Wetland Biomass to Bioenergy

Phase 1 Redacted Report

March 2013

Phase 1 Report

Appendices

EcoCZERO Greengas Limited

Phase I Report "Wetland Biomass Competition) 29th March 2013

EcoCZERO have with their associates and contractors developed a working relationship to successfully implement trial product production for field scale operational assessment.

The design and sourcing of components has reached an agreement in principal stage with the aim of being able to commence detailed design and construction within the project timescales.

Loglogic have agreed to increase the capacity of their tried and tested Softrack with increased track size, power and stronger transmission to achieve minimum ground pressure and increase productivity and demonstrate the ability to use biomethane as the power source.

Loglogic have reached agreement with El-Ho Ab in Finland to develop their equipment to provide the cutting and harvesting component of the project equipment. It involves considerable adaption and changing of existing manufacture of tried and tested equipment and process.

The overall specification of the equipment has been agreed and the design has moved away from the drawing board and into detailed design.

Loglogic and EcoCZERO have reached agreement for the basis of manufacture trial and demonstration of the equipment.

EcoCZERO have established relationships with Fiat Power Train (FPT) in Italy to develop their natural gas engines to a suitable standard to provide correct power and torque operation to suit the application of biomass harvesting and transporting. FPT have a similar mission in developing the agricultural use of their gas engines to run on biomethane in the interests of sustainable and emission free food production.

The FPT development is currently on trial with Steyr in Austria which is a subsidiary of Case New Holland (CNH) where a similar engine is being trialled in tractors.

Refuelling systems using compression and storage of natural gas as RTF are available but need adapting to the AD plant and production requirements for biomethane. It is important to design the refuelling system to be portable and the gas storage on the larger soft track to be capable of rapid refuelling and able to avoid too much vaporisation cooling during the equipment operation. This will be a development which will be necessary to fine tune after the initial trial machine is produced.

Section 1 – Full Scale Technology Assessment

1.1 Detailed description of the end to end process

- **Physical access to the selected site for equipment and movement of material,**

  Physical access will be increased by deployment of aluminium/composite bog mats for the duration of the harvest period enabling other essential reserve activities to benefit. This will prevent damage during the harvesting period and extend the capable access and increase the harvested potential thereby increasing the overall reserve management.

  The material will be harvested and extracted by low ground pressure equipment. Operation of the equipment will be under discipline and consideration of damage by compaction, damage by turning and repositioning of the equipment and overcutting of the biomass.

  The equipment developed will weigh 3000 kg when empty and carry a maximum payload of 3,500 kg when full providing an operating ground pressure of 1.84 psi

- **Cutting and collection methods. Please include machinery specifications**.

  The biomass will be cut by a front mounted double chop forage harvester which direct cuts the biomass with rotary flails to an auger which control feeds the biomass into a multiple blade chopping paddle. The paddle provides sufficient impetus to the accurately chopped material to enable it to be discharged into tracked bulk bin carriers travelling alongside. The bulk bin carriers, when sufficiently full to exclude travelling damage, convey the chopped material to a hard standing transport point to transfer the material into sealed bulk carrier farm tractors and trailers.

  The biomass harvester will be mounted on a low ground pressure tool carrier platform developed from previous smaller designs constructed by Loglogic. This design involves

  1.the use of longer rubber track bases which uniquely have track edges which accommodate the absorption of ground surface profile changes avoiding excess surface damage in operation and turning

  2. The tool carrier platform will house 6 biomethane tanks which will be located to balance loading and consumption weight deficit to ensure that the harvesters operation is never compromised and causing resultant damage, and creating safety issues during operation.

3. The power source being biomethane powered will require development of existing hydraulic drives and gearboxes to enable suitable and efficient onsite operation.

4. The material will be collected with similar low ground pressure tool carriers carrying lightweight walking bed bulk bins. Walking bed design will reduce damage and improve safety at the time of unloading caused by elevated tipping and inappropriate weight transfer. These machines will be developed with biomethane engines. The bulk bins will be suitably loaded within a discipline to avoid surface damage from overloading.

- **The form in which harvested material is to be collected and transported to the site boundary or off site.**

  The wetland biomass will be harvested at a chopped length of 40 -60 mm and transported in bulk bins carried by low ground pressure tool carriers to a suitable loading spot for transfer to tractor and sealed trailer transport to the anaerobic digestion plant.

- **Methods and distances of transportation, for equipment to the site and biomass off of the site.**

  The AD plant is proposed at a pre-advised location which offers suitable Biomethane to Grid injection capacity in close proximity. The injection capacity is critical to the viability of an AD Biomethane to Grid plant and the location is very often unique. In this case the AD site has been evaluated as suitable in respects of viability and planning. The distance to deliver the wetland biomass from point of harvest to the AD plant is approximately15 miles using agricultural tractors and trailers running on biomethane. Each load capacity will be 31m3 and payload approximately 14 tonnes. The trailers are designed to close water tight and have retractable tighten down sealed covers to ensure bio security and avoid rainfall and water ingress.

- Any storage requirements for the harvested / processed material or equipment, for example the area of any dedicated storage required, any associated resources, and the timescales for these requirements.

  The intention is to direct cut harvest the wetland biomass and deliver straight to the AD plant for feedstock comingling to avoid vastly different gas and digestate yields and values. It is important for a Biomethane to grid injection plant to operate in an uninterrupted and consistent manner. Dilution effect of comingling the feedstock will ensure reliability. Therefore there will be no requirement for any storage requirement.

- **On site processing requirements.**

There will no onsite processing requirements.

- **Utilisation of energy from processed material,**

  The energy is produced as biogas which is cleaned to produce biomethane which has compliance with the 1962 Natural Gas standard. This will be compressed into Road Transport Fuel (RTF) biomethane at a demand level and the residue will injected into the gas grid. The RTF biomethane refuelling station will be at the AD plant and the BtG injection point is between the Pressure Swing Adsorption plant and the medium pressure gas main. The reserves will be encourage to be the end users of RTF on the basis that fuelling the management operation from a renewable source , avoiding particulate emissions and minimising NOX emissions has considerable merit.

- **Projected energy yields from different vegetation types.**

  Energy yields from the different types of feedstock will vary from biomass type and harvesting times. Harvesting times must consider reserve ecosystem impact and energy value, and therefore ideally to maximise energy output within the constraint period harvesting should be post bird nesting and while the biomass is still green Biogas yields per tonne of feedstock will be 140 standard cubic metres(scm) per tonne of fresh cut reed at 32%TS and 160 scm per tonne of wet grassland/soft rush silage at 32% TS

- **Production and treatment of any waste material / bi-products**.

  No waste is produced in the process apart from water vapour and renewable carbon dioxide. Development efficiencies will reduce the levels of carbon dioxide produced.

- **Potential use of bi-products.**

  Bi-products are liquid and solid digestate which are used within the feedstock growing regime as recycled plant nutrient. Research has been conducted into the merit of both solid and liquid digestate in further applied use in the areas of food production. The liquid digestate is proven to be of suitable consistency to provide the nutrient requirements for bio algae production and bio hydroponics. The organic content of the digestate, with consistent and renewable origins has the potential for creating components for a renewable organic chemical industry. This is the subject of current biorefining research and a point of business growth opportunity.

- **Any inputs required by the process e.g. chemicals, power.**

There are no other inputs required during the biomass harvest or in the operation of the AD plant. Electricity use will be from the plants own sustainable source.

- **Any re-cycling aspects.**

  Plant nutrients and organic matter separated out in the AD plant in the form of digestate will be used to recycle and create sustainability in the feedstock growing process.

- **Identifying losses, inefficiencies and emissions.**

  The process being timely, complete and of a sufficiently large scale will have no losses and only token inefficiencies and emissions which are regarded as neutral in effect.

- **Predicted bioenergy conversion efficiencies.**

- **BIOENERGY EFFICIENCY**

- It has been assumed that bioenergy efficiency is defined as the energy available in the biomethane output relative to the energy contained in the biomass feedstock input expressed as a percentage. All calculations have been performed in terms of net calorific values.

- **Biomass Energy Input**

Biomass Feedstock	Annual Input at 68% moisture content (t/a)	Net Calorific Value at 68% Moisture Content (MJ/t)	Biomass Energy Input (10^6 MJ/a)
Grass	41,600	3,790[(a)]	158
Reeds	900	3,410[(b)]	3
Forage Maize	3,750	3,620[(c)]	14
Forage Rye	3,750	3,980[(d)]	15
Totals	**50,000**	**-**	**190**

- Notes

- (a) Net calorific value for grass at 68% moisture content; ID 613 Phyllis 2, www.ecn.nl, accessed 29 April 2013.

- (b) Net calorific value for reed canary grass stems at 68% moisture content; ID 2058 Phyllis 2, www.ecn.nl, accessed 29 April 2013.

- (c) Net calorific value for maize straw at 68% moisture content; ID 401 Phyllis 2, www.ecn.nl, accessed 29 April 2013.

- (d) Net calorific value for rye straw at 68% moisture content; ID 547 Phyllis 2, www.ecn.nl, accessed 29 April 2013.

- Biomethane Energy Output

- 5,075,252 Nm^3 biomethane at 32.9 MJ/Nm^3 = **167 x 10^6 MJ/a**

- Bioenergy Efficiency

- (167×10^6)/(190×10^6) x 100% = **88%**

- **Measures to improve efficiency.**

  It is predicted that the process will become more efficient in the coming years as post treatment gases are comingled and re-digested with other renewable gases thereby increasing the carbon consumption and increasing energy output by up to 40%.

1.2 Regulatory requirements

The North Petherton AD site is under planning approval consultation currently involving a consent to be gained for the construction of an AD plant as an agricultural operation with an associated silage store. This site and consent are important because the suitable connection point and biomethane injection capacity are specific to the location.

The harvesting of wetland biomass traditionally has been interpreted as harvesting a crop as a source of fodder for livestock or reed for roofing material. Therefore the harvesting of wetland biomass and the direct feeding of it into an agricultural anaerobic digestion plant is considered as an agricultural activity or cropping. There is no waste created, handled or disposed off.

Harvesting Wetland Biomass form the reserves in the manner proposed is not subject to any EA permitting requirements.

Duty of care is very important and evaluation of environmental impact risk and applied contingencies is part of the operational code. The risks are Physical damage to the reserves which will be mitigated by timely operation and decision criteria in deployment management.

Biosecurity for the reserves and leaving the reserves. Mitigation will be a clean and sealed operation. Non native species seed spreading will be eliminated by the AD process rendering the seeds unviable.
Currently there is DEFRA regulation governing non native species and injurious weeds and application of disciplines will ensure that there is no impact or breach.

Currently the Environment Agency will only be able to regulate the storage and no permitting is required prior to construction.

Changes in regulation are inevitable and an evolution of best practice bespoke permitting is anticipated both for the AD plant and the silage store.

Design is in anticipation with an intention to create best practice.

Best practice has much easier justification when the scale of the project is sufficiently economic.

The EU Water Framework Directive legislation is emerging, requiring compliance with pollution risk and the creation of mitigation measures.

Industry thoughts are supportive of overarching bespoke permitting for AD plants and their cradle to grave operation.

Currently because the operation is agricultural and does not involve the use of any waste materials there is no permitting requirement.

Feedstock assessment during OFGEM accreditation is linked to the LCA values and environmental and feedstock suitability. Inefficient carbon neutrality is indicated as a hurdle to being RHI eligible and accreditation.

1.3 Detailed mass and energy balances of the proposed process

(See Appendix 1 Mass and Process Flow Diagrams)

1.4 Carbon and Energy Life Cycle Assessment

Background

North Energy Associates Ltd conducted life cycle assessment (LCA) for the Phase 1 work of EcoCZERO Greengas Ltd. This involved developing a bespoke MS Excel workbook for calculating total primary energy inputs (as indicators of energy resource depletion) and prominent greenhouse gas (GHG) emissions, consisting of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (as indicators of global climate change). The workbook uses a standard format, provides full transparency and contains necessary functionality to represent all major operational and design options under consideration for the currently-projected North Petherton ORP. As configured in Phase 1, this system is based around an anaerobic digestion (AD) plant with an annual feedstock input capacity of 50,000 t/a and an annual output rating of 5,075,252 Nm^3/a of biomethane with a 97% CH_4 content by volume[1].

Biomass Feedstock Provision

The workbook reflects the proposed supply of biomass feedstock with an assumed average moisture content of 68% by weight from 9 different types of biomass source:

- wetland grassland (267 ha providing 6,600 t/a of grass silage)
- wetland reed beds (41 ha providing 900 t/a of biomass)
- conservation grassland (304 ha providing 7,500 t/a of grass silage)
- permanent grassland (217 ha providing 7,500 t/a of grass silage)
- arable (2 year) grassland (101 ha providing 5,000 t/a of grass silage)
- arable (4 year) grassland (101 ha providing 5,000 t/a of grass silage)
- long-term arable (8 year) grassland (222 ha providing 10,000 t/a of grass silage)
- forage maize (76 ha providing 3,750 t/a of whole maize)
- forage rye (101 ha providing 3,750 t/a of whole rye)

The workbook addresses all activities involved in the harvesting of biomass feedstock from wetland grassland and reed beds, and conservation and permanent grassland. Cultivation and harvesting activities are covered for the provision of forage maize and rye as annual crops. In addition to cultivation and harvesting of arable (2, 4 and 8 year) grassland, the workbook incorporates establishment activities for these sources of biomass feedstock's which are annualised accordingly. Options for fuelling all machinery and equipment with either 100% mineral diesel or biomethane are accommodated in the workbook.

GHG emissions from the manufacture of all necessary artificial fertilisers are taken into account. In addition to the application of artificial fertilisers to certain sources of biomass feedstock's, it was assumed that digestate from the AD plant would be applied, in proportion to relative biomass feedstock provision, to permanent and arable (2, 4 and 8 year) grassland, and forage maize and rye. The annual output of

[1] Based on data available from "Feedstock Production Program: Projected North Petherton ORP" EcoCZERO Ltd., Cheltenham Spa, United Kingdom, 18 February 2013.

digestate was assumed to be 12,650 t/a in solid form and 23,297 m^3/a in liquid form. It is envisaged that solid digestate will be delivered for subsequent spreading as part of the return trips of tractors and trailers, whilst liquid digestate would be transported by means of tankers. In all cases, options for fuelling vehicles with either 100% mineral diesel or biomethane are provided in the workbook.

Where appropriate, soil N_2O emissions from the application of artificial nitrogen fertilisers, digestate and crop residues are taken into account in the workbook. In particular, standard assumptions and emissions factors have been adopted from the relevant publications of the Intergovernmental Panel on Climate Change.

Transportation of feedstock to the AD plant is envisaged by means of tractors and trailers. It was assumed that biomass feedstock would be sourced within a 24 km radius of the AD plant, giving an average round trip transport distance of 9 km. The options of fuelling tractors with either 100% mineral diesel or biomethane are included in the workbook.

Anaerobic Plant Design

The AD plant includes facilities for the unloading, final chopping (if necessary), clamping/storage (if relevant) and loading of biomass feedstock into the digester. The expected annual biogas production rate is 9,494,500 Nm^3/annum with a 55% CH_4 content. The workbook contains options to provide heat for the digester by either a biogas-fired boiler or a biogas-fired combined heat and power unit, although the former option has been adopted for the Phase 1 design. This meant that all electricity required for the plant was imported. Two options for the source of imported electricity are incorporated into the workbook; grid electricity or dedicated wind power generation. The latter option was assumed for the Phase 1 design. The electricity requirements of the AD plant consist of electric-powered biomass feedstock chopping and loading equipment, digester stirring, pumping etc., a pressure swing absorption unit for upgrading biogas, and, depending on the options chosen, compression for gas network injection and/or transport fuel supply. The workbook addresses CH_4 and N_2O emissions from biogas combustion (although these are relatively small) and excludes associated CO_2 emissions as these are biogenic.

With the Phase 1 design using dedicated wind generation to meet all electricity demands of the AD plant, the relevant GHG emission factor[2] is very low at 0.0247 kg eq. CO_2/kWh (due mainly to turbine construction). This can be compared with a

[2] "Gesamt-Emission-Modell Intergrierter Systeme (GEMIS) Version 4.5" Germany, 2008.

total GHG emissions factor[3] for grid electricity in the United Kingdom for 2004 of 0.584 kg eq. CO_2/kWh.

Reference Systems/Counterfactuals

Two reference systems are taken into account in the workbook; current management of wetland reed beds and grasslands. Associated GHG emissions were calculated using data provided on current management practices[4]. The GHG emissions associated with current management of wetland reed beds includes emissions from petrol consumption in the brush cutter and pedestrian mower, diesel consumption in a 4 x 4 vehicle and trailer used to transport equipment and labour, and the manufacture and maintenance of all equipment and vehicles. In the case of current management of wetland grassland, GHG emissions arise from diesel consumed by a tractor involved in cutting, rowing, turning, baling, removing bales from site and transporting of baled hay to a farm within a 33 km radius. Additionally, GHG emissions associated with the manufacture and maintenance of all machinery are taken into account. It should be noted that the current management of wetland grassland results in the production and use of a product in the form of poor hay for feed and animal bedding. With the use of such wetland grassland as a source of biomass feedstock in the projected North Petherton ORP, such material will not be available and hay will be required from another source. This is taken into account in the workbook by evaluating the GHG emissions associated with the conventional production and transportation of hay. This has the effect of reducing the counterfactual GHG emissions of this particular reference system.

[3] "Primary Energy and Greenhouse Gas Multipliers for Fuels and Electricity, United Kingdom 2004" NF0614Energy0402.xls, North Energy Associates Ltd., for the National Non-Food Crops Centre, York, United Kingdom, October 2009.
[4] "Additional Information for LCA Counterfactuals for the DECC Biomass to Bioenergy Project" S. Mills, RSPB, United Kingdom, 28 February 2013.

Methodology

As specified in the relevant instructions[5], the appropriate methodology for this LCA is the British Standard Institution's Publicly Available Standard (PAS) 2050[6]. However, it is noted that subsequent advice specified that the methodology in the Renewable Energy Directive[7] (RED) should be applied. Additionally, it was indicated that GHG emissions from both the manufacture of all equipment and from reference systems must be taken into account although these are specifically excluded from the RED. This meant that the remaining aspects of the RED relevant to this LCA were as follows:

- global warming potentials of 23 kg eq. CO_2/kg CH_4 and 298 kg eq. CO_2/kg N_2O,
- co-product allocation by energy content (although this does not apply since the only co-products are biogas and digestate and all digestate is used internally with system), and
- use of replacement generation for determining the GHG emissions credits for any surplus electricity sold by the CHP unit (although this is not assumed to be the adopted in the design reported here)

Based on this interpretation of the relevant methodology, subsequent results can be regarded as consistent with consequential LCA which is appropriate for policy analysis.

[5] "Wetland Biomass to Bioenergy: Phase 1 Report and Phase 2 Application Guidance" URN 13D/003, Department of Energy and Climate Change, London, United Kingdom, 2010.
[6] "PAS 2050 – Specification for the Assessment of Life Cycle Greenhouse Gas Emissions of Goods and Services" Publicly Available Specification, British Standards Institution, London, United Kingdom, October 2008.
[7] "Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC" European Commission, Brussels, Belgium, 2009.

Results

The following breakdown of results, per MJ of biomethane injected into the gas network, was derived from the workbook for the Phase 1 design involving the specified mixture of biomass feedstock's and an AD plant which uses a biogas-fired boiler for heat and electricity from dedicated wind power generation:

1. Contribution	2. Primary Energy Inputs 3. (MJ/MJ)	4. Total Greenhouse Gas Emissions 5. (kg eq. CO_2/MJ)
6. Harvesting Wetland Grassland	7. 0.0015	8. 0.000098
9. Harvesting Wetland Reed Beds	10. 0.0002	11. 0.000015
12. Harvesting Conservation Grassland	13. 0.0017	14. 0.000112
15. Harvesting Permanent Grassland	16. 0.0073	17. 0.002474
18. Establishing, Cultivating and Harvesting Arable (2 year) Grassland	19. 0.0063	20. 0.002062
21. Establishing, Cultivating and Harvesting Arable (4 year) Grassland	22. 0.0058	23. 0.001949
24. Establishing, Cultivating and Harvesting Arable (8 year) Grassland	25. 0.0117	26. 0.003850
27. Cultivating and Harvesting Forage Maize	28. 0.0093	29. 0.002211
30. Cultivating and Harvesting Forage Maize	31. 0.0082	32. 0.001993
33. Transporting Wetland Grass	34. 0.0049	35. 0.000384
36. Transporting Wetland Reeds	37. 0.0007	38. 0.000052
39. Transporting Conservation Grass	40. 0.0056	41. 0.000436
42. Transporting Permanent Grass	43. 0.0056	44. 0.000436
45. Transporting Arable (2 year) Grass	46. 0.0037	47. 0.000291

48. Transporting Arable (4 year) Grass	49. 0.0037	50. 0.000291
51. Transporting Arable (8 year) Grass	52. 0.0019	53. 0.000152
54. Transporting Forage Maize	55. 0.0007	56. 0.000057
57. Transporting Forage Rye	58. 0.0007	59. 0.000057
60. AD Plant Construction and Operation	61. 0.0024	62. 0.000425
63. Transporting Digestate to Permanent Grassland	64. 0.0003	65. 0.000023
66. Transporting Digestate to Arable (2 year) Grassland	67. 0.0002	68. 0.000016
69. Transporting Digestate to Arable (4 year) Grassland	70. 0.0002	71. 0.000016
72. Transporting Digestate to Arable (8 year) Grassland	73. 0.0004	74. 0.000031
75. Transporting Digestate to Forage Maize	76. 0.0002	77. 0.000012
78. Transporting Digestate to Forage Rye	79. 0.0002	80. 0.000012
81. Gas Network Injection	82. 0.0001	83. 0.000009
84. Reference Systems/Counterfactuals	85. -0.0102	86. -0.000753
87. Totals	**88. 0.0733**	**89. 0.016709**

The following breakdown of results, per MJ of biomethane available as transport fuel, was derived from the workbook for the Phase 1 design involving the specified mixture of biomass feedstock's and an AD plant which uses a biogas-fired boiler for heat and electricity from dedicated wind power generation:

90. Contribution	91. Primary Energy Inputs 92. (MJ/MJ)	93. Total Greenhouse Gas Emissions 94. (kg eq. CO_2/MJ)
5. Harvesting Wetland Grassland	96. 0.0015	97. 0.000098
8. Harvesting Wetland Reed Beds	99. 0.0002	100. 0.000015
01. Harvesting Conservation Grassland	102. 0.0017	103. 0.000112
04. Harvesting Permanent Grassland	105. 0.0073	106. 0.002474
07. Establishing, Cultivating and Harvesting Arable (2 year) Grassland	108. 0.0063	109. 0.002062
10. Establishing, Cultivating and Harvesting Arable (4 year) Grassland	111. 0.0058	112. 0.001949
13. Establishing, Cultivating and Harvesting Arable (8 year) Grassland	114. 0.0117	115. 0.003850
16. Cultivating and Harvesting Forage Maize	117. 0.0093	118. 0.002211
19. Cultivating and Harvesting Forage Maize	120. 0.0082	121. 0.001993
22. Transporting Wetland Grass	123. 0.0049	124. 0.000384
25. Transporting Wetland Reeds	126. 0.0007	127. 0.000052
28. Transporting Conservation Grass	129. 0.0056	130. 0.000436
31. Transporting Permanent Grass	132. 0.0056	133. 0.000436
34. Transporting Arable (2 year) Grass	135. 0.0037	136. 0.000291
37. Transporting Arable (4 year) Grass	138. 0.0037	139. 0.000291
40. Transporting Arable (8 year) Grass	141. 0.0019	142. 0.000152
43. Transporting Forage Maize	144. 0.0007	145. 0.000057

46.	Transporting Forage Rye	147.	0.0007	148.	0.000057
49.	AD Plant Construction and Operation	150.	0.0024	151.	0.000425
52.	Transporting Digestate to Permanent Grassland	153.	0.0003	154.	0.000023
55.	Transporting Digestate to Arable (2 year) Grassland	156.	0.0002	157.	0.000016
58.	Transporting Digestate to Arable (4 year) Grassland	159.	0.0002	160.	0.000016
61.	Transporting Digestate to Arable (8 year) Grassland	162.	0.0004	163.	0.000031
64.	Transporting Digestate to Forage Maize	165.	0.0002	166.	0.000012
67.	Transporting Digestate to Forage Rye	168.	0.0002	169.	0.000012
70.	Transport Fuel Compression	171.	0.0065	172.	0.000951
73.	Reference Systems/Counterfactuals	174.	-0.0102	175.	-0.000753
76.	**Totals**	**177.**	**0.0797**	**178.**	**0.017651**

Net Savings

These results can be set in context by contrasting them with the total GHG emissions of so-called fossil fuel comparators consisting of natural gas and diesel. Ideally, GHG emissions factors for fossil fuel comparators should be calculated using the same methodology as that adopted here. Unfortunately, published comparators are not calculated in exactly the same way. In particular, the standard emissions factors for natural gas and diesel available for company GHG emissions reporting[8] do not include emissions associated with the manufacture of plant, equipment, machinery and vehicles, although these are usually relatively small contributions[9]. Additionally, these emissions factors adopt different global warming potentials[10]. However, it is possible to make some adjustments for these

[8] "2012 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting: Version 1.0" by AEA Technology plc, Harwell, United Kingdom, 28 May 2012

[9] It might also be noted that the standard GHG emissions factor for natural gas relates to the availability of this fuel <u>after</u> it has been delivered via the gas network. However, reasonable comparison is still possible if it is assumed that biomethane is injected into the intermediate or distribution network where it is likely to be used relatively locally.

[10] Global warming potentials of 21 kg CO_2/kg CH_4 and 310 kg eq. CO_2/kg N_2O.

differences which enable approximate comparisons in the form of net GHG emissions savings[11].

On this basis, the subsequent fossil fuel comparators are 0.06299 kg eq. CO_2/MJ for natural gas and 0.0929 kg eq. CO_2/MJ for 100% mineral diesel. This results in net GHG emissions savings of 73.5% for biomethane injected into the gas network and 81.0% for biomethane used as transport fuel.

It should be noted that these estimates of net GHG emissions savings are different from those obtained by the strict application of the RED methodology to the evaluation of biofuels (transport biomethane) or its extension to sustainability criteria for bioenergy[12][13] (biomethane used for heating, cooling and electricity generation via the gas network). However, the workbook has the capability of deriving results with these specific methodologies (which exclude GHG emissions from machinery manufacture and reference systems/counterfactuals). In this context, the estimated total GHG emissions for biomethane injected into the gas network or used as a transport fuel is 0.016085 kg eq. CO_2/MJ. This can be compared with RED-compliant fossil fuel comparators. The relevant fossil fuel comparator for diesel/petrol is 0.0838 kg eq. CO_2/MJ which gives a net GHG emissions saving of 80.8% for biomethane used as a transport fuel. Unfortunately, there is no specific fossil fuel comparator for gas entering the network since sustainability criteria apply to delivered energy (heating, cooling or electricity). Assuming that the biomethane delivered by the gas network is used to provide heating in a boiler with 80% thermal efficiency, then the total GHG emissions would be 0.020111 kg eq. CO_2/MJ. This can be compared with a fossil fuel comparator of 0.0870 kg eq. CO_2/MJ for heating to give net GHG emissions savings of 76.9%.

- The long term impact of burning these feedstock's in conventional boilers, and measures / adaption's that can be made to counteract such impact.

Full emission tests should be undertaken during trials within Phases 2 and 3 .

1.5 Emissions

Evaluation of the relative magnitude of the emissions of oxides of nitrogen (NOx) and particulates (PM_{10}) likely to be associated with the production and use of biomethane from the projected North Petherton ORP was carried out by North

[11] Net GHG emissions savings = 100% x (total GHG emissions for biomethane - total GHG emissions of fossil fuel comparator)/total GHG emissions of fossil fuel comparator.

[12] "Report from the Commission to the Council and the European Parliament on Sustainability Requirements for the Use of Solid and Gaseous Biomass Sources in Electricity, Heating and Cooling" SEC(2010) 65 and 66, European Commission, Brussels, Belgium, June 2010, http://ec.europa.eu.

[13] "Renewables Obligation: Sustainability Criteria for Solid and Gaseous Biomass for Generators (greater than 50 kilowatts)" Reference 184/11, Office of Electricity and Gas Markets, Birmingham, United Kingdom, 19 December 2011, www.ofgem.gov.uk.

Energy Associates Ltd. This involved using the bespoke MS Excel workbook developed for the LCA study to identify and quantify potential sources of these particular emissions. In particular, this focused on sources of direct NOx and PM_{10} emissions from the Phase 1 system design which were identified as:

- diesel combustion in machinery involved in the provision of biomass feedstock's (116,369 l/a),
- diesel combustion in tractors transporting biomass feedstock's to the AD plant (60,682 l/a),
- biogas combustion in the boiler providing heat to the AD plant (266,770 Nm^3/a with 55% CH_4 content), and
- Diesel combustion in vehicles transporting digestate to selected sources of biomass feedstock's (5,380 l/a).

In addition, it was noted that counterfactual emissions would arise from the current management of wetland reed beds and grassland. The sources of direct NOx and PM_{10} emissions from these reference systems were identified as:

- petrol combustion in brush cutters and pedestrian mowers (5,545 l/a),
- diesel combustion in 4 x 4 vehicles for transportation of machinery and labour (2,195 l/a),
- cut reed burning (462 t/a at 68% moisture content),
- diesel combustion in machinery involved in the cutting, rowing, turning, baling removing and transporting of hay bales (15,834 l/a), and
- avoided diesel combustion of conventional poor hay production and transportation (9,468 l/a)

Approximate estimates of NOx and PM_{10} emissions were derived using standard data on the net calorific values for diesel (35.9 MJ/l), petrol (32.2 MJ/l) and biogas (18.7 MJ/Nm^3 at 55% CH_4 content), and published information[14] on the following direct emissions factors:

179. Source of Direct Emissions	180. Emission of Oxides of Nitrogen 181. (g NOx/MJ)	182. Emissions of Particulates 183. (g PM_{10}/MJ)

[14] "UK Emissions of Air Pollutants" NETCEN National Atmospheric Emissions Inventory, Harwell, United Kingdom.

184. Diesel Combustion[15]	185. 0.9877	186. 0.09385
187. Petrol Combustion	188. 0.0727	189. 0.00425
190. Biogas Combustion[16]	191. 0.8970	192. 0.00580
193. Biomethane Combustion[17]	194. 0.0898	195. 0.00102

Information on emissions from cut reed burning is not readily available. Instead, approximate emission factors of 1,100 g NOx/t of dry biomass and 720 g PM_{10}/t dry biomass were used[18].

Based on the Phase 1 system design for the AD plant with an annual biomass feedstock input of 50,000 t/a and an annual biomethane output rate of 5,075,252 Nm^3/a (with a net calorific value of 32.9 MJ/Nm^3/MJ at 97% CH_4 content), the following approximate estimates for overall potential emissions, per MJ of biomethane, and their breakdowns were derived:

196. Contributions	197. Emission of Oxides of Nitrogen 198. (g NOx/MJ)	199. Emissions of Particulates 200. (g PM_{10}/MJ)
201. Feedstock Provision	202. 0.025	203. 0.0024
204. Feedstock Transportation	205. 0.013	206. 0.0012
207. Anaerobic Plant Operation	208. 0.027	209. 0.0002
210. Digestate Transportation	211. 0.001	212. 0.0001
213. Counterfactuals	214. -0.003	215. -0.0008
216. Biomethane Combustion	217. 0.090	218. 0.0010

[15] Assumed equivalent to combustion emissions of road transport (HGV) fuel.
[16] Assumed equivalent to total emissions of biogas.
[17] Assumed equivalent to combustion emissions of natural gas.
[18] "Estimates of Biomass Burning Emissions in Tropical Asia Based on Satellite-derived Data" by D. Chang and Y. Song, Journal of Atmospheric Chemistry and Physics, Vol. 10, p. 2335 – 2351, 2010.

219. Totals	220. 0.153	221. 0.0039

It can be seen that the main direct source of NOx and PM_{10} emissions arise from the actual combustion of biomethane. Aside from this, the main direct sources of NOx emissions from the Phase 1 system are diesel combustion in agricultural machinery and biogas combustion in the AD plant. The main direct source of PM_{10} emissions is due to diesel combustion in the AD plant.

These estimates can be compared with the following total emissions for the production and combustion of natural gas and 100% mineral diesel:

222. Fossil Fuel Comparators	223. Emission of Oxides of Nitrogen 224. (g NOx/MJ)	225. Emissions of Particulates 226. (g PM_{10}/MJ)
227. Natural Gas	228. 0.093	229. 0.0011
230. Diesel	231. 1.003	232. 0.0954

This suggests that the production and use of biomethane has higher NOx and PM_{10} emissions than those of natural gas, but very much lower than those for 100% mineral diesel.

1.6 Process cost analysis

This section relates to the **full scale technology**, and should include:

- A discounted cash flow analysis of the full-scale project over its lifetime, accounting for the capital costs, revenues and operating costs (e.g. labour, consumables, waste disposal, overheads, sub contracts, maintenance etc.).
- The cost of energy (e.g. £/MWh, £/MJ) associated with the technology solution and how this compares to other forms of energy.

- The rate of return on investment.

1.7 Exploitation

- **Protection and use of any IP.**

  The developments which are being undertaken are predominantly applying previously developed IP in product and process to create a solution. It is likely that specific solutions which are patentable will be identified in the development. These will be applied for an operated under the guidance of DECC award IP regulation. Such IP and product development will be trademarked in the interests of both EcoCZERO and Loglogic and then protected by copyright.

- **Agreements with the land managers for harvesting and collection of biomass**

  The EcoCZERO AD plant at North Petherton will be supported by a specific Organic Resource Partnership (ORP) which is responsible for the production and delivery of feedstock to the plant and or its silage store.

  The ORP will invite agreement from the reserves managers on the basis of a share farming arrangement with parties producing biomass under a supply agreement delivered to the AD plant and or its silage store.

  The agreement will effectively create considerable cost savings for the management of the reserves, enable target management to be achieved and provide a small reflective income for the creation of renewable energy.

  The agreement will have a management program which respects and prioritises the requirement of the reserves.

- **Negotiations and agreements with end users of the bioenergy.**

  The bioenergy produced is biomethane which is intended for gas grid injection and fuel for the operation of the equipment used in harvesting and delivering the feedstock to the plant.

  Ecotricity being the JV partner in EcoCZERO have provided an “off take agreement” and a “power purchase agreement” for all of the biomethane produced and grid injected from the North Petherton AD plant. This will include the biomethane from the digestion of wetland biomass.

- **Commercialisation plans and market potential**

The Joint Venture arrangements between Eco CZERO and Loglogic have the commercial intention of developing the equipment to supply a market created by EcoCZERO projects where harvesting marginal areas of the landscape contribute towards renewable energy generation.

The need for sustainable renewable biomethane will lead to productivity being achieved form feedstocks and feedstock production areas throughout the country, which have previously been considered as in accessible. Powering the equipment with biomethane ensures carbon efficiency in production and maintains a high level of carbon neutrality.

Anaerobic Digestion is a natural process which will significantly improve in efficiency and over a period of time greatly contribute towards the countries renewable commitment.

Agricultural influence through grazing livestock has managed the landscape over many centuries, but now because of lowly productivity large tracts of land are losing their management leading to proliferation of rush , bracken and rank grass land.

The equipment development enables the productive management of these areas whilst protecting and enhancing the viability of the ecosystem there in contained.

Different operational regimes will require further development of the core equipment and this will be a considerable extension to the business of Loglogic.

- **Scalability and adaptability to different land types**

The development of larger scale equipment enhances the description of use from maintenance equipment to production equipment.

The development is to design flexible suitability to varied land type harvesting but in all cases requiring a low ground pressure operation and operational stability. The application will be to challenging sites from steep mountain sides harvesting bracken to marsh o harvest rush and wet grassland.

It would be possible to use the same equipment to harvest seaweed between the tides in productive locations.

This scale of equipment is limited to the operational conditions of working in an irregular and sometimes inaccessible landscape. We feel that the size, power, fuel source and ground pressure of the equipment is designed at a size which is optimum to ensure productivity, safety of operation and the lowest physical environmental impact.

Deployment could be all over the country and the equipment must fit onto road transport easily. The operational fleet module will consist of a harvester feeding 2 low ground pressure tool carrier mounted bulk carriers.

Scalability is in multiples of fleet modules to achieve the targeted harvest. Thereby matching the demands of the AD plant and the area of wetland? Upland biomass to be harvested.

Design will also enable the fleet module to be transported on one heavy goods vehicle movement from site to site.

The anticipated annual harvesting capacity of each fleet module is expected to be 800 hectares and up to 16,000 tonnes.

The attraction for EcoCZERO to develop this equipment with Loglogic is to

1. Enable Sustainable Practice in Energy Production

It is anticipated that AD energy production from land produced sources will have an impact on available land for food production.

The ability to recycle plant nutrient produced through digestate management will contribute to the creation of sophisticated, sustainable and controlled food production opportunities, which carry increased efficiency and productivity from the same food source.

The digestate produced from wetland biomass does not contribute to the vitality of the reserve and when applied to other land in safe proximity will increase fertility and productivity of that land or in growing medium use.

2. To be able to maintain and enhance the landscape environment

The productive landscape particularly in environmentally sensitive can suffer from vegetation overburden resulting in changes to the biodiversity which are not beneficial to the existing and weakened ecosystems. The ability to manage and deploy nutrient stripping to these areas is therefore beneficial. The targeted areas of landscape management assistance proposed are wetland biomass harvesting, wetland and hill rush and bracken

3. To Become and Ecosystem Service

Deployment of the equipment developed for maintaining the landscape environment and its associated ecosystems amounts to an Ecosystem Service. EcoCZERO is engaged with pilot schemes to evaluate Payment for Ecosystem Services under the DEFRA approach to Environmental Stewardship.

4. Develop Environmental Solution Value

With the evolution of impact of the EU Water Framework Directive, Eco CZERO are engaged with DEFRA, Natural England and the water utilities to develop water catchment interception and management as a means of reducing plant nutrient and agrichemical penetration of the water systems. The principles are to develop reed beds for bioremediation and nutrient stripping. The reed beds will be harvested and managed productively to create habitat and a source of fuel for renewable energy creation and source of renewable plant nutrient supporting the agri-environment.

Report Conclusion

Phase 1 work involved the evaluation of the potential of achieving the project aims of producing renewable energy in an efficient and economic manner.

Clearly the highest value achieved from renewable energy generation is when the support from renewable subsidies achieves a prior to mid contract term capital payback.

The capital costs versus productive limits determine breakeven points and ultimate payback period.

Scale of generation therefore plays an important part and determines residual project value post subsidy contract term.

Wetland Biomass is an important source of sustainable feedstock for renewable energy production but volumes available and difficulty in harvest determine its viability for small scale renewable energy production.

The evaluation and life cycle analysis exhibit promising results for the harvest of the wetland biomass for inclusion in a nearby AD plant which is already capitalised and has the capacity to absorb the production when comingled with existing feedstock.

The investigation and design work conducted with Loglogic , FPT and CNH outline considerable future opportunity to make a large contribution to sustainable renewable energy production throughout the country. The combined opportunity has merit for exploitation throughout the World.

The Life Cycle Analysis of the combined project of the AD plant being partly supported from Wetland Biomass concludes a potential 81% carbon neutrality (appendix 2 LCA)

The Bioenergy Efficiency of the project has a base line of 88% which we believe will rise to significantly with the application of current R&D in the AD sector.

The contribution of harvesting the wetland biomass from the reserves will achieve a cost saving of 100 % in reed and wet grassland and rush management and an attributable income of £60 per hectare of reserve area harvested.(appendix 3 EcoCZERO process cost analysis)(appendix 4 Reserve process cost analysis)

Appendices

Appendix 1. Wetland Biomass Flow Report Book

Appendix 2. DECC Phase I Report Unit Flow Chart

Appendix 3. EcoCZERO Wetland Biomass LCA (Life Cycle Analysis) Workbook

Appendix 4. EcoCZERO Process Cost analysis

Appendix 5. Reserves Process Cost Analysis

Appendix 6. Cost of Energy Comparison

Appendix 7. Cost Breakdown

Appendix 8. Timeline and Invoicing Plan

Appendix 9. North Petherton AD Plant Mass Flow Summary

Appendices will be available for public scrutiny subject to applicant screening following requests to info@czero.co.uk.