OPTIMAL MODELLING OF DISTRIBUTED ENERGY SYSTEMS IN THE RETAIL SECTOR

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Background

Combined Heat and Power (CHP) are a widely spread technology that burns natural gas to produce electricity and heat. While they provide good financial returns, they do not help in the context of decarbonisation. These aspects can be improved by coupling with an absorption chiller (ABO), an equipment that would use the waste heat from the CHP to produce refrigeration (Combined Cooling Heat and Power (CCHP)), making it particularly suitable for use in the retail sector. However, a major barrier to their widespread adoption is the lack of confidence from investors.

Aim of Research

- Investigate optimal sizing and operational strategy of CHP and CCHP in order to minimise investment payback period or maximise CO_2 emissions savings
- Compare the two technologies using relevant performance indicators (KPIs)
- Understand how KPIs change with variations in external parameters
- Understand the store conditions that make investment in CHP or CCHP systems viable.

Methodology

A techno-economic model was developed in Python in order to simulate the half-hourly operation of CHP and CCHP systems, with 20 supermarkets in the UK used as a case study to investigate their viability. The store that presented the shortest payback period would then be used as a detailed case study to understand the optimum operational strategy of equipment, as well as to preform the sensitivity analysis. The methodology used in this research is presented in Figure 1.

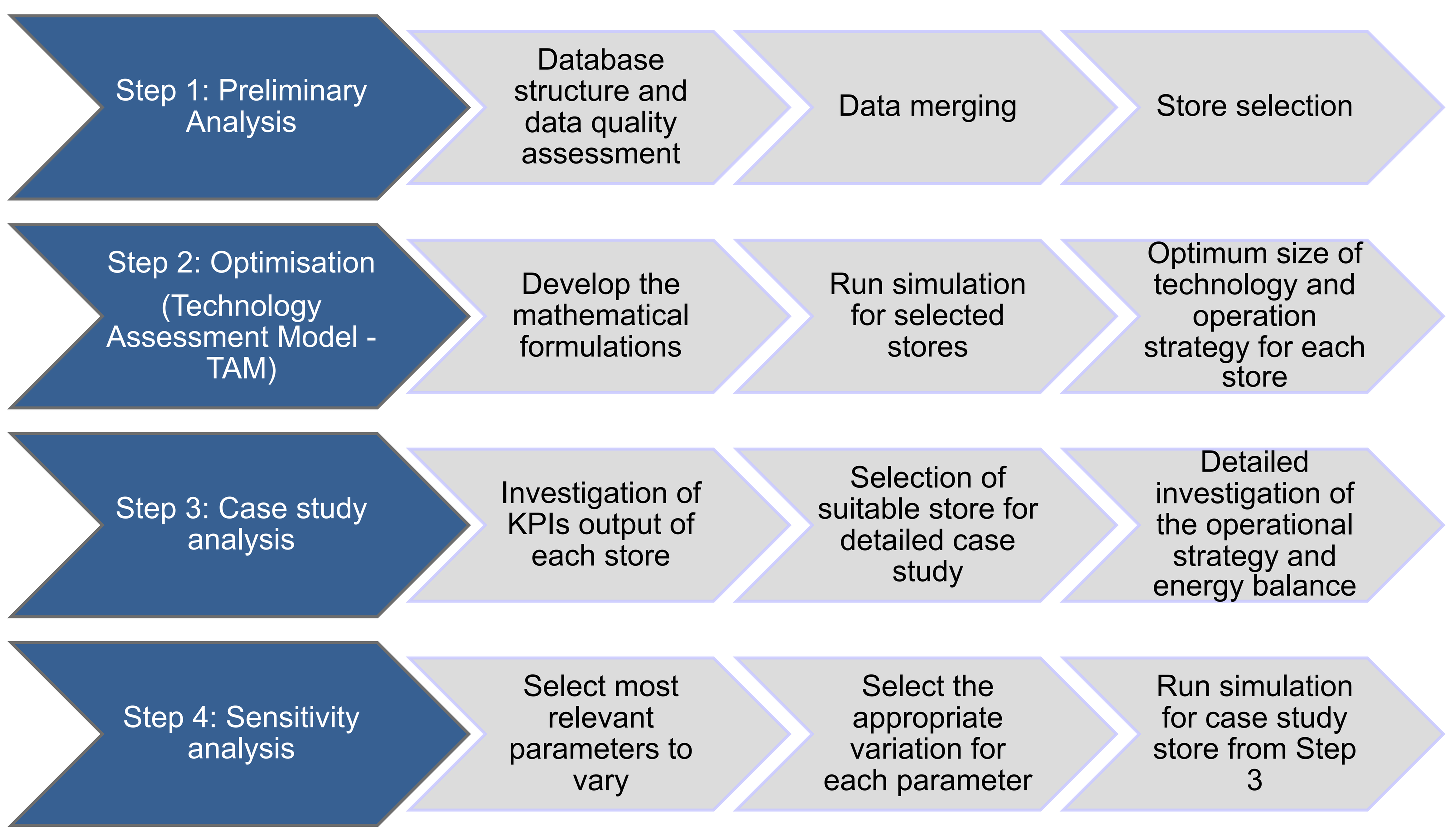

Figure 1: Project methodology

Technology Assessment Model (TAM)

TAM was designed to optimise for two objective functions:

- Minimum investment payback period
- Maximum annual CO_2 savings

Using different technical and store-specific parameters from an extensive database, using real-time electricity tariffs for each region [1], and simulating store operation and energy balance for every half-hour for the duration of one year, TAM selects the optimum size and operational strategy (part-load) of the CHP or CCHP system, in order to meet the specific objective function. Benefits of technology are computed in relation to a business-as-usual (BAU) scenario, when no technology is installed and all energy demand is met from grid imports. It is worth noting that a CHP-only configuration was not designed for CO_2 optimisation, since there are no environmental benefits from this technology. A high level representation of TAM is presented in Figure 2.

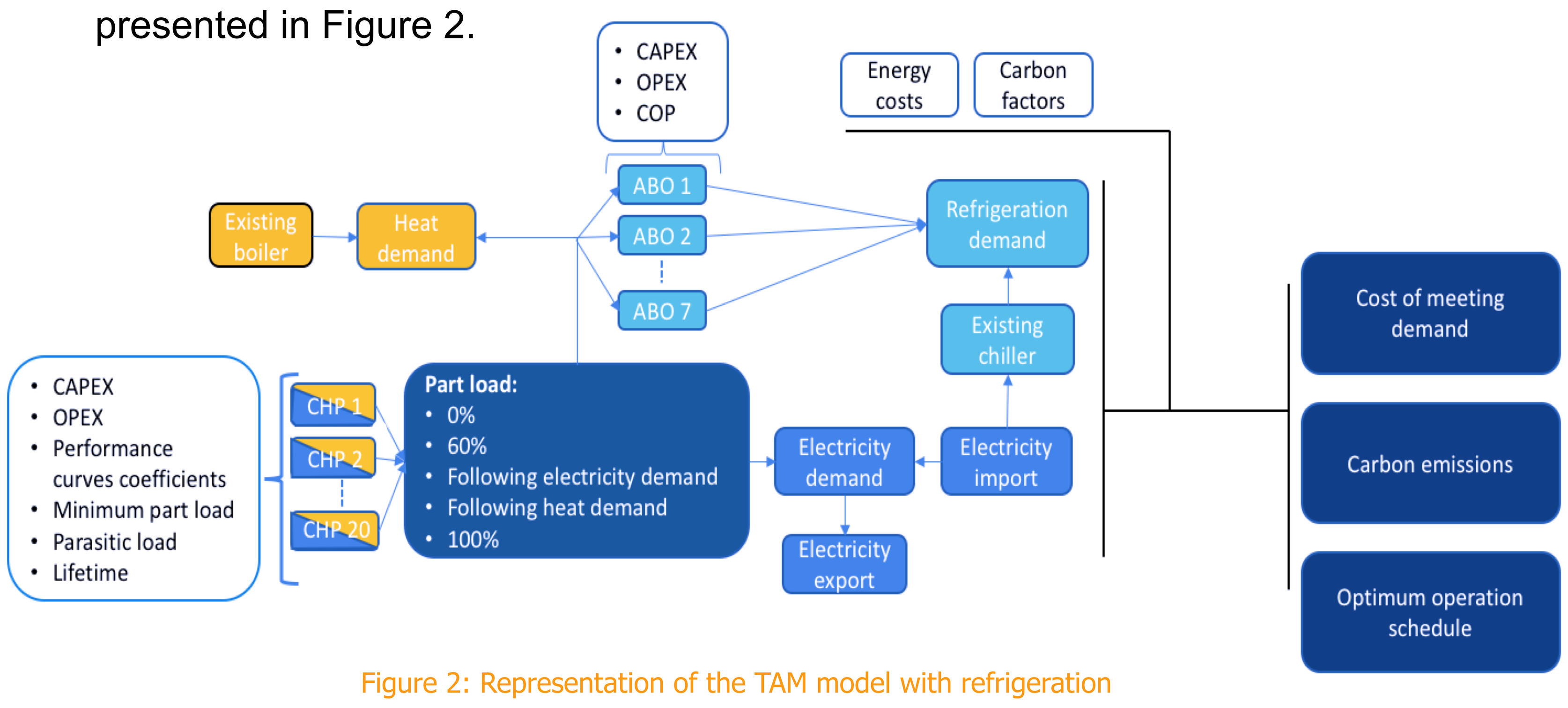

Figure 2: Representation of the TAM model with refrigeration

Results & Discussions

In a CHP-only configuration almost all heat demand is met from production, boiler operation being needed only at times when it is not effective to run the CHP at the minimum part-load (60%). There is a significant amount of waste heat and almost no electricity export, signifying that an electricity demand following strategy is preferable. The case is different when the CHP is coupled with an ABO unit and refrigeration is being considered, in the payback optimisation. A more stable source of cost savings (i.e. electricity, heat and refrigeration) make the CHP operate almost constantly, minimum part-load outside store opening times and generally full load during opening times. Finally, in the CO_2 optimisation, the CHP would be running almost 100% of the time at full-load. Figure 3 shows the daily store cost for one year for the three scenarios under the minimum payback period optimisation. Finally, Figure 4 shows the distribution of payback periods (left) and of CO_2 savings (right) for all the CHP-ABO configurations analysed, under the two optimisations, for the most suitable store.

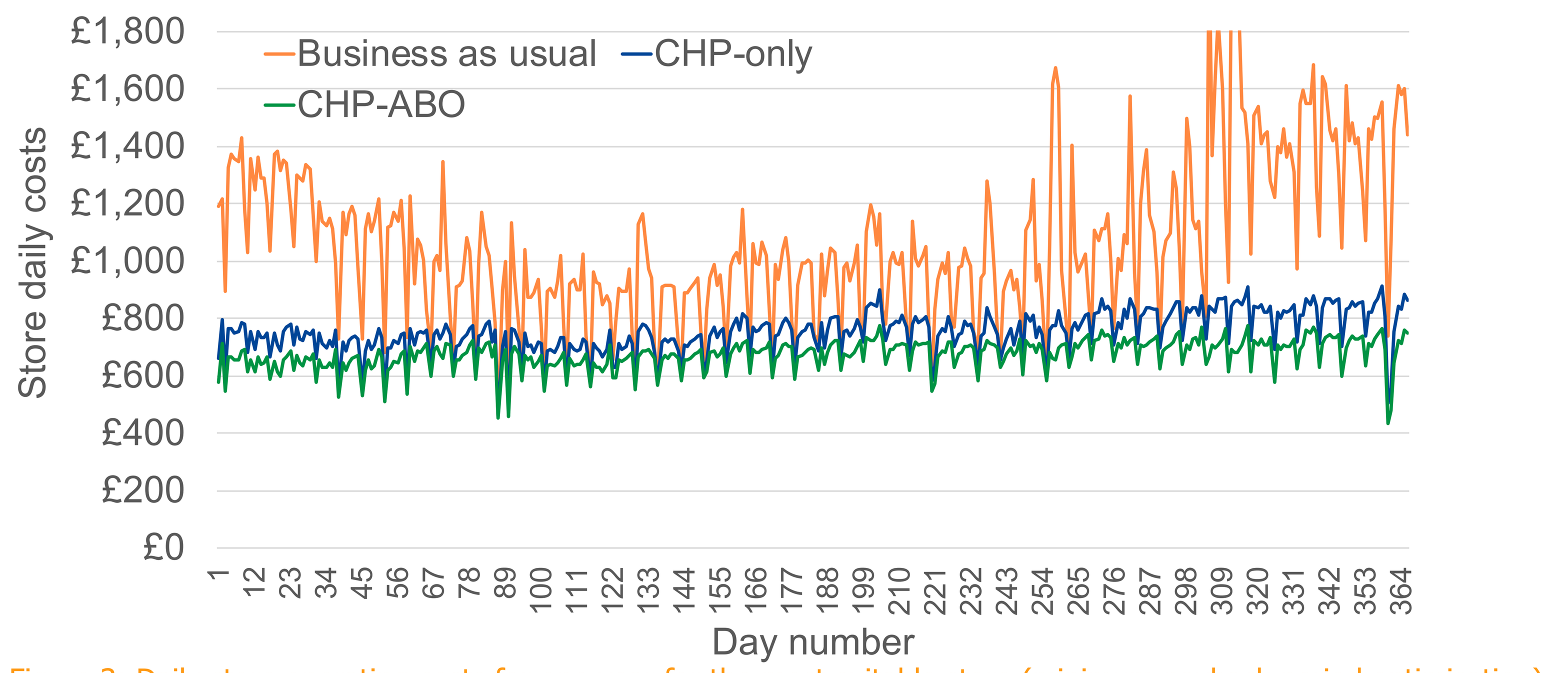

Figure 3: Daily store operating costs for one year for the most suitable store (minimum payback period optimisation)

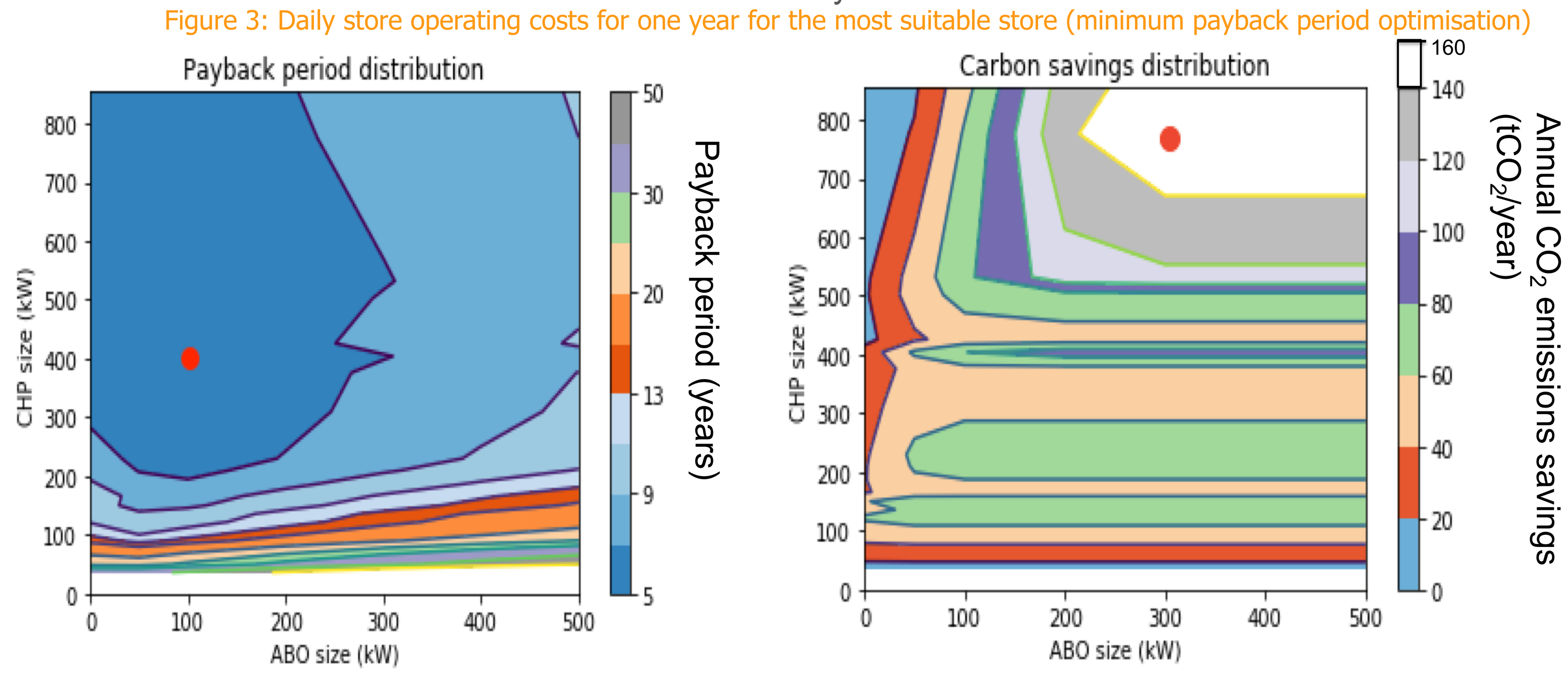

Figure 4: Distribution of optimisation results for less than optimal CHP-ABO configurations for the most suitable store (red dot – optimal configuration from TAM)

Conclusions & Recommendations

- Optimally sized and operated CHP-only configurations can lead to cost savings in the region of 20-35%, with payback periods around 7-9 years, compared to BAU, however increase CO_2 emissions by 0-10%.
- CHP-ABO configurations increase the cost savings from a CHP-only option by 0-7%, have a CAPEX 10-15% higher, and achieve payback periods in the range 5-7 years, while also reducing store emissions by approximately 3% (relative to BAU).
- Optimisation for maximum CO_2 savings results in oversized systems, solutions that are not realistically viable. However, they could be used in a multi-objective optimisation together with the payback period, to provide a better image of the trade-offs.
- When optimised for payback period, a CHP-ABO can meet almost all the electricity and thermal demand of the store, and approximately half the refrigeration.
- Annual cost and carbon savings of CHP-ABO configurations are more resilient to fluctuating energy prices, compared to CHP-only. Additionally, the financial returns of either configuration would not be affected by grid decarbonisation. In both cases, higher upfront costs significantly increase payback periods.
- Heat-to-power (H/P) & refrigeration-to-power (R/P) ratios should not be used alone when trying to assess the viability of a CHP/CCHP system in a building. They should be used together with the annual electricity and refrigeration demands, respectively.
- Shortest payback periods for a CHP-only configuration were found in stores with H/P of 0.4 – 0.8 and above 1,800 MWh(e)/year, and, additionally for an ABO unit, above 1,000 MWh(c)/year.

References

[1] Acha, S. et al. (2016) Modelling Real-Time Pricing of Electricity for Energy Conservation Measures in the UK Commercial Sector. Available at: https://spiral.imperial.ac.uk/bitstream/10044/1/38809/2/Modelling real-time pricing of electricity_Final.pdf (Accessed: 5 August 2018).