Deploying and Managing LUMI Supercomputer, Sustainably

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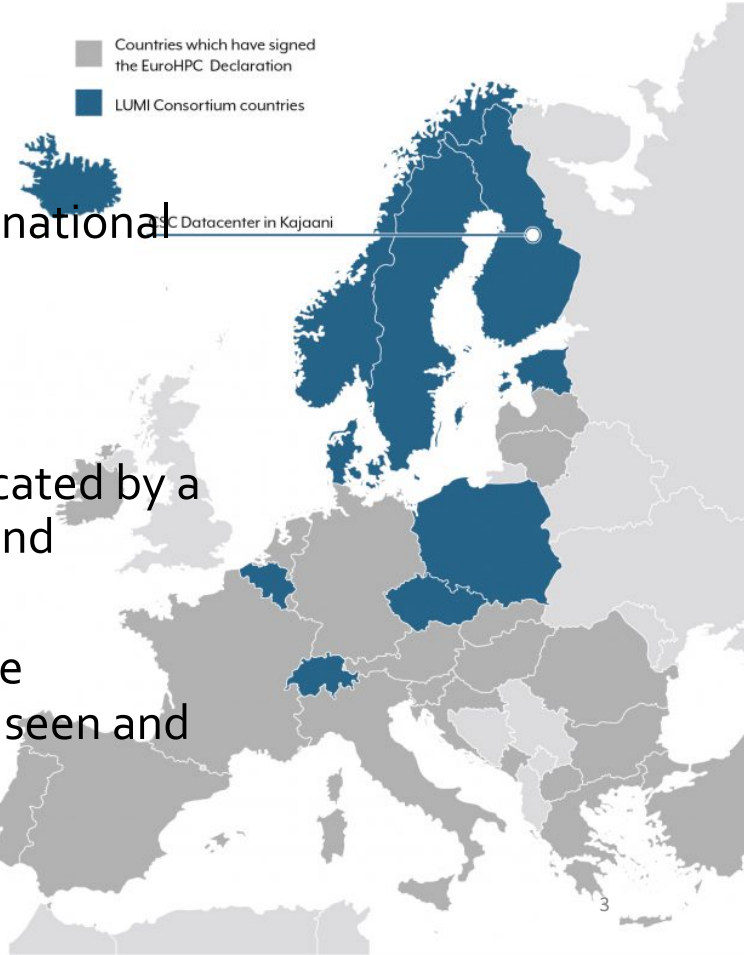
Outline

- Overview of LUMI & LUMI DC
- Monitoring LUMI and future ambitions
- On environmental sustainability of operating HPC systems

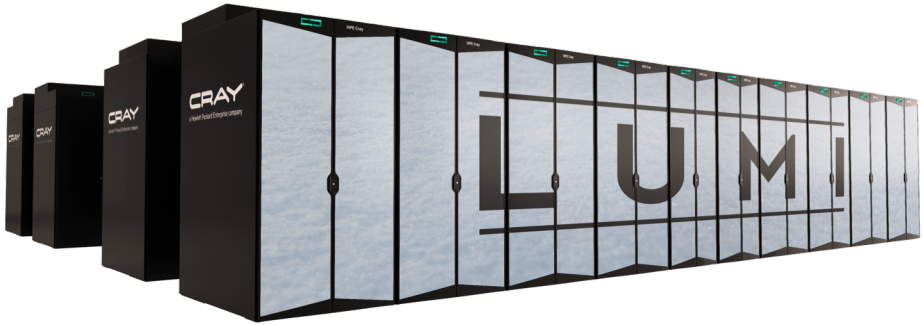
LUMI Consortium

- Unique consortium of 10 countries with strong national HPC centers
- 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 (cf. PRACE Tier-0 access) and available for all European researchers
- The shares of the LUMI partner countries will be allocated by local considerations and policies – seen and handled as extensions to national resources



LUMI

LUMI: one of the fastest supercomputers in the world



- LUMI will be an **HPE Cray EX** supercomputer manufactured by **Hewlett Packard Enterprise**
- HPL performance over **375 petaflop/s** makes the system one of the world's fastest
  - Partial system listed 05/22 with 152 Pflop/s, #3 Top500
  - #3 also in Green500 and HPCG

1 system

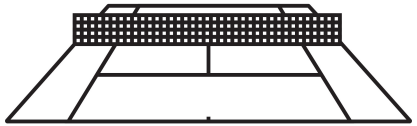
375 Pflop/s

Sustained performance

Computing power equivalent to

1 500 000

Modern laptop computers



Size of two tennis courts

Modern platform for

High-performance computing, Artificial intelligence, Data analytics

Based on GPU technology

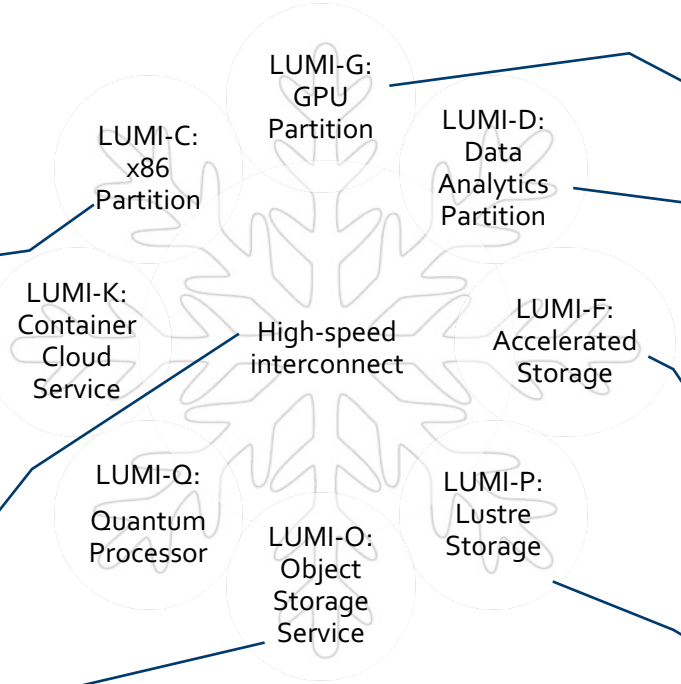
LUMI, the Queen of the North

LUMI is a Tier-0 ***GPU-accelerated supercomputer*** *that enables the convergence of* ***high-performance computing***, ***artificial intelligence***, *and* ***high-performance data analytics.***

- Supplementary CPU partition
- 196,000 AMD EPYC CPU cores

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

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



Tier-0 GPU partition: over 550 Pflop/s powered by 10,240 AMD Instinct MI250X GPUs

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

8 PB Flash-based storage layer with extreme I/O bandwidth of 2 TB/s and IOPS capability. Cray ClusterStor E1000.

80 PB parallel file system

LUMI timeline

Pilot use
Extended beta testing
LUMI-C regular access
LUMI-G development access

Q3/2022 **Final Configuration**
- LUMI-O, -K
General availability

2020

2021

2022

System procurement:
November 2019 – August 2020

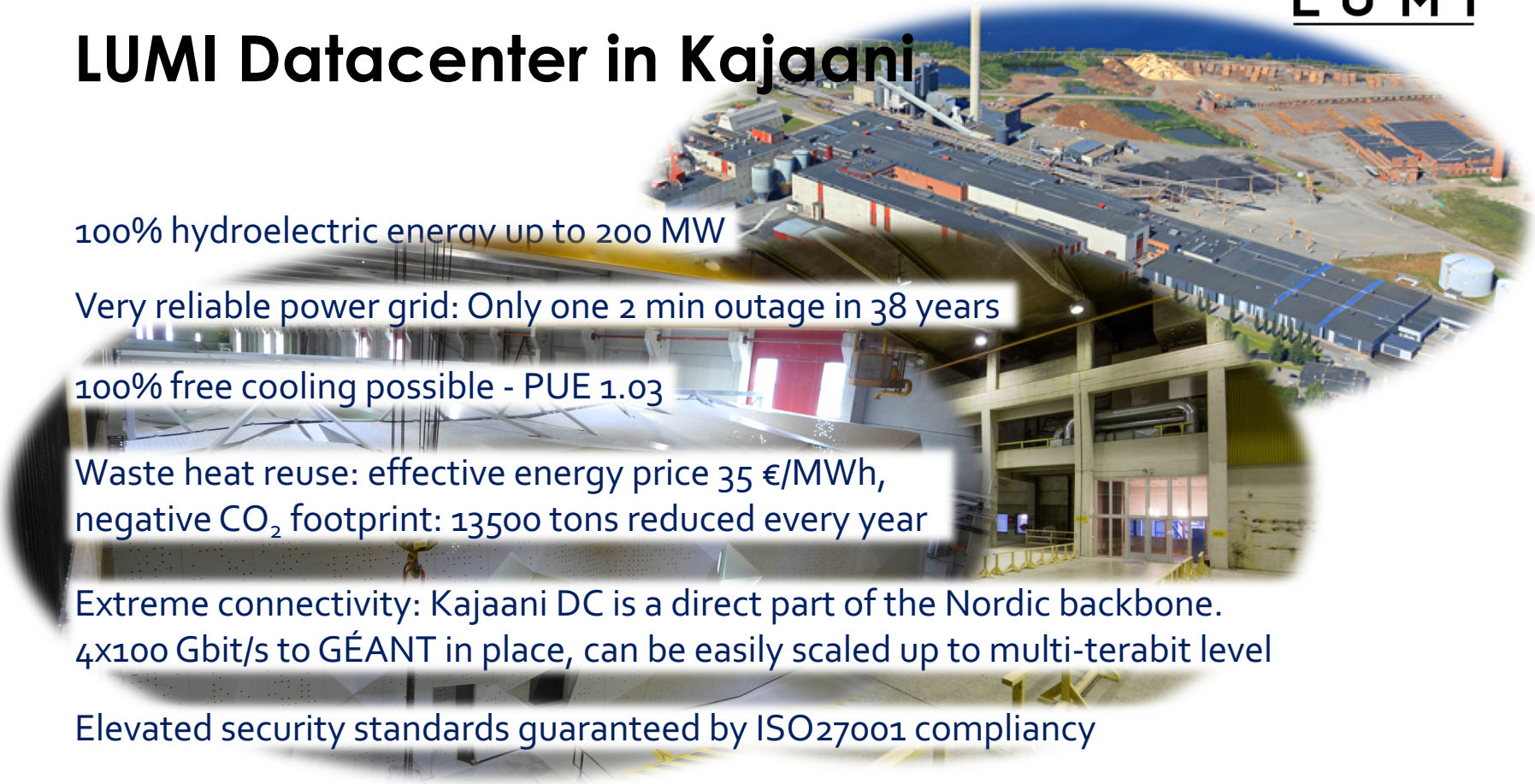
Data center preparation ready Q1/2020

1st phase Q4/2021
- LUMI-C, P, F, D
- Early Access Platform

Q2/2022
- Gradual deployment of LUMI-G
- LUMI-C NIC upgrade

In customer use 01/01/22

LUMI Datacenter in Kajaani



100% hydroelectric energy up to 200 MW

Very reliable power grid: Only one 2 min outage in 38 years

100% free cooling possible - PUE 1.03

Waste heat reuse: effective energy price 35 €/MWh,
negative CO_2 footprint: 13500 tons reduced every year

Extreme connectivity: Kajaani DC is a direct part of the Nordic backbone.
4x100 Gbit/s to GÉANT in place, can be easily scaled up to multi-terabit level

Elevated security standards guaranteed by ISO27001 compliancy


RENFORSIN RANTA
RATA
LUMI
KONE

LUMI power monitoring and building management system

LUMI

- LUMI data center infrastructure monitoring and management is provided by Fidelix which is a pioneer in smart building automation. More than 8000 points connected to BMS system.
- Power is monitored by ABB, Schneider electric and Carlo Gavazzi power monitoring products.
  - Power monitoring accuracy is between ±0.5-1% with max. sample rate of 4096 samples/s @ 50Hz
- All monitoring data is collected to building management system database

Future ambitions with operational data analytics

LUMI

	Building infrastructure	System hardware	System software	Applications
Prescriptive	• Switching between types of cooling, tuning of cooling machinery • Responding to anomalies	• Cooling optimization at system level • CPU frequency tuning • Tuning of hardware knobs	• Intelligent placement of tasks and threads • Plan-based scheduling • Power and KPI-aware scheduling	• Auto-tuning of HPC applications • Code improvement and recommendations
Predictive	• Predicting DC KPIs • Predicting cooling demands • Modeling cooling performance	• Forecasting hardware sensors • Component failure prediction • Predicting CPU instruction mixes	• Simulating HPC systems and schedulers • Predicting HPC workloads	• Predicting job durations and resource use • Predicting performance profiles of code regions
Diagostic	• Fingerprinting DC crises • Anomaly detection • Infrastructure stress testing	• Node-level anomaly detection • System-level root-cause analysis • Network contention issues	• Diagnosing data locality issues • Detection of software anomalies • Identifying sources of OS noise	• Application fingerprinting • Performance patterns • Diagnosing code-level issues
Descriptive	• PUE calculation • Facility data processing • Dashboards	• ITUE calculation • System performance indicators • Dashboards	• Slowdown calculation • Scheduler dashboards	• Job performance • Job data processing • Job-level dashboards

Adapted from Bates et al MODA 2021

Part II: On the environmental sustainability of HPC installations

Considerations for a HPC system's carbon footprint

LUMI

- Data center level choices
  - Power: used electricity, power-usage efficiency
  - Waste heat reuse
    - District heating, sorption cooling, water preheating, desalination, biomass processing, greenhouses,…
  - Construction/retrofitting of the data center
  - Intelligent operations via advanced monitoring
- System level choices
  - ICT manufacturing
  - Eco-efficiency of the hardware and software ("science per watt")

Benefits of the brownfield solution

We assume having **reduced the CO2 footprint of LUMI data center construction by over 80%** with the brownfield solution vs. constructing an all-new building for LUMI

Materials - building shell 5,700 ft² (530 m²) office facility	Tonnes of CO_2	Percentage of total
Foundation (concrete)	4.7	4%
Flooring (concrete slab, insulation)	39.9	31%
Ceilings (plaster board)	2.3	2%
Structure (steel beams)	15.4	12%
External walls (brick, insulation)	32.1	25%
Internal walls (wood frame and plasterboard)	8.7	7%
Stairs (concrete)	1.1	1%
Windows (glass and frame)	0.59	0.4%
Internal doors (particle board)*	-0.4	-0.3%
External doors (plastic)	0.6	0.5%
Roof (wood, concrete, insulation)	23.4	18%
TOTAL	128.3	100%

For a 1 MW DC, source: Schneider-Electric white paper 66

Waste heat utilization

- **95% of LUMI's waste heat can be re-used in the district heating system of Kajaani**
  - Energy costs go down by 37% as local energy company pays for the waste heat.
  - As an alternative, 100% free cooling available, PUE 1.03
- With LUMI's heat, the local energy company can reduce the use of oil that corresponds in CO_2 emissions to removal of 3000 cars from traffic

100 %

Carbon-neutral energy

CO_2 footprint

-13 500T

Co_2 eq/emissions

LUMI produces

20 %

of Kajaani's district heating needs

DRY AIR COOLING FOR BACK UP ~ 9 MW

DISTRICT HEATING NETWORKS ~ 10 MW
-Renforsin Ranta Business Park
-CITY of Kajaani

LUMI

+31 °C

+45 °C

+60 °C

+80 °C

Maximum heat production approximately 10 MW

HEAT EXCHANGERS

HEAT PUMPS

Electricity to heat pumps is CO_2 free.

+32 °C

+44 °C

+32 °C

+44 °C

HPC load Max. 9 MW

In addition of DLC there is approximately 1 MW of capacity for the air-cooled servers (e.g. storage). This IT is free-cooled.

LUMI system level choices

- ICT equipment life cycle
  - Responsibility and sustainability required and rewareded in the CfT
- Operations and energy efficiency
  - In the procurment, performance figures normalized with energy
  - LUMI will be at top of Green500 (#3 05/22) over multiple lists
- Other considerations
  - Benchmark applications included cases important for green transition (climate models, materials science)
  - LUMI is strongly positioned as an instrument for climate research, especially EU's Destination Earth programme

Concluding remarks

- Green-ness of a HPC installation starts on the data-center level choices, especially contracted source of energy
- Carbon-neutral (even negative) HPC operations possible already today
- Advanced facility and system monitoring vital for adaptive optimization of the operations

LUMI

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EuroHPC Joint Undertaking

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European Union European Regional Development Fund

REGIONAL COUNCIL OF KAINUU

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