



quantum datacenters power requirements



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quantum-energy-initiative.org/

why

- most quantum technologies will add an incremental energetic cost to existing ICT.
- it is time to work on this as quantum technologies and applications are designed.

what

- build a **new** science and engineering field.
- create full-stack methodologies and standards to **evaluate**, **optimize**, and **benchmark** quantum technologies energy consumption.

how

- QEI workshops (2023 in Singapore, 2025 in Grenoble, 2026 in Barcelona, 2027 in Lisbon).
- QEI IEEE standards Working Group.
- ≈30 industry partners including IBM, Quandela, etc.
- EIC Pathfinder Challenge, etc.



QEI 2025 (Grenoble) and 2026 (Barcelona)

creating a scientific and engineering field

the initial call

a nascent research field

standardization

Perspective

PRX QUANTUM 3, 020101 (2022)

Quantum Technologies Need a Quantum Energy Initiative

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[prxquantum 3.020101](https://prxquantum.3.020101)

a first full-stack methodology

PRX QUANTUM 4, 040319 (2023)

Optimizing Resource Efficiencies for Scalable Full-Stack Quantum Computers

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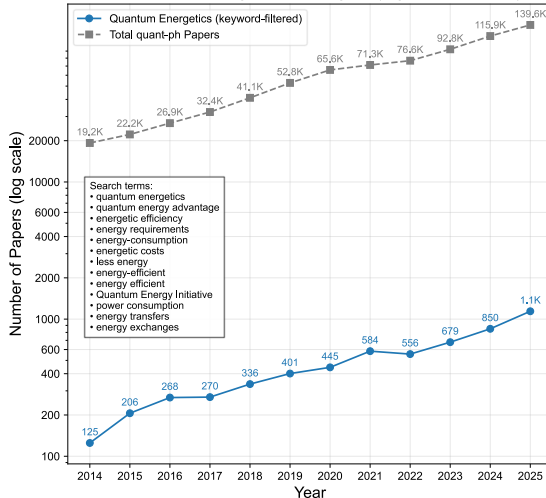
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[prxquantum 2.040335](https://prxquantum.2.040335) [arxiv 2112.04022](https://arxiv.org/abs/2112.04022)

arXiv Papers Mentioning Quantum Energetics (Log Scale, 2014–2025)



IEEE.org | IEEE Xplore | IEEE Standards | IEEE Spectrum | More Sites

IEEE

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STANDARDS
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IEEE P3329 Quantum Energy Initiative (QEI) Working Group



Title: Standard for Quantum Computing Energy Efficiency

Scope: This standard defines energy efficiency metrics for quantum computing gate-based, quantum annealing, quantum simulation. It compares the performance of the computation to its energy consumption. The performance is defined at the quantum level and at the end user level. The definition applies to all Quantum 80-qubit technologies, including the classical and quantum control chains, to various quantum processors, both noisy intermediate scale Quantum (NISQ) era and fault-tolerant, as well as to quantum annealers and simulators.

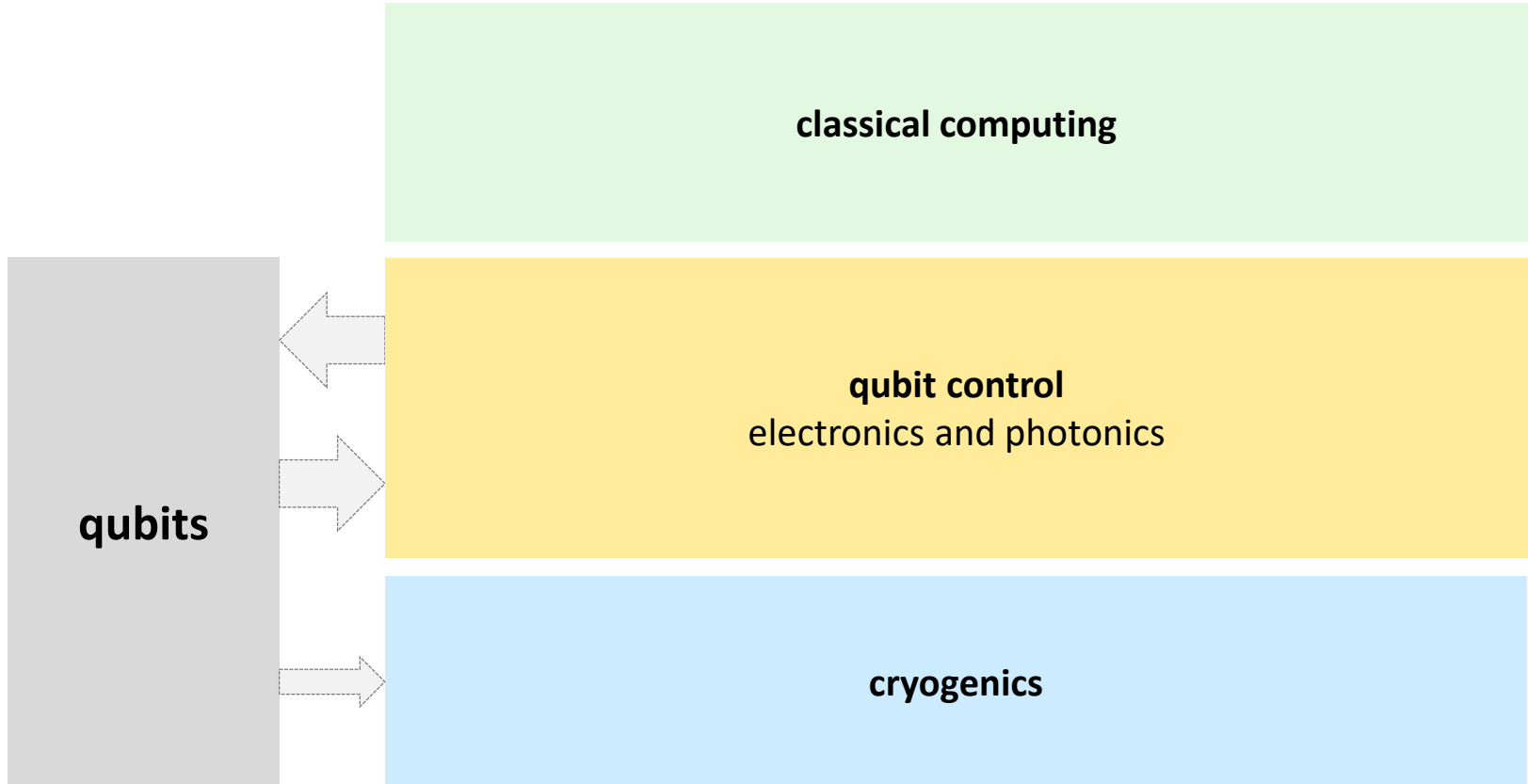
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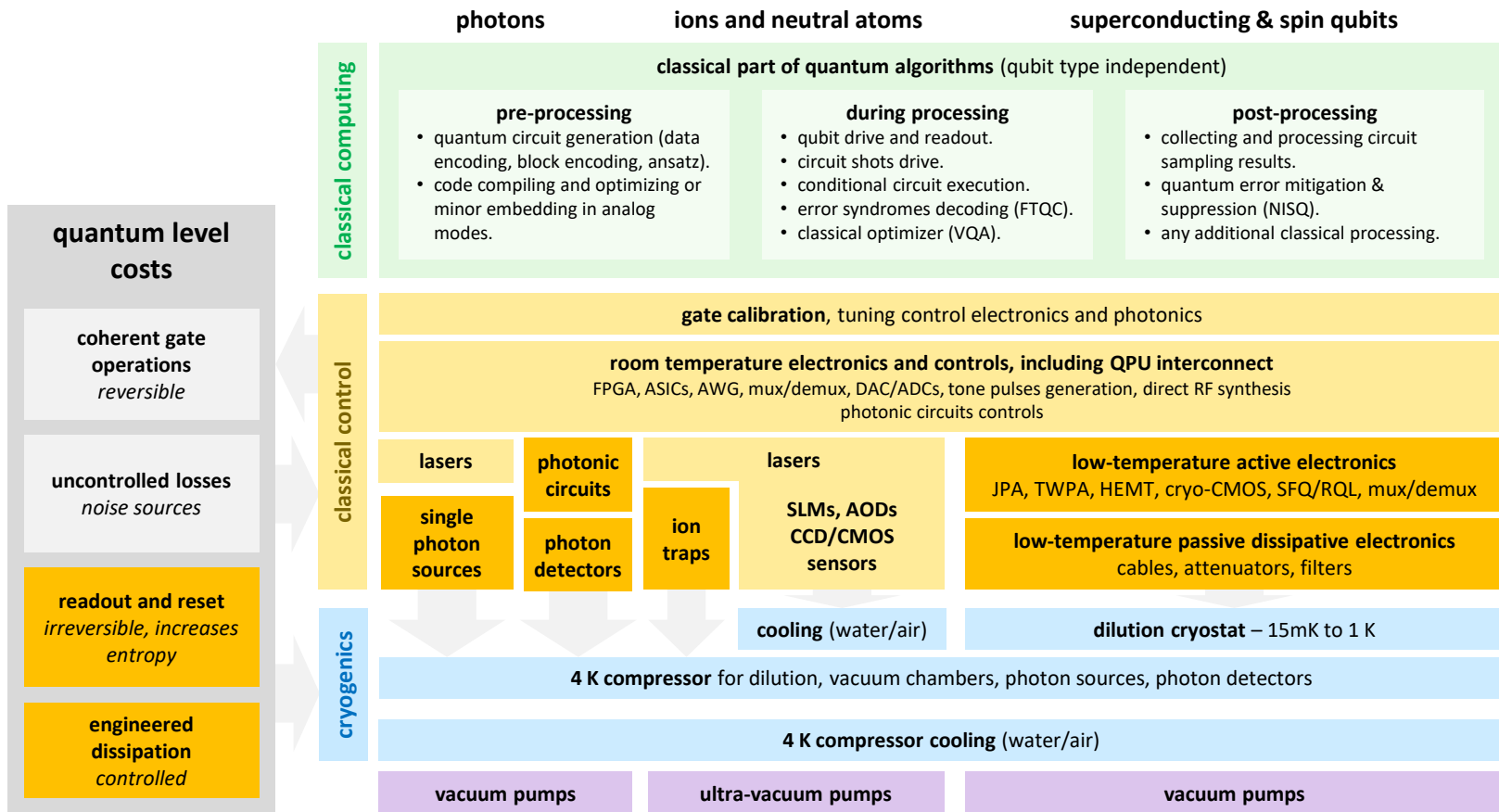
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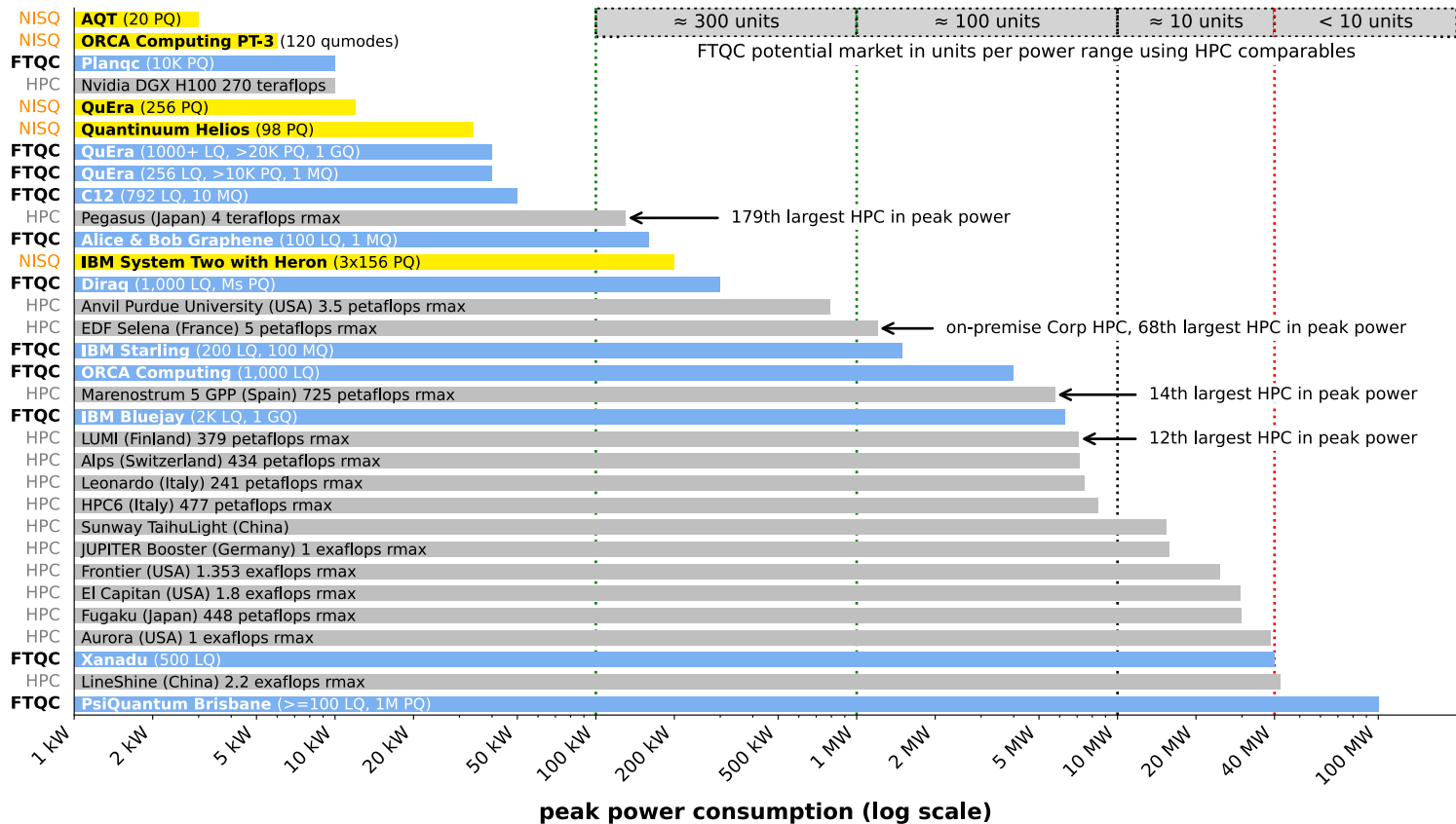
energy consumption sources



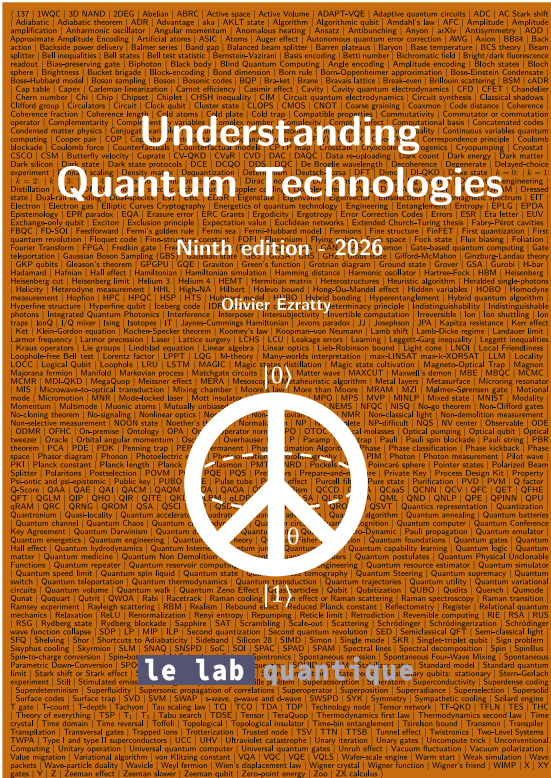
accounting for all energetic costs



first FTQC vs HPC power estimates



estimate base power for various FTQCs and actual for existing largest HPCs. WW and NISQ QCs. HPC source: TOP500 and Nvidia. FTQC sources: vendor data or data reconciliation. PQ: physical qubits, LQ: logical qubits, MQ: megaqubit (logical operations), TQ: teraqubit.



1,822 pages

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including a 23-page
dedicated section on
quantum energetics

5.4 Energetics

The main motivation for creating quantum computers is their potential capacity to solve intractable problems in non-exponential times, or at least with significant acceleration in practical cases, even though not being exponential. This should make it possible to solve problems that are inaccessible to conventional HPC and that of the supercomputers. In some cases, the use of some NISQ architecture using quantum error mitigation, it will only be "just" somewhat faster or sometimes, provide better results. In with quantum machine learning or some many-body quantum physics simulations.

How this computing capacity translates in terms of energy consumption is a key open question, particularly as ICT (Information and Communication Technologies) energetic costs are skyrocketing, being currently amplified by the broad adoption of LLM-based consumer online tools.

This opens a Pandora's box of questions that we'll try to address in this part:

- **ICT lessons.** What is dissimilar and similar between classical computing and quantum computing when learning from History? What can we learn from the data? What went wrong, particularly with AI? Also, what is the real size of the AI power surge?
- **First assessment.** How we already reached some energetic quantum advantage with the quantum supremacy experiments, starting with Google Sycamore in 2019? Contrarily, should we worry as some industry vendor roadmaps have started to build enormous systems, way larger than the first mainframes in the 1940s, or even, larger than the most powerful deployed exascale supercomputers? Or should we believe other vendors like D-Wave, on the opposite side, who claim that their systems are energetically frugal? Do we have an idea of the potential energy consumption of large scale quantum computers, the one that will deliver on the promise to extend the reach of computing?
- **Cost vs value.** What can we do to estimate the size of the energetic problem or benefit of quantum computers? What will be their use cases and the related market size? The question is intertwined with the broad applications prospect, the expectations to see the advent of some quantum "ChatGPT moment" and granular market forecasts. Responding to these questions deals with a mix of science and technology, applications and software, and economics. Sizing the market potential depends on the viable applications that will be tested in the future and the volume of end-user organizations who will need it. Market volume estimates range between a subset of the supercomputing market and a large chunk of the cloud server segment!
- **Quantum computing energetics.** How is this discipline organized with its quantum level (with quantum thermodynamics and quantum energetics) and all macroscopic energetics, with enabling technologies? What are the scaling challenges with FTQC? How to assess the first energy resource estimates published, mostly in academic papers?

discipline organized with its quantum level (with quantum thermodynamics and quantum energetics) and all macroscopic energetics, with enabling technologies? What are the scaling challenges with FTQC? How to assess the first energy resource estimates published, mostly in academic papers?

• **Energetic advantage.** What is the real source of a potential energetic advantage with quantum computing? Parallelization? Entanglement? Reversibility? Will quantum computing generate some potential energetic advantage for use cases that is still workable with classical solutions? Will we see cases beyond that scale consume a reasonable amount of energy, particularly when they need thousands of logical qubits? We do not yet have the answer. It is a new research area worth the effort. How will we benchmark and optimize the energy consumption of quantum computers?

• **Power resource estimates.** How do you estimate the energy consumption of existing and future quantum computers and define a potential energetic advantage? That's a tricky question for future systems which are only designed "on paper". And it must also consider the significant cost of the classical systems that are necessary to run these QPUs. What is the current outcome from the academic world with regards to analyzing, estimating, and optimizing the energetic cost of quantum computers?

• **Qubit types differences.** Will there be some difference between the various qubit types and quantum computing paradigms like analog and gate-based quantum computers?

• **Actions.** What can be done to limit the pitfalls encountered with other technologies like D-Wave, on the opposite side, who claim that their systems are energetically frugal? Do we have an idea of the potential energy consumption of large scale quantum computers, the one that will deliver on the promise to extend the reach of computing?

5.4.1 ICT lessons

The energetic footprint of all digital tools (information and communication technologies) is already significant. It was 5.2% of global electricity consumption in 2022, including manufacturing costs. The 6.1% for 2020 and 7% for 2030 are forecasts which combining various sources [2118, 2119] (Figure 1323).

ICT energetic footprint tends to be focused on looking at the energetic consumption of products while they are used. It can be completed by carbon and greenhouse gas emission footprint analysis, which is emblematic of the whole lifecycle of ICT products [2120]. It leads to the concept of "carbon pricing" which encompasses a whole sophisticated lifecycle analysis of ICT products.

Since quantum computers are serverless systems, we'll



Understanding Quantum Technologies

Ninth edition - 2026 Key Takeaways

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le lab quantique

short version
42 pages



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