Let’s Wait Awhile: How Temporal Workload Shifting Can Reduce Carbon Emissions in the Cloud

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ABSTRACT

Depending on energy sources and demand, the carbon intensity of the public power grid fluctuates over time. Exploiting this variability is an important factor in reducing the emissions caused by data centers. However, regional differences in the availability of low-carbon energy sources make it hard to provide general best practices for when to consume electricity. Moreover, existing research in this domain focuses mostly on carbon-aware workload migration across geo-distributed data centers, or addresses demand response purely from the perspective of power grid stability and costs.

In this paper, we examine the potential impact of shifting computational workloads towards times where the energy supply is expected to be less carbon-intensive. To this end, we identify characteristics of delay-tolerant workloads and analyze the potential for temporal workload shifting in Germany, Great Britain, France, and California over the year 2020. Furthermore, we experimentally evaluate two workload shifting scenarios in a simulation to investigate the influence of time constraints, scheduling strategies, and the accuracy of carbon intensity forecasts. To accelerate research in the domain of carbon-aware computing and to support the evaluation of novel scheduling algorithms, our simulation framework and datasets are publicly available.

CCS CONCEPTS

• **Social and professional topics** → **Sustainability**; • **Software and its engineering** → *Cloud computing*.

KEYWORDS

temporal workload shifting, carbon-aware scheduling, green computing, resource management, data center

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1 INTRODUCTION

Reducing the energy demand of data centers is a major concern of research and industry alike, as it is a key driver of operational expenses and largely determines the carbon footprint of cloud computing. The extent of these efforts is most evident in the fact that data center energy consumption has grown at a much slower rate over the past decade than previously assumed [41]. This success can be attributed to technological advances such as improved processor and storage-drive efficiency on the one side, but even more importantly to the steady shift of cloud computing towards highly energy-optimized hyperscale data centers [14] that already account for roughly 50 % of all compute instances [41]. Despite all the efficiency gains, data centers worldwide consumed an estimated 205 TWh of electricity in 2018, which amounts to approximately

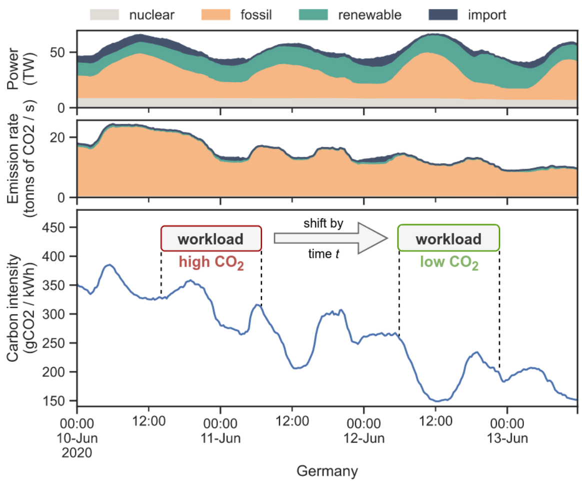

Figure 1: Power consumption, emission rate, and resulting carbon intensity in Germany, June 10-13. Scheduling workloads at times when the carbon intensity is expected to be low, can reduce the carbon footprint of data centers.