# *IMPACTS OF DEMAND RESPONSE AND SURPLUS HEAT RECOVERY IN DATA CENTRES ON THE DANISH ENERGY SYSTEM*

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## Overview

**Data centre electricity demand is expected to boom in the coming years.** Data centres are estimated to have consumed 200-250 TWh in 2020, equivalent to about 1% of global electricity demand [1]. This consumption has remained relatively stable over the last decade as energy efficiency measures have offset the impact of growing demand. However, it is uncertain how long this trend can continue [2,3]. It is estimated that data centre electricity consumption in the European Union will increase by 28%, from 76.8 TWh to 98.5 TWh, in 2018-2030 [4].

**This rise in energy demand is likely to hinder energy transition efforts, with very practical risks at national and regional levels due to the geographically clustered development of this industry.** Countries such as Denmark, recently ranked as the “best location for data centres” [5], offer the right conditions to attract large data centres and are currently facing rapid development of them [6]. For instance, Apple, Facebook, and Google have opened large MW-scale premises since 2019, with plans to expand them further in the coming years [5,7]. As a result, Danish data centre energy use is expected to grow from 0.88 TWh to 8.8 TWh in 2020-2030, reaching about 15% of national electricity demand by the end of the period [8]. This situation creates unprecedented needs to expand electricity supply and reinforce electricity grids [6] that might jeopardise the achievement of current energy transition targets. The Danish parliament has committed to reaching carbon neutrality by 2050, a 55% share of renewable energy by 2030, and a non-fossil district heating supply of 90% as early as 2030 [9,10].

**Despite this sustainability risk, data centres offer new, previously overlooked opportunities to support the transition**. The smart integration of data centres into electricity systems offering flexibility services via energy storage and into district heating systems by recovering surplus heat would actively support the least-cost energy transformation of both systems and bring new benefits to data centre operators [11]. On the demand side, data centres equipped with thermal storage can modulate the consumption of their cooling systems, bringing benefits such as further integration of non-dispatchable energy sources and cost savings by displacing peak generators. On the generation side, facilities equipped with heat pumps could feed surplus heat into the district heating network, helping to reduce costs and further decarbonise the heat supply. In any case, the potential of these measures depends on data centre features like proximity to district heating networks and cooling technology, among others.

**This article aims to quantify the economic, environmental, and technical impacts of integrated data centres providing surplus heat and demand response, taking Denmark as a case study.** This research aims to inform energy planners and policymakers of the conditions under which today’s fastest-growing economic sector can become a player in the transition and contribute to reaching our decarbonisation targets.

## Methods

**This study utilises the Balmorel energy system model, allowing a bottom-up cost-minimisation of both electricity and district heating sectors** [12]. This article also builds on past studies that integrated additional sectors in the model, such as hydrogen production and electric cars [13], allowing a representation of the current main dynamics at play in the region. The present study further develops and extends the model to represent data centres as independent actors, with a portfolio of investment opportunities in cooling and thermal storage units to enable demand response, and heat pumps to surplus heat recovery. The model represents the energy systems of Denmark and its neighbours (Germany, Norway, and Sweden). The energy demand of data centres in Denmark is estimated using current forecasts from the Danish Energy Agency based on known data centre projects in the pipeline [8,14]. Several scenarios are developed based on technologies allowed in the data centre portfolio to analyse the individual potential benefits of demand response, surplus heat recovery, and the synergies between the two.

## Results

For each scenario, our results show the energy generation mix, capital and operating costs for generation and transmission, and carbon emissions. Based on these results, the impact of data centres is assessed by analysing displaced heat and electricity generation, cost savings from deferred investment and avoided operation of peaking generators, the level of investment and operational use of equipment integrated into data centres, and the reduction in carbon footprint associated with data centres. Preliminary results show that data centre integration impacts the Danish energy system compared to a business-as-usual scenario where data centres remain passive. We observe substantial reallocation of investments from traditional energy infrastructure to data centre equipment and a significant contribution from surplus heat in district heating. The results also highlight the extent to which integrated data centres accelerate the shift to renewable energy sources and the fulfilment of climate targets.

## Conclusions

The expected rapid development of the data centre industry poses a challenge to the Danish energy transition. Nevertheless, data centres can become a valuable interface to exploit synergies between the electricity and district heating sectors, whereby combined demand response and surplus heat recovery facilitate the adoption of un-dispatchable renewable energy sources and the provision of low-carbon heat. In this manner, data centres could actively reduce their carbon footprint, supporting a low-carbon digitalisation of our society and economy.

The methods and results shown in this article are not only relevant to Denmark but to any region facing a sharp increase in the deployment of large data centres or any other industry showing a similar structure of electricity demand and excess heat production. The relevance of investments in flexibility and surplus heat measures is examined in terms of their relative impact on the Danish system as a whole. The degree of adoption of these investments is also discussed based on the types of data centres that apply them. This article expects to shed light on effectively extending energy sustainability challenges within an industry to the overall energy system and the rest of the economy. In addition, the results of the alternative scenarios will help identify which data centre demand parameters have the most significant impact and should therefore be better represented and further investigated. Finally, the model will serve as a platform for future work to test policies promoting data centre integration.

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