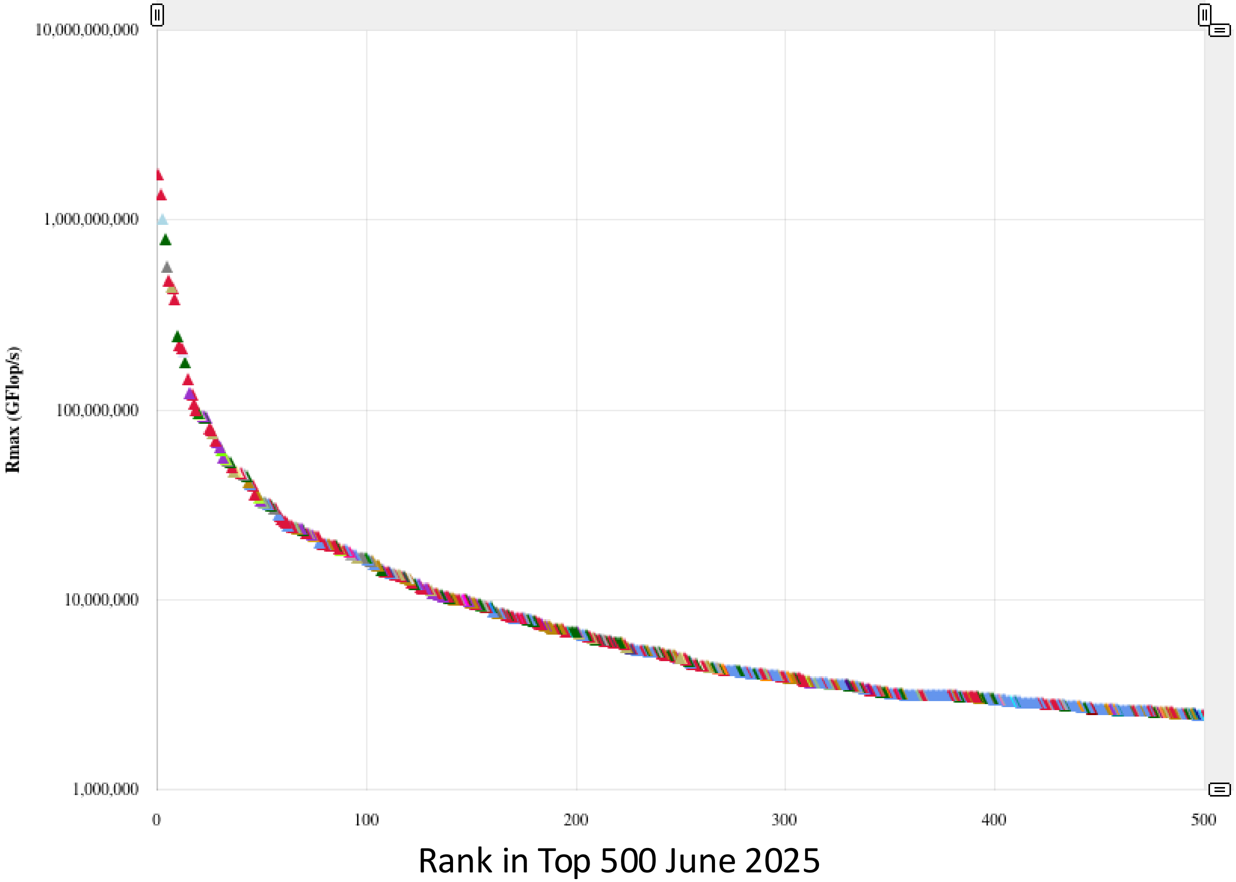
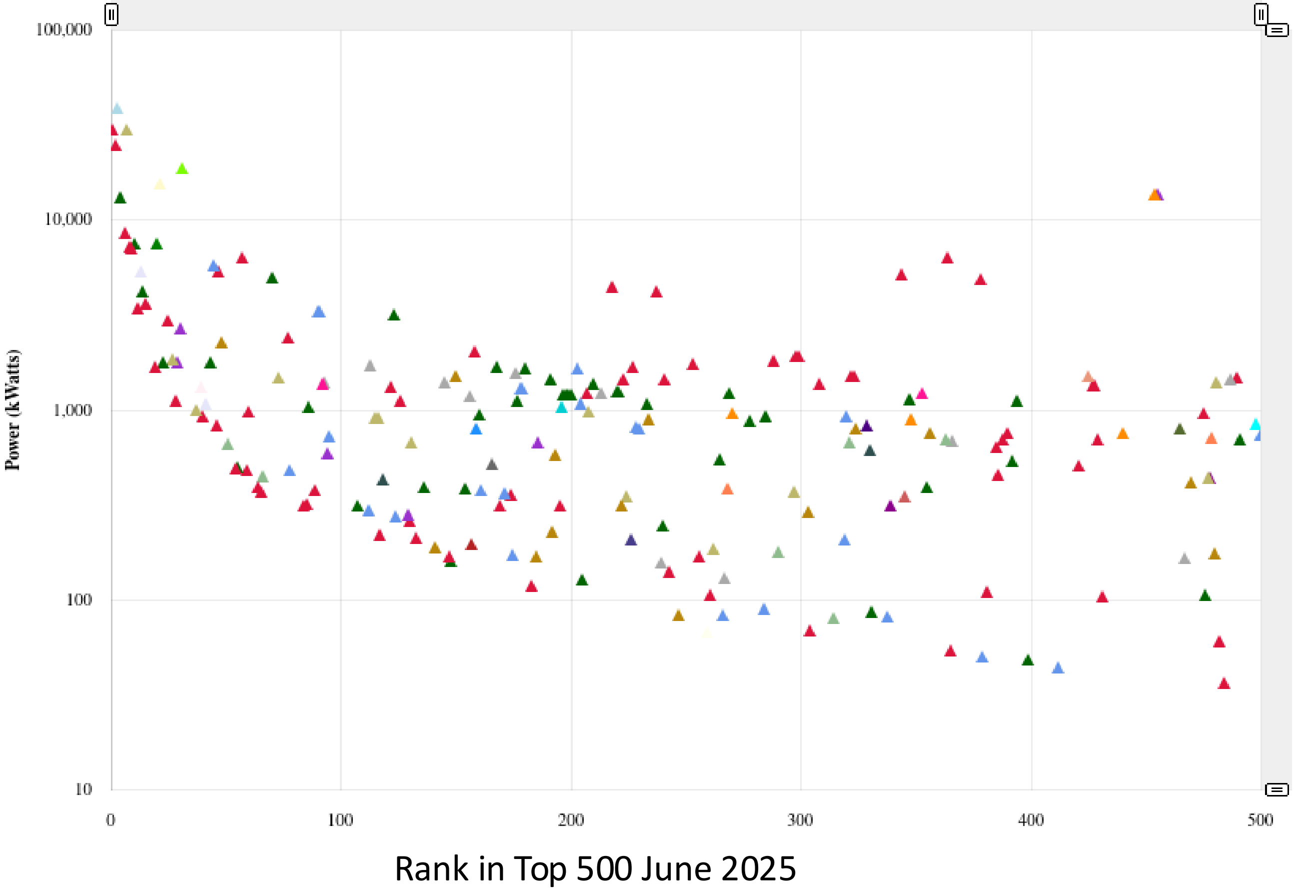
Enhancing Sustainable Research:
A holistic Approach to Sustainable Computing

SC4RC
EPFL
Georgios Sarantakos, Dr. Xavier Ouvrard

The Example of HPC Top 500: Performance and Power



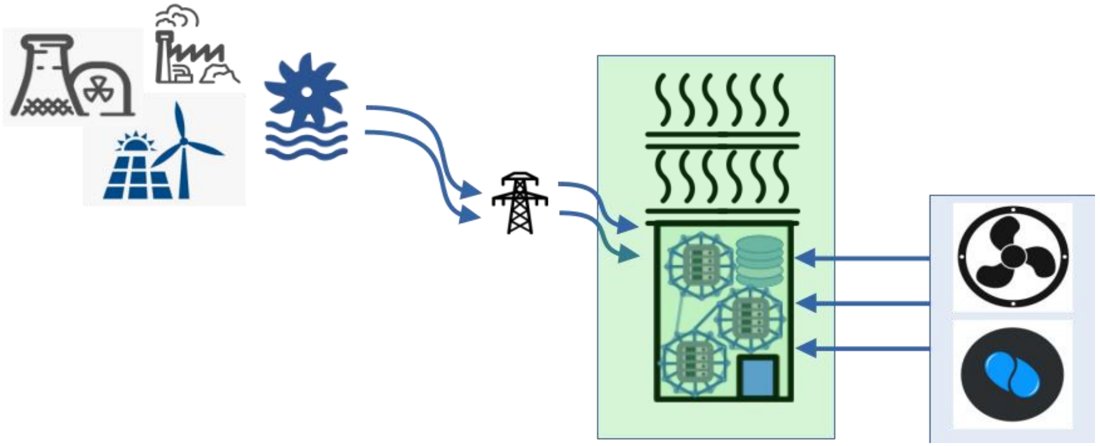


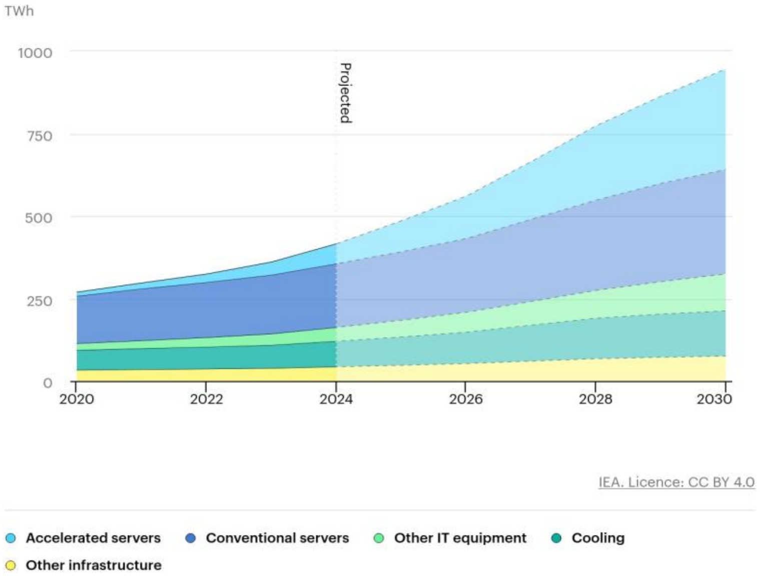
Source: https://top500.org/statistics/efficiency-power-cores/

Datacenters need to be sustainable:

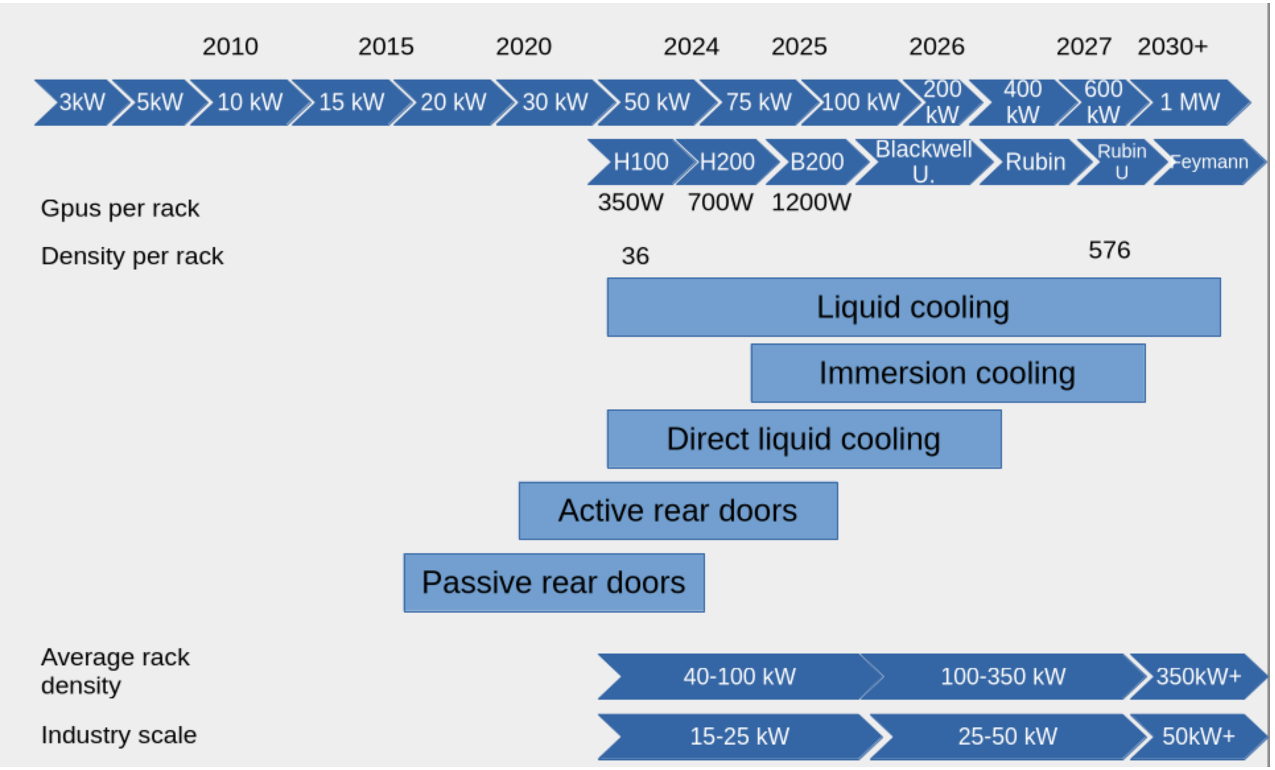
=> Compromise usage of expensive assets / environmental issues / acceptability for users

Datacenters, electricity and heat





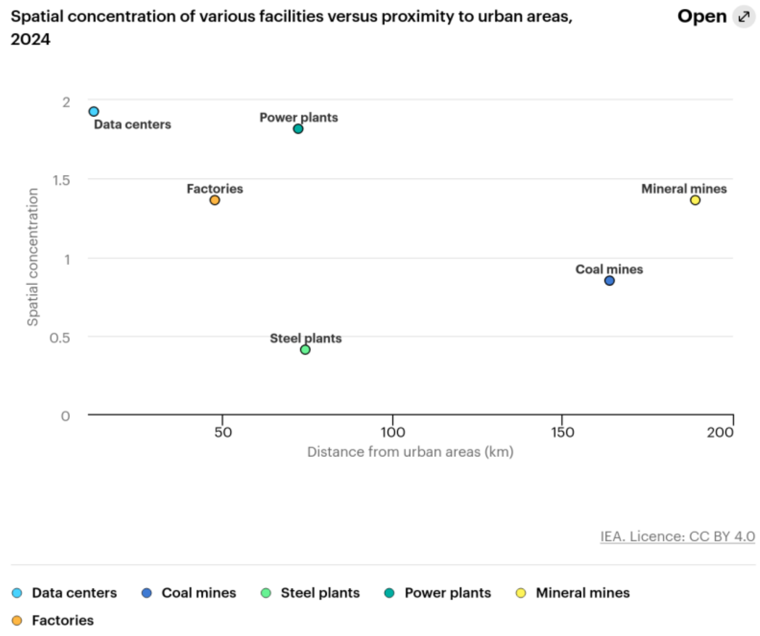
Source: IEA https://www.iea.org/reports/energy-and-ai



Sources: Vertiv, Nvidia, Open Compute Project

- Compute has an increasing demand in energy
- Heat must be reused

Datacenters, location and GHG



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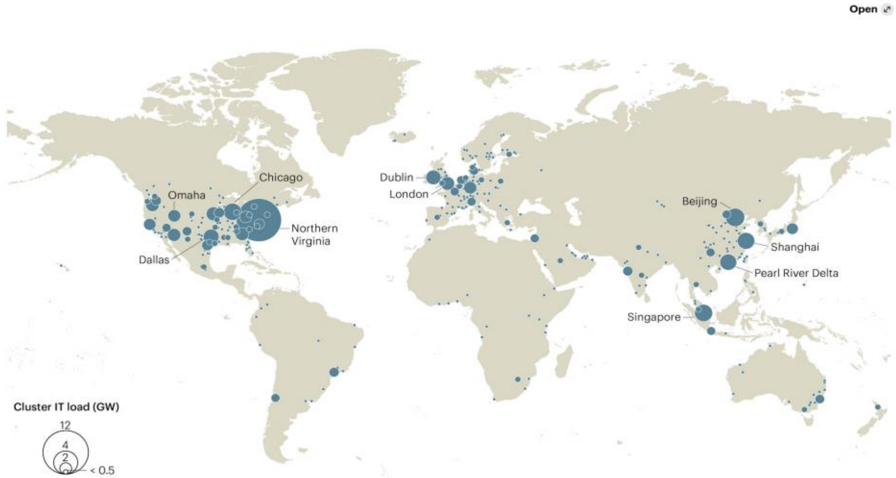


- Ireland DCs

= 20% total electricity demand

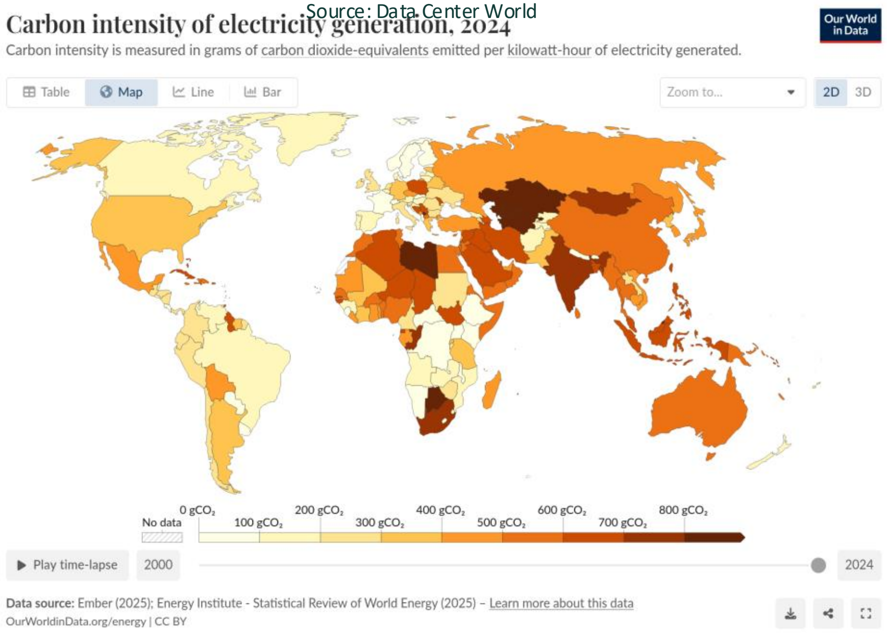
- USA

5 states upper than 10%

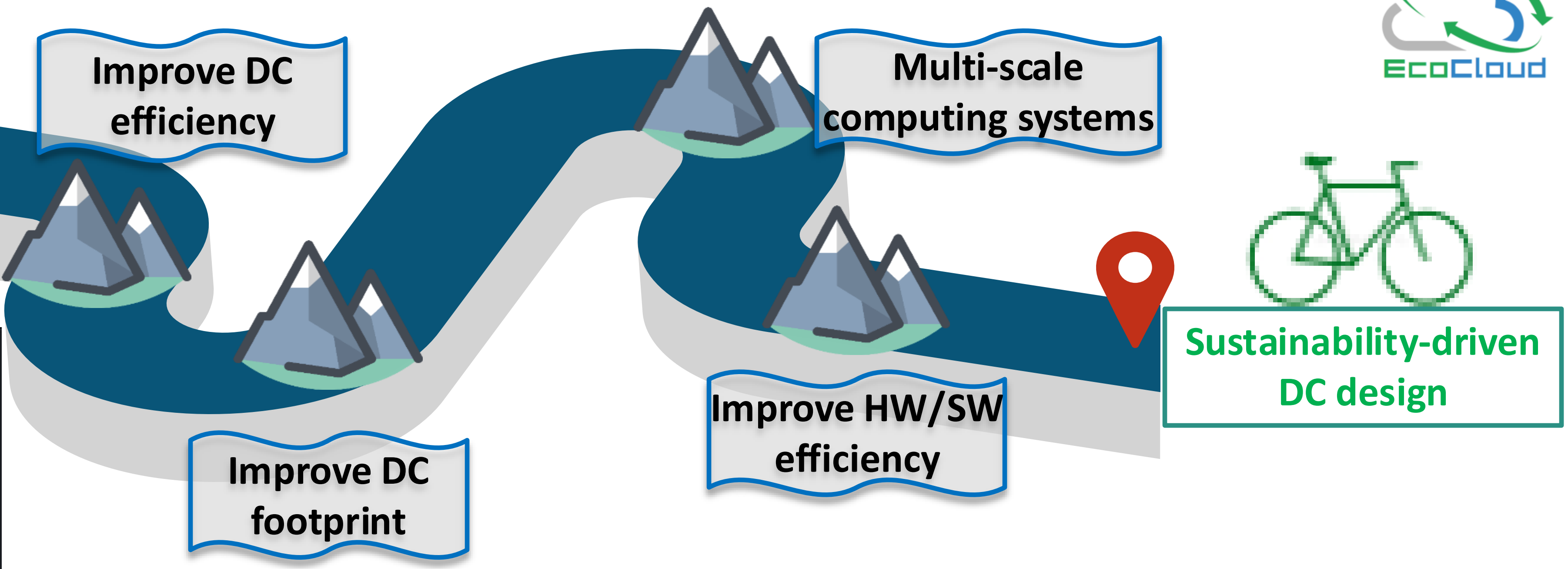
Source: Data Center World

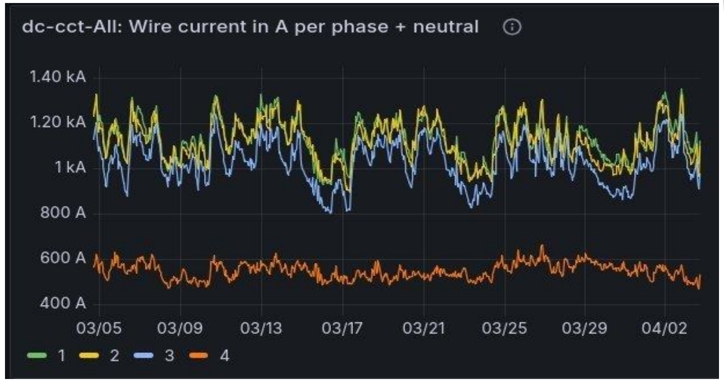
Datacenters need to be sustainable:
=> Compromise usage of expensive assets / environmental issues / acceptability for users

EPFL's new DC integrating PV generation, water cooling, and heat recovery for campus heating



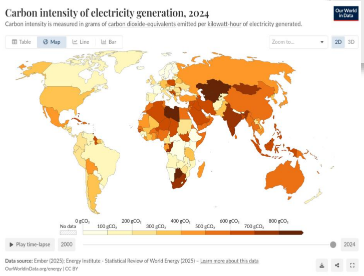
From performance- to sustainability-driven DC design

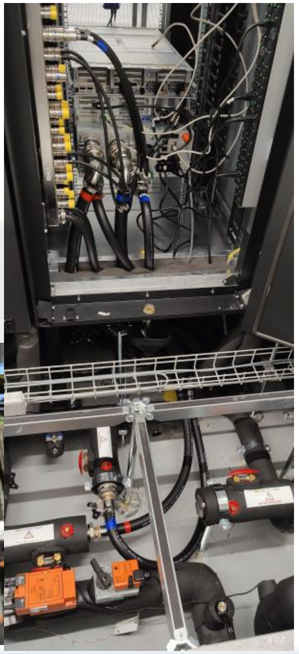


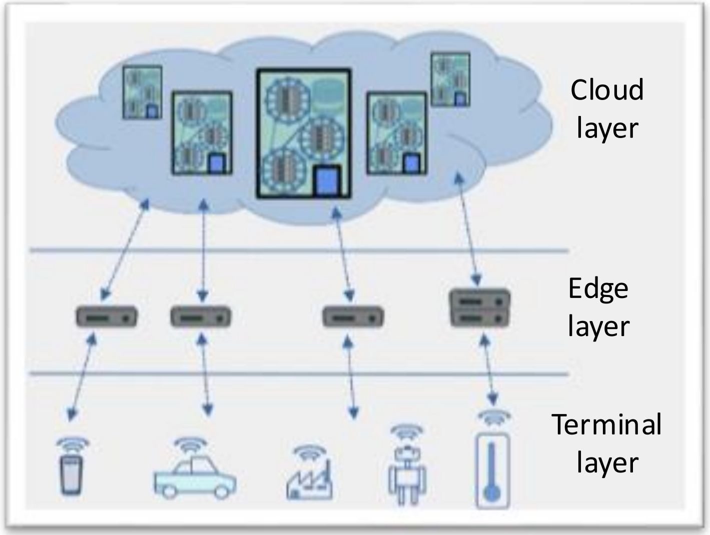


ECOGreen

A crystal ball to assign sets of jobs to DCs







Source: Dr. Xavier Ouvrard, EcoCloud[1]

[1] X. Ouvrard, et al., "Special session: Challenges and opportunities for sustainable multi-scale computing systems," 2023.

Flagship projects – Heating Bits

HEATING BITS EcoCloud

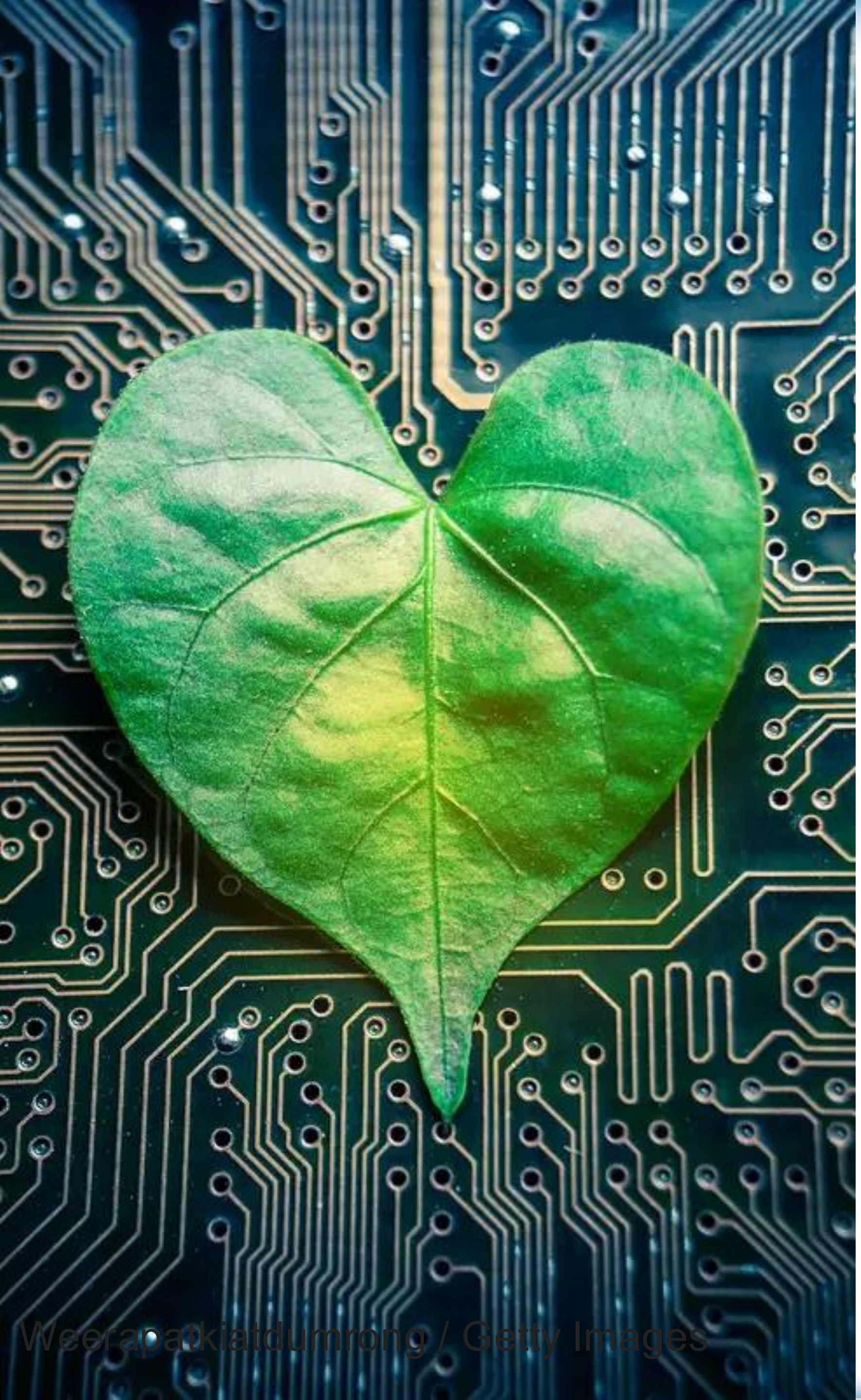
Goal: develop technologies to reduce the carbon footprint of data centers

Key points:

- Financed by EPFL's S4S program
- Started in Sep 2023 for 3+3 years
- Involves 6 laboratories and EcoCloud

Involvement of EcoCloud:

- Small scale experiments
- Compatibility of hardware solutions



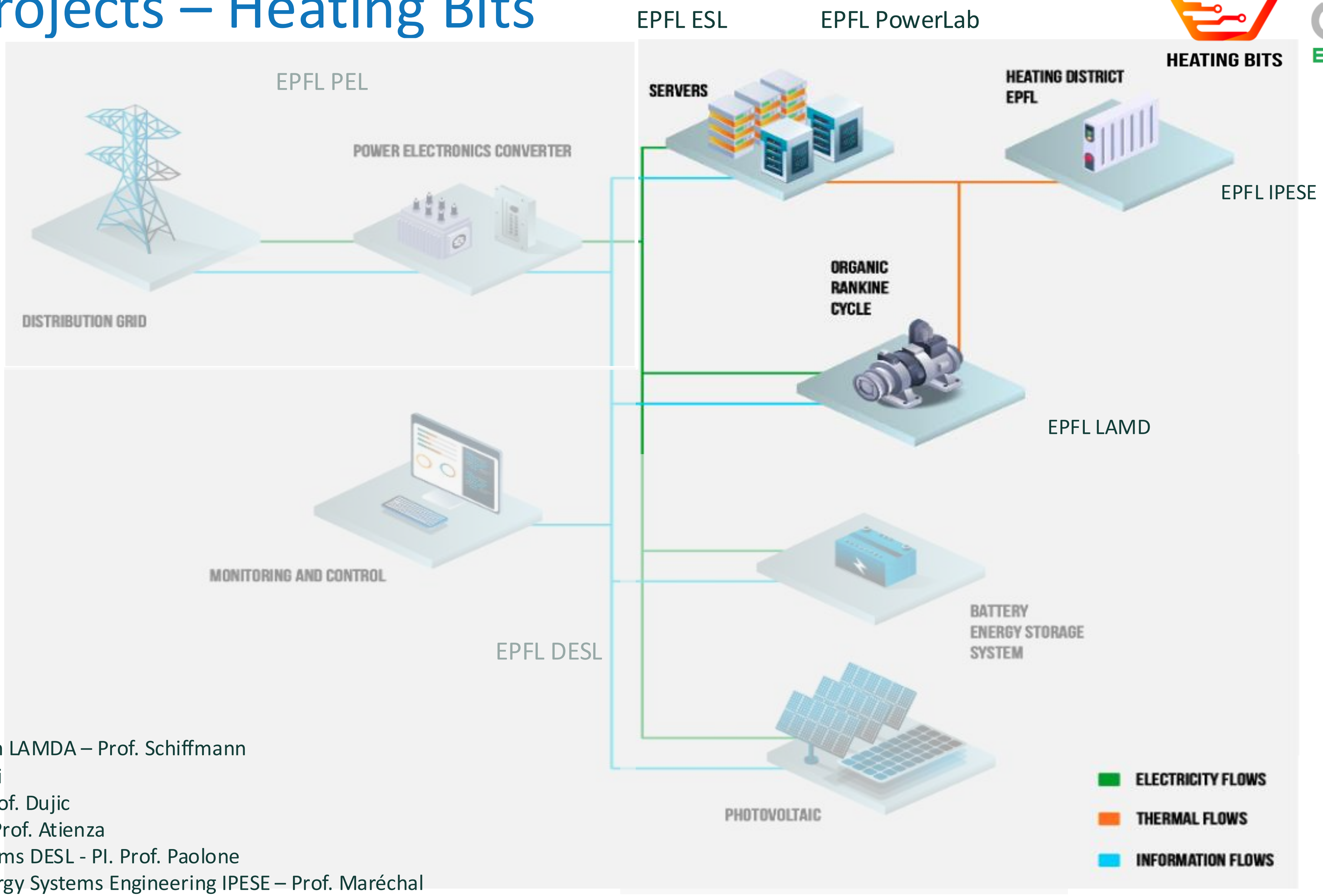
Goals of the project

HEATING BITS

EcoCloud

- Develop a set of technologies and controls for **heat recovery and utilization with least emissions footprint**;
- Validate the solutions in a **first-of-its-kind demonstrator benefiting the entire EPFL campus leveraging EPFL research and tech transfer**.
- **Involve DCs stakeholders: DCs owners and operators, power utilities and technology providers.**

Flagship projects – Heating Bits



Project Partners

EPFL PowerLab – Prof. Matioli
EPFL Applied Mechanical Design LAMDA – Prof. Schiffmann
EPFL EcoCloud – Prof. DeMicheli
EPFL Power Electronics PEL – Prof. Dujic
EPFL Embedded Systems ESL – Prof. Atienza
EPFL Distributed Electrical Systems DESL - Pl. Prof. Paolone
EPFL Industrial Process and Energy Systems Engineering IPESE – Prof. Maréchal

Heat recovery and heat-derived electricity generation

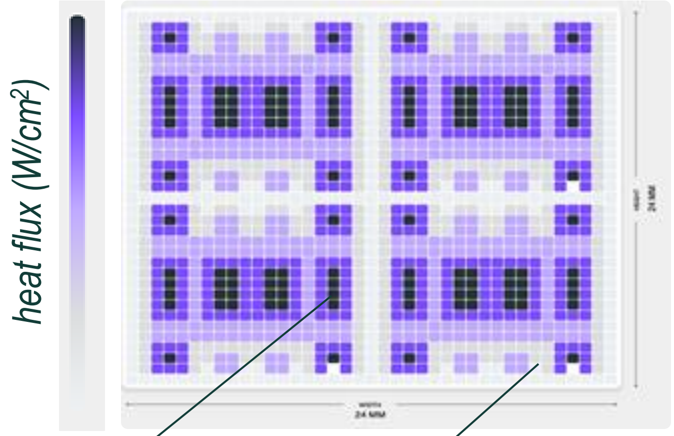
Aim: Innovative on-chip cooling technology to efficiently remove heat from data center CPUs (Nature 2020)

The system is being scaled up to 400 CPUs and GPUs in the EPFL datacenter.

Impact: This cooling system provides:

a. 3x-greater cooling capacity and
b. high temperature coolant (75^{o}C) for subsequent energy recuperation.

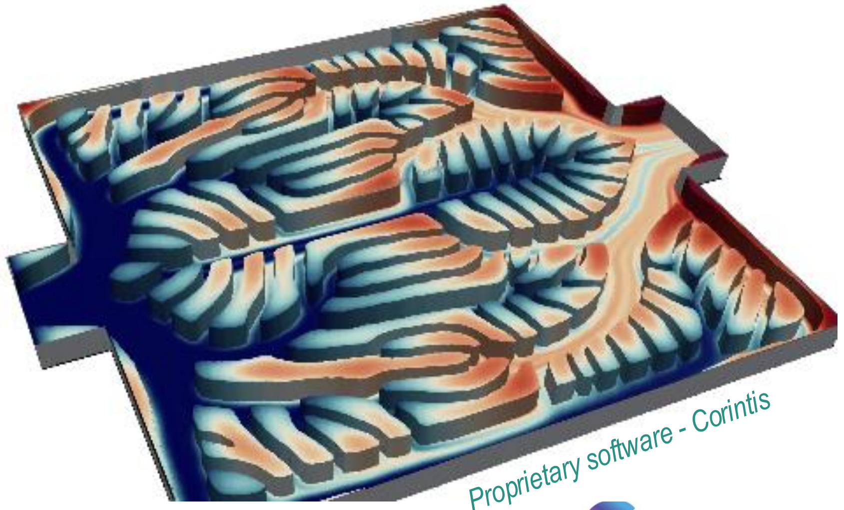
Heat map of the CPU



High heat flux regions

Low heat flux regions

Optimized microfluidic cold plate



Server integration

Server blade prototype

[Nature2020] R. van Erp, et al., "*Co-designing electronics with microfluidics for more sustainable cooling*," **Nature**, vol. 585, no. 7824, pp. 211–216, Sep. 2020.

Waste heat to electricity

Aim: Generation of **power from the heat extracted from CPUs**

Instead of wasting the heat, this solution valorises thermodynamic potential via power cycle (Organic Rankine Cycle) and re-inject power into direct current-bus

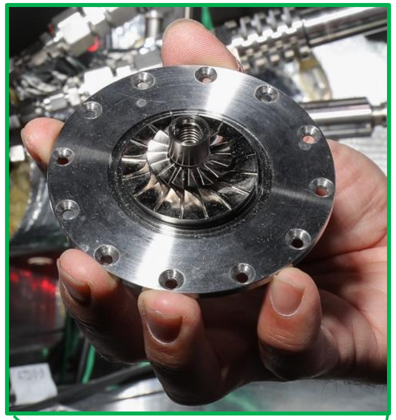
Impact:

First fully oil-free (compact) small-scale ORC:

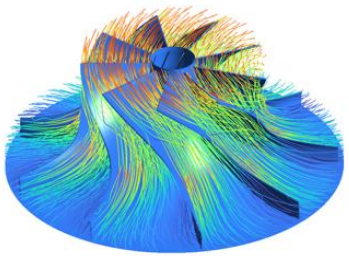
- Net power output ~4.7 kW
- Thermal efficiency ~9%
- Exergy efficiency ~60%

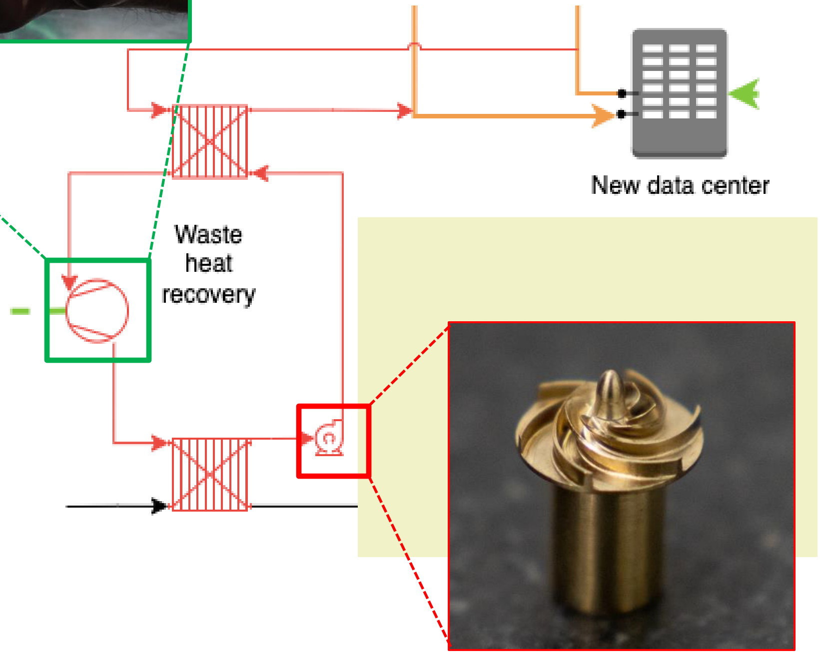
At the EPFL DC scale, from the heat recovered:

- 86.6% goes into the heating network and
- 10% converted back into electricity



CFD simulation of ORC turbine





Prof. Jürg Schiffmann (EPFL LAMD)

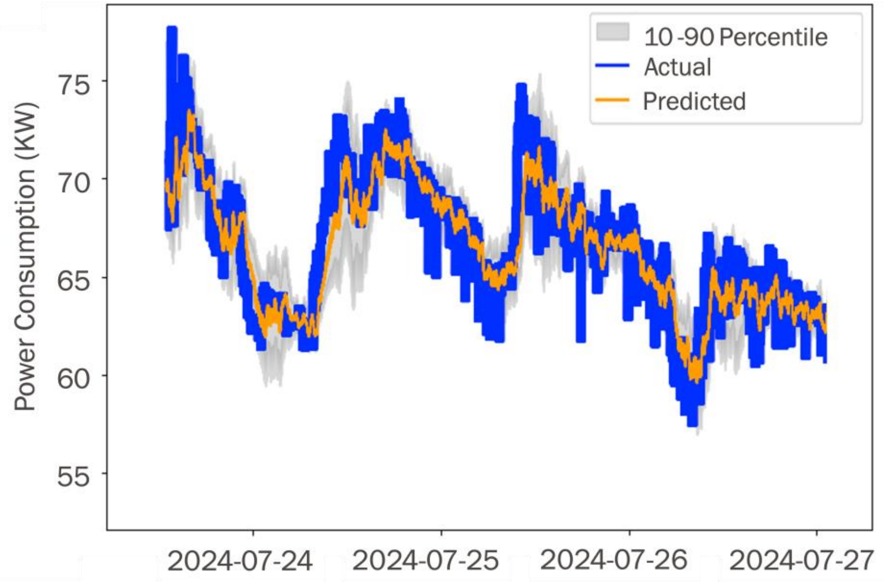
DC power consumption and distribution prediction of applications running inside the VMs

HEATING BITS EcoCloud

Aim:

1. **Predict the workloads** of virtualized DCs to be executed
2. Develop new **hardware accelerators** use on reconfigurable hardware for EPFL key workloads

This work builds on previous projects with cloud providers (Huawei, Meta)



Impact

- Maximize racks' **energy efficiency** and minimize **DCs carbon footprint** (Target: 50% savings vs 2019)
- Accurate short- and long-term power forecasts

Prof. David Atienza (EPFL-ESL)

Power distribution and conversion architectures for DCs

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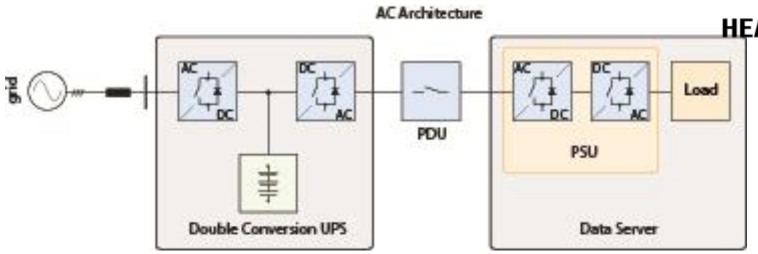
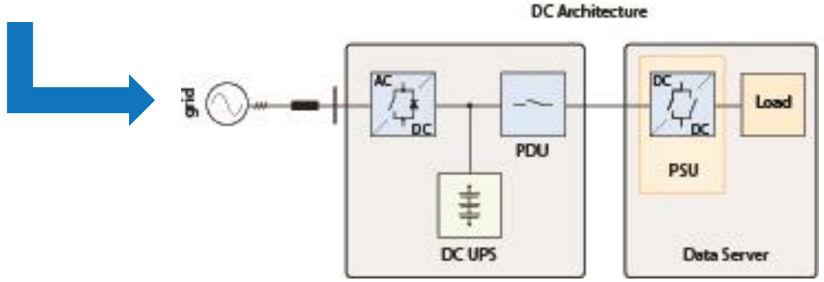
EcoCloud





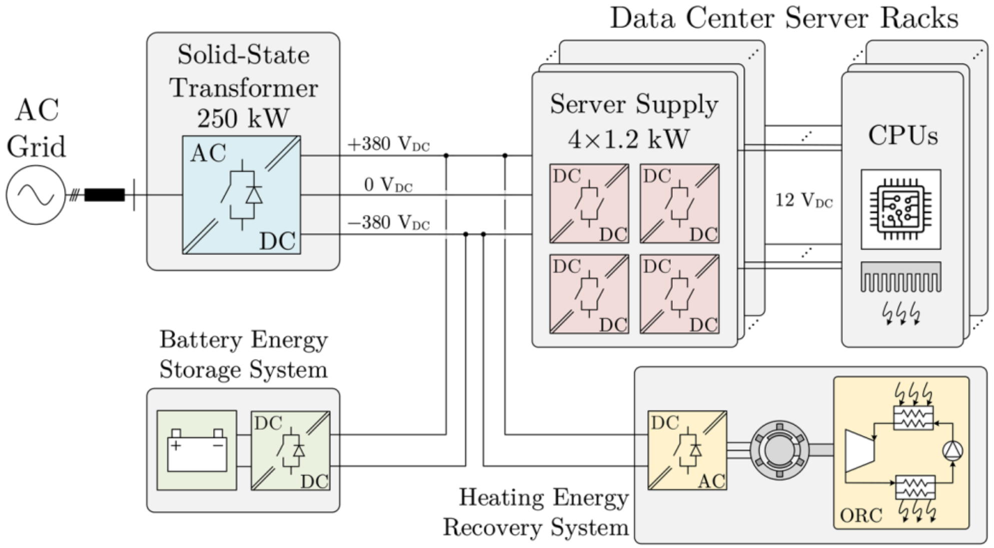
Aim: Improve the **efficiency and reliability of power delivery** in the Data Centers by moving from ac to Direct Current (dc) distribution

Activities involve the design and realisation of:

- The main HVdc power distribution supply (ac/dc stage – **Solid-State Transformer**)
- The Server Supplies (**dc/dc stages** – 4 units × each server blade)

Impact:

- Reduces number of conversions and **improves efficiency** (≅98% ([1])
- Facilitates **integration of batteries and dc sources** (e.g., PV)
- Increases overall system **reliability**



[1] J. Huber et al. PES, ETHZ

Prof. Drazen Dujic (EPFL PEL)

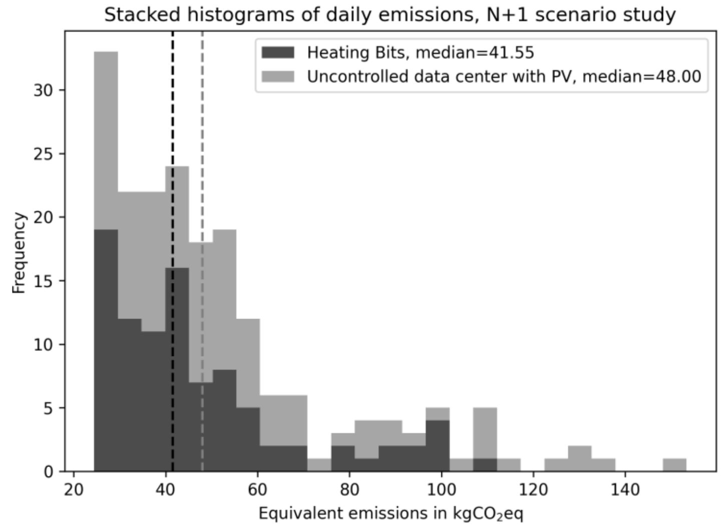
Multi-energy system integration and CO2eq content assessment

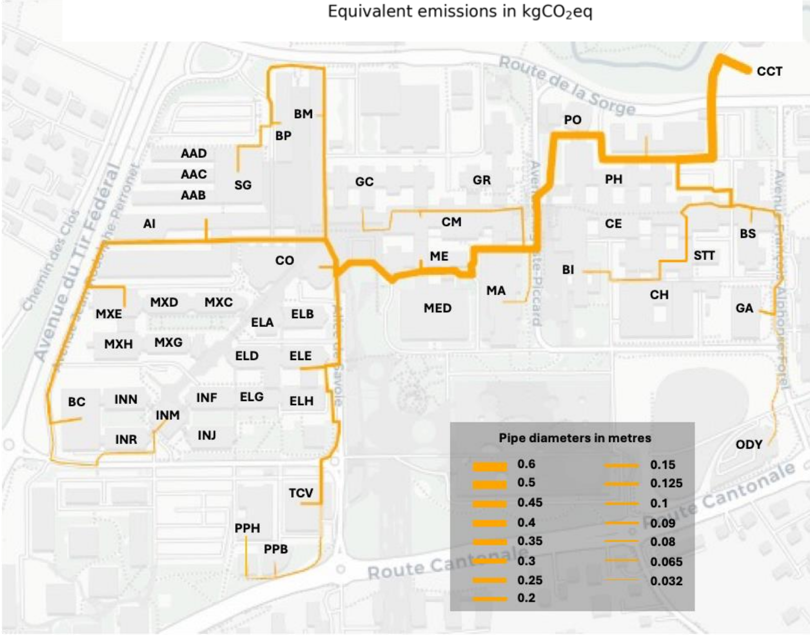
Aim: Strategic **optimal system operation** to supply electricity, heating and cooling services while minimizing the overall CO_2 emissions.

- **Carbon- and market- aware control framework** of the overall energy system of the DC designed (DESL)
- **District heating network** of the EPFL Lausanne campus modelled (IPESE)
- **EPFL DC sized** to optimise data processing self-sufficiency and PV self-consumption (IPESE)

Impact:

- **15% of carbon footprint reduction** vs uncontrolled DC with PV (workload flexibility not considered)
- Up to **40% of the EPFL campus heat demand** could be met with the heat generated by a 10 MW DC





Layout of EPFL's DHN. Line width is correlated with volume of water.

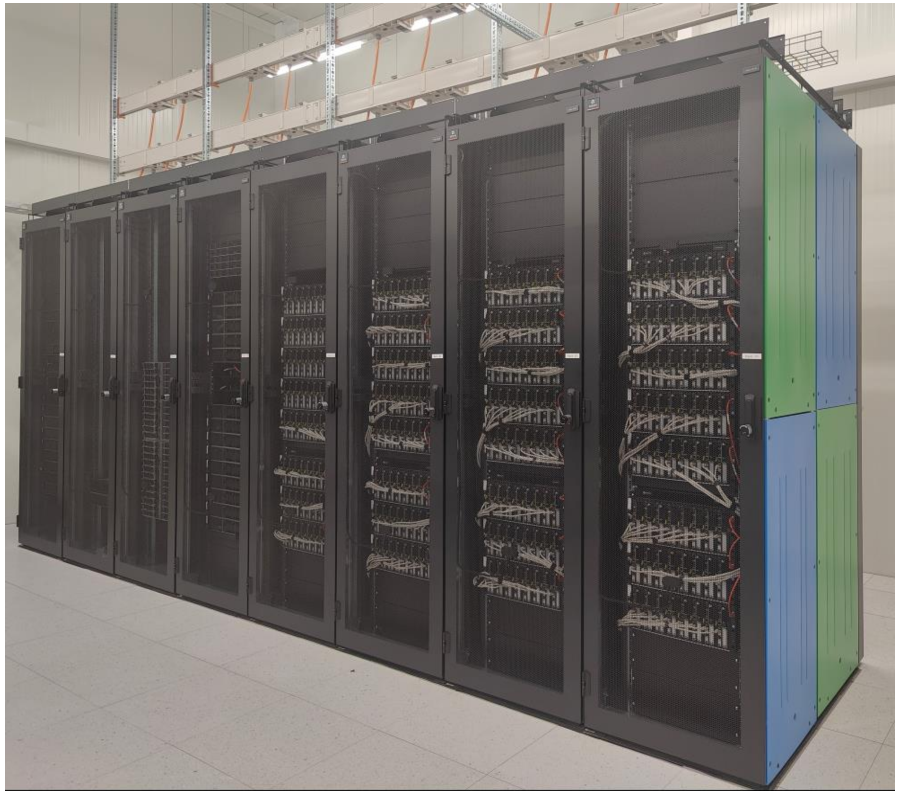
Prof. Mario Paolone (DESL) + Prof. François Maréchal (IPESE)

Next step: Demonstration at the systemic level

EcoCloud

Phase II: Q4 2026 – Q3 2029

The solutions developed and validated at the lab-scale will be integrated at the EcoCloud facilities for the system validation.



Activities will be supported by the HeatingBits Industry Board that consists of:

NVIDIA.

EATON

LEM
Life Energy Motion

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE

primeo energie

Navitas

ENOGIA

SONCEBOZ

Dr. Xavier Ouvrard, Prof. Giovanni De Micheli (EcoCloud)

Thank you for your attention!

Questions?

EPFL – Heating Bits

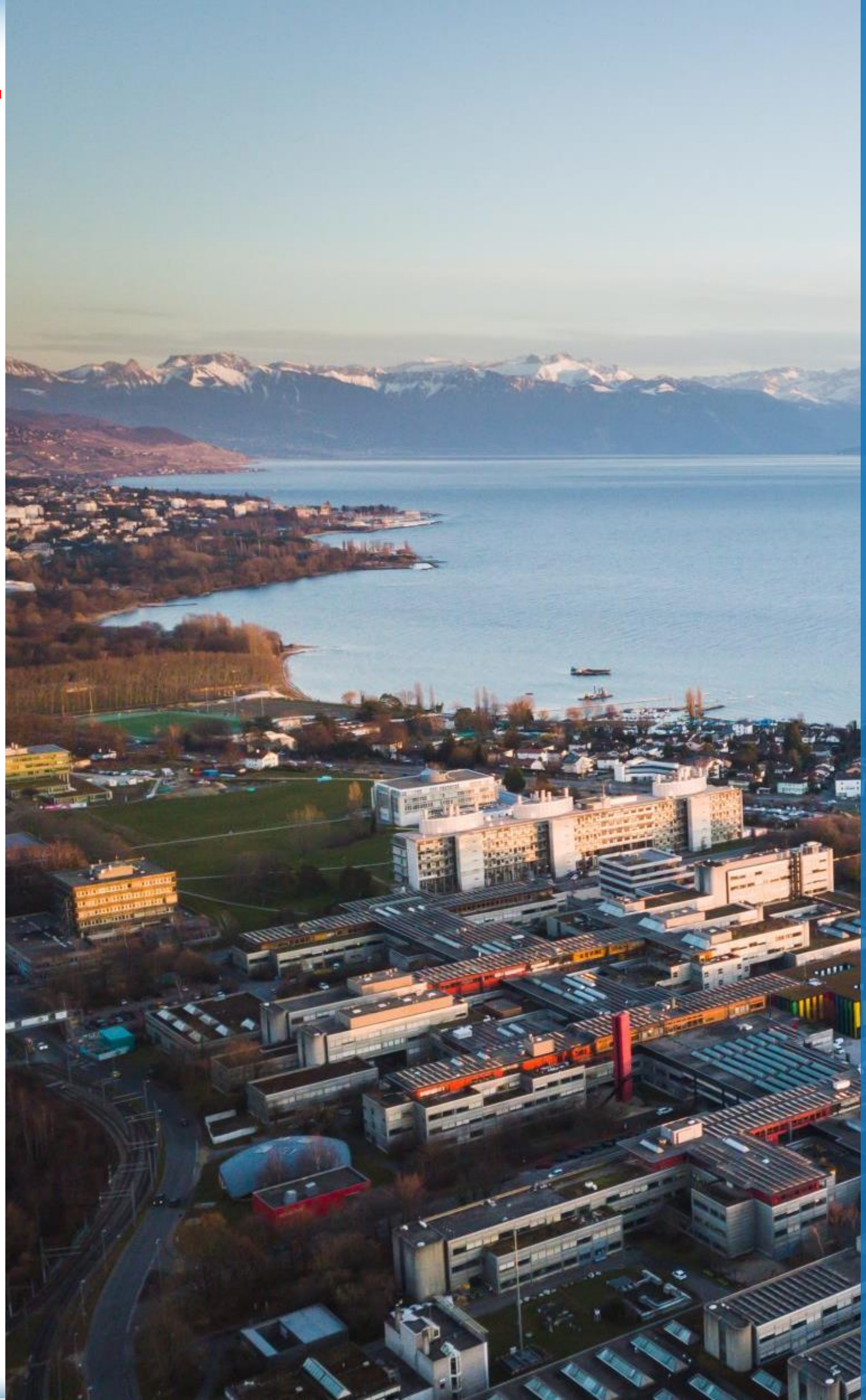
georgios.sarantakos@epfl.ch

EPFL – EcoCloud

xavier.ouvrard@epfl.ch

contact.ecocloud@epfl.ch

BACKUP SLIDES



EcoCloud’s experimental area

Experimental area: What is available as computing resource

- Several state-of-the-art dual socket servers:
  - Intel:
    - 8553Y IceLake 32C,
    - Intel 5418N 20C Sapphire Rapids
    - 6448Y 32C Sapphire Rapids: 2 with air cooling, 2 in DLC
    - 2 Xeon Gold 6240 with 4 Nvidia V100
  - AMD
    - EPYC 7763 64C Zen 3 Milan
    - EPYC 9554 64C Zen 4 Genoa
    - EPYC 9575F 64C Zen 5 Turin
  - Link in 100G by switches or direct links: specific configuration on demand

How can EcoCloud help its community?

- Experimental area
  - EcoCloud has an experimental area of about 100 m^2 + 20 m^2 in CCT
  - Experiments on IT sustainability and IT for sustainability
  - Fully instrumented, data available to researchers

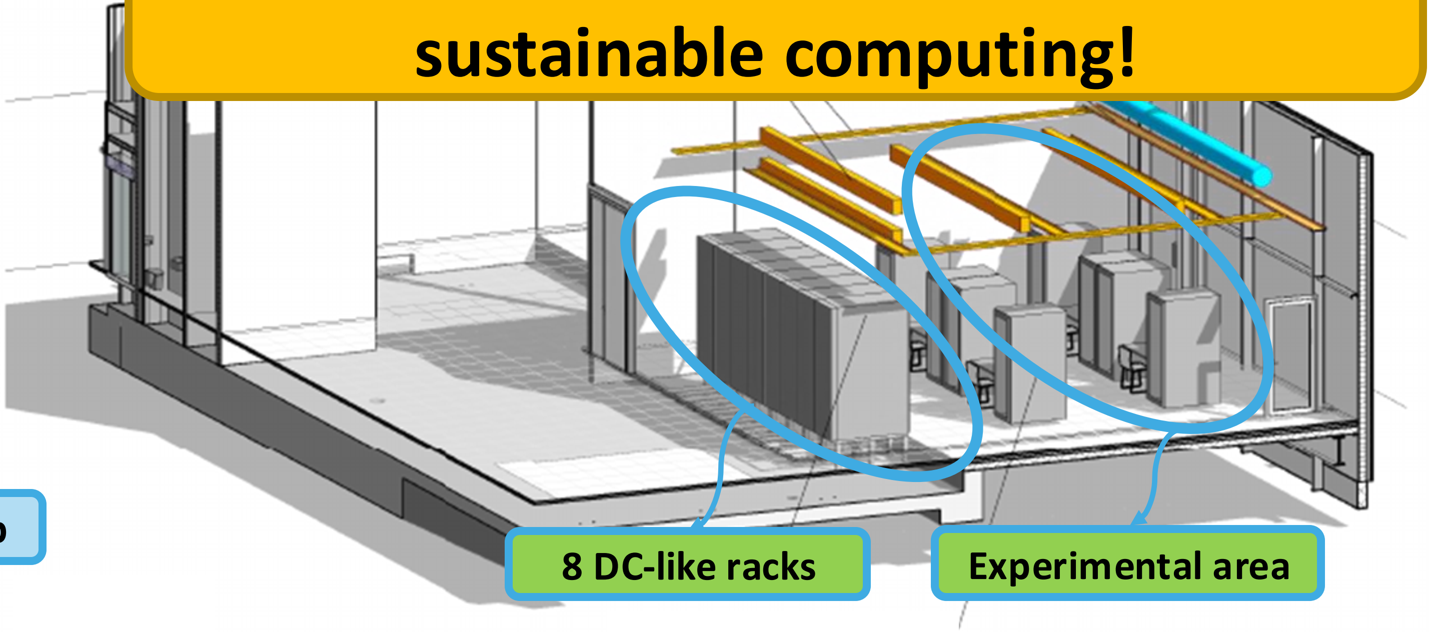
- Characterization of energy efficiency at:
  - Software level
    - Test algorithms on different generation hardware
    - Energy consumption externally instrumented with full monitoring
  - Hardware
    - Different power management techniques
    - Energy-efficiency of FPGA-based accelerators

  With possibly tailored configurations
- Experiment:
  - Different liquid cooling solutions
    - Rack, server and chip
  - Experiment heat recovery solutions

EcoCloud's experimental facility for sustainability

- ~100 m^2 of space for experiments on sustainable computing
  - Recycled clusters
  - SoA servers
  - Donations
- Experimental support: two spaces
  - 35 kW/50 kW passive door air liquid cooling doors
  - Possibility to have soon CDUs on some racks
  - Monitoring: energy, temp., etc.
  - Cooling: air or water cooling

Contact us to test any ideas on sustainable computing!



8 DC-like racks

Experimental area

Racks with air/water passive cooling

Controlled setup

Cooling sub-station

Full supervision in-line with EPFL systems