Institution: Staffordshire University

Unit of Assessment: 15 – General Engineering

Title of case study: Sustainable energy research applications and solutions

1. Summary of the impact

This case study describes interdisciplinary impacts developed from research of the Sustainable Energy theme. They examine conversion of energy from alternative sources; from power generation using pyrolysis or biomass burners to energy harvesting of waste heat from electronic components. In all cases the aim is clear: to develop systems that make sustainable energy production a reality. This has important impacts in advancing efficiency and reliability in renewable energy technologies. Importantly, through a number of externally funded projects, this group's members have directly influenced local, national and international companies and governmental bodies. In some cases influencing decisions and having direct impact on efficiency, value from investment and even on balance sheets. In summary, they have conducted numerous energy audits, produced a minimum of 6 best practice case studies, influenced the renewable strategies of at least 52 countries, regions or industries and are recognised as the centre for biomass fuel quality assessment.

2. Underpinning research

This case study developed from a series of innovative projects. Traditionally Al-Shemmeri conducted research in the thermo-fluids discipline. In the 1990's he conducted research with the Jordanian government looking at using multi-criteria decision making for the ranking of water projects [1]. Following this individual change of direction and the scientific community's recognition of the importance of environmental factors the group's focus changed to the examination of renewables per se. This culminated in Al-Shemmeri *et al.* building expertise around research on the design of sustainable energy sources and a number of related areas of renewable energy [2,3,4]; the setting up of the Centre for Energy Efficient Systems; and founding of two new research laboratories in biomass and thin film organic photo-voltaics. The quantum modelling (with Harvard) provides some theoretical underpinning to PV developments.

The impacts discussed in this case study are based on research that commenced in 2002 through a series of externally funded programmes in collaboration with Talbotts Heating Ltd, and Bowman Power.

ETSU Grant No.375/8, value £357,859
30 kWe Biomass Fuelled Indirect Fired Micro Turbine conducted between November 2002 and October 2004.
DTI Contract B/T/00809/00/00, value £1,000,000
100 kWe Biomass Fuelled Indirect Fired Micro Turbine conducted between October 2004 and October 2006.
DTI Contract TP/7/LOW/6/S/M0520F, value £500,000
10kWe biomass indirect fired CHP system conducted between September 2007 and August 2009.

Historically the research started with the design and development of heat exchangers for use in biomass systems and the development of a biomass fuelled turbine-generator set. However this work soon developed to the examination of the biomass and alternative fuel systems themselves and the fuels they rely upon [2]. Associated with this was the development of unique expertise in the energy audits of existing systems with a view to improving overall system efficiency. Recent work includes areas such as the testing of biomass solids in system performance, the performance and emissions evaluation of absorption refrigeration cooling from biomass waste heat, and biodiesel blending impacts on emissions and efficiency [3,4,5]. This unique expertise led to the group being invited to lead the ARBOR project; a collaboration of European partners examining and influencing the supply chain in the biomass market. This project has led to the team becoming the central point for the testing of the quality of biomass fuels within the EU, and the building of unique full size biomass demonstrator units at Staffordshire University and other regional sites.

Members of this team have supported externally funded cross-university projects; these have been targeted at spreading the economic benefits message of renewables to European member states, regions and, more recently, to specific communities such as Senior Citizens.

Parallel work has focused on wind energy and rotating machine design to minimise energy loss. Current work also covers energy harvesting using thermoelectric technology and the development of new thermoelectric materials (including novel organic semiconductor PV systems in the new AWM sponsored Thin Film Laboratory) [6], and novel device structures. This area of research crosses boundaries with that in medical engineering.

3. References to the research

1. Al-Kloub, B., Al-Shemmeri, T., & Pearman, A. (1997). The role of weights in multi-criteria decision aid, and the ranking of water projects in Jordan. *European Journal of Operational Research*, *99*(2), 278-288.

2. Al-Shemmeri, T.T. and Oberweis, S. (2011) Correlation of the NOx emission and exhaust gas temperature for biodiesel, *Applied Thermal Engineering*, 31, 1682-1688.

3. Oberweis, S. and Al-Shemmeri, T.T. (2012) Emissions and performance from a biomass boiler for different solid biomass fuels, *International Journal of Renewable Energy Technology*, 3(4), 323–340.

4. Oberweis, S., Al-Shemmeri, T.T. (2011) Emissions and Performance of a Stationary Diesel Engine run on Biodiesel Blends, *International Journal of Oil, Gas and Coal Technology*, 4(4), 375-386.

5. OBERWEIS, Sacha and AL-SHEMMERI, Tarik (2009) *Design of a 20kW Biomass Heat Generator: CFD Modelling and Dissociation.* VDM, Saarbruecken (Germany). ISBN 978-3-639-15922-6

6. Oklobia, O and Shafai TS (2013). A quantitative study of the formation of PCBM clusters upon thermal annealing of P3HT/PCBM bulk heterojunction solar cell. *Journal of Applied Physics*.

4. Details of the impact

Economic impacts

- Over the previous five years, this group's research has led to improved performance and the development of new technologies for business (e.g GDM Rugeley; Woodwaste, Stafford; and ALSTHOM) [1-10].

- Research expertise has been central in securing and leading an INTERREG IVB biomass for energy project (Accelerating Renewable Energies through Valorisation of Biogenic Organic Raw Materials - ARBOR) [1,4,5]: a partnership of thirteen organisations [1,4,5] in Belgium, Germany, Ireland, Luxembourg, and the Netherlands. Its aim: to accelerate the sustainable development and use of biomass in the region in order to facilitate the achievement of EU 2020 energy objective related to the introduction of renewable energy sources and their utilisation.

- One of the main impacts is the development of 5 industrial scale demonstrator units (UK, UK, NL, NL, BE circa €3million) whose designs are influenced, heavily, by this group; but which in turn will heavily influence the EU biomass industry [1].

Working closely with innovative energy businesses, research led guidance to bodies such as small leisure centres to governments [1-10] has been provided or conducted.

- The research group conducts biomass fuel quality testing for European industry and government bodies (circa 100 batches per annum) [1,4,5].

- The technical knowledge and experience has been recognised by the EU with the newly formed European Centre of Excellence for Biomass [1].

To date several institutions have taken their advice and have changed practice or have invested in new facilities for example Eccleshall Biomass [2], Agripellets [1,3], and Staffordshire County Council.

- Directly this group has influenced the products of 14 regional and international industries: Four Ashes, Agripellets, Eccleshall biomass, Green bio-diesel, Talbott Energy, wood waste Stafford, Lower Reule Bioenergy, GDM, Institute for Future Energy Systems (DE), Inagro (Be), Zero Head Turbine (UK), BioGas hub (NL), Agri-Park (NL), Short Rotation Coppice (BE) [1,2,3,4,5,6,7,8].

- The work conducted by this group has influenced the work of other researchers; to date 29 publications have been produced [9].

- The research has been cited in over 47 other publications.

Impacts on public policy and services

- Members of CEES are providing the Secretariat for the Energy and Environmental Technologies Cluster [7] as well as academic representation on the National Physical Laboratory Thermoelectric Materials Industrial Advisory Group.
- 79 scientists, engineers and politicians (including the Egyptian Under-Minister for energy) trained in Energy Auditing and Renewable Energy Strategies [7]
- 6 country's MEPs and [1,2,3,4,5,7,8];
- 4UK and 3 EU local authorities/regions have received training and advice [3,4,5,7,8];
- This group has also provided technical tendering support in the area of renewable energy councils and authorities in Staffordshire.

Impacts on society, culture and creativity

- The research team have provided training for countries as well as local regions; notably including advising the local MP (the then Parliamentary Under Secretary of State in the Department for Energy and Climate Change), and the Egyptian Under Minister for Energy [8].
- Pre 2008 they were senior advisors for founding of Stafford SRB
- Beginners guide to renewable energy practice [2,6,7,8]

Impacts on Health

- Learning guides have been developed for Senior Citizens [6]
- Working with social care groups for renewable energy updating [6]
- Senior Engagement in the Green Economy –SEE Green, c €400k [6] - (Grundtvig, Lifelong Learning Programme), aimed to improve the knowledge of energy efficiency practice and schemes amongst Europe's senior citizens;

Impacts on practitioners and professional services

- A new handbook for energy audits has been published by J Wiley & Sons Ltd [9].
- Directly influenced universities, for example: UCD Dublin, Harper Adams, Aston, Swansea, NL, Gent (BE), Saarland (DE) [3,4,5,6,7,8,9].

The research is interdisciplinary and several cross-university projects use the expertise of this group.

- This group supports RESCO (Renewable Energy Supply Chain Opportunities managed by the University's IESR), an ex-poste evaluation of the project has shown that it successfully provided a forum for helping business to develop and change their relationship with renewable energy opportunities [3].

Impacts on the environment

The group have contributed to:

- RETS (Renewable Energies Transfer Systems) project [7] – an INTERREG IVC programme (€2million) - focused on specialist knowledge transfer in renewable energy for small to medium-sized municipal authorities across the EU;
- and SHAP (the Sustainable Housing Action Partnership) [8].
- Finally, CERES (an EU TEMPUS Programme €1.1million) whose aim is to assist in the development of a higher education renewable energy centre of excellence in Egypt [7].
- The group has completed over 100 energy audits for businesses across Europe.
- 6 Best Practice Case studies for the UK developed by this group.
- The group measures the quality of biomass fuels for the EU biomass industry [1,4,5].

5. Sources to corroborate the impact

[1]. ARBOR project – www.arbornwe.eu

[2]. Al-Shemmeri, T. (2002) Biomass to energy: project feasibility study, *Confidential Report to the Biomass and Renewable Energy Business Support Project Steering Group* – includes confidential data on Eccleshall Biomass Limited. http://www.eccleshallbiomass.co.uk

[3]. RESCO project: **http://www.resco.org.uk**

[4]. Centre de Recherche Public Henri Tudor, Luxembourg:

"The unique work Staffordshire University has carried out for us has allowed us to determine the benefits of removing dust from Miscanthus straw prior to combustion. The fuel quality assessment and energy density determination has proven this to be a viable technology in addition to the reduction in dust related issues during delivery and storage." (Contact Identifier 1)

[5]. Flemish manure association, Belgium:

"The work Staffodshire Unviersity has carried out for us has allowed us to determine feasibility of using chicken and pig manure as well as digestates for combustion purposes. In particular the ash content has helped us understand the potential problems this could cause on small scale combustors." (Contact Identifier 2)

[6]. SEE GREEN project http://www.see-green.eu/seegreensite/en/

[7]. RETS project http://www.rets-project.eu/
and http://www.rets-community.eu/

[8]. CERES project http://ceres.egeu-fund.org/

[9]. Staffordshire University database of outputs
http://eprints.staffs.ac.uk/cgi/search/archive/simple?screen=Search&dataset=archive&order=&q_merge=ANY&q=oberweis+al-shemmeri+&_action_search=Search

[10]. Localecon Associates, Staffordshire. (Contact Identifier 3)