Green Computing meets Distributed Systems

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Motivations

- ICT already accounts for **2% of global CO_2 emissions**
- Expected to consume **up to 20% of global electricity by 2030**
- Decisions on **software** increasingly affect emissions and energy

Society | DOI:10.1145/3603746 Keith Kirkpatrick

The Carbon Footprint of Artificial Intelligence

Looking for ways to cut the release of greenhouse gases attributable to AI use, at a time that usage is very likely to grow.

THE GROWING UTILIZATION of artificial intelligence (AI) is apparent across all facets of society, from the models used to enable semi-autonomous cars, to models that serve up recommendations on streaming or e-commerce sites, and in the language models used to create more natural, intuitive human-machine interaction. However, these technological achievements come with costs, namely the massive amounts of electrical power required to train AI algorithms, build and operate the hardware on which these algorithms are run, and to run and maintain that hardware throughout its life cycle.

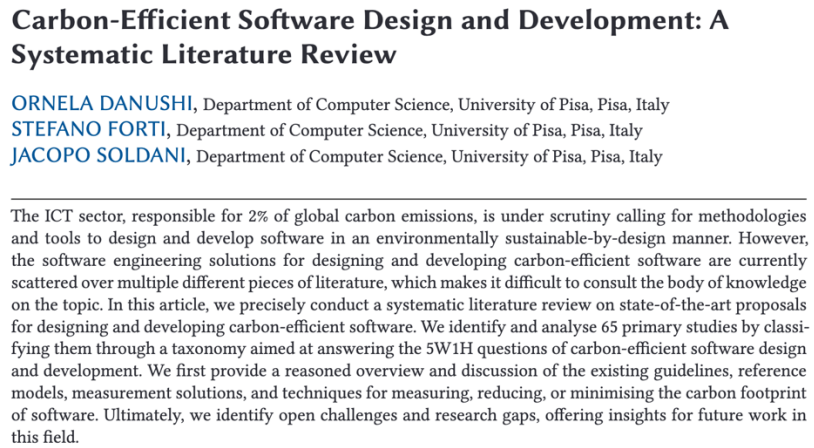
Communications of the ACM (2023)
https://dl.acm.org/doi/pdf/10.1145/3603746

We Need to Decarbonize Software

By Rina Diane Caballar • Illustrations by Elias Stein

The way we write software has unappreciated environmental impacts

IEEE Spectrum (2024)
https://ieeexplore.ieee.org/abstract/document/10491388/



Carbon-Efficient Software Design and Development: A Systematic Literature Review

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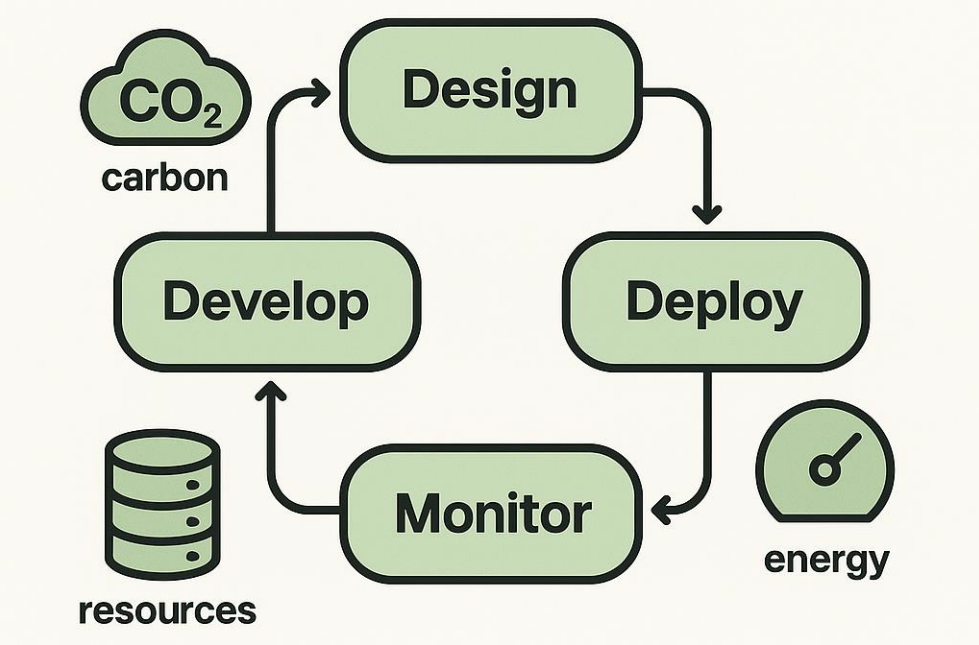
The ICT sector, responsible for 2% of global carbon emissions, is under scrutiny calling for methodologies and tools to design and develop software in an environmentally sustainable-by-design manner. However, the software engineering solutions for designing and developing carbon-efficient software are currently scattered over multiple different pieces of literature, which makes it difficult to consult the body of knowledge on the topic. In this article, we precisely conduct a systematic literature review on state-of-the-art proposals for designing and developing carbon-efficient software. We identify and analyse 65 primary studies by classifying them through a taxonomy aimed at answering the 5W1H questions of carbon-efficient software design and development. We first provide a reasoned overview and discussion of the existing guidelines, reference models, measurement solutions, and techniques for measuring, reducing, or minimising the carbon footprint of software. Ultimately, we identify open challenges and research gaps, offering insights for future work in this field.

ACM CSUR (2025)
https://dl.acm.org/doi/pdf/10.1145/3728638

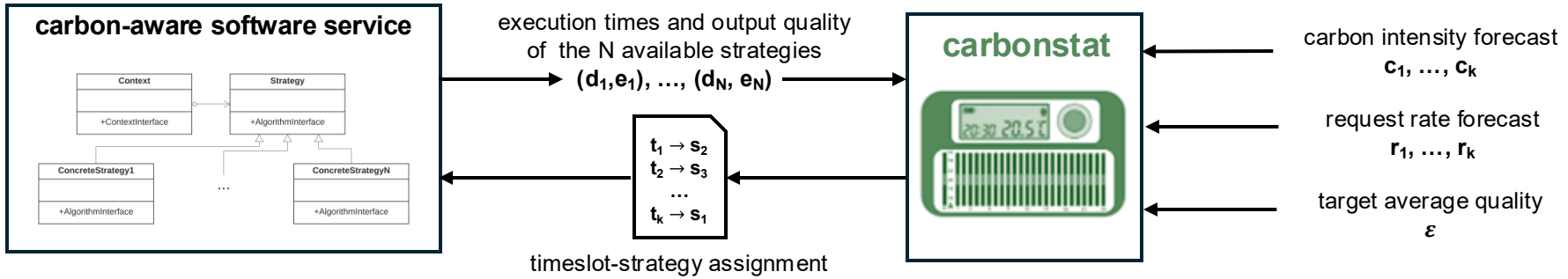
A software-centred perspective

- From **hardware-aware** to **carbon-aware** development
  - consider resources + energy + carbon
  - act at different stages:
    - design & architecture
    - configuration & tuning
    - deployment & orchestration

- Tooling needed along the whole lifecycle!



carbonstat

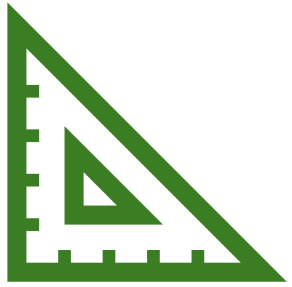


- Use of **Strategy Pattern** to offer multiple service flavours
- Minimise carbon, while guaranteeing avg output quality based on:
  - carbon intensity forecasts
  - workload forecasts
  - quality thresholds

Up to **50% CO_2 reduction**,
maintaining **desired output quality**!

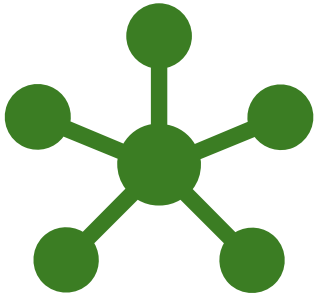
Forti, S., Soldani, J., Brogi, A., Carbon-aware software services, ESOCC 2025, https://doi.org/10.1007/978-3-031-84617-5_6

Work in progress



assess software sustainability using standard (e.g. ISO SCI)

green design patterns and support to make carbon-aware software



carbon- and QoS-aware cloud-edge networks (orchestration, routing, SDN)

Looking for…

- Opportunities to validate and extend these approaches
  - decentralised systems
  - applications (AI, HPC, …)
  - real-world use cases
  - …
- Open to co-design new solutions!

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

definition by the Brundtland Commission
of the overall goal of sustainable development
1987

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