

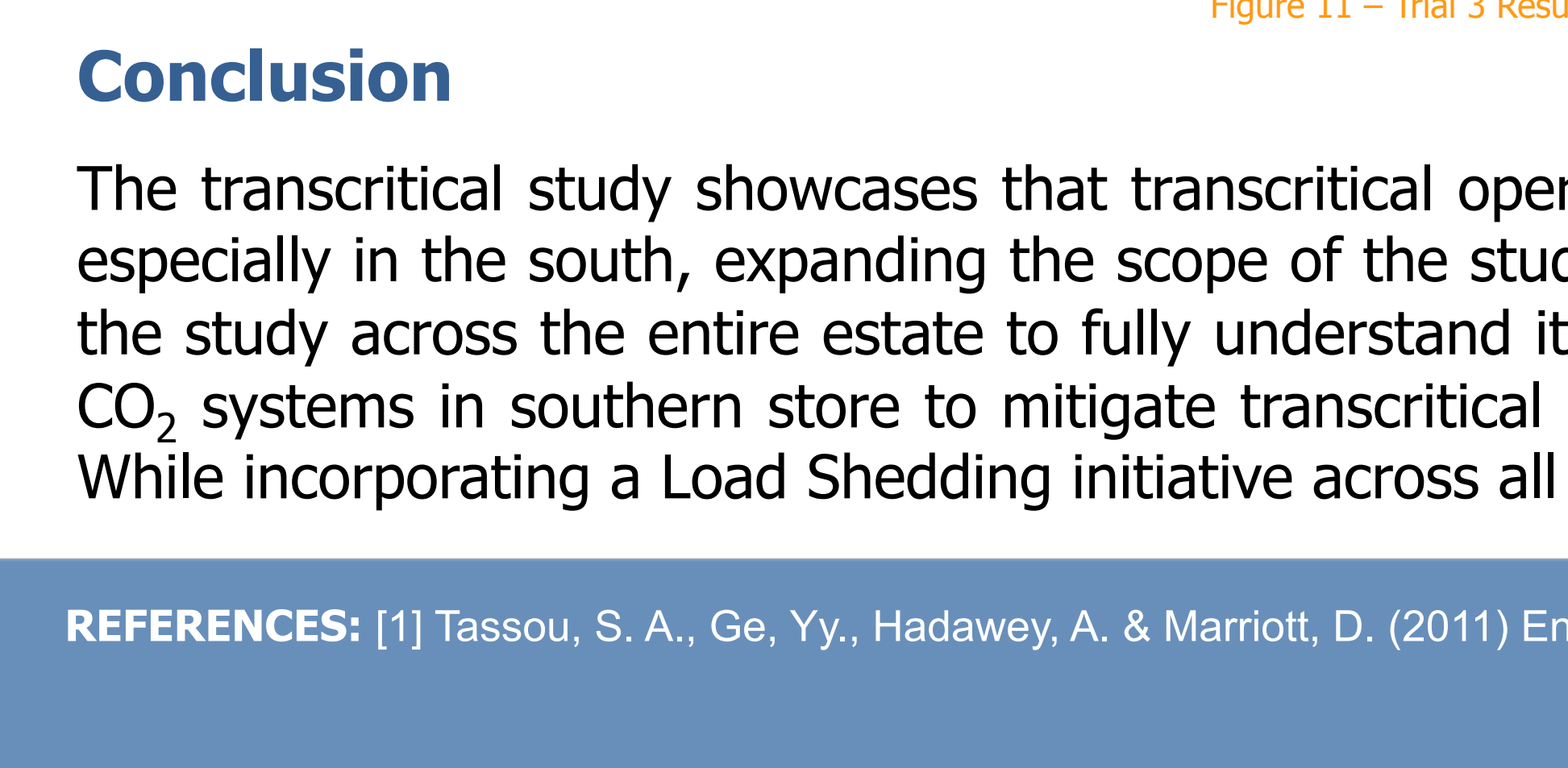
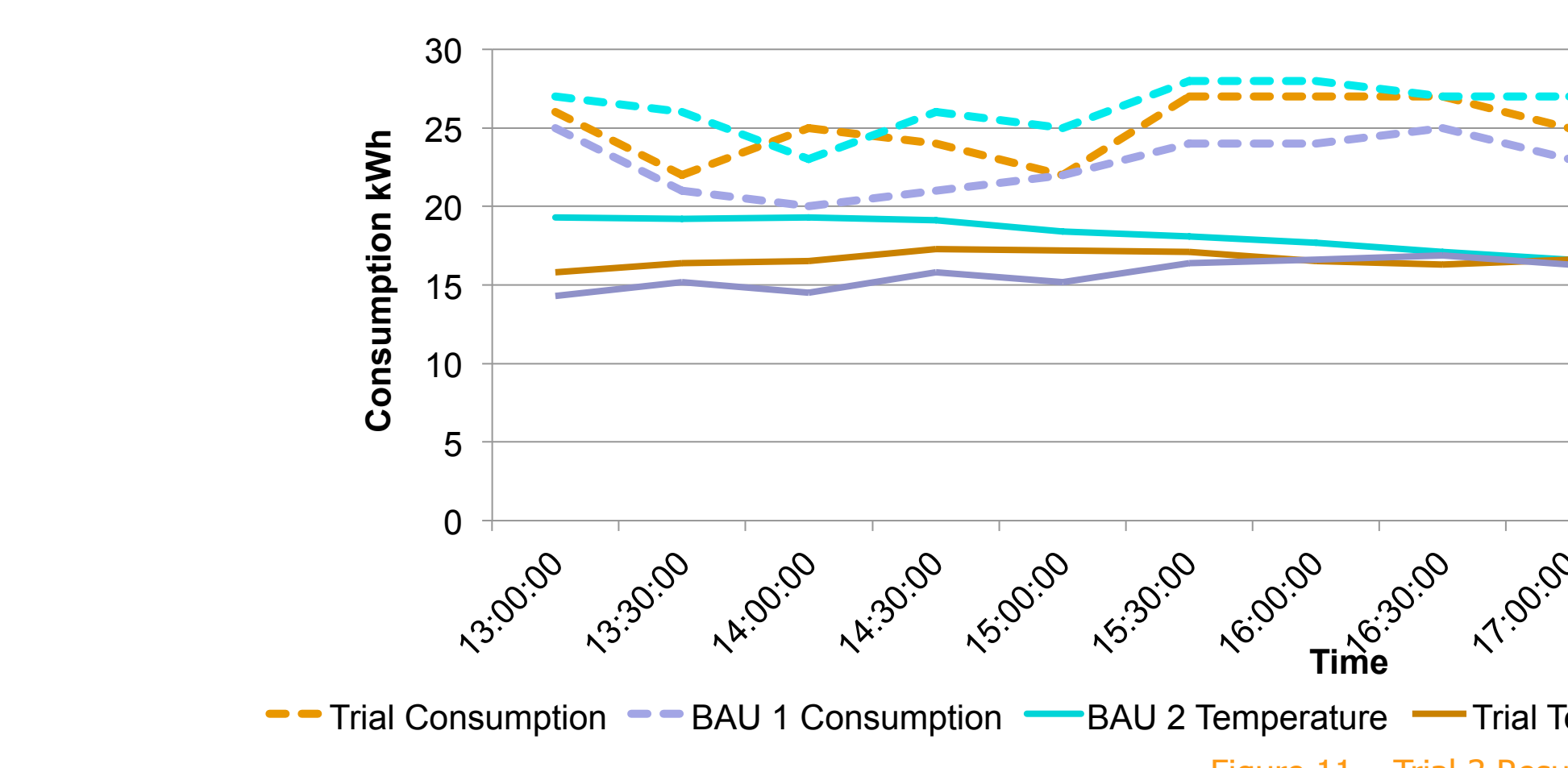
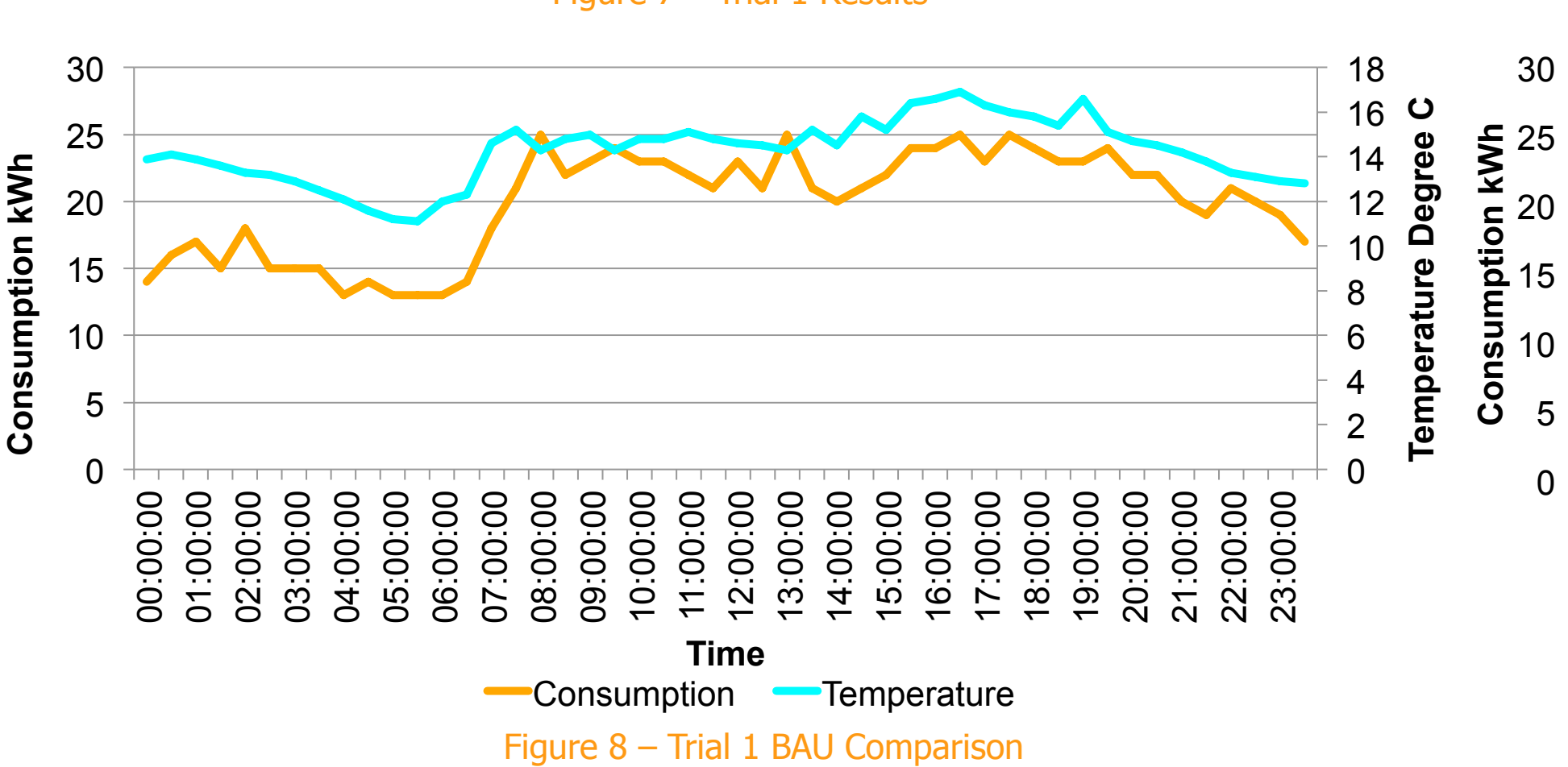
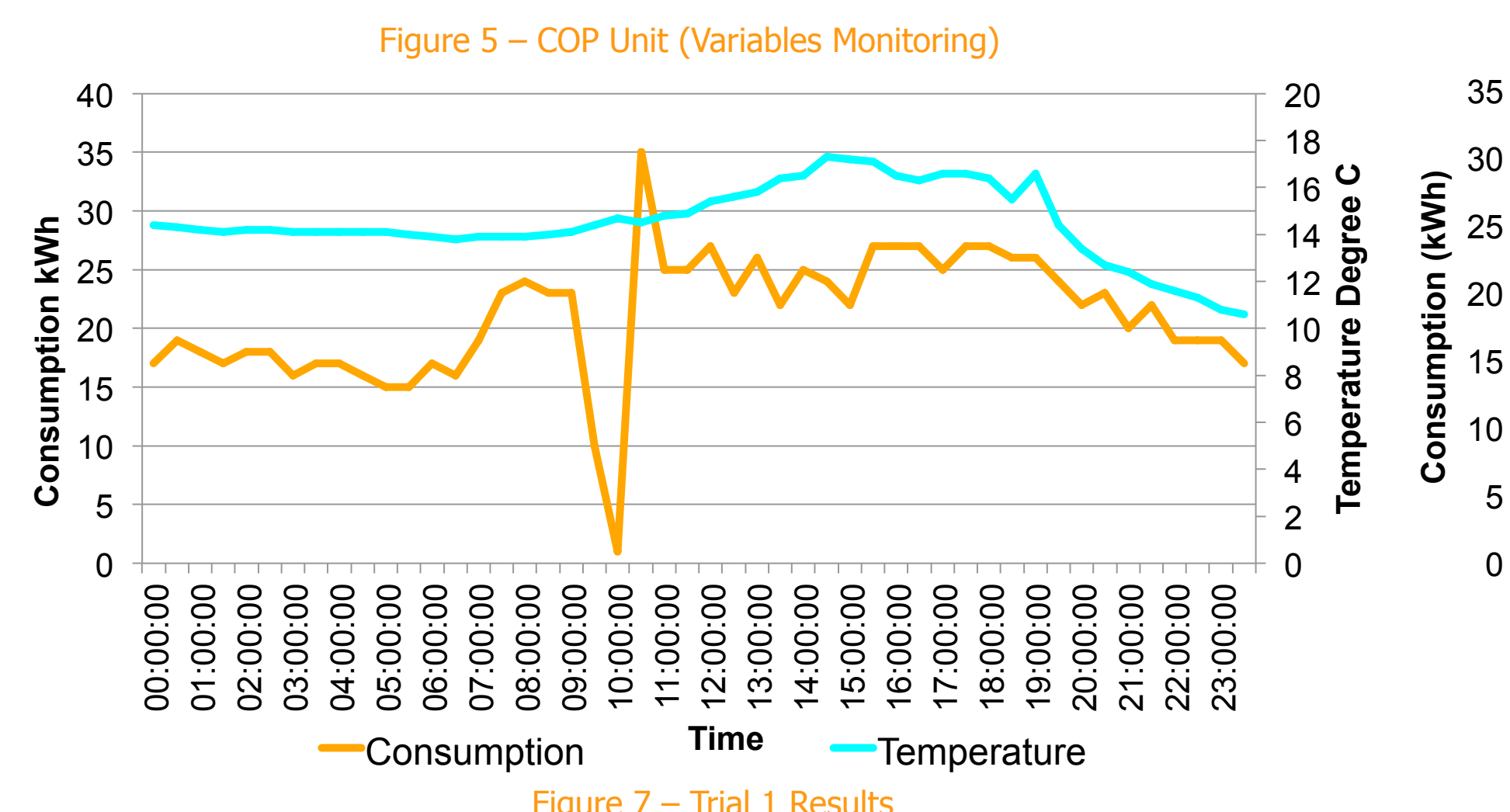
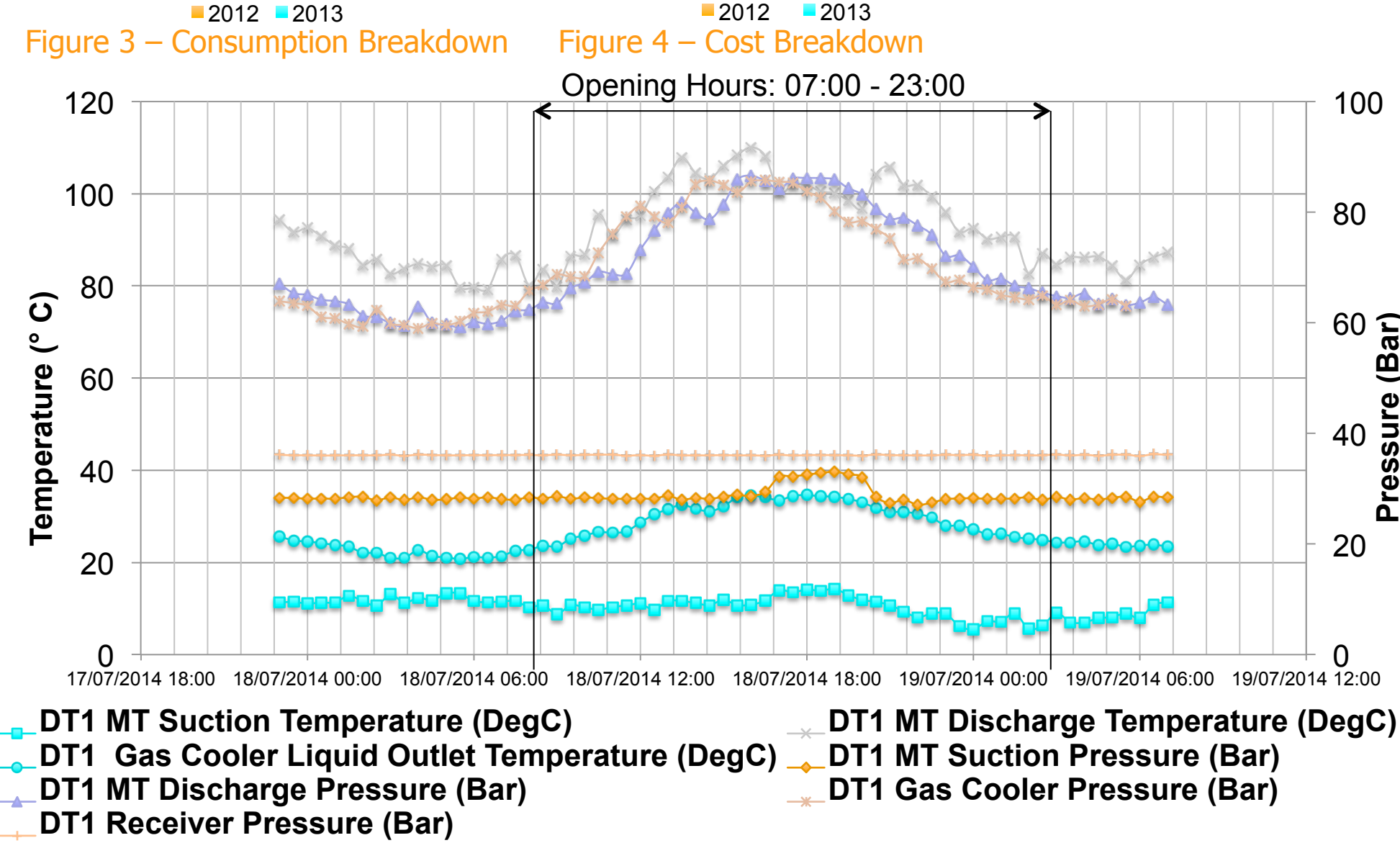
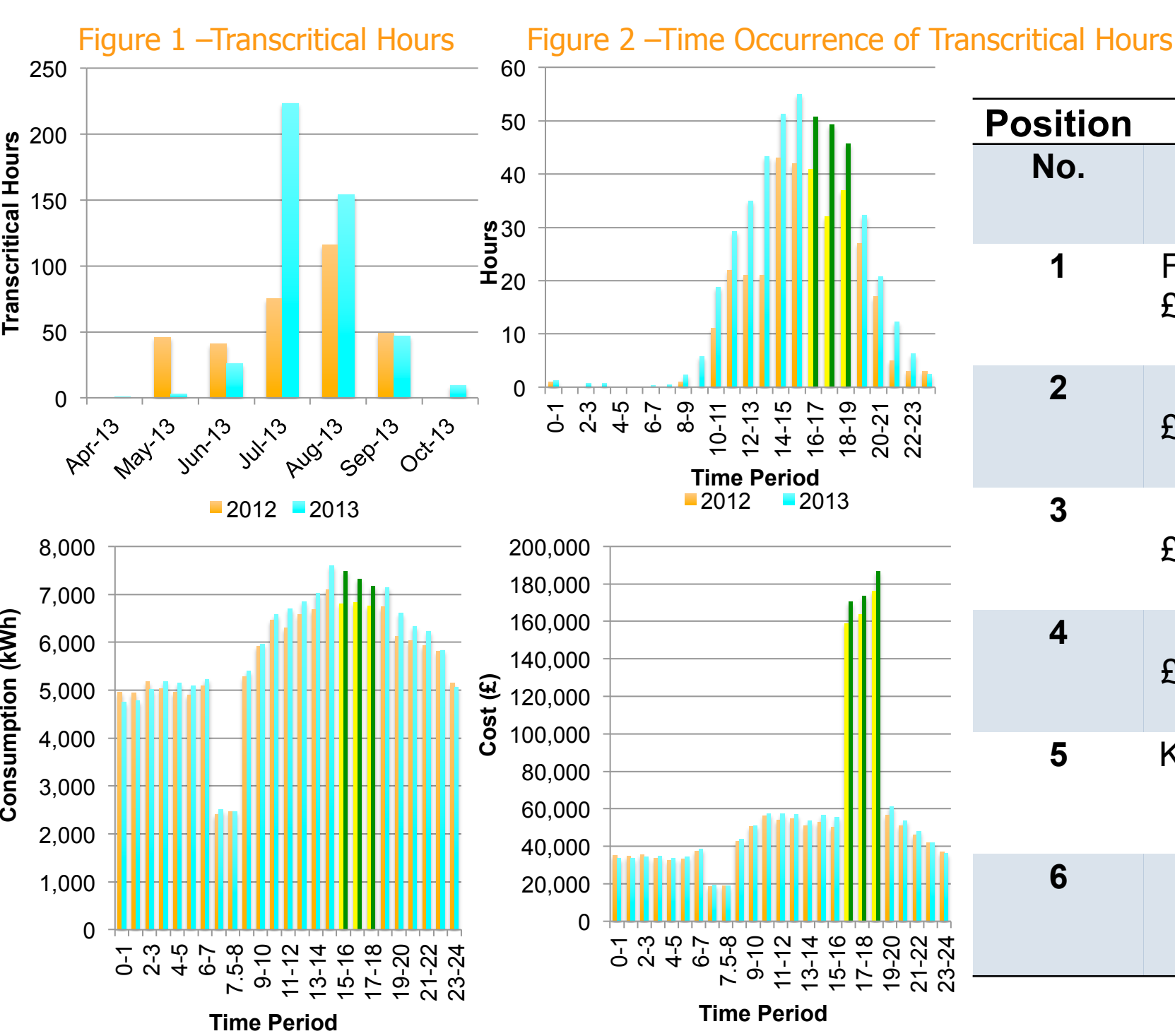
Enhancing the Recommissioning of A Retail Building - Refrigeration

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INTRODUCTION & AIM

Supermarket buildings have a voracious appetite for energy, accounting for roughly 120 TWh_{el} of energy in the UK alone of which refrigeration can account for 50%. Related Greenhouse Gas (GHG) emissions equate to 4 MtCO₂ (1% of the UK's total) [1]. Subsequently Sainsbury's has set out CO₂ reduction goals, a 30% reduction in 2020 and by 50% in 2030. Within this plan the decision has been made to switch to CO₂ refrigeration, offering significant CO₂ savings over older systems, however these systems encounter problems as they run transcritical during periods of warm ambient temperatures, resulting in decreased efficiency and increased energy consumption. Given the proportion of consumption by refrigeration, this is a significant issue.

The goal of this project is to examine the scale of this transcritical issue across a selection of CO₂ stores, examine ways to mitigate its effects via advance control strategies, investigate additional tools that can monitor CO₂ system performance and investigate technologies that could be used in tandem with or alternatively to CO₂ systems that provide consumption benefits.



RESULTS

Position No.	Cost		Transcritical Hours		Consumption		Cost Per Trans. Hour	Size ft ²
	2012	2013	2012	2013	2012	2013		
1	Faversham £3,047,697	King's Lynn £4,817,134	Faversham 837 hours	Faversham 1114.25 hours	Faversham 311,811 kWh	King's Lynn 499,843 kWh	Hythe 141.61 £/hr	King's Lynn 72,196 ft ²
2	Hythe £3,044,047	Carlisle £4,477,201	Stamford 633 hours	Stamford 889 hours	Hythe 303,652 kWh	Carlisle 392,267 kWh	Carlisle 81.06 £/hr	Carlisle 59,069 ft ²
3	Stamford £2,787,681	Faversham £3,124,188	Hythe 316 hours	Hawick 719.25 hours	Stamford 261,721 kWh	Faversham 318,193 kWh	King's Lynn 75.29 £/hr	Hythe 35,759 ft ²
4	Hawick £1,983,457	Stamford £2,882,546	Hawick 290 hours	King's Lynn 645.25 hours	Hawick 199,731 kWh	Hythe 277,027 kWh	Faversham 46.36 £/hr	Faversham 28,396 ft ²
5	King's Lynn N/A	Hythe £2,755,093	King's Lynn N/A	Carlisle 553.25 hours	King's Lynn N/A	Stamford 268,005 kWh	Stamford 40.36 £/hr	Hawick 23,922 ft ²
6	Carlisle N/A	Hawick £2,067,641	Carlisle N/A	Hythe 291.75 hours	Carlisle N/A	Hawick 207,274 kWh	Hawick 35.29 £/hr	Stamford 21,104 ft ²

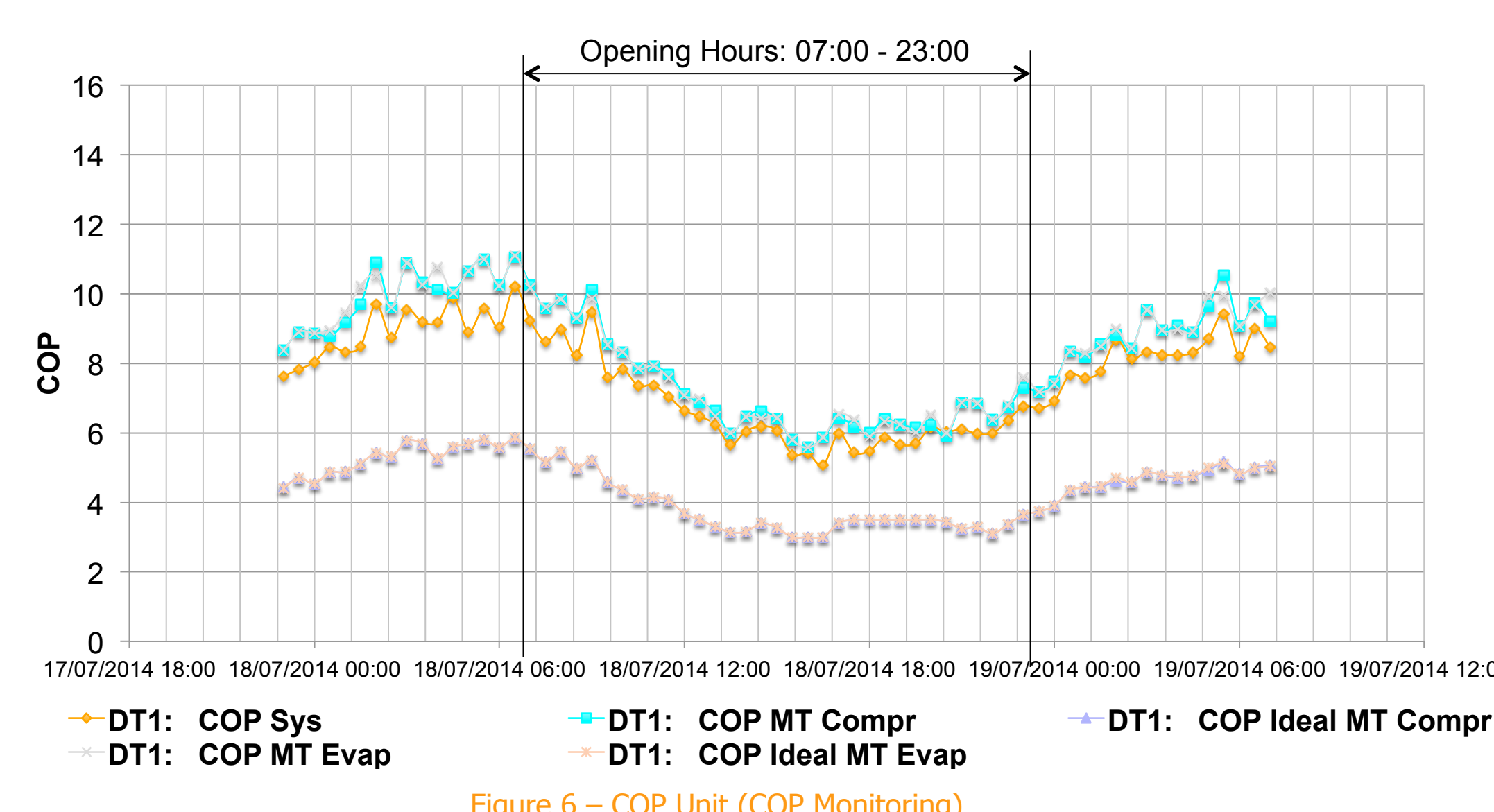
1. Transcritical Study

This study incorporates a range of Sainsbury's stores situated across the UK in order to determine the scale and variation of the transcritical operation with respect to location and ambient weather conditions. Figures 1 – 4, graph results for pack DT1 at Stamford while all stores are ranked according to various criteria in table 1. From observation a number of the apparent trends include:

- Tackling transcritical issues in the more southerly stores would provide the most cost benefit for Sainsbury's.
- Store size affects cost of transcritical operation.
- High proportion of transcritical hours during high DUoS Periods
- Ground Source Heat Pump stores do run transcritical but do help mitigate transcritical operation.

2. COP Monitoring Unit Analysis

The new LM-350 COP monitoring unit from Danfoss in Sainsbury's Leicester North was analysed to determine its suitability in an maintenance and energy management role for refrigeration systems. Figures 5 & 6 showcase some of the variables that it can monitor. Changes in COP can indicate how well the system is running, while variables such as Discharge Pressure can indicate when a system is running transcritical (above 73 Bar). However, it was found that Ideal COP was running lower than running COP, an obvious error with the unit that was reported to Danfoss for investigation.



3. Energy Initiative Trials

Advance control strategies were trialed in an actively trading Sainsbury's store (Leicester North) with the goal of proving that they can reduce consumption and hence be applied during high cost Duos and Triad periods to reduce costs:

- 1. Load Shed** – This involves shutting down pack operation completely in order to save energy. A 45 minute shut down was trialed in store. It was found that load shed over that period saved 68 kWh in energy, see figures 7 & 8. If this initiative was applied to the 2013 Triad charge period, it is estimated £3,272 in electricity, Duos & Triad costs would potentially have been saved in 2013.
- 2. Evaporator Temperature Increase** – Cabinet evaporator temperature set points were increased by 0.5 and 1.0 °C, respectively, over BAU set points for a period of 5 hours each. From analysis of results there was negligible consumption benefit to this initiative (0.5°C - 252 kWh vs. BAU - 256 kWh and 1.0 °C - 267 kWh vs. BAU - 255 kWh). The comparison can be seen in figures 9 & 10.
- 3. Narrow Pack Optimisation (Po) Neutral Zone** – It was thought that narrowing the neutral zone from 4K to 3K would save energy as this would reduce compressor reaction time to temperature changes. From analysis it was deduced that this had negligible consumption benefits as the quantity of stop/start cycles counteracted reduced compressor reaction time (Average Consumption: Trial - 25.46 kWh vs. BAU 1 - 23.08 kWh and BAU 2 26.23 kWh). Figure 11 showcases this result.

4. Qualitative Analysis of Cool Thermal Storage (CTS) and Alternative Refrigeration Technologies

Apart from control strategies, use of technology can help mitigate transcritical issues. These technologies and their suitability for the food retailer are summarised in the table below. It was determined that Phase Change Materials were the most suitable tech and could help mitigate consumption during high DUoS periods and warrants further investigation.

	Maturity	Maintenance	Scalability	Commercial Suitability
Phase Change Materials	Above Average	Good	Good	Good
Magnetic Refrigeration	Average	Average	Average	Average
Metal Hydride Refrigeration	Poor	Good	Average	Average

Table 2

Conclusion

The transcritical study showcases that transcritical operation is a significant problem across the estate, especially in the south, expanding the scope of the study in tandem with the COP unit can help expand the study across the entire estate to fully understand its scale. Incorporating new PCM technology with CO₂ systems in southern store to mitigate transcritical operation could provide significant cost savings. While incorporating a Load Shedding initiative across all stores could significant Triad charge reductions.