Feasibility report from the ‘Driving Innovation in AD’ programme which looks at the potential for on-site anaerobic digestion at Hook Norton Brewery Co. Ltd, in Oxfordshire.

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Abstract

This Driving Innovation in AD (DIAD) project brings together the National Energy Foundation (NEF), Clearflau Ltd., Hook Norton Brewery and Hook Norton Low Carbon Limited (HNLC). There is an opportunity for the UK to increase the uptake of Anaerobic Digestion (AD) by small and medium sized enterprises (SME's) and on industrial sites with limited output of suitable feedstocks, and in communities as is happening in other markets like Germany and Austria.

The feasibility study undertaken as part of the DIAD project assessed potential for deployment of a small scale on-site AD plant in the brewery sector. During the feasibility phase, the project partners evaluated the scope for installation of a small on-site AD plant at the brewery site and undertook lab trials to evaluate the use of membranes to enhance performance, optimise solids retention in the digester and facilitate watercourse discharge of residual cleansed effluent.

As part of the next phase, a small anaerobic treatment plant (SATP - a 50 kW thermal unit) is to be located at Hook Norton Brewery, to act as a technology demonstrator and catalyst for the deployment of AD in the sector and on other similar sites. In addition to providing a solution for handling production residues at Hook Norton, it will facilitate the development of a modular AD system that provides a means of delivering on site AD for SME food and drink processors at a much smaller scale than is currently possible with existing designs of AD plants.

The design for the DIAD project is based on Clearflau’s Small Scale Production Plant (SSPP) trial unit with specific modifications including modularisation and use of membranes. The next phase will trial and optimise the system, not just for the brewery sector but for the wider food and drink industry. This will take the process to a much smaller scale and include membranes in the design, to provide water quality at a level suited for discharge directly to a local stream.

The high-rate AD process maximises chemical oxygen demand (COD) removal (at least 95-99%) and consequently biogas output, due to highly effective mixing of the liquors in the anaerobic reactor and sustained exposure of the active biomass to the incoming COD load. This breaks the link between solids retention time (up to 50 days - necessary to optimise biogas output) and liquid retention in the digester tank (reduced to less than 5 days). This limits required tank size and hence capital and operating costs for this highly mixed system.

For the feasibility phase Clearflau used micro-filtration membranes. This significant innovation will reduce chemical (polymer) consumption compared with the established solids flotation process used on the plant Clearflau supplied at BV Dairy and will produce a much cleaner residual fluid for watercourse discharge.

Laboratory testing undertaken during the feasibility phase on the effluent from the brewery has shown that the AD plant will produce 7 Nm$^3$/h of biogas with 60% methane content. This translates to 44 kW thermal over 24 hours with an RHI rate of 7.1p /kWh, this equates to £75 per day, or about £27,500 per year.

Based on the initial feedstock supply, the incentive revenue and additional savings of about £25,000 per annum, the project will provide a net revenue of about £52,400 per annum.
Executive Summary

There are significant opportunities for uptake of AD in the UK by small and medium sized enterprises (SME's), as well as for communities. Compared with our European neighbours like Germany, much more needs to be done to stimulate this sector. A lack of demonstration sites for smaller scale (sub 100kW) AD plants is one of the main barriers identified in the DEFRA's recent AD Strategy that is being addressed by WRAP's Driving Innovation in AD (DIAD) programme and this on-site micro AD project.

This DIAD feasibility study is for a small scale on-site, modular AD plant to be located on the site of the Hook Norton Brewery, a well-known family brewery with a national profile. The project brings together the National Energy Foundation (NEF), Clearflau Ltd. (a British AD technology company), plus the Hook Norton Brewery and Hook Norton Low Carbon Limited (HNLC) - a local community enterprise.

Clearflau has already demonstrated how their high-rate liquid AD technology can be optimised for larger food and drink processors. The plant built for BV Dairy in Dorset, (operational since early 2011) is digesting processing effluent and dairy co-products, supplying renewable energy to site while also cutting its carbon footprint. It has been operational for over 18 months as a demonstration plant for the UK food sector.

The focus of the project partners is delivery of a micro-scale AD plant on the brewery site, treating the effluents and co-products from the production process, in a design that will maximise biogas output and optimise project payback. Clearflau has developed a compact AD plant that can treat bio-waste from SME sites. It will allow companies to make use of heat (and power) generated in the production process, replacing purchased fossil fuels and reducing treatment costs. Post treatment, the plant could facilitate grey water recycling for use on site or for watercourse discharge.

These on-site AD plants are able to treat trade effluent and higher strength materials generated on-site, but unlike other high-rate AD systems, can accommodate fats and greater variability in solids content. They lower effluent treatment and energy costs by:

- reducing costs of running aerobic plants or by cutting sewer discharge costs;
- cutting costs of disposal of residual sludge or high strength waste materials; and
- reducing energy costs, as fossil fuels are replaced by renewable energy.

The Hook Norton project, led by the National Energy Foundation and Clearflau has, in the feasibility phase, shown that the feedstock can be effectively digested and also trialled the membrane technology. With support from WRAP and others, the next step is to further develop the system and install a demonstration plant at the brewery. The scope will include:

- design of an AD plant for operation on brewery and other sites;
- enhancing the design of the solids management system by using membranes;
- improvements to the process design to optimise output and ease of operation; and
- 2 years demonstration on the Hook Norton Brewery site.

At Hook Norton Brewery, the Small Anaerobic Treatment Plant (SATP) will be processing about 55m$^3$ per day – compared with over 200m$^3$ per day at BV Dairy. The process equipment will be installed in a 40ft modular unit with an external reactor tank (in the trial unit the AD reactor is fitted inside the module). It will offer the same robust approach to on-site AD shown at BV Dairy.
The process effectiveness is based on extension of the period for which bio-degradable solids are retained and re-circulated in the reactor to enable methanogenic bacteria to fully digest degradable solids and optimise biogas output. For this project Clearfläeu will use robust hollow fibre micro-filtration membranes. This approach to bio-solids recirculation will reduce chemical (polymer) consumption compared to the flotation process used at BV Dairy. During the demonstration phase further design and development work will be undertaken on:

- **Scale Optimisation**: The AD plant will be a micro scale unit.
- **Discharge Optimisation**: Membrane thickening will optimise solids capture.
- **Membrane Optimisation**: A commercial trial will evaluate operating costs.
- **Design Optimisation**: Off-site assembly will limit costs for subsequent units.
- **Maximising Biogas Output**: The output of biogas will be relatively modest and the demonstration phase will explore how biogas output can be optimised.

The data generated in the laboratory trials undertaken was very encouraging and we are confident that the system will achieve the required discharge standards. However, more detailed design work is required to translate the trial results into effective operation of the Hook Norton plant.

The biogas from the on-site AD plant at Hook Norton will be fed to a new process boiler. Anticipated capital investment is £475,000. The annual RHI revenue will be about £27,400 per annum. The reduction in oil purchase costs will be about £15,000 per annum and the reduction in water treatment costs about £10,000 per annum. Net overall revenue is £52,400 per annum, with an anticipated payback of around 9 years. It is anticipated that with further enhancements to the process it should be able to bring this down to less than 6 years for future projects. This is one of the goals of the next phase of the project.

There will be other costs incurred by Clearfläeu during the demonstration phase that will not be included in any payback calculations for the AD plant. This includes an extensive visitor and communications programme in support of the project. The partners have identified an emerging market for smaller scale AD at business and community level. This includes AD on breweries plus dairy and food processing sites and other industrial sectors. The partners will also support Clearfläeu in the dissemination of initial information on the Hook Norton project.

The commercialisation plan for the SATP unit in the SME sector is:

- Preparation of Hook Norton demonstration site (Q2 2013).
- Production of updated SATP marketing material (Q3 2013).
- Installation of SATP demonstration unit in the USA (Q4 2013).
- Follow up opportunities to deliver 1st 5 projects (Q4 2013).
- Delivery of SATP units in food and drink sector (Q1 2014).
- Development of extended pipeline for the SATP (Q3 2014).

With a viable commercial demonstration site at Hook Norton, the project team are confident that the project will help stimulate increased interest in smaller scale AD in general, as well as on-site industrial AD technology. It is also expected that multiple orders will reduce the production costs for the SATP unit by up to 25%. Clearfläeu is budgeting for future multiple sales due to the experience with the Hook Norton project and confidence it will provide to clients. The adoption of this and other on-site renewable technologies in the SME sector will provide access to on-site renewable energy, with a major impact on its carbon footprint.
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Glossary

S-COD – Soluble Chemical Oxygen Demand
T-COD – Total Chemical Oxygen Demand
S-BOD – Soluble Biological Oxygen Demand
TSS – Total Suspended Solids
VSS – Volatile Suspended Solids
TKN – Total Kjeldahl Nitrogen
NO₃ – Nitrate
TN – Total Nitrogen
NH₄ – Ammonia
PO₄-P – Ortho-Phosphate
SO₄ – Sulphate
CO₂ – Carbon Dioxide
1.0 INTRODUCTION AND BACKGROUND

1.1 Hook Norton Project Consortium

This feasibility study brings together the National Energy Foundation (NEF), Clear/fäau Ltd., Hook Norton Brewery and Hook Norton Low Carbon Limited (HNLC).

- NEF has been working nationally to optimise and demonstrate new and innovative approaches to energy efficiency and renewables since its foundation in 1990. NEF sees the need for a number of successful, optimised AD solutions as being critical to establishing AD alongside other renewable technology options regularly considered by SMEs in the UK.

- Clear/fäau has demonstrated how their high-rate through-flow AD technology can be optimised for larger food and drink processors. The plant at BV Dairy (BVD) in Dorset, completed in 2010, has been operational for over 18 months. Built with funds from the Environment Transformation Fund (ETF) managed by WRAP, it is a demonstration plant for the food sector. The proposed small scale design for the DIAD project includes some specific modifications of the processes used at BV Diary, including modularisation and use of membranes. The project will trial and optimise the much smaller scale system for the brewery sector.

- Hook Norton Brewery has already taken steps to reduce energy demand through discussions with the Carbon Trust on basic energy and water efficiency upgrades. They are now actively considering how to make the step change in the level of on-site renewable energy production. In partnership with HNLC they have already obtained planning permission for installation of 20kWp of PV towards site electricity demand but of more significance in carbon reduction terms, is this project which shall address their heat demand through AD.

- HNLC is a social enterprise with £400K of assets that has demonstrated over the last 3 years how they can maximise energy savings across the community as a whole by coordinating the skills and resources of the wider community (www.hn-lc.org.uk). To date, HNLC has supported the brewery in its efforts to identify the most appropriate AD technology for its needs. It will also help to raise the capital needed for construction and provide technical input to the on-going operation of the AD plant when it has been installed.

The project consortium is working together to ensure that the proposed on-site AD plant is suited to the operational needs of the brewery. In addition to reducing energy and treatment costs it will also be integrated with other carbon reduction activities in Hook Norton village. In addition to provision of a technical solution for brewing residues, the project will aim to provide some benefits to the community, including supply of nutrients to the allotments and at a later stage possible inclusion of other feedstocks in the digester feed.

However, the primary focus of this feasibility phase was technical appraisal of the innovative aspects of the project and the design of the proposed plant. This was undertaken alongside a laboratory trial of the digestion process with the application of membrane technology with the results of this trial impacting on the final design.
1.2 On-Site Small Scale Digestion Technology

Clearfleau Ltd, a British AD technology company, provides on-site treatment solutions for effluents and by-products. The company is currently building medium scale (mainly under 500kW electrical output) on-site AD projects, in the distillery, confectionary, food and dairy sectors.

A modular version of Clearfleau’s liquid digestion system has been deployed for trials on confectionery, dairy and beverage production sites and in the bio-fuel sector. Although the company is building a number of medium scale on-site AD plants, there is an opportunity to develop even smaller scale plants, based on a commercial version of the mobile unit for sites with more limited feedstock volumes and space.

Image 1: SSPP (mobile trials version)

![Image of SSPP (mobile trials version)](image)

This approach has been shown to work at throughput of over 200m³ per day at BV Dairy but with interest being shown by processors with lower throughput, Clearfleau is developing a design for under 100m³. For this project, in addition to enhancing the design of the SSPP unit, the plant will include an external AD tank and well as micro-filtration membranes for bio-solids recirculation.

1.3 Technology Development and Project Concept

Based on this feasibility report and the trials that have been undertaken using the membrane based thickening system, further funding is being sought from the WRAP DIAD program to help develop the detailed design for the AD unit for installation on the Hook Norton Brewery. The intention is also to demonstrate that small scale high-rate AD can, with appropriate design and technical development, be adapted for SME sites.
With respect to Hook Norton Brewery, the project aim is to optimise the treatment process for production effluent and residues, while maximising on-site generation of biogas. The AD plant will be located on the brewery site, adjacent to the existing treatment facility that it will eventually replace. The site will be managed by the project partners, including Hook Norton Low Carbon and as a demonstration site it will include visitor access.

At Hook Norton Brewery, the small scale AD unit is designed to process up to 70m$^3$ per day – compared with over 200m$^3$ per day for the existing design at BV Dairy; the COD load is also much lower. The SATP unit will be positioned on site but with an external reactor tank (in the SSPP trial unit the AD reactor is located inside). The SSPP trials unit was developed to run trials on a range of feedstocks and has undertaken 8 trials in the past 3 years. The unit includes process control and monitoring equipment and a small laboratory.

A specific advantage for the food processing sector is that this is the only high-rate AD process able to digest fatty effluents. While this does not apply to Hook Norton’s feedstock, for other sites this means that all bio-degradable materials generated in the production process can be accommodated in the digester. Due to the extended solids retention time, the design is able to optimise biogas output (this can be up to 20% higher than other high-rate AD systems). This also facilitates a major reduction in effluent treatment costs.

The effectiveness of this high-rate AD process, which maximises COD removal (95-99%) and hence biogas output, is due to highly effective mixing of the liquors in the anaerobic reactor and the sustained exposure of the active biomass to the incoming COD load. This is achieved by breaking the link between solids retention time (of up to 50 days) and liquid retention in the digester tank (reduced to about 5 days). This limits tank size and hence capital and operating costs for this highly mixed system.

This enables the slow acting methanogenic bacteria to fully digest the bio-degradable solids. The challenge that is being addressed is to do this on a smaller scale, with an AD unit that can be manufactured off-site in order to minimise production costs and limit the impact of installation on busy, confined industrial sites. The aim will be to bring pre-commissioned units to site for connection to the on-site feedstock. It is expected that hundreds of SME food processors will be able to make use of small scale AD technology.
2.0 PROJECT OBJECTIVES

2.1 Process optimisation for small-scale digestion
The feasibility phase has included initial design activity supported by laboratory based digestion trials, including membrane thickening on representative samples of the brewery feedstock. This phase of the DIAD project and the initial design work has produced a fully costed design, partly based on the laboratory trials. This consists of a micro scale AD unit designed to fit the confined site. The design has been based on data generated in the ongoing laboratory trial and initial design drawings are included in this report.

The on-site AD unit will comprise a small external digester tank (under 150m$^3$ in capacity) and a modular unit with all process equipment mounted inside. The residual digestate (solids) can be used for direct land application with PAS110 compliance; especially through linkage to the Hook Norton allotment society (the existing drains will be diverted to exclude any human sewage from the AD plant, at relatively low cost).

There are a number of ways in which the project will satisfy the outcomes that have been specified by WRAP for the DIAD program. These include:

- optimisation of the digestion process to facilitate water course discharge;
- membrane integration with the solids management system;
- design optimisation based on modular system and manufacturing efficiency; and
- replicating process efficiency (COD removal/biogas output) at smaller scale.

Image 3: Mobile trials unit being installed

2.2 Process optimisation to ensure discharge to water course
A key element to be demonstrated on the Hook Norton site is the evolution of Clearfléau’s innovative solids handling system in the AD plant. This will use membrane thickening and although Clearfléau have used membranes for trials on a dairy feedstock in 2011, this will be the first installation on a fully commercial unit. The membranes will replace the polymer based system that has been used in the dairy sector and other higher solids projects.

Due to the membrane filtration pore size and extent of COD removal, the AD plant is able to achieve water course discharge standards for sensitive water systems. The permitted BOD discharge concentration to the Hook Norton water course is 40 mg/l. It may be possible to use grey water on-site for boiler feed but discharge of cleansed effluent to the local stream,
currently running at a historically low level, will deliver an environmental benefit for the site, through enhanced flow below the site, which will be evaluated in the detailed design phase.

By removing up to 99% of COD in the digestion process, minimal post digestion polishing and water aeration will be required prior to watercourse discharge, using the existing biotower. The bio-tower is currently used to reduce the COD level by about 50%, prior to the discharge to the local sewer. This low energy process uses natural aeration by cascading the water through a packed media. The aim is to use the same plant as a process to reduce the final biodegradable material. The cleansed water will then be passed as dilution water to the local sewage works or achieve the required quality to allow discharge to the local brook. This will be decided during the final design phase, following discussions with the EA.

2.3 Optimisation of membrane performance and integration

The in-line membrane unit will ensure the capture of all biomass (but not the nutrients) for return to the digester, enabling optimisation of biogas output and a reduction in operating costs, through limiting chemical use. This project will reduce the on-site consumption of chemicals in two ways, by reducing existing use in the waste water treatment plant as well as requiring an overall lower chemical use in the AD plant. For other similar projects it will facilitate grey water recycling, without resorting to other expensive post digestion treatment (or polishing) as on some Clearfléau sites (e.g. Scottish distillery project with discharge to the River Spey).

Membranes have been used with biological systems but the process needs further, on-site evaluation to balance operating costs against capital costs for the application in AD. Also we will use the Hook Norton project to evaluate membrane effectiveness and to refine the design to balance capex against operating costs; a higher number of membranes will reduce pumping power consumption but will increase cleaning costs.

Cleaning frequency and chemical consumption also need to be evaluated in a commercial environment. This project will allow extended operation on the brewery site and as with the BV Dairy project, the next phase will provide invaluable operational experience under fully commercial conditions.

2.4 Optimisation to allow replicability through modular design

The D1AD contribution towards the demonstration phase, as well as the cost of the feasibility phase, has helped progress development of the system, while laboratory trials on the brewery feedstock have allowed the project team to evaluate COD removal and gas output.

The system to be used in the SSPP unit to be installed at Hook Norton has incorporated a number of enhancements based on the feasibility trials. These include:

- integration of membrane plant into the container;
- redesign of the chemical storage and dosing area;
- integration of a bigger heat exchanger into the unit; and
- redesign of mixing and sludge pump layout.

These aspects are fundamental to ensuring that the on-site AD plant can be built at a cost effective price that will ensure commercial viability. The AD reactor tank and the modular unit will be manufactured off-site and wet tested prior to installation at the brewery and on-site commissioning. This will enhance the efficiency of the manufacturing processes and with a move to mass production, reduce the unit cost for future plants.

We hope the project and use of the Hook Norton site as a commercial demonstrator will encourage the micro brewing sector to evaluate on-site AD. SATP sales will also generate
manufacturing jobs with suppliers and in the sub-contractor that is used to assemble the SATP unit, as well as potential export opportunities for the UK.

### 2.5 Maximising COD removal and biogas output

The system is designed to optimise COD removal based on degradation of degradable solids in the digestion process. The digestion process is explained in a schematic drawing in section 5.1 *The Liquid Digestion Process* and results of the digester/membrane trial can be found in section 3.4 *Laboratory trials*.

Gas output volume is limited due to the relatively low strength of the brewery feedstock (with a much lower COD than for dairy feedstocks). Hence the demonstration phase will be used to assess additional feedstock materials, such as liquor from the ‘brewery mash’ or out of specification beer that can be added to enhance loading and biogas output. In the demonstration phase we will continue to evaluate the biogas potential and alternative uses for the biogas on the site.

The initial plans are to feed biogas to a new biogas boiler, which will mean the AD plant will qualify for the RHI at the 7.1p per kW rate. In addition, the project team will explore other uses for biogas in the local community, particularly if during the final design phase any additional feedstocks can be identified for the digester, thereby increasing gas output.

### 2.6 Overall Project Expectations

The DIAD programme has two project streams focused on the AD sector, namely:

- optimisation of processing and product manufacture at all scales of AD; and
- reduction of costs and complexity for development of smaller scale AD.

The Hook Norton project will deliver against both these programme aims. For the first DIAD objective, optimising biogas production in a high-rate AD is a key output of the feasibility project and subsequent implementation, particularly for low strength brewery feedstock that doesn’t have the same biogas potential as other feedstocks. Without a demonstration unit in the smaller scale brewing sector, uptake of the technology is likely to be slow.

The additional dimension of combining a high-rate AD process with an enhanced membrane technology should increase process efficiency and also produce an extremely high quality and reliable discharge. A demonstration that revenue from energy generation and minimising waste costs can be combined in a single cost-effective application will help make decision-making for the food and beverage industry more compelling. NEF will work with *Clearflau* to showcase the project and this approach to AD.

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**Image 4:** Interior of the mobile trials unit
3.0 STATE OF TECHNOLOGY

3.1 Development History
The objective of reducing complexity and the cost of smaller scale AD is fundamental to the development of the sector. This includes elements such as modular design, the off-site construction and combining on-site energy generation with effluent treatment. This project will have outputs applicable to this work stream. The model of a local business working in combination with a community social enterprise will also be particularly relevant to enable small scale AD to be applicable to both farm-based plants and community projects.

As well as BV Dairy, Clearflau has embarked on projects with Diageo and Nestle. The former will be operational in early 2013. The company expects to be engaged on at least 4 sites in 2013 (in the dairy and beverage sectors but also treating bio-fuel residues). Support from WRAP has enhanced development of this technology. Clearflau has increased its workforce, adding 11 new jobs in 2011 and 2012, following the opening of its Bracknell engineering office and expansion of the project delivery team. Further jobs will be created in 2013, in part based on the planned sales of SATP system and likely project opportunities in Ireland and Germany.

Modular design is part of the scope for the Nestle project in Newcastle. A number of units have been constructed off-site and these are being located on the Fawdon site following the installation of the main digester tank. This approach lowers costs and reduces the impact on the manufacturing, build time and development of small scale AD.

3.2 Technology Platform
The design will include process control and monitoring equipment and a small lab in the unit. The commercial version of the SATP unit will not only demonstrate how it can be used to treat liquid brewery residues but also that on-site AD technology is viable at this scale, providing a cost-effective biogas supply to the site, while reducing effluent treatment costs.

Based on the design and trial work that has been undertaken during the feasibility phase, including the laboratory trials, the full scale demonstration of the Hook Norton project will, in a fully commercial environment, showcase the following:

- biogas production with a skid mounted mobile AD plant, treating liquid brewery waste;
- direct use of the resulting biogas for the heat requirement at the brewery;
- cost effective use of advanced membrane technology to allow the direct discharge of cleansed effluent into the local watercourse;
- modular, off-site construction to reduce costs and minimise on-site disruption; and
integration with on-site PV to create a low carbon exemplar for the brewing industry, including possible power supply to the local community.

3.3 Wastewater characteristics

Prior to the laboratory trials the wastewater at Hook Norton was sampled over a period of 10 days. A 24 hour composite sampler and temperature logger were installed on the brewery site in the pH correction building. The collected data are shown below:

### Table 1: 24 hour composite sample results

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The average soluble COD (S-COD) in the digester feedstock is quite low and this should be increased by reducing the water consumption in the brewery during the post installation demonstration phase. The variability in the figures shown in Table 1 is a result of the variability in feedstock used for the trial. Based on prior experience this step and the intake of wastewater with higher COD, (e.g. the liquor discharged with the spent grains) will increase the overall COD concentration and hence the biogas yield. The anticipated reduced flow of water in the feedstock could also facilitate a decrease in the size of the digester and its ancillaries.

From experience in past trials on grain based feedstocks, with the SSPP unit on biofuels and distillery sites, the S-BOD of brewery wastewater should be 50% of the S-COD, but it cannot be higher than the concentration of S-COD, because of known degradability of the feedstock and because the S-COD contains the S-BOD and inert COD. The TSS figures seem to be very low for a brewery. This is in part due to high water use which is being addressed, alongside diversion of the foul sewer discharge. There will also be a lower solids discharge from the anaerobic digester during normal operation so the volume of sludge disposal from the site will be lower than for other feedstocks. All other results are in line with expected outcomes.

The average temperature of the effluent stream to the pH correction sump over the past two months was 22.6°C, with a maximum 33.8°C and minimum 10.4°C. The temperature seems to be quite low for a brewery site and this appears to have something to do with the storage time in the current aerated balance tank. The ambient air is used to mix the contents of the tank and by doing so, reduces the water temperature. It is expected that the temperature for the demonstration project will be higher as jet mixing without aeration will be applied and this will reduce the energy demand of the system required to heat the digester.
The membrane system installed downstream of the AD, should achieve COD removal rates of up to 99%, as residual COD is tied in with the biomass which is then removed by the membrane. For the implementation phase of the project, discharge to the local water course will require some removal of ammonia (NH₄) and phosphate (P) from the residual, cleansed effluent. At the brewery the existing trickling filter, combined with an anoxic compartment and clarifier will achieve the nutrient removal rates required for watercourse discharge as is conducted at most biological nutrient removal plants.

Despite the limitations of the feasibility study data, which was in part due to the restricted time available for the trial, this was a useful exercise and combined with other lab and on-site trials that have been undertaken on comparable feedstocks, Clearflou is confident that it can improve on the performance during the on-site demonstration phase in 2013/14.
### Table 2: Temperature Hook Norton effluent 14th April – 12th June 2012

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### 3.4 Laboratory trials

The laboratory trial unit at consists of an 18 litre anaerobic reactor followed by the membrane plant that was installed for this project. The anaerobic reactor converts the soluble organic load of the brewery wastewater into biogas and solid biomass. The membrane plant thickens the sludge and residual water is discharged free of solid matter. The following photographs show the lab scale anaerobic reactor and membrane unit.
Image 5: Anaerobic reactor

Image 6: Membrane plant

Image 7: Combined plant
The laboratory trial was undertaken in two phases. On 8th May 2012, manual feed of Hook Norton Brewery wastewater to the anaerobic reactor was started. This allowed the anaerobic sludge to be adapted to the wastewater feed. In the second phase the membrane unit was installed with the AD reactor (week 4 commencing 28th May) and put fully into operation on 1st June 2012. The digester/membrane plant consists of the following items of equipment:

- digester vessel, including top entry mixer;
- pH/temperature probe;
- gas flow meter;
- inverter driven recirculation pump (centrifugal);
- membrane element;
- discharge valve and inlet/outlet pressure gauges; and
- feed/permeate pump; and Digital Timer Unit (DTU).

The centrifugal pump, set to a fixed speed, recirculates sludge from the digester through the membrane element and back into the digester. The digester feed pump and permeate pump are controlled by the DTU and operate simultaneously at the same flow-rate. The permeate (COD out) is sampled and analysed on a daily basis. The results are shown in the table 2:

### Table 2 Anaerobic digester/membrane plant results

<table>
<thead>
<tr>
<th>Date</th>
<th>COD in [mg/l]</th>
<th>COD out [mg/l]</th>
<th>COD efficiency [%]</th>
<th>Biogas production [l/gCOD]</th>
<th>CH4 production [l/gCOD]</th>
<th>FM ratio [gCOD/gVSS]</th>
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Throughout the trial, the average temperature of the digester was kept at 34.2°C, with an average pH of 7.3. The average retention time for the wastewater feedstock within the digester/membrane plant was approximately 2.6 days at a dry solids content of 1.95%. These figures are a good indicator for design of the full scale digester. The trial was completed on 28th June having achieved a satisfactory level of operation.

Although the laboratory biomass was of a reasonable sludge age from previous work to treat the feed prior to installing the membranes, the 28 days duration of the trial was not long enough for acclimatisation. Nevertheless it was a good indicator of performance. On a full scale unit the longer cell residence time would enable a proper acclimatisate biomass to form.

The variability in COD feed observed in the table above changed with pH. The lower COD figures were at a low pH for simple cask washing. The higher pH resulted with the higher COD which would have been a disruption to the process stability which is normally balanced out prior to treatment. References on other anaerobic digesters treating brewery wastes have seen similar variability in performance and better balancing will be achieved on site than was available for the lab unit used in the trial and with continuous feedstock supply to the digester.

In the final period of the membrane phase of the trial, the feed to mass (FM) ratio averaged at 1.0 gCOD/gVSS. This ratio continued to improve as the trial was brought to a conclusion, but is still considered to be low for an anaerobic digester. Although this has the advantage of being in the safe range and wouldn't have a limiting factor on the efficacy of the process. The ratio will improve with the commercial scale unit that will be installed in Hook Norton as the feeding mechanism will allow continuous supply of the new feedstock into the digester.

During the first 5 days of the membrane trial the COD decreased gradually and the system reached a COD removal efficiency of ~90%. However, cavitation within the recirculation pump of the membrane plant resulted in under-performance of the digester. The cavitation inhibited the pump from pumping sludge continuously through the membrane and back into the digester. The wastewater feed into the digester is situated downstream of the membrane unit and due to the intermittent recirculation wastewater accumulated in the pipework to the digester. This is a situation that will not occur in the full scale unit due to design changes.

The consequence of the cavitation resulted in shock loads to the digester and an increase in COD. The outlet COD reached a peak concentration of 1,783 mg/l and in combination with a low inlet COD concentration (where COD was decreased by 45% compared to the previous batch) resulted in an efficiency of 23%. Over a short duration the system settled down and the COD removal efficiency increased to over 90%. For the rest of the trial the existing recirculation pump was replaced by a peristaltic pump, to prevent further cavitation.

In the latter part of the trial, COD efficiency increased to a maximum of 96%. The average biogas production rate during the membrane trial was 0.68 l/g COD and a methane content in the biogas of 56%, which is considered higher than normal for this type of feedstock.

Overall the trial undertaken on the Hook Norton feedstock has confirmed the expectation of overall performance based on earlier trials. The addition of the membrane based thickening process was accomplished without any significant issues. Problems that were encountered had more to do with the feeding mechanism for the laboratory digester. These issues are being addressed with the design of a new trials unit that is based at York University.

The interruptions to the trial occurred because of problems with the pumps which failed or became gas locked. These problems persisted until the end of the trial. Due to these issues it was difficult to collect consistent data from the operation of the lab based digester. Overall
performance of the membrane in producing very low COD permeate was as anticipated. The full scale SATP unit has a different feeding mechanism that will avoid the issues experienced during the laboratory trial and operation will be stable. The project partners are confident in the ability of the AD system to remove up to 98% of COD from the brewery waste waters.

4.0 LEGISLATION ISSUES

The project partners have sought to address the key legal aspects pertaining to this project for each of the areas of legislation listed and have focused on specific aspects that are the most relevant to the site and the aims of the project.

For this project, key issues that must be addressed at the Hook Norton site are:

- Duty of care: the AD plant will replace an existing effluent treatment process (but will use part of the old plant for polishing) and enhance the quality of effluent discharge. The system will be designed by highly competent and experienced process engineers.
- Operator competence: as part of the project supply the plant operators will be trained by Clearfleau during the commissioning process, as is the case with the large scale plants that are being built by Clearfleau.
- Health and safety: the unit is designed to comply with health and safety requirements. The on-site activity will be limited to installation of the system, which will be conducted as per the necessary method statements.
- Planning Permission: Hook Norton will engage with the local planners based on the design produced during the feasibility phase. However, as the SATP unit is mobile and it is our understanding that planning requirements will be less onerous.

At this stage the brewery has not had detailed discussions with the planners and the EA but these discussions will be initiated when the project gets underway in early 2013.

Effluent quality: the use of membranes will ensure a high quality for the post digestion liquors. It is anticipated that following discussions with the Environment Agency during the final design phase of the project, it will be possible to secure a permit for discharge to the nearby stream. Hook Norton will engage with the EA about the appropriate sampling and testing regime but in the interim the cleansed water will be discharged to sewer.

The cleansed effluent will be discharged to sewer with a significantly lower discharge COD. However, once it has been demonstrated that the AD plant can achieve this level of COD removal, the project team will undertake exploratory discussions with the EA in early 2013 to ensure that they are fully briefed on the project. It is already known that the EA are encouraging Hook Norton Brewery to improve their effluent treatment system.

The data generated from the lab trial will be reported to the regulatory authorities as part of the planning process. Discussions will be set up with the local planners, with whom Hook Norton have a good on-going relationship and also with the local Environment Agency officers as well as their national adviser.
5.0 TECHNICAL APPRAISAL

5.1 The Liquid Digestion Process
AD is an established and well known process in which micro-organisms will break down degradable material in the absence of oxygen. The process is widely used to treat industrial wastewaters and is now also seen as a renewable energy source. An efficient on-site anaerobic process produces biogas (methane, hydrogen and carbon dioxide), a source of renewable energy that can be used in the production processes on site (Figure 8).

Image 8 AD process schematic

There are basically four key bacterial processes involved in the production of methane from organic waste waters: Hydrolysis of materials into smaller organic molecules such as simple sugars amino acids and fatty acids. Acidogenesis converts sugars and amino acids into simpler molecules. Acetogenic bacteria then convert the longer chain organic acids into acetic acid, along with gases such as hydrogen, and carbon dioxide. Methanogenesis then converts the acids to methane, carbon dioxide and water.

In recent years the basic AD process has been developed and refined as it has been adapted to a wider range of feedstocks. This, combined with a better understanding of anaerobic reaction processes, as well as enhanced automation and control, has reduced dependence of the digestion process on manual intervention. Subsequently the operation and maintenance of AD plants has become less onerous.

Improved process efficiencies have also resulted in wider adoption of AD in the UK and the technology is now being considered one of the most effective systems for decentralised energy generation, with a more diverse range of possible applications than was anticipated by the regulatory agencies. This plant will provide a valuable resource for trade bodies and agencies to familiarise themselves with small-scale AD and its capability in the SME sector.

5.2 Process Operation
Clearfléau has developed an advanced, continually mixed AD reactor, designed to handle a range of liquid residues and other feedstocks from industrial sites. The high-rate liquid AD process aims to maximise biogas output to deliver energy back to the factory.

This has been demonstrated at a fully commercial scale on the BV Dairy site but this project will showcase the technology at a much smaller scale, and also includes a number of system enhancements, including:
- use of micro-filtration membranes to improve solids retention and also the final quality of the cleansed water discharge;
- redesign of the SSPP unit to allow the external location of the digester tank that will allow greater flexibility on feed volume;
- internal rationalisation of the system to improve the process and enhance the ease of maintenance; and
- additional design enhancements to reduce the capital cost of the unit and the costs of on-site plant operation.

The small scale SATP unit can be adapted to take multiple feedstocks or single streams, as required for the specific site and the process is tailored to the available materials.

The process effluent and wastewater to be fed to the digester will need to be screened for gross solids (large non degradable items that have inadvertently got into the feedstocks), prior to being passed to a storage/balance tank. In the tank the wastewater will be thoroughly mixed to keep any fine solids in suspension.

Feed from the balance tank will be passed through the mixing pump to the digester vessel. If the wastewater temperature is too low, some of the sludge will be re-circulated through a secondary heat exchanger to maintain a 35-38 deg C temperature in the digester vessel. The sludge heat exchanger is housed in the SATP unit.

The feed into the digester tank is a combined flow of digester tank content that is being re-circulated and a small volume of the new inflow material. This incoming feed is mixed with returned sludge from the membrane plant as well as the nutrients and the other liquors that are being returned to the digester as part of the mixing process.

In addition, pH correction is made to the feed as it enters the digester. Monitoring of the digester ensures the pH is maintained in the reactor and the temperature is kept at an optimum level. This is standard practice on AD plants and the process control system will ensure that any adjustments can be made by the operator as required.

Post digestion, the treated effluent is pumped into the membrane plant for solids separation. The concentrated sludge is pumped back into the digester and the permeate is discharged to the existing aerobic treatment plant, which is retained to provide a final polishing stage prior to discharge — initially to sewer but eventually to the stream. All the surplus sludge will be pumped to the sludge tank, dewatered and could then be used for direct land application.

Gas produced from the AD process is stored in the headspace of the digester tank; it is expected to be above 60% methane as seen at AD plants on other brewery digesters and low in hydrogen sulphide. Ferrous salts are added as part of the AD process to fix most of the sulphide and remove it from the biogas. The biogas can be used in a boiler, with minimal pre-treatment.

### 5.3 Comparison with existing process

The existing process at the Hook Norton site is an aerobic treatment process that has been upgraded on a number of occasions. The changes envisaged in this project are intended not only to generate a modest energy output on-site but also to provide a more sustainable treatment solution for the effluent and co-products from the brewing process. This is based on the fact that aerobic treatment has a greater energy demand and hence a higher carbon footprint. On-site digestion is not only able to reduce treatment costs but also the carbon footprint of production and effluent treatment. This will be demonstrated at Hook Norton.
There are two recognised treatment options for wastewaters, anaerobic and aerobic. The anaerobic system operates in an oxygen free atmosphere while the aerobic process requires air to be passed into the biomass to encourage growth. Both processes produce excess bacteria that must be disposed of. But anaerobic systems produce one tenth of the volume of biomass compared to aerobic systems. See the comparison of both processes below:

**Image 9: Comparison aerobic/anaerobic process**

<table>
<thead>
<tr>
<th>Process</th>
<th>COD (%)</th>
<th>CO₂ (%)</th>
<th>Effluent (%)</th>
<th>Sludge (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic</td>
<td>100</td>
<td>55-70</td>
<td>5-30</td>
<td>5-15</td>
</tr>
<tr>
<td>Aerobic</td>
<td>100</td>
<td>40-50</td>
<td>1-10</td>
<td>50-60</td>
</tr>
</tbody>
</table>

In addition to modest revenue from the energy generated on site, the introduction of AD technology will reduce the site’s carbon footprint. The anaerobic process has a relatively low ‘slave’ energy demand, whereas aerobic treatment requires power for aeration. A reduction in treatment energy, combined with energy use on-site and further carbon savings from the reduced need for off-site haulage and use of the residual sludge as a fertiliser, will produce a significant reduction in the carbon footprint of the disposal process (see Table 3 below).

The carbon footprint for AD compared with conventional aerobic treatment used at Hook Norton, is seven times smaller. The limited solids output produced by the anaerobic system is suitable for direct land application, with enhanced nutrient availability.

In addition to contributing flow to the adjacent stream, which has had a low flow for some time, the AD plant will limit the risk of higher COD discharge from the. The anaerobic system is more biologically stable when compared with an aerobic system and hence offers a more robust treatment process.

The aerobic biomass grows at a faster rate and responds quickly to changing conditions and as a consequence is less tolerant to change. Also the closed loop process will minimise any odour risk from the site compared to the alternative of aerobic treatment.
### Table 3: Carbon comparison between treatment processes

<table>
<thead>
<tr>
<th></th>
<th>Aerobic</th>
<th>Anaerobic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Running Energy</strong></td>
<td>1.5 kWh</td>
<td>8 kWh</td>
</tr>
<tr>
<td><strong>Electrical Power Available</strong></td>
<td>None</td>
<td>14 kWh (CHP unit) generated</td>
</tr>
<tr>
<td><strong>Electrical surplus</strong></td>
<td>None</td>
<td>+6 kWh</td>
</tr>
<tr>
<td><strong>Carbon footprint electrical</strong></td>
<td>0.8 kgCO₂/h</td>
<td>76 kg CO₂/d</td>
</tr>
<tr>
<td><strong>Required Heat</strong></td>
<td>None</td>
<td>+ 20 kWt (5degC waste)</td>
</tr>
<tr>
<td><strong>Heat available</strong></td>
<td>None</td>
<td>- 21 kW</td>
</tr>
<tr>
<td><strong>Heat surplus</strong></td>
<td>None</td>
<td>- 1 kW</td>
</tr>
<tr>
<td><strong>Carbon footprint heat</strong></td>
<td>None</td>
<td>7.2 kgCO₂/d</td>
</tr>
<tr>
<td><strong>Sludge</strong></td>
<td>62 kg/d</td>
<td>25 kg/d</td>
</tr>
<tr>
<td><strong>Carbon footprint sludge</strong></td>
<td>9.6 kgCO₂/d</td>
<td>3.8 kgCO₂/d</td>
</tr>
<tr>
<td><strong>Carbon Footprint</strong></td>
<td>29 CO₂/d</td>
<td>58.2kg CO₂/d credit</td>
</tr>
</tbody>
</table>

Figures calculated on Annual average 291 kg COD/d (BOD:COD ration 1:2).  
* Sludge figure as 0.15 kgCO₂/kg Sludge, ** Heat as gas equivalent at 0.272 kgCO2/kWh, *** Electrical 0.527 kgCO₂/kWh

### 5.4 Benefits of the anaerobic digester/membrane system

The current system design being installed by Clearfēau on larger sites consists of a highly mixed digester followed by a conventional flocculation process for solids capture and return to the digester. The new system replaces flocculation with membrane based solids removal.

The highly mixed digester system is unaffected by inert, slowly degrading solids when compared to Up-flow Anaerobic Sludge Blanket digesters, but it does require a biomass separation system. This separation system requires chemicals to agglomerate the solids as floc, allowing a low percentage of solids to pass forward. The membrane will retain all the solids without use of polymer. However, membranes can get biologically fouled and so need cleaning. The membrane cleaning requirements will be further evaluated with the next stage as this was not really possible in the laboratory trial.

Compared to the current solids removal process being deployed by Clearfēau on commercial sites, the membrane system has the following advantages:

- the dosage of polymer for flocculation of the biomass is not required;
- the system can operate at higher solid concentrations with a subsequent higher solids discharge;
- operating at higher solid concentrations can decrease the reactor volume and increase contact time;
- the membrane system captures solids enabling the effluent to the next process step to be free of solids; and
- the membrane is simple to automate and control and more predictable in performance, flux-rates (flow through the membrane/m²) and pressure.

The power consumption of a membrane system is higher compared to a flocculation process but savings in chemical consumption makes it a cost effective system. Although effective membrane cleaning is required, it is automated to limit operator involvement and consumes a nominal amount of caustic and hypochlorite. The frequency of cleaning is not predictable and needs to be evaluated.
6.0 ECONOMIC/COST BENEFIT ANALYSIS

The economic benefits of on-site AD are based on its ability to cut effluent treatment costs and also site energy costs. The anticipated energy savings (from the lower energy demand for effluent treatment and the generation of the renewable energy fed into the brewery) are supplemented by revenue from renewable energy incentives, in this case the RHI, as biogas is fed to a boiler. Although a small scale project will not match the return on investment of larger projects, it should be financially attractive. The proposed plant design, to handle the feedstock used in the laboratory trial, will cost £475,500. See summary in Table 4 below.

Table 4: Capex anaerobic digester/membrane plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering &amp; Design</td>
<td>100,860</td>
</tr>
<tr>
<td>Digester &amp; related equipment</td>
<td>170,690</td>
</tr>
<tr>
<td>Membrane Plant</td>
<td>129,830</td>
</tr>
<tr>
<td>EICA</td>
<td>57,000</td>
</tr>
<tr>
<td>Biogas Boiler &amp; Flare</td>
<td>17,120</td>
</tr>
<tr>
<td></td>
<td>475,500</td>
</tr>
</tbody>
</table>

The information summarised below is based on data drawn from the laboratory trial and other data provided by the brewery. Clearfluo’s high-rate digester achieves a reduction in COD load of at least 95% for residual discharge from the plant but based on the trials, this should increase to 99% with the membrane system. The post digestion treatment costs to allow watercourse discharge (as on other Clearfluo plants) are a considerable element of some projects and membranes avoid the need for this cost. The aim of the project is also to contribute to a reduction in the cost of the membrane unit, through design improvements and value engineering, based on experience at Hook Norton.

At Hook Norton, very limited additional treatment will be needed prior to discharge of the membrane permeate to the stream. Due to expected changes in the feedstock supply for the full scale project the average COD concentrations in the trial feedstock (collected at the brewery and delivered to the lab) taken from a 24 hour composite sampler installed at Hook Norton are 50% lower compared with the concentration given in Table 1.

Table 4: Hook Norton flow and load conditions

<table>
<thead>
<tr>
<th>Units</th>
<th>Flow</th>
<th>Average</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOD</td>
<td>Average</td>
<td>2,644*</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>Average</td>
<td>5,288</td>
</tr>
<tr>
<td></td>
<td>TSS</td>
<td>Average</td>
<td>640*</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>Average</td>
<td>8.0</td>
</tr>
</tbody>
</table>

* Assumed concentration based on previous trials and industry data

Treatment volume in the reactor is based on 55 m$^3$/d total discharge. The digester vessel is likely to be about 132 m$^3$ in volume, with a diameter of 6m. Ancillary equipment will be located within the unit which will be adjacent to the digestion tank. Biogas will be fed to an
on-site Anaerobic Digestion – Hook Norton Brewery

The AD unit will provide a modest on-site renewable energy supply for the brewery. The FiT is currently set at 14.7p per kW for AD plants producing less than 250kWe. The Renewable Heat Incentive (RHI, available from October 2011), pays 7.1p per kW, for up to 200kWt of heat from biogas combustion. Feeding the biogas to a new biogas boiler will only secure the RHI and hence the revenue per kWh will be lower but using biogas directly for heat in the brewery process is a more efficient use, without the losses that result from running small scale CHP units. Potential RHI/FiT income from the AD plant is indicated in Table 6.

### Table 6: Available power/heat from treatment process

<table>
<thead>
<tr>
<th>Use of biogas directly for heat</th>
<th>Value</th>
<th>Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Only – Heat Value (RHI only)</td>
<td>44 kWh</td>
<td>£ 75 per day (RHI) / £ 27,400 per annum</td>
</tr>
<tr>
<td>Total Heat Revenue</td>
<td></td>
<td>£ 27,400 /annum</td>
</tr>
<tr>
<td>Use of biogas to run a small CHP unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Value (CHP)</td>
<td>14 kWh</td>
<td>£ 47 per day (FIT)* / £ 15,460 per annum</td>
</tr>
<tr>
<td>+ Heat Value (CHP)</td>
<td>21 kWh</td>
<td>£ 34 per day (RHI)** / £ 11,270 per annum</td>
</tr>
<tr>
<td>Total CHP Revenue</td>
<td></td>
<td>£ 26,730 /annum</td>
</tr>
</tbody>
</table>

* Updated Renewable electricity Feed in Tariff (FIT – from Oct 2011) of 14p per kW

** Renewable Heat Incentive (RHI - from Oct 2011) 7.1p per kW of surplus heat, limited to 199kW.

Given the similar levels of RHI revenue and the local heat demand from the brewing process, we recommend the AD plant is linked directly to a new process boiler. Hence a 44kWh heat value is used here on as the basis of the economic analysis. The reduction in oil purchase costs for the brewery (equivalent to 44 kWh per year) will be about £15,000 per annum and reduction in water treatment costs payable to Thames Water about £10,000 per annum.

On the basis of the anticipated capital investment of around £475,500, with overall revenue of £52,400 per annum, the anticipated payback will be around 9 years. This AD project will provide a reasonably long payback, partly due to the low load being fed to the reactor but also because this is the first plant to be built to this design, which is why WRAP support is being sought. However, as with the BVD project the expectation is that this will be lower for subsequent projects, with a reduced capex (reflecting value engineering and future multiple unit supply) as well as more efficient operation, plus higher biogas outputs, based on higher load feedstocks. These aspects will be fully evaluated as part of the next phase.
7.0 OVERALL ENVIRONMENTAL IMPACT

7.1 Wider environment benefits
There are three main aspects to the environmental impact of the project: impact on the activities of the brewery; wider benefits for the community and the local area, and; showcasing AD as part of one of the exemplar communities in England responding to climate change. The environmental benefits of an AD process for operation of the brewery are as follows:

- energy recovery from waste due to the generation of biogas;
- nutrient rich sludge which can be used as fertiliser and soil conditioner;
- the system is biologically stable compared to an aerobic system; and
- the heat generated by burning biogas in a boiler or CHP plant can be reused in other processes.

The Hook Norton Brewery is one of the oldest operating industrial brewery sites in the UK and has many traditional attributes that minimise its environmental impact, such as use of gravity to feed materials through the production process. The quality of its product is greatly enhanced by traditional processes. More recently the brewery has put in place updates to its processes to reduce energy use and minimise water consumption. The adoption of AD on the site will reduce the carbon emissions of the site significantly and provide a very visible signal of the brewery’s commitment to sustainability.

However, this project goes beyond the reduction in the carbon footprint of the brewery operation by providing a number of community benefits:

- reduction in possible odour risks from the effluent treatment process;
- supplementing the existing river flow with high water quality discharge to the nearby stream, which is now running at a lower level than for a number of years;
- Provision of residual bio-solids (with PAS 110 compliance) from the plant as a soil improver for potential direct land application; and
- Demonstration that as well as residents in the community being actively engaged in reducing their carbon emissions through social enterprise, the main business and employer in the community is playing a leadership role

Finally, when Hook Norton was selected as one of 22 exemplar communities taking action on climate change for England & Wales in 2010, it was the only community to mention AD as one of the technologies to be considered. The DIAD programme will allow those early ideas to be turned into reality and ensure a higher profile for the small scale AD plant, through the increasingly active and high profile community sector.

Hook Norton Low Carbon (www.hn-lc.org.uk) is already being followed as one of the national exemplars in the sector, so a readily deployable system could be rapidly taken up by those communities that can identify appropriate feedstocks. The wider environmental impact, if up to 6,000 or more communities were to actively consider how to make best use of organic wastes, particularly in smaller scale AD, would have a significant environmental impact. Although the focus of this study was on the assessment of the membrane based AD technology on an industrial site, there will be opportunities to involve communities in such projects. Hopefully DIAD will also encourage wider use of smaller scale AD in communities
8.0 PHASE 2 – DEMONSTRATION

8.1 Methodology for demonstration
The laboratory unit was the template for the full scale plant for phase 2, along with the SSPP mobile trial unit. During the laboratory trial it was possible to gain experience of operational parameters, frequency of backflushing and flux-rate to partially optimise the process in relation to solids in the digester. Operation of the full scale plant will help to optimise the hydraulic conditions and confirm the performance in relation to the digester solids. Higher solids in the digester will reduce digester size and so running cost in terms of mixing. The system will be developed as a user friendly automated process with as little human intervention as possible.

8.2 Project timescale and milestone payments
The timescale will run from January 2013 for over 2 years.

<table>
<thead>
<tr>
<th>Action</th>
<th>Time in weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>2</td>
</tr>
<tr>
<td>Procurement</td>
<td>2</td>
</tr>
<tr>
<td>Fabrication</td>
<td>12</td>
</tr>
<tr>
<td>Delivery</td>
<td>6</td>
</tr>
<tr>
<td>Installation</td>
<td>6</td>
</tr>
<tr>
<td>Commissioning</td>
<td>4</td>
</tr>
<tr>
<td>Monitoring</td>
<td>2 years</td>
</tr>
<tr>
<td>Milestone Payment</td>
<td>30% 40% 25% 5%</td>
</tr>
</tbody>
</table>

8.3 Commercialisation of Technology
Clearfléau have been seeking to develop its SSPP unit for commercial applications over the past 18 months and have developed considerable experience of successfully digesting a range of feedstocks. The SATP unit is based on the desire to respond to enquiries received for a smaller modular version of its innovative AD system that can be used on SME sites.

Commercial interest has in part been based on knowledge of the mobile SSPP unit and the research undertaken by Clearfléau suggests there should be a considerable market for the AD unit, not just for breweries but also dairy and food processing sites as well as other small scale facilities in the pharmaceutical sector. A number of enquiries have been received since the Hook Norton secured the DIAD funding.

Research undertaken and enquiries received from companies in the UK and in other markets, suggest there could be considerable demand for this on-site AD technology. Not only is the modular AD unit suited to smaller breweries (the main growth sector in brewing) but other smaller producers, such as speciality cheese makers or speciality food processors. These are often located on confined sites and off-site manufacture is a key aspect of this project. The mobile unit will just require connection to the feedstock, power, water and the sewer.

Research has also indicated that there are opportunities to export this system to the EU and the US. It is expected that in addition to boosting adoption of on-site AD solutions, this will generate significant jobs with sub-contract manufacturing partners that are working with Clearfléau on the development of this project. Also it will impact on the ability of smaller food and drink producers to adopt carbon reduction measures and reduce their energy costs.
The aim is to develop a mass production market for small scale AD units that in due course will not only bring the full cost of the basic containerised AD unit down to below £400k (excluding boiler or CHP) but also open up a significant export market, both in the USA and a number of EU countries. We hope that within three years we will be selling up to 30 of these SATP units per year, with a significant proportion being exported.

It is expected that the small engineering team working on the project will be expanded to include support for installation, commissioning and service support. The company has recruited 11 people in the past 18 months and expects to take on a further 3 or 4 employees in 2013, for this and other projects.

8.4 Cost of commercial installation for Phase 2

The equipment is being supplied by Clearfléau, working with several key suppliers. The financial model for development of the SATP has not been fully developed but we expect to supply one more unit in 2013, up to 5 in 2014, and 10 in 2015. The units will be fabricated by a sub-contractor that has already undertaken assembly work for Clearfléau for 3 years and worked on the BV Dairy project.

As with the BV Dairy project, NEF and Clearfléau will support any WRAP PR activity linked to the DIAD programme. This project will contribute to the development of small scale AD in the UK and Clearfléau expect to increase employment and also to generate export revenue once the system is fully commercialised. In addition, these plants will make a contribution to carbon reduction in the SME sector of the UK food industry, not just cutting the carbon impact of effluent treatment but also due to reduced fossil fuel use. NEF and Clearfléau are confident that the commercialisation plans in place for the commercial SATP unit are realistic.

The project funding provided by WRAP will initiate the project on the Hook Norton brewery site, which unlike the distillery market, is a sector in which Clearfléau has as yet not been able to have much impact, as its feedstocks are generally weaker and hence produce less biogas. The membrane based system is better suited to this sector. Clearfléau also expects to deliver SATP projects in the dairy sector, where we have had some enquiries from smaller cheese makers and other speciality food processors. We are confident the anticipated total cost per unit for the smallest version of the SATP will provide an acceptable return on investment but, a sustained period of operation on the site is crucial to this strategy.

8.5 Delivery of the demonstration phase

The timescale in Table 7 above is conservative. The AD unit will be operational in Q4 2013, with on-going support and training activity after the initial four week commissioning phase. The project includes 2 years as a demonstration site, alongside on-going monitoring and technology development activity. The timescales and milestones are conservative and based on experience with the supply of the container based plant for the Nestle project (with multiple containers). The main sub-contractor has built the modular units for Nestle. These are about to be delivered and meet Nestle’s high quality standards, as was confirmed when inspected prior to delivery to the Fawdon site.

The design team have been working on concepts for the SATP unit for some time and are confident that its performance will match the trial version. It will also show how this high rate liquid AD system can operate on a commercial site. As part of the final design, a full risk evaluation will be undertaken for the installation (6 weeks), the commissioning and the operation of the plant when on site. Clearfléau has an experienced project management team that are fully qualified for managing all the health and safety aspects of the project.
The on-site demonstration phase will last for 2 years and include a visitor programme, with organisations like EBEC and REA, who have supported activities at BV Dairy’s site. In addition the team will work with trade associations in the brewing sector (see below) with whom we already have contact. NEF will use its network to bring visitors to the site and Hook Norton Brewery will be happy to showcase the project in its industry.

The WRAP offices are located close to the demonstration site and it is hoped that it will feature in occasional visits hosted by WRAP. The demonstration programme and related activities will also include the following communication activities.

**Organised visits:** These will start in Q4 2013 and will be hosted by Clearfléau, as well as HNLC and NEF. It is likely that there will be no more than 2 per month to avoid imposing on the operations of the brewery.

- **Seminar/group visits:** Several will be run each year, with bodies like Campden BRI, IBD (Clearfléau are members), BFBI, the Society of Independent Brewers, the Maltsters Association and the Speciality Cheesemakers Association plus the FDF and Dairy UK. It is hoped that WRAP being located close to the site will participate in some events.
- **Other PR material:** information leaflets will be produced jointly by the partners plus a DVD (see [www.clearfléau.com](http://www.clearfléau.com) for a 4 minute video on the BV Dairy project). We will also use social media (Linked In and Twitter) to promote the project and also feature WRAP and the DIAD project. The focus of this activity will be small scale AD for SMEs.
- **Community aspects:** A local engagement plan will be drawn up, to showcase the unit to the wider community and to raise local awareness. Interpretation boards will located in the brewery visitor centre which has a significant throughput of visitors in its own right, to view the brewing process of one of the few remaining independent family breweries. These will be similar to those installed at BV Dairy and planned for Nestle.
- **Conferences:** Speakers from NEF, HNLC and Hook Norton, as well as Clearfléau, will feature the project at seminars and conferences, when they have speaking slots. Also at renewables and food and beverage exhibitions. This will include events organised by WRAP, plus shows like Foodex and the Worldwide Distilled Spirits Conference, which Clearfléau already attend.

In addition Clearfléau will make use of the SSPP unit on the Hook Norton site to undertake further design and engineering development on the project, including further development of the membrane system to enhance performance and also reduce capital and operating cost. The Hook Norton SATP unit will also be used in conjunction with the existing trial SSPP unit as part of on-going efforts to enhance the technology at this scale. It will also be used to further evaluate and develop membrane thickening and integration of membranes with AD.

**8.6 Industry impact and commercialisation**

NEF are confident there is an opportunity to develop the mobile SATP unit on a modular basis as a commercial system for smaller food and drink processors. As well as providing a demonstration site in the West Midlands, the project is focused on developing a commercial AD system able to operate on confined sites.

Once the operational phase is underway, the markets to be targeted as part of the planned communication activities will include; micro-breweries (the growth sector of the brewery market), smaller dairy processors (farm house cheese-makers and ice cream manufacturers), and other food and beverage producers. We talked to a number of smaller speciality food companies at the Foodex Show (NEC March 2012). Another exciting market sector that has been identified is the pharmaceutical sector, including nutraceutical manufacturing sites.
With a viable commercial demonstration site at Hook Norton, the project team are confident they can stimulate increased interest in on-site AD, as happened with the larger plant design on the BV Dairy project. The location of a unit on a well-known Midlands brewery will ensure the project has a high profile and it will also be possible to use the site to show the system to international visitors – due to its close proximity to the Birmingham transport hub.

8.7 Key personnel
The key personnel involved in the feasibility phase, including the trials and involved in the design of the on-site AD plant for the brewery are:

Derek Rodman – Clearfläau Project Manager
Derek Rodman is a highly experienced wastewater engineer with extensive process design experience in potable and waste water both in the UK and overseas. Based at Clearfläau’s engineering office (Bracknell), he is responsible for process, electrical and engineering design, procurement, through to provision of on-site implementation support. In addition to taking the lead on the process design of the main plant, Derek has been responsible for setting up the trial and the integration of the membrane unit, with the laboratory trial unit.

Dirk Hedemann – Clearfläau Process Engineer
Dirk Hedemann is a senior process engineer with extensive experience of AD, he previously worked for both Paques and Veolia Water Solutions and Technologies. Dirk has been taking the lead on the operation and monitoring of the trial, alongside his process design role for the main plant. He has also liaised with the site personnel at the brewery. He will continue to be the main operational contact with Hook Norton Brewery.

Other members of the project team were involved in preparation of this report:

Richard Gueterbock – Clearfläau Project Sponsor
Richard Gueterbock the founder director of Clearfläau and is responsible for marketing, business development and communications. He is involved in a number of the company’s technology related projects, as part of the on-going development of the technology to fit with various market requirements, and is taking the lead on commercial exploitation of the SSPP units in the brewing, dairy and other sectors.

Tim Lunel – formerly Chief Executive Officer, National Energy Foundation
Dr Tim Lunel, was Chief Executive of The National Energy Foundation until Nov 2012. As the rapporteur for the Community & Localism workstream of Defra’s AD Strategy, he is taking the lead on the local elements of the project and institutional aspects of the project. Tim also work closely with Hook Norton Brewery on their carbon reduction activity and will take the lead in the integration of the AD project with the solar PV installation if this is pursued.
www.wrap.org.uk/diad