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ScienceDirect

Energy Procedia 123 (2017) 30–35

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Sustainable Energy and Resource Use in Food Chains, ICSEF 2017, 19-20 April 2017, Berkshire, UK

The impact of the UK's emissions reduction initiative on the national food industry

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Abstract

This study aims at determining the technology combination that provides the lowest emissions and energy cost for the food-industrial sector. Using a linear optimization objective function in determining the least-cost pathway, data from various sources were compiled to perform simulations on two scenarios; a business as usual (BAU) case and an 80% greenhouse gas (GHG) emissions reduction. Even in the base case, the emission level reaches 21% of 1990 levels; a reduction of 39% over the simulation period. This indicates that even without the imposition of GHG constraints on the food sector, it is economically more beneficial for the industry to migrate from fossil fuels. This migration takes place by replacing energy from LPG, LFO, Kerosene, HFO, Coal and Natural gas with biomass, biogas and CHP electricity. Economic benefits arise from the fact that biogas and biomass are produced from wastes which are generated onsite within food factories, hence the avoidance of purchasing energy feedstock from the market. The change in energy consumption between the two scenarios is similar due to the prevalence of least-cost solutions and similar energy and food demand requirements. However, the reduction in emissions are greater in the 80%-GHG case than the BAU case; 52% compared to 39% for the BAU case, for 2050 relative to 2010. This is largely owing to decarbonization of grid electricity. This study finds that the food-industrial sector has the potential to exceed this 80% reduction target to a value of 92%, due to the availability of onsite feedstocks to generate biogas. In this simulation, of all waste produced, 92% of waste feedstock is consumed in AD and CHPs, whilst the remaining 8% is dried and processed to be burned in biomass boilers.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Sustainable Energy and Resource Use in Food Chains.

Keywords: Food indutrial sector; Energy consumption; Emissions

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Peer-review under responsibility of the scientific committee of the 1st International Conference on Sustainable Energy and Resource Use in Food Chains.
10.1016/j.egypro.2017.07.281

1. Introduction

The UK food sector accounts for 18% of the national energy consumption [1]. Of this, the food industrial sector (manufacturing and processing) contributes 15% [2] and employs 10% of the UK work force [2]. The food industrial sector refers to the processes undergone by food products whereby raw materials are cleaned, sorted, combined and altered/processed to produce finished products which are easier and more convenient to consume. This makes the sector a crucial segment of the food chain and pillar of the UK economy. These processes are generally energy intensive and some facets may require significant energy efficiency enhancement or energy shifts in order to abide by the UK's energy and greenhouse gas (GHG) emission reduction initiatives.

This study focuses on the technology improvements/alterations required by the UK food industrial sector in order to reduce their GHG emissions. The UK is committed to reducing GHG emissions by 80% in 2050, compared to 1990 levels [3], despite Brexit economic and political tensions [3]. Divided into carbon budgets, the phases for emissions reduction are 57% by 2030 and 80% by 2050 [3]. Current policies are however expected to only deliver half of these emission reductions [4], and significant policy improvements are required to re-align the economy to these targets. These include keeping effective policies such as: vehicle fuel efficiency standards, F-gas regulations, Courtauld waste commitments and energy efficient product labelling. On the other hand, technological energy efficiency improvement policies, agricultural policies (such as the Common Agricultural Policy) and energy trade policies would require reinforcements, particularly as the UK dissociates itself from the EU [4].

In this analysis, we investigate the most cost effective manner to attain the UK's emission reduction targets by employing a national and collaboratively developed linear programming tool known as the UK TIMES model (UKTM). The model aims at identifying energy and technology hotspots within the UK food industrial sector in order to understand which sectors and what technologies to strategically fund in order to have the maximum potential impact and contribution to GHG emission reductions. The model encapsulates all sectors of the economy and hence provides a broad analysis of the UK economy and food industrial sector, as opposed to studying the food industrial sector in isolation.

2. Methodology

As mentioned, this work feeds into a wider national model known as the UKTM (UK TIMES Model), which consists of various academic, industry and governmental departments, which aim to optimize the technology mix for all sectors across the UK. This study employs the linear programming technique to analyze the applicability of technologies the UK food processing sector. Linear programming techniques have been widely used in modelling technology applicability for difference sectors [5-8], where the objective function - total costs or net profit margins - can either be minimized or maximized, subject to technical, economic, environmental and resource constraints. The IEA-ETSAP TIMES (The Integrated MARKAL-EFOM System) model generator is used here to link the technologies, energy and cost structures in a partial equilibrium model, and together with a technology-rich foundation, it allows the estimation of energy dynamics over a long-term horizon [9]. TIMES uses a linear optimization objective function which determines the least-cost pathway by minimizing the total discounted system costs in order to satisfy the farm's energy demands, subject to technical, economic, environmental and resource constraints. Through the use of a partial equilibrium solution strategy, the model does not provide feedback on other sector changes, and assumes perfect foresight as decisions are made with full knowledge of future policy, technical, economic developments and available resources [10].

Data were obtained from various sources, and has been presented and debated by leading food manufacturers and food federations. The food industrial sector was divided according to the SIC2007 classifications, which segments the food sector into different food categories, such as meat/meat products and fish, fruits and vegetables etc. The technology cluster studied consists of systems for space heating, hot water, drying, direct fire and Combined Heat and Power (CHP).The simulations were performed by considering two scenarios, a 'Business As Usual' (BAU) case (where there are no imposed GHG emissions constraints), and the scenario whereby the 80% GHG emissions reduction is imposed on the model. The model disaggregation and technology mix studied in this paper are illustrated in Fig. 1, whereby the energy parameters (costs and availability) are obtained from the wider UKTM model, analyzing the energy generation sector, which then feeds into the Food Industry (IFD) module developed in this paper. Note that the development of UKTM has been undertaken in advance of Brexit, and the model outputs (pre-Brexit) aim to provide a basis for policy development largely focusing on technological efficiency and costs. Scenarios can then be used to factor in trade, economic and political instabilities.

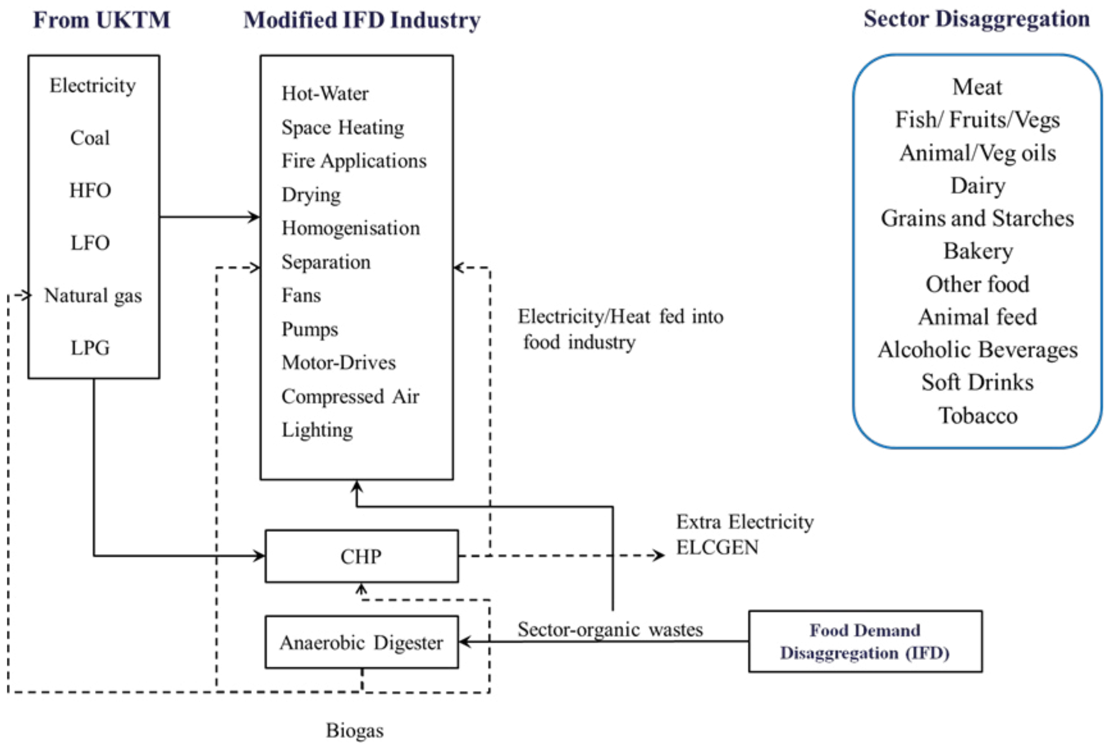

Fig. 1. Food industry disaggregation schematic

3. Results and Analysis

Fig. 2 show the energy trends in the BAU case. We observe that even in the BAU case, the emission level reaches 21% of 1990 levels, or a reduction of 39% over the simulation period, until 2050. This indicates that even without the imposition of GHG constraints on the food industry, it is economically more beneficial for the industry to migrate from fossil fuels. From the results, we observe that this migration takes place by replacing energy from LPG, LFO, Kerosene, HFO, Coal and Natural gas with biomass, biogas and CHP electricity. In this case, the economic benefits arise from the fact that biogas and biomass are produced from wastes which are generated onsite food factories, hence the avoidance of purchasing energy feedstock from the market.

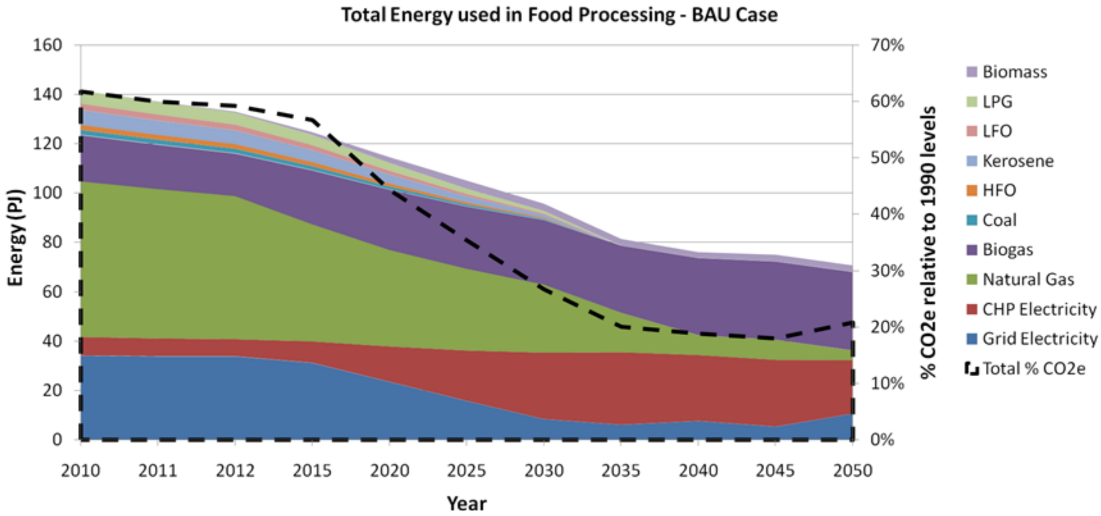

Fig. 2. Energy trend for the BAU case

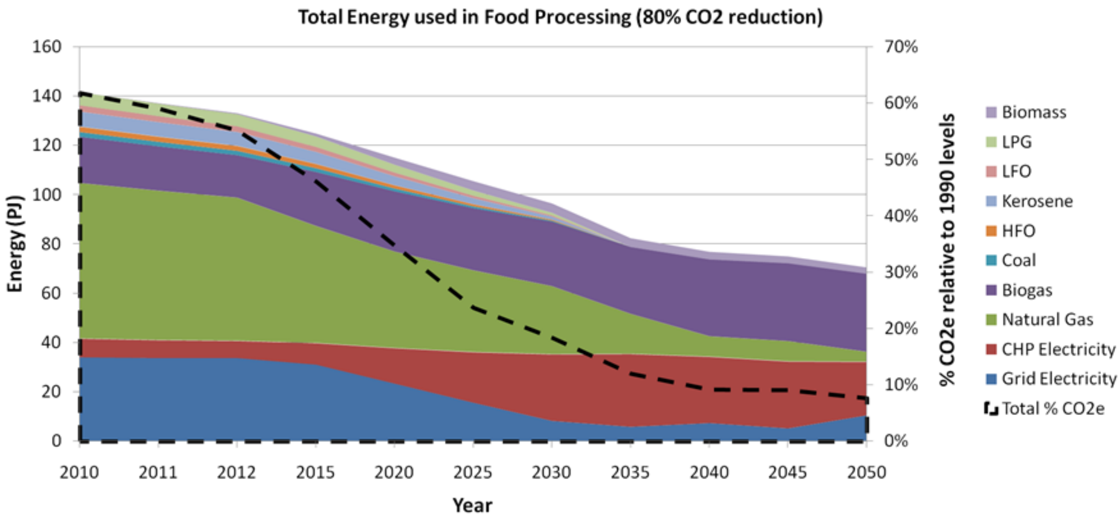

Fig. 3. Energy trend for the 80% emissions reduction case

From Fig. 2 and 3 we observe that the change in energy consumption in the 80%-GHG case is similar to the BAU case. This is, partly because the energy requirement of the food industry is the same for both the BAU and 80%-GHG cases (due to same food demand). And also, because the BAU case already achieves a least-cost (capital and operational costs) solution with regards to sourcing energy and adopting efficient technologies, mainly through the adoption of AD technology.

The reduction in GHG emissions however is greater in the 80%-GHG case than the BAU case; at 52%, compared to the 39% for the BAU case in 2050 relative to 2010. This reduction shows that although the UK GHG reduction is imposed at 80%, relative to 1990 levels, the food industry has the potential to exceed this reduction to a value of 92%. This is largely due to the emissions associated with the consumption of grid electricity being reduced and the availability of onsite feedstocks to generate biogas. Note that the feedstock considered for AD in UKTM includes all organic wastes such as food, sludge, and effluents, and excludes the feedstock that goes to animal feed.

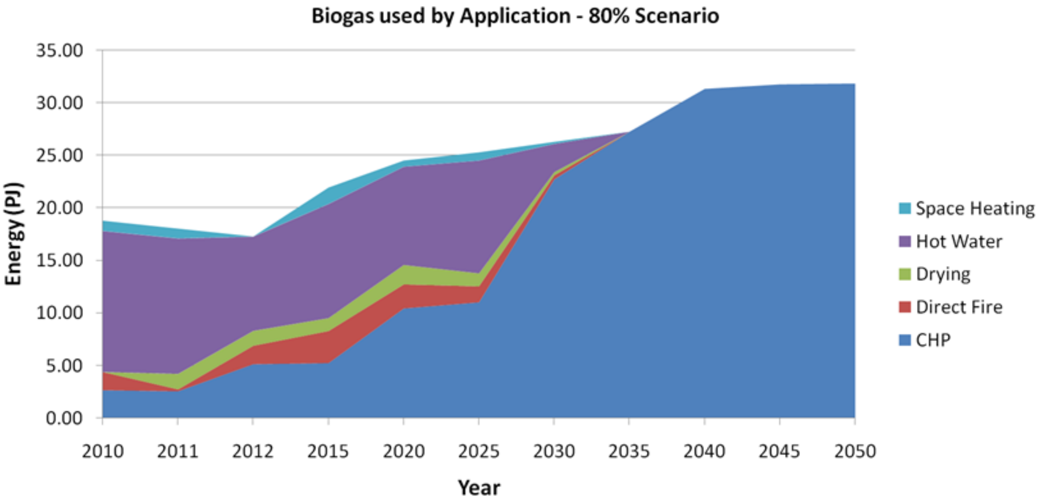

Fig. 4. Use of biogas throughout simulation

We observe from Fig. 4 that the total amount of biogas used in the sector increases in the 80% GHG emissions case (the trend is similar for the BAU case), but with the bias tending towards the use of biogas for CHP as it generates both heat and electricity. In general, approximately 92% of waste feedstock goes to AD and is consumed through CHPs, whilst the remaining 8% is dried and processed to be burned in biomass boilers. Additionally, towards the end of the simulation, i.e. 2050, biogas is only used by CHP, and part of the hot water requirements of the industry is produced through heat pumps using electricity generated by on-site CHP.

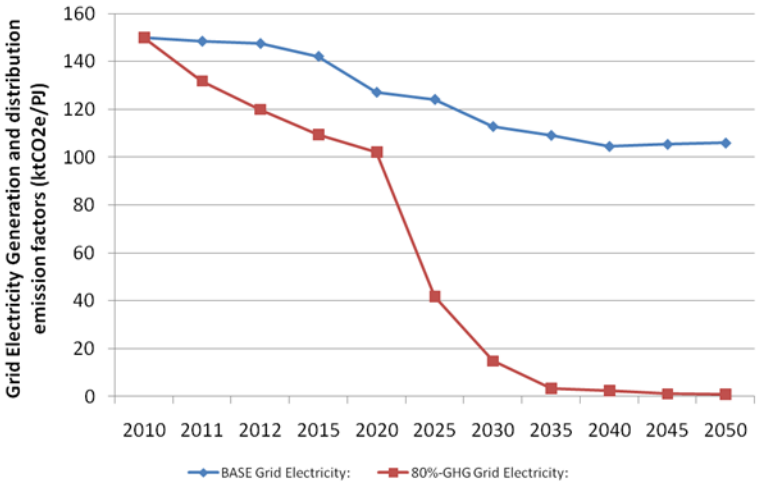

Fig. 5. Emission factors associated with grid electricity

The main difference between the BAU and the 80%-reduction cases arises from the fact that the emissions associated with grid electricity are different. These emissions are calculated in UKTM based on the least costs solutions to satisfy the constraints. In the UK, power generation produces the highest amount of emissions (36% of total) and also has high potential for emissions reduction due to the current large amount of fossil fuels employed. In these regards, the UKTM model has shown that with the imposition of the 80%-GHG reductions, the UK power sector will drastically change towards renewable and nuclear power, and the associated carbon emission factors will also change as shown in Fig. 5.

4. Conclusions

This study examines the changes in the food industry as the UK imposes a national reduction in GHG gas emissions of 80% towards 2050. This has repercussions throughout the economy, including the food industrial sector. The results from this study show that although the energy usage is similar for both the base and 80% reduction cases, the emissions are different. This is mainly due to the fact that the grid has been decarbonised with renewable and nuclear energy sources. The study also demonstrates that the use of organic wastes (food, sludge, effluents) in the food industry is seen to contribute significantly to energy production. These refer to wastes excluding the current ratio which are re-used, such as animal feedstocks. This study shows that in order for the UK to reach its 2050 emissions target, significant emphasis will be placed on grid decarbonisation, as opposed to sector-wise technology efficiency improvements. This is largely due to lower overall costs and the ability to affect a wider array of sectors from smaller number of alterations, as opposed to each sector improving their technology efficiencies. This includes the adoption of electricity generation technology such as nuclear, wind and solar.

Acknowledgements

This study was made possible from the funding received from RCUK for the establishment of the National Centre for Sustainable Energy Use in Food Chains (grant no. EP/K011820/1), as well as contributions made by industry partners and other stakeholders in the Centre. The Authors would also like to thank the UKTM team at UCL for their collaboration and for providing the original UKTM model.

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