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Data center design and location: Consequences for electricity use and greenhouse-gas emissions

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ABSTRACT

The rapidly increasing electricity demand for data center operation has motivated efforts to better understand current data center energy use and to identify strategies that reduce the environmental impact of these buildings. This paper builds on previous data center energy modeling efforts by characterizing local climate and mechanical equipment differences among data centers and then evaluating their consequences for building energy use. Cities in the United States with significant data center activity are identified. Representative climate conditions for these cities are applied to data center energy models for several different prototypical space types. Results indicate that widespread, effective economizer use in data centers could reduce energy demand for data centers by about 20–25%, equivalent to an energy efficiency resource in the US of ~13–17 billion kWh per year. Almost half of the potential savings would result from better airflow management and proper control sequences. The total energy savings potential of economizers, although substantial, is constrained by their limited potential for use in server closets and server rooms, which together are estimated to account for about 30% of all data center energy demand. Incorporating economizer use into the mechanical systems of larger data centers would increase the variation in energy efficiency among geographic regions, indicating that as data center buildings become more energy efficient, their locations will have an increasing effect on overall energy demand. Differences among regions become even more important when accounting for greenhouse-gas emissions. Future data center development could consider site location, along with efficiency measures, to limit the environmental impact attributable to this increasingly prominent economic sector.

1. Introduction

Increased reliance on the storage, transfer, and processing of digital information throughout all aspects of society has caused significant growth in data center energy use. These buildings house information technology (IT) equipment, such as computer servers, as well as storage and network devices. In the United States, data center energy use doubled between 2000 and 2006 to about 60 billion kWh annually and is expected to continue to rapidly increase [1–3]. While growth projections made before the current economic downturn may overestimate near-term growth in data center activity, a recent evaluation showed that significant growth continued at least through 2008 with data centers consuming ~70 billion kWh during that year [4]. That level of energy use corresponds to emissions of $\sim 1.2 \times 10^{13}$ g y^{-1} of fossil carbon (42 Mt/y of CO_2), based on the average carbon intensity of 160 gC/kWh for US electricity production [5].

Non-IT components in data centers—heating ventilation and air-conditioning (HVAC) equipment, uninterruptible power supplies (UPS), and building lighting—account for approximately half of data center electricity demand [6]. Total data center energy demand is often characterized with a simple metric, the power usage effectiveness (PUE) [7], which is defined as the ratio of the total data center building load to the data center IT equipment load. Based on industry consensus regarding data center practices, previous estimates have applied a PUE of 2.0 to represent current average data center energy efficiency, implying that IT and non-IT energy use are equal [1,2,4]. However, IT equipment operates in data centers of significantly different types and sizes, which could affect actual PUE values. Masanet et al. [4] apportioned estimates of national IT energy use among different data center space types

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