Institution: University of South Wales

Unit of Assessment: B15

Title of case study: Optimisation of Anaerobic Process Technology

1. Summary of the impact

This case study describes the impact of the research work relating to anaerobic process technology undertaken within the Sustainable Environment Research Centre (SERC) and its industrial interfacing arm, the Wales Centre of Excellence for Anaerobic Digestion (AD). Anaerobic process technology is used globally to produce renewable energy, and other resources from wastes and low value biomasses. These impacts can be grouped into the following areas:

- Informing Government Policy
- Development of industry guidance, best practice, protocols and regulation
- Driving innovation and the implementation for more efficient anaerobic digestion and biohydrogen production technologies, nationally and internationally.

2. Underpinning research

The research team of Dinsdale, Guwy, Esteves, Hawkes DL & FR, Premier and Patterson have conducted fundamental and applied research for more than 30 years in the use of anaerobic processes for waste treatment and renewable energy production. This research focused on four main themes: process monitoring and control; system design; pre & post treatment of feedstocks and digestates; and life cycle analysis, policy and economic evaluation.

Process Monitoring and Control
Since 1998 we have improved the process monitoring and control of anaerobic digestion processes by identifying critical monitoring/control parameters and by developing novel process instrumentation and control models. These microbial, biochemical and chemical parameters (e.g. volatile fatty acids and bicarbonate alkalinity, biogas composition and microbial profiling) have become essential in improving process understanding and control.

These systems helped national (Insource, Welsh Water, Aqua Enviro, AMEC Global Renewables, (see letters 1 and 2) and international (RWE-Thames Water Plc.) companies by providing an insight into how complex and difficult substrates could be treated at industrial scale more effectively. The summary of the report related to monitoring and control of AD and biogas plants that the AD Centre published in conjunction with Vienna Technical University has been published in 7 European languages (see report 1).

System Design of a Two stage Biohydrogen/Biomethane process
We have developed and pioneered a number of innovative process designs. These included two stage anaerobic processes to improve process stability and efficiency of waste conversion. Funded research with Thames Water extended the first stage of a two stage AD system (employed at full scale) to produce biohydrogen. SERC's research has been highly referenced and has been reported in International Energy Agency (IEA) documentation and at the U.S. Senate to the U.S. Department of Energy at a special meeting in November 2012. The work helped the IEA approve the new strategy for HIA IEA Task 21 (see report 2 and letter 3).

Pre & post treatment of feedstocks and digestates
We have investigated the use of pre-treatments for difficult feedstocks e.g. sewage sludge, municipal solid wastes and ligno-cellulosic and related process impacts as well as the processing of digestates including their use as an enhancer for biopolymer accumulation by bacteria.

Life Cycle Analysis, Policy and Economic Evaluation
We have benchmarked AD systems operating at full scale across Europe for a variety of feedstocks focusing particularly at treating food wastes and the valuable outputs they produce (see

report 3). This research effort promoted AD systems in the UK, in particular it changed key policy direction and supported biogas incentives. Our Life Cycle Analysis work supports the development of regulation at EU level e.g. EU Commission's drafted Directive which specifies the 'Sustainability Criteria for Solid and Gaseous Biomass Used in Electricity and/or Heating and Cooling and Biomethane Injection Into the Natural Gas Network'.

3. References to the research

Journal Publications:

1. Patterson, T., Esteves, S., Dinsdale, R. and Guwy, A. (2011) Life cycle assessment of biogas infrastructure options on a regional scale. Bioresource Technology, 102 (15): 7313-7323.
2. Reed, J.P. Devlin, D., Esteves, S.R.R., Dinsdale, R., and Guwy, A. (2011) Performance parameter prediction for sewage sludge digesters using reflectance FT-NIR spectroscopy. Water Research, 45 (8): 2463-2472.
3. Dinsdale, R.M., Premier, G. C., Hawkes, F.R, and Hawkes, D.L. (2000) Two-Stage Anaerobic Co-Digestion of Waste Activated Sludge And Vegetable Matter In Inclined Tubular Digesters. Bioresource Technology, 72, 2, 169-183.
4. Cruwys, J.A., Dinsdale, R.M., Hawkes F.R. and Hawkes, D.L. (2002) Development of a Static Headspace Gas Chromatographic Procedure For The Routine Analysis of Volatile Fatty Acids In Wastewaters. Journal of Chromatography A, 945: 195-209.
5. Massanet-Nicolau, J., Guwy, A., Dinsdale, R., Premier, G., and Esteves, S. (2010) Production of Hydrogen from Sewage Biosolids in a Continuously Fed Bioreactor: Effect of Hydraulic Retention Time and Sparging. International Journal of Hydrogen Energy, 35 (2) 468-478.
6. Williams, J. Williams, G., Dinsdale, R., Guwy, A. and Esteves S. (2013) Monitoring methanogenic population dynamics in a full-scale anaerobic digester to facilitate operational management. Bioresource Technology, 140: 234–242.

4. Details of the impact

A. Informing Government Policy

SERC through the AD centre has worked closely with the Welsh Government to encourage the deployment of anaerobic process technology for waste treatment and energy generation. During the late 1990s and early 2000s the Local Authorities in Wales, following the general UK steer were largely pressing ahead with the implementation of composting facilities, which demanded significant energy input. Through the research of Esteves and Patterson, and their continued dialogue with the WG, led to a new approach to meet legislation and financial conditions. SERC research provided input to government (see letter 4), local authorities and companies in developing AD plants as a viable option. Building on the research output, a thorough review of AD plants across Europe was commissioned in 2007 (see report 3) with subsequent evidence and support provided in the last 5 years to AD stakeholders (see letter 5). As a result of SERC's research, the Wales Centre of Excellence for Anaerobic Digestion was established in 2008 with a remit to assist with the development of AD. Since its launch the Centre has provided a number of key outputs to Government and local authorities:

1. A number of awareness raising events aimed at disseminating technical and non technical information relating to AD in order that decisions relating to the procurement of AD plants could be made.
2. Provision of direct advice and support to Government (see letter 4) in order to allow the development of a centrally led procurement process. This has included specific input relating to digestate characteristics, treatment options and end of waste criteria (Esteves, see report 4) and the life cycle impacts related to the AD and biogas processes (Patterson and Esteves). The Centre has also attended regular meetings with Government groups including the Planning Task Group which provided advice to local authorities relating to planning issues associated with developing AD plants and the AD Digestate Marketing Group which considered how best to manage the digestate produced from the AD process.

The impact achieved is worldwide, as research findings and guidance are disseminated through the Wales Centre of Excellence's web portal available to stakeholders all over the world. The website statistics show that every month around 300 to 500 users access the information globally. For example, consultants working on behalf of the Australian and Canadian Governments have benefitted from the research and guidance provided.

B. Development of Industry Guidance, Best Practice and Regulation

SERC through the AD Centre has worked with a number of industrial and regulatory groups to develop the framework of guidance, best practice and regulations within which the emerging AD industry will work. This has included:

- Animal By Products Regulations
- Environmental Permitting
- PAS110 (see report 4)
- Anaerobic Digestate Quality Protocol
- Utilisation of Biogas from Non Conventional Sources

C. Driving innovation and the implementation for more efficient anaerobic digestion and biohydrogen production technologies, nationally and internationally

The Wales Centre of Excellence for Anaerobic Digestion / SERC has worked with companies across Wales and the UK in order to develop a robust AD infrastructure and to develop new and improved processes. To date, this has included assisting 45 companies in Wales (through ERDF funding to the AD Centre). The AD Centre has also provided technical services to over 30 companies across the UK who are directly involved in the development of AD opportunities. In the (£6 million ERDF funded) CymruH2Wales project, 125 companies have been assisted in the area of hydrogen and biomethane technologies, resulting in 13 spin-off R&D collaborations worth more than £2 million additional industrial and government investment. We are one of the two research partners supporting all the activities included above (A-C) through the IEE Biomethane Regions project (2011-2014) in 11 European countries; and our impact is extended through this project to a wider European audience.

Research activities are also developing a number of monitoring protocols and methods that allow future operators to run their plants more efficiently. These include:

1. A methodology to measure the biogas potential of feedstocks that has been developed and implemented in our laboratories and provided to the companies listed above funded by the International Water Association (see report 5)
2. Non invasive Fourier Transform – Near Infra Red spectrometer based method for monitoring the performance of AD reactors
3. Microbiological assays for the monitoring of microbial populations in anaerobic reactors – applied in the field to monitor the performance of AD plants.
4. Hydrolysis and enzyme optimisation in biogas plants

5. Sources to corroborate the impact

Reports in the Public Domain:
Report 1 – AD Monitoring Review and Guide
http://www.walesadcentre.org.uk/CaseStudies.aspx
(summary report translated to 7 other European languages)
Report 2 – IEA Hydrogen Implementing Agreement – Task 21 Biohydrogen
http://ieahia.org/pdfs/AR2011/2011AR.swf
Report 3 – Anaerobic Digestion of Biodegradable Municipal Waste (BMW)
http://www.walesadcentre.org.uk/CaseStudies.aspx
Report 4 – PAS 110

http://www.wrap.org.uk/content/bsi-pas-110-producing-quality-anaerobic-digestate
Report 5 - Anaerobic Biodegradation, Activity and Inhibition (ABAI) Task Group
http://orbit.dtu.dk/fedora/objects/orbit:78807/datastreams/file_2928020/content &
http://www.iwahq.org/78/communities/specialist-groups/list-of-groups/anaerobic-digestion.html

Example of letters from government and industry including:
Letter 1 Aqua Enviro
Letter 2 AMEC Global Renewables
Letter 3 International Energy Agency - Hydrogen Implementing Agreement
Letter 4 Welsh Government
Letter 5 Anaerobic Digestion and Biogas Association