

How much electricity does a quantum computer need?

The question is attracting attention amid rising energy use by classical computing data centers.

By **Jenessa Duncombe**

Edward Parker was thinking about who might use a quantum computer to hack the controls of a US chemical plant when he noticed something odd in the literature. The physicist was working on post-quantum cryptography recommendations for the US Cybersecurity and Infrastructure Security Agency in 2023 as part of his work at the nonpartisan think tank RAND. But first, Parker needed to answer another question: Who'd be capable of building a quantum computer in the first place?

Parker found that the quantum computing literature focuses more on the number of qubits, short for quantum bits, a system could handle, rather than on the resources—particularly the energy and money—to run one. He wasn't the only one to notice. A small but growing number of researchers, and in some instances, governments and companies, are focusing on the resource needs of quantum computing.

Classical computing data centers' climbing energy use, fueled by AI models, has prompted pushback (see *PT*'s 2024 article "Will AI's growth create an explosion of energy consumption?"). Data centers consumed 1.5% of electricity worldwide in 2024, according to the International Energy Agency, and consumption is anticipated to more than double by 2030. Ireland, where data centers consume over

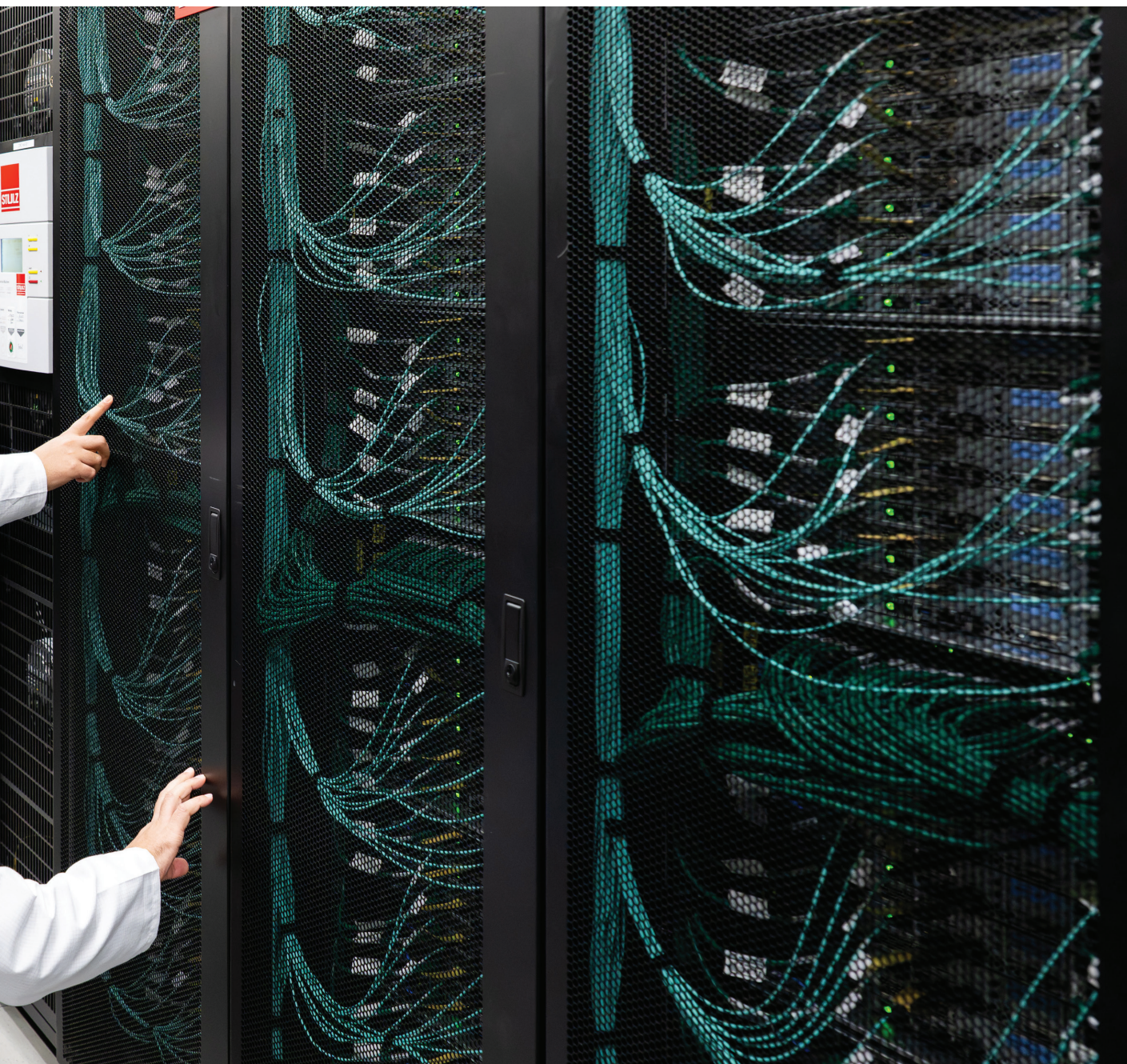


20% of the country's electricity, has limited the building of future data centers near Dublin. Fourteen states in the US have introduced legislation banning data centers in recent years.

Quantum computers are not nearly as ubiquitous as the classical computers that populate data centers. The technology is so nascent that the most scalable design of qubits is still an open question.

Quantum computing today does not reliably solve useful, practical problems. Road maps at several companies say they'll have a useful quantum computer by the end of this decade.

▼ The 54-qubit quantum computer Euro-Q-Exa was networked into this supercomputer at the Leibniz Supercomputing Centre in Germany. Scaling up quantum computing, and the energy it would take to do so, is an emerging topic in scientific circles. (Photo by Sebastian Widmann, © European Union, 2026, licensed under CC BY 4.0.)



Understanding quantum computing energy use requires unpacking how the technology uses energy and exploring efforts to increase efficiency. “I would say it’s never too early to be thinking about those things,” says David McCollum, an energy scientist at Oak Ridge National Laboratory.

A noisy enterprise

In the future, quantum computers could tackle specific problems in hours that would take classical supercomputers many years to run. A classical bit can only represent 0 or 1, but a qubit can represent 0, 1, or a superposition of both. As more qubits are added, the number of states the system describes increases exponentially, whereas classical bits scale linearly. Because of this, it’s tempting to think that quantum computers would be more energy efficient than classical computers.

But quantum computers lag in something classical computers are good at: reliability. Quantum computers use quantum states to hold information, and small disturbances in the physical environment can lead to the destruction of the information through decoherence. Today’s quantum computers have error rates many orders of magnitude higher than those of classical processors. Quantum computing today is classified as noisy intermediate scale, as opposed to fault tolerant.

The energy consumed by quantum computers boils down to what’s needed to fight noise, says Marco Fellous-Asiani, a quantum computing researcher at Inria, a French national research institute. Safeguards depend on the qubit type: cryogenic cooling for superconducting qubits, high-powered lasers for neutral-atom qubits, and cooling and laser systems for some trapped-ion qubit designs.

All require energy-costly quantum error correction.

For instance, superconducting qubits are at their least noisy at temperatures around 10–35 millikelvin, two orders of magnitude lower than the temperature of outer space and of the magnets in CERN’s Large Hadron Collider. The cooling system accounts for approximately 80% of the power consumption of a noisy intermediate-scale superconducting quantum computer, according to a May preprint from a group of quantum computing researchers.

Efforts to reduce quantum noise are ongoing, and qubits may rapidly improve in that area in the years to come. Once systems ramp up to thousands or millions of qubits, control electronics that manipulate qubits’ quantum states may become the energy-hungry part of quantum computers, says Raja Yehia, one of the authors of the May preprint. Yehia is a postdoc in quantum information theory at ICFO, the Institute of Photonic Sciences in Barcelona, Spain.

“Given the early stage of quantum computing and the lack of clarity as to which type of qubit will become predominant, it is hard to put firm figures on how much energy will be needed,” says Celia Merzbacher, the executive director of the Quantum Economic Development Consortium.

Back of the envelope

Still, some early estimates exist. In 2023, RAND researcher Parker calculated the electricity demand for a hypothetical superconducting quantum computer with 20 million noisy qubits to crack a 2048-bit RSA key, a widely used public-key cryptography system. He came up with 890 megawatt-hours, the electricity needed for roughly 85 US households for one year. Parker concluded that it would be difficult for

a bad actor to build and conceal a quantum computer anytime soon, let alone afford one. The electricity for that task alone would cost \$64 000 in 2023 dollars. He and fellow RAND scientist Michael J. D. Vermeer shared the results in a working paper.

What about the energy use of integrating fault-tolerant quantum computers into classical computing data centers? A new analysis by Oak Ridge’s McCollum and colleagues tackled this question using superconducting qubits. The researchers projected that by the 2040s, integrated quantum-classical data centers would have a system-level power demand of an order of magnitude similar to that of today’s data centers.

Quantum engineer Olivier Ezratty compared the power consumption of leading quantum computers with existing supercomputers in a presentation last year. He presented rough projections of the future base power of six quantum computers, each scaled up to 4000 logical qubits, that are under development by leading companies. The power ranged from under 1 megawatt to over 100 megawatts. Most landed within range of the top supercomputers today. The calculation was not peer reviewed and was for demonstrative purposes; Ezratty says that most industry vendors do not openly share power consumption information.

Steering the ship

If estimates are so varied today, why go about making them at all? Zeki Seskir, a researcher at the Institute for Technology Assessment and Systems Analysis in Germany, says that quantum researchers have the most control over eventual outcomes now, not later. Seskir cites the Collingridge dilemma: Harmful consequences of a technology may be hard to under-

stand when it is nascent, the dilemma goes, but those consequences become extremely difficult to control after the technology matures.

The Quantum Energy Initiative is addressing the question of what researchers and companies can do today to support energy-efficient design. The group began in 2022 after a call to action was published by Alexia Auffèves, at the time a quantum physicist at the French research organization CNRS. More than 700 people have signed up online to join the volunteer-run community, which has hosted three in-person workshops since 2023.

Counterintuitive results can arise when optimizing for energy efficiency. In a 2023 paper, a group of researchers introduced a method for modeling the connection between computational accuracy and energy consumption. Testing their metric noise resource technique on an idealized full-stack computer, the researchers found in some instances that raising the temperature of superconducting qubits while adding more quantum error correction yielded a larger yet more energy efficient computer, without losing accuracy.

Along with an energy utility, French quantum computing companies Quandela and Alice & Bob received €4.5 million (about \$5 million) from the French government to study the energy efficiency of quantum computers compared with that of classical systems. Using the metric noise resource method, Quandela identified energy-efficient regimes for its photonic quantum computer. Its computer was more energy efficient than a classical computer in solving a certain algorithm, despite having a greater runtime, the scientists from the company wrote in a preprint.

A standard under development by an IEEE working group aims to define energy-efficiency metrics for the sector. Working-group chair Fellous-Asiani, speaking in his personal capacity and not as a representative of the group or IEEE, says the standard under development quantifies the energy of solving a given problem at a given accuracy regardless of qubit type. It could one day serve as the basis for benchmarks comparing the energy efficiency of different quantum computers.

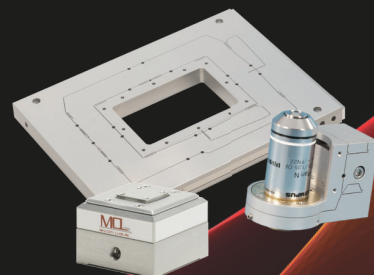
Of course, if quantum computers do not achieve widespread use, their energy demands could matter very little. For instance, supercomputers used for weather forecasting, aerospace research, and other research tasks consume paltry amounts of energy compared with what commercial data centers consume, says Ezratty, who is a cofounder of the Quantum Energy Initiative. Even if quantum computers are energy intensive, their impact could be relatively low if they stay in the realm of specialized research.

Another complicating factor is the possibility of the hypothesized rebound effect: when the lower costs resulting from energy-efficiency improvements actually encourage consumption and thus dampen the effects of the innovation. If commercially relevant quantum computing becomes more energy efficient, companies could simply buy more computers or computing time.

To find the answers, Sesikir calls for exploring impacts as early as possible. “Technology and innovation are not science,” he told the audience during his presentation at the Quantum Energy Initiative’s 2023 workshop. “Although we might be scientists, we need to be aware that the consequences are different.”

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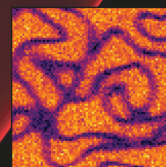


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