Data Centre Refurbishment with the aim of Energy Saving and Achieving Carbon Net Zero

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Abstract. Queen Mary University of London (QMUL) as part of the refurbishment of one of its's data centres will install water to water heat pumps to use the heat produced by the computing servers to provide heat for the university via a district heating system. This will reduce the use of high carbon intensity natural gas heating boilers, replacing them with electricity which has a lower carbon intensity due to the contribution from wind, solar, hydroelectric, nuclear and biomass sources of power sources.

The QMUL GridPP cluster today provides 15PB of storage and over 20K jobs slots mainly devoted to the ATLAS experiment. The data centre that houses the QMUL GridPP cluster, was originally commissioned in 2004. By 2020 it was in significant need of refurbishment. The original design had a maximum power capacity of 200KW, no hot/cold aisle containment, down flow air conditioning units using refrigerant cooling and no raised floor or ceiling plenum.

The main requirements of the refurbishment are: To significantly improve the energy efficiency and reduce the carbon usage of the University; Improve the availability and reliability of the power and cooling; Increase the capacity of the facility to provide for future expansion; Provide a long term home for the GridPP cluster to support the computing needs of the LHC and other new large science experiments (SKA/LSST) into the next decade.

After taking into account the future requirements and likely funding allocation, floor space in the data centre and the space available to house the cooling equipment the following design was chosen: A total power capacity of 390KW with redundant feeds to each rack; 39 racks with an average of 10KW of power per rack (flexible up to 20KW); An enclosed hot aisle design with in row cooling units using water cooling; water to water heat pumps connected to the universities district heating system

An overview of the project, it's status and expected benefits in power and carbon saving are presented.

1 Introduction

The Queen Mary University of London (QMUL) GridPP high throughput computing cluster provides 15PB of storage and over 20K jobs slots and over 220 servers. At full capacity it

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consumes 150KW of power. The original facility that hosts the cluster was built and commissioned in 2004. It was built on a tight budget with compromises and limited knowledge of how to build such a facility. It provided a 200KW facility over 22 shallow depth, open racks. There is no raised floor and no hot/cold air containment. By early 2020 all of the original chillers were broken and a interim solution using 150KW of temporary chillers was installed. This limits the performance and efficiency of the data centre. The racks lack the depth to house modern storage servers.

Requirements for future big science such as the High Luminosity LHC, DUNE, SKA and LSST mean that there is a need to expand and maintain support for the cluster over the next 15 years. Increasing energy costs and man made climate change mean that there is a need to improve the energy efficiency.

It is clear that the data centre needs to be refurnbished and expanded with an aim to improve energy efficiency to support our science requirements for the future.

2 Constraints

Before committing to a refurbishment an alternative option is to move the GridPP cluster to a purpose built remote data centre. This has been done by some other GridPP sites. However, many of the offsite data centres capable of supporting the required power and cooling requirements are full or too expensive, and have increased remote management overheads. This option has not been considered further.

The QMUL Mile End campus is a highly constrained site with protected historic buildings, cemeteries and surrounded by conservation areas, parks and transport links. There is no alternative existing space suitable for a data centre and no space for a new building till after 2030. The only option is to reuse the existing space.

The UK government has imposed a legal requirement for the UK to reach net zero on carbon emissions by 2050. QMUL in response has a heat decarbonisation plan to achieve a 30% reduction in carbon dioxide emissions over the next six years [1]. As a major energy user on campus the data centre refurbishment will need to contribute to the net zero goals of the university.

QMUL has a district heating system linking half the buildings on campus (district heating system are unusual in the UK). Gas fired boilers provide the heating for this system. We can take advantage of this by using the heat from the data centre to reduce the gas used in heating.

Any solution must be affordable with the allocated budget and deliverable within a reasonable time scales.

With these constraints in place a project has been developed as is outlines in the next section.

3 Solution

The final project will see the data centre expanded to 39 racks with an average 10KW per rack, providing 390KW of power and cooling, essentially doubling the size of the original facility. The racks are situated in three rows.

Several ideas to improve energy efficiency in data centres that have informed are design choices are discussed in [2] [3]. To improve the energy efficacy of the cooling we have implemented hot aisle containment with in row cooling units. The device inlet temperature has been raised to 26^{o}C, from 18^{o}C, while the hot aisle will be 41^{o}C. The in row cooling units will use chilled water at 17^{o}C and output warm water at 26^{o}C. The benefits of hot aisle containment are discussed in [4].

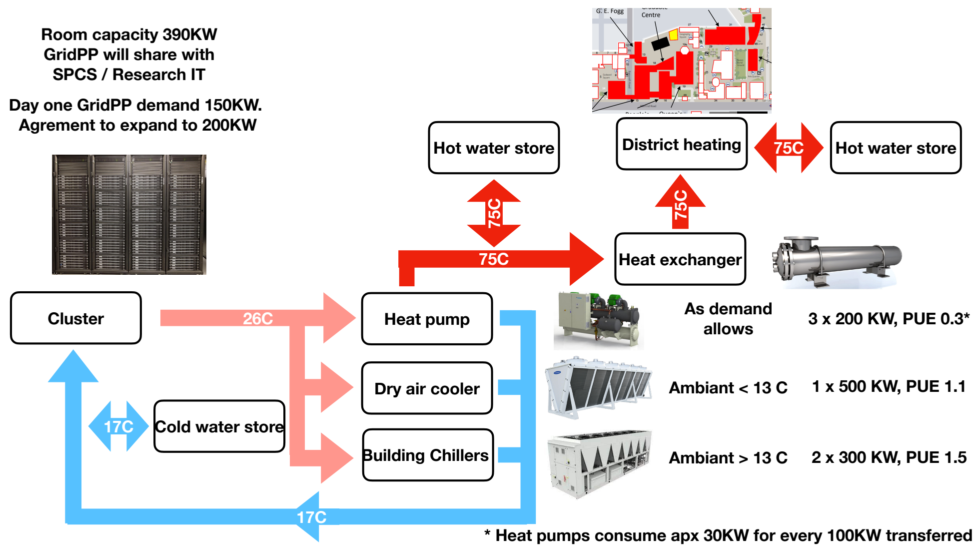

Figure 1. Simplified diagram of the cooling circuit

The warm water output will be chilled by one of three methods as depicted in Figure 1. Heat pumps will raise the warm water temperature to 75^{o}C, a heat exchanger will transfer this to the district heating system where it will provide heating and hot water for several buildings on campus. In order to make efficient use of the hot water supply the district heating system will be upgraded with hot water storage tanks which are expected to be mostly used overnight when demand for heating and hot water is low. In the case where there is not the demand for heating in the district heating system or where there is a fault in the connection. A highly efficient dry air cooler will be able to cool the warm water back to 17^{o}C as long as the ambient temperature is below 13^{o}C. Finally the building chillers will be able cool the the water circuit all year round but are the least energy efficient option.

In additional the data centre will have new flooring, lighting and cable management. New power supplies and distribution with redundant dual 32 amps power feeds per rack will also be installed.

4 Evaluation

In order to understand the cost benefit of the refurbishment and justify the investment required an evaluation of the full project (39 rack, 390KW capacity with heat recovery), compared with a minimal project that would just replace the existing facility (26 racks, 260KW capacity without heat recovery) has been carried out. Best practice was followed by using the UK governments "Green Book" on project appraisal and evaluation in central government [5]. To calculate the carbon and energy savings the supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal was used [6]. From this we are able to obtain an estimate for energy price and electricity carbon intensity for the lifespan of the project.

Table 1 summarises the results of the evaluation. While there is significant extra cost in the full project, approximately £1Million more, the cost savings from the heat recovery mean that the project will pay for itself in 7 years. To understand where the cost savings come from it is important to note the following. 1) In the data centre the heat has already been produced by the computers (doing useful work) the heat is considered as cost free. 2) the cost in transferring this heat to the heating system by the heat pumps consumes an additional 30% more power (e.g. for every 10KW of heat transferred the heat pumps consume an additional 3KW). 3) The data centre would have needed to be cooled, assuming a typical PUE of 1.3, the power used by the heat pumps would have equaled the power used in cooling the data centre. The end result is that heat pumped into the district heating system is essentially free. It should be noted that both solutions will provide energy efficiencies through improved cooling compared with existing facility which are not included in the payback time. Demonstrating the cost saving of the full project was vital to obtain the University funding for the full project.

Table 1. Comparison of cost and benefit of two costed options for the refurbishment of the data centre

Scope	Minimum scheme: No Heat recovery	Full scope: Heat recovery and dry air cooler
Racks	26	39
Cooling capacity (KW)	260	390
District heating connection	NO	YES
Indicative cost (UKP)	1.5M	2.5M
15 Year carbon saving at 2/3 capacity (Metric Tons CO_2)	0	8172
Pay back (years)	NA	7

As well as cost saving from using heat recovery, Table 1 also shows that the full project will produce a carbon saving. Figure 2 show the carbon intensity of UK electricity. Historically the majority of UK electricity was generated from coal. More recently coal has been replaced by natural gas which resulted in a significant drop in CO_2 emissions. Typically by 2023 40 to 50% of electricity production in the UK is from low carbon sources (nuclear, wind hydro, biomass, solar) [7]. Low carbon electricity production is expected to increase significantly over the next ten years. From the data in Figure 2 we are able to estimate that the project will deliver a carbon saving of over 8000 Metric tonnes of CO_2. To put this into context this is the equivalent of charging your mobile phone one billion times or planting 135,125 trees for 10 years (also known as carbon offset) [8]

5 Summary

The refurbishment project of the data centre that hosts the QMUL GridPP cluster has been funded by the university and is expected to be completed by March 2024. The project will double the capacity of the data centre while significantly improving the energy efficiency and will contribute to the universities decarbonisation plan. Future developments that will enhance energy efficacy and heat recovery include extending the district heating system to include the student accommodation and replacing the existing building chillers, which are 15 years old, with newer, more energy efficient units. Once the benefits of the project have been proven the building of a new, larger, facility maybe possible with a potential expansion of the district heating system to a neighbouring local hospital.

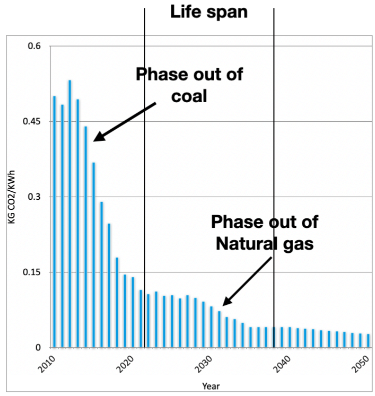

Figure 2. Carbon intensity of UK electricity production, measured and predicted, in KG of CO_2 per KW hour. For comparison the carbon intensity of natural gas in the UK is 0.18 [6]

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