Modelling and Optimisation of Distributed Energy Resources in Food Retail Buildings: An Investment and Management Approach

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AIM

Explore the optimal implementation and operation of gas-fired internal-combustion co-generation (CHP) units, when integrated with supplementary heat recovery and conversion technologies to satisfy heat, refrigeration and electrical non-refrigeration demands in food-retail buildings while achieving cost and carbon savings.

BACKGROUND

More than 70% of the total energy requirements of food-retail buildings is linked to the electricity demand, which is expected to further rise in the forthcoming years (Tassou, 2011). For that reason, food-retail companies' focus is currently set on technologies, able to reduce the total energy consumption and the associated emissions. CHP engines are increasingly receiving attention, as they can result in both energy and carbon savings in food-retail buildings, with the operational strategy playing a pivotal role in maximizing these benefits (Cedillos, 2015). Heat-conversion technologies leveraging the excess thermal energy made available by the CHP units to generate more electricity or heat, can lead in further reductions in the primary energy consumption.

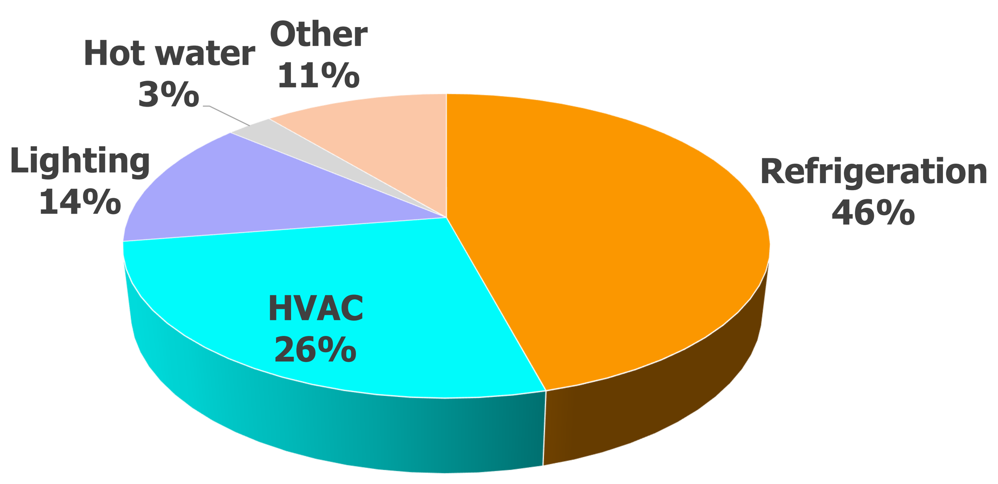

Figure 1: Energy consumption breakdown in food-retail buildings (DEFRA, 2007)

METHOD

- Two case studies conducted:
  - i. Supermarkets
  - ii. Distribution Centres (DC)
- **Optimisation model** developed for the selection of the optimal technology portfolio in the buildings examined;

TECHNOLOGY OPTIONS CONSIDERED	
First case study	Second case study
I. Single-CHP units II. CHP and integrated ORC units	I. Single-CHP units II. CHP and integrated ORC units III.CHP and Absorption chillers (AC)

- Objective of the optimisation model: either minimisation of total cost of satisfying energy demand or minimisation of total attributed emissions;
- Business-as-usual scenario: grid-imported electricity, heat provided by on-site boiler, refrigeration provided by mechanical vapor-compression chiller.

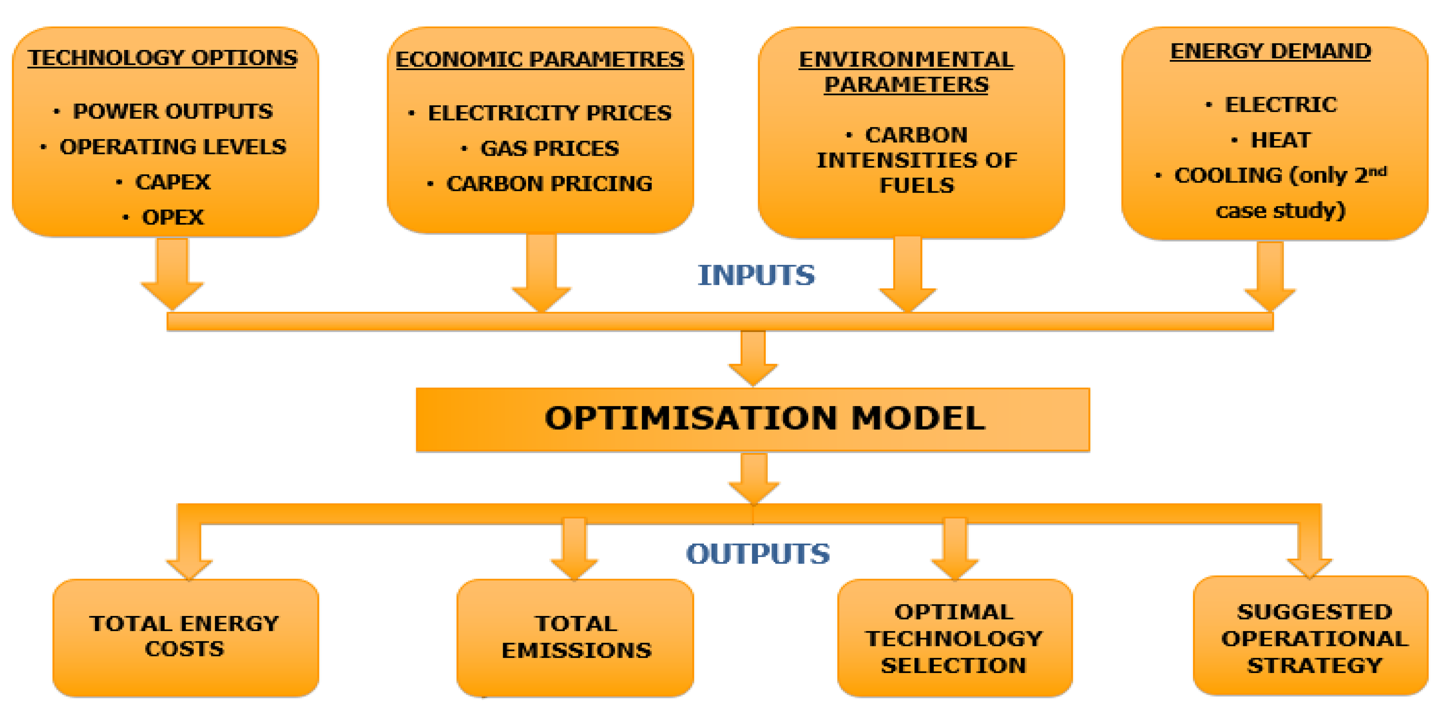

Figure 2: A representation of the optimisation model developed

RESULTS

In both case studies, the minimum GHG emissions optimisations select CHP&ORC units as the optimal technology option. The minimum cost optimisation might indicate CHP&ORC as the optimal solution in both case studies with both tested fuels, but the biomethane-fuelled CHP &AC solution in the second case study results in a total cost only 1.25% higher than the one obtained for CHP&ORC. Hence, they can be regarded as equally beneficial for the DC case, if biomethane is the fuel utilised.

Table 1: Results obtained for the cost optimisation of the two case studies

	Supermarket store (1st case study)		Distribution Centre (2nd case study)		
Technology selected	CHP 530kWe & ORC 100kWe		CHP 1280kWe & ORC 150kWe		CHP 1520kWe & AC 600kWth
Fuel used	Natural Gas	Biomethane	Natural Gas	Biomethane	Biomethane
Average annual cost savings	32.5%	38.2%	31.5%	37.8%	37.1%
Average annual carbon savings	18.9%	99.3%	18.5%	99.8%	99.8%
IRR	40%	45.6%	32.7%	37.8%	29.3%
ROI	321%	380%	229%	277%	186%
Payback period	4 years	4 years	5 years	4 years	5 years

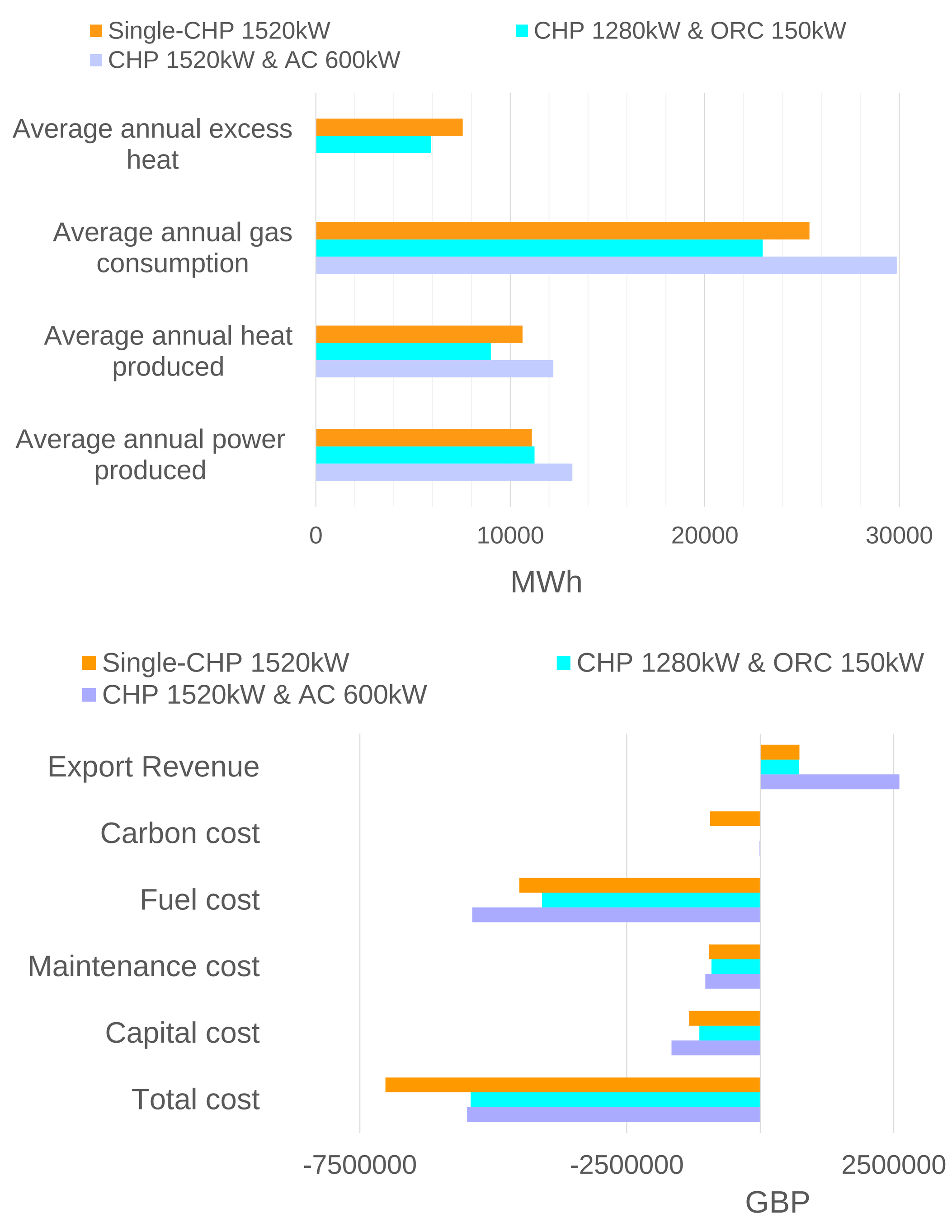

Figure 3: Performance (top) and cost (bottom) comparison between the technology options

Operational strategy

- For the optimal CHP&ORC solution, electricity is only imported from the grid when the units' outputs cannot cover the demand;
- Electricity is being exported when optimising for the cost, during time intervals when the export tariff meets its peak value;
- In the minimum GHG scenario, the exported electricity is almost zero;
- The selected units in both case studies, can cover the entire thermal demand, thus, the on-site boiler is not contributing to the heat generation;
- Electricity exported for the CHP&AC solution is four times greater than in the CHP&ORC case;
- When CHP&AC are selected, the boiler and the mechanical chiller contribute to the heat and cooling generation respectively.

FINDINGS

- Heat-conversion technologies integrated in CHP systems can result in cost savings compared to single-CHP options as well as to the business-as-usual scenario of satisfying building's energy demand;
- Biomethane-fuelled CHP&ORC units lead to zero-carbon systems, while natural-gas fuelled units can obtain emissions' reduction around 19%;
- Benefits entailed by biomethane-fuelled CHP&ORC and CHP&AC are directly comparable in buildings with high refrigeration demand;
- The optimisation model developed can constitute a generic tool for the selection of technology portfolios in other commercial buildings.

REFERENCES

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Tassou, S. A., Ge, Yy., Hadawey, A. & Marriott, D. (2011) *Energy consumption and conservation in food retailing*. Applied Thermal Engineering, 31 (2-3), 147-156.