LUMI, artificial intelligence and quantum computing

Tomasz Malkiewicz, CSC – IT Center for Science Ltd & Nordic e-Infrastructure Collaboration (NeIC)

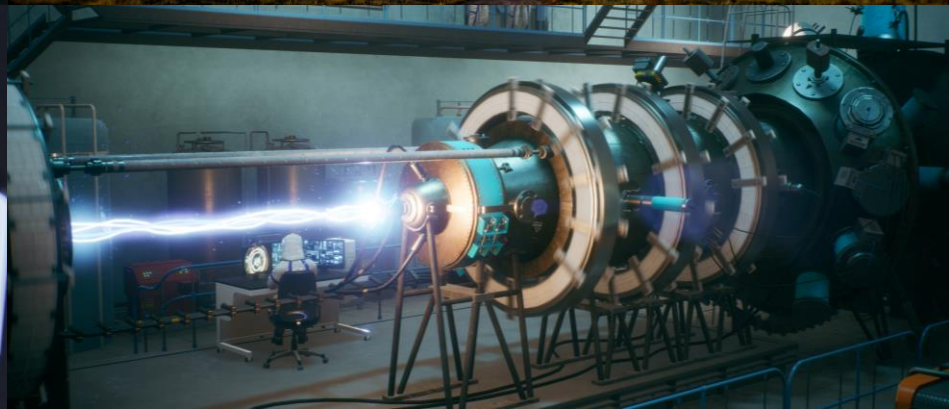
15.09.2022 Warsaw

LUMI is an HPE Cray EX Supercomputer

LUMI

What is a supercomputer?

LUMI



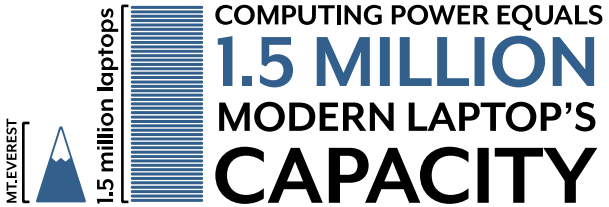
LUMI is 3rd fastest supercomputer in the world

LUMI

PEAK PERFORMANCE OVER

550 PETAFLOP/S

= performs 550 x 10^{15} calculations per second



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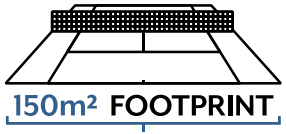
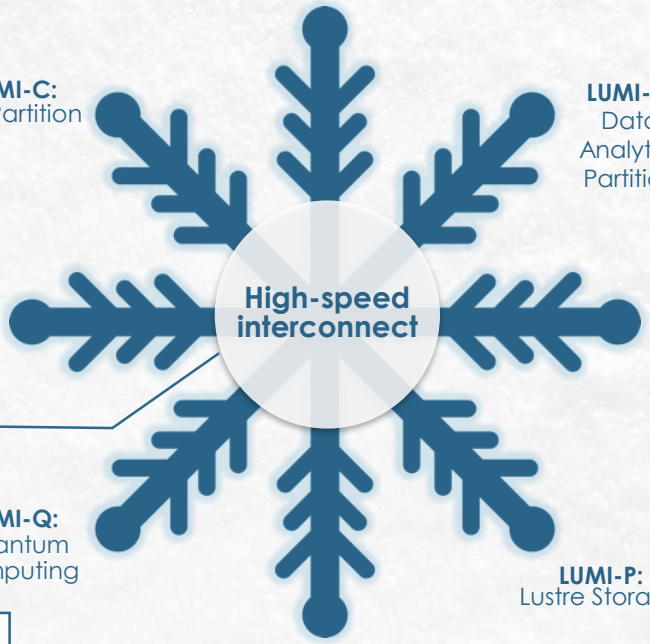


High-performance computing | **AI** | Data analytics

Modern architecture



LUMI-G: GPU Partition

GPU partition: over **550 Pflop/s** powered by AMD Radeon Instinct™ MI250X GPUs

LUMI-C: x86 Partition

Supplementary CPU partition: **200,000** AMD EPYC CPU cores

LUMI-D: Data Analytics Partition

Interactive partition with **32 TB** of memory and graphics GPUs for data analytics and visualization.

LUMI-K: Container Cloud Service

Possibility for combining different resources within a single run. HPE Slingshot technology.

LUMI-F: Accelerated Storage

8 PB Flash-based storage layer with extreme I/O bandwidth of 2 TB/s and IOPS capability.

LUMI-Q: Quantum Computing

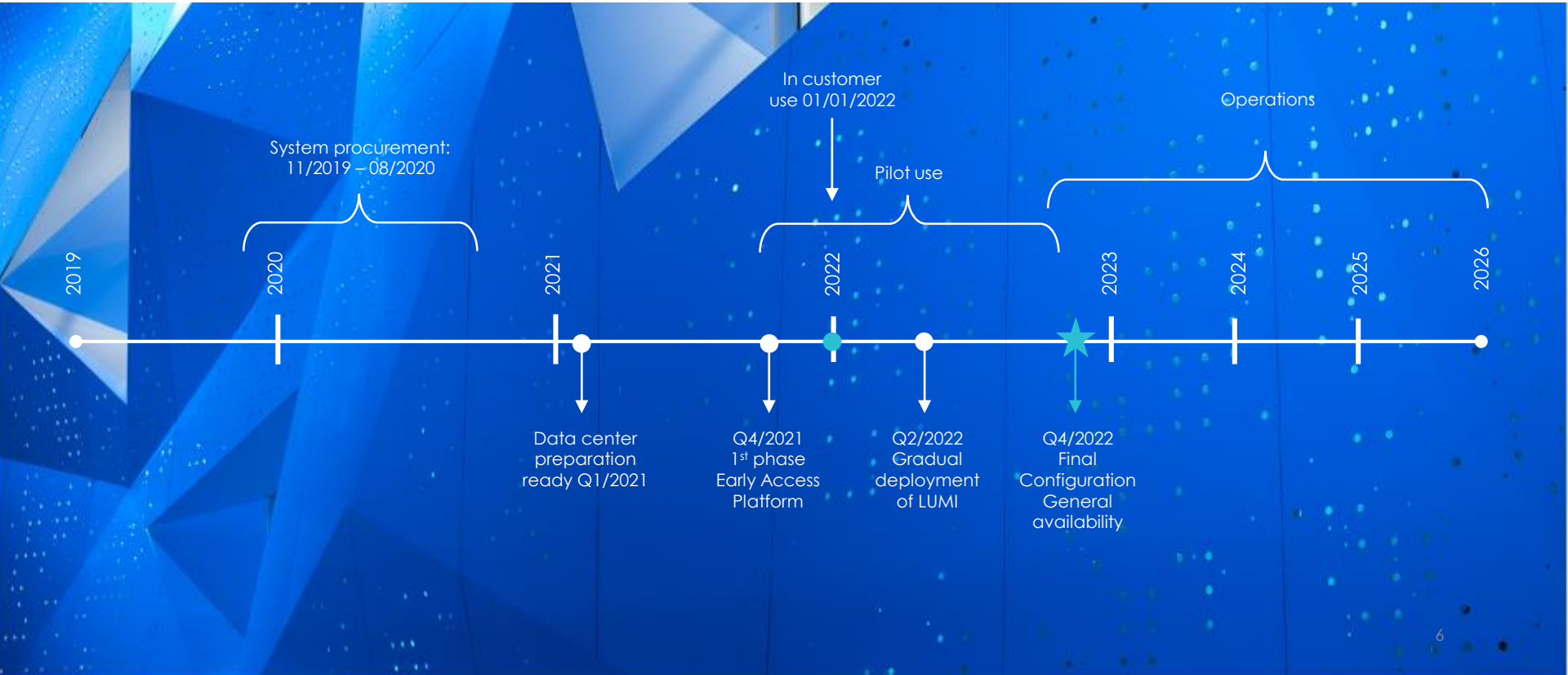
LUMI-P: Lustre Storage

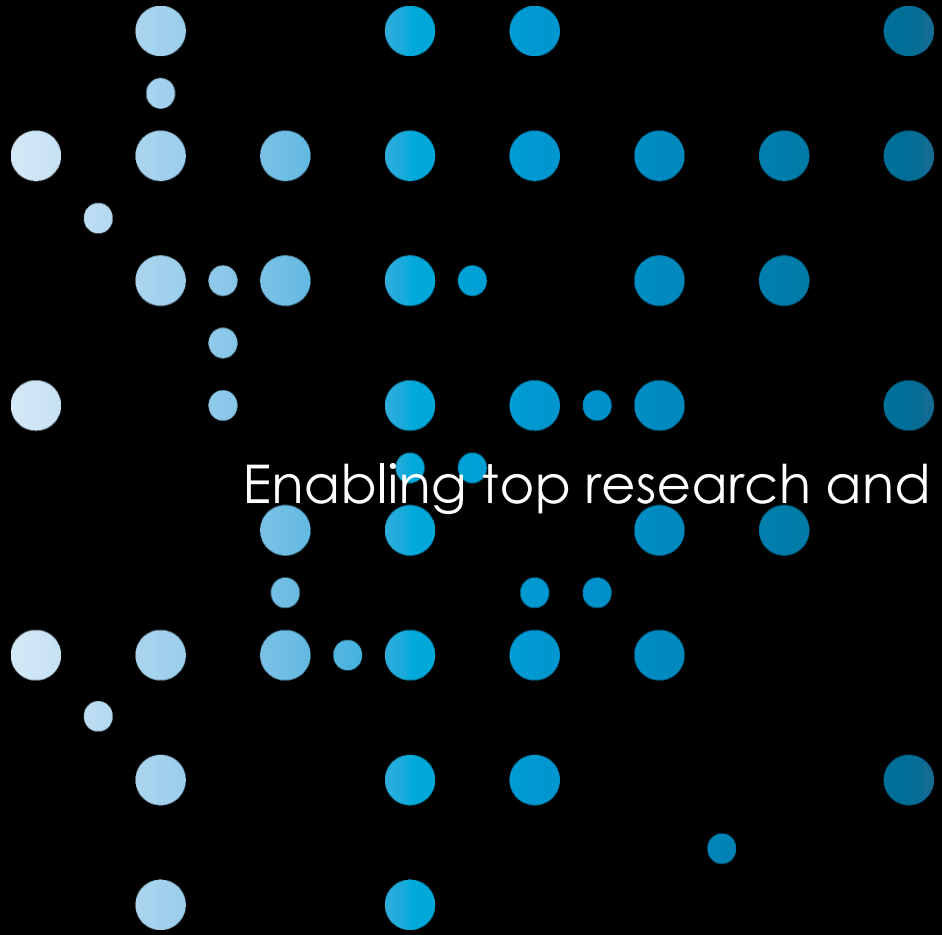
80 PB parallel file system

LUMI-O: Object Storage Service

30 PB encrypted object storage (Ceph) for storing, sharing and staging data.

LUMI timeline

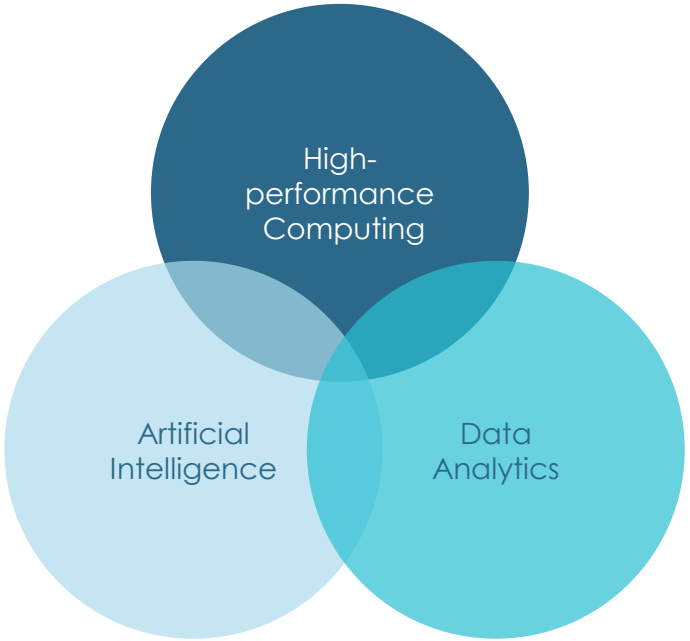




LUMI

Enabling top research and scientific breakthroughs

- The convergence of High-performance Computing, Artificial Intelligence and Data Analytics will be key for solving the great scientific and societal challenges.

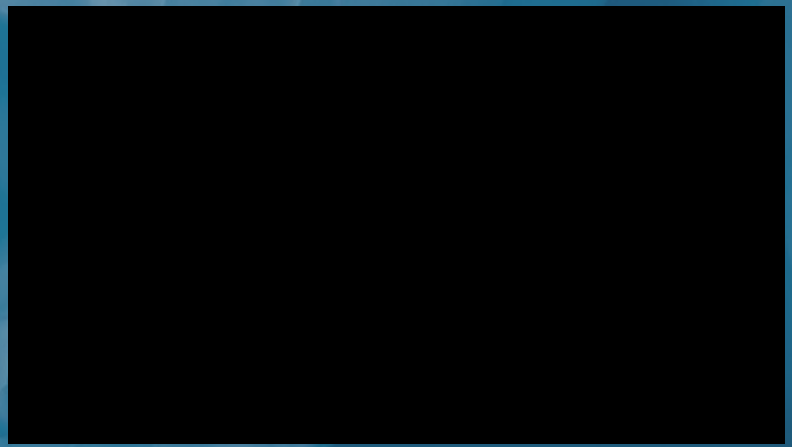


CLIMATE CHANGE

How will living conditions change when the climate is warming?

Climate simulations

Climate simulations are critical in climate modelling to understand climate change and to reduce the impact of climate change by finding the most appropriate and cost-efficient counter-actions.



TREATMENT OF DISEASES

Shedding light on the causes of illness and improving personalized medicine: sequencing and analyzing of full genomes combined with data analysis and correlations to clinical data.

Life Sciences

Advanced computing plays a key role in all levels of modern medicine and health, and will have tremendous impact for personalised medicine.

Researchers are already able to rapidly identify genetic disease variants, and it will become possible to identify diseases that are caused by combinations of variants, with treatments and drugs tailored both to the individual patient and the exact state of the disease.

TIME CRITICAL MODELLING

Fast-track for urgent computing needs in time- and mission-critical simulations, e.g., related to national or EU threat or other major crisis, e.g., pandemics.

LUMI

ARTIFICIAL INTELLIGENCE

LUMI is a one of the worlds leading research platforms for AI.

LUMI enables the convergence of high-performance computing, artificial intelligence, and high-performance data analytics.

Self-driving vessels and cars

Research and teaching of algorithms for self-driving cars and ships with unprecedented computing power.

Image: Groke Technologies

Natural language processing (NLP)

Artificial intelligence already plays an invisible role in everyday life. It works e.g. in speech recognition systems (e.g. smart speaker).


The EuroHPC Joint Undertaking.
Leading the way in European Supercomputing.

EuroHPC
Joint Undertaking

LUMI

The EuroHPC Joint Undertaking pools EU and national resources in high-performance computing

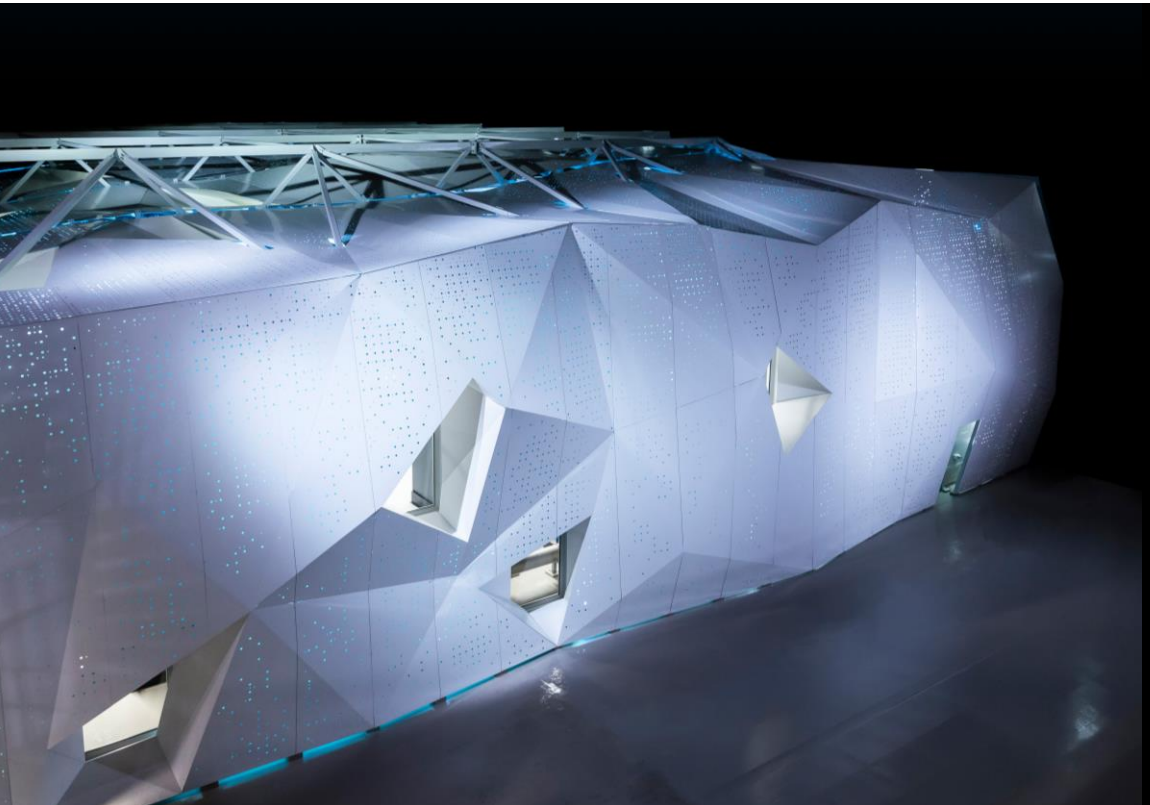
- acquiring and providing a **world-class supercomputing and data infrastructure** for Europe's scientific, industrial and public users
- supporting an ambitious research and innovation agenda

The first generation of EuroHPC systems announced in June 2019

- 3 pre-exascale systems to Finland, Italy and Spain
- 5 petascale systems to Czech Republic, Bulgaria, Luxembourg, Portugal and Slovenia

EuroHPC
Joint Undertaking

LUMI



LUMI supercomputer is the first co-investment ever of this scale in scientific computing.

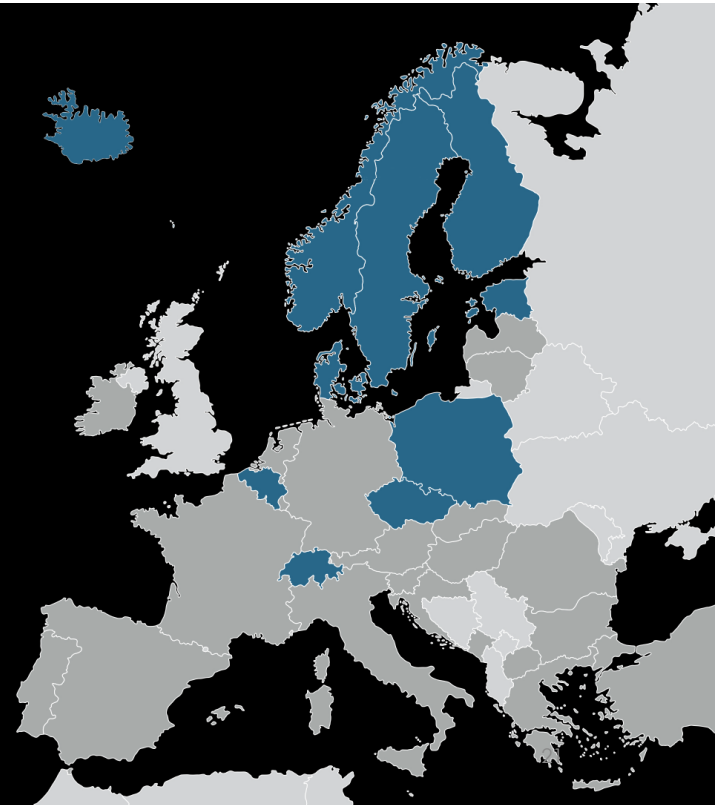
The total budget of the EuroHPC pre-exascale system in CSC's data center in Kajaani is over 202 million Euros. Half of this funding comes from the EU and the other half from the consortium countries.

EuroHPC
Joint Undertaking

LUMI

A unique collaboration between ten LUMI consortium countries and the EU to build and operate a world-class supercomputer.

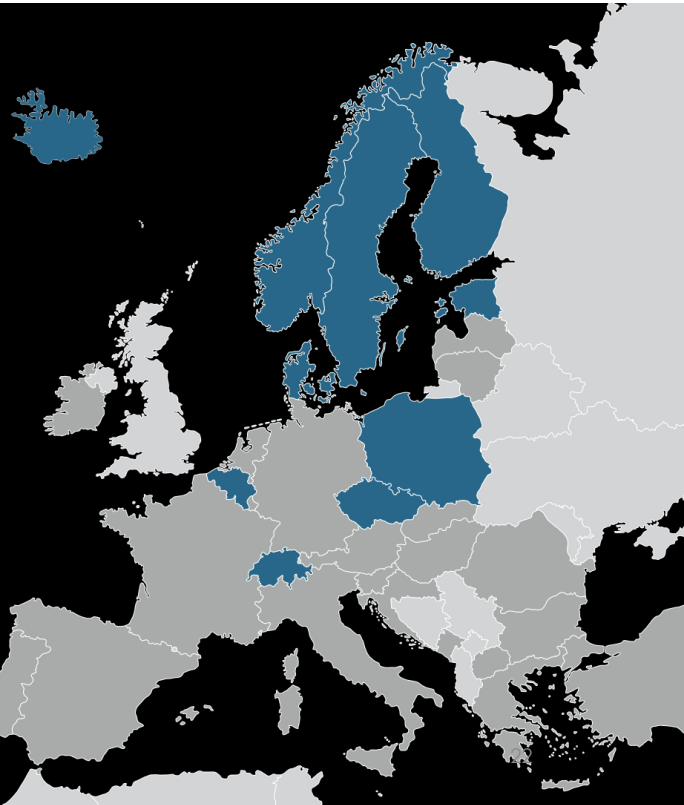
LUMI research infrastructure provides a high-quality, cost-efficient and environmentally sustainable HPC ecosystem based on true European collaboration.



The consortium continues a solid tradition of collaboration in HPC training and education, user support and data management services.

The resources of LUMI will be allocated per the investments. The share of the EuroHPC JU (50%) will be allocated by a peer-review process and available for all European researchers.

www.lumi-supercomputer.eu/get-started/



EuroHPC
Joint Undertaking

LUMI

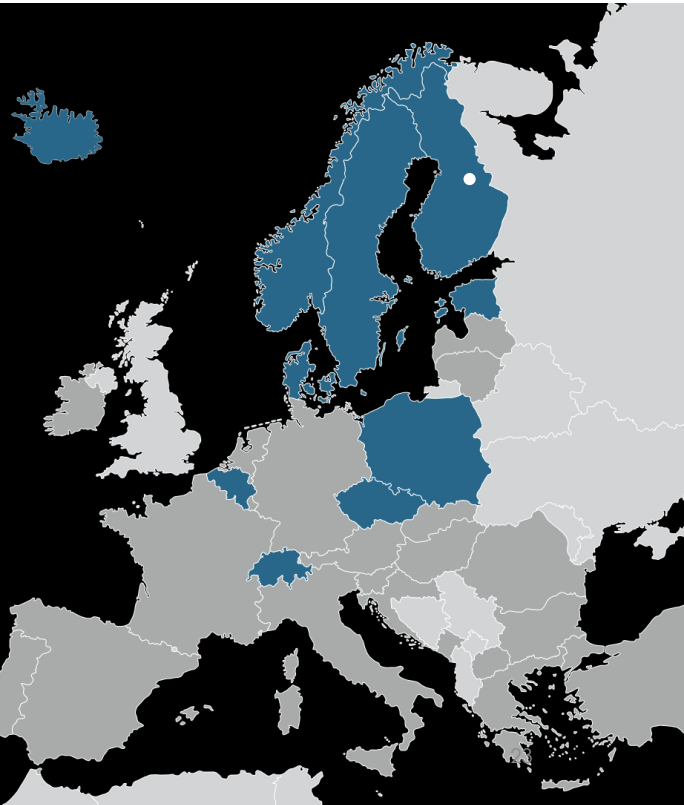
Powered by

CSC

LUMI is powered in Finland by CSC and is located in CSC's datacenter in Kajaani.

CSC – IT Center for Science is a Finnish center of expertise in information technology owned by the Finnish state and higher education institutions.

CSC provides internationally high-quality ICT expert services for higher education institutions, research institutes, culture, public administration and enterprises.

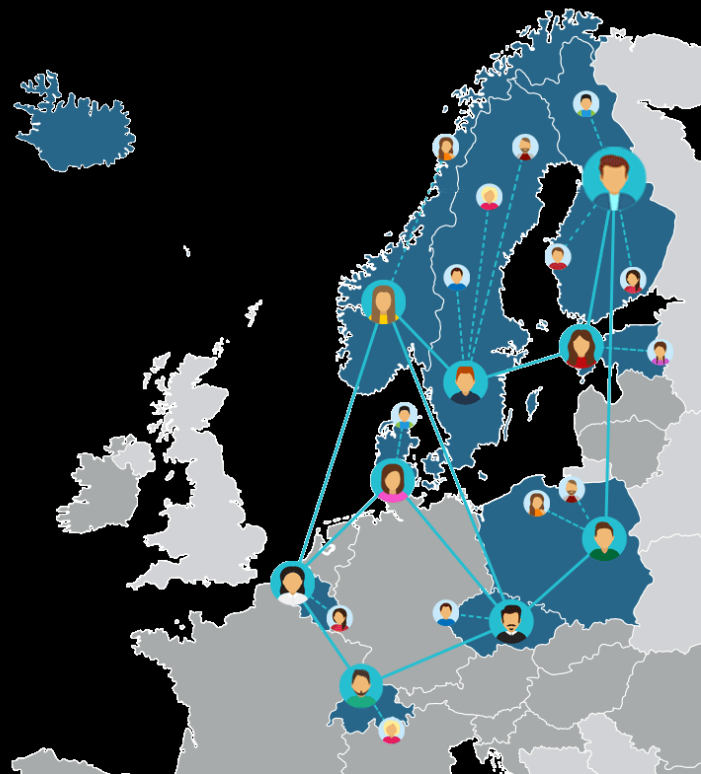


LUMI User Support

LUMI User Support and a centralized help-desk by the distributed LUMI User Support Team

- The model is based on a network of dedicated LUMI experts: each partner will provide one full-time person for the task
- User Support Team will also provide end-user training, maintain the software portfolio and user documentation of the system

In Finland CSC will be providing "Level 3" support (e.g. application enabling, methodology support) via its existing services as well as the EuroHPC Competence Center.




LUMI
Boosts European competence and
business to the next level

Up to 20%

of LUMIs capacity

is reserved for

European industry

and SMEs

LUMI

- **To boost innovation and new data-driven business** in areas such as platform economy and AI.
- LUMI world-class computing resources will **bring European RDI to the next level**
- Unparalleled computing and data management capacities for researchers in academia both and industry will **open up possibilities to address novel research questions**
- LUMI research infrastructure will **position Europe as one of the global leaders in supercomputing**

Promoting the European Green Deal

A vibrant data center ecosystem in Kajaani

KAJAANI DATA CENTER
POWERED BY CSC

ISO 27001
SECURITY
STANDARDS

World-class environmental sustainability and cost-efficiency

LUMI

Up to 200 MW

100%

renewable energy produced with hydropower

Negative

CO_2 footprint

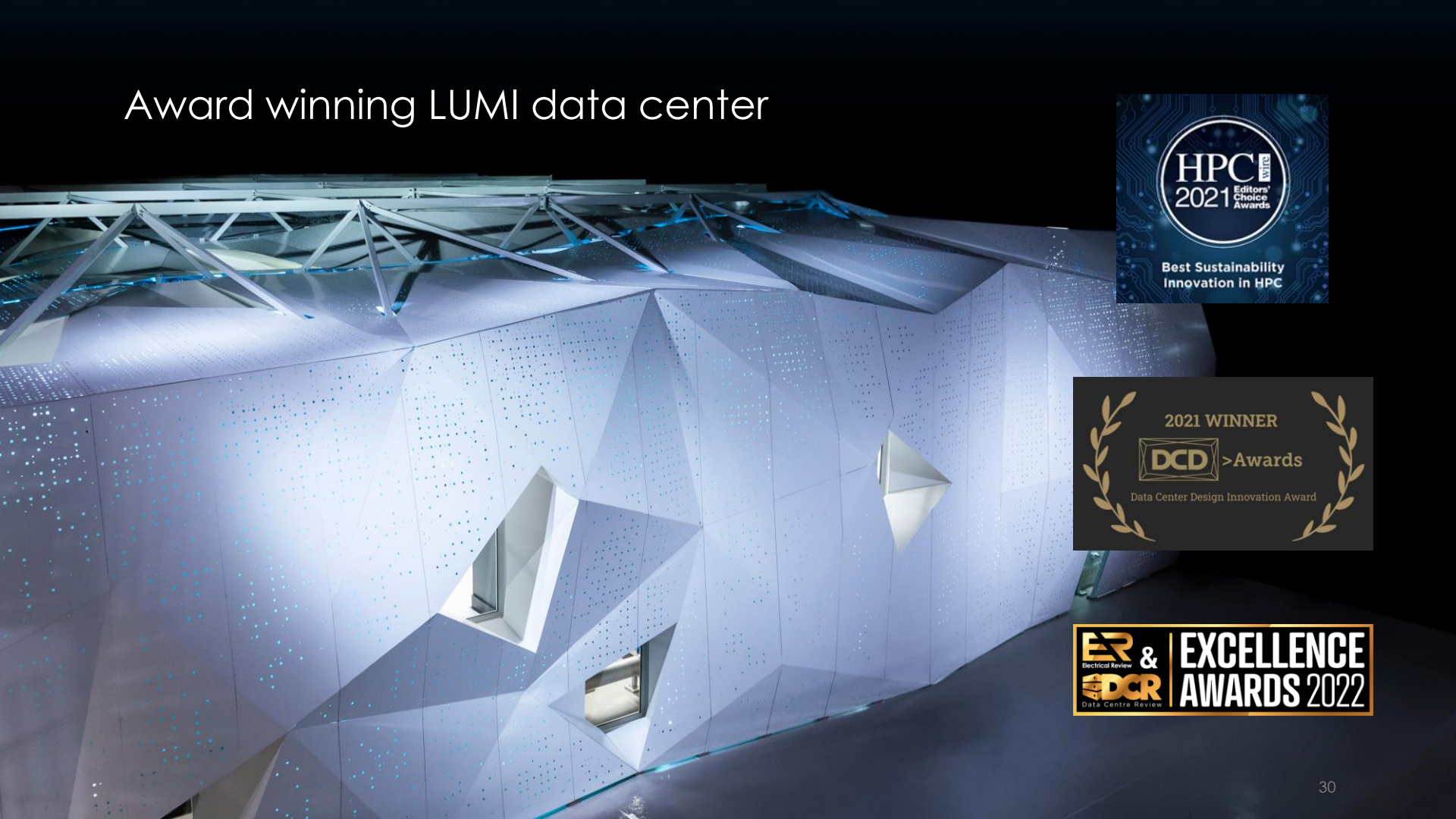
-12400 T Co_2eq

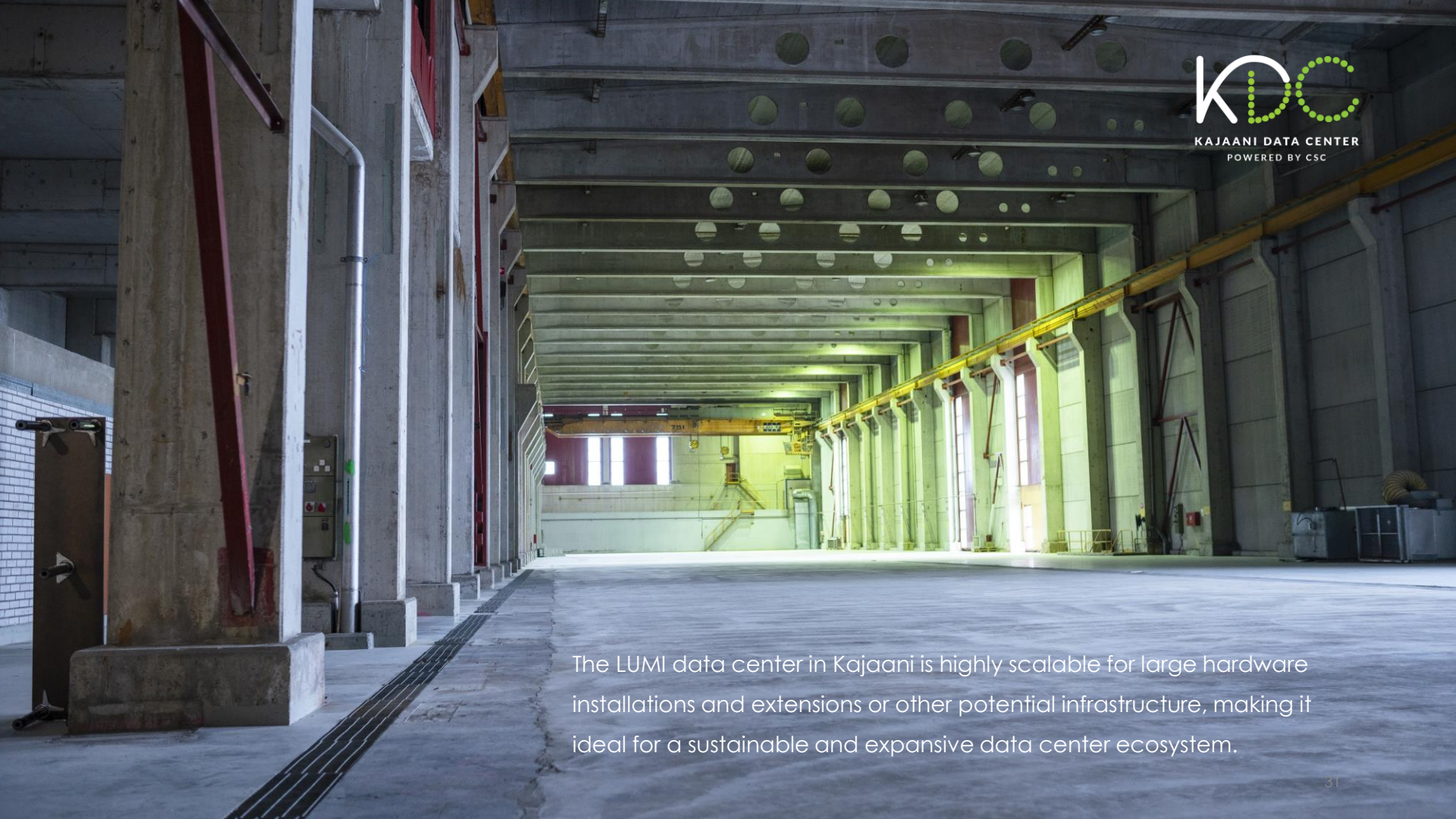
Waste heat covers

20%

of the yearly district heating needs of Kajaani

Award winning LUMI data center

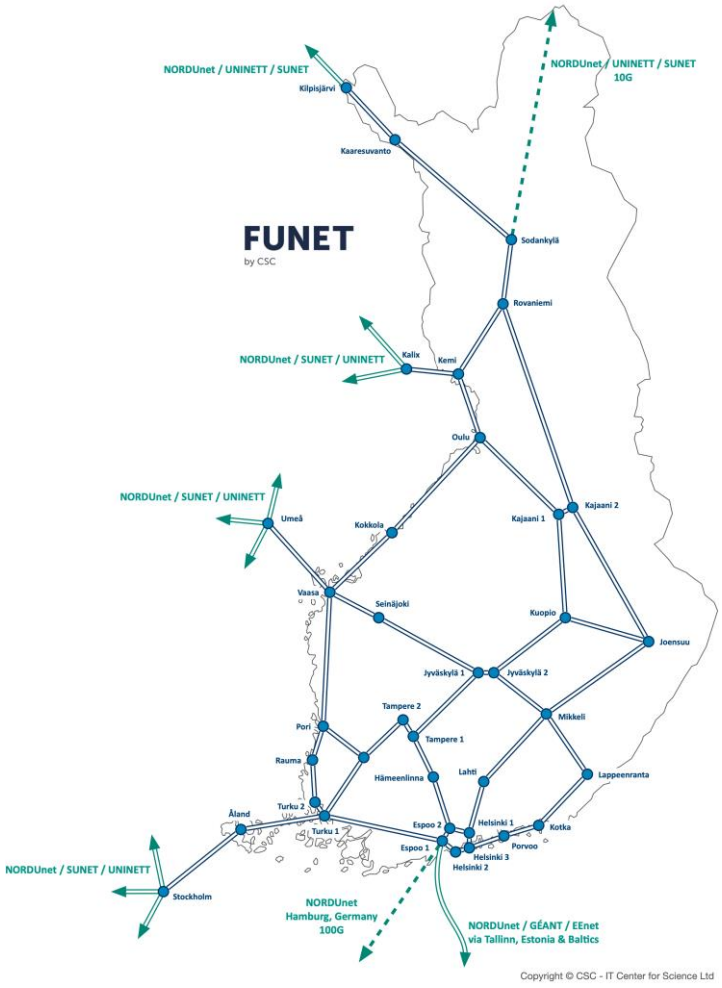




The LUMI data center in Kajaani is highly scalable for large hardware installations and extensions or other potential infrastructure, making it ideal for a sustainable and expansive data center ecosystem.

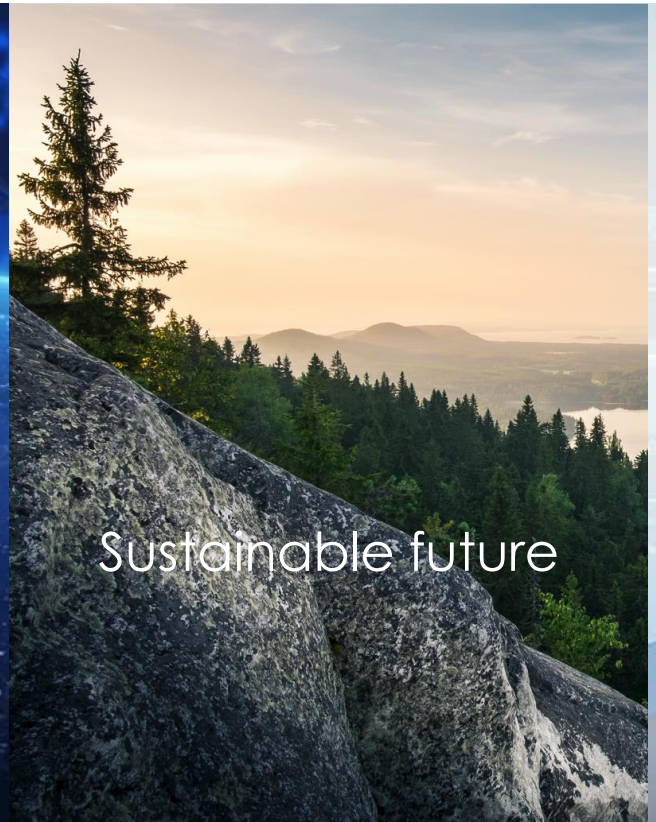
The reliable high-speed data communications networks of the data center are designed specifically for HPC

- LUMI research infrastructure is a **direct part of the Nordic backbone**
- Scalability for multi-terabit transmission needs already today, and readiness for future transmission technologies
- The Funet 2020 network supports the EuroHPC installation perfectly **without needs for additional investments**
- The next-generation NORDUnet connects the Kajaani LUMI site to GÉANT, ensuring European-wide availability of any HPC resources installed in Kajaani



What makes LUMI a success story?

LUMI



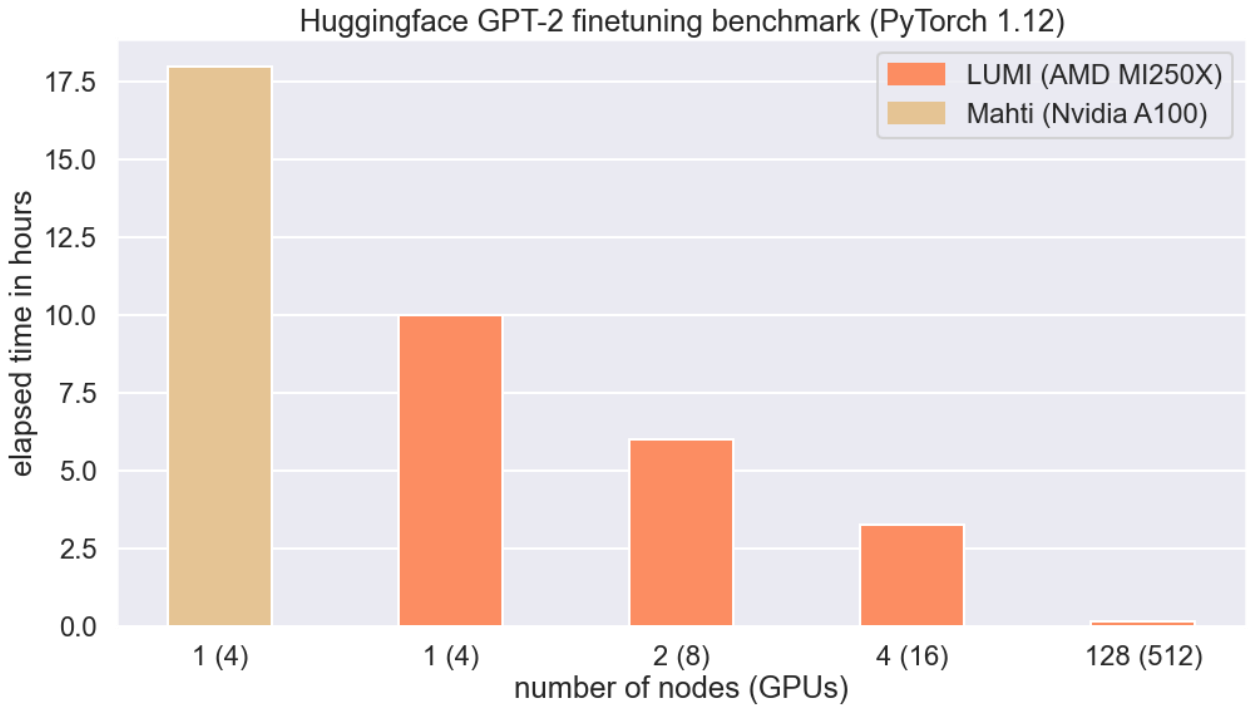
LUMI and Artificial Intelligence

LUMI for AI

LUMI

- LUMI is powered by AMD Radeon Instinct™ MI250X GPUs
  - ROCm instead of CUDA, MIOpen instead of cuDNN, RCCL instead of NCCL, …
  - Each GPU contains 128 GB of memory
- ROCm versions of standard frameworks readily available:
  - PyTorch
  - TensorFlow
  - JAX

Example benchmark



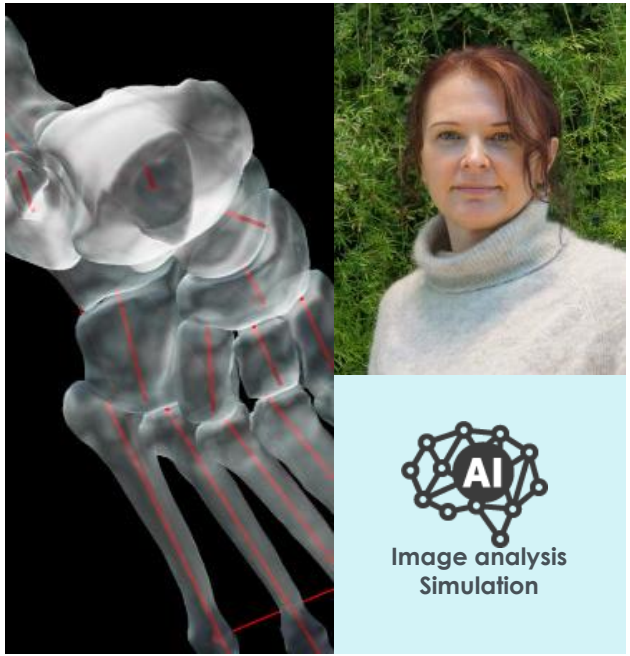
First Finnish LUMI AI research projects

LUMI

- **Cancer diagnosis and grading:** ComPatAI – Artificial-intelligence driven computational pathology (Pekka Ruusuvuori, Teemu Tolonen)
- **Open NLP models for Finnish:** F3AI – Foundation For Finnish Artificial Intelligence, (Sampo Pyysalo, Jörg Tiedemann)
- **Prostate cancer detection:** HistoEncoder – A foundation model for all digital histological samples (Antti Rannikko, Esa Pitkänen)
- **Machine translation:** LumiNMT – Multilingual neural machine translation on LUMI scale (Jörg Tiedemann)

DISIOR – analysis of medical images

LUMI



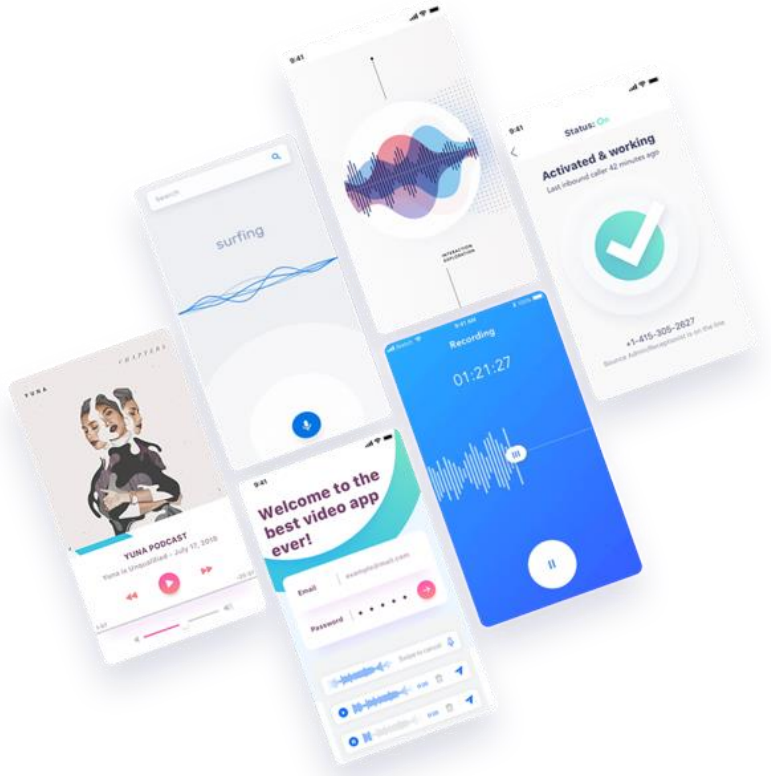
Disior is a Finnish company developing 3D image analytics software for clinicians.

"The technology we are using is strongly based on mathematical modelling: analyses, artificial intelligence, simulations and optimization. Therefore, powerful computing capacity and data management infrastructure is of utmost importance for us. The LUMI infrastructure will open up totally new possibilities for us which we may exploit"

Anna-Maria Henell, CEO of Disior Ltd

Speechly – spoken language understanding

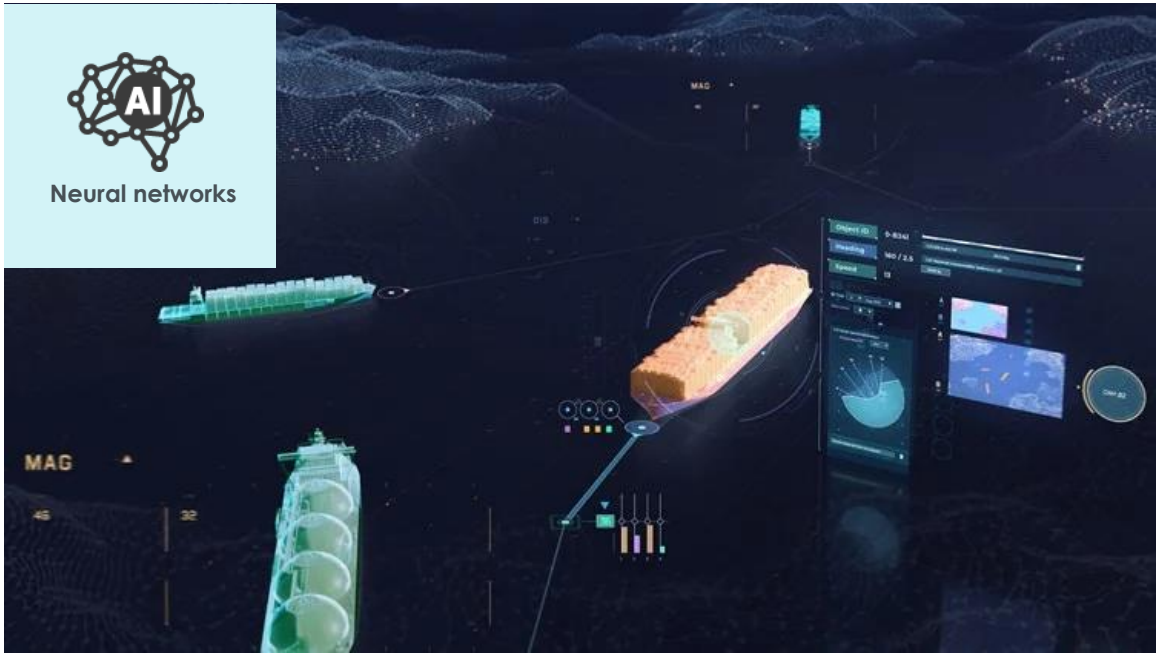
Speechly, a Finnish start-up company, has developed a new type of technology for understanding real-time spoken language, combining speech-to-text with Natural Language Understanding in a novel way, enabling fast and complex voice interactions.



AI

Neural networks

Groke Technologies – Towards safer navigation and fully automated vessels with AI



Groke Technologies is a Finnish company that focuses on developing intelligent methods for autonomous navigation to improve safety at sea.

High-performance computing (HPC) plays a vital role in optimizing machine-learning models for computer vision.

What can LUMI do for business?

LUMI

Cooperation between universities and research institutes

Competence development supported by domain experts and data management services

Opportunity for business growth

World-class cost-effective computing capacity

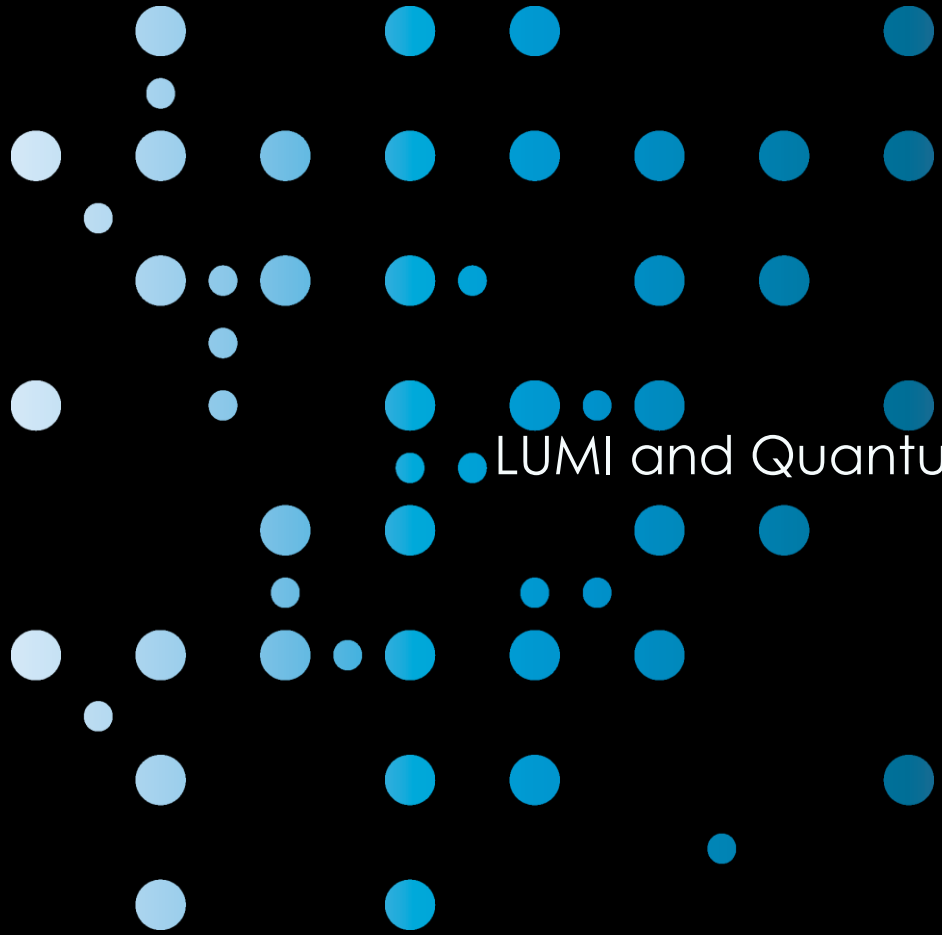
Data securely in Finland

Reliable and efficient network connections

Business use – how to get involved?

LUMI

PRIVATE–PUBLIC ENGAGEMENT	EUROHPC JU ALLOCATION	NATIONAL AI PROGRAMS
• Project in cooperation with a research organization and a private sector partner • Free of charge if results are published • Market price charged for projects with closed results	• Pay per use model – market price to be announced • PRACE SHAPE equivalent programs for SMEs – EuroHPC Development Access Calls	• E.g. Business Finland in Finland



LUMI and Quantum Computing

Supercomputers 💙 Quantum

LUMI

What is a quantum computer?

- A quantum computer is a device that exploits quantum mechanical phenomena to perform a calculation
- Enables **extremely powerful solutions to *certain* types of problems** and completely new science

What is a quantum computer *not*?

- A quantum computer **is *not*** a superfast version of a standard computer – **it is different**
- Speeds up some types of calculations remarkably, others not at all

Quantum computers will not replace supercomputers, but instead the two will *merge*

- Therefore, important to **stimulate co-creation between the HPC and QC communities**

End-users will need **early-access** to HPC+QC in order to make their **workflows quantum-ready**

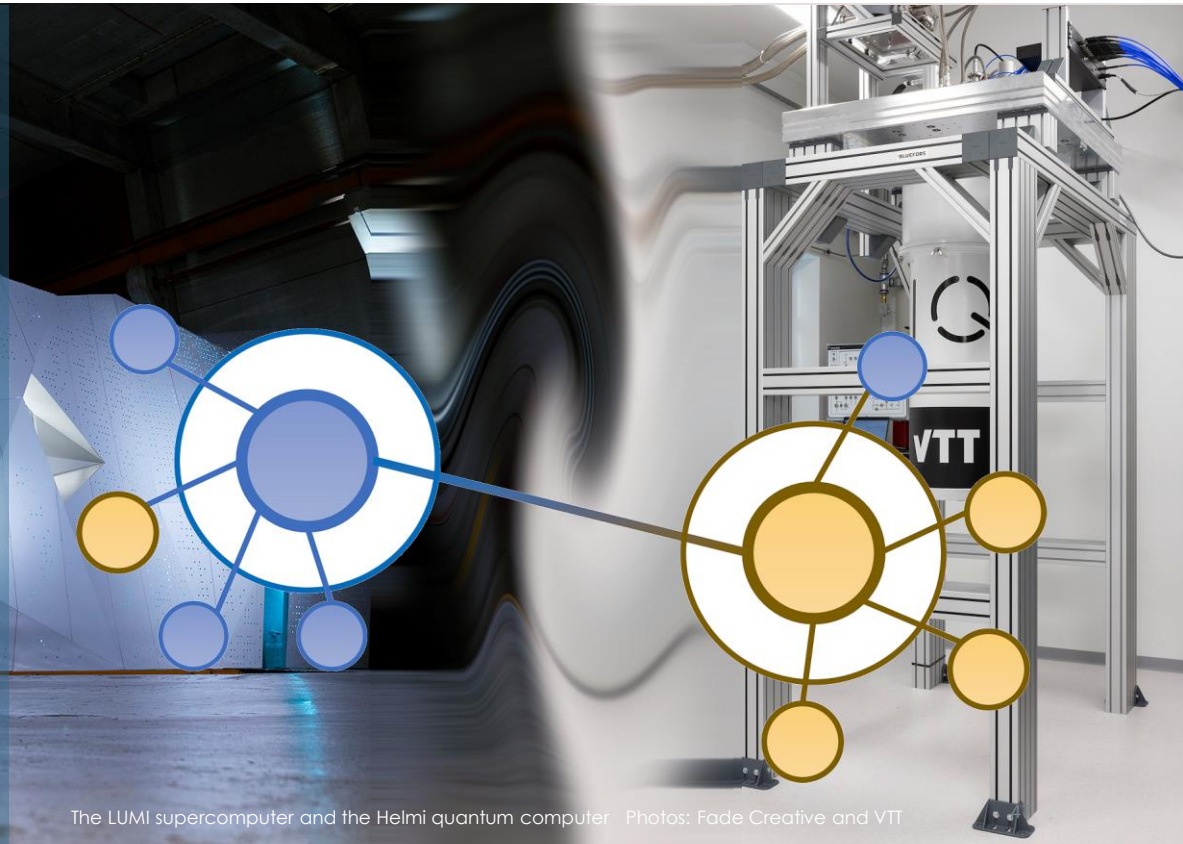
- The **transition from classical** CPUs/GPUs **to quantum** QPUs requires fundamental rethinking of problems and algorithms
- Requires **time, resources, and support.** The CPU -> GPU transition was child's play in comparison!
- Expected that the demand for QC resources will become "standard" among users of *most* HPC centres

Ideal platform for connecting HPC and QC

LUMI

- Fastest (and greenest) in Europe
- **Leading AI platform**: machine learning and HPC *for* quantum tech
- 20% reserved for industry

Through LUMI, researchers will have access to one of the most powerful **hybrid HPC+*n*QC** resources in the world, available for **quantum accelerated research and development**

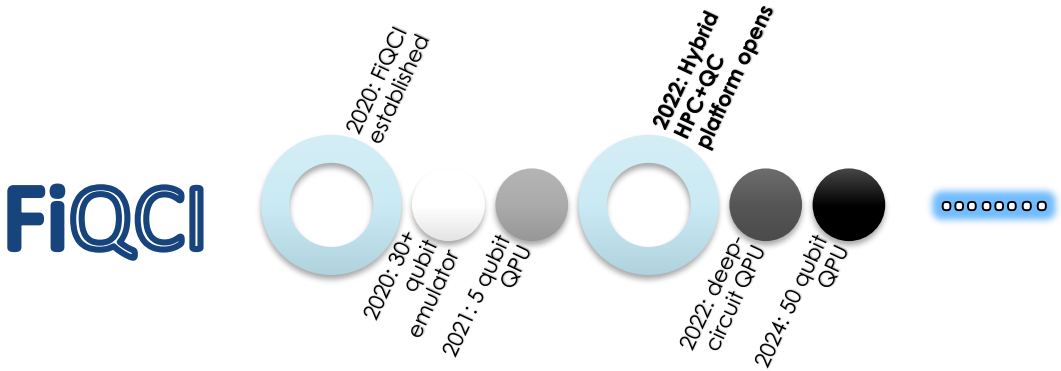


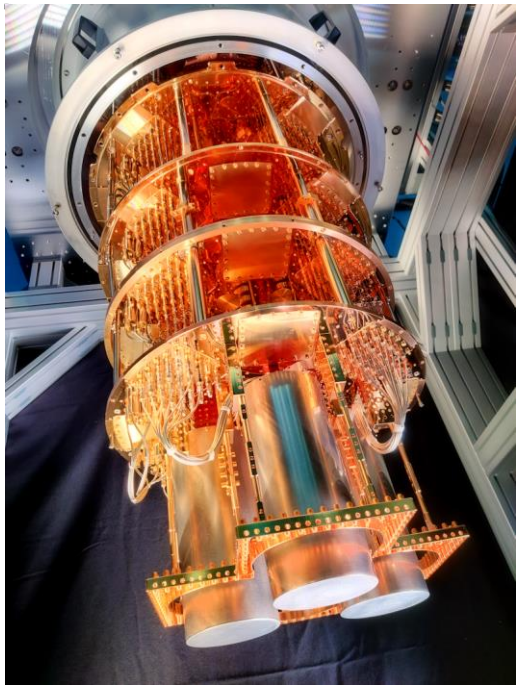
The LUMI supercomputer and the Helmi quantum computer Photos: Fade Creative and VTT

In the process of integrating several quantum computers to LUMI

Important to provide our users with a **broad selection of quantum resources**, as soon as possible

- Kvasi, the Atos QLM 30+ qubit emulator available since 2020
- Ground-work by the Finnish Quantum-Computing Infrastructure (FiQCI) with VTT and Aalto University





LUMI and quantum computing

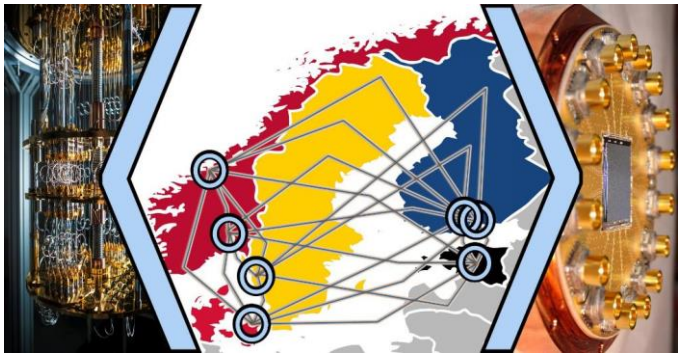
NordIQuEst, funded by NeIC

- Cross-border collaboration and integration
- 7 partners from 5 countries
- Started 1.4.2022

Combine several HPC resources and quantum computers into one unified platform: **HPC+*n*QC**

- QAL 9000 / Sweden
- Helmi / Finland
- **LUMI / EuroHPC**
- eX3 / Norway

Success requires collaboration across national borders – the QC know-how is dispersed across the world!



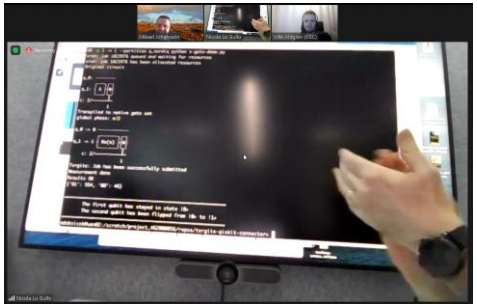
Quantum computing with LUMI

LUMI

LUMI-Q

CHALMERS

VTT



30.3.2022: First quantum job submitted through the LUMI queueing system

- Connected one LUMI-C node in Finland to the QAL 9000 QC in Sweden, and successfully ran a cross-border quantum job

11.5.2022: Connected LUMI and the VTT Helmi quantum computer

- Integrated with identity management, resource allocation, full HPC resources, *etc.*

Near-future: Implement the LUMI-Q concept

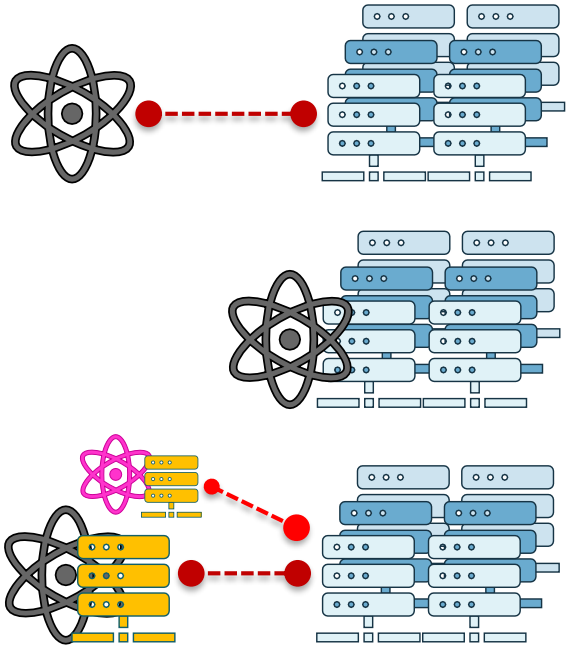
- Set up a **pan-European distributed HPC+*n*QC** environment
- Combine several HPC and quantum resources in a unified manner, keeping local contact points
- Build a full HPC+QC software stack, based on permissive open-source licences.

3 different ways of connecting QC with HPC

LUMI

- **Stand-alone**, cloud access
- **Co-located** in the same premises
- **Distributed**, with QPU and HPC resources physically distant

Come with different levels of complexity for the full software stack



Stand-alone: medium to high latency

Co-located: low-latency

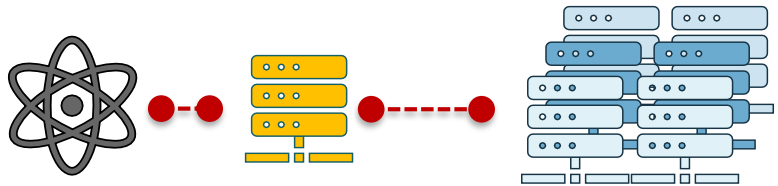
Distributed: low-latency

Co-located and distributed

LUMI

The software stack for a distributed approach requires somewhat more work than the co-located approach

- Need to take care of one additional communication step between classical and HPC (not completely trivial)



- User authentication needs to be done twice (rather trivial)
  - Need personnel at more than one physical location

Why make distributed work?

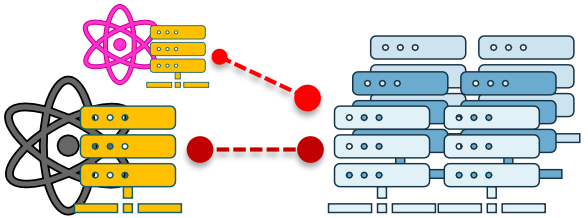
LUMI

With the software stack in place, easy to add additional QC resources

- Needs only location of a classical server next to the QPU (+internet)
- **Increases diversity and inclusiveness**
- Users can access several QPUs from the same computing environment
- Facilitates **time-sharing** of QPU resources

QC and HPC can be optimally located, separately

- HPC in large data centres with sufficient and affordable electric power
- QC in shielded environments: temperature, vibrations, other noise sources



Article | Published: 16 June 2021

Correlated charge noise and relaxation errors in superconducting qubits

C. D. Wilen, S. Abdullah, N. A. Kurinsky, C. Stanford, L. Cardani, G. D'Imperio, C. Tomei, L. Faoro, L. B. Ioffe, C. H. Liu, A. Opremcak, B. G. Christensen, J. L. DuBois & R. McDermott

Nature **594**, 369–373 (2021) | Cite this article

across the millimetre-scale chip. The resulting correlated errors are explained in terms of the charging event and phonon-mediated quasiparticle generation associated with absorption of γ-rays and cosmic-ray muons in the qubit substrate. Robust quantum error correction will require the development of mitigation strategies to protect multiqubit arrays from correlated errors due to particle impacts.

LUMI

Thank you for your attention!

LUMI

Tomasz Malkiewicz

CSC – IT Center for Science Ltd &

Nordic e-Infrastructure Collaboration (NeIC)

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www.lumi-supercomputer.eu

contact@lumi-supercomputer.eu

EuroHPC Joint Undertaking

The acquisition and operation of the EuroHPC supercomputer is funded jointly by the EuroHPC Joint Undertaking, through the European Union's Connecting Europe Facility and the Horizon 2020 research and innovation programme, as well as the Participating States FI, BE, CH, CZ, DK, EE, IS, NO, PL, SE.

Leverage from the EU 2014–2020

European Union
European Regional Development Fund

REGIONAL COUNCIL OF KAINUU

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