Institution: BRUNEL UNIVERSITY (H0113)

Unit of Assessment: 12-Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Tri-generation and CO_2 refrigeration systems for energy and CO2 emission savings in the food retail industry

1. Summary of the impact (indicative maximum 100 words)

Refrigeration alone accounts for 30-60% of the total energy consumption of retail food stores and 15-20% of carbon footprint of retail food chains in the UK. Since 2001, Prof Tassou and his research team at Brunel have been conducting research on combined heat and power (CHP), tri-generation (simultaneous production of electrical power, heat and refrigeration) and CO_2 refrigeration systems for food retail applications. With their 25 industrial partners, these technologies were quickly exploited by large retail food stores such as Marks and Spencer, Sainsbury's and Tesco. Since 2010, Marks and Spencer has reduced its carbon emissions from refrigeration and air conditioning by 60% from the 2006/7 baseline, saving over £4 million. 160 Sainsbury's stores have the new CO_2 refrigeration system as of 2013 and they plan to have it installed in all 250 stores by 2014, saving over 70,000 tonnes of carbon footprint, equivalent to a financial saving of £3.6 million. They also provided training for the CO_2 refrigeration system to 200 refrigeration service engineers in 2012. Tesco claims that using the CHP and the CO_2 refrigeration system in its first 'environmental store' has reduced 70% of its overall carbon footprint since its opening in 2009, of which a third comes from the CHP plant and a fifth from the new refrigeration system.

2. Underpinning research (indicative maximum 500 words)

CHP is the local simultaneous generation of electrical power and thermal energy, whereas tri-generation is the technology that uses some or most of the thermal energy generated by the CHP system to produce cooling and refrigeration. Tri-generation avoids the transmission losses of the central electricity distribution grid and can provide very high energy utilisation efficiencies when it is possible to utilise continuously all the thermal energy available from the local power generation system. The concept has been investigated by Brunel researchers led by Prof. Tassou and applied to the food retail industry that has simultaneous needs for electrical power, heat energy and cooling/refrigeration. This application has the potential for high energy utilisation efficiency because the energy requirement for cooling and refrigeration increases in the summer months when demand for space heating reduces. The research, which has already spanned 12 years (2001-2013), was funded by Defra, TSB and up to 25 industry partners. The work was awarded the Kenneth Lightfoot Medal of the Institute of Refrigeration in 2007/08.http://www.ior.org.uk/ELI7SBBJ

A feasibility study on low temperature absorption refrigeration systems for food engineering applications (AFM177, 2001-2002), funded by Defra and industry partners Safeway Stores plc and Bond Retail Services Ltd, showed that such a system, driven by the waste heat of a CHP system, could lead to 25% running cost savings compared to the purchase of electrical power from the national grid and using it to drive vapour compression refrigeration systems in the store. A second Defra grant award, 'Tri-generation in the Food Industry' (AFM196, 2004-2006), was used to develop a proof of concept tri-generation system for performance analysis and demonstration purposes. The project involved: Safeway Stores plc, Bond Retail Services Ltd, Apex Air Conditioning and Bowman Power. The project led to the development of a commercial size tri-generation test facility for food retail applications (the only one in the UK at the time) and proof of principle rigs for demonstration of the performance characteristics of the technology. The project received significant publicity and generated substantial commercial interest. It also won the 2005 Energy Institute's *Innovation Award* sponsored by ExxonMobil.

http://www.energyinst.org.uk/content/files/AwardsSupp06_Whole.pdf

A TSB funded project 'Minimisation of Emissions from Food Retailing' (N0070A, 2007), led by Tesco Property Services Ltd and partnered by Brunel, Doug Marriott Associates, Somerfield, Space Engineering, Cogenco, Danfoss and Iceland, considered technologies for the minimisation of emissions in food retail stores. These technologies included CHP, tri-generation and CO_2 refrigeration systems. The work led to the application of these technologies at Tesco environmental

stores.

To exploit the potential offered by the use of CO_2 (a natural working fluid with insignificant global warming potential) as a secondary refrigerant in retail food applications, and remove the risk of loss of refrigeration in the event of failure of the tri-generation system, an innovative integrated CO_2 refrigeration and tri-generation system was developed under project AFM251 (2007-2010) funded by Defra and 14 industry partners including retailers Tesco and Somerfield Property Services Ltd, and equipment manufacturers Cogenco, Danfoss, GEA Bock, Bowman Power, Bond Retail Services Ltd, amongst others. http://www.racplus.com/features/tri-generation-set-to-become-more-popular/8609679.article.

Further optimisation of CO2 refrigeration systems for the food retail industry was carried out by projects funded by GEA Searle (2011-2013), Sainsbury's and Bond Retail Services Ltd.

3. References to the research (indicative maximum of six references)

References:

Tassou, SA, Chaer, I, Sugiartha, N, Ge, Y-T, Marriott, D. Application of trigeneration systems to the food retail industry. *Energy Conversion and Management*, **48**, 2988-2995, 2007. DOI: http://dx.doi.org/10.1016/j.enconman.2007.06.049

Sugiartha, N, Chaer, I, Marriott, D, Tassou, SA. Combined heating refrigeration and power system in food industry, *Journal of the Energy Institute*, **81**, 185-190, 2008. DOI: http://dx.doi.org/10.1179/014426008X370960

Tassou, SA, Marriott, D, Chaer, I, Sugiartha, N, Suamir, N. 'Trigeneration – A solution to efficient use of energy in the food industry', presented before the Institute of Refrigeration at the Institute of Marine Engineering, Science and Technology, 80 Coleman Street, London, 2008.

Ge, Y-T, Tassou, SA, Chaer, I, Sugiartha, N. Performance evaluation of a tri-generation system with simulation and experiment, *Applied Energy*, **86**, 2317-2326, 2009. DOI: http://dx.doi.org/10.1016/j.apenergy.2009.03.018

Sugiartha, N, Tassou, SA, Chaer, I, Marriott, D. Trigeneration in food retail: An energetic, economic and environmental evaluation for a supermarket application, *Applied Thermal Engineering*, **29**, 2624-2632, 2009. DOI: http://dx.doi.org/10.1016/j.applthermaleng.2008.11.018

Ge, Y-T, Tassou, SA, Chaer, I. Modelling and performance evaluation of a low-temperature ammonia–water absorption refrigeration system, *International Journal of Low-Carbon Technology*, **4**, 68-77, 2009. DOI: http://dx.doi.org/10.1093/ijlct/ctp015

Ge, Y-T, Tassou, SA. Control optimisation of CO2 cycles for medium temperature retail food refrigeration systems, *International Journal of Refrigeration*, **32**, 1376-1388, 2009. DOI: http://dx.doi.org/10.1016/j.ijrefrig.2009.01.004

Suamir, I.N., Tassou, S.A., Marriott, D. Integration of CO_2 refrigeration and trigeneration systems for energy and GHG emission savings in supermarkets, *International Journal of Refrigeration*, **35**, 407-417, 2012. DOI: http://dx.doi.org/10.1016/j.ijrefrig.2011.10.008

Ge YT, Tassou SA, Suamir IN. Prediction and analysis of the seasonal performance of tri-generation and CO_2 refrigeration systems in supermarkets, *Applied Energy*, **112**, 898-906, 2013. DOI: http://dx.doi.org/10.1016/j.apenergy.2012.12.027

Suamir IN, Tassou SA. Performance evaluation of integrated trigeneration and CO2 refrigeration systems, *Applied Thermal Engineering*, **50**, 1487-1495, 2013. DOI: http://dx.doi.org/10.1016/j.applthermaleng.2011.11.055

Research Grants:

- A feasibility study on low temperature absorption refrigeration systems for food engineering applications. Funded by DEFRA (AFM 177), Total award value: £95,650 (Oct 2001–Sept 2003).
- Tri-generation in the Food Industry - Funded by DEFRA (AFM196). Total award value: £425,900. Value to Brunel £209,600. Collaborating organisations: Bowman Power, Safeway Stores PLC,

Bond Retail Services Ltd, Apex Air Conditioning, Greggs PLC. (Sept 2004 - Nov 2006).

- Minimisation of Emissions from Food Retailing – Funded by TSB (N0070A) (Industry lead Tesco Property Services Ltd) Partners: Tesco, Brunel, Doug Marriott Associates, Somerfield, Space Engineering, Cogenco, Danfoss, Iceland. Total award value: £141,551, 2007.
- Integration of tri-generation and CO_2 based refrigeration systems for energy conservation in the food industry. Funded by DEFRA (AFM251) and 14 Industrial partners (Apr 2007 – Oct 2010). £682,350.
- Design Optimisation of CO_2 Gas Cooler. Funded by GEA Searle Ltd. £55,000 cash funding + £50,000 equipment support, Oct 2011 – Sept 2013.

4. Details of the impact (indicative maximum 750 words)

The research on CHP and tri-generation with CO_2 refrigeration system over the last 12 years has developed technologies, design and simulation models for sizing and optimum integration of the technologies for maximum performance and energy utilisation efficiency. The projects involved more than 25 industrial partners, ensuring fast commercial exploitation and dissemination of the research results. Major supermarkets in the UK such as Marks and Spencer, Sainsbury's and Tesco have quickly responded to the environmental and economic benefits of the technologies. Subsequently, they have embedded the installation of the CHP and tri-generation with CO_2 refrigeration system into their business strategies.

The industrial partner, GEA Searle, has introduced and supplied the CO_2 refrigeration system to Marks and Spencer. Marks and Spencer's Plan A (2010-2015) commits it to addressing its environmental impacts. One of its key objectives is to reduce carbon emissions from refrigeration: it aims to reduce carbon emissions from store refrigeration by 50% by 2015; to use the CO_2 refrigeration systems in all new store refrigeration installations from 2010; and to replace HCFCs by 2014 and HFCs by 2030 (Objective 10.15 Store Refrigeration, Marks and Spencer Plan A). In its 2013 business review report, Marks and Spencer states that compared to a baseline of 129,000 tonnes in 2006/7, emissions were down by 20% in 2010/11, by 46% in 2011/12, and by 60% in 2013 (at 51,000 tonnes). The total financial saving in CO_2 emissions from 2010 to 2013 only is equivalent to over £4 million. Allowing for increases in store footage, emissions were down by 31% in 2010/11 and 54% at 4.3tCO_2e/1000 sq ft in 2011/12 from 9.4tCO_2e/1000 sq ft in 2006/7. The number of stores using the CO_2 refrigeration systems was increased from 28 in 2011 to 49 in 2012. [A-1, A-2, A-3]

Similarly, the collaborative research projects with Bond Retail Services Ltd and Hauser have led to the installation of CO_2 refrigerated cabinets in Sainsbury's. Sainsbury's aims to switch to the CO_2 refrigeration system in 250 stores by 2014. 160 stores (as of 2013) have the new CO_2 refrigeration system and all new stores are fitted with the CO_2 refrigeration system as standard. Sainsbury's expects that this could 'save over 70,000 tonnes of CO_2 compared to [its] current refrigerated trailer fleet'. [B-1] This is equivalent to over a £3.6 million saving. Reflecting this commitment, in 2012 Sainsbury's provided 'hands-on' training for around 200 refrigeration service engineers so that they became familiar with the CO_2 refrigeration system. [B-2]

Tesco, in collaboration with the Carbon Trust Standard and Brunel, developed the CHP and tri-generation with CO_2 refrigeration system with the aim of saving over 10,000 tonnes of carbon footprint. [C] It installed the CHP and tri-generation with CO_2 refrigeration system in its first 'environmental store' in Cheetham Hill, Manchester, which opened in Jan 2009. Tesco states that 'the 52,000 sq ft store has a carbon footprint 70% smaller than stores built in 2006'. In addition to the sustainable construction features of the store, Tesco acknowledges that the CHP plant alone has reduced the carbon footrpint of the store by a third and the CO_2 refrigeration system by a fifth. [D-1] This store was followed by the Ramsey store in Cambridgeshire, the world's first zero carbon supermarket, which also exploited the same CHP and tri-generation with CO_2 refrigeration technologies. [D-2]

5. Sources to corroborate the impact (indicative maximum of 10 references)

A-1. Marks and Spencer, Review of the year 2013, see Objective 10.15 Store Refrigeration on p30:

http://planareport.marksandspencer.com/docs/33722_M&S_PlanA_Pillar3.pdf

A-2. Marks and Spencer, How We Do Business Report 2012, see Objective 10.15 Store Refrigeration on p25:

http://corporate.marksandspencer.com/file.axd?pointerid=24f35ecfc08e4eb1992603107c4ec51a&versionid=619cffef296544449482fc52510c135a

A-3. Marks and Spencer, How We Do Business Report 2011, see Objective 10.15 Store Refrigeration on p29:
http://corporate.marksandspencer.com/documents/publications/2011/how_we-do_business_report_2011

B-1. Sainsbury's, Press release (6 Sept 2013) World's first naturally refrigerated trailer is trialled by Sainsbury's:

http://www.j-sainsbury.co.uk/media/latest-stories/2013/20130906-worlds-first-naturally-refrigerated-trailer-is-trialled-by-sainsburys/

B-2. Sainsbury's, Press release (11 Oct 2012) Sainsbury's addresses green skills to deliver carbon reduction:

http://dea.brunel.ac.uk/rdco2/files/Cogenco_Brunel_2010.pdf

C. Tesco acknowledges its commitment to develop the CHP and tri-generation with CO_2 refrigeration system with the Carbon Trust Standard and Brunel University in order to save over 10,000 tonnes of carbon footprint in its Corporate Responsibility Report (2006). See p54:

http://www.tescoplc.com/files/pdf/reports/tesco_cr_review_2006.pdf

D-1. Tesco – Building environmental stores (31 March 2009)

http://www.igd.com/our-expertise/Sustainability/Greenhouse-gases/3742/Tesco---Building-environmental-stores/

D-2. Tesco – Ramsey store in Cambridgeshire, the world's first zero carbon supermarket
http://www.globalcstorefocus.com/1003/1.html

Contactable:

- Engineering Manager – Airside Products, GEA Searle, can corroborate the environmental and economic impacts in relation to Marks and Spencer's reduction of its carbon footprint.
- Managing Director, Bond Industries Ltd, can corroborate the environmental and economic impacts of CO_2 refrigerated cabinets in relation to Sainsbury's reduction of its carbon footprint.
- Director, Doug Marriott Associates Ltd, can corroborate the overall research impacts on the food retail industry through the development of the CHP and the tri-generation with CO_2 refrigeration system.