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CO_2 refrigeration system heat recovery and thermal storage modelling for space heating provision in supermarkets: an integrated approach

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BACKGROUND

- The greenhouse gas (GHG) emissions reduction targets set by the UK government [1] have led to an increase of CO_2 refrigeration systems in the food retail industry[2].
- An excellent opportunity for heat recovery arises with the growing number of CO_2 refrigeration systems due to their high operating pressures.
- The large amount of heat that can be recovered has led the food retail industry to consider the possibility of a **CO_2 refrigeration integrated heating and cooling (RIHC) system** i.e. a refrigeration system which would provide both the space heating and the cooling to the food cabinets of the store.

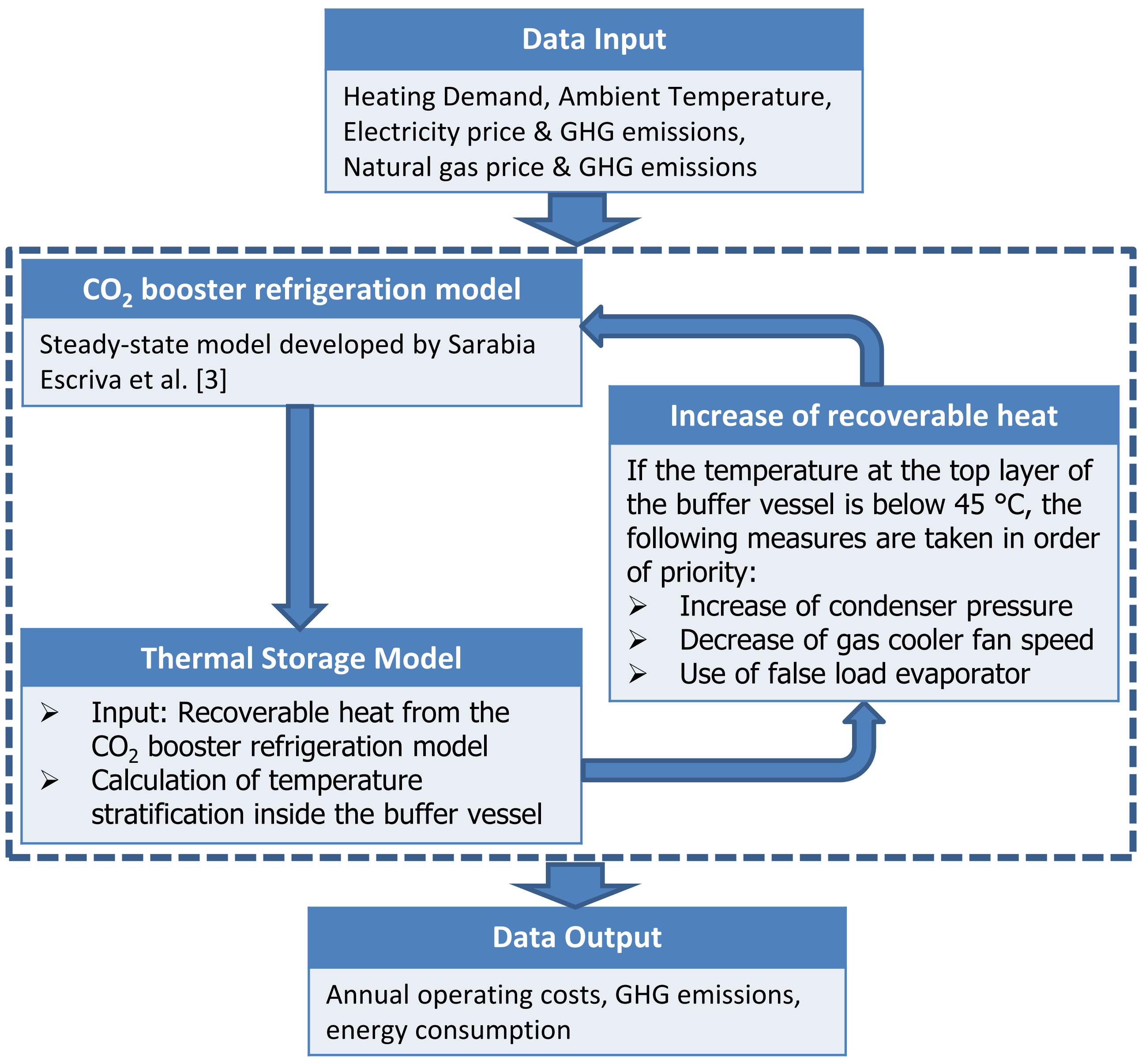
RESEARCH AIM

The aim of this research project was to study the performance of a supermarket RIHC system with thermal storage and evaluate its potential to reduce operating costs and carbon emissions compared to a conventional system for which a gas boiler is used in order to provide the space heating to the store.

METHODOLOGY

A one-dimensional implicit finite difference model was developed in order to simulate a thermal storage system. A buffer vessel filled with water was used as the heat storage device and was discretized into 10 layers for the purposes of this model. The thermal storage model was then integrated into the CO_2 booster refrigeration system developed by Sarabia Escriva et al. [3] to simulate a RIHC system with thermal storage. A timestep of 10 minutes was used for the simulations.

Figure 1 – Schematic of the model structure used to simulate a RIHC system with thermal storage



CONTROL STRATEGIES FOR SPACE HEATING PROVISION

Baseline Case – Gas boiler:

The space heating is provided exclusively by a gas boiler.

Case 1 – Heat Recovery + Gas boiler:

The space heating is provided by using the heat recovered from the heat exchanger of the refrigeration system and a gas boiler for heat supplementation if necessary.

Case 2 - RIHC system without thermal storage:

The space heating was provided exclusively by the refrigeration system directly from the heat exchanger.

Case 3 – RIHC system with thermal storage:

The recoverable heat from the refrigeration system heat exchanger is transferred to a buffer vessel which must always be maintained at a temperature of at least 45 °C in order to provide the required space heating.

Case 4 – RIHC system with thermal storage and a floating condenser pressure for additional heat recovery:

A floating maximum condenser pressure limit for additional heat recovery is employed in order to minimize the energy consumption at each timestep.

Case 5 – RIHC system with thermal storage modified for additional heat accumulation during winter:

Accumulation of heat in the buffer vessel in addition to the amount required to keep it at 45°C in order to reduce the peak recoverable heat requirements from the refrigeration system during winter weekdays.

RESULTS

Figure 2 – Annual Operating Costs

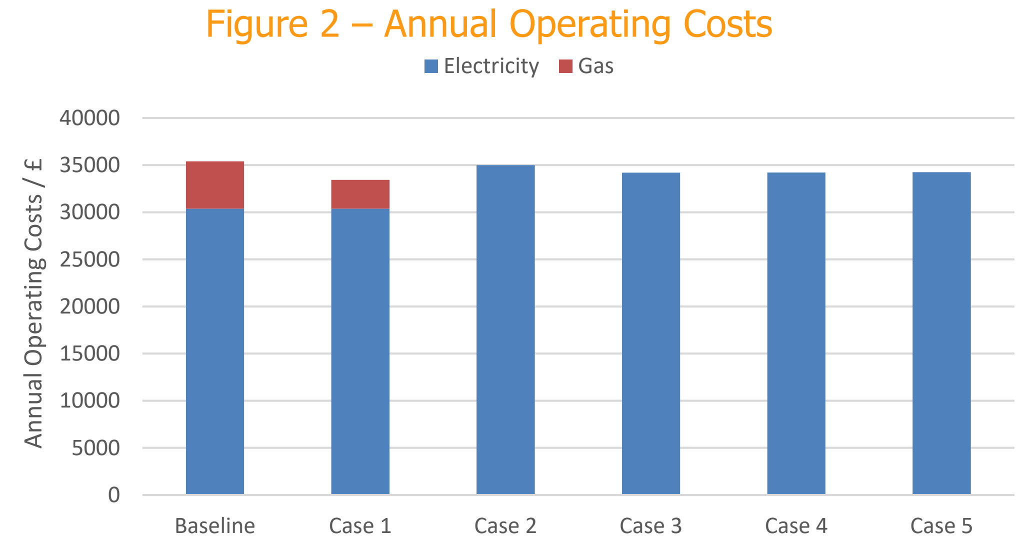


Figure 3 – Annual GHG emissions

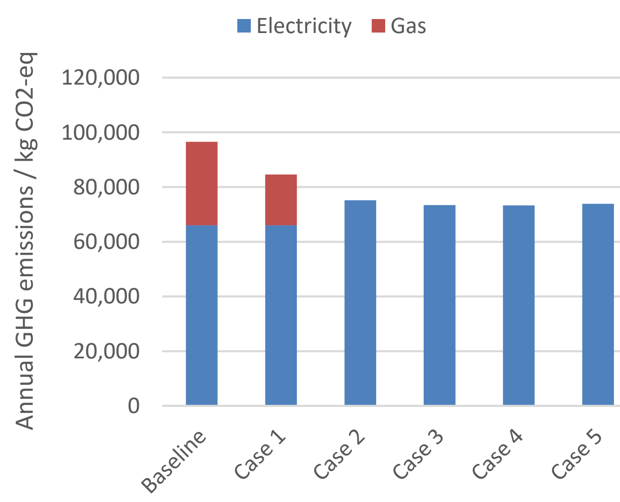
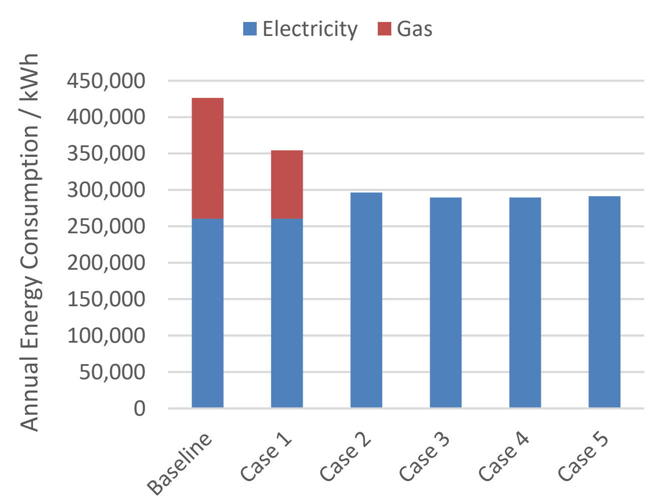


Figure 4 – Annual Energy Consumption



CONCLUSIONS

- A CO_2 refrigeration integrated heating and cooling system with thermal storage is a viable solution for the provision of both the cooling to the food cabinets and the space heating to a supermarket.
- It would lead to an annual increase of operating costs by 3% compared to a conventional heat recovery with a gas boiler solution.
- However, it would also lead to a significant decrease of annual GHG emissions and energy consumption by 13% and 18% respectively compared to a heat recovery with a gas boiler system.
- The selection of the size of the buffer vessel and consequently, the maximum amount of heat that can be stored is constrained by the capacity of the compressors of the refrigeration system.

REFERENCES

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