

Stratford-on-Avon District Council

Assessment of a Bio Anaerobic Digester Proposal near Kineton, Stratford-on-Avon

Gap Analysis and Carbon Emissions Assessment

Reference: 293148-00

| 21 August 2024

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1. Introduction

Ove Arup and Partners Ltd (“Arup”) has been appointed by Stratford-on-Avon District Council (the Council) to review a number of selected documents and statements submitted in support of a planning application for a bio-anaerobic digester in Kineton, Stratford-on-Avon (Planning application [22/02935/FUL](#)). The review was undertaken in two stages and this report documents the findings and advice from Arup over the course of the whole review and is intended to assist the Council in its decision-making role as Local Planning Authority (LPA).

The commission covered two main tasks:

Task 1 – Gap Analysis

A gap analysis of several key documents as identified by the Council, that were submitted with the planning application to provide a high-level view on the methodology applied, as well as any benefits or adverse impacts claimed.

The initial review, concluded on 21st June 2023, focused on a high-level assessment of gaps to demonstrate the overall quality of the submission. The documents initially reviewed were:

- Planning, Design and Access Statement (DAS) (Ref 404.11923.00002 V1 September 2022)
- Air Quality Assessment (AQA) (Ref 404.11923.00004 Phase 11 v1.0)
- Agricultural Land Assessment (ALA) (Ref 2002/1 5th May 2022)
- Preliminary Ecological Appraisal Report (PEAR) (Ref 404.11923.00002 fv1 September 2022)

The Council used the Arup review to request additional information and clarifications from the applicant. Acorn provided Stratford-on-Avon District Council with a response to the initial review and amended documents, which were subject of a second review concluded in June 2024, again by Arup. The documents considered in the second review were:

- Arup GAP Analysis – Acorn Response, August 2023
- Air Quality Assessment - v1.2, August 2023
- Transport Statement - v2.2, June 2023 (In respect of air quality related issues only)
- Carbon Calculation Methodology – 12.08.2023, updated following Arup report.

Task 2 – Carbon Emissions Benchmark Assessment

A high-level assessment was undertaken by Arup to interrogate the scope and boundaries used to support the claim that the scheme will capture circa 13,500 CO₂ per year¹. Our initial review (conducted in June 2023) focussed on the submitted document *Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power* (18 January 2023).

In April-June 2024, Arup considered responses from Acorn addressing each point raised, providing a final comment on Acorn's response to our June 2023 findings.

Development description²:

Construction of anaerobic digestion facility, comprising silage clamps, digester tanks, lagoons, administrative buildings, landscaping and access on land at Hardwick Farm, Butlers Marston, Warwickshire

The proposed development would accept in the region of 92,000 tonnes per annum of feedstock per annum from the applicant's landholding and local farms, which would undergo a process of controlled decomposition (anaerobic digestion) within the Anaerobic Digestion (AD) facility. This anaerobic digestion generates biogas which is upgraded on site into biomethane, before being removed by tanker to a central facility for injection into the national grid. The AD facility would have the capacity to produce approximately 20,466,506 Nm³ of biogas per annum.

¹ As referenced in paragraph 1.3 of the Planning Design and Access Statement

² Taken from Planning Application Form for 22/02935/FUL and Paragraph 1.3 of the Planning Design and Access Statement



Figure 1 Development Location Plan

2. Review Findings and Next Steps

2.1 June 2023 Original Findings

Arup carried out a document review in line with the above scope and formed an opinion on whether, subject to the qualifications set out in Appendix A, the documents have been prepared with reasonable skill and care and provide a reasonable overview of the principle of the development and any associated risks in granting planning permission for the scheme.

In our assessment we identified gaps, as matters where the LPA could check and challenge the applicant on the details provided within the application. Each of the following sections contain a table which sets out the paragraph and section reference of the document reviewed. Arup's comments and the recommended actions are set out per document review.

This report provides advice to the Council to assist them in the matters that they can consider in their decision-making role as LPA as required by primary legislation (Section 38A of the Planning and Compensation Act 2004 and Section 70 of the Town and Country Planning Act 1990) and as transposed to national policy, the National Planning Policy Framework (NPPF) states that “...that applications for planning permission be determined in accordance with the development plan, unless material considerations indicate otherwise. The National Planning Policy Framework must be taken into account in preparing the development plan and is a material consideration in planning decisions” (paragraph 1.2).

2.2 June 2024 Updated Comments

Table 1 provides a summary of Arup's most recent findings. This update reflects the evaluation and analysis conducted since our last review in June 2023. It includes critical insights and revisions based on new data, further research, and feedback received from Acorn.

Our original findings, and updated comments are:

Table 1: Summary of Arup's review

Reference	Arup's Original Findings (June 2023)	Arup's Updated Comment (June 2024)
Benefits of the scheme	Given the matters we have raised with regard to the information provided by the applicant, in our assessment, it would be difficult for the LPA to demonstrably understand the significant benefits of the scheme to demonstrate that requirements of policies AS.10 and CS.3 have all been met. In addition, we have identified areas where additional information could be sought from the applicant to ensure appropriate clarity on the proposed development and any potential controls that could be applied to such a scheme. This includes input from the Environment Agency.	It is evident from Arup's review that there remain some significant concerns regarding the applicant's methodology and the quantifiable carbon benefits of the anaerobic digestion plant, particularly due to uncertainties surrounding the Carbon Capture, Utilisation, and Storage (CCUS) system. However, based on Arup's assessment of a worst case scenario it is Arup's opinion that, in line with local policy, the scheme would likely be beneficial in terms of renewable energy generation and carbon reduction, whilst limiting or mitigating adverse environmental impacts arising from the operation of the plant. Whilst the general principle of locating the facility in a rural area to minimise vehicle movements is supported by Arup it should be noted that our assessment has not covered the impacts of traffic on local roads and the wider network. From

		a carbon perspective, the only mitigation provided by the plant is the carbon capture scheme. As advised elsewhere, Arup advises that the scheme should be evaluated without considering carbon capture as a direct climate benefit. Acorn has evidenced how its scheme complies with the requirements of planning policies and environmental guidelines in their rationale for site selection* and planning strategy, highlighting a commitment to mitigating environmental impacts, which we would expect could be secured through appropriately worded planning conditions. The shortcomings we have identified in Section 2.7 mean that the revised Carbon Intensity Methodology submitted by the applicant, does not clearly demonstrate the level of benefit or harm. However, even when considering the worst-case scenario calculations Arup has undertaken, this indicates that the project's emissions would be within a reasonable range. This includes accounting for the additional emissions due to the energy required for operating the CO2 upgrader and potential increases from using LNG instead of natural gas. Despite these factors, the carbon intensity of the project, on balance, would be likely to remain within acceptable limits as set by Ofgem and Non-Domestic Renewable Heat Incentive (NDRHI) guidance. Furthermore, the integration of the CCUS system to produce CO2 for the food and beverage industry has the potential to support a sustainable business model that contributes to the economy, but only provided that the industry is happy to accept CO2 produced by these means, something that has not been evidenced in the submission and can therefore be currently given little weight. It should be noted however that even if the CO2 is sold to the food and beverage industry, this CO2 will eventually make its way back into the atmosphere. The food and beverage industry does not represent an end-use that permanently captures, stores, and removes carbon from the atmosphere. While there are several ways one could potentially argue that this business model is 'sustainable' if more information were provided, such as what source of CO2 it would be replacing in the market, considering carbon capture as a climate benefit is not one of these ways. Considering these elements, it is our opinion that the proposal appears able to meet the necessary policy requirements, providing benefits that align with both the objectives of policies AS.10 and CS.3. This opinion is based on a review of the selected planning application documents examined by Arup, listed in section 1 only and is therefore not informed by the wider application documents and representations made on the application. Ultimately it is for the LPA, as decision maker, to weigh all of these considerations in the planning balance.
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		*It was not part of Arup's brief to undertake a review of any specific potential alternative sites and consideration of the applicant's evidence in this regard is a matter for the Council to assess.
Air Quality Assessment	Whilst we have noted some comments on figures included in the Air Quality Assessment, addressing these should not materially affect the report's conclusions.	Whilst Arup made recommendations on the methodology we raised no fundamental points in respect of the conclusions of the applicant's assessment. In response to the previous comments, Acorn has revised the Air Quality Assessment, incorporating some minor updates, as detailed in table 2.4 below. These updates have not changed the overall conclusion of the report, that the construction phase assessment and operational phase assessment both conclude that the Proposed Development would result in a 'not significant' effect.
Agricultural Land Assessment	Regarding the Agricultural Land Assessment, we advise that further clarification and field evidence is required to satisfy the classification of subgrade Grade 3b to allow the LPA to understand the impacts of the scheme on agricultural land and policy AS.10.	As referred to in table 2.5 below, it would have been beneficial to provide the full profiles for each of the sampling points. Currently, the documentation in Section 2.3 includes detailed information only for Pit 3, while such details are absent from the appendix. However, these profiles are not essential for our findings, given that the soil conditions are predominantly limited by wetness, justifying the classification as subgrade Grade 3b. However, providing these comprehensive profiles would allow the Local Planning Authority (LPA) to better understand the impacts of the scheme on agricultural land in alignment with policy AS.10 and enhance the overall clarity and comprehensiveness of our assessment. It is a matter for the LPA to decide whether to pursue this further.
Ecological Impact	We have identified a number of gaps in the Preliminary Ecological Appraisal Report where we consider the supplied information may not be sufficient for the LPA to understand the ecological impacts of the scheme, including potential impacts upon European Protected Species (bats, great crested newts and dormice), and how this complies with policy CS.6 Natural Environment and paragraph 174 of the NPPF within reasonable doubt.	Whilst the applicant appears to accept all of our previous points and agree that an EcIA and a CEMP are needed, as of April 2024, an Ecological Impact Assessment (EcIA) has not yet been uploaded to the Stratford-on-Avon E-Planning System or provided to Arup for review. Therefore, there remain gaps identified in the Preliminary Ecological Appraisal Report, particularly concerning the potential impacts on European Protected Species such as bats, great crested newts, and dormice. Completing and submitting this assessment will enable the Local Planning Authority to fully understand and evaluate the ecological impacts of the scheme, consistent legislative requirements, including the Environment Act 2021, Conservation of Habitats and Species Regulations 2017 and the Wildlife and Countryside Act 1981, and with policy CS.6 Natural Environment and paragraph 174 of the NPPF. The LPA will need to review this document, as indicated in the comment within Table 2.3, before making a decision.
Carbon Assessment	The carbon assessment has not proved the carbon benefits from the proposed development within reasonable doubt, with the following matters identified that bring in to doubt the benefits that have been depicted: – No evidence has been provided as to the Carbon Capture, Usage and Storage (CCUS) facility that would be used, and at this scale such a facility is not expected to be financially viable from the available research. CCUS	Whilst the applicants have responded to all our previous points, the associated revisions to <i>Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power</i> (dated 12 th August 2023) do not sufficiently clarify the methodology of the assessment or resolve the uncertainty regarding the accuracy of the results. In particular, the boundary of the carbon calculations and sufficient

	provides for approximately a third of the carbon savings claimed by the development, and more evidence would be required for the developer to evidence these benefits from the proposal. – The assessment does not consistently follow the latest national policy and guidance, including that from BEIS and the Renewable Heat Incentive. Whilst not mandatory for assessing planning applications, in the absence of Local Plan policy this guidance provides the best available industry approach to assess the carbon benefits of the proposal. It should be noted that the scheme would need to follow this guidance if they were to seek to claim relevant incentives from Government for the development. – The assessment is also compounded by the number of inconsistencies and errors in the data presented. These will have some impact on the carbon benefits presented in the report, although this is not expected to be as significant as the points raised above.	justification of the carbon capture scheme are potentially the most impactful of the numerous errors throughout the report. However, Arup’s own, high-level, estimates to adjust the carbon intensity results to reflect our perceived worst-case carbon scenario (based on the information in the revised methodology), suggest that even with these uncertainties, the scheme still meets the carbon intensity emission guidelines set by the Non-Domestic Renewable Heat Incentive (NDRHI) scheme.
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2.3 Planning, Design and Access Statement

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
DAS1	1.6/consultation response	In section 1.6 the applicant has acknowledged that all operational anaerobic digestion facilities must be operated in a manner which is compliant with the environmental permitting regulations, as regulated by the Environment Agency (EA) and that advice will be sought. The Environment Agency has commented that this application requires an Environmental Permit. Further consultation is required with the EA to confirm their position, in order to obtain the most relevant and up to date advice from the regulator. There are several permits that fall under the heading of Anaerobic digestion including use of the resultant gas and storing digestate. The EA will be able to advise which permit is applicable. In addition, should the LPA be minded to grant planning permission, any conditions need to meet the legal tests and guidance in the NPPF and Planning Practice Guide. The clarity on other regulatory controls are important to establish those that are relevant for any planning permission.	LPA could seek advice from the EA with regards to permitting outside the Town and Country Planning remit.	The Arup conclusion is an action for the LPA to consult further with the Environment Agency if the LPA consider this to be necessary. However, the Planning process and the Environmental Permit process are separate and the question of which Permit will be applicable will not affect the information required to be submitted in the planning application. Acorn has pre-consulted the EA and state that they believe that they can comply with SR2021 No.8 which is a standard rules permit.	Noted, no further comments to make. The LPA would need to consider what conditions are necessary to attach to any planning permission, should it be granted.
DAS2	1.4 National Planning Policy for Waste	In section 1.4 the client has recognised ‘although the development is not considered a waste development, it is important to recognise there will be some waste products at the site’. No further information has been provided.	Seek clarification from the applicant on what waste products there will be at the site and how they will be stored.	The PDAS states in Section 1.3 that the agricultural by products would comprise poultry litter, farmyard manure and dairy slurry. These will be stored in enclosed buildings. The LPA are welcome to ask for more information on these products and storage.	Noted, no further comments to make Arup would expect the Council to require submission of details to provide assurance on appropriate storage / processing / disposal of waste in order to avoid unacceptable impacts on the living conditions of nearby residents.
DAS3	1.3 Proposed Development	LPA could consider if other types of products were to be imported on to the site, including more waste (noting that there are waste Anaerobic Digestors), what, if any planning	LPA could seek clarification points with the developer to inform its decision on how to	The application has been made based on the following feedstocks: energy crops such as silage, rye, maize and grass, straw and poultry litter, farmyard manure and dairy slurry. If new	Noted, no further comments to make. For clarity, the LPA may consider adding this as an informative to the decision notice should planning permission be granted.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
		considerations / controls they need to consider and put in place if consent were to be granted.	structure any potential planning permission.	feedstock types were to be brought in e.g., food waste, Acorn would need to apply for a variation to the planning permission and the environmental permit and those applications would be supported by the necessary technical assessments and would be decided on their merits. No changes to the application documents are required as a result.	
DAS4	6.2.1 Policy CS.3 and AS.10	Policies CS.3 and AS.10 are key matters to determine the principle of the scheme, with proposals needing to demonstrate (amongst other requirements): • Positive and negative effects, that detrimental impacts at construction, operation and decommissioning stage are appropriately minimised, mitigated and compensated. • All applications for renewable energy development should be accompanied by adequate supporting information, which assesses the extent of possible environmental effects and how they can be satisfactorily mitigated. • All other types of development or activity in the countryside, unless covered by a specific policy in the Core Strategy, will need to be fully justified, offer significant benefits to the local area and not be contrary to the overall development strategy for the District. Given the comments raised in this assessment, particularly on the carbon emissions benchmark assessment section, the information included in the application has gaps which would make it difficult for the LPA to understand the significant benefits of the scheme.	At this stage, given the matters raised regarding the information provided by the applicant, it would be difficult for the LPA to understand the significant benefits of the scheme to show that requirements of policies AS.10 and CS.3 have all been met.	AS.10 Ultimately it is role of the LPA to consider the proposed development against planning policy. Nevertheless, the planning application and technical assessment have been undertaken with the requirements of the relevant planning policies in mind, including policies CS3. And AS10. We understand that Stratford on Avon District Council, like most councils, priorities the re use of brownfield land for new development. Policy AS.11 sets out a number of Large Rural Brownfield Sites, designated for re use and redevelopment. However, the uses proposed for these sites include housing, tourism, office and leisure uses, and therefore would not be suitable for an anaerobic digester. The location of AD sites Is subject to significant scrutiny by a team of experts in Acorn prior to entering into the planning process. Anaerobic digestion (AD) plants are ideally located in rural areas, where they are close to the source of feedstock and where the resulting digestate can be used in place of artificial fertilisers, on	Noted, no further comments to make. The LPA need to be satisfied that the policy has been met.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
		In addition, whilst the applicant's policy assessment addresses a number of points of policy CS.3 and AS.10 of the Development Plan, it is silent on how the scheme has considered the requirements of these policies when it comes to brownfield land, and the proposal location and scale.		nearby arable land. It would make no sense to transport crops and manures from rural areas, into AD facilities in an urban area or industrial site, only to export the digestate back out to the rural area. The feedstock for the Hardwick AD will be sourced from local agricultural land and farms. The choice of location minimises transport distances to ensure Acorn's process and carbon intensity remains negative. The site has a good connection to the A422, which connects to the M40 to the east and the A429 to the west. Aside from the simple logic of a rural location, the location of AD plants is constrained by the Environment Agency's (EA) guidance on facilities (SR2021 No 7: Anaerobic digestion facility) which states that AD facilities should not be sited within any of the following , unless it can be shown that adverse effects can be satisfactorily managed or mitigated: • groundwater source protection zone 1; • 10 metres of a watercourse; • A specified Air Quality Management Area (AQMA); • 200 metres of the nearest sensitive receptor (unless the stack height is greater than 7m (or "3m effective height)).	

2.4 Air Quality Assessment

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
AQ1	Table 2-1 Applied Air Quality Assessment Levels	PM2.5 air quality standard reduced to 10 ug/m3 following Environment Act 2021 consultation conclusions in December 2022.	The report could be updated to acknowledge that the PM2.5 figures are targets not a standard, although this is unlikely to materially affect the report's conclusions.	This change in air quality standard changed following issue of the AQA (August 2022). This amendment has no impact upon conclusions of the assessment.	Noted, no further comments to make.
AQ2	Section 3.5 CHP Emissions Screening	European and Nationally designated sites apply to the first assessment criteria of LT <1% and ST <10%	The report could be updated to address this, although this is unlikely to materially affect the report's conclusions.	Wording added to clarify this point, however as there are no European or nationally designated sites within the relevant screening distances this has no impact upon the assessment.	Noted, no further comments to make.
AQ3	Section 6.7 Ammonia	Ammonia as a relevant pollutant for human health is set out in Table 2-1 Applied Air Quality Assessment Levels, however, impacts at human health receptors appear to have been screened out with no discussion.	The report could be updated to provide information as to the potential impacts of ammonia emissions at nearby human health receptors, although this is unlikely to materially affect the report's conclusions.	The AQAL for ammonia is set out in Table 2-1 for context only (i.e., to illustrate that the threshold for potential human health impacts is very high in comparison to ecological sites). Assessment of potential human health impacts as a result of ammonia does not fall within the required scope of assessment, determined in consideration of the low level of ammonia emissions from the Site and the high human health AQALs. As noted by ARUP this is "unlikely to materially affect the report's conclusions."	Noted, no further comments to make.

2.5 Agricultural Land Assessment

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments (01/12/2022)	Arup Conclusion	Acorn Update	Arup Comments
ALA1	2.1	The report indicates that the survey was carried out using handheld augers to examine soils at a frequency of one boring per hectare for a detailed assessment. This is in accordance with Natural England Technical Information Note TIN049, Second edition 19 December 2012, Agricultural Land Classification: protecting the best and most versatile agricultural land. The NE TIN049 sets out the industry guidance for field surveys. This is adequate. The land is classed as Grade 3b agricultural land. This complies with the Natural England Provisional Agricultural Land classification maps, which are accessible online. There is limited evidence to support justification of the soil classification of Grade 3b. There are no field logs or soil descriptions provided. We would expect to see further details for the following: • Soil parent material and soil type • Description of survey methods • Description of the soils. The report provides a snapshot example from one observation pit only, in section 2.3. From the information provided, there is insufficient information to conclude whether this is a Subgrade 3b or subgrade Grade 3a. Grade 3a is defined as best most versatile (BMV) soil, good quality land and is afforded greater specialist protection under national planning policies and guidance.	Further clarification and field evidence is required to satisfy the classification of subgrade Grade 3b as presented in the ALC application document. Soil logs, photographs and descriptions could be provided as evidence of the field survey. The following evidence shall be included in the field data: • Soil parent material and soil type • Description of survey methods • Description of the soils. The LPA could confirm the grade of agricultural land before a decision on the application is made. If evidence suggest Grade 3a soils are present, the LPA could consider how this should be addressed, including whether mitigation measures would be suitable to protect the loss of soils. In this regard, it should be noted that policy AS.10 sets out that proposals will be assessed against the principles of sustainable development, including the need to seek to avoid the loss of large areas of higher quality agricultural land.	A full soil pit profile description is provided: see paragraph 2.3 of LRA report. Full survey logs for each of the eight investigation points are provided in the appendix to the report. Further clarification is needed on this statement. Soil parent material and soil type – Published geological information is described in paragraph 1.5 (mudstone); published soils information is provided in paragraph 1.6 (Denchworth Association). Further clarification needed from the reviewer. Description of survey methods— these are fully detailed in paragraph 2.1 of the report. Further clarification needed from the reviewer. Description of the soils – the soils are fully described in paragraphs 2.2 to 2.4. Further clarification needed from the reviewer. The standard method for Agricultural Land Classification (see Natural England Guidelines) is to undertake hand auger investigations at a density of 1 per hectare, supported by one full pit investigation per soil type. This is exactly what has been undertaken and fully recorded. To summarise our findings: a detailed study has been undertaken by a highly experienced ALC surveyor from a reputed specialist company, in full accordance with the MAFF (1988) ALC Guidelines. The study found that soils were consistent with published mapping	It would be beneficial to provide the full profiles for each of the sampling points. Currently, Section 2.3 includes detailed information for Pit 3 only, and this level of detail is absent in the appendix. In our opinion these profiles are not deemed essential to determination and Arup advise that the Council could accept the findings as meeting the requirements of Policy AS.10, given the soil conditions are primarily limited by wetness (hence a grade 3b). However, they are typically expected to be included within an ALC report. Including these profiles would offer more clarification and enhance the robustness and comprehensiveness of the document.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments (01/12/2022)	Arup Conclusion	Acorn Update	Arup Comments
				(Denchworth wet clay soils formed in Jurassic mudstone). Agricultural Land Classification is limited to Subgrade 3b by the restricted drainage and high clay content/workability of the soils. All of the investigations are fully logged and described. Mike Palmer (Msc, PhD, MISoilSci) Director at Land Research Associates has confirmed the study has provided all the evidence needed for the LPA to determine that best and most versatile land (Grade 1 to Subgrade 3a) is not present on this site. He has expressed confidence that any other experienced ALC surveyor would have graded this land as Subgrade 3b.	

2.6 Preliminary Ecological Appraisal Report

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
PEA1	Overall Approach and 1.3 Purpose of this Report	The purpose of a PEA is to identify potential ecological constraints and opportunities and make recommendations in terms of design, mitigation and further surveys (where necessary). As section 1.3 identifies, it is not within the scope of a PEAR to assess the impacts resulting from a final development design or to commit to mitigation measures. This information should be included within a separate Ecological Impact Assessment (EcIA) Report, as per CIEEM guidelines. The further comments on the PEA report relate to the need to turn recommendations into enforceable commitments to avoidance, mitigation, and enhancement within an EcIA. The Executive Summary recommends production of an Ecological Management Plan (EMP) to be secured through planning condition. An EMP should provide detailed mitigation proposals to expand upon clear principles of mitigation stated within an EcIA submitted prior to determination of the application.	Further information required from the applicant in the form of an EcIA which could set out the impacts of final development design / mitigation measures. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that an Ecological Impact Assessment (EcIA) should be produced to assess the potential impacts resulting from the development and describe any required mitigation actions	Whilst the applicants appear to accept all previous points, and agree that an EcIA and a CEMP are needed, as of April 2024, an Ecological Impact Assessment (EcIA) has not yet been uploaded to the Stratford-on-Avon E-Planning System or provided to Arup for review. The Council will need to secure submission of an EcIA, consult and assess its merits, prior to determination.
PEA2	1.1 Site Description	This section identifies that the site is bounded by a tributary of the River Dene. No further description or assessment of this watercourse is provided within the habitat baseline or recommendations of the report. The habitat baseline for the watercourse should be described. It is likely to be an important ecological feature, even if it is only seasonally wet (section 3.3.6 describes a 'dry ditch' as part of the baseline description of suitability for riparian mammals). An EcIA should set out how the development	Further information required from the applicant in the form of an EcIA to describe avoidance and mitigation measures that will be included to minimise adverse impacts to the ecology of the watercourse. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	The drainage scheme and the bund are designed to isolate the site from water courses. We agree that an EcIA report should include a description of the adjacent watercourse as well as assessing any potential impacts resulting from the development and a required avoidance, mitigation measures.	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
		has been designed to be sensitive to the presence of an adjacent watercourse. The EcIA should describe the avoidance and mitigation measures that will be included within the construction and operational phases of development to minimise adverse impacts to the ecology of the watercourse and wider catchment.			
PEA3	Executive Summary Section 4.3.1	The Executive Summary states that the report includes a recommendation for additional surveys for great crested newt. This is not the case. Section 4.3.1 states the results of a GCN scoping survey, mentioning four ponds within 250m of the site being dry at the time of survey. No methodology is provided for this survey to explain which ponds were assessed and their proximity to the site, who undertook the survey or (critically) when the assessment was undertaken. This information is required to consider whether the conclusion with regards to great crested newt is reasonable.	Further information required from the applicant with regard to a methodology for the surveys conducted. No methodology was provided for the survey of great crested newt. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that details of the great crested newt survey including methodology, results and any required actions, mitigation measures resulting from it should be detailed within an EcIA report	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.
PEA4	3.2.3 and 4.2	The mature and semi-mature trees that occur at the boundaries of the site are only described as part of the hedgerow baseline as 'scattered trees some of which are mature'. Therefore, the only recommendation relating to the trees is the retention of a 5m buffer adjacent to the hedgerow. It is evident from the Arboricultural Implications Assessment and the ground level assessment for bat roosts, that several semi-mature and mature native trees are present, including several supporting extensive deadwoods. These are likely to be valuable	Further information required from the applicant in the form of an EcIA to assess the ecological value of the semi-mature and mature trees on site and make clear commitments to avoidance and protection measures that will be implemented for both trees and hedgerows. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that the EcIA report should include recommendations for mitigation measures relating to trees and hedgerows	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
		ecological features. An EcIA should assess the ecological value of the semi-mature and mature trees on site and should make clear commitments to avoidance and protection measures that will be implemented for both trees and hedgerows.			
PEA5	3.3.6	The ground level tree assessment for bats identifies three trees with moderate potential to support roosts. The Arboricultural Implications Assessment submitted with the application recommends several of these trees for reduction works. An EcIA should identify whether tree reduction works associated with the scheme can avoid the features with significant bat roosting potential that have been identified. If such features are proposed for removal, further bat surveys should be undertaken to confirm the presence or absence of roosts within the features to be removed. This information would be required to inform the impact assessment for bats and determine any mitigation and licensing requirements.	Further information required from the applicant in the EcIA to identify whether tree reduction works can avoid the features with significant bat roosting potential identified. If such features are proposed for removal, further bat surveys could be undertaken to confirm the presence or absence of roosts within the features to be removed. This information would be required to inform the impact assessment for bats and determine any mitigation and licensing requirements. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that an EcIA report should include an assessment of potential impacts from the proposed development on roosting bats and should recommend any required mitigation measures.	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.
PEA6	4.3.2 Reptiles	Precautionary staged clearance of vegetation is recommended as a mitigation measure for reptiles. An EcIA should specifically identify the areas of habitat with potential for reptiles that will be lost and where such mitigation measures would be implemented.	Further information required from the applicant in the EcIA that could identify the areas of habitat with potential for reptiles that will be lost and where such mitigation measures would be implemented. Without this, there may not be sufficient information for the LPA	Any required precautionary method of works to be undertaken during construction works to avoid impacts on protected species should be detailed in a Construction and Environmental Management Plan for Biodiversity.	Noted, as of April 2024, there has not been a Construction and Environmental Management Plan for Biodiversity uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
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			to understand the ecological impacts of the scheme.		line with the previous comment, before making a decision.
PEA7	4.3.3 Birds	The PEAR identifies that the site has high potential to support breeding birds, including priority species. An EcIA should include an assessment of the impacts of the scheme on farmland bird species, including any mitigation and compensation measures to be provided for habitat loss.	Further information required from the applicant in the EcIA that could include an assessment of the impacts of the scheme on farmland bird species, including any mitigation and compensation measures to be provided for habitat loss. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that an EcIA report should include any measures required to mitigate or compensate for impacts on farmland birds including habitat loss.	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.
PEA8	4.3.4 Bats	The commitment to a sensitive lighting strategy for bats is welcome. This commitment should be included in the EcIA with specific reference to the lighting strategy which evidences the measures to be implemented.	Seek clarification from the applicant with regard to commitment to sensitive lighting strategy for bats. This commitment could be included in the EcIA with specific reference to the lighting strategy which evidences the measures to be implemented.	Agree. The lighting strategy will be referenced within the EcIA. Acorn is committed to a sensitive lighting strategy towards bats.	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.
PEA9	4.2 Priority Habitats and 4.3.5 Hazel dormouse	The PEAR concludes that 'hazel dormouse could be impacted by any loss of hedgerow' but concludes there will be no loss of hedgerow. The site proposals appear to lose hedgerow loss to facilitate access at both the northern and southern boundaries. Figure 1 of the PEAR, UK Habitat Survey, does not show baseline hedgerows in these locations but they appear present on aerial imagery.	Further information required from the applicant to clarify hedgerow loss. This commitment could be included in the EcIA and should clarify the extent of hedgerow loss, assess any ecological impacts and identify mitigation measures to be implemented. Without this, there may not be sufficient information for the LPA to understand the ecological impacts of the scheme.	We agree that an EcIA report should detail the extent of hedgerow loss and any required mitigation measures for hazel dormouse as a result. Detail of this could also be described in a Construction and Environmental Management Plan for Biodiversity	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.

ID	Paragraph / Section Reference	June 2023		August 2023	April 2024
		Arup Comments	Arup Conclusion	Acorn Update	Arup Comments
PEA1 0	Executive Summary	The Executive Summary includes a summary of a Biodiversity Net Gain Assessment. This is not a summary of content that appears anywhere else within the PEAR. It would be logical for a BNG assessment of the final design to be appended to the EcIA.	Seek clarification from the applicant with regard to BNG as there is no additional information provided. It would be logical for a BNG assessment of the final design to be appended to the EcIA.	We agree that the BNG Assessment report including the Metric calculations should be appended to a final EcIA report	Noted, as of April 2024, there has not been an Ecological Impact Assessment (EcIA) uploaded to the Stratford-on-Avon E-Planning System for review. The LPA will need to examine this document, in line with the previous comment, before making a decision.

2.7 Carbon Emissions Benchmark Assessment

This section summarises Arup's comments on the revised *Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power*, dated 12th August 2023.

The most significant failing of the methodology as presented is in not explicitly and clearly stating the boundaries used for the assessment. While Acorn indicates that they aim to follow NDRHI guidance, a discussion of the boundary (or preferably a robust boundary diagram) is essential to demonstrating compliance and facilitating a full and accurate review of the methodology and results.

This failing is particularly evident in the consideration of carbon capture, utilisation and storage (CCUS). While the carbon capture scheme may be financially viable and previously implemented in the United Kingdom (as Acorn indicated in their responses, refer to Appendix B), this does not inherently mean that carbon capture may be included as a CCUS “credit” within the carbon assessment. From a whole-life carbon perspective, we typically advise to only take credit for carbon capture if the carbon is permanently stored and removed from the atmosphere; the “storage” aspect of “carbon capture *and storage*” is truly essential to its climate benefits. Similarly, the NDRHI guidance (NDRHI, 2013) allows subtraction of emission savings due to “carbon capture and storage/replacement,” which also suggests that carbon must be stored to take this credit.

However, the *Planning and D&A Statement* indicates the captured carbon dioxide will be sold within the food industry; in this application, the captured carbon would eventually make its way back into the atmosphere. Without indication that the captured carbon will be permanently stored, and without a clear boundary diagram provided in the methodology to clarify, Arup advises that carbon capture should not be taken as a credit to the carbon calculations, and the LPA should evaluate this proposal according to the carbon intensity without CCUS. Note that CCUS provides for nearly half of the carbon savings claimed by the development. CCUS is essentially the difference between a scheme that is net negative in emissions and removing carbon from the atmosphere (taking credit for CCUS) and a scheme which has emissions greater than zero (not taking credit for CCUS).

The uncertainty of the assessment is further compounded by several inconsistencies and errors in the data presented within the revised *Carbon Calculation Methodology*, summarised in Table 2 below. These will impact on the carbon impacts presented in the report, although these effects are expected to be less significant than the effects of the boundary and CCUS items mentioned above.

To examine the impact of these errors on the overall viability of the Hardwick facility, Arup has estimated the carbon emissions (in units of carbon dioxide equivalents, or CO₂e) associated with the scheme according to what we perceive to be a worst-case scenario based on the relatively limited information available in the revised *Carbon Calculation Methodology*. The conditions of this perceived worst-case scenario are defined in Table 2, along with the calculation inconsistencies they are designed to address.

According to Arup's estimations, the total annual emissions of the Hardwick facility would be 6,860 tCO₂e/year, resulting in an emission factor for biomethane of 17.06gCO₂e/MJ. This estimate is shown in Table 3 along with the carbon intensities presented in the revised *Carbon Intensity Methodology* and the related benchmark guidance.

Under NDRHI guidance, the carbon intensity of biomethane must be below 34.8gCO₂e/MJ to be considered sustainable (NDRHI, 2013). The equivalent threshold provided by Ofgem guidance is 24gCO₂e/MJ (Ofgem, 2022), though certain aspects of the calculation requirements differ under Ofgem guidance. This is summarised in Table 3 **Error! Reference source not found.** Therefore, while the perceived worst-case scenario for the biomethane emission factor

is larger than the original calculation, it is still within the guidance. Also, while the scheme will have net greenhouse gas emissions greater than zero, it is still less carbon intensive than meeting the same energy needs from natural gas directly (approximately 24ktCO₂e/year).

Table 2. Summary of inconsistencies and associated perceived worst-case scenario

Area of inconsistency	Description of the inconsistency within Acorn's revised <i>Carbon Intensity Methodology</i>	Perceived worst-case scenario
Inconsistencies which Arup has adjusted in the worst-case calculation:		
Carbon capture, utilisation, and storage (CCUS)	As the boundaries are not clearly defined, the methodology does not sufficiently demonstrate that the captured carbon is stored and removed from the atmosphere, and therefore does not demonstrate that credit can be taken for CCUS.	Assume the CCUS system is operational to produce CO ₂ for the beverage industry; include the emissions from the energy required to operate the CO ₂ upgrader. However, don't take additional credit for the captured carbon, as we assume it is eventually released back into the atmosphere rather than being permanently stored.
Stage 3: Processing emissions	The revised <i>Carbon Intensity Methodology</i> does not clearly define the boundaries and calculation method used for "Stage 3: processing emissions", and how these differ when CCUS is operational and non-operations. Assuming that the only difference between the two scenarios is the amount of carbon captured by the CCUS system, the processing emissions in the scenario without CCUS would have been underestimated.	The worst-case scenario is that the only difference in processing emissions when the CCUS is and is not operational should be the captured itself. Thus, add 1,686 tCO ₂ e/year to the total annual emissions to account for this worst-case scenario.
Natural gas carbon emissions factor	The revised <i>Carbon Intensity Methodology</i> and the <i>Planning and D&A Statement</i> are inconsistent regarding the source of natural gas used on anaerobic digestion site and at the injection hub, i.e. whether it is from the gas grid or from liquified natural gas (LNG).	According to DESNZ (Department for Energy Security and Net Zero, 2023), the lifecycle emissions of LNG are 5% higher than those of natural gas supplied by the grid. As a worst-case, assume both the anaerobic digestion facility and the injection hub utilise LNG to meet all natural gas needs. Since it is difficult to track in the methodology document exactly which emissions are due to natural gas use, we considered a worst-case where the emissions from the entire scheme are increased by 5%.
Inconsistencies which do not warrant adjustment per the worst-case calculation:		

Biogas carbon emissions factor	The revised <i>Carbon Intensity Methodology</i> does not sufficiently reference the source of the biogas emission factors utilised in the calculations. The factors do not appear to match the recommended 2023 BEIS emissions factors.	The emission factors used in the revised <i>Carbon Intensity Methodology</i> are larger than the recommended 2023 BEIS emissions factors. This would result in a more conservative calculation, so Arup has not adjusted this portion of the calculation.
Propanation	Acorn's responses indicate that propanation will not be required since it connects to the high-pressure gas grid, but this is inconsistent with the planning statement (which notes that propanation will be provided as required).	In Arup's experience, Acorn is correct that biomethane connections to the high-pressure gas grid do not typically require propanation. If this were to change (and propanation were to be required), it would impact the submitted carbon calculations since gas injected into the grid is typically about 4% propane and 96% biomethane by volume (SGN Commercial Services, n.d.).
Odorization	Acorn's response and revised methodology are inconsistent in how and if odorant is included in the calculations.	In Arup's experience, the odorant would have only a small impact on the overall carbon emissions, so we have not included this in the worst-case calculation.
Transport emissions	The methodology to calculate transportation emissions for feedstock and digestate is not clearly documented and appears to be internally inconsistent.	Arup's investigation specifically into the transport emissions suggests that the figures presented within the revised <i>Carbon Intensity Methodology</i> are likely a worst-case scenario, so Arup has not made an adjustment to this portion of the calculation.
Natural gas supply at the injection hub	The documentation does not specify whether the 1,000 m ³ /h of natural gas required at the injection hub is a peak supply or constant supply requirement, so we are not able to confirm if this is or is not consistent with the indicated annual natural gas requirement of 365,000 m ³ /year.	Arup compared the indicated annual natural gas requirement (365,000 m ³ /year) to data for a similar plant reported by CNG Services Ltd (CNG Services Ltd, 2021). The annual natural gas requirement (365,000 m ³ /year) appears to be similar to the CNG Services Ltd analysis, with respect to the amount of biomethane injected into the grid. Since this annual requirement seems to be in line with other industry data, Arup has not made an adjustment to this portion of the calculation.
Biomethane energy density	The documentation does not specify whether the annual biomethane injected into the grid is given as net calorific value (NCV, the energy content of the fuel as you would see from a standard boiler or gas fired appliance) or gross calorific value (GCV, the maximum possible thermal energy which could be	The NDRHI guidance requires emissions to be reported per unit of energy, where energy is reported as NCV. The energy values presented in the revised <i>Carbon Intensity Methodology</i> appear to be within a reasonable range for NCV, so we have not adjusted this portion of the calculation.

	obtained from the heating system such as a condensing boiler).	
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Table 3: Carbon intensity summary

	Reference	Annual GHG emissions (tonnes CO ₂ e /year)	Carbon intensity (g CO ₂ e / MJ)	Comparison to Ofgem guidance (maximum 24 gCO ₂ e/MJ)	Comparison to NDRHI guidance (maximum 34.8 gCO ₂ e/MJ)
Hardwick average carbon intensity (with CCUS)	Revised <i>Carbon Intensity Methodology</i>	-7,866	-19.56	Within guidance	Within guidance
Hardwick average carbon intensity (without CCUS)	Revised <i>Carbon Intensity Methodology</i>	4,847	12.05	Within guidance	Within guidance
Arup calculated worst case scenario	Arup calculations	6,860	17.06	Within guidance	Within guidance

For additional information, please refer to the appendices:

- Appendix B includes our comments on the original carbon calculation methodology (per the review conducted in June 2023) and Acorn's subsequent responses.
- Appendix C includes our revised responses (in detail) to each of our original comments, in response to Acorn's responses (Appendix B) and the revised *Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power*, dated 12th August 2023.
- Appendix D includes a technical analysis and summary of Arup's calculations to estimate the carbon intensity of the facility in what we perceive to be a worst-case scenario, from the information given in the revised *Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power*, dated 12th August 2023.

Appendix A – Disclaimers and caveats

- Our assessment was carried out based only on the submitted reports as detailed in Section 1. No other reports, drawings or application documents have been reviewed unless to clarify points in the main assessment.
- Our assessment focussed on matters relevant to the adequacy and methodology of the technical reports we were appointed to review. Matters of adherence to planning process and procedures and the merit of design or other technical / specific matters were not reviewed, such as technical drawings and the transport statement. As such this assessment does not constitute a recommendation from Arup on whether the planning application should be granted or refused.
- The Council advised that the scheme is not considered a waste planning application (the applicant has referred to waste policies in the Design and Access Statement), and we have not sought to review this decision.
- Arup is not the author of the reports reviewed as part of this commission and has not been involved in conducting surveys pursuant to which the conclusions in the reports have been made.
- Arup has not advised on the scope of the reports reviewed as part of this commission and has not been involved in the detailed analysis of the information collected pursuant to the surveys referred to above.
- Arup has not monitored the methodology adopted by the consultants in the preparation of the reports.
- The conclusions drawn in the reports are those of the respective authors but, within the limited scope of Arup's involvement, Arup has no reason to doubt the validity of such conclusions beyond the scope of this commission.

Appendix B – Carbon Emissions Benchmark Assessment – June 2023

comments and responses

ID	Paragraph / Section Reference	June 2023		August 2023
		Arup Comments	Arup Conclusion	Acorn Update
C1	Carbon Intensity Methodology - throughout	The scope used to report upon is the Renewable Heat Incentive (RHI) Guidance (Sustainability Self-Reporting Guidance), this RHI scheme closed in 2021.	The scope used is relevant, however using BEIS' 'Methods of calculating greenhouse gas emissions: "actual value method" and "default value method"' would offer a more up to date guide. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1078316/ghg-savings-methodology.pdf Whilst not mandatory for assessing planning applications, in the absence of Local Plan policy this guidance provides the best available industry approach to assess the carbon benefits of the proposal. It should be noted that the scheme would need to follow this guidance if they were to seek to claim relevant incentives from Government for the development.	This project will inject biomethane at a gas grid-connected injection hub in Banbury, which is already accredited under the Non-Domestic Renewable Heat Incentive (NDRHI) scheme. Although the scheme is closed to new applicants in 2021, this project has NDRHI accreditation dating back to 2018, which is why this is the scope used to report upon. We note Arup's conclusion that the scope used is therefore relevant. Additionally, there are over 100 biomethane projects in the UK, and with the exception of only a very few, these are all accredited under the RHI and therefore apply the same Carbon Accounting Methodology. We agree that using BEIS' 'Methods of calculating greenhouse gas emissions: "actual value method" and "default value method"' would offer a more up to date guide, and we are familiar with this methodology, whose application would result in a lower carbon intensity value for biomethane produced at this project – primarily through the application of 'manure credits' which are not offered in the NDRHI methodology. However, this methodology was developed by BEIS specifically for the Green Gas Support Scheme, rather than the NDRHI scheme. As the intention is for this project to inject gas at an injection hub that operates in accordance with the NDRHI scheme, Acorn believes that the latter should remain the primary scope for reporting carbon intensity.
C2	Planning, Design & Access Statement, p.2 Carbon Intensity Methodology - p.1	The 13,500 tonnes of CO ₂ captured per year in the Planning, Design & Access Statement does not appear in the Carbon Intensity Methodology - instead it says that Carbon Capture, Usage and Storage (CCUS) will capture 14,134 tonnes CO ₂ . Similarly, the Planning, Design & Access Statement states that the project will save 32,670 tonnes of	Numbers should be consistent across all submitted documents with regard to tonnes of CO ₂ captured. This discrepancy means that it is insufficiently clear how much carbon the development is going to save. Figures have also been used inconsistently and potentially inaccurately. The report could be updated to address this to allow the LPA to understand the carbon benefits of the scheme.	The value of 13,500 tonnes of CO₂ captured per year used in the Planning, Design & Access Statement was based upon the best available (conservative) estimate at the time of planning application. The value of 14,134 tonnes of CO₂ captured per year in Carbon Intensity Methodology used as its basis (1) the latest laboratory sampling of feedstocks to be used in the project and (2) the latest technical specification from the manufacturer of the CO₂ upgrading equipment that Acorn plans to use at this project.

ID	Paragraph / Section Reference	June 2023		August 2023
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		CO ₂ each year compared to standard natural gas emissions, but the Carbon Intensity Methodology says it will be 34,394 tonnes of CO ₂ e.		
C3	Carbon Intensity Methodology, p.1, p.13	CCUS is not expected to be financially viable at this scale. BEIS (2018) research indicates that CCUS may need to operate on biomass power plants at a scale of 300 MW or more in order to be viable: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/864688/BEIS_Final_Benchmarks_Report_Rev_4_A.pdf It is important to request evidence of the CCUS facility that they are proposing to use to support the assessment. Is there evidence that CCUS will capture all of the CO₂ from the processing of biogas? For blue hydrogen, for example, it is not expected to capture all of it. The methodology states that biomethane production will have a CO₂e intensity, or embodied carbon (scope 3 emissions), of -17.94g/MJ, which equates to -64.58 gCO₂e/kWh. This would not be possible without highly efficient CCUS. For comparison, BEIS data	From the available research, it appears that CCUS is unlikely to be financially viable at the scale the applicant is relying on. Without CCUS a third of the carbon savings claimed will not be achieved. The following would be required to provide robust evidence to consider the proposal: 1) Requests evidence that CCUS with biogas production can capture all of the CO₂ produced, or account for the carbon impact of some of it leaking. 2) Requests evidence that CCUS at this scale is financially viable and for reliable plans. 3) If CCUS is not viable, then requests that carbon intensity calculations are adjusted accordingly. 4) If CCUS is viable, then requests that the emissions associated with the CCUS process itself are included. Whilst CCUS is not within the description of the development and is not part of the proposal on the site, it does contribute a notable proportion of the carbon saving figures of the proposal.	None of the cases referred to in the BEIS (2018) research referred to here (i.e., • Case 8 – Biomass CFB boiler with post-combustion carbon capture; • Case 9 – Biomass CFB boiler with oxy-combustion carbon capture; • Case 10 – Biomass IGCC with pre-combustion carbon capture) are representative of the type of CO₂ upgrading facility that will be used at Hardwick. In the cases referred to in the BEIS (2018) research, CO₂ is captured from significantly less concentrated streams of flue gas than at the Hardwick facility, which will be upgrading a stream of gas that is already >98% CO₂ concentration and using an CO₂ upgrading system that is integrated with the biogas upgrading unit. This results in a CO₂ upgrading method that is significantly more efficient than the cases cited in the BEIS (2018) research. To further increase efficiency, it is proposed to install an integrated biogas and CO₂ upgrading solution at the Hardwick plant, which will use membranes as the basis of both methane and CO₂ upgrading. An example of this type of technology is shown here: https://www.bright-renewables.com/purepac-medium/ CO₂ upgrading using this type of technology is successfully operational at dozens of AD plants across Europe and the UK. The UK Govt met with several AD plants with CO₂ capture following the most recent CO₂ supply crisis. There was a shortage of CO₂ supply in the UK and several AD plants have adopted this technology. There are at least 10 in the UK and the income stream makes this financially viable. Indeed, the price of CO₂ has increased substantially over the last few years. Responses to specific points in ‘Arup Conclusion’:

ID	Paragraph / Section Reference	June 2023		August 2023
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		(UK Government GHG Conversion Factors for Company Reporting) equates to +40.93 gCO₂e/kWh without CCUS. Appendix B includes a detailed analysis of how the viability of CCUS in the facility will impact the overall carbon intensity of the project. If CCUS was not implemented, the facility would generate an estimated +6,919 tCO₂e/year, compared to the quoted figure of -7,215 tCO₂e/year. Furthermore, CCUS can be an energy-intensive process and may include the shipping and transportation of the captured carbon. The emissions associated with these activities should be considered and accounted for.		(1) The efficiency of CO₂ capture from the CO₂ upgrader is 92.5%, as some of the liquid CO₂ used for upgrading is used within the upgrading process. This has already been taken into account in the CO₂ methodology, and is now more explicitly referred to in the document. (2) Capture and utilisation of CO₂ from anaerobic digestion plants is a well-proven method, both in the UK and overseas. Ten anaerobic digestion plants in the UK are already successfully using this approach to upgrade all CO₂. Most of these plants use the same membrane technology that Acorn proposes to use at Hardwick to upgrade and liquefy the CO₂ produced at the anaerobic digestion plant. Some examples of anaerobic digestion plants that already successfully produce and utilise CO₂ by supplying it into the market as a replacement for fossil-derived CO₂ are: Some examples of anaerobic digestion plants that already successfully produce and utilise CO₂ by supplying it into the market as a replacement for fossil-derived CO₂ are: • Poundbury: https://www.biocarbonics.com/news/2021/6/24/the-prince-of-wales-opens-pioneering-green-co-capture-facility https://www.apsleyfarms.com/sustainable-co2/ • Apsley Farms https://www.apsleyfarms.com/sustainable-co2/ The business case for supply of locally-produced CO₂ into the industry has been boosted significantly since the time of the BEIS (2018) research referred to here. At that time, the majority of the supply of CO₂ to UK industry was from two sites – the ammonium nitrate production facilities in Ince and now Billingham, both of which have now closed permanently (see for instance: https://agritradenews.co.uk/news/2022/06/09/cf-to-close-ince-factory/ and https://adbioresources.org/newsroom/cf-industries-proposes-to-close-billingham-fertiliser-plant-what-does-it-mean-for-ad/). This has resulted in significant shortages of CO₂ supply in the UK, and a demand for new sources of local supply such as from Acorn's facilities.

ID	Paragraph / Section Reference	June 2023		August 2023
		Arup Comments	Arup Conclusion	Acorn Update
				Referring to the 2018 paper doesn't reflect development in GGR tech that has taken place since then, and neither does it take account of the changing commercial and regulatory environment. For instance, the introduction and expansion of the UK's Emissions Trading Scheme (ETS) and other carbon intensity-focused policy, as well as a significant development in voluntary emissions reductions of companies, has driven an increase in demand for locally produced, biogenic sources of CO₂. (3) N/A: As above, CCUS is financially viable. Furthermore, advanced commercial discussions are taking place with offtakers of CO₂ for the supply of biogenic CO₂ from Acorn to replace fossil-derived CO₂, in accordance with the quantities to be produced in this project. (4) CCUS is already included in the description of the development and all planning drawings - e.g., see Section 1.3 of the PDAS. The carbon methodology includes the emissions associated with the upgrading process – for instance, 1,616,663 kgCO₂e are associated with 'CO₂ upgrading' in table 17
C4	Carbon Intensity Methodology – p.1, p.12 & p.15	The methodology uses a carbon intensity for natural gas of 67.59gCO₂e/MJ, which equates to 243.3 gCO₂e/kWh. The source of this data is BioGrace, which is not UK-based. Natural gas has different carbon intensities in different countries it would be more appropriate to use published BEIS UK gas carbon intensities. BEIS data (UK Government GHG Conversion Factors for Company Reporting) equates to 31.1 gCO₂e/kWh for embodied carbon of natural gas or 182.5 gCO₂e/kWh for combustion of natural gas, which are both significantly lower than that used by the applicant.	The report could be updated to address this issue to allow the LPA to understand the carbon benefits of the scheme. The following would be required to provide robust evidence to consider the proposal: 1) Use BEIS GHG Conversion Factor data for carbon emissions associated with natural gas rather than European figures. 2) Request clarification throughout the Carbon Intensity Methodology of whether emissions associated with natural gas are for embodied carbon (scope 3) or combustion of the gas (scope 1), or both (with a clearly worded rationalisation). 3) Update both the carbon intensity calculations where natural gas is used in processing and the benchmarking of the embodied carbon of biomethane against natural gas accordingly.	This has now been updated in accordance with Arup's comments. (Nonetheless, it should be noted that BioGrace is the source of many of the data used in Ofgem's carbon calculator tool for NDRHI). Biograce has been used by the EU for all biofuel and bioenergy schemes. It is commonly used by the dept. for transport (DfT) in the UK for the Renewable Transport Fuels Obligation (RTFO), and by DECC/DBEIS/DESNZ/Ofgem schemes. As this is produced by the EU and widely used across Europe it is considered a very reliable data source. We have updated all relevant carbon intensity values to the latest UK Government values, from UK Government Department for Energy Security & Net Zero, Greenhouse gas reporting: conversion factors (2023). For natural gas, the originally used whole-life emissions value from BioGrace IV has now been replaced with the latest values for UK grid gas, and further broken down into the embodied carbon associated with producing natural gas (scope 3 emissions), and the

ID	Paragraph / Section Reference	June 2023		August 2023
		Arup Comments	Arup Conclusion	Acorn Update
		The boundary of the figure used by the applicant is not clear. Does it include the embodied carbon (scope 3 emissions) associated with producing natural gas, the carbon emissions associated with combustion of the gas (scope 1), or possibly whether it includes both to give whole-life emissions? This is an important distinction as the data is used in comparison with the scope 3 emissions associated with biomethane (with scope 1 CO₂ emissions implied to be carbon neutral), claiming an annual saving of 34,371 tonnes of CO₂e compared to natural gas. Appendix B includes a more detailed discussion of how this affects savings against natural gas.	Ofgem's Non-Domestic RHI Sustainability Self-Reporting Guidance includes standard input data provided by BEIS and suggests using the carbon calculator, also owned by BEIS. The carbon emissions factor of gas is typically consistent within a network (for instance the UK gas grid), so using input data from other countries would not be comparable. https://www.ofgem.gov.uk/publications/non-domestic-rhi-main-guidance	carbon emissions associated with combustion of the gas (scope 1), scope 2 and out-of-scope emissions are not relevant here. Therefore, the updated whole-life emissions value for natural gas is 66.02 gCO₂/MJ, which is the sum of the Scope 1 (56.72gCO₂/MJ) and Scope 3 (9.30gCO₂eq/MJ) emissions values for carbon intensity value for grid-supplied natural gas in UK Government Department for Energy Security & Net Zero, Greenhouse gas reporting: conversion factors (2023). For biogas, the emissions value is 9.36gCO₂eq/MJ, which is the sum of the Scope 1 (0.06gCO₂/MJ) and Scope 3 (9.30gCO₂eq/MJ) emissions values for carbon intensity value for grid-supplied natural gas in UK Government Department for Energy Security & Net Zero, Greenhouse gas reporting: conversion factors (2023).
C5	Carbon Intensity Methodology - p.1	The Carbon Intensity Methodology states that biomethane produced at Hardwick Green Power will result in 7,215 tonnes CO₂e being captured and stored annually. Biomethane is, in theory, carbon neutral due to carbon being sequestered into the feedstock and then released again upon combustion. However, once the embodied carbon (scope 3 emissions) associated with production of the gas is included and non-CO₂ emissions accounted for, the whole life emissions will be positive: an estimated 6,919 tCO₂e/year. This can only be reduced if CCUS is used successfully to capture and store some of the carbon released from the feedstock (see C3 on CCUS). This is	The report could be updated to address this issue to allow the LPA to understand the carbon benefits of the scheme. A more transparent approach should be taken to whole-life carbon emissions in the Carbon Intensity Methodology, acknowledging that CCUS is essential to achieving a carbon negative outcome (see C3 on CCUS), and benchmarking against standard BEIS data for biomethane without CCUS and for natural gas, in order to demonstrate whole-life carbon savings. According to Ofgem's guidance, biomethane is considered sustainable if the lifecycle greenhouse gas emissions are less than or equal to 24g CO₂e per MJ of biomethane injected to the grid. Whether or not this is achieved at Hardwick Green will be dependent on the viability (or not) of CCUS (see C3).	As above, all sources have been updated in the carbon methodology report to the latest UK Government-published values, and further clarity has been provided of how these are allocated to separate scopes. The value of 24g CO₂e per MJ of biomethane injected to the grid is the maximum permissible carbon intensity value according to the Green Gas Support Scheme. As above, this project will operate in accordance with NDRHI methodology, according to which the equivalent value is 34.8gCO₂e/MJ. As already explained, this installation will supply biomethane to the grid under the NDRHI scheme, not GGSS. Nonetheless, we note that even using the worst-case figure of 6,919t CO₂e/year in Appendix B, this would equate to 17.2gCO₂e/MJ, which is still significantly lower than the required value of 34.8gCO₂e/MJ in the NDRHI Guidance and the required value of 24gCO₂eq/MJ of biomethane in the green gas support scheme

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		discussed in more detail in Appendix B. Calculations conducted by Arup, using standard BEIS data (UK Government GHG Conversion Factors for Company Reporting) for comparison, show that annual whole-life emissions (scope 1 & 3), including both production (the emissions to produce the gas including transport of the feedstock and gas) and combustion, would be as follows at the volume to be produced at Hardwick Green Power: ▪ BEIS data, natural gas: 23,863 tonnes CO₂e/year ▪ BEIS data, biomethane without CCUS: 4,615 tonnes CO₂e/year ▪ Hardwick calculations, biomethane without CCUS: 6,919 tonne CO₂e/year ▪ Hardwick calculations, biomethane with CCUS: -7,215 tonnes CO₂e/year	https://www.ofgem.gov.uk/publications/green-gas-support-scheme-guidance	
C6	Carbon Intensity Methodology - p.15	The embodied carbon of the products used to treat the biomethane at the grid injection site do not appear to be accounted for – e.g. odorization, propane. Non-Domestic RHI Guidance on carbon accounting requires inclusion of the following: Vol.1, pg. 116: "The estimate must be for total biomethane injected into the grid in a year (inclusive of any additives such as propane)". Pg 113: "Equipment required to	The report could be updated to address this issue to allow the LPA to understand the carbon benefits of the scheme. This could include the embodied carbon of products used to treat the biomethane at the grid injection site in the carbon calculations as per the RHI guidance. Without this, the applicant cannot show they have complied with relevant Government guidance.	The hub is designed to eliminate the requirement for propanation as it is connected to the high-pressure gas grid. The principle is the same as the Portsdown Hill injection hub operated by SGN in Portsmouth, where biomethane from anaerobic digestion plants is transported by the virtual pipeline and injected into the grid without propanation (there is no facility to add propane at the Portsdown Hill site, which has a grid injection capacity of c.6000m³/hour). Odorant will be added at the injection hub. The impact on carbon intensity is expected to be negligible, but we will incorporate this into the model as it is not currently included. It is noted that the NDRHI Guidance does not require the carbon intensity of propane to be taken into account as part of the carbon

ID	Paragraph / Section Reference	June 2023		August 2023
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		convert raw biogas into biomethane suitable for injection [...] CO2 and oxygen removal, pressurisation equipment, propanation, odorant equipment. Vol.2, pg. 119: "Biomethane may require the addition of propane to bring it to the required quality (calorific value) to inject on to the gas network."		calculation of 'eligible biomethane' as the functional unit for the LCA is the biomethane molecules and propane is excluded from the LCA analysis accordingly. Emissions from the operation of "Equipment required to convert raw biogas into biomethane suitable for injection [...] CO2 and oxygen removal, pressurisation equipment, propanation, odorant equipment." Have already been considered in the energy input for hubs.
C7	Carbon Intensity Methodology - throughout	There is generally a lack of references to sources for most of the carbon intensity input data throughout the methodology and a heavy reliance on BioGrace for carbon intensity data.	Ask the applicant to include references to all source material for carbon intensity data, so it can be scrutinised. Data should originate from a credible, UK source i.e. BEIS, wherever it is available.	This is noted, and all sources have been updated to the latest relevant UK sources, as above.
C8	Carbon Intensity Methodology - Annex 1	The table suggests that transport emissions include transportation of feedstock to biogas plant for rye, grass, maize and straw only, and not for farmyard manure, poultry litter or pig slurry. Whereas on p.9 emissions associated with transportation of all of these feedstocks is included in calculations.	The report could be updated to correct the discrepancy between transportation emissions included on p.9 and those in the Transport column of Annex 1. The document is generally inconsistent, and should be improved to give more credibility to the reporting.	Transport emissions include transportation of all feedstocks to biogas plant. The report has been updated where necessary to ensure consistency. Generally wastes are exempt from GHG emissions calculations (under RHI) as the carbon benefits are obvious (avoided methane from landfill or unmanaged manure, for example). However, under newer schemes (GGSS) transport of waste does need to be accounted for.
C9	Carbon Intensity Methodology - p.7	The carbon impact of transport associated with digestate spreading on feedstock crops – from biogas facility to farm - does not appear to be accounted for. According to RHI Guidance this should be included.	As per the RHI guidance, we would recommend the applicant includes the carbon impact of transporting digestate from the biogas facility to farm in the carbon calculations - perhaps, if feasible, as extra weight loaded onto vehicles on their return journey from taking feedstock from farm to installation. Without this, the applicant cannot clearly evidence they have complied with relevant Government guidance.	To be updated.

ID	Paragraph / Section Reference	June 2023		August 2023
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C10	Carbon Intensity Methodology - p.14	The distance of the round trip from biogas plant to injection hub is stated as 21.6 miles, but 17.4 miles was used in the carbon calculations. This makes an insignificant difference to the overall carbon intensity of the Hardwick project (0.0007%) but is worth correcting for accuracy.	The report could be updated to correct this information for consistency. This is a minor point, but adds to the inconsistency of the overall application.	Updated accordingly.

Appendix C – Carbon Emissions Benchmark Assessment – April 2024

updated comments and responses

This appendix includes our revised responses (in detail) to each of our original comments (Appendix B), in response to Acorn's responses (Appendix B) and the revised *Acorn Bioenergy – Carbon Calculation Methodology for Hardwick Green Power*, dated 12th August 2023.

C.1 C1 – Scope (NDRHI vs BEIS)

The revised documentation continues to use the NDRHI methodology, as Acorn indicated in the response. Arup maintains that the BEIS methodology referenced would offer more up-to-date results, but acknowledges Acorn's decision to continue with the NDRHI methodology, given the key pieces of information provided in the response:

1. This project is accredited under the NDRHI scheme.
2. Acorn has indicated that applying the BEIS methodology “would result in a lower carbon intensity value for biomethane produced at this project – primarily through the application of ‘manure credits’ which are not offered in the NDRHI methodology.” Thus, the NDRHI method currently used results in a more conservative estimate of carbon intensity (i.e. higher carbon intensity) and would be considered a worse-case scenario in terms of the planning application.

However, the revised *Carbon Intensity Methodology* has not yet established clear calculation boundaries as applied to this specific project. This is most significant failing of the methodology as presented. While Acorn indicates that they aim to follow NDRHI guidance, a discussion of the boundary (or preferably a robust boundary diagram) is essential to demonstrating compliance and facilitating a full and accurate review of the methodology and results.

For example, one potential discrepancy with the requirements of the NDRHI Sustainability Self-Reporting Guidance (2021) section 5.18 is the treatment of carbon capture. The calculation may take credit for “carbon capture and storage/replacement” in the NDRHI methodology. However, the *Planning, Design & Access Statement* (Table 4-1) indicates that the captured carbon will be sold to the food industry, which is arguably not carbon capture and storage, since the carbon will be released back into the atmosphere after its use in the food industry (i.e. it is not permanently stored). This is discussed further in Appendix D.

C.2 C2 – Discrepancy between planning application and carbon intensity methodology

The revised documentation cites the following figures for tonnes of CO₂ captured per year:

- *Planning, Design & Access Statement* - 13,500 tonnes CO₂ / year
- Revised *Carbon Intensity Methodology* (Table 18) – 14,399 tonnes CO₂ / year

Similarly, the revised documentation cites the following figures for total CO₂ emissions saved per year, compared to standard natural gas emissions:

- *Planning, Design & Access Statement* – 32,670 tonnes CO₂ / year
- Revised *Carbon Intensity Methodology* (Table 1) – 34,414 tonnes CO₂e / year

While the carbon capture and savings figures are not identical in these two documents, the *Planning, Design & Access Statement* includes a more conservative estimate (i.e. less carbon captured, and higher carbon intensity), and thus would be considered a worse-case scenario in terms of the planning application.

C.3 C3 – Evidence of CCUS feasibility

Upon review of the evidence provided in the Acorn response (refer to Appendix B), the proposed membrane technology appears to have precedent projects which support Acorn's claim that the technology will be economically feasible at this project. However, several items of supporting documentation are missing and/or inconsistent from the documentation, including:

1. The revised *Carbon Intensity Methodology* (section 4.6 and Table 18) assumes that 7.5% of the CO₂ is lost during the CO₂ upgrading process. No reference or commentary is provided to justify this assumption.
2. There is still some discrepancy between and within the provided documents regarding the carbon emissions and capture figures. While these are small discrepancies within the scale of the project, they generally call the level of detail and accuracy of the report into question.
 - a. Total CO₂ emissions from heat, power, and methane slip: The revised *Carbon Intensity Methodology* (section 4.5) indicates annual emissions of 4,579,102 kg CO₂, but the calculations in Table 17 indicate annual emissions of 4,596,766 kg CO₂. No explanation is provided for the difference. There is <0.5% difference between these numbers.

- b. Biogas upgrader: The CO₂ emissions due to methane slip during the biogas upgrading process are inconsistent within the revised *Carbon Intensity Methodology*. The text (section 4.5) indicates annual emissions of 333 tonnes CO₂, but the calculations in Table 17 indicate annual emissions of 406 tonnes CO₂. There is (1.5%) difference between these numbers.
 - c. Paragraph 2 of section 4.5 has a small typo. The sentence should instead say "... in line **with** the Intergovernmental Panel...".
3. The revised *Carbon Intensity Methodology* (Table 2 and Table 14) suggests that manures and slurries are considered as potential feedstocks serving the facility. In Arup's experience, the beverage industry may not accept CO₂ produced via anaerobic digestion from some feedstocks such as sewage sludge and manures. In this case, either the anticipated feedstocks or the carbon capture process and end use would need to change from what is currently presented in the methodology.

C.4 C4 – Natural gas carbon intensity and calculation boundaries

Arup's June 2023 comments addressed two topics concerning how natural gas was included in the methodology: carbon intensity and calculation boundaries (i.e. scope 1 or scope 3). Each topic is addressed separately below.

Natural gas calculation boundaries (scope 1 vs scope 3)

- Acorn did not respond to this portion of the comment. However, the response implied acceptance of Arup's proposed approach because it suggests the related figures have been updated in the methodology. The revised *Carbon Intensity Methodology* indicates that scope 1 and scope 3 emissions for specific fuels are included, but it is still missing a clearly worded rationalisation to explain the entire scope of the methodology.

Natural gas carbon intensity

- Acorn's responses indicate that the report includes updated carbon intensity values accordingly to the most recent (2023) BEIS GHG reporting conversion factors. A summary of the updates, both in the updated methodology and the 2023 BEIS factors, is included below in Table 4 and updated in Appendix D. As demonstrated below, and contrary to Acorn's responses, the revised methodology does not actually seem to be using the 2023 BEIS data. Alternate data sources or an explanation of how the factors are derived are not provided in the methodology to explain the discrepancy.
- In terms of the planning application, the revised *Carbon Intensity Methodology* is generally less conservative than the BEIS GHG reporting factors, thus potentially underestimating the carbon intensity of the proposed plant.
 - When considering how many GHG emissions are displaced by the proposed plant, the revised *Carbon Intensity Methodology* uses a higher carbon intensity than the BEIS factor for grid-supplied natural gas. This would overestimate the displaced GHG emissions.
 - When considering the operations of the plant itself, the revised *Carbon Intensity Methodology* uses a smaller carbon intensity than BEIS (assuming the plant uses liquified natural gas, as indicated in the planning statement). This is a less conservative approach which underestimates the emissions associated with burning natural gas to support plant operations.

Table 4. Comparison of natural gas carbon intensities

Fuel	Units	Emission factors from Acorns response to C4	Emission factors based on the BEIS data (Department for Energy Security and Net Zero, 2023)		Notes
			Grid-supplied natural gas	LNG	
Natural gas scope 1	gCO _{2e} /MJ	56.72	50.81	51.20	Combustion-only emissions for natural gas (gross CV)
Natural gas scope 3	gCO _{2e} /MJ	9.30	8.39	18.09	Well-to-tank emissions for natural gas (gross CV)
Natural gas total	gCO _{2e} /MJ	66.02	59.21	69.29	Combustion plus production emissions

While the original comment did not include biogas, Acorn's response to this query also included biogas emissions factors. Again, these factors do not appear to match the 2023 BEIS factors, summarised below in Table 5. Also, while these figures are cited in the response (see Appendix B), they do not appear to be documented in the revised methodology. The emission factors used in the revised *Carbon Intensity Methodology* are larger than the BEIS values, meaning the emissions associated with biogas have been over-estimated. This results in a more conservative calculation.

Table 5. Comparison of biogas carbon intensities

Fuel	Units	Emission factors from Acorn's response to C4	Emission factors based on BEIS (Department for Energy Security and Net Zero, 2023)	Notes
Biogas scope 1	gCO _{2e} /MJ	0.06	0.06	Combustion-only emissions for biogas
Biogas scope 3	gCO _{2e} /MJ	9.30	7.89	Well-to-tank emissions for biogas
Biogas total	gCO _{2e} /MJ	9.36	7.95	Combustion plus production emissions

C.5 C5 – Biomethane carbon intensity and data benchmarking

Arup's June 2023 comments addressed the clarity of scope as well as the importance of CCUS when comparing to industry benchmarks and assessing the overall sustainability of the proposal.

Several details in the revised methodology still seem to be incorrect, including:

- The methodology does not fully describe the method and boundaries used to calculate the *Stage 3: Processing* emissions (section 7.2 of the revised *Carbon Intensity Methodology*). Our interpretation is that the processing emissions are underestimated. See Appendix D for further details.
- In the revised *Carbon Intensity Methodology* (section 4.3), the carbon emission factors used for natural gas and biogas appear to be incorrect. This was discussed in C.4.
- In the revised *Carbon Intensity Methodology*, section 7.2 is incorrectly titled. It should presumably read “Total Carbon Intensity not including CCUS.”

Note that Arup's calculations included in Appendix D **Error! Reference source not found.** have been updated using the 2023 BEIS data for comparison. While the emission factors used for natural gas and biogas in the revised *Carbon Intensity Methodology* mean the total annual emissions may have been underestimated, sensitivity tests conclude that the impact on the calculations is minimal enough to not affect the feasibility of the plant. See Appendix D for further details.

As Acorn suggested in their responses, the proposed facility seems to meet both Ofgem and NDRHI emissions guidance. The response has been addressed sufficiently in the introduction and it has been commented on that (with or without CCUS), the CO₂e intensity values for biomethane at this plant are estimated to be in compliance with the NDRHI guidance.

C.6 C6 – Propanation and Odorization

This comment requested clarity on if / how the embodied carbon of the products used to treat the biomethane at the grid injection site (e.g. propanation, odorization) were accounted for in the carbon calculations. Overall, the revised methodology and the response provided by Acorn do little to clarify this question, for the reasons outlined below.

Propanation: Acorn's response to item C6 in Appendix B indicates that the hub is designed to eliminate propanation as it is connected to the high-pressure gas grid. In Arup's experience, this justification is reasonable, as biomethane connections to the high-pressure gas grid do not typically require propanation. However, the type or pressure of the connection to the gas grid does not seem to be documented in either the *Planning and D&A Statement* or the revised *Carbon Intensity Methodology*. The *Planning and D&A Statement* (Table 4-1) notes that the injection hub will add propane to the biomethane tanks “as required;” it does not confirm Acorn's response that propanation is not required. If this were to change (and propanation were to be required, which is a

possibility per the currently submitted *Planning and D&A Statement*), it would impact the submitted carbon calculations since gas injected into the grid is typically about 4% propane and 96% biomethane by volume (SGN Commercial Services, n.d.).

Odorization: Acorn's response to item C6 in Appendix B is internally inconsistent, first suggesting that odorant will be added into the model as it is not currently included, and then indicating it had already been included in the input for the hubs. The revised *Carbon Intensity Methodology* did add a statement to clarify that odorant is included, but the related figures did not change from the original version of the methodology. This is reasonable, since the odorant would have only a small impact on the overall carbon emissions.

C.7 C7 – Appropriate referencing

While many references have been added through the reports, several pieces of data are not yet provided with adequate reference, including:

- Table 4, 5, 6, and 7 – emission factors associated with the different types of fertiliser. It is stated that the emission factors are from BioGrace IV, but accuracy can not be confirmed with a more details, clear reference.
- Table 9 – the embodied emissions associated with seeds and pesticides do not have references.
- Section 4.5 – the assumption that there is a 0.2% methane slip during the upgrading process does not have a reference.
- Section 4.6 and Table 18 – the assumption that 7.5% of the CO₂ is lost during the CO₂ upgrading process does not have a reference.

Additionally, per C.4, the BEIS referencing for the emissions factors of natural gas and biogas are inconsistent, as the numbers cited in the revised *Carbon Intensity Methodology* don't match the associated data from BEIS 2023.

C.8 C8 – Transport emissions (feedstock)

Arup's June 2023 response noted a discrepancy between transportation emissions within the report. While Acorn's response indicates that the report has been updated, the methodology has not been clearly described, and the figures presented are inconsistent.

The revised *Carbon Intensity Methodology* (Section 3.1) indicates an assumption that “all feedstock volumes are evenly distributed at mile intervals up the 10-mile procurement radius,” but no further information on distance is provided. We have queried these figures using the following calculation method for each combination of feedstock type and vehicle type:

$$CO_2 \text{ intensity (kg CO}_2\text{e)} = (N * d * i)_{100\% \text{ load}} + (N * d * i)_{0\% \text{ load}}$$

where N is the total annual vehicle trips, d is the average one-way vehicle trip distance (i.e. from farm to plant, or vice-versa) in miles, and i is the carbon intensity in kg CO₂e per mile (taken from the revised methodology, Table 13), each related to a trip taken either 100% or 0% laden. Since the average one-way vehicle trip distance is the same for either direction, this can also be simplified as:

$$CO_2 \text{ intensity (kg CO}_2\text{e)} = [(N * i)_{100\% \text{ load}} + (N * i)_{0\% \text{ load}}] * d$$

The results of this calculation are provided below in Table 6.

Under the stated assumption that the feedstock volumes are evenly distributed, we would expect the calculated average transport differences to be the same for all feedstocks (and equal to 2/3 of the 10-mile maximum transportation radius, or approximately 6.7 miles). Table 6 includes a back-calculated value for the assumed average distance, given the annual emissions in Table 14 of the methodology. Notably, these are not the same, and the distance for poultry litter is far greater than the stated 10-mile maximum. This suggests that the methodology is internally inconsistent, and the stated methodology may not be exactly what was used in the calculations.

However, Table 6 also includes the results of Arup's calculation for annual emissions, assuming a 6.7-mile one-way travel radius. The sum of the Arup-calculated emissions is 92,545 kg CO_{2e}, which is about 9% less than the 102,245 kg CO_{2e} stated in the revised *Carbon Intensity Methodology* (Table 14). While the methodology as described is insufficiently detailed and appears to be internally consistent, the results in the revised *Carbon Intensity Methodology* are more conservative (i.e. more carbon emitted, higher carbon intensity) than the Arup calculation, and thus would be considered a worse-case scenario in terms of the planning application.

Table 6. Arup's transportation calculations

Feedstocks	Mode	Back-calculated assumption for average miles per trip (one-way journey)	% difference with 6.7-mile expected average radius	Arup's calculation for annual kg CO _{2e} , assuming average 6.7-mile one-way travel distance
Rye Silage	HGV	5.3	-20%	11,924
Rye Silage	Tractor	5.5	-17%	19,397
Maize Silage	HGV	6.4	-4%	2,802
Maize Silage	Tractor	7.3	10%	4,316
Grass Silage	HGV	4.9	-27%	7,464
Grass Silage	Tractor	5.7	-14%	11,181
Straw	HGV	3.8	-42%	15,006
Poultry Litter	HGV	24.6	268%	10,004
Farm Yard Manures	Tractor	5.5	-18%	6,979
Slurry	HGV	5.5	-17%	3,473

C.9 C9 – Transport emissions (digestate)

The revised report includes additional detail on the transport required for digestate, as requested. However, the methodology questions described in C.8 above apply to the transport for digestate as well.

C.10 C10 – Distance between biogas plant and injection hub

As indicated in the Acorn response, this appears to be updated in the revised report.

C.11 Additional comments

C.11.1 Natural gas supply at the injection hub

The revised *Carbon Intensity Methodology* suggests that natural gas is required for heating at the injection hub, but the related figures and calculations are internally inconsistent.

First, the methodology doesn't explicitly note whether the natural gas is supplied via the gas grid or LPG; presumably, it is from the gas grid, but it would be worth clarifying since LNG is specified elsewhere in the reports for the anaerobic digestion plants. This was also highlighted in Section C.4.

Second, the revised *Carbon Intensity Methodology* Section 6.2 indicates that 1,000 m³/h of natural gas is required at the injection hub (serving all four similarly sized anaerobic digestion plants), though it does not specify if this is a peak supply requirement or a constant supply requirement. If it were constant supply, since the injection hub is operating 24/7, this would equate to 8,760,000 m³/year. However, Table 21 then indicates the annual natural gas requirement is 365,000 m³/year, which is significantly less than 8,760,000 m³/year, equivalent to the injection hub operating at 5% of its natural gas capacity, on average.

In terms of the carbon assessment, the key figure in the revised *Carbon Intensity Methodology* is the annual natural gas supply requirement, 365,000 m³/year per Table 21. To investigate the likely accuracy of this number, we compared to the data for the Scheme 3 plant in the CNG Services Ltd biomethane injection report (CNG Services Ltd, 2021), specifically the ratio between the injection hub annual natural gas supply requirement and the annual biomethane production. This ratio was very similar, as the Hardwick plant is only 6% less than the Scheme 3 CNG Services Ltd plant. Thus, we concluded that the stated figure of 365,000 m³/year is not unreasonable compared to other industry data, and that the 1,000 m³/h is likely a peak supply requirement used for design purposes.

C.11.2 Biomethane energy density

The NDRHI guidance (Section 5.2 of the NDRHI Sustainability Self-Reporting Guidance) requires biomethane lifecycle greenhouse gas emissions to be less than or equal to 34.8 gCO₂e/MJ, where the megajoules of biomethane are measured as the net calorific value. Neither the revised *Carbon Intensity*

Methodology nor the *Planning and D&A Statement* clearly state if the total energy associated with biomethane injected into the grid (402,114,255 MJ per year) has assumed biomethane with the net calorific value (NCV) or the gross calorific value (GCV).

The energy density of the biomethane produced is not given in the reports. However, we have back-calculated the energy density using a few factors in the revised *Carbon Intensity Methodology*:

- The total energy of biomethane added to the grid: 402,114,255 MJ per year
- Total volume of biogas produced: 20,466,506 m³

According to the IEA, the methane content of biogas is typically 45% - 75% (IEA, 2020). Combined with the factors above, this suggests the calculations used an energy density of the supplied biomethane within the range of 26.2 – 43.7 MJ/kg.

Also, according to the IEA, the typical NCV of biomethane is around 36 MJ/m³. Thus, the revised methodology could have used the correct energy intensity, though it is impossible to confirm as the report is not sufficiently detailed.

Appendix D– Technical appendix and calculations (updated April 2024)

Note that this appendix has been updated to reflect the figures in the revised methodology and the updated UK Government’s Greenhouse gas reporting: conversion factors 2023 dataset (Department for Energy Security and Net Zero, 2023).

D.1 Carbon Capture, Utilisation, and Storage (CCUS) sensitivity

The stated value in the Hardwick calculations of -7,866 tCO₂e/year total annual emissions includes CCUS. Specifically, this is the capture of 14,399 tCO₂e/year of greenhouse gases that would otherwise be expected to be emitted during the biogas processing stage.

However, Table 4-1 of the *Planning and D&A Statement* indicates that the captured carbon dioxide will be sold for use within the food industry. In this application, the carbon dioxide would eventually make its way back into the atmosphere. Arup would typically advise to only take credit for carbon capture if it was permanently stored and removed from the atmosphere.

Therefore, in this analysis, we investigate the use of CCUS technology at the anaerobic digestion facility as a sensitivity. **Error! Reference source not found.** shows the comparison between the annual emissions with and without CCUS, as presented in the revised *Carbon Intensity Methodology*. This calculation includes the energy required to operate the CCUS facilities but not taking credit for the carbon captured, which is the worst-case (and potentially most realistic, for CO₂ which is not permanently stored) approach for the whole-life carbon calculations.

CCUS is a key factor in whether the facility is net carbon positive or negative overall.

Table 7: CCUS emissions sensitivity

CCUS Scenario	CCUS efficiency (% CO ₂ e captured)	Annual emissions (tCO ₂ e/year)
Hardwick calculations presented in the revised <i>Carbon Intensity Methodology</i>	92.5%	-7,866
CCUS is operational, but no credit taken for the carbon captured	0%	6,534

D.2 Stage 3 processing emissions

The revised *Carbon Intensity Methodology* does not clearly define how the *Stage 3: Processing* emissions are calculated. The methodology notes that the processing emissions are negative when CCUS is operational (-9,745 tCO₂e / year, per Table 23) and positive when CCUS is not operational (2,968 tCO₂e/year, Table 24).

To query the methodology, we assume that the only difference between the *Stage 3: Processing* emissions for the plant with and without CCUS would be equal to the emissions that would have been captured by CCUS. Following this assumption the processing emissions have been re-calculated as follows:

$$\begin{aligned}\text{Processing emissions of the plant without CCUS} &= \text{Processing emissions of the plant with CCUS} + \text{amount of carbon captured by CCUS} \\ &= -9,744,922 \text{ kgCO}_2\text{e/year} + 14,399,304 \text{ kgCO}_2\text{e/year} = 4,654,382 \text{ kgCO}_2\text{e/year} \\ &= 4,654 \text{ tonnesCO}_2\text{e/year}\end{aligned}$$

The 4,654 tCO₂e/year of processing emissions calculated above is notably 1,686 tCO₂e/year than the 2,968 tCO₂e/year quoted in the *Carbon Intensity Methodology* Table 24. Thus, the worst-case estimation adds 1,686 tCO₂e/year to the estimate.

D.3 Natural gas emissions factor sensitivity

The revised *Carbon Intensity Methodology* and the *Planning and D&A Statement* are inconsistent regarding the source of natural gas used by the proposed Hardwick facility. The *Planning and D&A Statement* indicates "the site will import Liquid Natural Gas (LNG) to power the on-site natural gas CHP as grid connection at the location has not been possible". This is contradicted by Section 4 of the revised *Carbon Intensity Methodology*, which describes that the UK Government's latest default emissions values for grid-supplied natural gas have been used to calculate emissions from the heat and power requirements of the site. It is not clear in either the Methodology or the Planning Statement whether the natural gas used at the grid injection hub will be grid supplied natural gas or LNG. Using grid-supplied natural gas emission factors instead of the LNG emission factors could result in an underestimation of total CO₂e emissions, as the scope 3 emissions of LNG are almost double that of grid-supplied natural gas. The following sensitivity test has been performed to investigate the impact of these emissions on the total carbon intensity of the site.

As summarised in Table 4, the revised *Carbon Intensity Methodology* uses a natural gas emission factor of 66.02 gCO₂e/MJ. The BEIS emission factor (scope 1 + scope 3) for LNG is 69.29gCO₂e/MJ. If both the Hardwick facility and the grid injection hub requires LNG, then the emissions associated with natural gas will be 5% greater than those calculated in the Methodology (proportional to the 5% difference between the emission factor for natural gas used in the Methodology and the BEIS emission factor for LNG).

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