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Thermodynamics challenges of HPC and AI

- **Computation, thermodynamics and environmental impact**
- The Qarnot approach: reusing the computation heat
- Where is research heading?

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HPC environmental impact

Are cloud infrastructures as light as this cloud?

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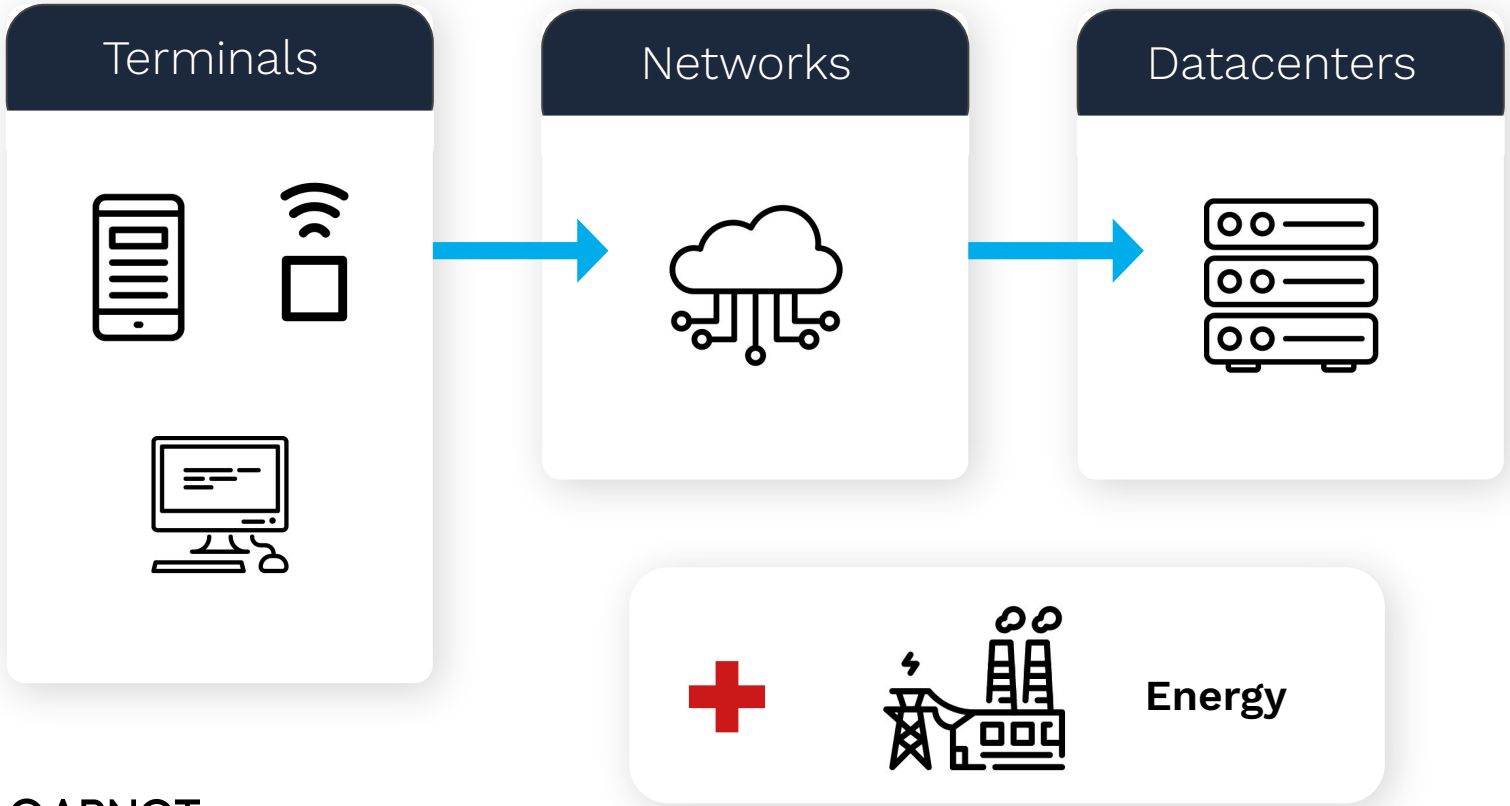
HPC environmental impact

Important infrastructures behind cloud services



HPC environmental impact

Important infrastructures behind cloud services

Internet cable laying vessel

Intel's Fab42 factory in Arizona, USA

Facebook datacenter in Texas, USA

Aluminium factory in Dunkerque, FR

HPC environmental impact

Important infrastructures behind cloud services

1,600 million tons of CO2 per year

4%+ **of global carbon footprint**
More than the aviation industry

9% yearly increase

Source: Lean ICT - Towards sobriety - The Shift Project - March 2019

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Hidden costs of computation

#1 Cooling system

PUE

Power Usage Effectiveness

$$\frac{EnergyIT + EnergyCooling + EnergyMisc}{EnergyIT}$$

Hidden costs of computation

#1 Cooling system

Source: Reported data center PUE figures in global Uptime Institute surveys from 2007 to 2020

Uptime Institute | INTELLIGENCE

Hidden costs of computation

#2 Fabrication

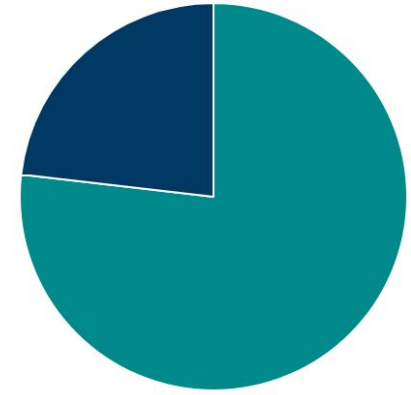
Usage
Manufacturing

USA

Global Warming Potential

5374 kgCO2eq

Dell PowerEdge C4130
Life span: 4 year(s)



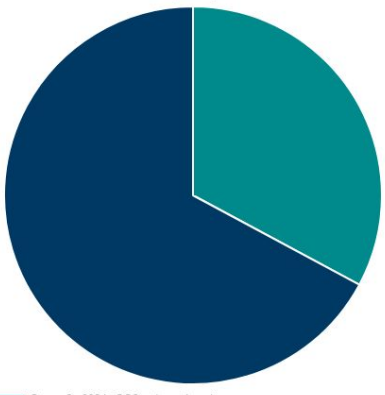
Scope 2 : 4129 kgCO2eq (use phase)
Scope 3 : 1245 kgCO2eq (manufacturing, transport and end-of-life phases)

France

Global Warming Potential

1854 kgCO2eq

Dell PowerEdge C4130
Life span: 4 year(s)



Scope 2 : 609 kgCO2eq (use phase)
Scope 3 : 1245 kgCO2eq (manufacturing, transport and end-of-life phases)

A focus on AI

GPT - Evaluation #1

GPT-3 (175B) training

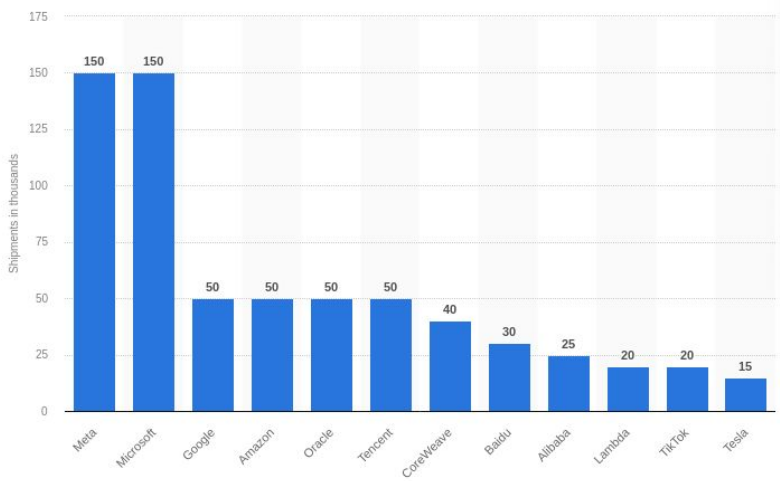
~500 tCO_2eq

Without inferencing
Without fabrication

Is it a lot?

A focus on AI

GPT - Evaluation #2



Estimated shipments of Nvidia H100 GPUs worldwide in 2023

Parameters

- **500k+** GPUs shipped
- **700W** TDP
- **x2** factor for server and DC
- **0,52 gCo_2eq/Wh** US mix

Carbon computation

- ~ 500 000 * 700 * 2 * 1/2 year
- ~ 3,1 TWh
- **~ 1,6 M tCO2**
- **~ 2*10⁶ AR Paris - NYC**

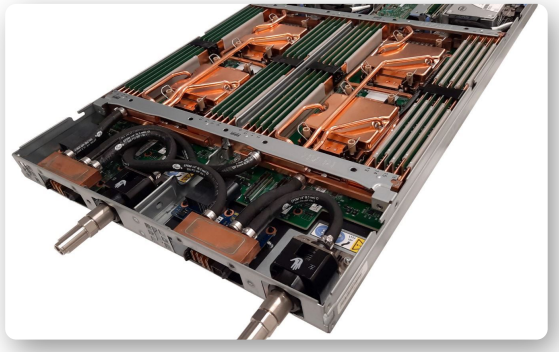
Without inferencing
Without fabrication
Without other GPUs sold this year and before

Beyond carbon footprint

Environmental footprint =
carbon footprint
+ water usage
+ abiotic depletion
+ …

Water usage

Abiotic depletion



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A hybrid approach

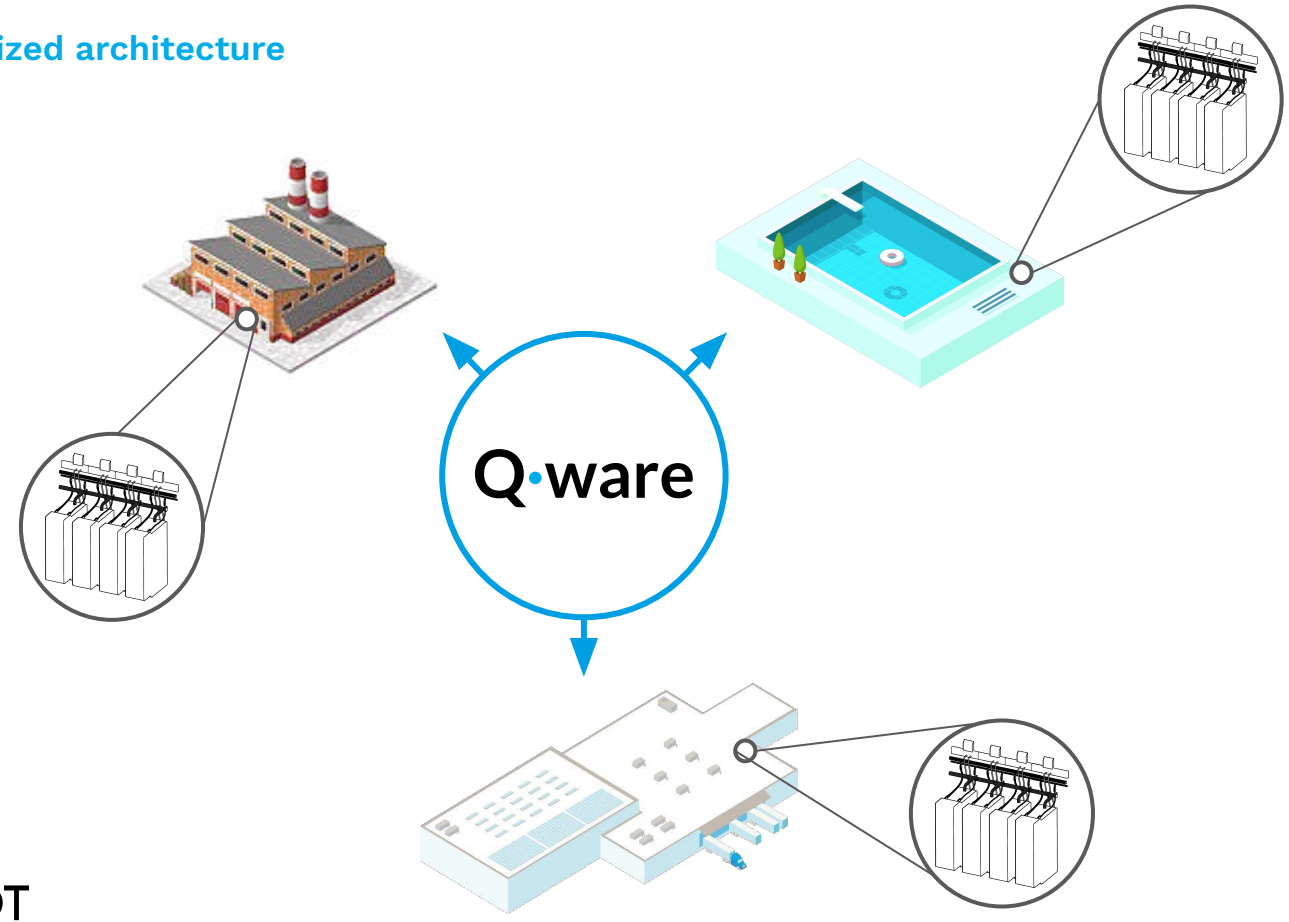
Two complementary industries

Cooling system of a data center
Google, Oregon, 103 MW

Heating system of a heat network
Sweden, 30 MW

A hybrid approach

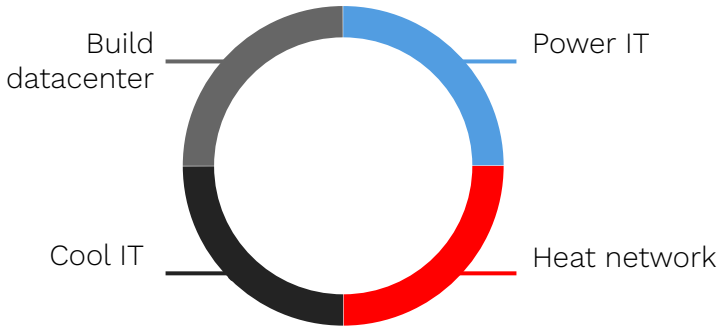
A decentralized architecture



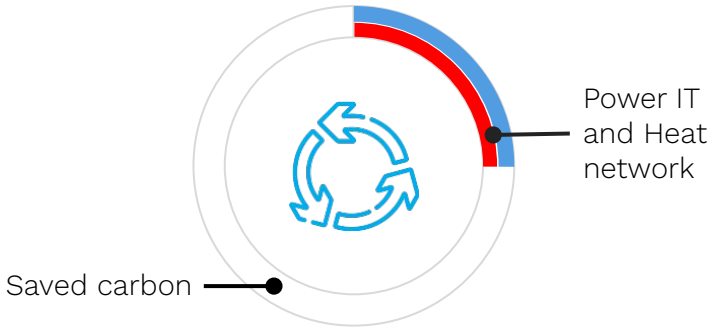
A hybrid approach

No new building, no cooling, and waste heat reused

Traditional model



Qarnot model



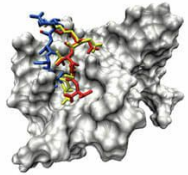
A hybrid approach

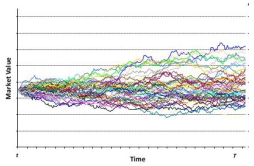
Business challenge #1: A new metric, the ERE

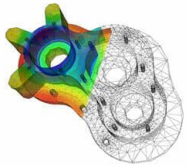
ERE

Energy Reuse Effectiveness

$$\frac{EnergyIT + EnergyCooling + EnergyMisc - EnergyReused}{EnergyIT}$$







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Computing
Clients who need computing power

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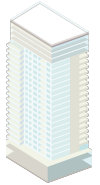
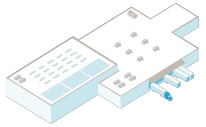
Building
Clients who need heat

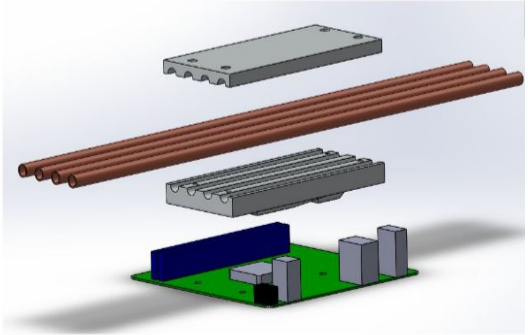
Computing boiler





A hybrid approach

Business challenge #2: A new hardware: the computing boiler



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- **Where is research heading?**

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Emerging research axes

Evaluation
Measure, simulate

Efficiency
Optimize systems: same usage, reduced footprint

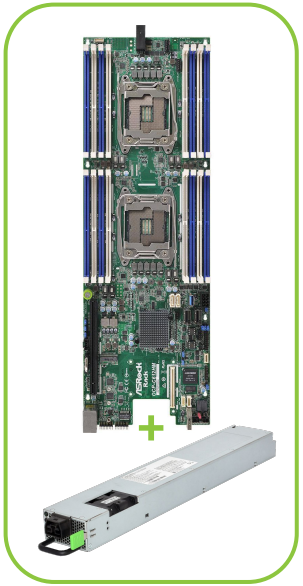
Sobriety
Redefine usages

Resiliency
Define systems that help facing partial breakdowns

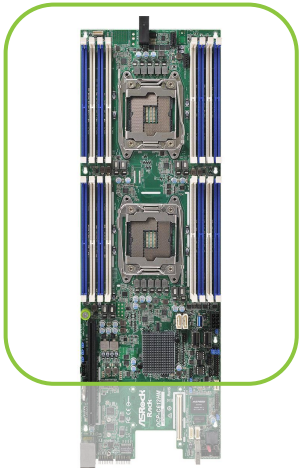
Emerging research axes

Evaluation: how to manage heterogeneous instrumentation?

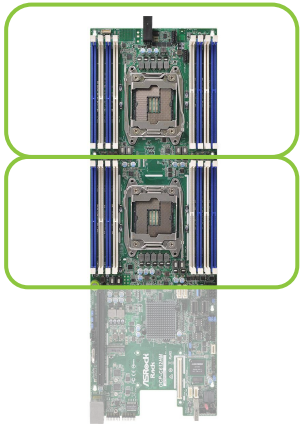
Wattmeter



BMC

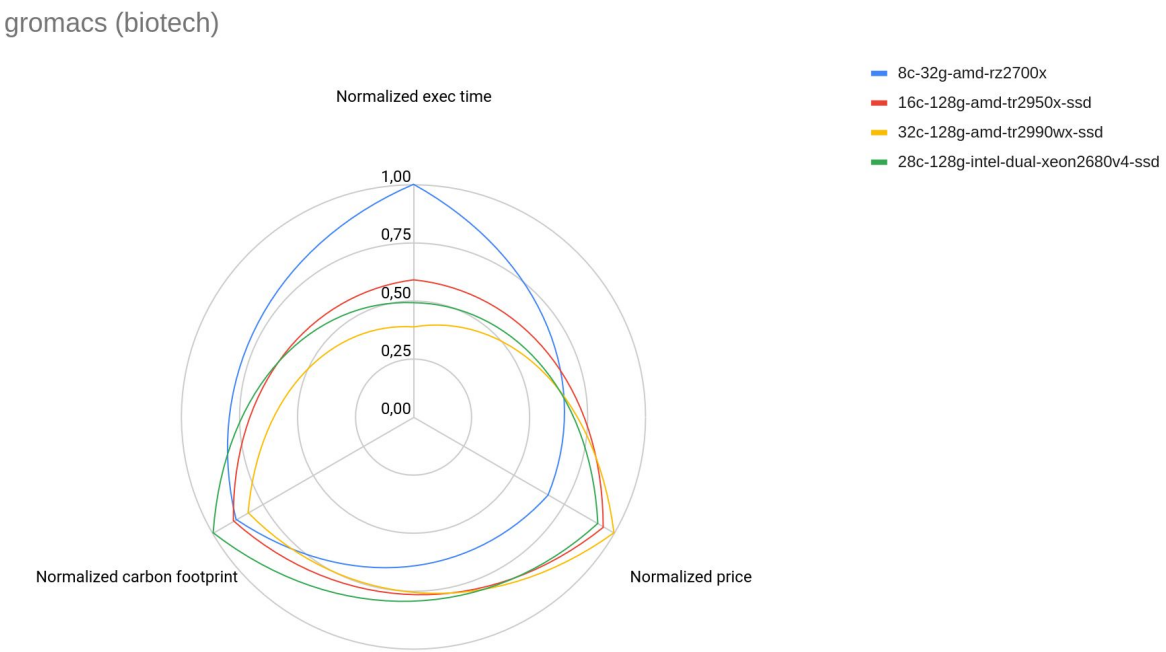


RAPL



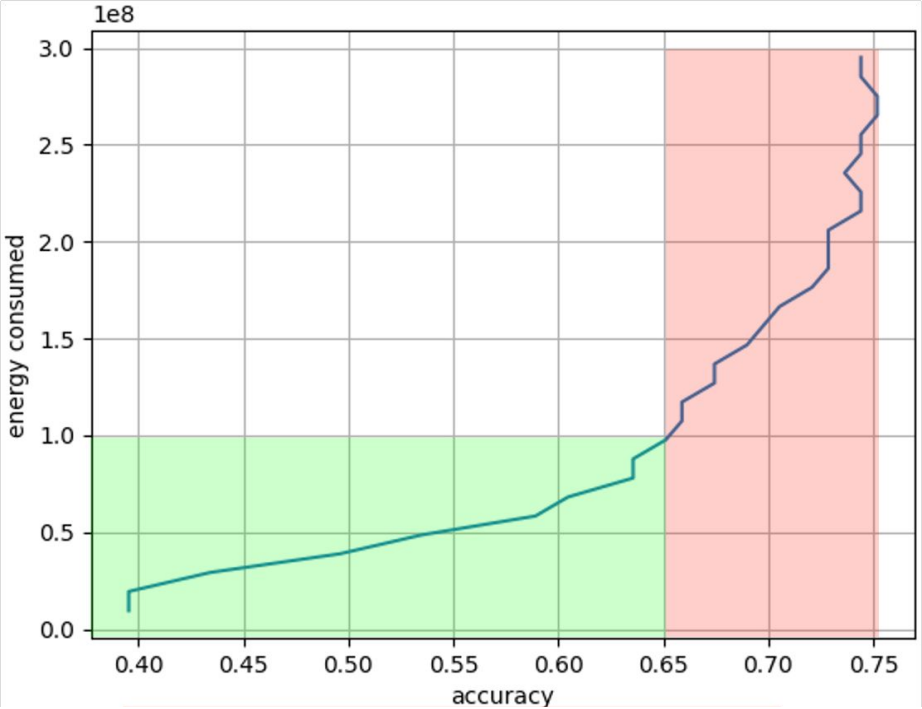
Emerging research axes

Efficiency: how to include environmental parameters in the scheduling policy



Emerging research axes

Sobriety: when should we stop a training?



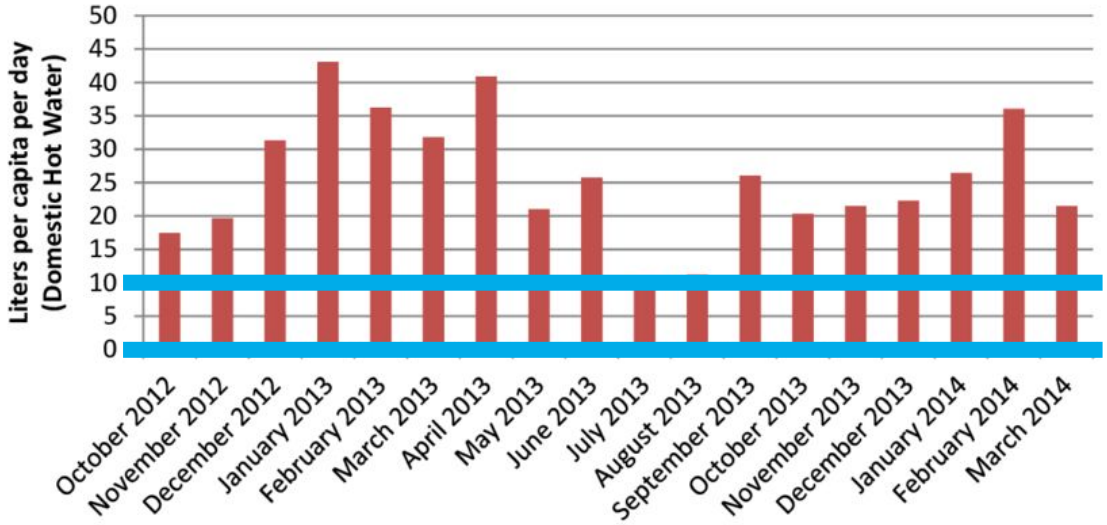
Questions ?

Thank you for your attention!

Jobs or internships: email jobs@qarnot.com or remi@qarnot.com

Bonus - QB•x

How do you do in the summer?



Bonus - Carbon facts

Carbon Facts

Name	**Using a QBx during a year**
Duration	**365d**

Saved Carbon Footprint **17.11** TCO_2e

Saved carbon footprint % **88.4** %

Energy

Total consumed energy	**39.48** GWh
Reused energy	**37.15** GWh
PUE (Power Usage Effectiveness)	**1.001**
ERE (Energy Reuse Effectiveness)	**0.06**
ERF (Energy Reuse Factor)	**94.1** %

Carbon

Qarnot carbon footprint	**2.25** TCO_2e
Equivalent European data center carbon footprint	**10.92** TCO_2e
Saved carbon footprint | compute service	**8.67** TCO_2e
Saved carbon footprint | heat service	**8.43** TCO_2e
Saved carbon footprint | compute + heat services	**17.11** TCO_2e
Saved carbon footprint %	**88.4** %

Water

WUE (Water Usage Effectiveness)	**0** L/kWh