Decision support tools for operation improvement of public sector multi-energy systems

Background: The public sector decarbonisation challenge

The UK is the first major economy to pass laws to bring all GHG emissions to net-zero by 2050

The public sector is expected to lead the decarbonisation agenda in the UK

- The public sector **consumes 6%** of the UK's energy supply
- The UK Government spends **over £2billion per annum** on its energy bills
- As the largest public sector organization NHS has committed to a voluntary target of a 50% target by 2025 and NetZero by 2050
- The higher education sector has a voluntary target of a 30% reduction in GHG by 2020/21 and a 50% reduction by 2030

The public sector multi-energy systems: Opportunities for decarbonisation

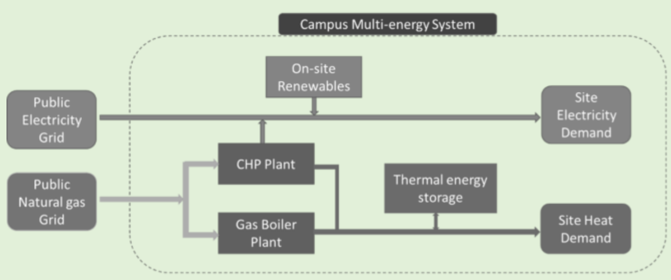


Figure 1. Energy Hub representation of a Campus scale multi-energy system.

The public sector energy systems are large users of power and heat. They typically own and operate their own on-site multi energy systems.

The operation and control strategies of the on-site building energy management systems (BEMS) for the control of energy assets (e.g.: CHP generators, Gas boilers, thermal/battery storage units, etc.) are presently rather simple, usually based on a set of pre-specified rules.

To optimise the import and export of energy, costs and carbon emissions, the operation strategy of the on-site BEMS should consider:

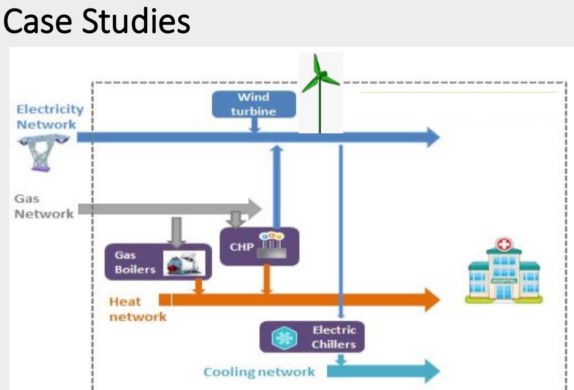
- Half hourly electricity price fluctuations (selling price, buying and distribution charges)
- Forecasts for renewable energy generation
- Forecast for weather conditions
- Estimates of carbon dioxide emissions and
- Opportunities for energy conversion on-site, and the optimal management of energy storage systems considering the synergies between different energy systems

Research Highlights

A practical approach for the operation improvement of campus multi-energy systems was implemented

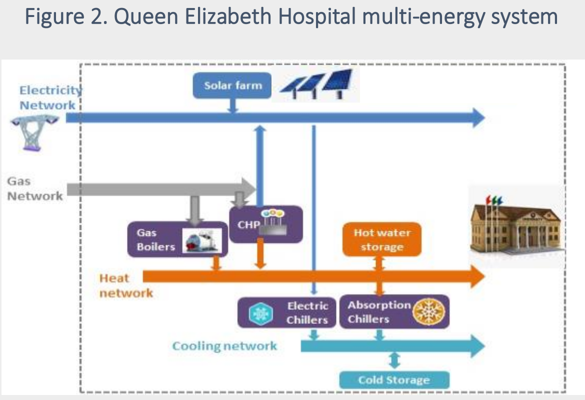
- A methodology for operation optimization of a campus energy system based on real time weather and price fluctuations was developed
- A process to translate optimization results into interpretable code for current BEMS was developed
- A method to create a digital twin which replicate the behavior of a multi-energy systems to test new control rulesets was developed
- Potential savings from implementing new rulesets were demonstrated on two case study multi-energy systems

Case Studies



Queen Elizabeth Hospital (QEH) energy system includes CHP generators, gas boilers and a wind turbine. QEH has a 200kW electricity maximum export connection with the local DNO.

Figure 2. Queen Elizabeth Hospital multi-energy system



University of Warwick (UoW) energy system has CHP generators and gas boilers to supply the heat and electricity demands of the campus. There is no electricity export.

Figure 3. University of Warwick multi-energy system

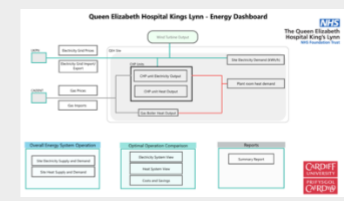
Methodology to improve the operation of public sector Multi-energy Systems

There are 'three' key steps in the methodology

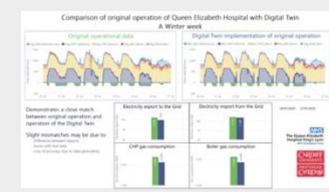
Figure 4. Key steps of the methodology

Outputs

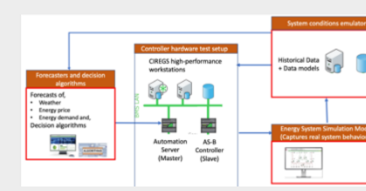
1. Energy dashboard for data-driven insights
→ Quantify potential cost/carbon/energy savings opportunities



2. Digital Twin for non-intrusive testing of new control strategies
→ A (real-time) digital replica of multi-energy system site
→ Collects historical operational data and real-time measurements from the site



3. Improved control rules to achieve the potential savings identified by the optimisation
→ Ability to respond to real-time weather and price forecasts
→ Strategies to improve the lifetime of energy assets



Results

Case study 1:

Table 1: Mismatches between the modelling and optimisation results and the new control rules (the percentage values within the bracket shows the cost saving % compared to the digital twin using existing rules)

Parameters	Digital twin using existing rules	Digital twin using new control rules	Optimisation model
Gas boilers running cost (£)	£175,381	£162,587 (-7%)	£156,639 (-11%)
CHP generators running cost (£)	£325,764	£359,427 (10%)	£372,457 (14%)
Electricity export revenue (£)	-£28,156	-£41,901 (49%)	-£48,609 (73%)
Electricity import cost (£)	£44,666	£15,294 (-66%)	£4,650 (-90%)

12% energy bill saving opportunity was identified compared to actual operation data (Approximately £90.000 per year) from operation optimisation

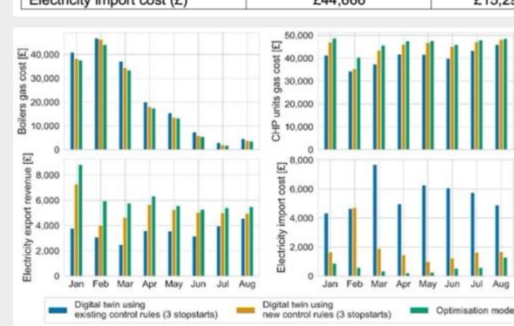


Figure 5. Cost saving opportunities of QEH system

The simulation of the energy system operation of QEH with new control rules demonstrates an improvement in reducing electricity imports, increasing electricity exports, reducing gas boiler use compared to the existing control rules.

Case study 2:

Table 2. Comparison between the operation of Digital Twin with existing control rules, optimisation results and Digital Twin with new control rules (the percentage values within the bracket shows % change compared to the Digital Twin using existing rules).

Parameter	Digital Twin using existing control rules	Optimisation	Digital Twin with new control rules 1	Digital Twin with new control rules 2
Electricity imported (MWh)	16,962 (0%)	7,754 (-54.3%)	16,375 (-3.5%)	16,539 (-2.5%)
CHP generators gas consumption (MWh)	124,771 (0%)	151,079 (+21.1%)	126,449 (+1.3%)	125,979 (+1.0%)
Gas boilers gas consumption (MWh)	14,140 (0%)	10,828 (-23.4%)	13,414 (-5.1%)	13,475 (-4.7%)
Heat dumped (MWh)	250 (0%)	7,812 (+3025%)	267 (+6.8%)	138 (-44.8%)

9.91% energy bill saving opportunity was identified compared to the Digital Twin with existing controls (Approximately £432,290 per year) from operation optimisation

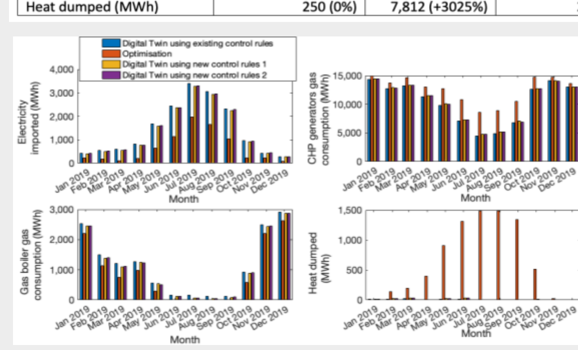


Figure 6. Cost saving opportunities of UoW system

The improvement of the thermal storage operation of UoW was investigated. The results from the simulation show some slight decrease in gas boiler consumption and electricity imported.

Discussion and Conclusions

This research identified gaps between theoretical improvements achieved by optimisation models and their practical applications. A methodology, supported by a set of tools, was developed to fill this gap. Results showed that improvements can be achieved but significant differences remain with the results from optimisation model. The development of forecasting tools combined with the enhancements of BEMS capabilities to operate with more complex rulesets may give opportunities to close this gap.

Acknowledgement

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