EcoCloud:
The Center for Sustainable Computing at EPFL

https://ecocloud.epfl.ch

EcoCloud: An EPFL research center for sustainable computing

- EcoCloud networks the EPFL research community around sustainability topics
  - IT cross-layer optimization from edge devices to the cloud
  - Promoting large multi-disciplinary projects including EPFL labs and industry
    - 35 faculty affiliated, 4 schools

- Three main research interests:
  - Transform IT infrastructure into an enabler for a sustainable society
  - Ensure the sustainability of the IT infrastructure
  - Disseminate best practices for IT infrastructure

- And a strong link with local and global industry
  - Industrial Affiliates Program (CHF 15 000 / year)

IT for a sustainable world: The Urban Twin project

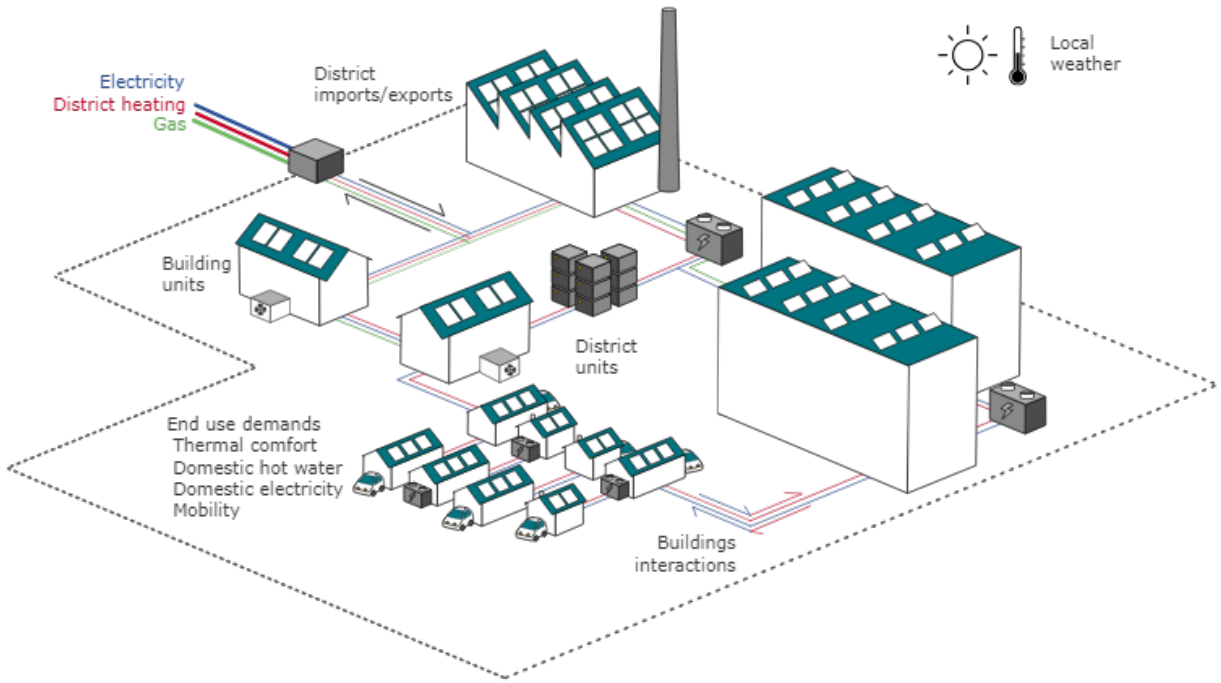
An urban digital twin for climate action – Assessing policies and solutions for energy, water and infrastructure

- Goal: Develop a digital model (twin) of a Suisse city
  - To support decision-makers in achieving sustainability goals
  - Probe effectiveness of new strategies and prevent problems
- A detailed model of critical urban infrastructure
  - Including energy, water, buildings and mobility
  - Need of new smart embedded sensors able to run AI/ML algorithms
- Need for efficient use of IT
  - Simulate the evolution of interlinked infrastructures under various climate scenarios
  - Efficiently execute advanced numerical models

Urban Twin is a joint initiative of the Board of the Swiss Federal Institutes of Technology

Urban Twin involves 12 EPFL laboratories (from the 4 schools) and 4 centers

Challenge: Scaling model from a single building to a complete city



- Building characteristics (materials, surfaces)
  - Type of heating/cooling installations
- Points of generation of renewable energy
- Weather models
  - Forecast insolation on buildings, temperature, wind, rain
- Vegetation areas
- Relations between buildings (e.g., local energy transfers)

REHO image source: https://reho.readthedocs.io/en/main/sections/3_Model.html

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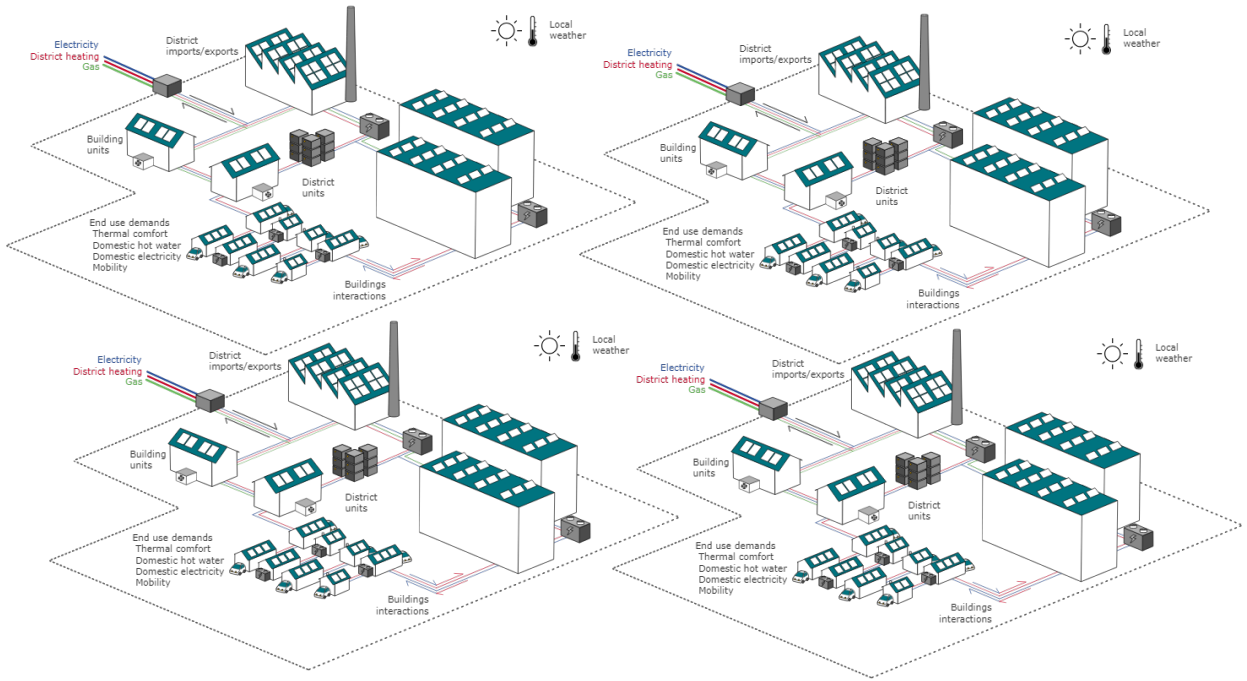

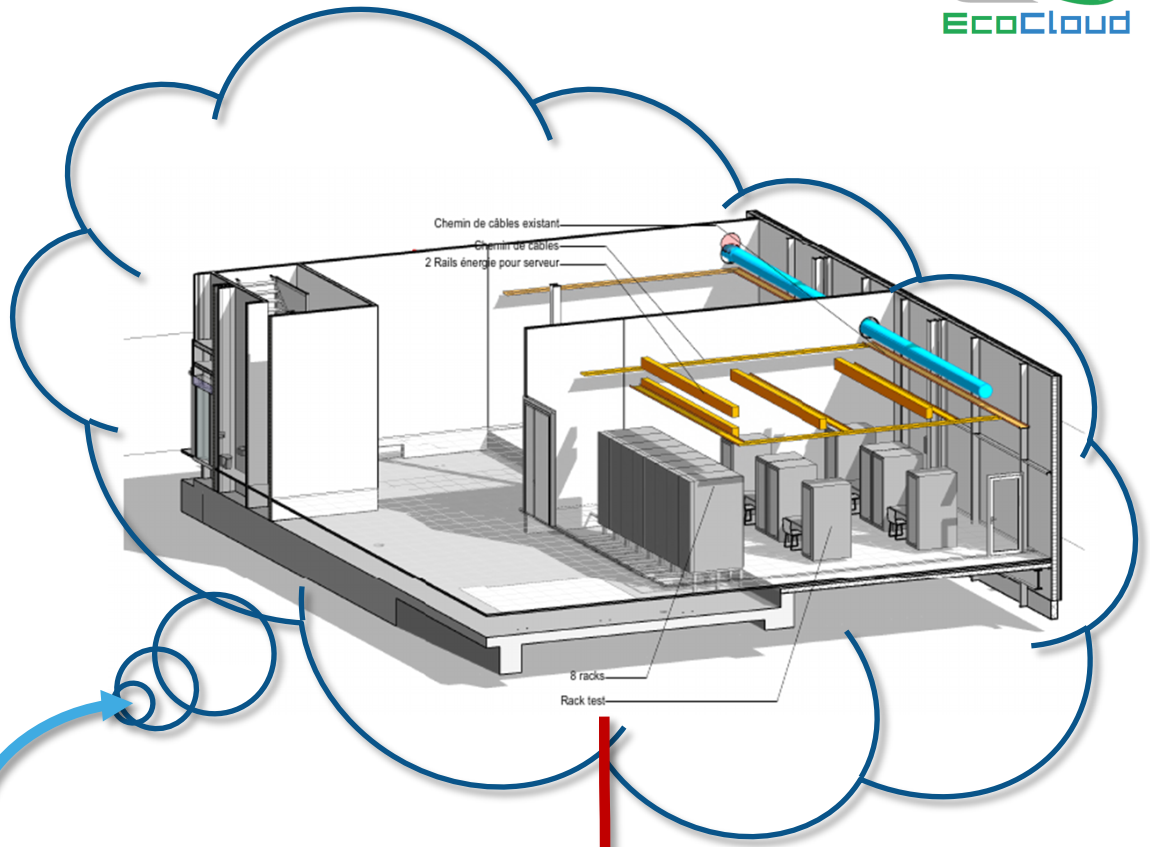

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- Relations between buildings (e.g., local energy transfers)
- Relations between neighborhoods

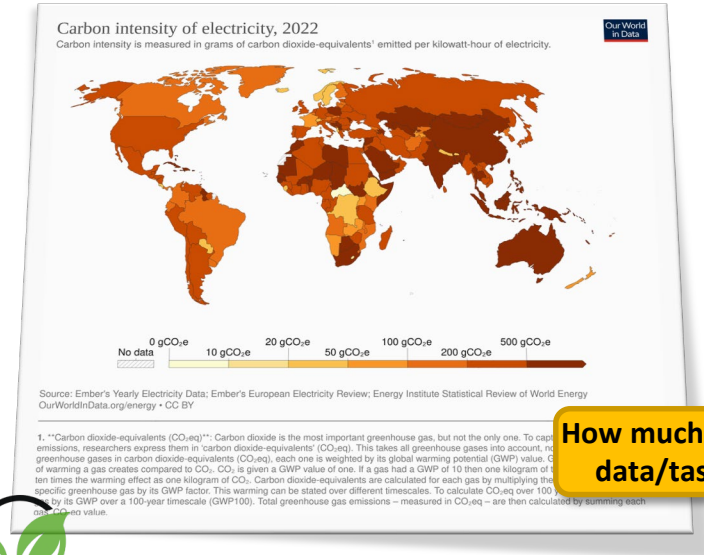
Energy demands per building for heating/cooling

Ensure that the models scale up and have reasonable energy demands

REHO image source: https://reho.readthedocs.io/en/main/sections/3_Model.html

But IT must not generate a larger problem itself... What can be done?

- Migrate tasks to DCs with lower carbon emission factor (CEF)



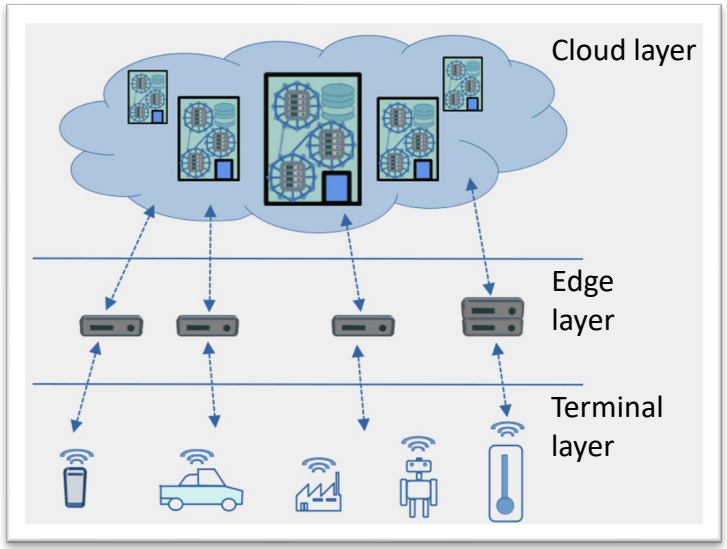
How much overhead from data/task migration?

A crystal ball to assign sets of jobs to DCs

- Improve DC efficiency

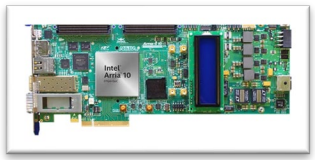
EPFL's new DC in the CCT building with PV generation, water cooling and heat recovery for heating of the campus

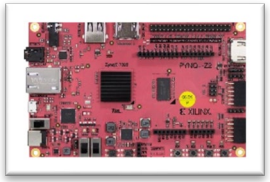
- Multi-scale computing systems
  - Distribute workload from terminals to cloud
  - Improved latency
  - Better privacy
  - Avoiding CO2 peaks in the DC



Source: Dr. Xavier Ouvrard, EcoCloud[1]

- Use accelerators for each specific workload (GPUs, FPGAs, ASICs)





Consider shifting from "time-to-completion" to "energy-to-completion"!

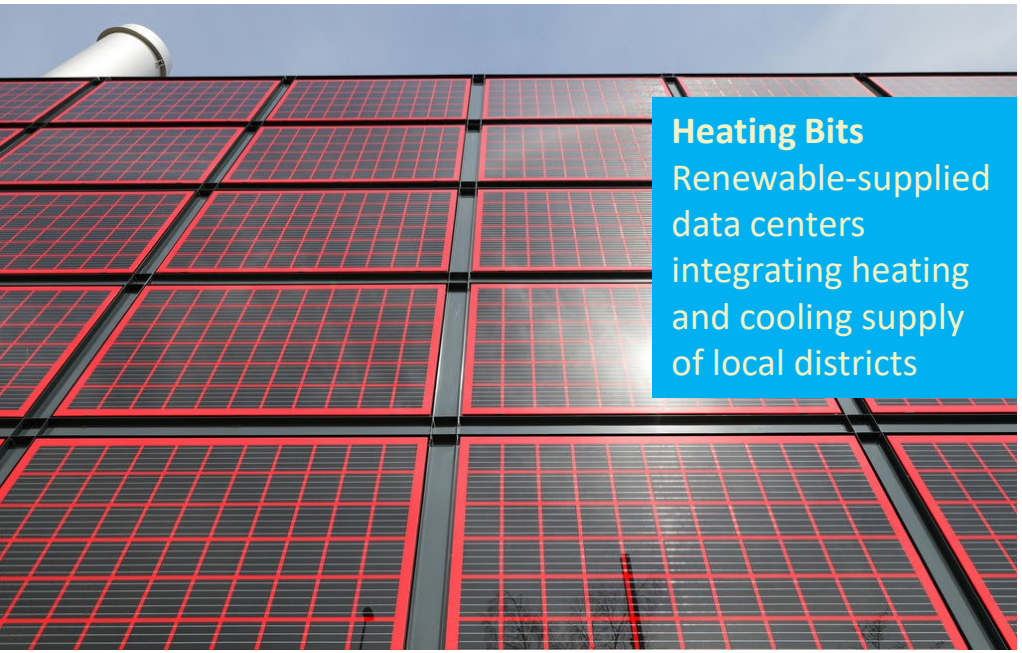
Example of accelerator (for ultra-low power biomedical devices)

Complex-valued FFT (1D)	ARM Cortex-M4 (cycles)	VWR2A[2] (cycles)	Speed-up
512	47926	7125	6.7 x
1024	84753	12405	6.8 x
2048	219667	30217	7.3 x

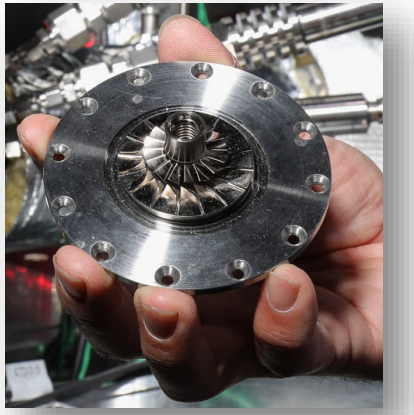
	ARM Cortex-M4 (uJ)	VWR2A[2] (uJ)	Energy Savings
App 1	0.74	0.26	64.7 %
App 2	0.74	0.13	82.9 %
App 3	1.1	0.47	56.0 %

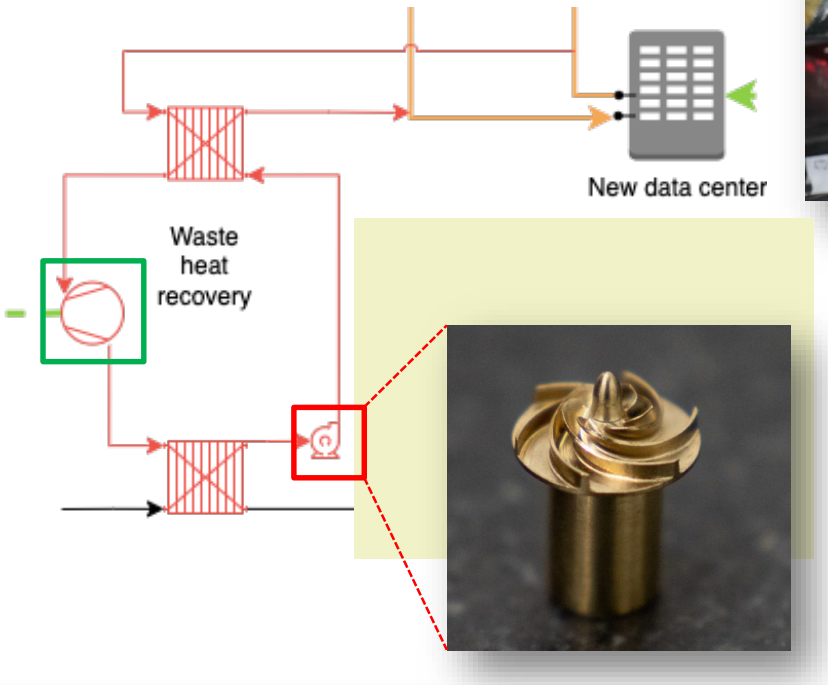
[1] "Special session: Challenges and opportunities for sustainable multi-scale computing systems," X. Ouvrard, et al. ESWeek, 2023.
[2] "VWR2A: A Very-Wide-Register Reconfigurable-Array Architecture for Low-Power Embedded Devices," B. Denkinger, et al. DAC, 2022.

Recovering heat at DC scale: The Heating Bits project



- Increase EPFL's DCs PUE and operate them with least CO_2eq
- High-temperature liquid microcooling
- Transform heat back into electricity (ORC)
- Improve reuse of waste heat for local district
  - Heating
  - Warm water





Funded by EPFL's Solutions4Sustainability (S4S)

- Involves 6 EPFL laboratories
- EcoCloud provides infrastructure and technical support

Improving IT efficiency

- Midgard: Reinventing virtual memory for post-Moore servers
  - Funded by Intel with ~ USD 1.5 M
  - 3 EPFL labs and 2 international partners
  - https://midgard.epfl.ch

Update the virtual memory design (1960s!) to cope with multi-terabyte memory hierarchies

- CHIMP: HW/SW co-design techniques for multi-objective optimization of heterogeneous 2.5D/3D chiplets
  - Funded by Intel with ~ USD 2.5 M
  - 2 EPFL labs and 2 international partners

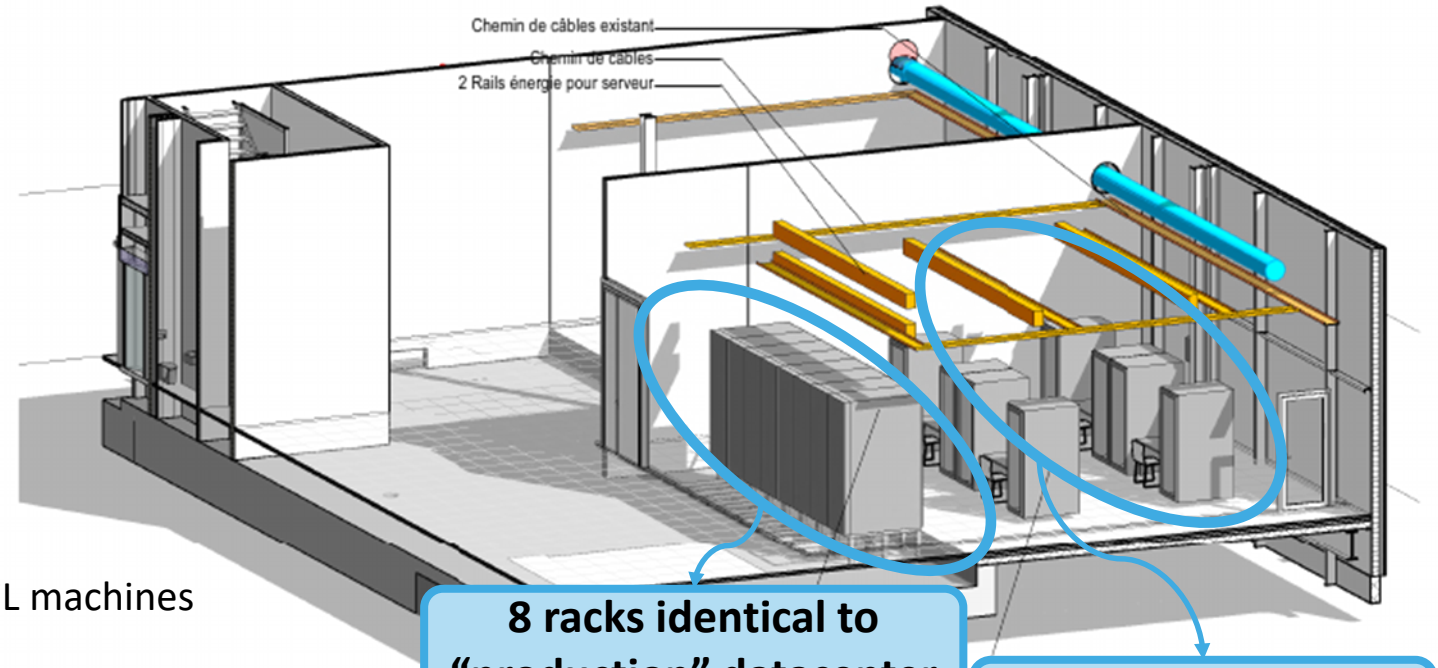
- Cloud, networking and edge computing
  - 2-year projects funded by Huawei with ~ CHF 5 M

- SEAMS: Sustainable & energy aware methods for SKA
  - Funded by SNSF and ANR (France)
  - Led by EcoCloud, 2 EPFL labs/platforms and 3 French partners
  - Explore bottlenecks and limitations of mainstream HW for radio astronomy signal processing and data reduction

Driving the shift from "time-to-completion" to "energy-to-completion"!

EcoCloud's sustainability experimental facility in EPFL's CCT

- ~100 m² of flexible space for experiments on sustainable computing
  - Available in Spring'24 ⚠
- Support for multi-lab projects
  - Urban Twin
  - Heating Bits
  - DL energy/carbon footprint characterization
- Experimental support
  - Direct current (DC) distribution
  - Energy consumption monitoring
  - Network topologies
  - Server fleet with modern and decommissioned EPFL machines

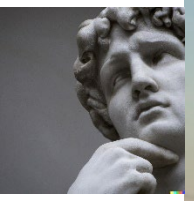


Racks with air/water passive cooling

Pipes for water cooling

Use of EcoCloud infrastructure:
– Unconventional research setups unfeasible in a production environment
– EcoCloud cannot provide "raw" computational capacity

These pictures correspond to the production side of the CCT DC and may not reflect the final EcoCloud infrastructure



Questions?

Thank you for your attention!

EPFL – EcoCloud

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