus mainly on the operational emissions which are the largest part. For the 25-year Phase 2 operation, the Applicant has identified in ES Table 19-9 emissions for (a) the direct Scope 1 operational emissions from the Autothermal Reformer (ATR) process; (b) Scope 2 emissions from imported electricity; and (c) indirect Scope 3 emissions including upstream well-to-tank ("**WTT**") emissions and (d) indirect Scope 3 emissions from uncaptured CO2 during transport and storage unavailability ("**T&SU**"), as well as other Scope 1, 2, and 3 emissions.

19 All the enumerated emissions in ES Table 19-9 are taken forward into my sensitivity test calculations (which produce total 25-year Phase 2 operation emission totals, see later). However, only the Scope 1 uncaptured CO2, and Scope 3 WTT and Scope 3 T&SU emissions are displayed in the graphs to keep the graphs simple and clear.

20 The majority of this submission will examine whether the description of the Scope 1 uncaptured CO2 and the Scope 3 WTT emissions in the ES is enumerated realistically given the context of:

(i) the current limitations of carbon capture technology, including recent reviews of existing CCS plants around the world;

(ii) the changing market in natural gas supply, and specifically the balance of UK sourced gas with imports; and

(iii) the rapidly evolving science on methane emissions and the realistic modelling of their impact on the global climate.

21 These are now each considered in turn. Further information may be found in the documents in the Appendices, especially those recommended above as "background reading". My intention in this section is not to go into vast detail which may be found elsewhere in the Appendices.

22 A later section will consider the implications for the legal aspects of the ES and EIA assessment made, and the assumptions within it.

3.1 The limitations of the carbon capture technology

23 The first key issue is that, as far as climate impacts are concerned, CCS has a poor track record of capturing Scope 1 emissions. Against this, the applicant is claiming that H2Teesside will capture 95% of the CO2 emissions generated by the Autothermal Reformer (ATR) process. I refer the ExA to the Appendix C where I provide a recent presentation (Appendix C: IEEFA presentation from March 2024) from the Institute of Energy Economics and Financial Analysis (IEEFA) who have recently researched the CCS market and reviewed existing commercial projects. I reproduce slide 12 below:

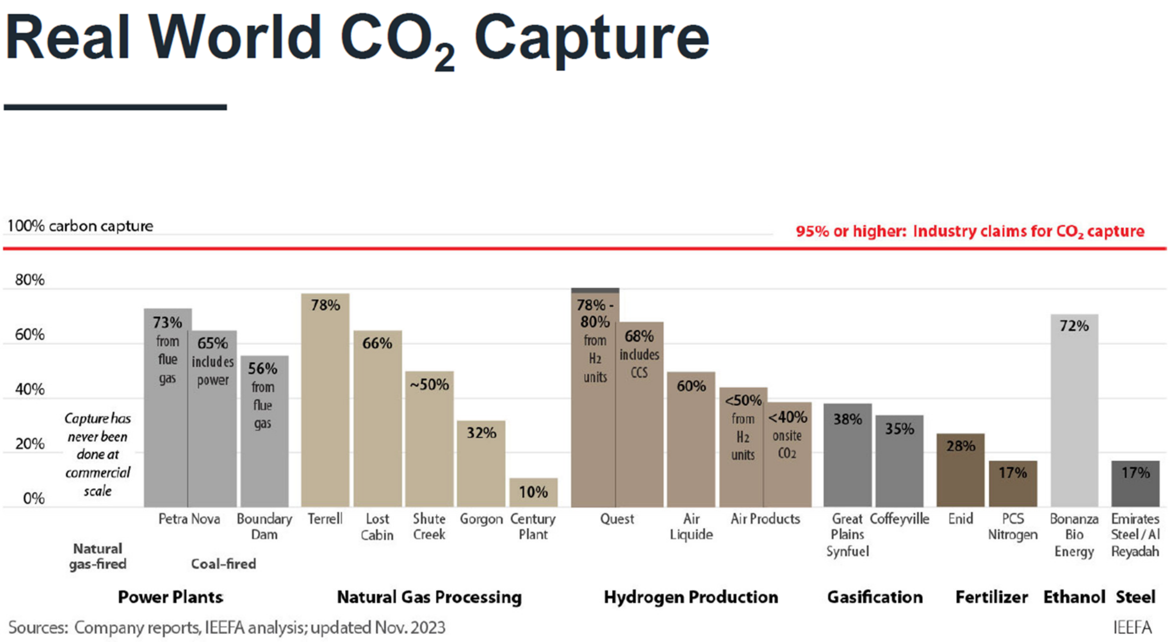


Figure 1: IEEFA: Real World CO2 Capture (2024)

24 There are only three commercial-scale hydrogen production facilities in the world currently operating with CO2 capture, as shown in the "Hydrogen Production" section of the slide above: Quest, Air Liquide and Air Products. In a related December 2023 paper (see Appendix D, page 18), IEEFA note that for hydrogen production, "*there are only three commercial-scale hydrogen production facilities in the world currently operating with CO2 capture. All use SMR technology to produce hydrogen. None of these facilities has captured even 80% of the CO2 they produce—and only one, Project Quest in Alberta, has captured 68% of its CO2. And it only appears to have achieved that level of performance if the emissions associated with the capture process are ignored. No CO2 has been captured at any commercial-scale facility using ATR technology.*" (ATR is the technology proposed for H2Teesside).

25 The data above shows that the Quest plant has achieved 78% capture rate from its Steam Methane Reforming (SMR)[8] unit(s): the emissions from the associated furnace to power the SMR have not been captured. Quest's website indicates that the average capture in 2023 was 75.2%. It is important to note that the type of flue gases from Quest and H2Teesside would

[8] The Carbon Tracker report (appendix B, Page 11, PDF page 14) explains:

> "*New CCUS-based hydrogen projects are mostly based on two technological pathways:*
>
> • *Steam Methane Reforming with CCS*
>
> •*Autothermal reforming (ATR) with CCS*
>
> *The main difference between the two is the heat requirement. SMRs require external heat that is generally produced via natural gas combustion, so carbon dioxide has to be extracted from both the gas mixture exiting the reformer and the flue gases of the furnace that provides heat to the process. On the contrary, in the ATR process, the reaction takes part in a single chamber without the need for external heat, so CO2 only needs to be removed from one source. For this reason, despite the ATR process being more expensive, it is becoming the standard solution for blue hydrogen projects, as it reduces the complexity and costs of carbon capture.*"

be very similar so the Quest plant may provide an existing reference for what would be possible in terms of capture rates at H2Teesside, and what would not be possible. The H2Teesside applicant has provided no evidence as to how it considers that it can achieve a 95% capture rate.

26 With respect to the Applicant's claim that H2Teesside will run at a capture rate of 95%, it has given no evidence that this level of capture is possible at a commercial level, and why it should now be possible when it has not been possible elsewhere. I note that the ExA at ExQ1/Q1.5.6 has requested that the applicant for a justification of a number of assumptions made at ES 19.5.58, including "*especially the scenario related to the 5% unabated CO2 referred to in the first bullet point*". I, therefore, await the Applicant's response at Deadline D2.

27 Further, the applicant also says at ES 19.5.58 that the carbon capture "*rate will be addressed by the Environmental Permit for the Proposed Development*". This is counter to the precedent set in recent DCOs for Net Zero Teesside and Keadby 3 (both Combined Cycle Gas Turbine (CCGT) gas fired power stations with CCS) where the required capture rate has also been dealt with in the DCO. I will address this later in this document.

3.2 Upstream emission factors: underestimated and don't reflect changes to natural gas supply

28 The Carbon Tracker "Kind of Blue" report sets out in detail the following issues which act together to compound the climate impact of blue hydrogen production in future scenarios, and in the 2031-2055 lifecycle of H2Teesside. I suggest that the CT report section 2 is referred to for more detail, noting particularly these points:

(i) The emission factors used for upstream emissions in the natural gas supply chain are underestimated. This is explained by two compounding factors – underestimating the methane leakage in any particular source of natural gas and underestimating the effects of the changing balance of UK natural gas between UK and Norwegian gas (lower upstream emissions) and imported gas, especially LNG (higher upstream emissions).

(ii) Although DESNZ publishes emissions factors annually (as used by the Applicant and which I sensitivity test later), underestimating has been historically perpetuated by using data self-reported by fossil fuel companies. In recent years, satellite and remote sensing has achieved much a more accurate picture of upstream methane emissions that is revealing this systemic underestimation.

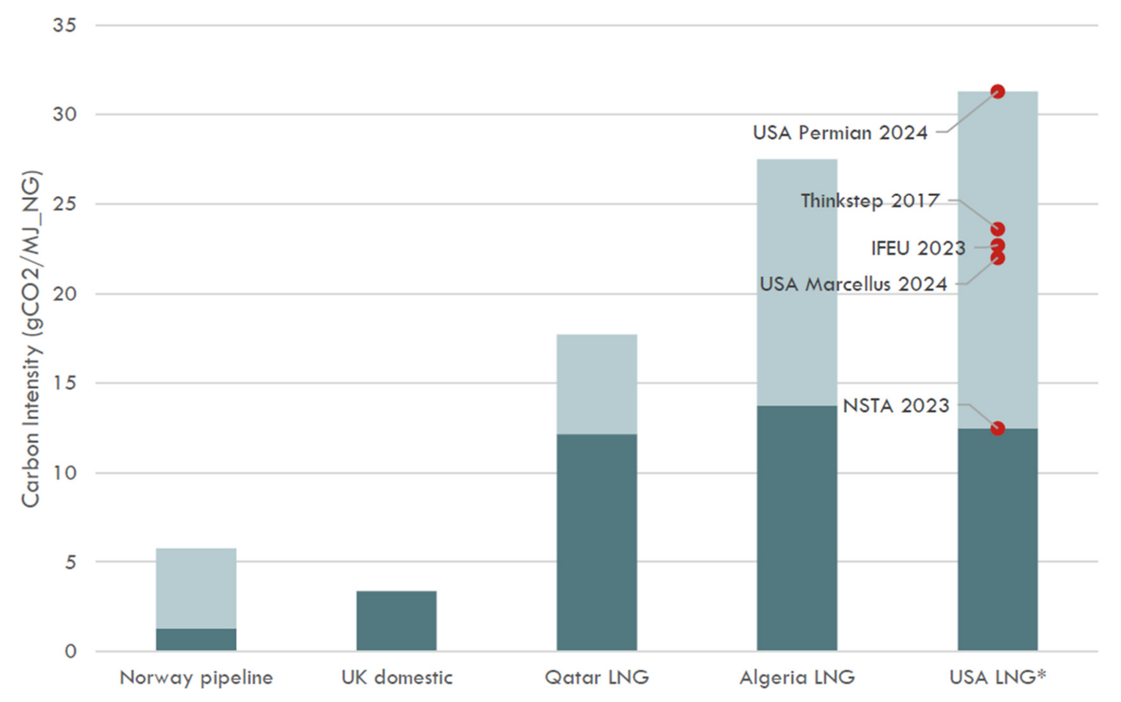
> "*Numerous independent reports have pointed out that there is still a large gap between the emissions self-reported by major fossil fuel companies and emissions estimated via satellites or remote sensing* [<footnote 26>]*. In particular, the IEA reports that most of the self-reporting is today based on reference values instead of measured emissions and that the difference between the two approaches could be massive.*" [Appendix B, page 14, PDF page 17]

(iii) The source of the natural gas is important given the very different scale of emissions possible.

> "*Upstream emissions vary widely depending on the origin of natural gas, due to different extraction processes (conventional, fracking), transportation (pipeline, LNG shipping) and the leakages in the full supply chain.*" [Appendix B, page 13, PDF page 16].

(iv) LNG imports have a much greater upstream emission footprint than UK domestic or Norwegian pipeline sources, see below.

FIG 7: NATURAL GAS UPSTREAM EMISSIONS VARY WIDELY DEPENDING ON THE ORIGIN COUNTRY AND TRANSPORT ROUTE



Source: Carbon Tracker (2024); based on multiple sources available in Appendix Table 5.

Figure 2: Carbon intensity for different Natural Gas supplies (reproduced from Carbon Tracker "Kind of Blue", page 13, PDF page 16 – *the lighter shading shows the range of carbon intensities*)

(v) UK sources of natural gas are declining, and imports are growing.

> "*Natural gas production in the UK has been in steep decline since the 2000s and, in the last ten years, it stabilised around half of the national supply with the rest being imported via pipeline (mostly from Norway) or LNG. Domestic production is expected to drop further in the coming decades while pipeline*

imports from Norway are also expected to decrease, though more slowly." [Appendix B, page 14, PDF page 17]

(vi) LNG imports are predicted to grow. DESNZ's December 2023 report "The role of gas storage and other forms of flexibility in security of supply"[9] (Appendix F, pages 19-20) , notes:

> "*… the UK's import dependence for both LNG and interconnector gas supply is projected to rise from a predicted 13% in 2023 to around 32% by 2030. This is forecast to peak at around 58% in 2045, falling to 50% by 2050. It is likely that LNG will make up a significant proportion of these future gas imports.*"

Although interconnector and LNG supplies are conglomerated in the above quote, based on DESNZ Statistics from March 2024, Carbon Tracker estimated that in 2023 LNG accounted already for 24% of the UK's total gas supply [Appendix B, Page 15, PDF Page 18].

Critically, the DESNZ December 2023 report identified that further research and analysis was required (Appendix F, pages 19-20) on the methane emission intensity from the gas supply:

> "*As we import more gas, we are also mindful that the level of greenhouse gas emissions from overseas extraction, liquefaction and shipping of LNG varies considerably and is, in many cases, higher than UKCS[10] production. NSTA research shows that the production and transportation emissions of CO2 associated with LNG imports are on average over quadruple the global emission intensity of UKCS gas production. Further research and analysis is needed to develop our understanding of the methane emissions intensity of different sources of gas supply.*"

29 The overall scale of CCUS planned in the UK will also become a driver for increased LNG imports. Carbon Tracker find that 4 GW of blue hydrogen and 9 GW of gas-CCS plants are planned by 2035 [Appendix B, Page 26-27, PDF Pages 29-30], and report that:

> *"We estimate that if all the gas-based CCUS projects proposed by the UK's Net Zero strategy are built, by 2035 new gas demand could two times greater than the projected domestic production requiring an inevitable reliance on LNG imports."*

30 Carbon Tracker have also developed a model of a long-term gas outlook built on UK Government and other projections which broadly shows that, even assuming the unlikely development of new gas licenses in the 2030s, the 2030s the share of imported LNG could

[9] DESNZ, December 2023, "Role of gas storage and other forms of flexibility in security of supply", https://www.gov.uk/government/publications/role-of-gas-storage-and-other-forms-of-flexibility-in-security-of-supply

[10] UK Continental Shelf

average around 50%[11]. This will be published shortly and made available to the examination at a future deadline.

31 The evidence is that imported LNG will play a significant role in meeting UK methane-gas demand. **Since cheaper pipeline gas will always be utilised first before turning to expensive LNG, any <u>extra demand</u> created by investing in new gas power stations or blue hydrogen production will, at a national level, be met entirely by imported LNG.** Life cycle assessments for new CCS-enabled plants, such as H2Teesside should therefore treat the methane gas input as 100% provided by LNG imports. Sensitivity test given later will provide estimates of the climate impacts when the upstream emission factor is calculated on a range of LNG scenarios.

32 The DESNZ emission factors are mostly based on a 2015 report from Exergia (Appendix Q). The nine-year old report does not reflect the latest scientific findings on upstream emissions, particularly the more accurate measurement by satellites and remote sensing available now. The evidence base of this Exergia report is most likely outdated. It is imperative for DESNZ to update its methodology and assessment of emission factors. Given that up-to-date emissions factors are not available, it is appropriate to use sensitivity testing for the ES based on more recent data and literature. This is what I have done in the section of sensitive testing.

33 In summary, the upstream GHG footprint for the UK natural gas supply is underestimated by existing emissions factors, and the growth of high carbon intensity imports are overlooked in emission factors. This is the case with the H2Teesside ES where a single emission factor based on historic average of data from underestimated self-reporting is used for the upstream emissions. *In short, the selected DESNZ emission factor is an out-of-date underestimate as shown by recent measurements by satellites or remote sensing, and does not reflect future scenarios of gas supply.*

34 I note that the ExA at ExQ1/Q1.5.6 has asked the applicant for a justification of its assumptions on “upstream ‘well to tank’ Methane (CH4) “emissions and “upstream emissions (well-to tank CH4 extraction)”. <u>The upstream emissions are a significantly greater proportion of the full lifecycle GHG emissions than losses due to lower than claimed carbon capture rates, as Carbon Tracker and IEEFA have shown, and I later show by sensitivity testing on the emission factor in this submission.</u> I await the Applicants response at Deadline D2.

35 The issues describe above for the upstream emissions emission factor are compounded further by the next issue of the Global Warming Potential (GWP) chosen to model methane emissions (and hence the emission factor).

[11] Lorenzo Sani, Carbon Tracker, personal communication, Sept 2024

3.3 The rapidly evolving science on methane emissions and their impact of the global climate

36 As said, the most significant carbon footprint for H2Teesside comes from methane and other upstream emissions in the supply of the gas. I have already described how the single emission factor used underestimates the climate impacts. However, the climate impact is further underestimated because the emission factors are based on using a 100-year Global Warming Potential (GWP) - GWP100 - for methane (natural gas) rather than a 20-year GWP – GWP20.

37 Appendix G provides a paper, now in press[12], by Professor Robert Howarth of Cornell University who has advised the US Government and given evidence to the Senate Climate Change Task Force. Professor Howarth explains the issue with the different GWPs as follows [Appendix G, page 17]:

> "*While the 100-year time frame of GWP100 is widely used in lifecycle assessments and greenhouse gas inventories, <u>it understates the extent of global warming that is caused by methane, particularly on the time frame of the next several decades.</u> The use of GWP100 dates to the Kyoto Protocol in the 1990s, and was an arbitrary choice made at a time when few were paying much attention to the role of methane as an agent of global warming. As the Intergovernmental Panel on Climate Change stated in their AR5 synthesis report, "there is no scientific argument for selecting 100 years compared with other choices" (IPCC 2013). The latest IPCC AR6 synthesis reports that methane has contributed 0.5º C of the total global warming to date since the late 1800s, compared to 0.75º C for carbon dioxide (IPCC 2021). <u>The rate of global warming over the next few decades is critical</u>, with the rate of warming important in the context of potential tipping points in the climate system (Ritchie et al. 2023). <u>Reducing methane emissions rapidly is increasingly viewed as critical to reaching climate targets</u> (Collins et al. 2018; Nzotungicimpaye et al. 2023). <u>In this context, many researchers call for using the 20-year time frame of GWP20 instead of or in addition to GWP100</u> (Ocko et al. 2017; Fesenfeld et al. 2018; Pavlenko et al. 2020; Balcombe et al. 2021, 2022). GWP20 is the preferred approach in my analysis presented in this paper, as was the case for our earlier lifecycle assessment of blue hydrogen (Howarth & Jacobson 2021). Using GWP20, LNG always has a larger greenhouse gas footprint than coal.*"

38 For these reasons, I will provide a sensitivity test on the emission factor used for H2Teesside well to tank ("WTT") emissions between using a 20-year Global Warming Potential (GWP20) of 82.5 and a 100-year GWP100 of 29.8: these are the values in the latest 6th Assessment report from the IPCC (202113). I also make an adjustment which takes into account CO2 in the upstream emissions (which is not subject to the GWP100 / GWP20 issue

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[12] In press in the peer-reviewed journal: Energy Science & Engineering - Accepted Sept 6, 2024

[13] Intergovernmental Panel on Climate Change. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte V, Zhai P, Pirani A, Connors S, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis M, Huang M, Leitzell K, Lonnoy E, Matthews J, Maycock T, Waterfield T, Yelekçi O, Yu R, Zhou B (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896

which pertains here to methane) – the method for this is described in Appendix A (in section 'Calculation of the "uplift factor" for the sensitivity tests on GWP20 instead of GWP100') and is based upon the data in the recent paper by Professor Howarth. The uplift factor for GWP20, taking into account upstream CO2 is 1.86 (as opposed to 2.77 which is the straight division of the GWPs ie: 82.5/29.8). This means that the atmospheric methane effects of H2Teesside are estimated in fair and realistic way, consistent with the latest scientific research.

39 As methane has a half-life in the atmosphere of around 10 years, the vast majority of its climate impact is in the first twenty years after leakage. This also is the timescale in which global climate policy has the objective to take rapid action to stabilise the global climate, and to limit future temperature rises. Professor Howarth identifies above that methane has been responsible for around 2/5ths of the global heating temperature rise to date.

40 The urgent need to reduce methane in the atmosphere is borne out by other recent scientific publications, including a recent paper in a leading journal, the Proceedings of the National Academy of Sciences (PNAS), which found that making sharp cuts to methane now could contribute to keeping temperatures lower by 0.26°C by 2050 ("the Dreyfus paper", see *Appendix H* and *Appendix I* for a useful explanatory press article).

41 This urgency was reflected, too, in the Global Methane Pledge (provided at Appendix J) now signed by over 150 countries[14] at the United Nations Climate Change conference in November 2021 (COP26), including the UK as COP26 host country, which stated "*Rapidly reducing methane emissions from energy, agriculture, and waste can achieve near-term gains in our efforts in this decade for decisive action and is regarded as the* ***single most effective strategy*** *to keep the goal of limiting warming to 1.5˚C within reach while yielding co-benefits including improving public health and agricultural productivity.*" (emphasis added). The Pledge is to slash methane emissions by 30% by 2030, compared to 2020 levels.

42 However, the International Energy Agency (IEA) propose in its "Global Methane Tracker 2022"[15] that methane should be reduced in fossil fuel operations by a much greater rate of 75%:

> *"Fossil fuel operations account for more than one-third of human-caused methane emissions. These emissions represent one of the best near-term opportunities for climate action because the pathways for reducing them are known and understood. Achieving a 75% reduction in emissions from fossil fuel operations, as set out in the IEA's Net Zero Emissions by 2050 Scenario would take the world most of the way towards fulfilling the Global Methane Pledge."*

[14] Now signed by over 150 countries, Carbon Brief, Appendix K

[15] This is only available as a website, and the website does not render neatly into a document (otherwise I would provide it as an Appendix) as the site is designed to be interactive. Ideally, this link should not be redacted – the IEA Global Methane Tracker 2022 is at: https://www.iea.org/reports/global-methane-tracker-2022

43 The IEA chart "Methane emissions from fossil fuels, historical and in the Net Zero Scenario, 2020-2030", reproduced below, shows methane leakage reducing from global methane production from 38.5 MtCH4 in 2020 to 13.3 MtCH4 in 2030 to meet the IEA's "Net Zero Emissions by 2050 Scenario" – <u>a 66% reduction in ten years</u>.

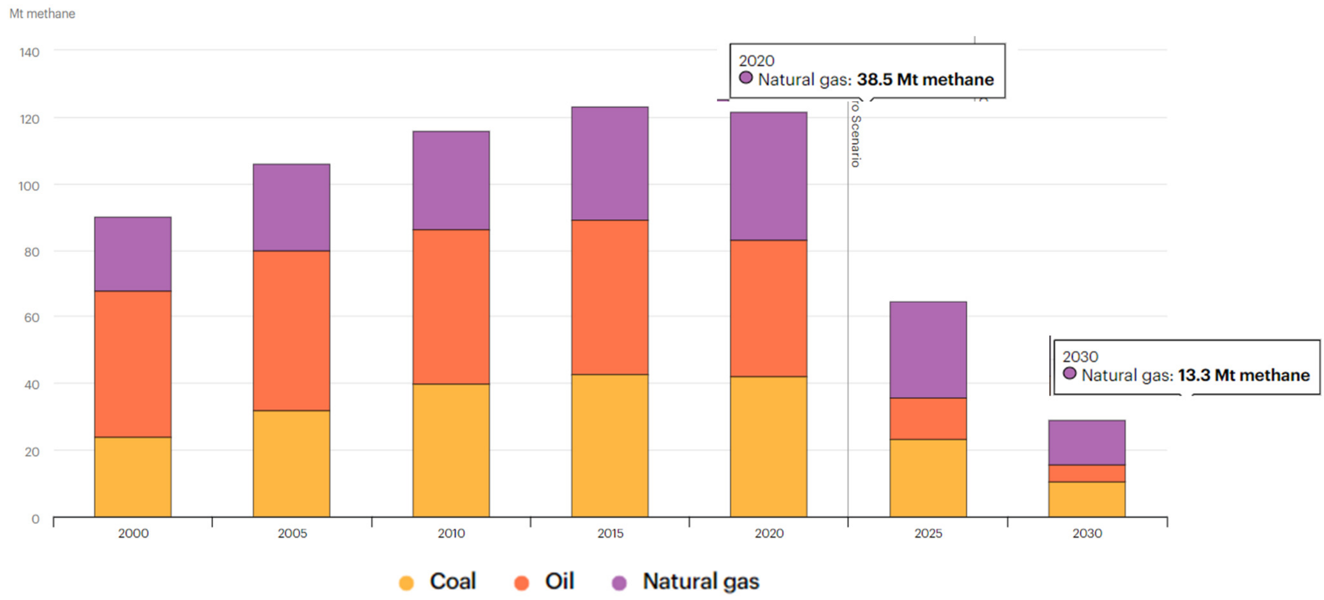

Figure 3: IEA projections for methane reductions 2020-2030 (reproduced from *IEA chart "Methane emissions from fossil fuels, historical and in the Net Zero Scenario, 2020-2030")*

44 Despite the 2021 pledge by many nations, methane emissions keep rising. A Carbon Brief report (dated September 2024, see Appendix K) re-emphasises "*cutting methane emissions is widely viewed as a crucial part of near-term efforts to tackle climate change*" but reports that "*levels of methane in the atmosphere have soared by record-breaking amounts since 2020*[16]*, according to new research*" with 34% of methane emissions coming from fossil fuels.

45 The largest proportion of the H2Teesside GHG footprint comes from methane in the upstream emissions in the supply of the gas. Even with CO2 capture rates much lower than the 95% claimed, the upstream methane emissions are the much greater effect (and this will be shown in this document). I have laid out above why methane must be reduced rapidly over a very short period of time, and how its climate impact must be enumerated so as to realistically capture its real impacts <u>which are short-term impacts</u> (ie: by using GWP20).

46 Before moving to the Environmental Statement, the EIA and the EIA process, there are two other issues raised in the next sections concerned other developments in the area close to H2Teesside.

[16] "*Recent years have seen the second (2020), first (2021), fourth (2022) and 14th (2023) largest increases in global methane concentrations since the US National Oceanic and Atmospheric Administration (NOAA) began recording this data in 1983.*", Carbon Brief, Appendix K

4 TEESSIDE LNG REGAS PLANT

47 The ExA will be aware that an EIA scoping report has been submitted to PINS for the Teesside Flexible Regas Port project[17] as the initial step for a DCO planning application. This project proposed by WaveCrest Energy is close to the H2Teesside project is for the construction and operation of a new Liquified Natural Gas (LNG) regasification terminal.

48 It is possible in the future that this project may directly provide natural gas, in the form of LNG imports, to the H2Teesside plant. This would make the composition of LNG in the natural gas supply for H2Teeside even greater than the increase expected to the national supply, described above.

49 Essentially this would mean that the H2Teesside would operate with an even higher GHG footprint due the greater share of LNG powering it.

50 I respectfully request that the ExA extend the examination to cover the implications of the Teesside Flexible Regas Port project on the GHG emissions from H2Teesside.

5 NET ZERO TEESSIDE POWER

51 The ExA will be aware that the proposed Net Zero Teesside (NZT) gas-CCS power station is also close to H2Teesside. The Secretary of State's decision letter for NZT[18] estimated the full lifecycle emissions of NZT to be +20,808,127 tCO2e at DL 4.48, and found these to be significant adverse at DL 4.58. Carbon Tracker estimate the emissions are much greater when upstream natural gas supply emissions are correctly estimated (Appendix B, section 5.2, page 24, PDF page 27).

52 The NZT project will provide carbon capture infrastructure necessary for the H2Teesside project to operate. The NZT project is therefore a "gateway" necessary for H2Teesside to operate, and H2Teesside is causally dependent upon it.

53 Even without the more realistic Carbon Tracker calculations for both NZT and H2Teesside, and my sensitivity tests later in the submissions for H2Teesside, the two plants together generate a very significant GHG footprint. The Applicant describes the H2Teesside emissions over the Phase 2 2031-2055 period as over 19MtCO2e which combine with NZT's 20.8MtCO2e over a similar timespan to make a combined total of around 40 MtCO2e. But for all the reasons given above this is a severe underestimate. When the 20.8 MtCO2e for NZT is combined with the sensitivity range which I later derive for H2Teesside, the range for both schemes is 54.09 MtCO2e to 120.51 MtCO2e. This does not include a similar sensitivity test analysis being done for NZT which would lead to a range of even higher GHGs.

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[17] See PINS website https://national-infrastructure-consenting.planninginspectorate.gov.uk/projects/EN040001/documents

[18] NZT Decision letter. Document: EN010103-002914 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-002914-Decision%20Letter_Net%20Zero%20Teesside%20Project.pdf

54 I respectfully request that the ExA extend the examination to cover the implications of this.

6 ENVIRONMENTAL STATEMENT, CHAPTER 19

55 Before embarking on my own analysis, which has as its starting place the Applicant's data, I note some points on the data on Chapter 19 where I cannot reproduce the Applicant's numerical data. It would be helpful to all parties if the Applicant could respond with clarification on these points below, and also that my understand is correct.

6.1 Total operation lifecycle emissions

56 In Table 19-9, the Applicant provides the Scope 1, Scope 2 and Scope 3 operation GHGs on an average over the Phase 1 and Phase 2 periods: the total annual averaged figure is 793,147 tCO2e. I understand this to be an average over 29 years. It is an average because the Scope 2 "Imported electricity" is based on UK electricity grid emissions intensities which rapidly decline between 2027 and 2055. At 19.5.67, the applicant estimates the operational emissions for the 25-year Phase 2 period at 19,133,421 tCO2e "over 25 years from the completion of Phase 1".

57 25 years at 793,147 tCO2e/yr sums to 19,828,675 tCO2e, so I assume the difference of 695,254 tCO2e is explained by the rapidly declining Scope 2 emissions. It would be helpful if the Applicant can confirm that this is correct[19] and also provide the annual values which it has calculated for the Scope 2 emissions between 2027 and 2055 (see next section).

6.2 Low Carbon Hydrogen Standard (LCHS) figures

58 The Applicant derives an emission factor of **16.62 gCO2e/MJ$_{LHV}$** for the Phase 2 production based on an energy output for the product hydrogen of 252,461 GWh [ES 19.5.69]. Summing the LCHS applicable emissions in Table 19-9 gives a total of 14,929,000[20] tCO2e over 25 years with the correction for the declining Scope 2 emissions[21]. This corresponds to **16.43[22] gCO2e/MJ$_{LHV}$**.

59 The Applicant derives an emission factor of **21.64 gCO2e/MJ$_{LHV}$** for the Phase 2 production based on an energy output for the product hydrogen of 252,461 GWh including non-LCHS-applicable emissions for "*combustion of residual CH4 in the H2 stream, construction, decommissioning, and T&S unavailability*" [ES 19.5.70]. Summing these additional

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[19] I factor this assumption into my calculations later.

[20] (8,713 + 135,960 + 3,196+ 448,843 + 412 + 36) * 25 = 14,929,000 tCO2e

[21] The 25-year Phase 2 Scope 2 emissions expressed annually are ((25 * 31,006) - 695,254) / 25 = 3,196

[22] (14,929,000 *1,000,000) / (252,461 *1000 * 3600) = 16.43

emissions gives a total of 20,009,040[23] tCO2e over 25 years. This corresponds to **21.25[24] gCO2e/MJ$_{LHV}$.**

60 Please can the Applicant explain the apparent small overestimates in their estimations of these emission factors. This may well be explained by how the Scope 2 are treated which is why I have requested the annual values used between 2027 and 2055.

61 For the purposes of this submission, I will use the figure of **16.43 gCO2e/MJ$_{LHV}$** for the emission factor corresponding to the LCHS applicable data in Table 19-9, and **21.25 gCO2e/MJ$_{LHV}$** for the emission factor corresponding the Applicant's calculation at ES 19.5.70, and refer to these as the corrected values.

6.3 Range of Uncertainties and reasonable worst-case scenarios

62 At 19.5.58, the Applicant sets out a list of assumption in its estimation of the operational emissions of the scheme. In paragraphs 19.5.76 - 19.5.79 under "Uncertainty in Impact Analysis", the Applicant discusses further "Hydrogen Fugitive Emission", "Short Lived GHG Gases", Effects from GHG Transport and Storage Network, "Natural Gas Leakage and Decarbonisation". I note the ExQ1/Q.1.5.6 which requests justification of assumptions further.

63 This submission effectively addresses this question. In a nutshell, the key issue with the ES, and the EIA of GHGs, is that only best cases have been provided: for example, the 95% capture rate. The project only works in terms of the GHG levels claimed in the ES, if the best-case assumptions apply every day for 25 years. This is clearly not the case in existing commercial system such as Quest as described above.

64 Further some of the assumptions are not even realisable best cases. For example, the emission factors used for upstream emissions are simply incorrect against recent science and measurements by satellites and remote sensing: so they underestimate the real impacts and are not even realisable as the evidence "on the ground" is already that they are erroneous.

65 To test the realistic range of possibilities, I have developed a set of sensitivity tests which are explained next.

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[23] **90,220 +** ((8,713 + 135,960 + 3,196+ 448,843 + 412 + 36 **+ 263 + 167,911**) * 25) **+ 90,220=** 19,313,790 tCO2e

NB: 90,220 is the estimated construction emissions, also taken to be the decommissioning emissions

[24] (19,313,790 * 1000000) / (252461 *1000 * 3600) = 21.25

7 GHG SENSITIVITY TESTING ANALYSIS

7.1 Rochdale envelope and Reasonable Worst-case

66 At ES 19.3.2, the Applicant claims to have adopted the principles of the "Rochdale envelope" approach to assess "*the maximum (or where relevant, minimum)/ realistic worst-case parameters for the elements where flexibility needs to be retained (building dimensions or operational modes for example).*"

67 For EIA of GHGs, such an approach is required by the IEMA Guidance (with which the Applicant says its assessment is in accordance at ES 19.1.1) when it states the assessment[25] "*methodology should result in a relevant, complete, consistent, transparent and accurate assessment of the reasonable worst-case. In most cases, the assessment should use activity data and emissions factors*".

68 The key issue that this submission raises is that the Applicant has not actually applied the Rochdale Envelope principles to its EIA assessment in Chapter 19. Activity data has been provided as in ES Table 19-7 for the Phase 1 operation which is itemised according the related GHG Scope. However, the translation of this activity data to a reasonable worst-case estimate of the GHGs associated with each activity has not been done in any real sense. As said above, essential the Applicant has built a best-case description of the GHGs emissions, and unrealisable best case. The Rochdale Envelope principle has not been genuinely applied, and the resulting GHG description is severe underestimate.

69 In the recent Finch[26] the Supreme Court judgment, Lord Justice Leggett explained that the overarching purpose of EIA is that if consent is given for a development it is given *with full knowledge of the environmental cost.* This is not the case with the H2Teesside ES Chapter 19 for GHGs: the Rochdale Envelope has not been applied, nor has a "full knowledge" EIA been produced. I examine this out in more detail, what a "full knowledge" approach means, in the later section on "Principles from recent case law".

70 Lack of "full knowledge" is particularly striking in the ES with respect to the *likely significant effects* of the three types of GHG emissions from the development which I now discuss and then develop sensitivity tests with the purpose of providing a "full knowledge" description of effects for EIA, these are:

(i) The future upstream emissions of the natural gas supply[27]. The applicant has used an emission factor which is outdated as it does not reflect the true upstream emissions as now measured by satellites and remote sensing, nor the likely future

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[25] Institute of Environmental Management and Assessment (IEMA) for Assessing Greenhouse Gas (GHG) Emissions and Evaluating their Significance (IEMA, 2022), under Step 3 "assessment Methodology", page 19

[26] *R (on the application of Finch on behalf of the Weald Action Group) v Surrey County Council and others*

[27] As related to the GHG Scope 3 emissions associated with the activity "Natural Gas Demand" in ES Table 19-7

sources of the natural gas supply. This has been explained above the section "Upstream emission factors: underestimated and don't reflect changes to natural gas supply"

(ii) The carbon capture rate[28], which the Applicant has fixed at 95% in its EIA, despite no commercial hydrogen plant delivering greater than 78% carbon capture, and as explained above.

(iii) Using a 100-year GWP for upstream methane emissions[29], which does not reflect the real climate impact in the 20-year near term period that released methane acts, instead of a 20-year GWP (ES 19.5.77) *which does reflect the real climate impact*.

7.2 Sensitivity Tests: overview of method

71 This submission now provides sensitivity tests on these three aspects which have been realistically designed to estimate the reasonable worst-case of the *likely significant effects* of the GHG emissions from the development (the receptor being the global climate[30]). Thus these sensitivity tests satisfy the Rochdale Envelope and apply a "full knowledge" approach to the EIA identification and description of likely significant effects which the Applicant's ES does not.

72 The sensitivity tests have been generated as follows:

(i) A spreadsheet has been produced which captures the Applicant's data in Table 19-9 of the "Average Annual GHG Emissions from Phase 1 + Phase 2".

(ii) As a preliminary step to verify consistency of my spreadsheet with the Applicant's data at Table 19-9, I sought to confirm the Applicant's estimate of the operational emissions over 25 years.

(iii) I then apply each sensitivity test to these items from Table 19-9. Further details are provided in each section below, but at an overview, these are :

(a) Scope 1: "Uncaptured CO2 emissions (5% that is not captured at 95% capture rate)"

(b) Scope 3: "Upstream emissions (well to tank methane extraction)". With respect to this estimate, sensitivity tests are done for both the emission factor itself and the GWP used.

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[28] As related to GHG Scope 1 "Uncaptured CO2 emissions" in ES Table 19-7

[29] As related to the GHG Scope 3 "Natural Gas Demand" in ES Table 19-7

[30] As stated by the Applicant at ES 19.5.2

(iv) For each sensitivity test, I calculate the corresponding estimate of the Phase 2 operational emissions over 25 years for the item. I calculate the LCHS applicable emissions and also the full emissions. I also calculate emission intensities to compare with the LCHS standard. For accessible presentation, I present below the results of each sensitivity test in graphs of the estimated operational emissions in MtCO2e compared to the application. The full spreadsheet is reproduced in Appendix A together with a single graph of all the sensitivity tests. A table of the LCHS emission intensities is also presented later.

7.3 Sensitivity test for natural gas supply emission factors : ST (1), ST (2) and ST (3)

73 In addition to the Applicant's estimate of the 25-year emissions, the Carbon Tracker "Kind of Blue" report (Appendix B) has developed three scenarios for the natural gas supply of H2Teesside. I adopt, here, the same <u>three</u> scenarios for the <u>three</u> sensitivity tests below on the <u>emission factor</u> used to model upstream emissions in the natural gas supply.

74 By background, the Applicant has used the DESNZ emission factor of <u>**0.423 kgCO2e/kg**</u> for the upstream emissions from the natural gas supply [ES 19.5.64]. The precise location of this factor is under spreadsheet tab "WTT-fuels", row "Natural Gas" comes from the DESNZ 2023 emissions factors (the Applicant's reference is "DESNZ, 2023g[31]" in ES Chapter 19). As reproduced below from the spreadsheet, this factor may also be expressed as 0.03021 kgCO2/kWh (Gross CV[32]): this corresponds to <u>**8.4 gCO2/MJ**</u>[33] of natural gas burned. My sensitivity test below will be based on using emission factors in units of gCO2/MJ, so it is important to understand this conversion from kgCO2e/kg.

Fuel	Unit	kg CO_2e
Natural gas	tonnes	423.16368
	cubic metres	0.33660
	kWh (Net CV)	0.03347
	kWh (Gross CV)	0.03021

Figure 4: Emissions factor for Natural Gas used in Application (reproduced from Applicant Reference: DESNZ, 2023g)

[31] Department for Energy Security and Net Zero (DESNZ) (2023g). "Greenhouse gas reporting: conversion factors 2023". https://assets.publishing.service.gov.uk/media/649c5358bb13dc0012b2e2b7/ghg-conversion-factors-2023-full-file-update.xlsx

[32] Calorific Value of natural gas burned

[33] = 0.03021 * (1,000,000 / 3,600)

75 ES Table 19-7 gives the natural gas demand as 60,500 kg/hr (Phase 1). And in Table 19-8, the corresponding upstream emissions are given as 224,422 tCO2e/yr (Phase 1), whilst Table 19-9 gives 448,843[34] tCO2e/yr (Phase 2).

76 The Applicant does not give its calculation of the upstream emissions (ie: 224,422 tCO2e/yr in Table 19-8) in the natural gas supply from the associated activity data (ie: 60,500 kg/hour in Table 19-7): however, I can reproduce it as in the footnote[35]. Carbon Tracker highlight that, in addition to upstream supply emissions, there are 1.5 gCO2/MJ of upstream emissions for UK transmission losses and venting[36]. These emissions are included in the DESNZ emission factor of 8.4 gCO2/MJ (ie 0.423 kgCO2e/kg) as used by the applicant[37].

77 The purpose of this sensitivity test is to generate a range of values for the upstream emissions corresponding to different emission factors. As stated above, I adopt the three scenarios from the Carbon Tracker "Kind of Blue" report as shown in the clipped table below (Table 1 from the Carbon Tracker report): "LNG Average", "USA LNG Mid" and "USA LNG High". This table of scenarios, and related emission factors, has been produced to adjust for UK underestimates and future variations in the natural gas supply, and is derived by Carbon Tracker based on Section 2 (Appendix B, Pages 13-17, PDF Pages 16-20) of the Kind of Blue report, and is reproduced below.

78 The Carbon Tracker report reaches these three scenarios based on considerable research into the upstream emissions of natural gas[38], based on recent data and scientific research. These, therefore, provide a good bases for sensitivity testing of the reasonable worst-case impacts of the development.

[34] A simple doubling of the Phase 1 figure (with rounding error of 1)

[35] At 8760 operating hours a year, the upstream emissions are 60,500 * 8760 * 0.423 = 224,181 tCO2e/yr. This is very close to Applicant's 224,422 tCO2e/yr [Table 19-8, Phase 1], and difference is assumed to be from rounding errors.

[36] See Carbon Tracker "Kind of Blue" (Appendix B), Table 7, Page 29 (PDF Page 32)

[37] See DESNZ, "2023 Government Greenhouse Gas Conversion Factors for Company Reporting, Methodology Paper for Conversion Factors Final Report", 2.17 d) "*For parts of the natural gas supply chain which occur in the UK (transmission and distribution and dispensing of CNG), data from DUKES (BEIS, 2022) is used to update the emissions for these activities estimated in Exergia.*" https://assets.publishing.service.gov.uk/media/647f50dd103ca60013039a8a/2023-ghg-cf-methodology-paper.pdf

[38] See Section 2 of the Carbon Tracker report in Appendix B, "Upstream Emissions of Natural Gas". 2 pages (Pages 13-14, PDF Pages 16-17). This section provides vital information on the underestimation of emission factors for upstream emissions by UK bodies such as North Sea Transition Authority (NTSA) and provides references (footnotes 21-26) which formed the basis of a review of emissions factors by Carbon Tracker.

TABLE 1: NATURAL GAS UPSTREAM EMISSIONS BASED ON SUPPLY SCENARIO

Source	Upstream emissions (gCO_2/MJ natural gas)	Notes
Pipeline Gas	2.3	Average of Norwegian and domestic gas
UK Average 2022	6.8	Average emission of UK's gas consumption in 2022
Average LNG (excl. USA)	17.5	Average of Qatar, Peru, Nigeria, Algeria
USA LNG Mid	22.4	Average of USA estimates
USA LNG High	31.3	LNG from the Permian Basin

Note: these values exclude grid transmission losses and venting which we estimate at 1.5 gCO_2e/MJ, see Appendix for sources Table 5-7.

Table 1: Carbon Tracker Report scenarios

79 Each sensitivity test is made by multiplying the "Upstream emissions (well to tank methane extraction)" value from the ES by the FACTOR calculated in the Table below.

	Emission Factor Sensitivity Tests			
		gCO_2/MJ	+ 1.5 gCO_2/MJ for UK Transmission/Venting	Relative to application FACTOR
	Application	8.40	8.40 (included)	1.00
ST (1)	LNG Average	17.50	19.00	2.26
ST (2)	USA LNG Mid	22.40	23.90	2.85
ST (3)	USA LNG High	31.30	32.80	3.90

Table 2: Emissions factors used of three sensitivity tests

80 The sensitivity test results are displayed below.

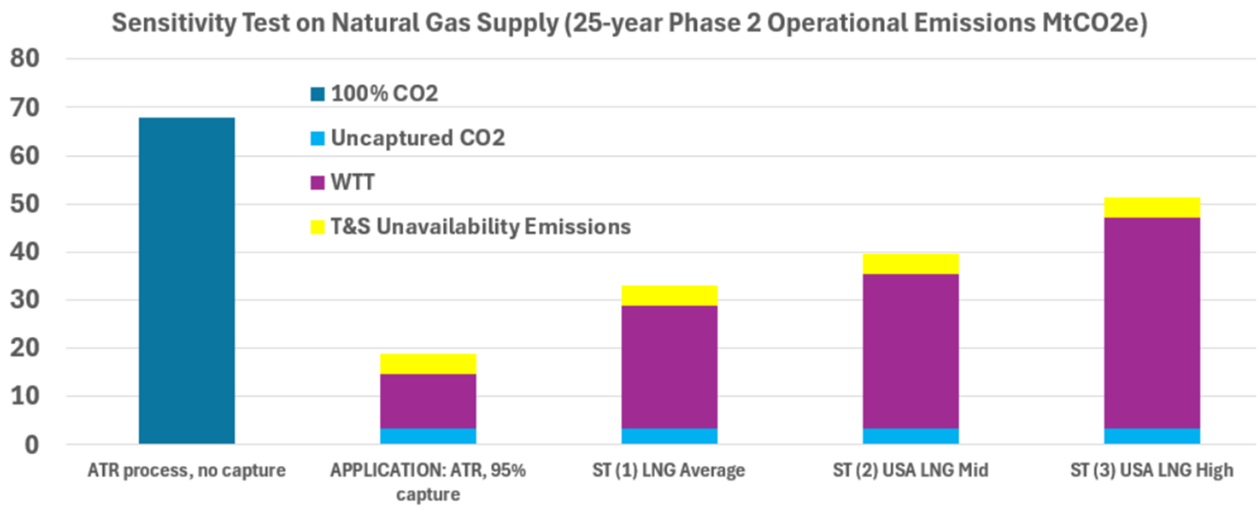


Figure 5: Sensitivity Test on Natural Gas Supply (25-year Phase 2 Operational Emissions MtCO2e)

81 The figure above compares, over the 25 years Phase 2 operation, the unabated ATR process emissions (ie just unabated Scope 1 emissions of 67.98 MtCO2e), the 25-year operation emissions submitted by the applicant (19.13 MtCO2e), and for each sensitivity test: ST (1) : 33.29 MtCO2e; ST (2) : 39.84 MtCO2e; and ST (3) : 51.73 MtCO2e.

82 My operational emissions figures differ from those of Carbon Tracker, and this is for two reasons: I use the Phase 2 data where Carbon Tracker used the Phase 1 data, and I have included additional emission sources from the EIA which are not included in the LCHS standard[39]. This is correct for EIA purposes.

7.4 Sensitivity test for CCS rate: emission factors: ST (4) and ST (5)

83 This sensitivity test investigates rates of carbon capture of less than 95%. I have based this sensitivity test on ST (2) USA LNG Mid, and then applied CCS rates of 90% and 80%. These values are reasonable given that IEEFA have shown that no commercial hydrogen CCS operation has reached over 78% capture rate to date (Appendix C, slide 12).

[39] These are the italicised items in Table 19-9

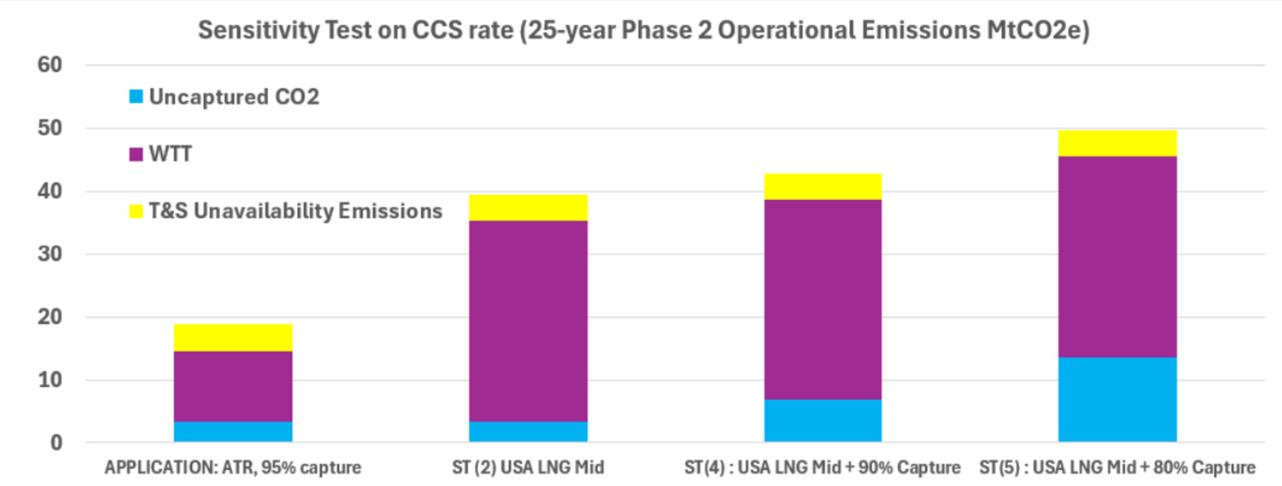


Figure 6: Sensitivity Test on CCS rate
(25-year Phase 2 Operational Emissions MtCO2e)

7.5 Sensitivity test for GWP: emission factors: ST (6), ST (7) and ST (8)

84 The latest 6th Assessment report from the IPCC (2021[40]) gives the 20-year Global Warming Potential (GWP20) as 82.5 and the 100-year GWP100 as 29.8. The Applicant uses the GWP100. This sensitivity test investigates using GWP20 rather than GWP100.

85 The DESNZ emission factor accounts for both upstream CO2 and upstream CH4. Therefore it is first necessary to calculate an "uplift factor" which represents just the difference to the GHGs by applying GWP20 instead of GWP100 to only the CH4 in the upstream emissions.

86 I have calculated this "uplift factor" by using data from Professor Howarth's paper (in press). The method is explained further in Appendix A in the section 'Calculation of the "uplift factor" for the sensitivity tests on GWP20 instead of GWP100'. A straightforward division of GWP20 by GWP100 would give an uplift factor of 2.77 (=82.5/29.8). The uplift factor which I derive, which allows for CO2 in the upstream emissions is 1.88. As Appendix A explains this is based on world-average on LNG shipping distances, and also an average of LNG vessel types – so the estimation of my uplift factor is based on average data, not worst-case data. However, I treat it as a reasonable worst-case for this analysis. This uplift factor of 1.88 is considered reasonable for all the scenarios given it averages these aspects, and is based on a detailed recent analysis of the full GHG effects for US exported LNG from the leading scientist Professor Howarth.

[40] Intergovernmental Panel on Climate Change. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte V, Zhai P, Pirani A, Connors S, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis M, Huang M, Leitzell K, Lonnoy E, Matthews J, Maycock T, Waterfield T, Yelekçi O, Yu R, Zhou B (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896

87 Having derived this "uplift factor", the method for these sensitivity tests is to simply apply it to the upstream emissions in three selected scenarios. The results are shown below.

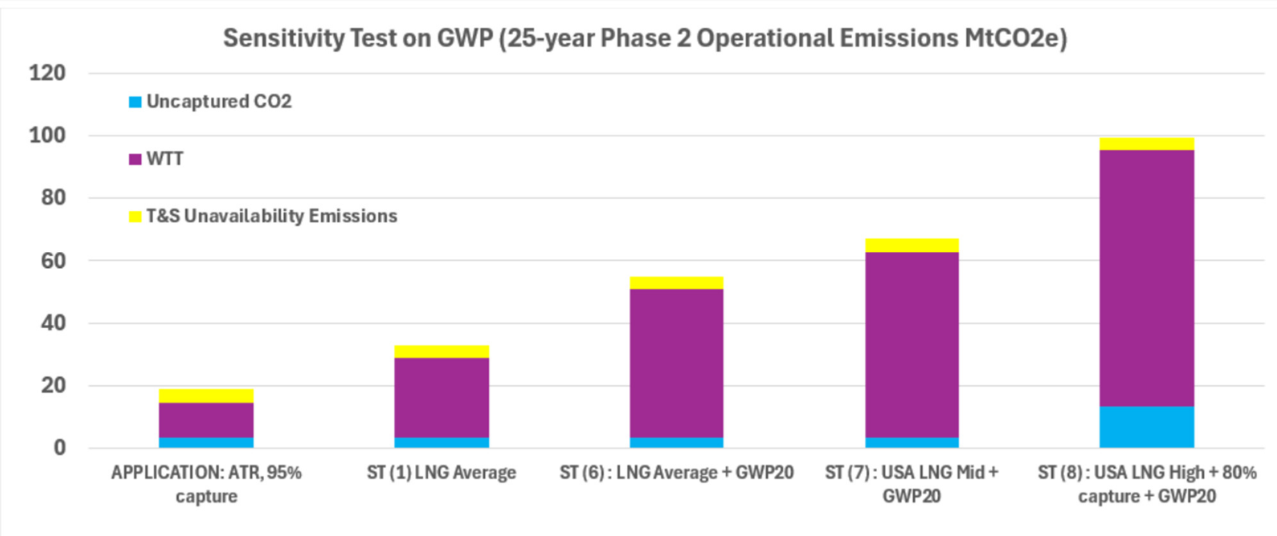


Figure 7: Sensitivity Test on GWP (25-year Phase 2 Operational Emissions MtCO2e)

88 A reasonable worst-case scenario is obtained in ST (8) for LNG imported from the USA with high upstream emissions ("USA LNG High") with 80% CCS capture and GWP20: in other words, it applies all three sensitivity test factors together. Note that ST (8) is considerably lower than IEEFA calculated using the DOE GREET modelling software (see Appendix D) as shown in the next section on LCHS compliance. So my analysis is far from being the worst-case analysis.

7.6 *Sensitivity tests results and LCHS compliance*

89 The Table below summarises the results from the sensitivity tests. The left-hand side gives the total emissions, and the Percentage increase compared to the Applicant's data at Table 19-9.

90 I have also calculated the emissions intensity of each sensitivity test (in column "LCHS Emission intensity $gCO_2e/MJ_{LHV}(H_2)$"). For comparison with EU and US data, emission intensities calculated as $kgCO_2e/kgH_2$ are also provided, the right-hand column provides the data in these units[41].

Scenario	TOTAL emissions MtCO2e	Percentage cf APPLICATION	LCHS applicable emissions MtCO2e	LCHS Emission intensity[42] gCO2e/MJ$_{LHV}$(H2)	Percentage relative to LCHS standard	LCHS Emission intensity[43] as kgCO2e/kgH2
APPLICATION: ATR, 95% capture [ES 19.5.69]	19.83	100%	14.92[44]	16.43[45] **	-17.87%	1.97
LCHS STANDARD				**20.00**		**2.4**
Applicant's example 25-year emissions including non-LCHS-applicable emissions [ES 19.5.70]			19.31[46]	21.25[47] **		2.55
ST (1) LNG Average	33.29	174%	29.09	32.01	+60.03%	3.84
ST (2) USA LNG Mid	39.84	208%	35.63	39.21	+96.04%	4.70
ST (3) USA LNG High	51.73	270%	47.52	52.29	+161.45%	6.27
ST(4) : USA LNG Mid + 90% Capture	43.24	226%	39.03	42.95	+114.74%	5.15
ST(5) : USA LNG Mid + 80% Capture	50.04	262%	45.83	50.43	+152.14%	6.05
ST (6) : LNG Average + GWP20	55.18	288%	50.97	56.09	+180.43%	6.73
ST (7) : USA LNG Mid + GWP20	67.37	352%	63.16	69.50	+247.49%	8.34
ST (8) : USA High + 80% capture + GWP20	99.71	521%	95.50	105.08	+425.39%	12.61

Table 3: Hydrogen emissions factors calculated from the sensitivity tests (Corrected figures[48] as explained above in section 6.2)**

91 The sensitivity test generates total Phase 2 operational emissions in the range 174% to 521% of the Applicant's calculation.

[41] The LCHS standard of 20gCO2e/MJ is equivalent to 2.4 kgCO2e/kgH2 (Appendix E, Carbon Tracker, "Curb your Enthusiasm", page 31, PDF page 34).

[42] The calculation here is based upon the energy output of H2Teesside being 252,461GWh over 25 years (ES 19.5.68). The emission intensity in units of $gCO_2e/MJ_{LHV}(H_2)$ is then given by

(**LCHS applicable emissions (MtCO2e)** * 1,000,000 * 1,000,000) / (**252,461** * 3,600 * 1,000)

[43] Converted from the $gCO_2e/MJ_{LHV}(H_2)$ column

[44] (8,713 + 135,960 + 3,196+ 448,843 + 412 + 36) * 25 = 14,929,000 tCO2e

[45] (14,929,000 *1000000) / (252461 *1000 * 3600) = 16.43

[46] **90,220 +** ((8,713 + 135,960 + 3,196+ 448,843 + 412 + 36 **+ 263 + 167,911**) * 25) **+ 90,220=** 19,313,790 tCO2e

NB: 90,220 is the estimated construction emissions, also take to be the decommissioning emissions

[47] (20,009,040 *1000000) / (252461 *1000 * 3600) = 21.25

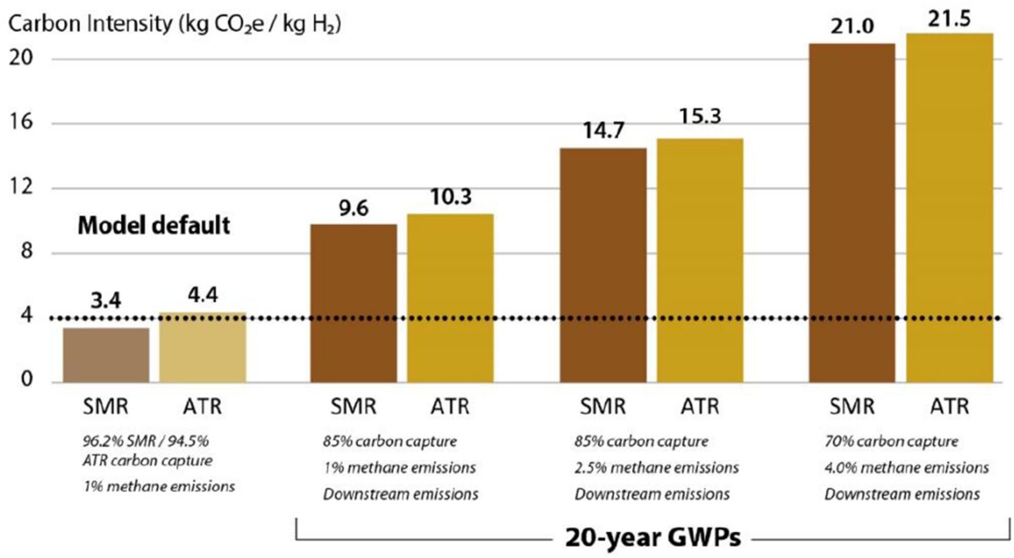
[48] The 25-year Phase 2 Scope 2 emissions expressed annually are ((25 * 31,006) - 695,254) / 25 = 3,196

92 Note that no scenario meets the LCHS standard, except the Applicant's application. Each sensitive test exceeds the standard by at least +50%, in a range of +60% to +425%.

93 A further calculation (not in the Table) shows that if the data at Table 19-9 is adjusted solely for a 90% carbon capture rate, then the 25-year LCHS applicable emissions are 18.33 MtCO2e corresponding to an emission intensity of 20.17 gCO2e/MJ_{LHV}[49], which exceeds the LCHS threshold. This shows that meeting the LCHS standard is sensitive to even a small failing to meet a 95% capture rate (although the overall more substantial sensitivity is to upstream emissions).

94 These sensitivity test should be contextualised by the IEEFA analysis where they ran the DOE GREET model using realistic assumptions including a GWP20 which models the real atmospheric impacts of methane over 20 years (see Appendix 4, page 26-27). Their results are shown below.

Figure 7: Range of Carbon Intensities Reflecting 20-year GWPs and More Realistic Real-world Assumptions About Methane Emissions, CO_2 Capture Rates and Downstream Hydrogen Emissions



Source: IEEFA runs with DOE's GREET model.

95 It is worth noting, by comparison, that the largest emission intensity from my sensitivity tests is 12.61 kgCO2e/kgH2 whilst the IEEFA model was to 21.5 kgCO2e/kgH2 for the comparable ATR process. This indicates that my calculations are conservative: they are certainly reasonable worst-cases, and not the worst-cases evident in the literature.

[49] See spreadsheet in Appendix B.

8 ENVIRONMENTAL IMPACT ASSESSMENT

96 This section discusses the implications of the sensitivity test analysis submitted against the legal principles of EIA as enacted by the 2017 regulations.

8.1 Principles from recent case law

97 In the recent Supreme Court judgment *R (on the application of Finch on behalf of the Weald Action Group) v Surrey County Council and others*, ("**Finch**") Leggatt, LJ laid out the principles of Environmental Impact Assessment which in the UK are based on the EIA Directive[50].

98 I note that the ExA at ExQ1/Q1.5.7 has requested that the applicant and IPs comment on the relevance of Finch to the assessment of GHG emissions in ES Chapter 19. My comments may assist the ExA on the question, but <u>they do not comprise a full, or formal, response[51] to ExQ1/Q1.5.7</u>. This section is written in the wider context of the submission in this WR that the Applicant has not presented out a "full knowledge" EIA of GHG is ES Chapter 19.

99 At Finch para 3, Lord Leggatt describes the overarching purpose of EIA as follows:

> *"3. Before a developer is allowed to proceed with a project which is likely to have significant effects on the environment, legislation in the United Kingdom and many other countries requires an environmental impact assessment ("EIA") to be carried out. The object of an EIA is to ensure that the environmental impact of a project is exposed to public debate and considered in the decision-making process. The legislation does not prevent the competent authority from giving development consent for projects which will cause significant harm to the environment. But it aims to ensure that, if such consent is given, it is given with <u>full knowledge</u> of the environmental cost."*

100 In a more recent judgment on September 13th 2024, *R (on the application of Friends of the Earth and another) v Secretary of State for Levelling Up, Housing and Communities and others* on the Whitehaven coal mine ("**Whitehaven**") Holgate, J refers to Finch and says at paras 60 and 61:

> *'60. The object of an EIA is to ensure that the environmental impact of a project likely to have significant effects on the environment is exposed to public debate and then considered in the decision-making process on whether development consent should be granted. It aims to ensure that if such consent is given, it is given with "full knowledge of the environmental cost" [3].*

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[50] Finch, 9: '*The 2017 Regulations are one of a number of UK statutory instruments designed to implement Directive 2011/92/EU of Page 4 the European Parliament and of the Council, as amended by Directive 2014/52/EU.*'

[51] That would require a much longer, in-depth analysis of the Finch judgment

> *61. I would add that the meaning of the expression "full knowledge" is well-established. For example, in R v Rochdale Metropolitan Borough Council ex parte Milne [2012] Env. LR 22 Sullivan J (as he then was) explained at [94] that "full knowledge" does not connote some abstract threshold of knowledge which must be attained. The legislation seeks to ensure that as much knowledge as can reasonably be obtained, given the nature of the project, about its likely significant effects on the environment is available to the decision-maker.'*

101 Under a section "What are "effects of a project"?", Leggatt, LJ says (Finch, 65):

> '*65. What are or are not "effects of a project" is, to state the obvious, a question of causation. An effect is the obverse of a cause.*'

102 Under a section "Predicting likely effects", Leggatt, LJ says (Finch, 72):

> *'72. Typically, when questions of causation arise in law the inquiry involves looking backwards to determine whether one past event caused another past event. In determining the required scope of an EIA, however, the inquiry is forward-looking. The question is: on the assumption that the project goes ahead, what possible future effects on the environment will constitute "effects of the project" which (if significant) must therefore be assessed? The EIA Directive answers that question by imposing the test of whether the effect is "likely". Thus, article 5(1)(b) requires the information provided by the developer to include "a description of the likely significant effects of the project on the environment" (emphasis added) and Annex IV further specifies what this obligation involves.'*

8.2 The issue for H2Teesside

103 The issues with the H2Teesside ES are different to that in Finch. In Finch, the issue was, in a nutshell, that the applicant had not scoped in the Scope 3 emissions (indirect downstream emissions from combusting the extracted fossil fuel); this has now been found unlawful.

104 On H2Teesside, the applicant has already accepted that indirect Scope 3 emissions from upstream natural gas supply are scoped into the EIA at ES Table 19-2 which includes "*GHG emissions from flare, methane extraction and well to tank*". The Applicant later identifies and describes for EIA purposes the upstream emissions in Table (19-8 and) 19-9 "*Upstream emissions (well to tank methane extraction)*". The applicant also scopes-in, identifies and describes for EIA purposes the indirect Scope 3 downstream emissions "*Uncaptured CO2 during transport and storage unavailability*" and "*Downstream emissions (combustion of methane in output H2 product)*" [ES Table 19-9]. So the issue is not whether indirect Scope 3 emissions, upstream and downstream, are included in the EIA Assessment.

105 Regulation 5(2) of the 2017 regulations provides that the EIA must *identify, describe and assess* the direct and indirect significant effects of the Development on, inter alia, climate.

106 The identification step is complex, and the problem with the H2Teesside ES lies here. Identification in EIA does not just mean identifying the types of emission which the Applicant has done. It also means identifying the effects that can influence the magnitude, or effect, of each type of emission which the Applicant has not done that.

107 An example in the H2Teesside ES is that the Applicant identified (and scoped-in) upstream methane emissions as a type of emission. However, the applicant did not then go on to identify all the effects which causally influence the magnitude of the upstream methane emissions, despite relevant recent science and knowledge on systemic underestimating and natural gas supply trends being widely available, as indeed presented in this submission and appendices. In this case, the knowledge of the causal effects which influence the upstream emissions "can reasonably be obtained" but that knowledge was not "obtained" by the Applicant. Consequently, the Applicant has not fully identified and described the causal effects on the upstream emissions in its ES. As Sullivan J (as he then was) explained, and recently restated by Holgate, J (see above) "full knowledge" means providing the decisions maker with "as much knowledge as can reasonably be obtained, given the nature of the project, about its likely significant effects on the environment.' This has not happened here. The ES, therefore, does not also meet the requirement in Finch that "if such consent is given, it is given with full knowledge of the environmental cost."

108 Consequently, the full knowledge of the environmental cost, which can reasonably be obtained for H2Teesside, has not been identified and then described in the Applicant's ES.

109 This submission is a genuine endeavour under the public participation enshrined in Regulation 3[52] of the 2017 regulations to move, at least, in the direction of providing, in the environmental information before the decision maker, the full available latest knowledge of the environmental costs. This submission is not based on trying to reach some unobtainable "abstract threshold of knowledge": it is based on scientific evidence which is widely accessible and quite reachable already.

110 Put simply, the objective of my sensitivity tests is to fill the gaps in the ES on the "full knowledge" on the environmental costs of H2Teesside, so that it meets the requirements as set out above. It also fills a hole in the application by doing the genuine Rochdale Envelope exercise which the Applicant did not actually do and deliver, despite claiming the intention to do so.

111 Fundamentally, the ExA and later the SoS is required to determine the following questions for the ES: whether the likely significant effects for both the direct and indirect emissions have been first identified, second described properly and enumerated correctly, and then thirdly that they have been subsequently assessed correctly.

[52] Regulation 3 defines "environmental information" as the environmental statement and "*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*".

112 I will deal with the third step of assessment separately. In summary, for the first and second steps of identification and description (enumeration) are concerned, key tests that, with respect, I suggest the ExA, and later the SoS, must consider and take into account are:

(i) whether the full knowledge of the environmental cost of the project has been described in the ES (Finch [3]); and

(ii) does the ES contain as much knowledge as can reasonably be obtained, given the nature of the project, about its likely significant effects on the environment (Whitehaven [61]);

(iii) have the possible future effects on the environment been adequately described (Finch [72]); and

(iv) has the EIA inquiry been "forward looking", and has it tested whether effects are likely (in the future), and then fully included and described them in the ES (Finch [72]).

113 From the evidence which I have presented, none of the above tests have been met in the ES.

114 In a "nutshell", at this stage, this comes down to whether the likely significant effects of the development on the global climate have been adequately identified and described with a "full knowledge" approach. The answer is that they have not been in the Applicant's ES.

8.3 The issues for the ExA and the SoS

115 The evidence which I have provided gives a comprehensive background to the GHGs generated by H2Teesside, based on the latest science and trends for UK natural gas supply. It shows that the ES does not adequately identify, describe, or enumerate, the likely significant effects on the global climate of the GHGs from the project.

116 My sensitivity testing shows that there is a huge range of predicted likely effects which have a much greater climate impact than the Applicant has disclosed. For example, with realistic modelling of atmospheric methane effects, the Phase 2 operation GHG emissions are 288%% to 521% greater than those of presented in the application. As already described, the 521% figure from ST (8) is not just a reasonable worst-case, it is actually a conservative estimate.

117 All the information which I have provided in this submission forms part of the "environmental information" before the examination and, later, the Secretary of State by Regulation 3[53] of the 2017 regulations.

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53 Regulation 3 defines "environmental information" as the environmental statement and "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".

118 Thus, I have provided compelling evidence that the GHG gas emissions from H2Teesside are much greater than those described in the ES by the Applicant.

119 However, in order to minimise the full scale and quantum of GHGs taken forward to the assessment stage, the Applicant hides behind various assumptions in the ES description. These assumptions are in direct opposition to the Rochdale Envelope principle. And despite, the evident underestimate of the GHGs in the ES, the Applicant has sought to provide reasons why its enumeration of the GHGs, with its associated assumptions, may be taken forward to the (third) assessment stage. These are now examined.

8.4 Assumptions in the ES

120 The ExA has been prescient to pose ExQ1/Q1.5.6 on the assumptions in the applicant's EIA assessment of GHG emissions; however, it is necessary to also examine the reasons given for these assumptions. I now look at this, starting by identifying the assumptions.

121 The key assumptions at issue are:

(i) the Proposed Development is designed to capture in excess of 95% of the carbon" [ES 19.5.58, 19.5.71];

(ii) the upstream well-to-tank emissions can be enumerated by applying a single known-to-be-out-of-date emission factor, which is also known to produce underestimates of the real effect, from DESNZ [ES 19.5.64];

(iii) the upstream well-to-tank emissions can be enumerated using a Global Warming Potential for methane over 100 years (ie GWP100) [ES 19.5.77] despite the gas having an atmospheric half-life of round 10 year, and that its most serious climate impacts occur in the first 20 years - making a GWP20 a much more realistic GWP for assessing the full climate impacts.

122 The reasons given for these by the Applicant are now examined in turn.

123 On 95% capture rate, <u>no evidence is given in ES Chapter 19 for this assumption at all</u>. This is despite the 95% figure being contested across the CCS industry, not just for hydrogen, and recent evidence that no commercial hydrogen CCS plant ever achieving more than 78% capture (see Appendix D, page 18). I await the applicant's response to ExQ1/Q1.5.6.

124 On the choice of emission factor:

(i) The Applicant gives their reasoning at ES 19.5.79. The Applicant acknowledges the paper of Bauer (Appendix L) that "*there is a degree of uncertainty in how much leakage of natural gas is likely in any given supply chain*".

(ii) A more recent independent analysis (paper by Riddick et al[54], Appendix O), with specific focus on the UK, and using the best available data to estimate methane emissions from flaring, combustion, processing, venting, and transfer found a total of 289 Gg (uncertainty range 112 to 1181 Gg). The emissions for venting alone, as taken from oil and gas operators' own reports to the North Sea Transition Authority, were 112 Gg[55]. Riddick et all concluded (Appendix O, page 10):

> *"The difference between current estimates used by NAEI and our estimates, which use more recent research findings, strongly suggests that the current methods of compiling national GHG inventories in the UK, and likely elsewhere, <u>are outdated (oldest EF derived in 1982) and systematically underestimate emissions.</u>"*

(iii) Another 2024 preprint study by Zhu et al (Appendix M, Page 12) analysed specific supply chains between the US and the UK and China, and found under reporting in official emissions inventories:

> *"Whether in Marcellus-UK or Permian-UK supply chain, the contribution of measurement informed methane emissions is significant. The percentage of methane emissions that are not captured by official emissions inventory is up to 40% in Permian-UK supply chain and 31% in the Marcellus-UK supply chain."*

(iv) However, the Applicant has <u>not</u> taken forward this issue of uncertainty into its ES in a "full knowledge" EIA approach by making any investigation into this uncertainty, and the systemic underestimation of upstream emissions. And then taking actions to ensure that its ES did not underestimate the GHGs from the scheme. Instead the applicant ignored the problem. This is despite a range of emerging literature on the dramatic range of climate impacts from variations in the natural gas supply (such as Appendix B and Appendix D).

(v) The Applicant says:

> *"There is a degree of uncertainty in how much leakage of natural gas is likely in any given supply chain, and whether it can be reduced. Whilst studies suggest it is possible that this leakage may be reduced, in turn reducing the carbon footprint of blue H2 (Bauer, et al., 2022), there are no reliable projections to base this on currently, so the current well-to-tank emissions of CH4 extraction, detailed in Section 19.5 and Table 19-8 and Table 19-9, are extrapolated over the*

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[54] Riddick & Mauzerall (2022) Likely substantial underestimation of reported methane emissions from United Kingdom upstream oil and gas activities Energy Environ. Sci., 2023, 16, 295-304

[55] Uncertainty range 78-146 Gg allowing for inaccuracy in measurements of gas volume released

lifetime of the Proposed Development from current Government conversion factors which account for leakage (DESNZ, 2023g)."

(vi) These two sentences confuse several issues. Essentially, they appear to suggest that because there are no reliable projections on how leakage may be reduced (ie: mitigating leakage), that it is satisfactory to use the current Government conversion factor and "flat-line" it in to the future (measuring leakage). What the Applicant means by "extrapolated" here is simply applying the same factor across the years 2031-2055 (Phase 2) ie: flat-lining the factor (it is not really extrapolation). <u>What the Applicant has not addressed is that the chosen emission factor is based, in the first place, on historic underestimated data and does not reflect the long-term changing supply in natural gas.</u>

(vii) The Applicant then says that this "*approach is supported by the recent Net Zero Teesside decision*" (NZT). By background, I provided evidence at the NZT planning examination that the emission factor for upstream methane emissions used in the NZT ES, being the same DESNZ factor (but from a different year's data publication), was an underestimate and inadequate for the EIA from the outset of the NZT examination[56]. Whilst the SoS in the Net Zero Teesside did not require a change in "approach" with respect to the emissions factors used, she did acknowledge the "likelihood of variation in future emission factors" (NZT Decision Letter[57], 4,54):

> *"CEPP responded to the all-party consultation of 20 December 2023 on 19 January 2024. CEPP reiterated its concerns with the emissions factors used by the Applicants, questioning whether the emissions factors provided by BEIS/DESNZ are the correct ones to use and further questioned the use of the natural gas factor as the fuel supply for the Proposed Development will also include a proportion of liquefied natural gas. The Secretary of State, taking into account information gathered through the Examination and previous consultation responses, remains satisfied with the approach taken by the Applicant, <u>notwithstanding the likelihood of variation in future emission factors.</u>"*

Several factors are now different since the Net Zero Teesside DCO examination:

(a) There is considerably more data available now than when the NZT ES was drafted. Key new data sources are the Carbon Tracker report (and the references and footnote 26 within the Kind of Blue report) [Appendix B], the IEEFA report [Appendix D], the Howarth paper

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[56] NZT examination, Climate Emergency Planning and Policy Deadline D2 WR submission [REP2-061]. Document: EN010103-001652 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-001652-Climate%20Emergency%20Policy%20and%20Planning%20-%20Written%20Representations.pdf

[57] NZT Decision letter. Document: EN010103-002914 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-002914-Decision%20Letter_Net%20Zero%20Teesside%20Project.pdf

[Appendix G] and the Zhu paper [Appendix M and N]. These each point to realistic and reachable (ie not "abstract thresholds of knowledge") information which may be used to model future upstream emissions.

(b) The sensitivity tests provided in this submission provide an approach to determining the reasonable worst-case for the upstream emissions for the EIA.

(viii) The Applicant concludes ES 19.5.79 as follows:

> "*Whilst the upstream well-to-tank emissions are a major contributor to the GHG assessment, this should be seen in the context that the H_2 produced will likely be used by industrial users who currently rely on unabated natural gas or fossil fuel consumption.*"

This does not justify the limited choice of emissions factor. The point being made here is whether the later use of the hydrogen may be claimed as an offset to the GHG emissions from H2Teesside. This suggested approach has not been formulated in a legitimate way within the EIA regulations, as will be discussed elsewhere in my section on the assessment step.

125 Finally with respect to modelling the climate impacts of upstream methane emissions in accord with its short-term, but extremely potent, atmospheric and climate destabilising effects:

(i) The science has been well established on the atmospheric methane cycle for decades[58]. Professor Howarth has explained above that the adoption of the GWP100 Global Warming Potential was a quirk due to an expedient, historical choice made back in the 1990s when methane's impact on the global climate was not being widely studied. He also quotes many researchers now calling for GWP20 to be used instead across regulatory and climate account frameworks, and makes it the preferred approach in his recent paper (Appendix G).

(ii) The Applicant goes against this clear best practice and gives its reasoning at ES 19.5.77. However, the applicant first acknowledges that fugitive emissions (methane leakage) do have a greater effect in the short term :

> *"This means that the effect of fugitive emissions is far higher if considered on a shorter time horizon such as 20 years."*

(iii) But then states:

[58] For example, see Ehhalt, D. H. (1974). The atmospheric cycle of methane. *Tellus*, **26**(1–2), 58-70. https://doi.org/10.3402/tellusa.v26i1-2.9737

> *"A 100-year timespan has been used in this assessment as it is the timeframe used in the low carbon hydrogen standard (DESNZ, 2023d)."*

This is astounding given the scale of the different modelled effects as shown by my sensitivity tests. The realistic modelling of climate impacts including short-term 20-year impacts, for example for the Carbon Tracker "LNG Average" scenario (the lowest impact LNG scenario) estimates a 25-year Phase 2 operation emissions total of **55.18 MtCO2e** ("ST (6)", see Table 4 in Appendix A) whereas the unrealistic modelling ignoring short-term impacts for the "LNG Average" scenario estimates the emissions as **33.29 MtCO2e** ("ST (1)", see Table 4.

So the Applicant here just assumes the DESNZ value for EIA purposes, despite knowing that it severely underestimates the GHG emissions and the climate impact because it uses GWP100 rather than GWP20.

At this stage, the Applicant appears not to consider investigating other approaches to describing and estimating the upstream emissions. It does not consider making a "full knowledge" approach to the EIA, for example, by using a modelling system such as DOE GREET, or making sensitivity tests using GWP20.

The use of the DESNZ emission factor for the LCHS standard does not assist the Applicant in justifying its use for EIA. EIA process concerns assessment of environmental impact, and it does not follow other regulatory regimes. The EIA process requires a "full knowledge" approach to the GHGs based on identifying and describing likely significant effects. In any case, the LCHS should adopt GWP20 in line with the recommendation by Carbon Tracker for the UK to consider adopting GWP in its climate reporting to reflect the increased short-term climate impact of methane emissions accurately. (Appendix B, page 6, PDF Page 9).

(iv) A further reason is given as:

> *"A100 year timespan is also used in the pathways used to inform the sixth carbon budget (CCC, 2023)."*

Unfortunately, this is a case where the Climate Change Committee (CCC) has also underestimated the impacts of upstream methane emissions by not including accurate modelling of the effects of methane in the atmosphere, via GWP20, into their work. CCC is clearly in this case not using the best scientific approach. The use of GWP100 by the CCC does not assist the Applicant in justifying its use for EIA. Again, EIA process concerns assessment of environmental impact, and it is not required to follow the CCC's practice.

(v) Finally the Applicant says:

> *"Therefore the use of 100-year timespan for GWP values is considered best practice in terms of identifying significance and alignment with the UK's Net Zero goals."*

(vi) For EIA purposes, the choice of GWP is clearly not best practice, as it is not a "full knowledge" approach to EIA which requires as much knowledge as can reasonably obtained. The applicant makes this statement following the previous sentence where it acknowledges that fugitive emissions (methane leakage) do have a greater effect in the short term.

126 Returning to the issues for the ExA and SoS, I previously posed four key tests, based on case law, which should be considered with respect to the EIA steps of identification and description (enumeration) of the likely significant effects of GHGs from H2Teesside on the global climate. These were:

(i) whether the full knowledge of the environmental cost of the project has been described in the ES (Finch [3]); and

(ii) does the ES contain as much knowledge as can reasonably be obtained, given the nature of the project, about its likely significant effects on the environment (Whitehaven [61]);

(iii) have the possible future effects on the environment been adequately described (Finch [72]); and

(iv) has the EIA inquiry been "forward looking", and has it tested whether effects are likely (in the future), and then fully included and described them in the ES (Finch [72]).

127 I have presented a compelling case above by analysis of the Applicant's key assumption with respect to a 95% CCS capture rate, upstream well-to-tank emissions, and modelling realistic atmospheric methane climate impacts that none of these above tests have been met. Simply put, the ES is not based on "full knowledge" "as can be reasonably obtained", and possible "future effects on the environment" and "whether they are likely": these aspects have not been described in the ES despite a wide knowledge base to draw upon.

128 My conclusion is that the ES is faulty in this respect, and it must be extended to cover the gaping holes in its EIA identification and description of GHG impacts. This is required before the EIA assessment stage can even be considered: the identification and description of effects must be complete before an assessment including of significance can be made.

9 ASSESSMENT AND SIGNIFICANCE

9.1 Contextualisation Against Carbon Budget Delivery Plan (CBDP)

129 At Table 19-11, the Applicant presents a comparison of the 25-year (residual) operation emissions against "Relevant CBDP Sectoral Carbon Budget Projections".

130 There are these issues with the data for the fuel sector:

(i) For fuel supply, the Applicant used the figure 10,778,563 tCO2e. The fuel supply emissions correspond to the "Upstream emissions (well to tank methane extraction)" emission in Table 19-9 described as 448,843 tCO2e/yr. For 25 years, the corresponding figure is 11,221,075 tCO2e. Please can the Applicant explain the apparent shortfall in their estimation of 442,512 tCO2e.

(ii) My sensitivity tests give a range of 25.38 MtCO2e to 81.6 MtCO2e for the WTT emissions (see full spreadsheet in Appendix A). Therefore, it is preferable to express the CBDP sector comparison as a range.

(iii) However, the comparison percentage is not straightforward because the well to tank emissions include emissions from both within and outside UK territory depending on the natural gas supply. The Climate Change Act 2008, and hence the Carbon Budgets, only deals with territorial emissions. The ex-UK upstream emissions are treated as consumption emissions by the UK. One would need to know the projected split of UK and ex-UK gas supply for every year between 2031 and 2055.

(iv) Given the unknown as to the split between territorial and consumption emissions, the following can be said for the 6th Carbon budget given that the 5-year budget RESIDUAL Fuel Supply emissions are 48,000,000 tCO2e. The 5-year emissions H2Teesside 25-year emissions are 2,244,215 tCO2e (Application), and sensitivity test range 5,076,201 tCO2e to 16,319,280 tCO2e.

(v) This means that the WTT emissions from H2Teesside are the equivalent of 5% (application) and 11% - 34% (sensitivity tests) of the fuel supply residual emissions. However, not all of the emissions would be accounted for as the CBDP sector emissions as the emissions are a mixture of territorial and consumption emissions.

(vi) The 34% figure (a reasonable worst-case as discussed above) shows that the climate impact of the project under a reasonable worst-case sensitivity test is very large in terms of the combined territorial and consumptions emissions when compared the UK allocation of fuel supply emissions in the 6th carbon budget. For EIA, this is the "full knowledge" climate impact.

131 For the power sector residual emissions, summing uncaptured ATR process emissions, "flare pilots, flue gas, vent and seal leakage", and imported electricity, and "T&SU emissions" gives annual emissions of 0.32 MtCO2e (with the claimed 95% capture rate in the Application) and 0.48 MtCO2e at 90% capture rate, and 0.75 MtCO2e at 80% capture rate. This corresponds to 3.76% (95% capture), 5.38% (90% capture) and 8.61% (80% capture) of the Power sector residual emissions in the 6th carbon budget[59]. This data shows that using a "full knowledge" assessment and reasonable worst-case, the impact of the 6th carbon budget residual power sector emissions is over twice as much as in Table 19-11 when capture rates are modelled close (ie 80%) to the best commercial achievement (78%) for hydrogen CCS.

9.2 Significance assessment of the project

132 The Applicant states that the EIA assessment is "in accordance with best practice guidance from the Institute of Environmental Management and Assessment (IEMA) for Assessing Greenhouse Gas (GHG) Emissions and Evaluating their Significance (IEMA, 2022)" and provides a table of IEMA Significance Criteria at ES Table 19-4.

133 The Applicant then makes a significance assessment at ES 19.5.83 of **Minor Adverse** and **Minor Adverse** and **Not Significant** for the operational emissions. There is no explanation of how this significance assessment has been derived, and no reference the IEMA Significance Criteria at ES Table 19-4. There is no reasoned explanation. The applicant in particular has made no explanation of how the project is "*fully in line with measures necessary to achieve the UK's trajectory towards net zero*" which is part of the significance criteria for "Minor Adverse".

134 <u>I request that the ExA requests that the Applicant provides an explanation of how it reaches the conclusion that the project is Minor Adverse.</u>

135 Further, although it is unstated, I take the input to the Applicant's assessment to be the figure of 19,133,421 tCO2e for the 25-year Phase 2 operation emissions (ES 19.5.67). However, I have made a compelling case that this figure, based on the assumptions which have been identified above, should actually be much larger and is <u>not</u> the "full knowledge" description of the GHG emissions. For example, the reasonable worst-case sensitivity test ST (8), estimates the 25-years emissions as 99.71 MtCO2e.

136 Through the sensitivity tests, I have derived a range of 33.99 MtCO2e to 99.71 MtCO2e (see Table 3 above) for the 25-year Phase 2 operation emissions. 99.71 MtCO2e is the reasonable worst-case for EIA purposes. It is not clear how territorial and consumption emissions of this scale can possibly be consistent *with measures necessary to achieve the UK's trajectory towards net zero*. Given the legal requirement for a "full knowledge" description of the GHG emissions, and that on the basis of the environmental information now available, must also involve sensitivity tests on the 3 main assumptions identified, <u>I request that the ExA requests</u>

[59] These calculations are not in my sensitive tests, and have been calculated separately from my spreadsheet in Appendix A.

that the Applicant provides an explanation of how it reaches the conclusion that the project is Minor Adverse.

9.3 Cumulative emissions across the sector

137 The ExA in the Net Zero Teesside DCO examination "*did consider there is merit in an assessment of the cumulative effects on a sectoral basis*" (NZT, DL[60], 4.38). However, the NZT Applicant considered there was insufficient data to quantify it, and never provided one.

138 However, we are now two and half years later, and there is a wide amount of data available, both in the reach and extent of planned projects across the sector (see Carbon Tracker quote below), and in how to more realistically assess the GHGs from all the cumulative projects, based on a "full knowledge" EIA approach as has been described in this submission.

139 Carbon Tracker says (Appendix B, Page 27, PDF page 30):

> *"This issue raises important questions about the **UK's Net Zero strategy reliance on blue hydrogen and gas-CCS**. In particular, the current Net Zero strategy for the power sector recommends for 9GW of gas-CCS plants by 2035 and up to 18 GW by 205058. If these plants were run following the same principles of NZT Power EIA (i.e. baseload operations) they could generate massive amounts of CO2 emissions that put at risk net zero targets. For example, by 2035, emissions related to the 9 GW of gas-CCS targets could be between 12–19 MtonCO2e for the 'LNG average' and 'USA LNG high' scenarios respectively. Even assuming flexible power plant operations (capacity factor of 40%) emissions could reach 5–8 MtonCO2e per year. …*
>
> *In aggregate, the lifetime emissions of 9 GW of gas-CCS and 4 GW of blue hydrogen could total between 210 and 600 MtonCO2e and risk exhausting between 22% and 63% of the UK's Sixth Carbon Budget (2033–37). …*
>
> *If unaddressed, the climate impact of upstream emissions could derail the UK's net zero strategy."*

140 I respectfully request that the ExA requires a cumulative assessment to be made across the gas-CCS and blue hydrogen sector, based on current projections of planned roll-out. It is essential that the climate impacts, not just of an individual scheme like H2Teesside, but of the whole sector, as proposed, is understood. As far as GHGs are concerned, the "full knowledge" of it should be known sector wide, like an EIA of an isolated project should be "full knowledge". In the absence of such a sector wide cumulative assessment, it is not possible to make safe decisions – decisions that will not risk the UK's climate policies and Net Zero strategy – on the planning of individual schemes. I do sincerely hope that the ExA considers this request.

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[60] NZT Decision letter. Document: EN010103-002914 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-002914-Decision%20Letter_Net%20Zero%20Teesside%20Project.pdf

9.4 The hydrogen product

141 The Applicant introduces the notion that an additional significance assessment can be made by including the use of the hydrogen product at ES 19.5.84 - 19.5.88 to offset the emissions estimated for the project. There are a number of issues with this.

142 First, the issue of making claims of "substitution" of GHG emissions and speculating on such offsets of GHG emissions has recently been tested in the High Court in the Whitehaven Coal mine case[61] where it was quashed. Holgate, J said at Whitehaven [115 -116] :

> *"115. A similar analysis applies to the application of the 2011 Regulations in the light of the decision of the Supreme Court in Finch. It was for WCM to assess in its ES the very large amount of GHGs which would be emitted from the burning of the Whitehaven coal. In so far as WCM wished to claim that the US substitution effect would be just as large, so that there would be no net increase in GHG emissions, or alternatively that there would be some lesser offsetting effect, it was for WCM to produce information in its ES to demonstrate that point, including legal causation in relation to substitution. Regulation 22 of the 2011 Regulations confirms that it is the applicant who is responsible for producing information which is legally essential for a compliant ES.*
>
> *116. Following the Supreme Court in Finch at [152] to [154], WCM needed to produce full information (in the sense previously explained) on those two effects which it claimed balanced each other out (or resulted in some offset). The public was entitled to participate in a EIA process in which they could respond to such material. It was not for the public to have to produce key components of that information. I now turn to see what happened."*

This is an exact parallel. The applicant in Whitehaven claimed that two effects balanced each other, or result in some offset. In this application, H2Teesside are claiming that use of the product H2 would result in an offset of the GHG emissions from producing the hydrogen. However, the Applicant has provided no substantive information of the possible use of the product hydrogen, just a few sketchy lines: it certainly has not provided a "full knowledge" GHG assessment of the emissions, and how the emissions could be saved, underwritten by solid evidence of its feasibility. Further, in the case of H2Teesside, the Applicant has not produced a "full knowledge" assessment of the H2Teesside project itself as described above in detail: this means that the emissions from the H2Teesside project itself are very much higher than those disclosed in the ES: the description of GHGs in the ES are far from a reasonable worst-case. The notion that an additional significance assessment can be made by including the use of the hydrogen product from H2Teesside falls when the emissions from H2Teesside have not yet been properly described by the Applicant.

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[61] *R (on the application of Friends of the Earth and another) v Secretary of State for Levelling Up, Housing and Communities and others*

143 Even if the regulations allowed this approach (which they cannot on the current ES which is flawed because it is not a reasonable worst-case, and minimal information has been provided about possible substitution), then the regulations also require a "full knowledge" EIA for H2Teesside itself. As described above, the "full knowledge" description of the project a range of 33.29 MtCO2e to 99.71 MtCO2e (see Table 3 above) with 99.71 MtCO2e being a reasonable worst-case. The claims for "abatement" by displacing gas, diesel and coal in other applications need to be reconsidered against the "full knowledge" range of GHG emissions of the hydrogen sourcing project (ie H2Teesside). The Applicant has not provided this analysis.

144 The notional offsetting idea proposed also makes numerous assumptions. Issues and assumptions with the suggestion of blue hydrogen could be used in an existing gas CCGT plant include:

(i) that the hydrogen from H2Teesside appears at the location for its use with no further GHG emissions. For example, downstream emissions related to the compression and transport of hydrogen have not been provided. If hydrogen is transported long distances, the emissions related to compression and leakages can become substantial;

(ii) this is not just a matter of the GHGs, but also even if the necessary infrastructure, such as hydrogen ready pipelines exist;

(iii) leakages with hydrogen are much harder to limit (than with natural gas). The molecule is much smaller and can have high leakage through existing gas pipes;

(iv) the economics of the Applicant's proposal is undeveloped. Blue hydrogen will be very expensive: the applicant has not explained why operators of a hydrogen-ready power plant would choose to switch from gas to hydrogen when it is likely to start losing money. Either costs will have to come down, or the government will have to pay out some form of subsidy to the power plant operators to make it profitable. The Applicant has not assessed or quantified the economic case;

(v) burning hydrogen in gas CCGT will need existing hydrogen storage on-site because hydrogen cannot be piped at a fast enough rate to meet the demand of the combustion process (because it is a very light gas compared to natural gas);

145 Michael Leibreich's hydrogen ladder[62] is a high respected infographic on hydrogen and is reproduced in Appendix R, unedited, under the Creative Common Licence v4.0.

[62] Version 5 is reproduced in Appendix R under the Creative Common Licence v4.0 https://creativecommons.org/licenses/by/4.0/deed.en . The material has not been edited. The Hydrogen Ladder source is at https://www.linkedin.com/pulse/hydrogen-ladder-version-50-michael-liebreich/ *Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023. Concept credit: Adrian Hiel, Energy Cities. CC-BY 4.0*

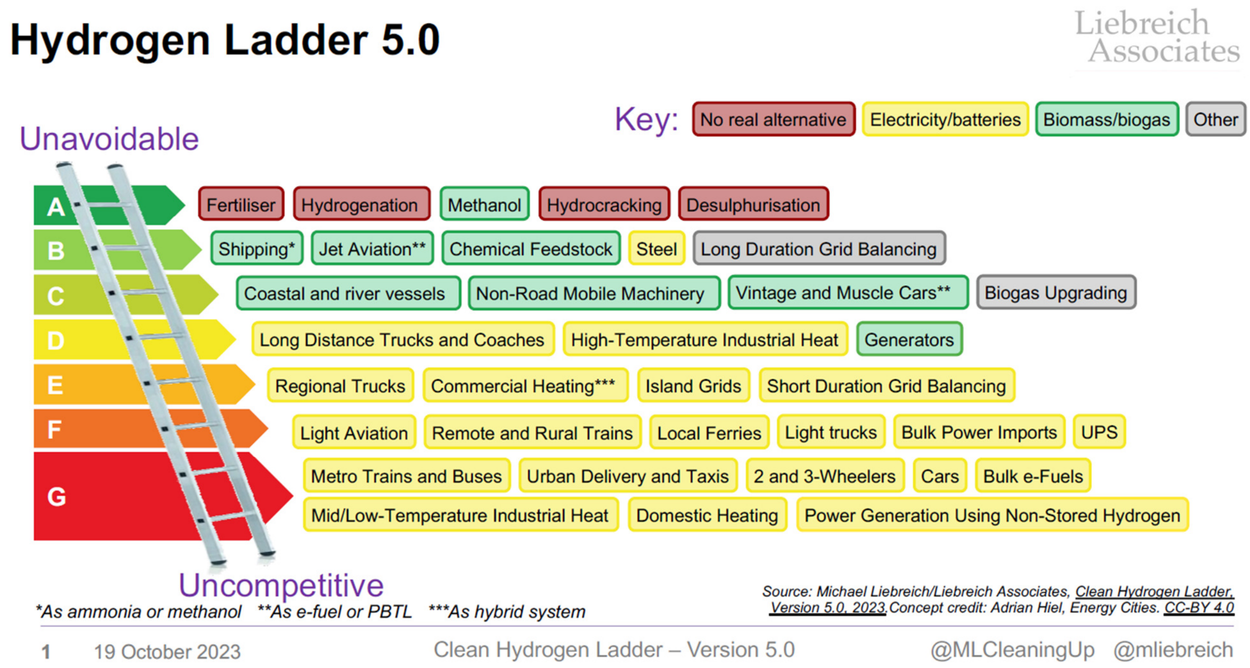

Figure 8: Michael Leibreich's hydrogen ladder V5.
Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023. Concept credit: Adrian Hiel, Energy Cities. CC-BY 4.0

146 The Ladder shows "Power Generation Using Non Stored Hydrogen" is actually assessed as one of the worst possible uses of hydrogen (on row G, the so called 'row of doom' – highly uncompetitive). This reflects the inefficiency and expense of the entire process chain starting from gas, creating to hydrogen, capturing carbon, transporting hydrogen and then burning it in a turbine.

147 I estimate that the carbon intensity of electricity generated by burning hydrogen in existing CCGT plants (blue H2-CCGT) to displace gas comes in the range of 278.64 gCO2/KWh to 914.80 gCO2/KWh for my sensitivity tests[63] (see spreadsheet in Appendix A): each sensitivity test has a <u>greater</u> carbon footprint compared to the Applicant's figure of 236.14 gCO2e/kWh for gas combustion that might be notionally displaced. The applicant has not provided the "full knowledge" range of electricity carbon intensities for blue H2-CCGT in its comparison. Further, in the "assessment", there is no reasoned justification given for its Beneficial and Significant significance: even if the regulations allowed this approach, there is no possibility for a reasoned conclusion on the impacts and their significance.

---

[63] Carbon Tracker estimate that the GHG footprint of electricity generated from blue H2-CCGT (blue hydrogen combusted in existing CCGT plant) is 370 gCO2/KWh (Appendix B, Page 19, PDF Page 22) for their "USA LNG High" scenario. I calculate 461.88 gCO2/KWh for this scenario because I include all the emissions where the CT estimate is based on LCHS applicable emissions.

10 DCO PROVISIONS

148 In ES 19.5.43, the Applicant states that "the capture rate will be addressed in the permit". This is wholly inadequate and does not follow precedent in decision letters on recent similar schemes.

149 The Net Zero Teesside decision letter [64] shows that a provision was included in the DCO that required "at least 90% of the total carbon emissions generated by the power plant must be captured at all times during its commercial operation". Previously, a similar provision was included in the Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order 2022. The Net Zero Teesside decision letter explains this at DL 4.24.

> "*ClientEarth proposed the inclusion of a provision in the DCO requiring that at least 90% of the total carbon emissions generated by the power plant must be captured at all times during its commercial operation. They suggested drafting to mirror that in the definitions section of the Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order 2022, to provide for the applicable minimum capture requirements on the operation of the generating station applying when it is operating "at full load". The Applicants considered that the EP and DPA would sufficiently address this issue and the ExA concluded that the EP would provide appropriate controls to secure the capture rate. The Secretary of State has considered this issue and the representations of the Applicants, the EA and ClientEarth. Whilst the EA has stated that it is likely that a 95% capture rate would be provided for in the EP, an amendment to the definitions section of the DCO as proposed by ClientEarth will secure a minimum capture rate in the DCO itself and is consistent with the approach in Keadby 3. The DCO has been amended accordingly.*"

150 I respectfully request that the ExA considers if a similar provision can be drafted in the H2Teesside DCO so that a minimum capture rate is secured in the DCO itself. The capture rate should be 95% reflecting the assumptions in Applicant's ES.

151 I respectfully request that the ExA also considers if a similar provision can be drafted in the H2Teesside DCO so that the natural gas supply to the H2Teesside plant must be compliant with the LCHS standard.

[64] NZT Decision letter. Document: EN010103-002914 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-002914-Decision%20Letter_Net%20Zero%20Teesside%20Project.pdf

11 CONCLUSIONS

My conclusions are captured by the list of 15 key points made in my Summary section.

12 SIGNED

Dr Andrew Boswell,
Climate Emergency Policy and Planning, October 3rd, 2024

13 APPENDIX A : Data, graphical summary and notes of sensitivity test method

13.1 Data including sensitive test data

MtCO2e	100% CO2	Uncaptured CO2	Flare pilots, flue gas, vent and seal leakage	Imported electricity	WTT	*Downstream emissions (combustion of methane in output H2)*	Worker transport	Maintenance	T&S Unavailability Emissions	ANNUAL	TOTALMtCO2e	Percentage cf application	LCHS TOTAL MtCO2e	Electricity kg CO2/MWh	LCHS Emission intensity gCO2/MJ	LCHS Emission intensity gCO2/MJ_H2	Percentage relative to LCHS standard
ATR process, no capture	67.98									2.72	67.98	355%	67.98	651.17	8.98	74.80	273.99%
APPLICATION: ATR, 95% capture	-	3.40	0.22	0.079	11.22	*0.01*	0.01	0.00	*4.20*	0.77	19.13	100%	14.93	143.00	1.97	16.43	-17.87%
Applicant's example 25-year emissions including non-LCHS-applicable emissions [ES 19.5.70]		3.40	0.22	0.08	11.22	*0.01*	0.01	0.00	*4.20*	0.77	19.31	101%	19.31	185.00	2.55	21.25	6.25%
ST (1) LNG Average	-	3.40	0.22	0.08	25.38	*0.01*	0.01	0.00	*4.20*	1.33	33.29	174%	29.09	278.64	3.84	32.01	60.03%
ST (2) USA LNG Mid	-	3.40	0.22	0.08	31.93	*0.01*	0.01	0.00	*4.20*	1.59	39.84	208%	35.63	341.34	4.70	39.21	96.04%
ST (3) USA LNG High	-	3.40	0.22	0.08	43.82	*0.01*	0.01	0.00	*4.20*	2.07	51.73	270%	47.52	455.22	6.27	52.29	161.45%
ST(4) : USA LNG Mid + 90% Capture	-	6.80	0.22	0.08	31.93	*0.01*	0.01	0.00	*4.20*	1.73	43.24	226%	39.03	373.90	5.15	42.95	114.74%
ST(5) : USA LNG Mid + 80% Capture	-	13.60	0.22	0.08	31.93	*0.01*	0.01	0.00	*4.20*	2.00	50.04	262%	45.83	439.02	6.05	50.43	152.14%
ST (6) : LNG Average + GWP20		3.40	0.22	0.08	47.27	*0.01*	0.01	0.00	*4.20*	2.21	55.18	288%	50.97	488.28	6.73	56.09	180.43%
ST (7) : USA LNG Mid + GWP20		3.40	0.22	0.08	59.46	*0.01*	0.01	0.00	*4.20*	2.69	67.37	352%	63.16	605.04	8.34	69.50	247.49%
ST (8) : USA LNG High + 80% capture + GWP20	-	13.60	0.22	0.08	81.60	*0.01*	0.01	0.00	*4.20*	3.99	99.71	521%	95.50	914.80	12.61	105.08	425.39%

Table 4: ***Data including sensitive test data***

13.2 Figure of all sensitivity tests

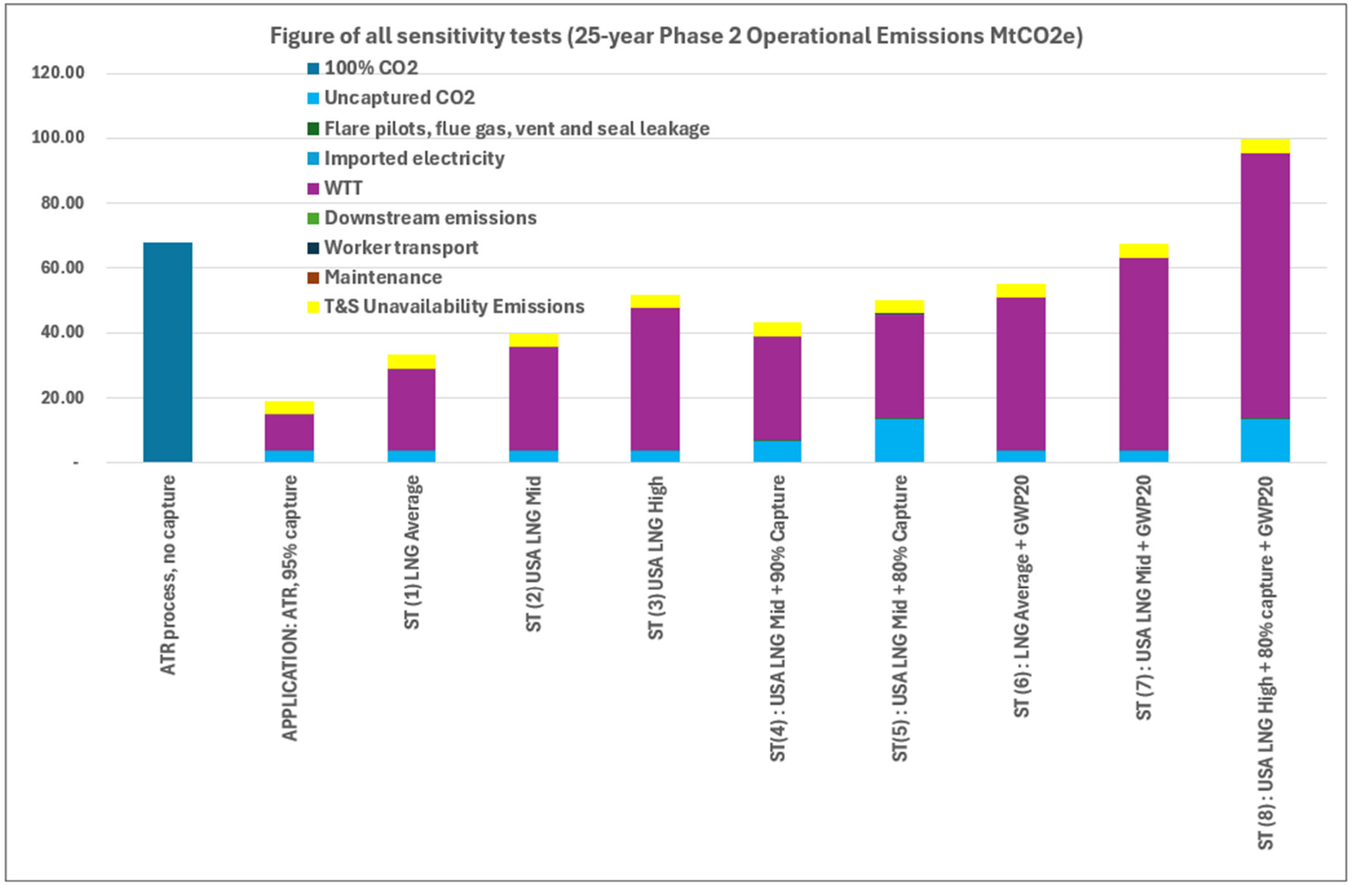

Figure 9: ***Figure of all sensitivity tests***

13.3 Calculation of the "uplift factor" for the sensitivity tests on GWP20 instead of GWP100

152 Table 3 of Professor Howarth's recent paper [Appendix G, page 30] gives a full lifecycle GHGs for LNG "*or 4 different scenarios for shipping by tanker, <u>using world-average voyage times (38 day round-trip).</u> Methane emissions are shown both as mass of methane and mass of CO2 equivalents based on GWO20. Values are per final mass of LNG consumed.*"

153 In the table below, and as a starting place, I have extracted the top-level numbers for each LNG tanker scenario.

Howarth Table 3	GWP20	g CO2e/kg			
	TOTAL CO2	Upstream CO2	CH4 (GWP20)	TOTAL (GWP20)	Upstream TOTAL (GWP20)
Steam-turbine tankers powered by LNG	4,202	1,452	3,566	7,768	5,018
4-stroke engine tankers powered by LNG	4,101	1,351	3,927	8,028	5,278
2-stroke engine tankers powered by LNG	4,046	1,296	3,661	7,707	4,957
Diesel-powered tankers	4,114	1,364	3,256	7,370	4,620

Table 5: Howarth paper: world average shipping times : GWP20

154 I then apply a GWP20 -> GWP100 conversion (= 0.36 = 29.8/82.5) to the methane emission column to generate the equivalent table as GWP100.

Howarth Table 3	GWP100	g CO2e/kg				
	TOTAL CO2	Upstream CO2	CH4 (GWP100)	TOTAL (GWP100)	Upstream TOTAL (GWP100)	GWP20/ GWP100
Steam-turbine tankers powered by LNG	4,202	1,452	1,288	5,490	2,740	1.83
4-stroke engine tankers powered by LNG	4,101	1,351	1,418	5,519	2,769	1.91
2-stroke engine tankers powered by LNG	4,046	1,296	1,322	5,368	2,618	1.89
Diesel-powered tankers	4,114	1,364	1,176	5,290	2,540	1.82
					AVERAGE	1.86

Table 6: Howarth paper: world average shipping times : GWP100 (converted to GWP100 and extraction of uplift factor)

155 The right-hand column above divides the GWP20 "Upstream TOTAL" data from the first table with the GWP100 "Upstream TOTAL" data from the second table. The uplift factor (1.86) is then taken as the average of the values derived for the four shipping methods.

14 APPENDIX A2: RESUME, Dr Andrew Boswell

I am a retired scientist: now an environmental consultant and independent researcher, 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[65], now Climate and Nature (CAN) Bill. Interested party and expert witness on many current UK infrastructure planning examinations[66].

[65] https://www.ceebill.uk/bill

[66] 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

15 APPENDIX B: Sani, L, Carbon Tracker, June 2024, Kind of Blue

Supplied as separate document

16 APPENDIX C: Morrison, K, IEEFA, March 2024 "The Good, the Bad, and the Ugly reality about CCS (Carbon Capture and Storage)"

Supplied as separate document

17 APPENDIX D: David Schlissel, Anika Juhn, IEEFA, September 2023, "Blue Hydrogen: Not Clean, Not Low Carbon, Not a Solution"

Supplied as separate document

18 APPENDIX E: Sani, L, Carbon Tracker, March 2024, "Curb your enthusiasm"

Supplied as separate document

19 APPENDIX F: DESNZ, 2023, "The role of gas storage and other forms of flexibility in security of supply"

Supplied as separate document

20 APPENDIX G: Howarth, R, September 2024, "The Greenhouse Gas Footprint of Liquefied Natural Gas (LNG) Exported from the United States", In press in the peer-reviewed journal: Energy Science & Engineering

Supplied as separate document

21 APPENDIX H: Dreyfus et al, May 2022, "Mitigating Climate Disruption in Time: A Self-Consistent Approach for Avoiding Both Near-Term and Long-Term Global Warming".

Supplied as separate document

22 APPENDIX I: Press Article on The Dreyfus Paper, May 2022.Guardian, May 23rd 2022

Supplied as separate document

23 APPENDIX J: GLOBAL METHANE PLEDGE, NOVEMBER 2021

From website: https://www.globalmethanepledge.org/

Supplied as separate document

24 APPENDIX K: Carbon Brief, September 2024, Q&A: Why methane levels are rising with no 'hint of a decline'

From website: https://www.carbonbrief.org/qa-why-methane-levels-are-rising-with-no-hint-of-a-decline/ /

Supplied as separate document

25 APPENDIX L: Bauer et al, 2021, On the Climate Impacts of Blue Hydrogen Production

Supplied as separate document

26 APPENDIX M: Zhu et al, 2024, "Geospatial Life Cycle Analysis of Greenhouse Gas Emissions from US Liquefied Natural Gas Supply Chains"

Supplied as separate document

27 APPENDIX N: Zhu paper, 2024, supplementary data

Supplied as separate document

28 APPENDIX O: Riddick & Mauzerall, 2022, Likely substantial underestimation of reported methane emissions from United Kingdom upstream oil and gas activities Energy Environ. Sci., 2023, 16, 295-304

Supplied as separate document

29 APPENDIX P: Riddick paper, 2022, supplementary data

Supplied as separate document

30 APPENDIX Q: 2015 report, Exergia, Study on Actual GHG Data for Diesel, Petrol, Kerosene and Natural Gas

Supplied as separate document

31 APPENDIX R: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, October 2023.

Supplied as separate document