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DEVELOPING STRATEGIES TO ACHIEVE ZERO CARBON IN A FOOD FACTORY

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ABSTRACT

The Government has set a target to achieve zero carbon non domestic buildings by 2019. Currently all new non-domestic buildings are assessed using Part L2A of the Building Regulations, to establish the carbon emissions emitted from the building. This research will investigate the feasibility of achieving zero carbon emission in the existing food factories that do not comply with the Part L of Building Regulations. In order to establish the energy benchmarks, an existing food factory built in 2003 was used as a case study. This building currently uses 856 MWh of energy and emits 280 tonnes of carbon to the atmosphere per year. Simulations were carried out to compare and identify suitable renewable systems that would be most suitable for these types of buildings. Since the main energy usage in the food factories are for heating and cooling, the simulation results have identified several low and zero energy systems that can greatly offset the carbon emissions. Interviews show that cost is the main driving factor in the food manufacturing industry and the target of zero carbon building targets by 2019 set by Government in the current economic condition is very ambitious.

INTRODUCTION

The overall aim of this of this report is to identify suitable systems that can reduce energy consumption in food factories and thus lower carbon emissions. This is achieved by investigate energy usage in different types of food factories in order to understand how to combat the problem of carbon emissions in theses type of buildings. Low energy and zero carbon buildings need to be developed for a number of reasons, mainly due to global warming and the ever depleting supply of fossil fuels.

The motivation behind this project is based on the current interest from the members of the food and drink industry into the actual possibility that a zero carbon food factory by 2019. Carbon emissions from the industrial sector contribute to almost a third of the carbon emissions in the United Kingdom. There are policies and procedures in place for domestic and public non-domestic buildings but no clear indication of how industrial buildings such as food and drink factories will be able to meet the expected carbon emission requirements by 2019.

What is zero carbon?

Zero carbon is an aspiration that a building can be built and operate without producing any carbon emissions. This means that low and zero carbon technologies generating energy for the grid (gas or electricity) can offset carbon emissions produced by the building. Communities and Local Government stated that "zero carbon means that a home should be zero carbon (net over the year) for all energy use in the home." (UK Green Building Council, 2007). This definition is applied to non-domestic buildings but the following items of energy use are deemed to be excluded from zero carbon:

• Energy used for 'industrial processes'(though credit would still be given for district heating schemes)

• "Lifetime carbon impact of technologies (i.e. any carbon emissions associated with manufacture as well as use)"

• Transport emissions

• Actual behaviour of people occupying the buildings

• A full consideration of embodied carbon

• Actual appliance use in new buildings (assumed averages are considered)

• Green tariffs

• Offsetting, that is improving the energy efficiency of an existing building in lieu

(Carbon reductions in new non-domestic buildings, UK Green Building Council, 2007)

Carbon emissions

"In order for the UK to meet the emissions reduction targets of the Climate Change Act, most recommendations are to improve existing buildings. By 2050 half the emissions from the non-domestic sector will be from buildings built before 2020. "Integration is the key to deliver a nearly zero carbon built environment" (HM Government, 2010).

The industry needs to be structured to indicate design and construction and must be geared through legislation and incentives. The low carbon construction document (HM Government 2010) the government makes approximately 25 recommendations on what should be done to new buildings and existing ones in order to tackle the low carbon conundrum.

Three priorities have been identified:

• Incentives for owners and occupiers

• Provision of comprehensive transparent and robust information

• Imbedding of 21st century integration design and construction processes

The existing policy tools available to achieve lower carbon emissions are the Building Regulations Part L, the Building Research Environmental Assessment Method (BREEAM) and the Merton rule.

METHODOLOGY

The method in which the data is obtained within this report is through site visits to an existing local factory, interviews with owner and also leading industry experts, and using simulation to model the most cost effective scenario systems. The thermal model is based upon the case study which is an existing building that was built in 2003. The model has been constructed using Integrated Environmental Solutions (IES) software and the architectural tender design documentation.

This report initially investigates the actual operation of the food manufacturing industry and the attitude of the owners/managers to energy saving and carbon reduction.

This has been carried out through site visits, collection of actual energy consumption and interviews with owner and the leading industry experts.

To achieve a zero carbon food factory, the actual processes that influence the carbon emissions together with different systems to offset these carbon emissions were simulated. These different low carbon and renewable systems that were simulated using the IES software could provide an accurate production of carbon emission per year.

This research identifies the low and zero carbon technology schemes capable of offering the required percentage reduction in proportion of the total energy demand of the building. This is done by summarising the energy consumption for the development and associated CO_2 emissions for the case study building. The analysis will also include indicative payback periods for the certain technologies and will identify the most economical technologies suitable for food factories.

CASE STUDY BUILDING AND SIMULATION

Currently the construction industry is in a 'transition period' where there are modern renewable energy sources available, but many of our current buildings in the UK and around the world still operate using fossil fuels to generate the power required for the building. The industry is also on the 'brink' of new technologies becoming available such as fuel cells and the development of nuclear fusion for power stations, however with the latter being decades away from a working power station.

It is the belief of many of 'experts' from the United Kingdom that "Britain can eliminate emissions from fossil fuels and break our dependence on imported energy by 2030 by significantly increasing energy efficiency and by installing massive renewable energy generation." (Zerocarbon Britain 2030, 2010)

Under the European Union Commitment in 2008, the United Kingdom is to deliver 15% of its energy supply from renewable resources and one way in which this can be achieved is that the UK must develop a policy of 'zero carbon' buildings. The UK government has outlined a plan to ensure that all domestic properties are to be zero carbon by 2016, public non-domestic buildings by 2018 and all other buildings by 2019. (COUNCIL, U.K.G.B., 2008)

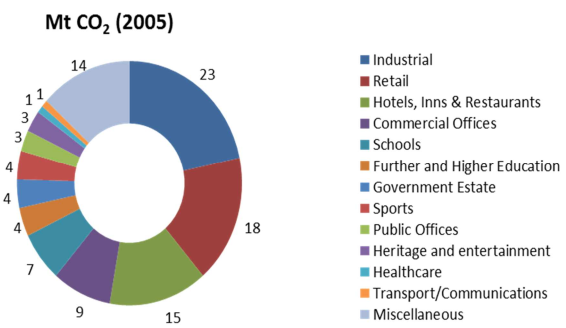

Figure 1 Emissions by sector (Carbon Trust 2009).

Of these different sectors, the industrial sector (warehouses, factories etc.) make up the largest percentage of CO_2 emissions in the UK, (see Figure 1).

As shown in Figure 2, third of the existing non-domestic buildings are more than 70 years old and three-quarters are over 25 years old (Kemp,M et al, Zero Carbon Britain 2030, 2010). These existing old buildings do not satisfy the current Building Regulations requirements resulting in large energy losses from these commercial buildings.

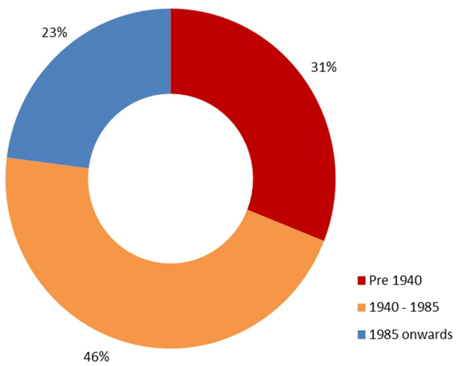

Figure 2 The age of non-domestic building stock (Carbon Trust 2009)

The majority of the emissions produced from the food and drink industry are from the burning of fossil fuels to provide large quantities of heat in steam boilers, ovens and driers, which lead to “direct” CO_2 emissions. Figure 3 illustrates how the energy is being used within the food and manufacturing sector. Looking at the breakdown, energy use in a food factory can be itemised as follows; heating, refrigeration, pumps, compressed air, lighting and ventilation.

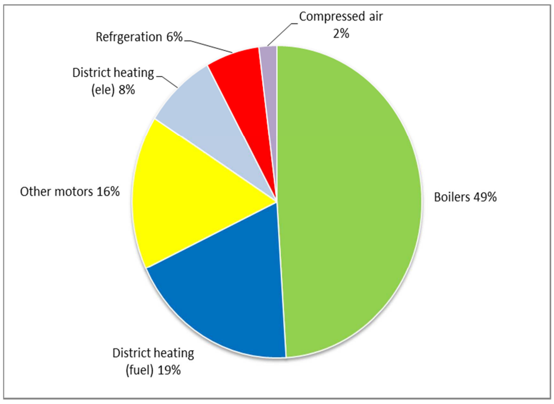

Figure 3 Average breakdown for emissions for the food and drink industry (Food and Drink Federation, 2007)

Site Visit

The case study, a local small jam factory, was surveyed and the owner interviewed to establish an understanding of how a small commercial manufacturing business was operated, and its effect on energy consumption. At first glance during the walk about in the existing small factory, the extensive heat and heat wastages were very obvious. This wastage of resources is mainly due to the existing inefficient equipment in the factory. The collected energy data were used to break down the energy consumption in the building. The energy break down of this factory is very similar to the one shown in Figure 3 and is presented in Figure 4. In this case study the majority of the energy usage is some form of heating using a boiler. Mainly in the food canning process, as it is very steam intensive and boilers make up 70% of the energy usage.

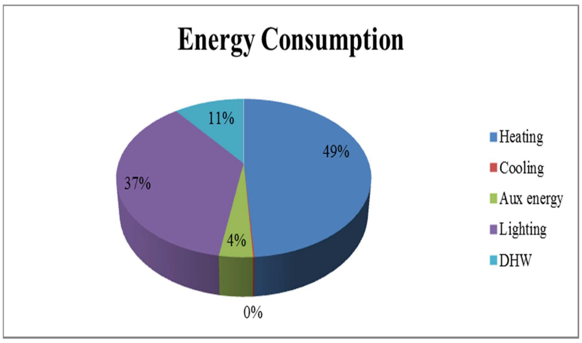

Figure 4 HVAC Energy Summary of the case study

The Heating, Ventilation and Air-conditioning (HVAC) energy summary illustrates the percentage energy consumption of the separate building services within the building. The main energy consumption in the food factory is the heating load which counts for almost half of the building, with the lighting load making up 37% of the total building energy usage.

Interviews

Interviews were carried out with the owner of the case study building and two other leading food industry experts.

The owner of the case study building is well aware of the energy use and also wastages, but due to financial restrictions has not taken any steps to meet the current environmental challenges. The general mind set is that economics and business sense come before the need to reduce the carbon emissions, despite the owner being aware of the government targets and knowing that it would be morally correct. The owner would be happy to use heat recovery and renewable systems in his factory grounds, providing that they are affordable and have a very short payback period.

The first industrial expert in carbon emissions in the food industry posed the question of:

“How do you design a food factory without producing excessive amounts of carbon?”

One of the processes that this expert highlighted is the amount of waste produced in factories. Any waste from factory processes need to be designed into a new factory so that the waste can be recycled and packaging and waste targets can be achieved. The Government target to achieve zero carbon by 2019 may not be achievable but by setting a target like this, creates a market for the renewable energy technologies.

A food factory that utilises cooking and cooling processes generates so much energy which eventually becomes waste energy. The idea of collective zero carbon footprint food factories and the idea of ‘food parks’ has been investigated. However, these food parks are not going to be built as currently the margins for profit do not make it a feasible investment opportunity. Despite the Government zero carbon targets, everything is cost driven, especially in this current economic climate.

Another industry expert, when asked in his professional opinion from dealing with businesses trying to achieve zero carbon, he stated that the majority of businesses will only be prepared to adapt their buildings to low zero carbon buildings if they can recoup the costs. If there was pressure on the retailers from the government, then this would drive the change.

The interviews show that waste is a big problem in the food manufacturing industry, whether it is waste from packaging or energy waste from steam being expelled into the atmosphere and the site visits to the case study factory have confirmed this.

Thermal Modelling

The simulation of the case study was carried out to investigate whether a zero carbon food factory is actually feasible.

The thermal modelling work has been carried out using the dynamic thermal software developed by Integrated Environmental Solutions (IES) and has been used to analyse the annual energy consumption for different building systems strategies and establish whether or not zero carbon can be achieved. The thermal model has been simulated using the IES package <VE> Compliance – for Part L2 calculations and Energy Performance Certificates.

The simulations compare a base model which has been designed to replicate the existing factory building against other models which have been amended to improve the carbon emissions. The other models have used different energy sources such as biomass instead of gas and solar PV panels and wind turbines to offset the electrical loads.

The energy figures for the building were taken from the IES results rather than using the CIBSE TM46: Energy Benchmarks as this method would be more accurate. Evaluating this acquired data would then provide an indication as to which renewable technologies would be viable for the building. The low and zero carbon systems were investigated that will reduce the break down emissions given in Figure 4.

CHP

Combined Heat and Power (CHP) is an efficient, clean and reliable approach to the simultaneous generation of usable thermal energy and electrical power from a single fuel source. In a Sicilian pasta factory that uses cogeneration to provide its energy requirements, the factory requires thermal (heating) and electrical energy simultaneously, so combined heat and power systems are the most suitable.

Refrigeration Energy Usage

Refrigeration only contributes to 6% of the energy usage as shown in Figure 3. The average breakdown of the energy can change and chilled and frozen foods use approximately 60% of the energy where refrigeration is required in a food factory. Refrigeration systems regularly represent the largest use of electricity in food and drink factories such as chocolate factories, chilled and frozen food factories and breweries. It is possible to achieve up to 40% energy savings by installing an efficient refrigeration system.

Tri-generation

Tri-generation systems have potential efficiencies as high as 90% compared to 35% for electricity that is generated in a commercial power plant. The majority of these large tri-generation plants are in food factories and are now being extended to supermarkets. There are possibilities for the use of biomass CHP on a large scale due to the energy loads required and how much carbon that will be saved by the use of a biomass boiler. The biomass boiler is deemed to be 'nearly' zero carbon because the carbon emitted from the boiler is absorbed by the trees that are used as the fuel.

Pump and Fan Energy Usage

Energy is used for pumps, fans, specialist process machinery and mixers in a food and drink manufacturing factory. The electrical energy used for the operation of these systems can be reduced by as much as 20% if there are improved operation and control procedures in place. For most fans and pump systems, the power consumed is proportional to the cube of the flow rate, so reducing the volume flow rate by 20% will equate to a 50% power saving. "Food manufacturer Northern Foods in the UK is saving over £30,000 a year in electricity costs thanks to the installation of three ABB variable speed drives at its Riverside Bakery in Nottingham." (Tolvanen, 2008)

Lighting Energy Usage

Compared to twenty years ago, lighting systems that are available today are much more efficient and light fittings can be improved to distribute more light. Lighting control systems can reduce power consumption and an efficient building design will be able to maximise the benefit of natural daylight by the use of effective rooflights. Rooflights impact on both the heating and lighting requirements. Energy efficiency analysis recognised that carbon emissions could be reduced by up to 27% with the use of "very high efficiency lamps and luminaires" (Targetzero, 2010).

RESULTS & DISCUSSIONS

The results obtained from the site visits showed that the existing factory building did not pass the 2010 Part L2A compliance requirements and produced 70% more carbon emissions than the 2010 notional building. The thermal model study was used to simulate the case study building and obtain the energy consumption and carbon emissions.

Energy Demand

Using the Part L2A compliance simulation, the estimated energy demand and associated CO_2 emissions for the development is provided in Table 1 Building Summary.

Table 1 Building Energy and Carbon Summary

Floor area (m^2)	Fossil Fuel Demand (kWh/p.a.)	Electrical Demand (kWh/p.a.)	Total Energy Demand (kWh/p.a.)	Fossil Fuel CO_2 ($kgCO_2$/p.a.)	Electrical CO_2 ($kgCO_2$/p.a.)	Total CO_2 ($kgCO_2$/p.a.)
8260	509,825	346,702	856,528	100,945	179,245	280,191

Table 1 shows that in order to achieve a zero carbon emission building, in terms of Part L2A Compliance, 280,191kg of CO_2 needs to be offset using renewable energy technologies. This report aims to investigate all viable options to achieve the specified requirements providing recommendations for the technically feasible design schemes.

Carbon Demand Assessment – Part L compliant base building

Table 2, provides a detailed analysis of the Carbon emissions per HVAC service.

Table 2 Carbon Emissions Summary

CARBON	Heating	Cooling	Aux Energy	Lighting	DHW	Total
Fuel	Natural gas	Grid supplied elec	Grid supplied elec	Grid supplied elec	Natural gas	
Emisssions rating	0.198	0.517	0.517	0.517	0.198	
Summed total	82,880	718	15,778	162,749	18,065	280,190
Kg/CO2/m²/pa	10	0	2	20	2	34
% of Total	30%	0%	6%	58%	6%	100%
Total Carbon	280,190	($kgCO_2$/p.a.)				
Target	100%					
Target saving	280,190	($kgCO_2$/p.a.)				

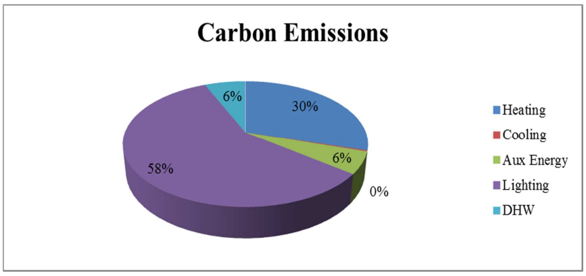

Figure 5 Carbon Emissions Summary

Figure 5 illustrates that the majority of the carbon emissions area due to the lighting load.

Low Zero Carbon Technologies Summary for this building

In order to achieve zero carbon for the case study, the percentage saving of carbon needs to be 100%. Due to the carbon emissions factors, and the actual HVAC service demands in the building, even if the energy saving is 100%; the carbon saving percentage is a lower figure.

The results in Table 3 show the percentage carbon savings for each renewable technology assuming that the technology is providing 100% of the energy load.

Table 3 LZC Carbon Summary

LZC System	LZC % of HVAC service	Annual Carbon Emissions LZC offset	% of Total Carbon	Installed capacity	Budget Cost	Simple payback	Payback including FIT/RHI/ROC
	%	($kgCO_2$/p.a.)	%	m²/kW	£	Years	Years
Solar Hot Water (m²)	100	18,065	6.4%	201	140,674	51.4	13.4
Wind (kW)	100	183,406	65.5%	179	671,233	19.4	6.4
PV (m²)	100	183,406	65.5%	2,399	1,279,640	36.9	9.0
Biomass Heating (kW)	100	82,880	29.6%	174	348,824	-85.3	20.6
Biomass Hot Water (kW)	100	18,065	6.4%	152	228,092	-255.8	18.6
Biomass Ht and DHW (kW)	100	100,945	36.0%	850	849,709	-170.5	12.4
CHP capacity kWt	100	100,945	36.0%	113	100,000	6.2	3.4
Biomass CHP capacity kWt	100	100,945	36.0%	113	290,000	17.9	8.1

The results show that the technology that saves the most carbon is the Biomass CHP, saving 86.9% of the buildings carbon emissions and the least efficient for this building is to use a Biomass boiler for the hot water usage only.

Developing a strategy to achieve zero carbon

When the Part L Building Regulations changed in April 2010, this essentially meant that a 25% improvement in carbon emissions was required on all future buildings. The proposed course of action with regard to compliance with building regulations and planning conditions is to reduce the requirements for energy to a minimum by maximising passive energy saving measures and specifying high efficiency systems and equipment.

Two scenarios have been considered within the building design that uses a selection of the renewable technologies available to achieve the target of 100%

carbon savings. Using on-site generation from low or zero carbon technology within the IES software can provide a scheme compliant with Part L2A of the Building Regulations with Carbon Emissions and a Building Emission Rate (BER) less than or equal to zero.

Scenario 1 – Biomass boiler, wind turbine and photovoltaics

Using the information obtained and selecting the technologies that provide the most carbon savings, in scenario 1, a combination of wind power, solar photovoltaics and biomass boiler illustrate that 100% carbon savings are viable.

Table 4 – Scenario 1

LZC System	LZC % of HVAC service	Annual Carbon Saving by LZC	Saving % of Total Carbon	Installed capacity	Budget Cost	Simple payback	Payback including FIT/RHI/ROC
	%	($kgCO_2$/p.a.)	%	m^2/kW	£	Years	Years
Wind (kW)	51	93,537	33.4%	91	342,329	19.4	6.4
PV (m^2)	51	93,537	33.4%	1,224	652,616	36.9	9.0
Biomass Ht and DHW (kW)	100	93,414	33.3%	850	849,709	-170.5	12.4

The IES simulation for Scenario 1, shown in Table 4 confirms that the building achieves a zero carbon emissions rating. The Part L 2010 compliance simulation provides the result of a zero carbon building with an emissions rating of -1.5kg CO_2/m^2.

Scenario 2 – Biomass CHP boiler and photovoltaic

The factory operates constantly over 24 hour period, therefore a CHP boiler would be the ideal selection for an energy system. This would provide the large heating and domestic water load that is required but at the same time, generates electricity that can offset the significant lighting and refrigeration loads. The results for a biomass boiler and PV panels (Scenario 2) are presented in Table 5.

Table 5 – Scenario 2

LZC System	LZC % of HVAC service	Annual Carbon Saving by LZC	Saving % of Total Carbon	Installed capacity	Budget Cost	Simple payback	Payback including FIT/RHI/ROC
	%	($kgCO_2$/p.a.)	%	m^2/kW	£	Years	Years
PV (m^2)	60	110,043	39.3%	1,440	767,784	36.9	9.0
Biomass CHP capacity kWt	70	170,449	60.8%	79	290,000	25.5	11.5

The IES, simulation confirmed that the Biomass CHP boiler and 1,440m² of PV panels provided a zero carbon building with emissions rating of -0.6 $kgCO_2/m^2$.

The IES Part L compliance simulations demonstrate that zero carbon emissions is possible from the building, however not feasible due to the costs involved.

CONCLUSIONS

The evaluation of the carbon emissions of the case study showed that the emissions for the building were 70% more than the Target Emission Rate. This report has investigated, through site visits and collection of energy data; the break down of energy consumption for a typical operation of a food factory operates in the United Kingdom. The interviews with leading industry experts have demonstrated that the Governments targets of achieving zero carbon emissions by 2019 are extremely ambitious.

The investigations and findings of this report highlight that there are a number of ways using renewable energy technologies that can improve energy efficiency, reduce energy use, reduced annual energy costs, and provide significant savings in carbon emissions. When a building such as a food factory has such high energy loads, the potential to save energy and reduce carbon emissions is extensive.

The energy data obtained from the base model provided guidance for a solution to obtain a zero carbon building. The first solution, Scenario 1, demonstrated that the building achieved zero carbon emissions using a wind turbine, photovoltaic solar panels and a biomass boiler. The building in Scenario 2 illustrated that zero carbon emissions were achieved using a Biomass CHP boiler and photovoltaic solar panels. From a financial point of view, Scenario 2 would be the cheaper option as the initial capital outlay is less and the payback period is shorter than Scenario 1.

The results show that 1,200m² of photovoltaic solar panels are required which in reality is very expensive and space consuming. Even on the food factory that has been modelled, there is not enough room to contain the PV panels on the roof.

Presumably, according to the Government, as the building would be classed as a net zero carbon emissions rated building; this would satisfy the zero carbon buildings policy. However, Part L calculations do not take into account process loads, which in this building is the steam requirement for the cooking of the meats using a 3,000kW gas boiler. A gas boiler running for twelve hours a day all year with an output of approximately 3,000kW will use 13,140MWh of energy per year, producing approximately 2,600 tonnes of CO_2 per year. It is unreasonable for the Government to claim that they are meeting the zero carbon emissions target when 2,600 tonnes of carbon is being emitted to the atmosphere from one factory alone.

"Becoming a low carbon economy will be one of the greatest changes our country has ever known. But it is a change for the better, for our economy, our society, and for the planet. This Carbon Plan shows how, together, we can make it happen.” (HM Government, 2011).

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