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Research Paper

Using data centres for combined heating and cooling: An investigation for London

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HIGHLIGHTS

- Data centres are very large energy consumers and consequently large carbon emitters.
- Data centres require cooling and usually reject heat to their surroundings.
- Data centre waste heat should be considered a resource and recovered and reused.
- Waste heat temperatures are usually low, but can be boosted using heat pumps.
- District heating is a promising reuse application for data centre waste heat.

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ABSTRACT

Data centres consist of data halls, or buildings, containing rows of IT server racks, which are used to store, process and transmit information from connected computer networks. There are estimated to be more than 2 million server racks in the UK. Data centres are large energy users, being currently responsible for at least 1.5% of the electricity demand for the whole of the UK and with increased internet use this is projected to grow by up to 20% per year up to 2020. Electricity is used both to power the IT servers and for the cooling equipment, such as air conditioning systems, which are used to remove the heat generated by the IT servers. This heat is normally discharged to the ambient air; however, if the heat could be recovered and reused, it would represent a significant heat resource. This paper describes the range of approaches available for the cooling of IT servers and their potential for waste heat recovery and reuse. One waste heat recovery application that has been recently proposed, for example by the UK's Department of Energy and Climate Change (DECC), is as a heat source for district heating networks. The use of heat pumps to boost the temperature of the waste heat rejected by data centres, in order to meet the heat input requirements for heat networks is explored in this paper, and the potential energy, carbon and cost savings available are presented. The matching of potential data centre waste heat sources to the heat requirements for a number of London districts is also reported.

1. Introduction

Globally data centres are estimated to consume between 1.1 and 1.5% of the world's total electricity supply, while for the US electricity consumption for data centres is estimated to be between 1.7 and 2.2% of the total [1]. Worldwide carbon dioxide equivalent (CO_2e) emissions from ICT have been estimated to amount to 2%, of which approximately 25% are due to data centres [2]. If a value of 1.5% of total electricity consumption is assumed for the UK, this would result in 2×10^6 tonnes of CO_2e emissions, from the electricity generation alone. It has been predicted that growth in the data centre market in the future will lead to annual increases in power demand of 15–20% [3], with a corresponding increase in carbon emissions. This highlights the need for significant improvements in data centre operating efficiency. The main options for increasing data centre efficiency and reducing carbon emissions are:

(i) to develop new high capacity, low power microprocessors
(ii) to improve IT work efficiency
(iii) to use renewable energy
(iv) to improve data centre cooling efficiency
(v) to recover and reuse waste heat from data centres

Constantly improving computer processor performance in line with Moore's Law [4] which predicts a doubling of the number of transistors per unit area on the processor every two years, has been

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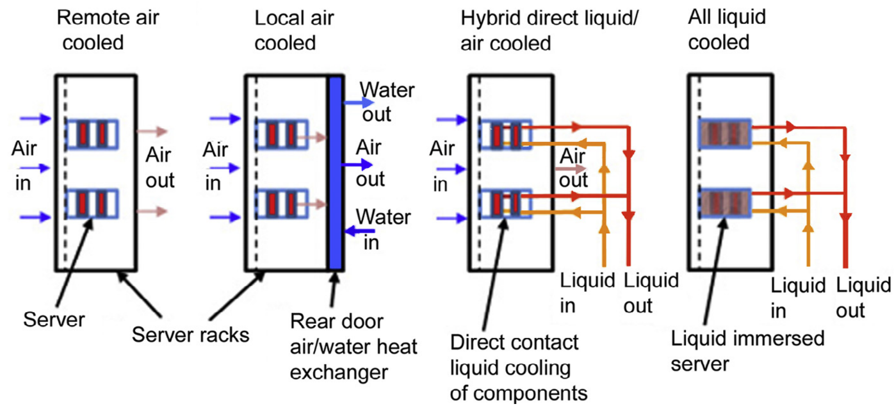

Fig. 1. Data centre cooling approaches.

one of the main reasons that the IT industry has been able to maintain its rate of growth over the last 50 years. Recent efforts to decrease power usage by microprocessors [5] have permitted microprocessor speeds and performance to increase, while slowing the rate of growth in power usage by IT equipment e.g. data centres.

Many IT servers operate at very low IT workloads e.g. 10% or less [6], which provides substantial capacity to cope with sudden increases in demand such as peak IT loads, however, for much of the time the servers are powered but idle, which is inefficient. A number of recent improvements such as consolidation and virtualisation of servers, however, permit much higher IT workloads e.g. up to 50% utilisation [7], which significantly improves IT efficiency.

The use of renewable energy for data centres offers the potential for large savings in both grid energy and carbon emissions. However, its effectiveness generally depends on the data centre location [8,9], for example the effect of local environmental conditions e.g. ambient temperature and humidity, and the availability of renewable resources such as solar, wind, geothermal or hydroelectric energy.

However, the current paper focuses on the last two options for improving data centre efficiency listed above, namely improving data centre cooling efficiency and recovering and reusing waste heat from data centres. The main approaches to data centre cooling are described below, and a number of options for recovering waste heat, including the boosting of waste heat temperatures using heat pumps are evaluated, in terms of the relative savings in energy and carbon emissions. The potential for reusing data centre waste heat as a source for district heating networks is considered, focussing particularly on the potential for supplying heat to the new heat networks that have been proposed for London [10].

2. Currently available options for data centre cooling

All of the electricity used by data centres is ultimately converted into heat, and needs to be removed, to ensure that the recommended data centre operating temperatures are not exceeded [11]. The most common data centre cooling method used at present is to use computer room air conditioners (CRACs), or computer room air handlers (CRAHs), together with chilled water. The cooling units are located within the data centre room, but are placed remotely to the IT servers, and therefore need to refrigerate the air for the entire room. Within the data centre room, the racks holding the IT servers are arranged in rows, usually in alternate hot and cold aisles, with chilled air being delivered to the cold aisles from beneath a raised floor. The warm air exiting the racks into the hot aisles is then recirculated to the CRAC/CRAH cooling units. The use of refrigerated air cooling can be very energy intensive accounting for up to 40% of the total electricity used by data centres [12]. In recent years efforts have been made to substantially reduce energy use by data centres by the application of alternative cooling methods, which can substantially reduce the energy used by air cooled data centres. These include: (i) the use of hot aisle and cold aisle containment methods (to prevent mixing of the hot and cold airstreams i.e. recirculation and bypass); (ii) the use of “free” (i.e. fresh) air cooling; and (iii) direct and indirect evaporative cooling of the incoming air.

An alternative cooling approach is to use local, or close coupled, air cooling methods. These include rack, in-row and rear door water cooling. In this case, the electronics are still air cooled, but heat is transferred to the cooling system much closer to the server racks, for example by means of a chilled water heat exchanger. This removes the need to cool the whole of the data centre room, which provides some efficiency gains. Another approach is to use direct liquid cooling using either water, dielectric or refrigerant fluids. This generally involves cooling only the hottest server components, such as the processors and memory chips, while the remaining lower temperature components are cooled using air. It is also possible to use all liquid cooling by totally immersing the server boards in dielectric fluid. Both one and two-phase liquid cooling systems are available. These new cooling systems are effective and require significantly less operating energy than conventional cooling systems. The different cooling approaches differ, however, in terms of the grade i.e. temperature of the waste heat generated.

A schematic summarizing the four main cooling approaches is shown in Fig. 1.

3. Waste heat from data centres

A range of waste heat recovery technologies with potential for application to data centres have been reviewed [3]. Possible uses include: (a) domestic space and water heating; (b) district heating networks; (c) organic Rankine cycle; (d) absorption chillers; (e) desalination; (f) biomass processing; (g) piezoelectrics; (h) thermoelectrics.

The simplest and probably the most efficient method of using waste heat from air cooled data centres at present is for building e.g. domestic, space and water heating. Waste heat recovered from the data centre air at e.g. 30–40 °C, can often be used directly, while lower temperature heat recovered from chilled water can be boosted using heat pumps [13]. Drawbacks include the fact that the ability to use the data centre heat by the building housing the data centre, or adjacent buildings, may be limited. A more flexible method of using data centre waste heat for space and water heating, with a steadier demand, is as a heat source for district heating. This is the main focus of the present research and will be discussed in detail later.