On the Limitations of Carbon-Aware Temporal and Spatial Workload Shifting in the Cloud

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Motivation

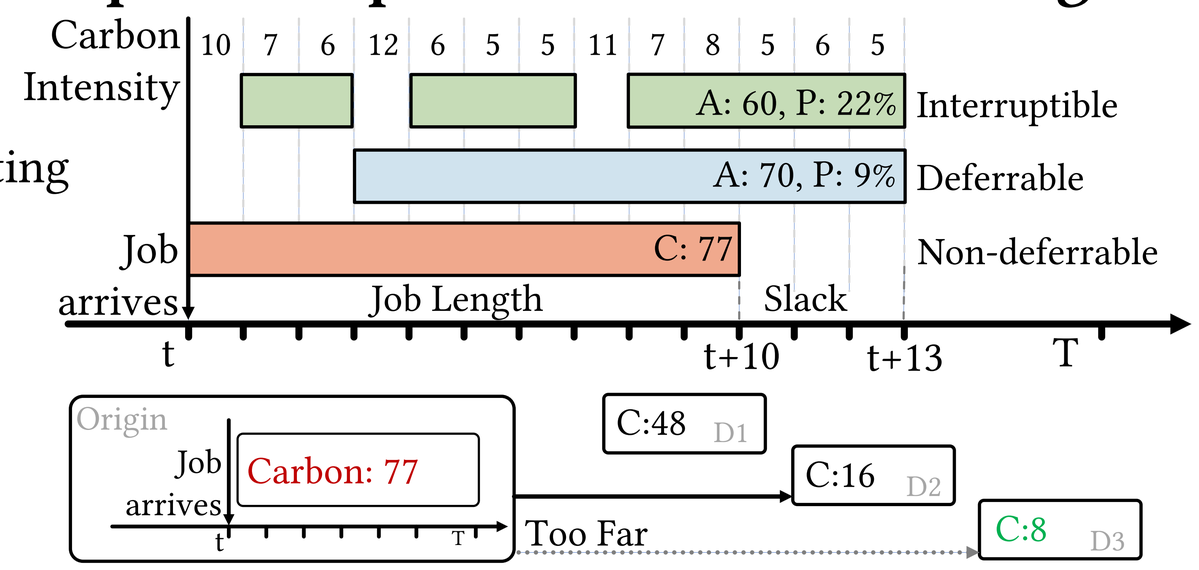
Objective

- Diversity in carbon intensity worldwide
- Unclear potential benefits of spatiotemporal workload shifting
- Quantify carbon reductions from workload shifting

Methodology

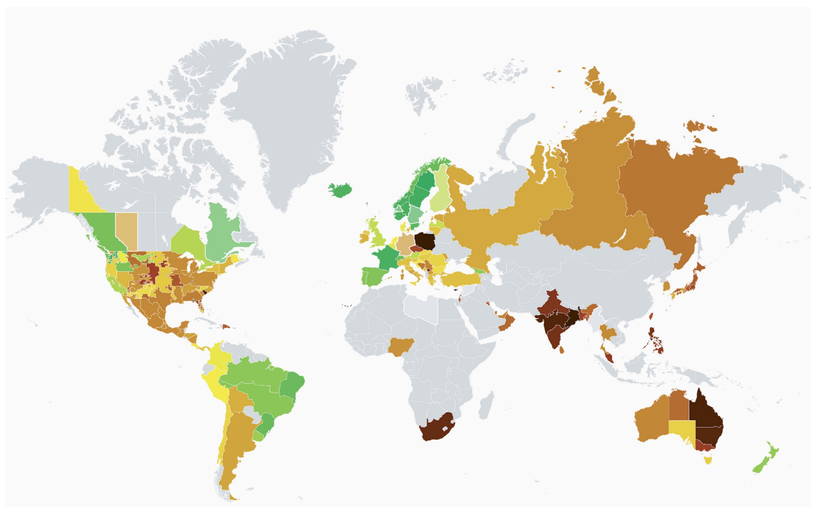
- Collect data from 123 regions worldwide, from 2020-2022
- 35 GCP, 24 Azure, 23 AWS, 7 IBM, 10 Alibaba locations
- Explore a variety of workload characteristics

Spatiotemporal Workload Shifting

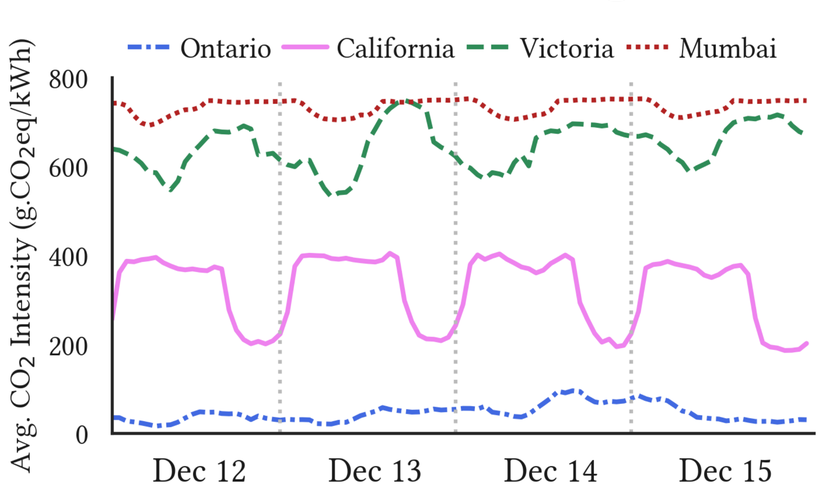


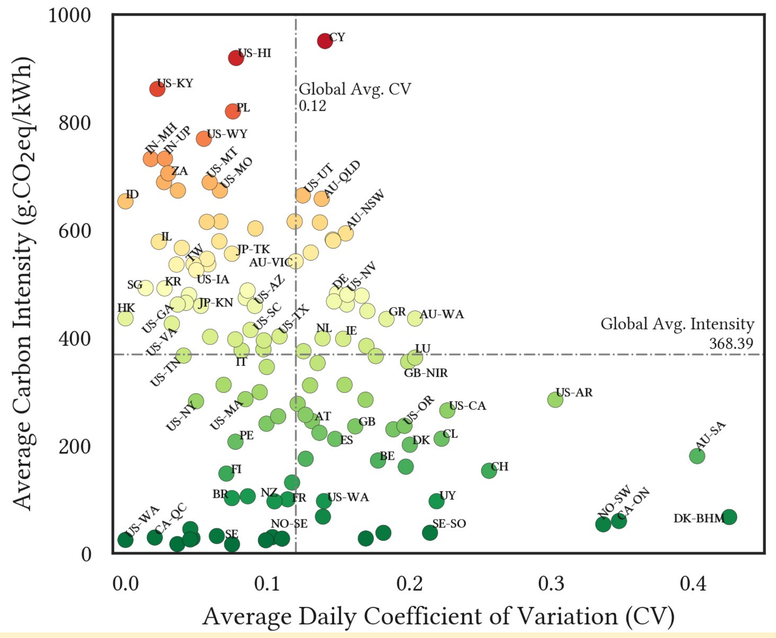
Global Carbon Analysis

Carbon Intensity Worldwide



Magnitude and Variation



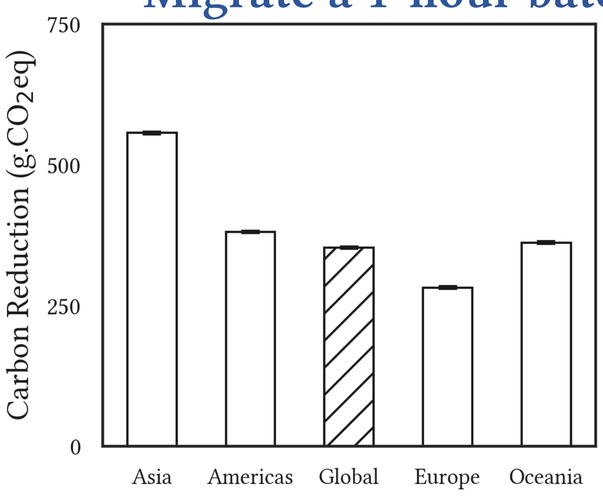


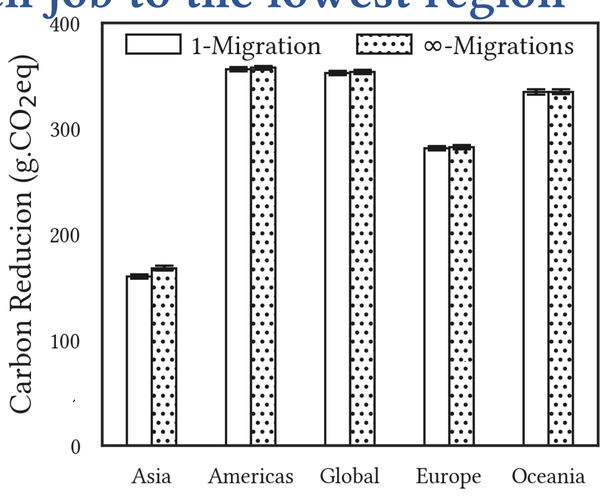
The potential for CO_2 reductions from spatiotemporal workload shifting depends on the **magnitude** and **variations** of the CO_2 intensity across time and locations

Spatiotemporal Workload Shifting

Spatial

Migrate a 1-hour batch job to the lowest region



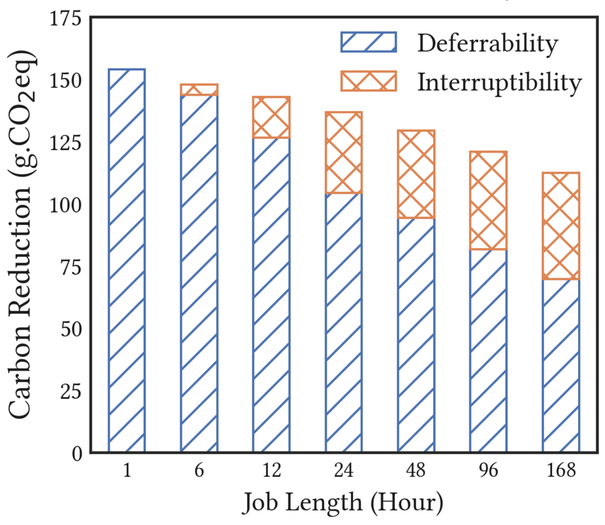


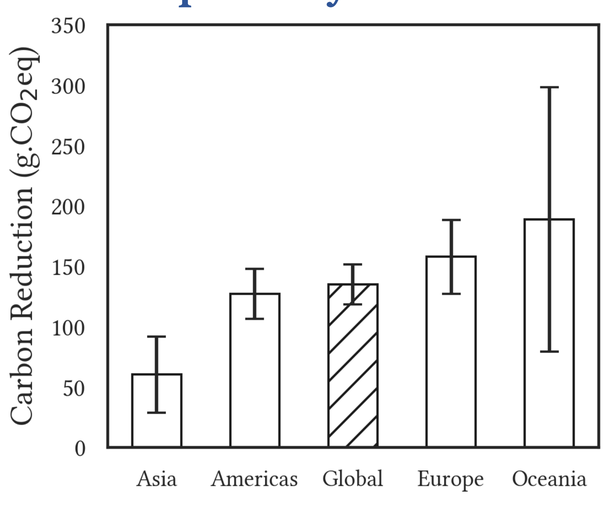
Global CO_2 emissions drop by 352 gCO_2eq

Migrating *once* yields most of the reductions

Temporal

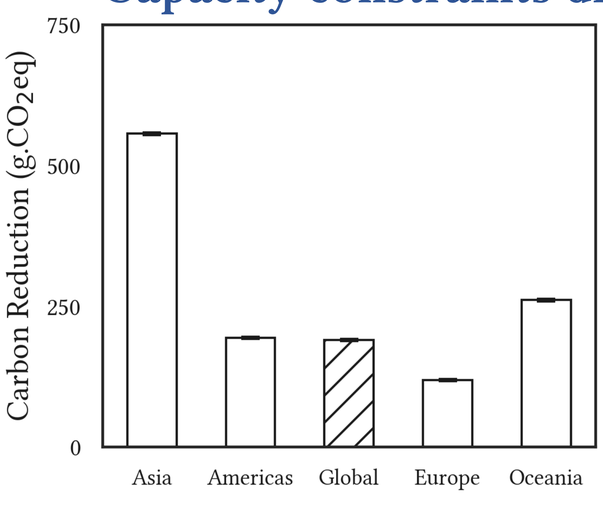
Deferrability and Interruptibility

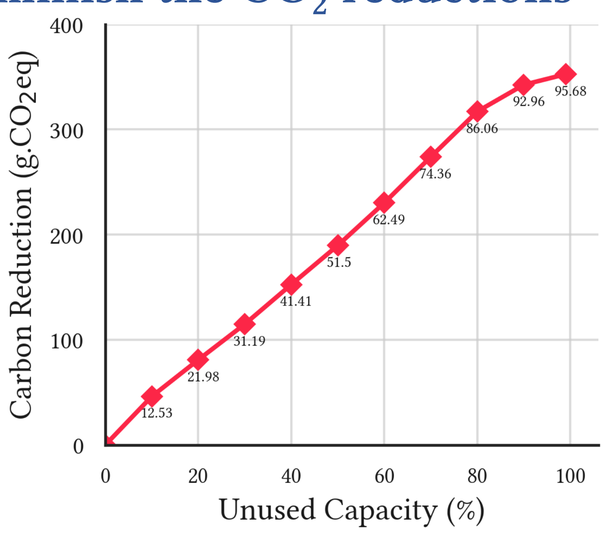




Temporal shifting are beneficial for *short jobs* and in regions with *high variations* in CO_2 intensity

Capacity constraints diminish the CO_2 reductions

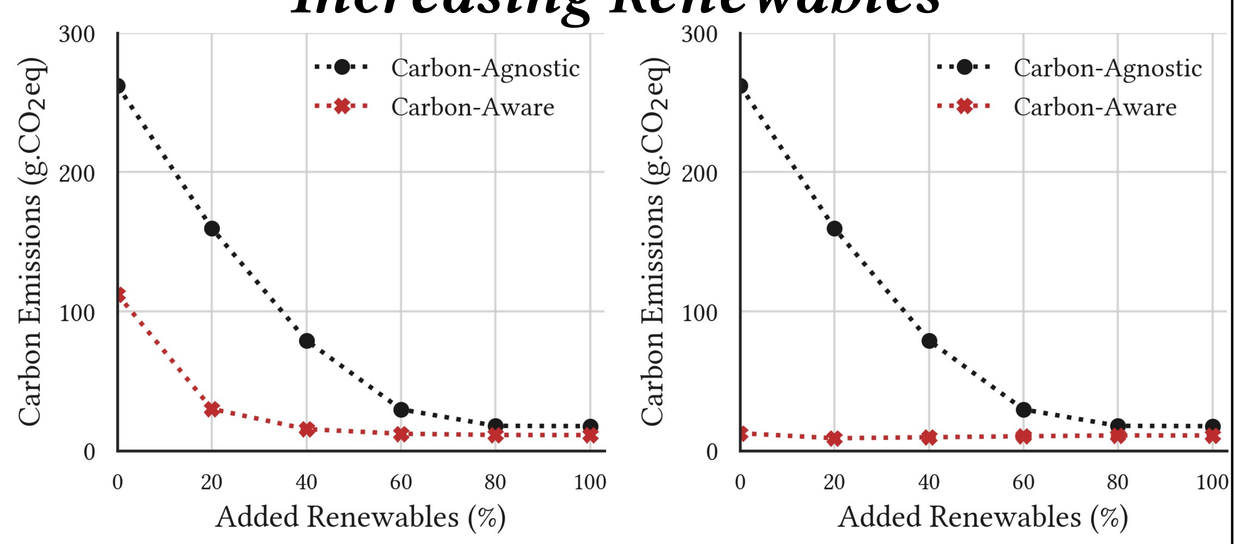




Global CO_2 emissions drop by 190 gCO_2eq

Required *high idle capacity* in low CO_2 intensity regions

Increasing Renewables



Carbon-agnostic scheduling also results in low CO_2 emissions
The benefits of carbon-aware scheduling *diminish*

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