Energy-Aware Dynamic Adaptation of Runtime Systems

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Common statistics

- **ICT contributes 2.1–3.9% of global emissions** [1]
- **ICT's share of GHGE projected to exceed 14% by 2040** [2]
- **Data centres alone are responsible for 1% of energy-related GHGE** [3]

It is clear that we have a big role to play as the ICT sector

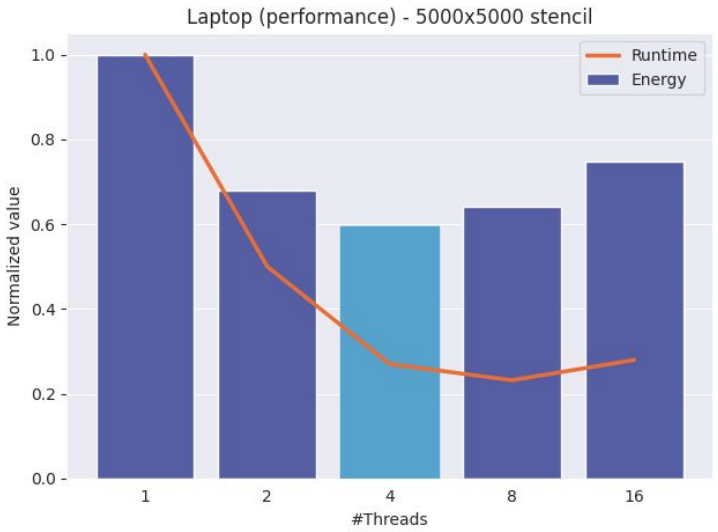
Developers want to act more sustainably

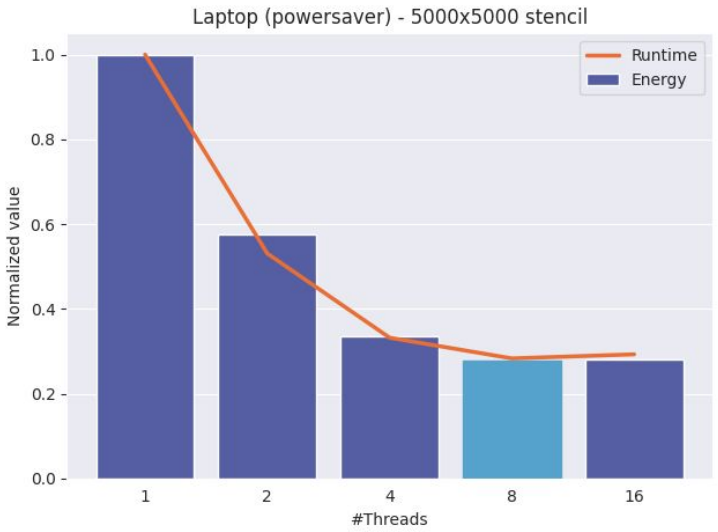
- **Don’t know how, beyond optimizing for runtime performance**

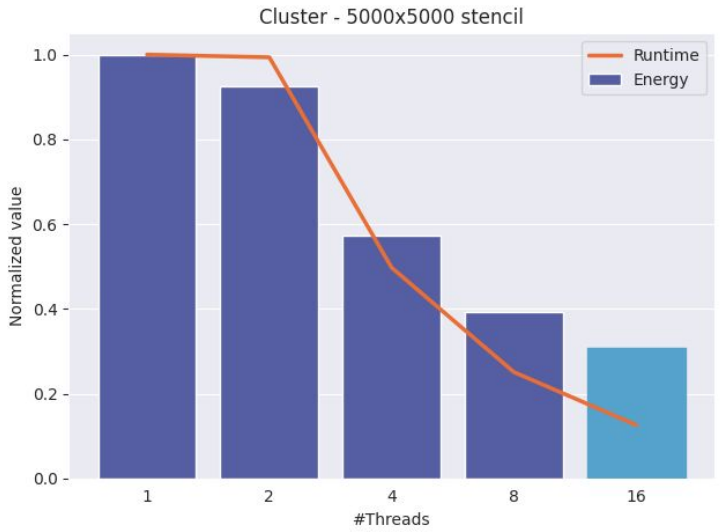
Not just algorithm-dependent

- **Hardware** (CPU, GPU, memory)
- **System state** (temperature, memory use)
- **System configuration** (power mode, multithreading)
- **Background load**
- **Input data**
- **…**

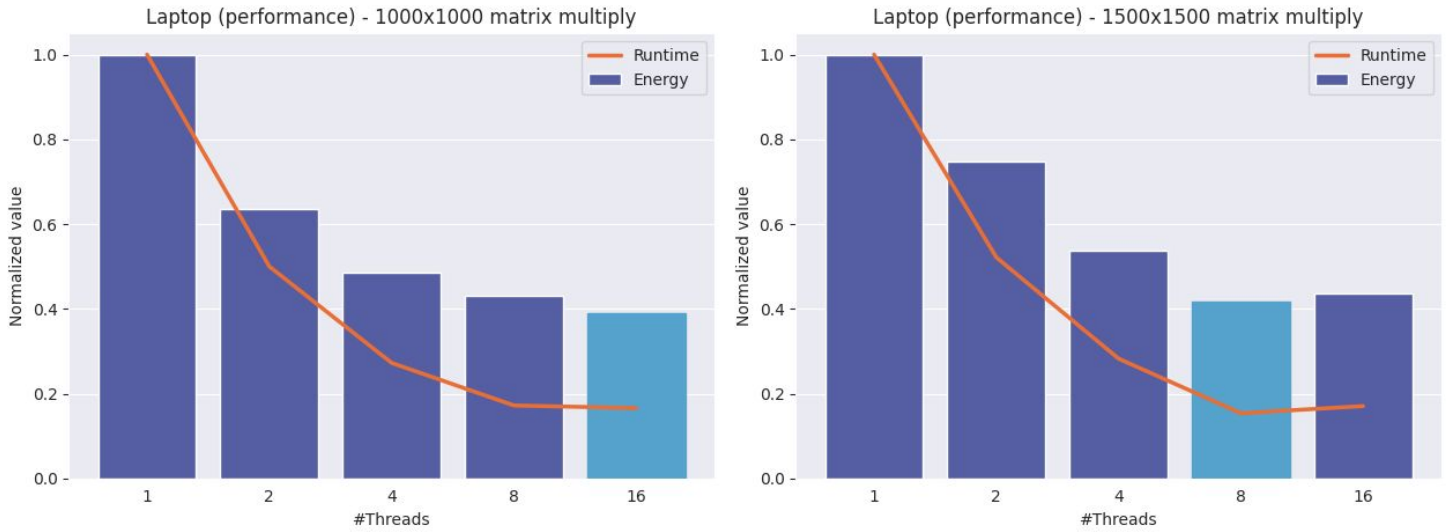
- **Configuration-dependent** (performance, powersaver)
- **System-dependent** (laptop, cluster)





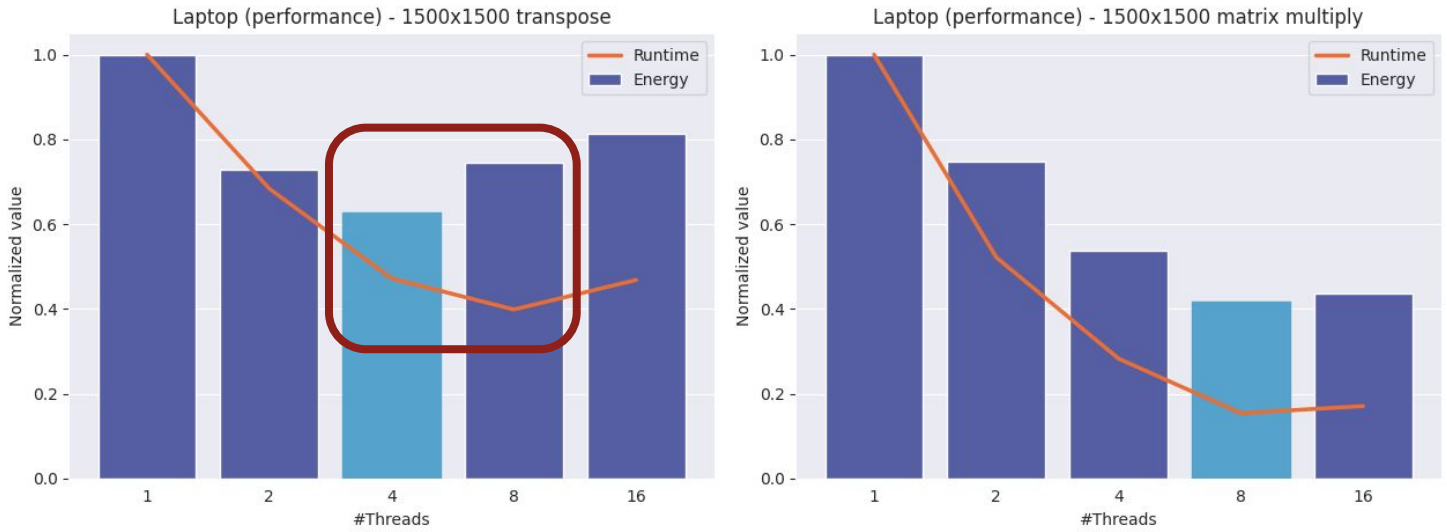


- **Input-dependent**



Differences within a program

- **Transpose step**
- **Multiply step**



Note: runtime-optimum is different

Energy optimising is highly context-dependent

- Often infeasible to manually find optimum
- A single optimum might not exist

An opportunity for compiler developers

- **Static program analysis?** (compiler-specific, runtime changes)
- **Initial profiling run?** (portability, additional overhead, runtime changes)
- **A dynamic approach!**

Standalone resource controller

- **No compiler knowledge needed**

Standardized communication

- **Receive performance metrics** (runtime, energy)
- **Provide control settings** (device, thread-count)

Proof of concept

- **Within 15% of manually generated – all knowing – oracle**
- **Up to 10% energy savings vs. reasonable static approaches**

Currently working on applying the approach to

- **Device selection**
- **Power capping**

Looking for real-world examples

[1] Charlotte Freitag, Mike Berners-Lee, Kelly Widdicks, Bran Knowles, Gordon Blair, and Adrian Friday. The climate impact of ICT: A review of estimates, trends and regulations. February 2021. https://doi.org/10.48550/arXiv.2102.02622

[2] Lotfi Belkhir and Ahmed Elmeligi. Assessing ICT Global Emissions Footprint: Trends to 2040 & Recommendations. Journal of Cleaner Production 177, March 2018. https://doi.org/10.1016/j.jclepro.2017.12.239

[3] IEA. Tracking Data Centres and Data Transmission Networks. Accessed 21 May 2025. https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks