Heating Bits
Reducing the Carbon Footprint of Data Centers

https://ecocloud.epfl.ch

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HEATING BITS

Motivations

Data centers (DCs) use **2% of global energy** and will reach **10% by 2030**.

Switzerland is one of the European countries with the **highest number of DCs (77).**

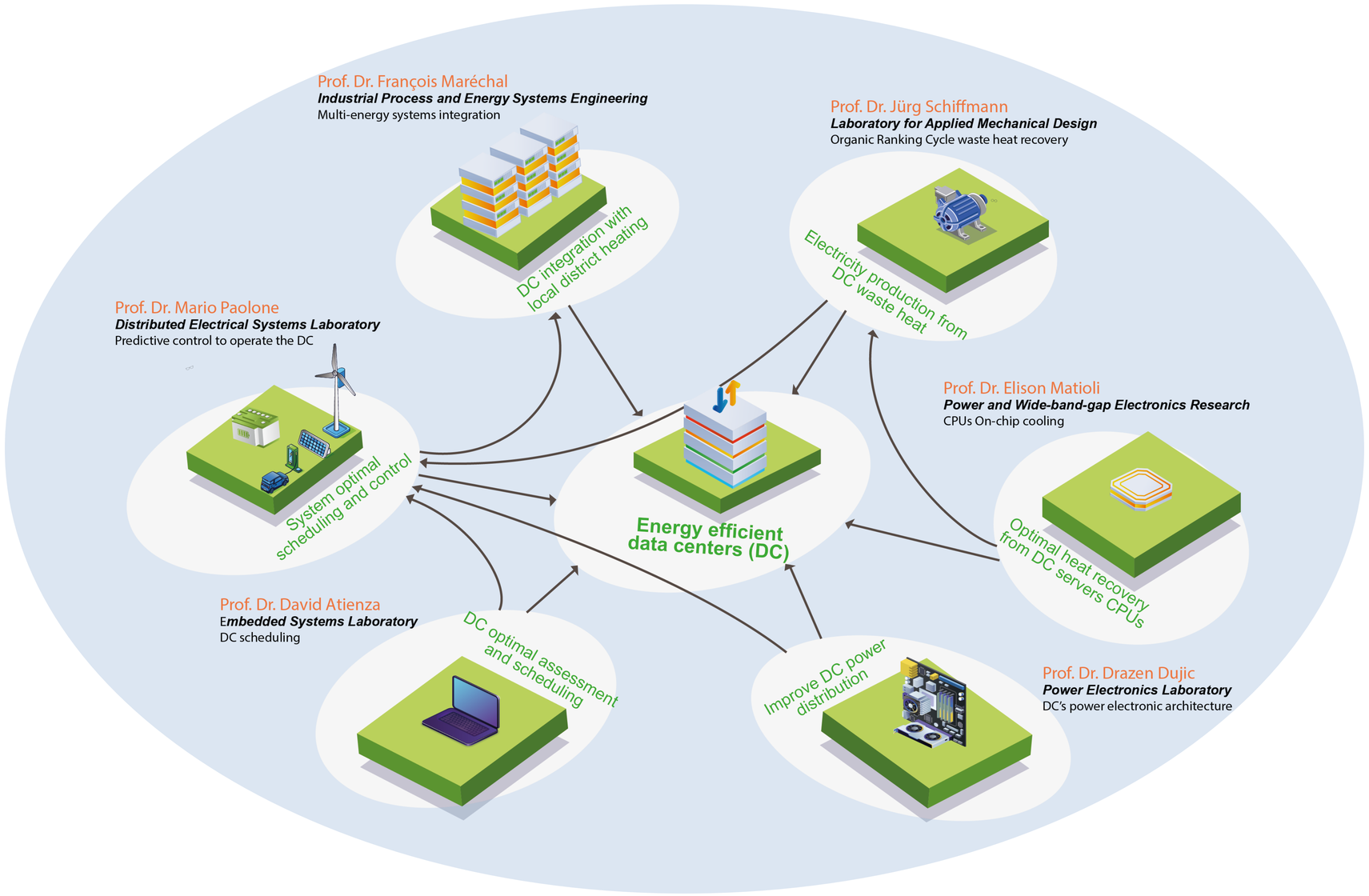
IT and energy supply represent today **44% of the EPFL CO_2eq emissions.**

The DCs expansion is associated with key energy and climate-related challenges:

- Impact on the power grid.
- Inefficient energy usage.
- Electricity-end-use carbon footprint.

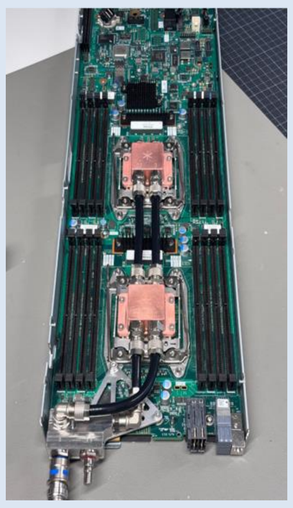
Objectives

- Develop a solution to **improve DCs' energy efficiency and reducing their carbon footprint** with special focus on the new EPFL DC
- Validate this solution in a **first-of-its-kind demonstrator** benefiting the entire EPFL campus
- Scale up through the EPFL EcoCloud to industry-grade DCs

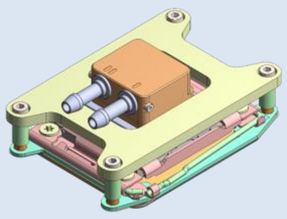


Optimal Cooling and Heat Recovery

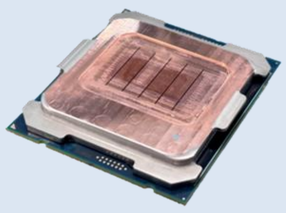
Cooling of CPUs, including demonstration of microfluidic-cooled devices in server blade prototype



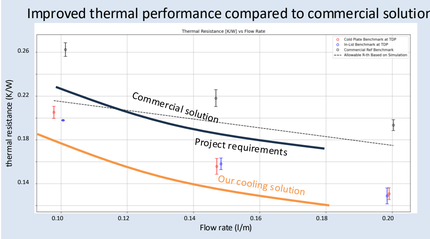
CPU Cold-Plate Assembly

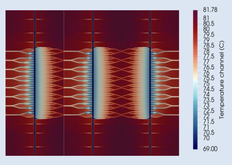


In-lid Etched CPU



Improved thermal performance compared to commercial solutions

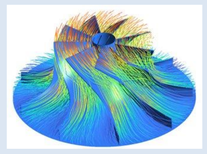


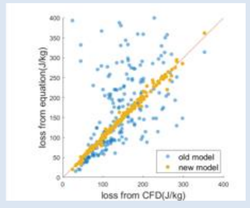


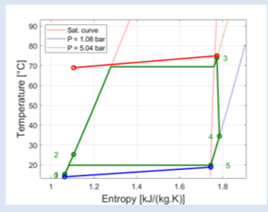
Waste Heat to Electricity

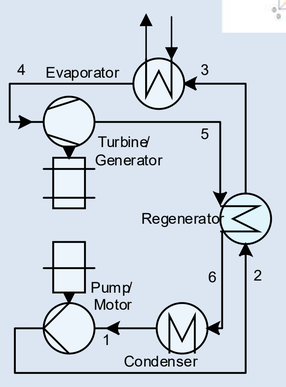
Heat valorization system with Organic Rankine Cycle

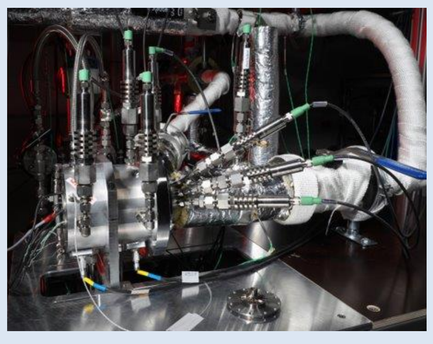
- Organic Rankine Cycle design
- 4th generation refrigerant as working fluid for high performance with health and safety prioritized
- 100% heat recovery from CPU of which
  - 86.6% goes into the heating network and
  - 10% converted back into electricity









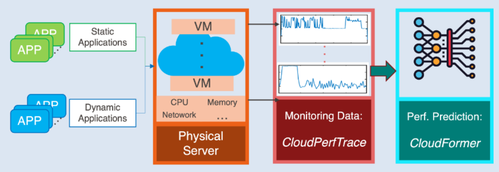


DC Power Consumption and Distribution Prediction of Application Running inside VMs

Workload performance prediction

Black-box workload simulation

- **CloudPerfTrace and Cloud Former**
- Handles unseen/unknown applications
- Accurate workload performance prediction for diverse applications
- Enables better resource allocation & efficiency



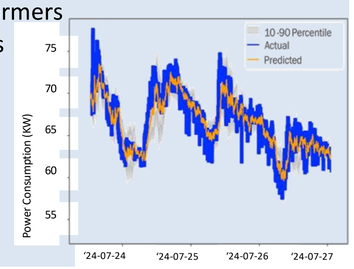
Method	MAE
OLS	49.09 ± 12.45
GLR	477.12 ± 1008.71
DT	15.03 ± 3.96
RF	10.78 ± 3.29
LSTM	15.42 ± 4.17
CF-Time	8.47 ± 1.89
CF-Feature	8.65 ± 1.55
CF	7.80 ± 1.55

Power Consumption Prediction

- CPU/GPU workload & power consumption data collected
- Development of a probabilistic forecasting model:
  - Based on Temporal Fusion Transformers
  - Captures long-range dependencies

Results

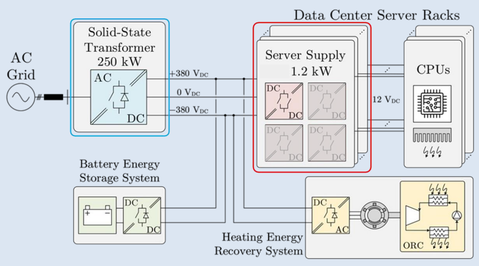
- Accurate short- and long-term power forecasts
- Direct impact: energy savings & improved system reliability



Power Distribution and Conversion Architectures

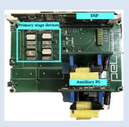
Improve efficiency, power density and reliability

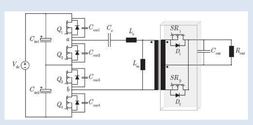
- Moving to high-voltage 800V DC distribution
- Simplifying power delivery
- Deploying scalable interface with medium-voltage (MV) grid



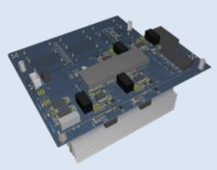
Results

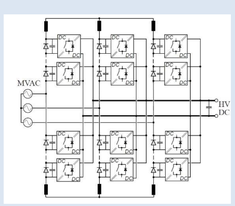
- 1.2kW 1MHz DC-DC power supply





- 250kW solid-state transformer (SST)





Multi-Energy System Operation

Carbon and market aware power system integration of DCs

- Long-term multi-objective planning for sustainable and grid-friendly DCs (e.g., ensure dispatchability; minimize carbon footprint and OPEX)
- Day-ahead electricity markets bidding strategy for data center, considering (a) resources, e.g., flexible workload; battery energystorage system; PV; ORC; (b) power grid constraints; and (c) minimize OPEX and carbon footprint, with risk-awareness
- Real-time control framework

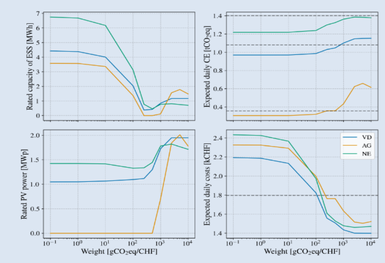
Results

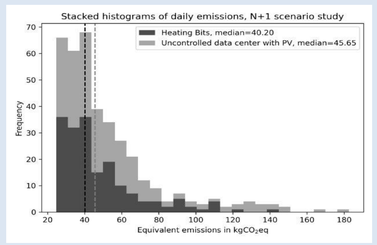
Long-term planning (for Switzerland)

- Max. 15% expected carbon emissions reduction (Neuchâtel)
- Max. 22% expected costs reduction (Vaud)

Day-ahead planning (for Heating Bits)

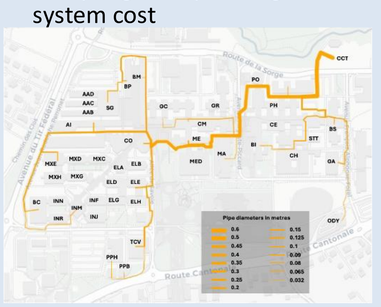
- Substantial CO_2 footprint reduction
- System stochasticity reduced by 60%

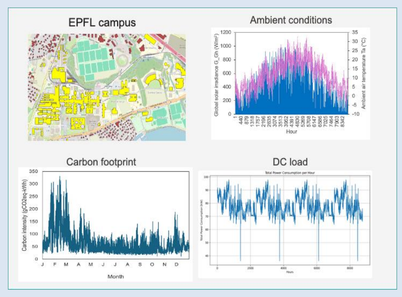




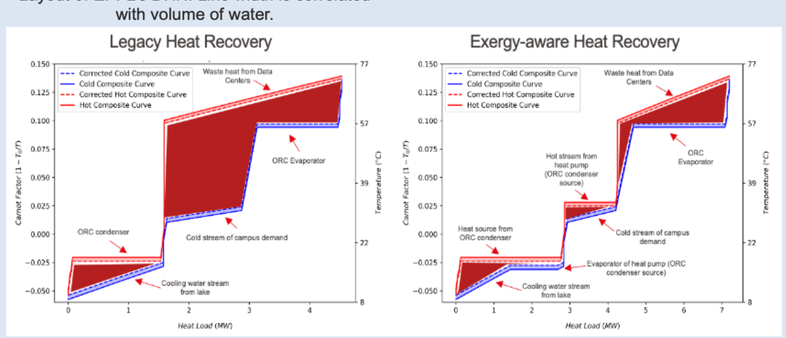
DC's integration into the district's energy system

- Development of the EPFL campus digital twin with the use of big data
- Legacy vs exergy-aware heat recovery strategy based on ORC's and heat pumps' different operating conditions
- Analysing the operating scenarios based on carbon footprint and system cost





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



Exergy destruction

The HeatingBits project is financially supported by the EPFL Solutions 4 Sustainability program.