

[video replay link](#)



# the energetics challenges of FTQC

**#QEI**  
the quantum energy initiative

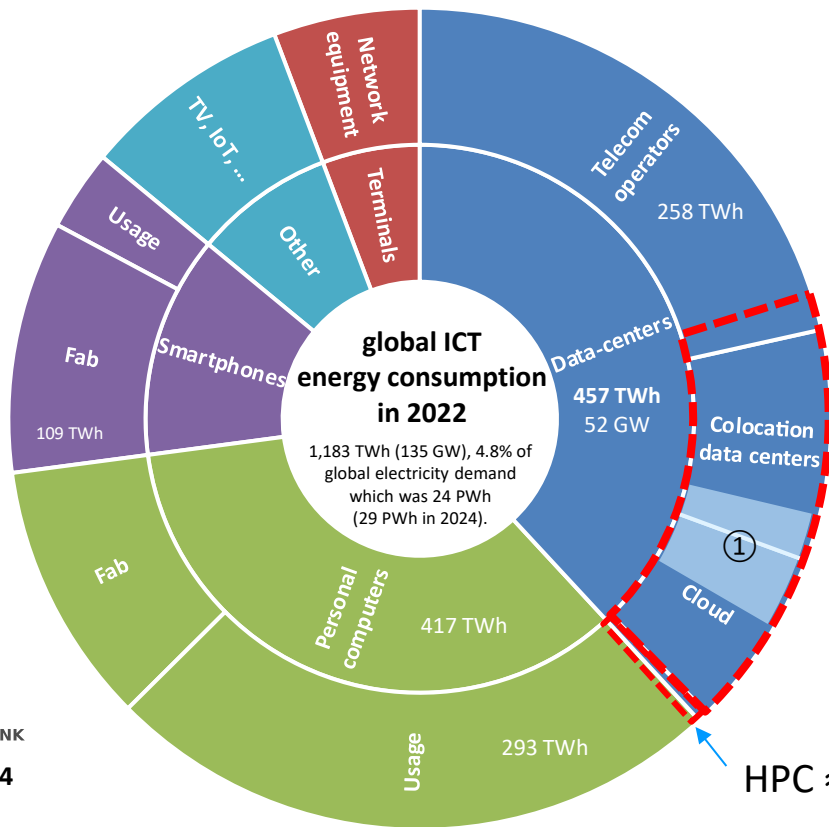
**Olivier Ezratty**

⟨ ... | quantum engineer | QEI cofounder | ... ⟩

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Q2B, Santa Clara, December 9th, 2025

# sizing QCs potential energetic impact



① ≈ 63 TWh and ≈ 7.2 GW for Google, Microsoft and Meta

ICT electricity consumption growth driven by AI data centers.

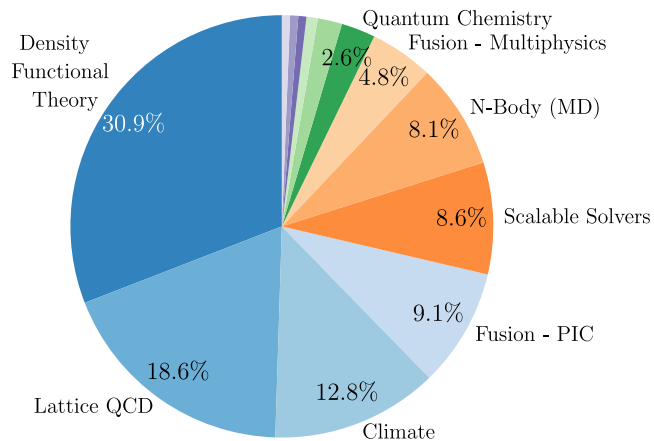
## quantum computing energetic footprint base references

with business operations applications (larger base)

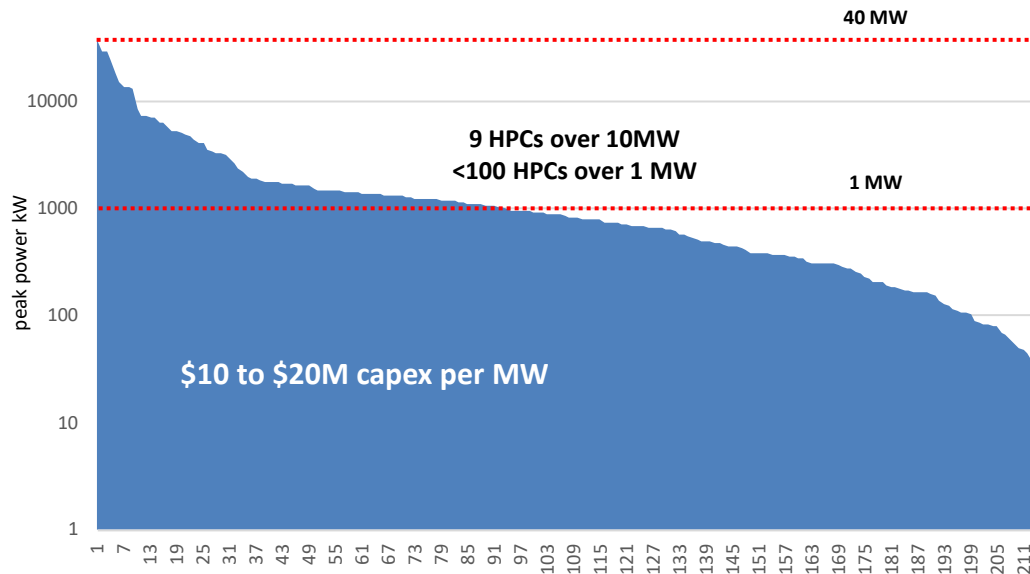
with fundamental and applied research applications (smaller base)

HPC ≈ 0.4%

# current largest HPCs power consumption



classical applications run on DoE supercomputers. Source: NERSC.  
<https://arxiv.org/abs/2509.09882>



distribution of the top documented 211 HPC peak power in the TOP500 as of June 2025

**HPC market drivers assumptions**

**usage and value**  
 scientific computing and ML

**funding**  
 majority of academic research public investments

**systems capex and opex**  
 energy opex  $\approx$  annualized capex

## why

- ICT energy consumption is growing in an uncontrolled way.
- energetics are usually an afterthought, like with LLMs.
- it's time to work on this as quantum technologies are being designed.

## what

- build new science and engineering.
- create full-stack methodologies to evaluate, optimize, and benchmark QT energy consumption.


## where

- academic and industry QEI workshops: Singapore (2023), Grenoble (2025), Barcelona (2026).
- APS 2025, ICQE 2025, France Singapore Symposium (Paris, 2025), Q2B Paris and Santa Clara (2025).
- online seminars, website.

### Quantum Technologies Need a Quantum Energy Initiative

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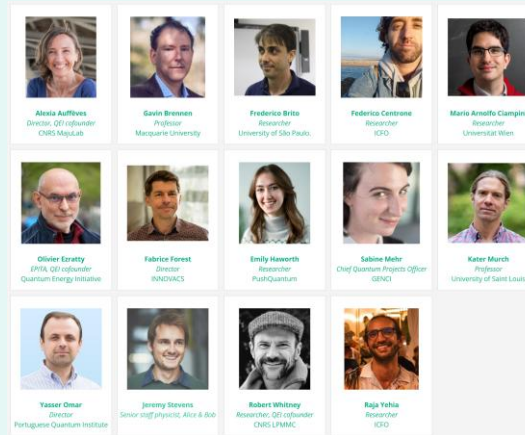
 (Received 18 November 2021; revised 11 April 2022; published 1 June 2022)

Quantum technologies are currently the object of high expectations from governments and private companies, as they hold the promise to shape safer and faster ways to extract, exchange, and treat information. However, despite its major potential impact for industry and society, the question of their energetic footprint has remained in a blind spot of current deployment strategies. In this Perspective, I argue that quantum technologies must urgently plan for the creation and structuration of a transverse quantum energy initiative, connecting quantum thermodynamics, quantum information science, quantum physics, and engineering. Such an initiative is the only path towards energy-efficient, sustainable quantum technologies, and to possibly bring out an energetic quantum advantage.



## who

- 4 cofounders.
- 14 scientific board members.



- 500+ community in >90 countries.
- >30 industry and academic partners.



# how

## first methodology (2023)

PRX QUANTUM 4, 040319 (2023)

### Optimizing Resource Efficiencies for Scalable Full-Stack Quantum Computers

Marco Fellous-Asiani<sup>1,2,\*</sup> Jing Hao Chai,<sup>2,3,4</sup> Yvain Thonnart<sup>5</sup> Hui Khoon Ng,<sup>6,3,7,†</sup>  
Robert S. Whitney<sup>8,†</sup> and Alexia Auffèves<sup>2,3,7,8</sup>

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## IEEE P3329 Quantum Energy Initiative (QEI) Working Group (2023-\*)



### BACQ benchmarking project (2023-\*)

### BACQ - Application-oriented Benchmarks for Quantum Computing

Delivering an application-oriented benchmark suite for objective multi-criteria evaluation of quantum computing performance, a key to industrial uses

## OEQC flagship project with EDF, Quandela, Alice&Bob, and CNRS (2023-\*)

Accueil > Actualité

## Lancement du projet “Optimisation Énergétique des Circuits Quantiques”, avec le CNRS, EDF, Quandela et Alice & Bob

25 septembre 2024

INNOVATION

## this talk's focus

### FTQC energetics paper (in preparation).

### The energetic challenges of fault-tolerant quantum computing

Marco Fellous-Asiani,<sup>1</sup> Pierre-Emmanuel Emeriau,<sup>2</sup> Jeremy Stevens,<sup>3</sup>  
Marco Pezzutto,<sup>4,5,6</sup> Yasser Omar,<sup>4,5,6</sup> and Olivier Ezratty<sup>7,8,\*</sup>

<sup>1</sup>Inria

<sup>2</sup>Quandela

<sup>3</sup>Alice&Bob

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<sup>7</sup>EPITA Research Lab

<sup>8</sup>Quantum Energy Initiative

putting quantum  
technologies energetic in  
the EU Quantum Strategy  
agenda (ongoing).

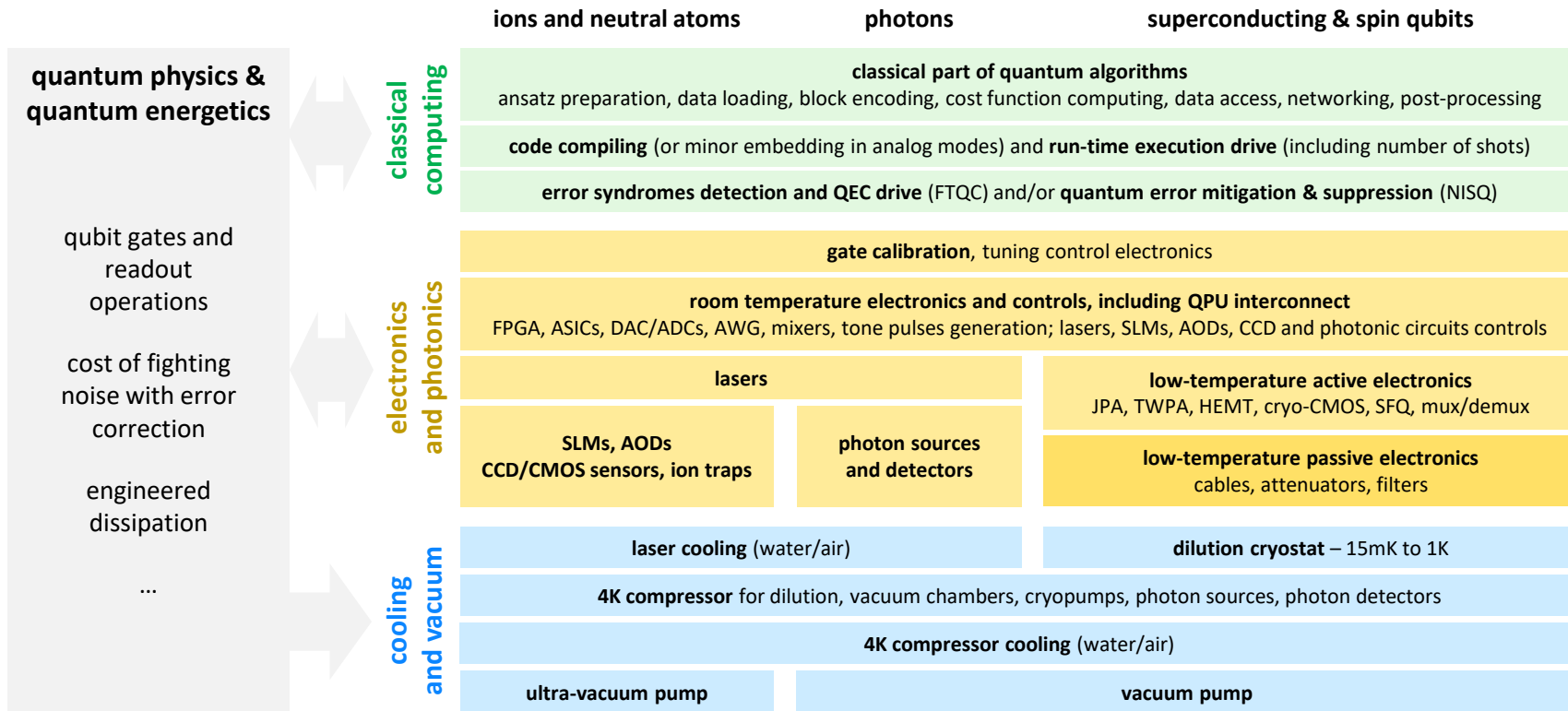


#QEI  
the quantum energy initiative



QEI roadmap  
(in preparation).

# full-stack energetic costs decomposition

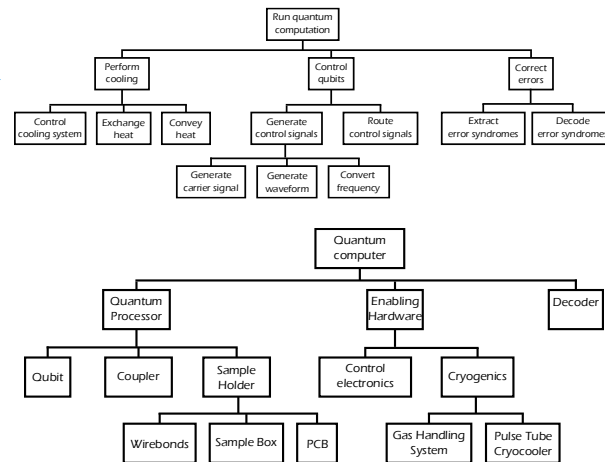


# energetic systems architecture approach

1. functional and product breakdowns
2. estimate baseline resources
3. optimize energy efficiency under constraints
4. mix reductionist and holistic approaches
5. handle operational trade-offs
6. measure and benchmark
7. integrate an economical view

detailed in  
next slide

FTQC energetics paper  
(in preparation).



credit: Jeremy Stevens, Alice&Bob

## The energetic challenges of fault-tolerant quantum computing

Marco Fellous-Asiani,<sup>1</sup> Pierre-Emmanuel Emeriau,<sup>2</sup> Jeremy Stevens,<sup>3</sup>  
Marco Pezzutto,<sup>4,5,6</sup> Yasser Omar,<sup>4,5,6</sup> and Olivier Ezratty,<sup>7,8,\*</sup>

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# from baseline estimates to optimizations

what

## baseline resources

- ◆ use state of the art existing technologies.
- ◆ adding individual components resources.
- ◆ evaluate or measure idle, average and peak power.

$$\text{[blue bar]} + \text{[blue bar]} + \text{[blue bar]} + \text{[blue bar]} + \text{[blue bar]} = 100$$

## reductionist optimizations

- ◆ account for future enabling technology developments.
- ◆ component level optimization.
- ◆ doesn't affect other components performance.
- ◆ doesn't add more noise.

$$\text{[blue bar]} + \text{[green bar]} + \text{[blue bar]} + \text{[green bar]} + \text{[blue bar]} = 90^*$$

## holistic optimizations

- ◆ interdependent optimizations.
- ◆ side effects on noise and task success metrics.
- ◆ various energy vs computing time or space-time trade-offs.

$$\text{[green bar]} + \text{[blue bar]} + \text{[green bar]} + \text{[blue bar]} + \text{[green bar]} = 70^*$$

examples

- ◆ all active components.
- ◆ classical computing (circuit preparation, compiler, error correction, post-processing, ...).

- ◆ cryogenics.
- ◆ control electronics.
- ◆ cable dissipation.
- ◆ compiler efficiency.

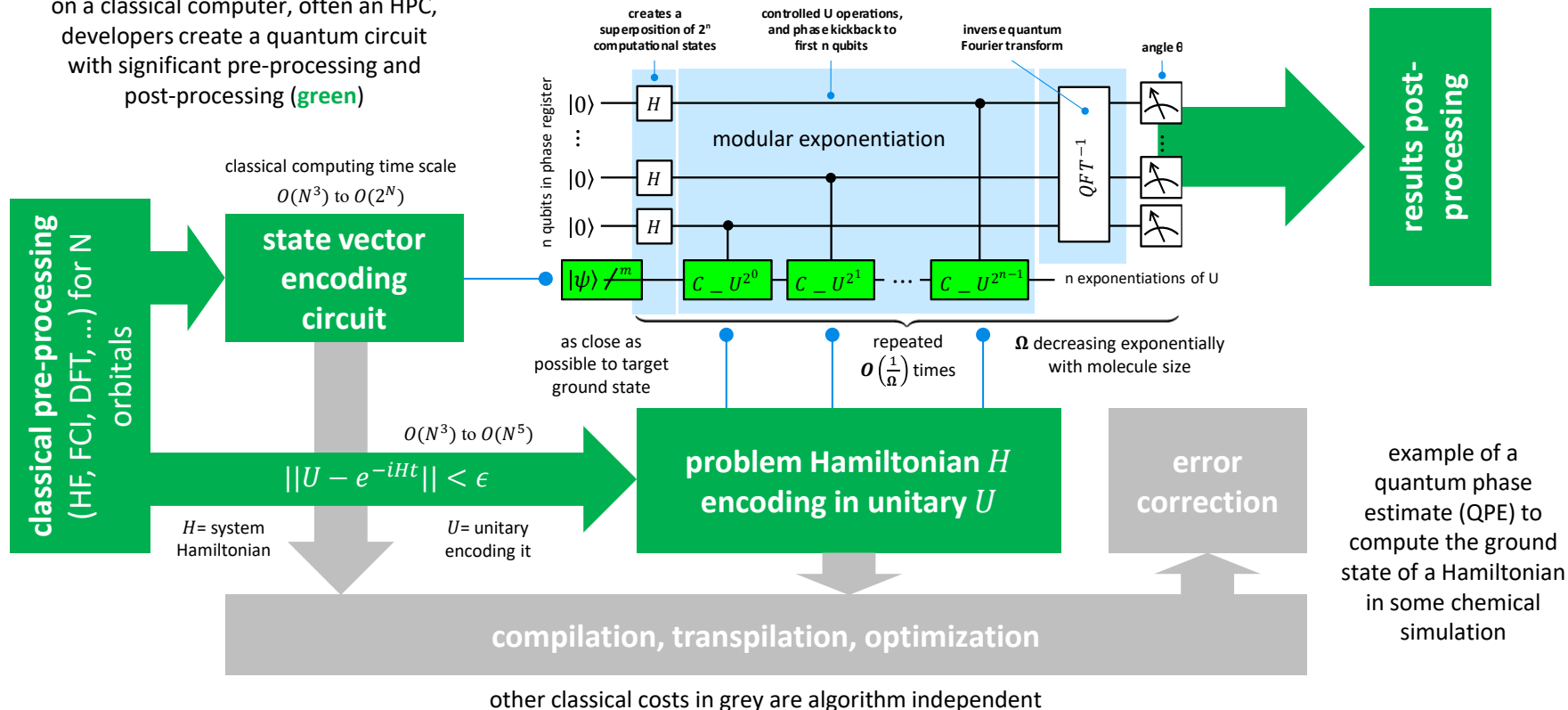
- ◆ moving electronics at cryogenic temperatures.
- ◆ using SFQ control electronics.
- ◆ changing qubit temperature.

\* % of baseline power or energy, for the sake of demonstration

**system generic (power) or task dependent with a success metric (energy)**

# pre- and post-processing classical costs

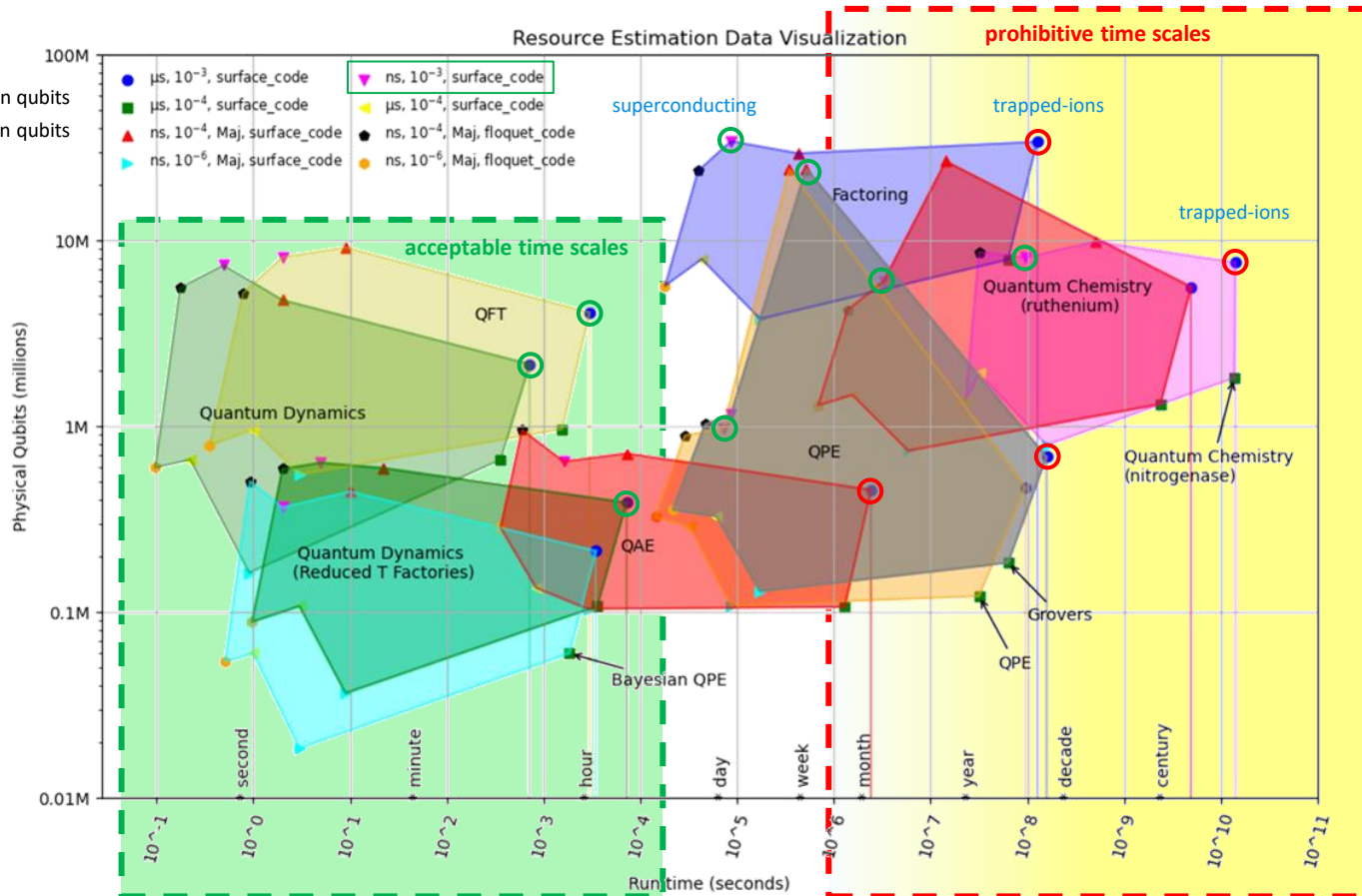
on a classical computer, often an HPC, developers create a quantum circuit with significant pre-processing and post-processing (green)



$\mu$ s gate times: trapped ion qubits  
 ns gate times: superconducting and silicon qubits

several scenarios are used with different physical qubit error rates and gate times. The realistic ones are with 99.9% fidelities and  $\mu$ s readout cycle times.

**one ultimate challenge will be actual computing times!**



The GQI Quantum Resource Estimator Playbook - Quantum Computing Report  
 by Doug Finke, Quantum Computing Report, August 2024.

# computing time optimization options

1

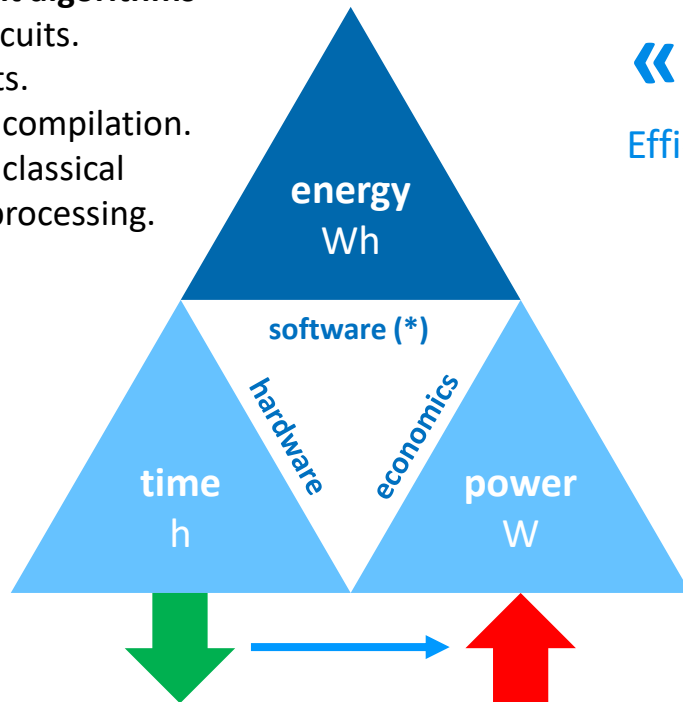
## more Efficient algorithms

- smaller circuits.
- fewer shots.
- optimized compilation.
- optimized classical pre/post-processing.

2

## Faster computing

- faster gates and readout, constrained by various limitations.
- faster classical-quantum cycles, including QEC, classical-quantum drive efficiencies.



« EFP »

Efficient-Faster-Parallel

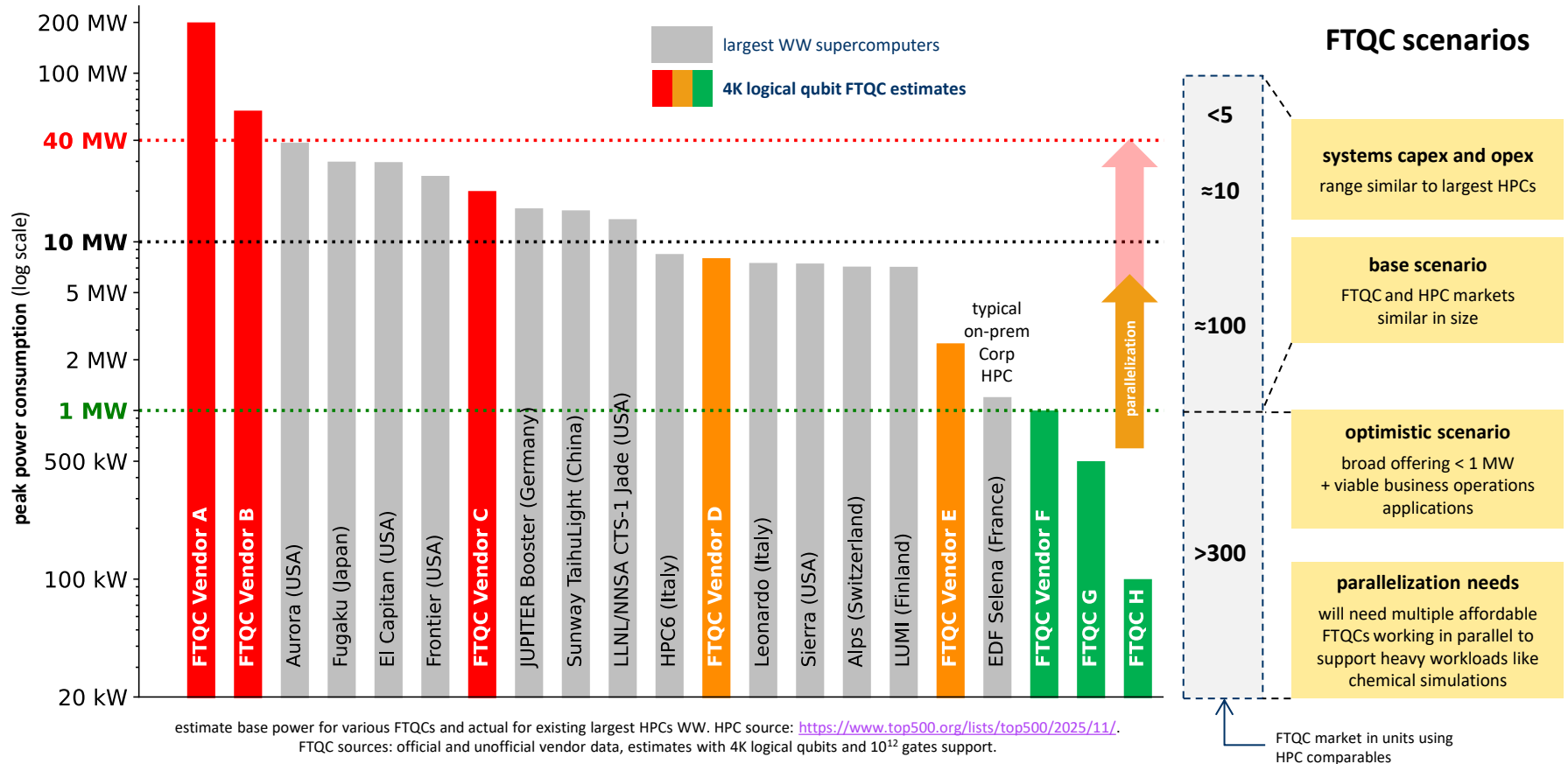
## Parallelizing circuit shots on multiple similar QPUs

- affordable FTQC QPUs (cost and total carbon footprint).
- manage pressure on electricity grid.

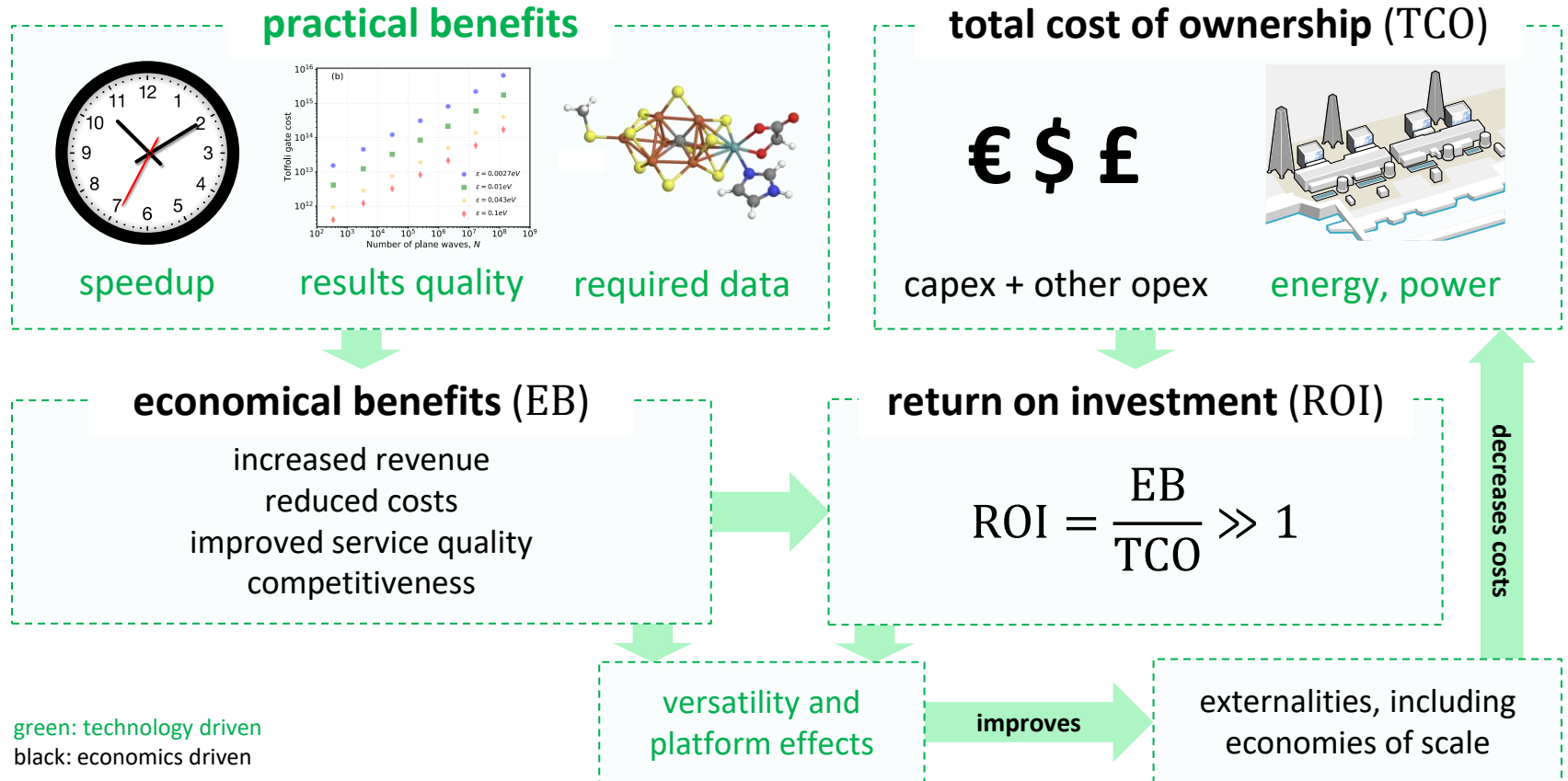
3

(\*) the total energetic cost of computing depends on other parameters like the cost per physical gate. The EFP framework is focused here on computing time optimization.

# FTQC vs HPC power baseline guesstimates



# technology and economics interplay



# discussion



get the slides

*now*