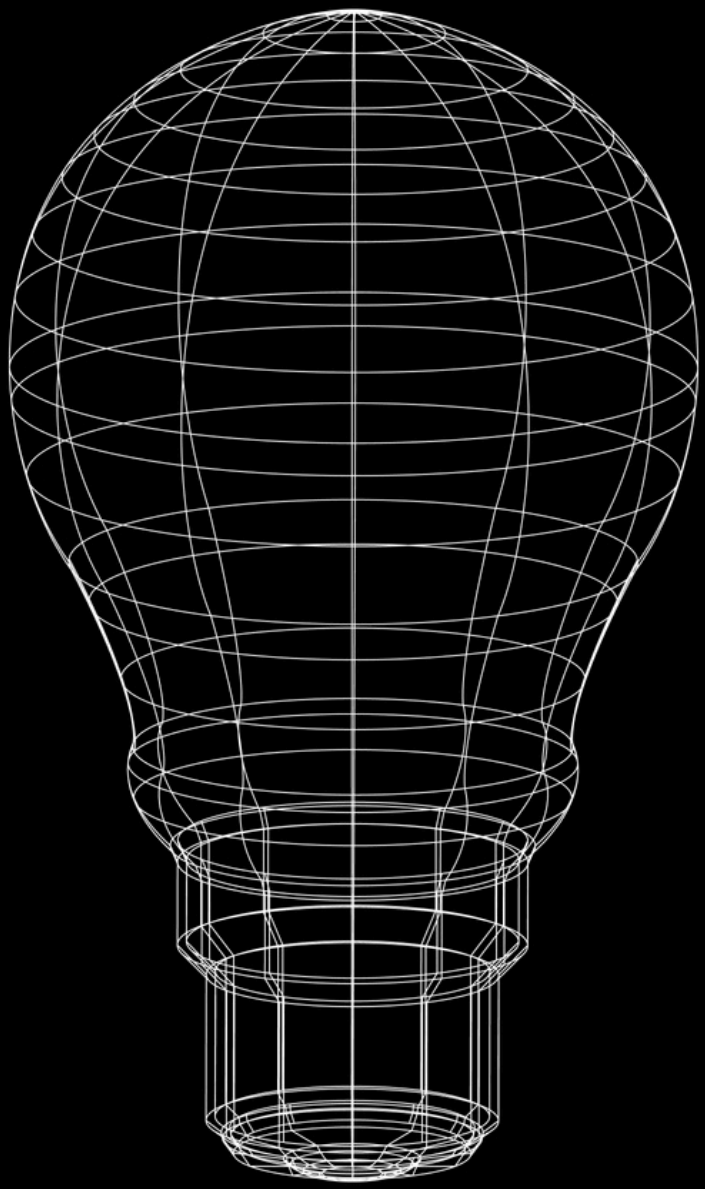


Energy efficiency and quantum compute

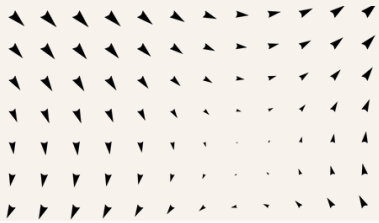
A BEGINNERS GUIDE

OQC

Global energy demand is set to increase by 50% over 2018-2050 to reach 264 trillion kWh, according to the U.S. Energy Information Administration.

SINCE 2010, THE NUMBER OF INTERNET USERS WORLDWIDE HAS MORE THAN DOUBLED, WHILE GLOBAL INTERNET TRAFFIC HAS EXPANDED 25-FOLD.

SOURCE: INTERNATIONAL ENERGY AGENCY



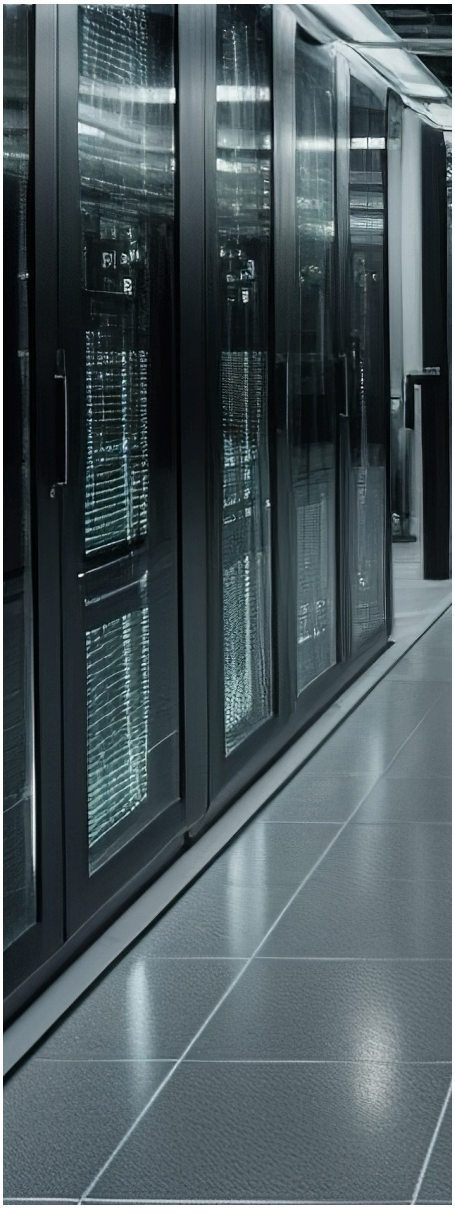
Across governments and industries, there is a growing acknowledgement that we need to act now to make genuine, lasting changes to reduce impact on the world around us. Most recently, the UK Government has stated its mission to make Britain a clean energy superpower in order to cut bills, create jobs, and deliver security with cheaper, zero-carbon electricity by 2030, accelerating to net zero. This October, the UK officially closed its last coal-fired power plant a year earlier than anticipated, marking the end of coal use to generate electricity in the country.

As the world becomes progressively connected and many aspects of our everyday lives have been improved through technological advancements, energy consumption and current infrastructure capabilities have begun to grapple the ever-increasing demand of global internet traffic powered by classical compute and the growing inclusion of AI.

The current trends of energy consumption from classical compute and AI are unsustainable, particularly as we see a rise in the use of AI: to process and analyse data, significant amounts of electricity is required. For example, a recent study found that generative AI could use around 33 times more energy than machines running task-specific software. To put this power consumption into perspective, Google has signed a deal to use Small Nuclear Reactors (SMRs), which are defined as having a maximum of 300 MWe, to generate the vast amounts of energy needed to power its artificial intelligence (AI) data centres. Further to this, they recently confirmed they are developing data centres that will 'consume more than 1GW of power' according to CEO Sundar Pichai.

Power for compute is sourced from the national grid, creating strain and concerns around capacity limitations and fuelling. Recently designated as Critical National Infrastructure (CNI), data centres are centralised facilities which physically house a range of pivotal IT equipment, and are used by organisations across a variety of industries to manage, process, disseminate and most importantly, securely store large amounts of data and applications.

USING A STAGGERING 460 TERAWATT HOURS OF ELECTRICITY IN 2022, THE WORLD DATA CENTRES ARE ANTICIPATED TO DOUBLE THIS FIGURE IN JUST FOUR YEARS, ACCORDING TO THE INTERNATIONAL ENERGY AGENCY.







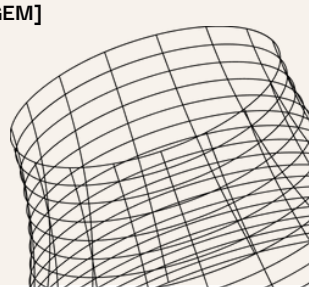
THESE EVER-INCREASING FIGURES CAN BE SEEN AT CONTINENT LEVEL, WITH RECENT RESEARCH BY SAVILLS REVEALING THE EUROPEAN DATA CENTRE POWER CAPACITY IS PROJECTED TO RISE TO APPROXIMATELY 13,100 MW BY 2027, REFLECTING A 21% INCREASE WHILE THE TOTAL INTERNATIONAL BANDWIDTH USAGE IN EUROPE IS PREDICTED TO RISE BY A 31% COMPOUND ANNUAL GROWTH RATE (CAGR) BY 2030.

As global energy networks grow, the sophistication of these infrastructures needed to sustain them also increases: particularly when factoring new load types through AI, which is seeing a soaring demand through business adoption. It is estimated that more than 3,000 new data centres sites across Europe will be required to meet the volume of traffic expected to route through colocation, edge and hyperscale facilities by 2025.

To address the pressing environmental concerns surrounding data centres and the energy consumption of services within them, there is a clear emphasis on sustainable practices:

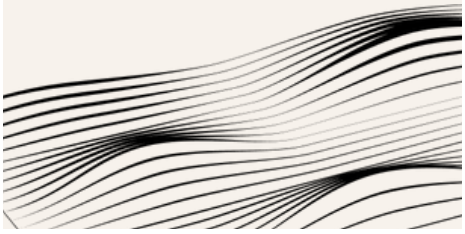
ACCORDING TO OFGEM, THE AVERAGE BRITISH HOUSEHOLD USES APPROXIMATELY 2,700 KWH OF ELECTRICITY AND 11,500 KWH OF GAS A YEAR.

[SOURCE: OFGEM]



IN 2020, THE DATA CENTRE INDUSTRY CONSUMES A SIGNIFICANT AMOUNT OF ENERGY—BETWEEN 196 TO 400 TERAWATT-HOURS ANNUALLY, EQUIVALENT TO 1% TO 2% OF GLOBAL ENERGY USAGE. THE EU ALONE REQUIRED 104 TWH FOR DATA CENTRES IN THE SAME YEAR.

[SOURCE: EUROPEAN ENVIRONMENTAL AGENCY]



including energy efficient hardware, innovative cooling systems and renewable energy sources. The residual heat alone from data centres can be repurposed for heating buildings and even public swimming pools, giving a secondary use to spent energy.

Key regulatory frameworks have begun to make incremental improvements, such as the EU Energy Efficiency Directive (EED), Australia's National Built Environment Rating System (NABERS, Singapore's Data Centre Energy Efficiency Scheme (DCS), the United States SEC Climate Risk Disclosures and the California Title 24 in the USA.

Similarly, the 2021 United Nations Climate Change Conference (COP26) set ambitious emissions reduction targets. Marking a historic capital relocation, with an anticipated annual investment of $4 trillion by 2030 to meet the critical goals outlined, COP26 and surrounding energy missions require a new way of thinking. Realising the commitment to net-zero emissions requires advancements in climate technology currently beyond reach.

The current challenges

Classical computing, despite its widespread use and versatility, faces several inherent inefficiencies that contribute to high energy consumption in data centres.

Many computational problems, particularly in fields such as machine learning, optimisation, and simulations, have a problem space that grows exponentially with the size of the input. In addition, classical algorithms often face inherent limitations in efficiently solving these problems.

As the time-complexity of computations increases, energy consumption increases in parallel. Similarly, as the size and complexity of the data increase, the number of operations required grows rapidly, leading to long computation times. The longer a problem takes to solve, the more continuous energy is consumed by the processors.

For instance, training a large machine learning model or running a detailed climate simulation can take days or even weeks of uninterrupted processing time. Therefore, they must run their processors continuously for the duration of these computations. The energy consumption accumulates over time, making these extended operations highly energy-intensive. In addition, these types of problems require not only significant processing power but also extensive memory and storage resources, all of which consume energy.

Unlike classical computers, quantum computers are anticipated to exhibit energy efficient solutions by handling some large computational tasks quickly, potentially contributing to a reduced energy consumption. By integrating quantum compute power into our current critical infrastructure, data centres could play a pivotal role in enabling a cleaner, greener future through sustainable technology adoption.



Quantum and data centres

It is expected that if a quantum computer performs just 5% of the tasks that a supercomputer does, it could result in annual savings of over $1 million and a reduction in energy consumption of nearly 10 gigawatt-hours per year.

As organisations around the world face limitations with power supply, computation capabilities and energy security, data centres are beginning to face the crucial challenge of scaling their infrastructure and capabilities, which will require innovations in a variety of areas including storage, networking and computing capabilities.

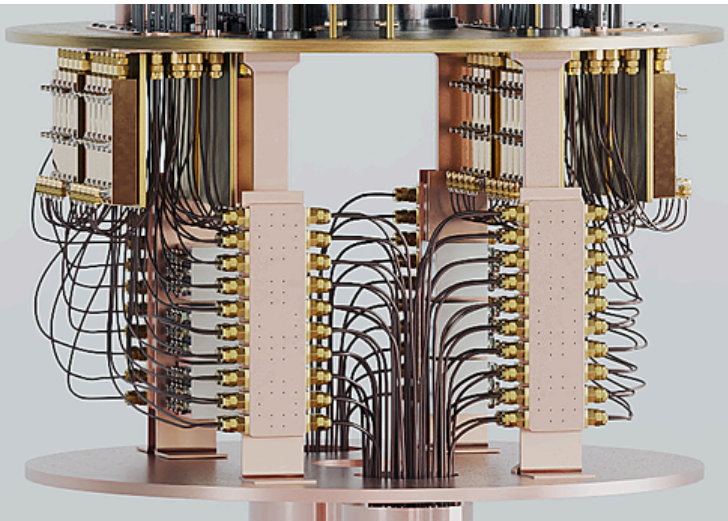
Major colocation data centre players provide not just the physical platforms, space, cooling, power and network, but also software defined infrastructure and service, metros, and a range of solutions unobtainable outside of their ecosystem (such a cloud direct connects).

These colocation data centres provide the optimum environment to utilise the power of quantum computing, not only allowing easy, secure access that will enable life-changing discoveries, but by helping to solve our growing computational needs, sustainably.

COLOCATION DATA CENTRES ARE A DISTINCT TYPE OF DATA CENTRE WHICH LEASES SPACE TO A CLIENT COMPANY TO STORE THEIR INFRASTRUCTURE, ALLOWING FOR DIFFERENT COMPUTING MODALITIES AND SERVICES TO BE COLOCATED. COLOCATION DATA CENTRES PROVIDE OPTIMUM PREMISES TO MERGE QUANTUM COMPUTING INTO THEIR PRE-EXISTING INFRASTRUCTURE.

The world's largest supercomputer Frontier, broke the exascale barrier in 2022 and topped the Green500 list for most efficient supercomputer at 62.68 gigaflops performance per watt.

OQC TOSHIKO GEN1 USES 35KW PER SYSTEM. AS THE SYSTEM SCALES TOWARDS HUNDREDS OF QUBITS, THE POWER DRAW IS EXPECTED TO REACH ~40KW WITH THE CPU + NW + CRYOGENICS OF TOSHIKO ALL REMAINING THE SAME.





Cryogenics and energy consumption

Cryogenics and cooling are one of the largest contributing factors to energy consumption. Many data centres have already begun exploring the optimisation of these systems through areas such as implementing liquid cooling technologies and improving airflow, which could make considerable efficiencies.

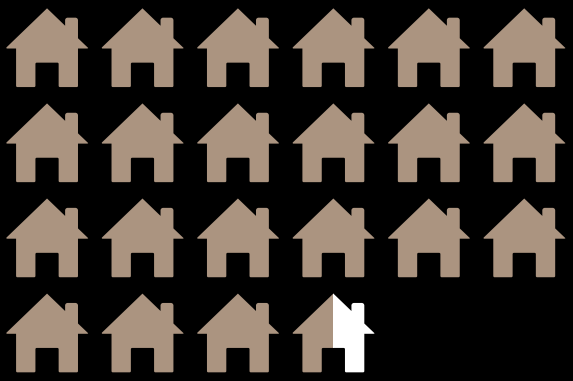
In superconducting qubits systems such as OQC's latest 32-qubit device, OQC Toshiko Gen1, cryogenics are used to achieve the necessary conditions for superconductivity and reducing decoherence and noise.

For example, a dilution refrigerator is a cryogenic platform that can cool bulk materials to temperatures around 10 mK (10 thousandth of a degree above absolute zero). Within these platforms, the cryocoolers are the most energy-intensive part. The cryocoolers typically use 10 kW of power each: when you combine the rest of the OQC's quantum computing system (such as the networking, control, and diagnostics) the total consumption currently only rises to approximately 35 kW. This energy use also remains consistent regardless of whether the quantum device is at full capacity or not. This benefit carries over to energy grids enabling clear base loads instead of variable loads.

OQC INTEGRATED THE WORLD'S FIRST QUANTUM COMPUTER INTO A COLOCATION DATA CENTRE, PIONEERING QUANTUM COMPUTE-AS-A-SERVICE (QCAAS) AND CREATING A SUSTAINABLE, FLEXIBLE, AND SECURE SOLUTION TO THE CHANGING DIGITAL WORLD. FIND OUT MORE IN OUR FREE QUANTUM COLOCATION RESOURCE.

AN OQC QUANTUM COMPUTER NEEDS 35 KW: THIS IS THE SAME AS POWERING

21.6 HOMES



To put this in perspective, an OQC quantum computer needs 35 kW - this is the same as powering 21.6 homes. In contrast, the Hewlett Packard Enterprise Frontier supercomputer (which is exceedingly powerful) is quoted to consume 21 megawatts of power. This consumes 600 times more power than OQC's quantum computer and is the equivalent of powering nearly 13,000 average British households.

Unlocking the potential of hybrid quantum compute

Quantum computers' advances and near-term quantum usage is adjacent to classical compute: where the quantum computer should offer some acceleration to the problem at hand or improve the accuracy over other methods. Hybrid compute integrates quantum processor units (QPUs) with classical processors to capitalise on the strengths of each. For example, a quantum computer can be employed to solve complex optimization tasks, and the results are integrated into a high-performance system for further analysis.

THE BASIC IDEA BEHIND HYBRID QUANTUM COMPUTING IS THAT QUANTUM COMPUTERS AND CLASSICAL SYSTEMS WORK AS CO-PROCESSORS ALONGSIDE ONE ANOTHER CARRYING OUT COMPUTATIONAL WORKLOAD.

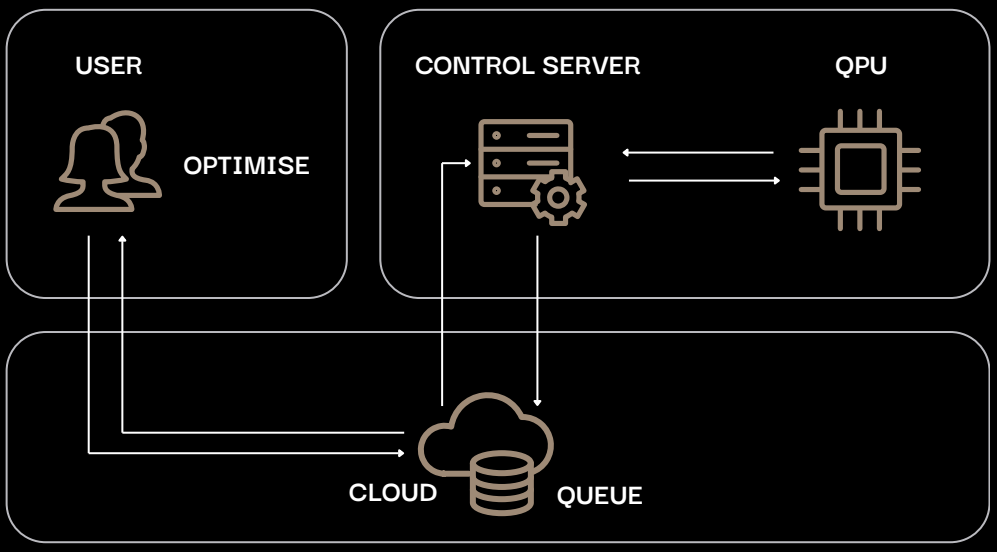
OQC established this symbiotic hybrid compute relationship by deploying into colocation data centres, positioning quantum compute capabilities at the heart of classical computing architecture and integrating NVIDIA's DGX systems GH200 Grace Hopper Superchip alongside our quantum systems, to conduct hybrid quantum-classical experiments. Hybrid architectures such as this through the cloud are critical to the adoption of quantum computing for users and businesses, providing seamless access to experiment.

Hybrid compute is one approach to solving some problems faster than a pure classical computer can, saving time on the classical compute and potential power. This progression in compute is pivotal to progressing towards the fault-tolerant quantum computing required to accessing predicted energy efficiencies.

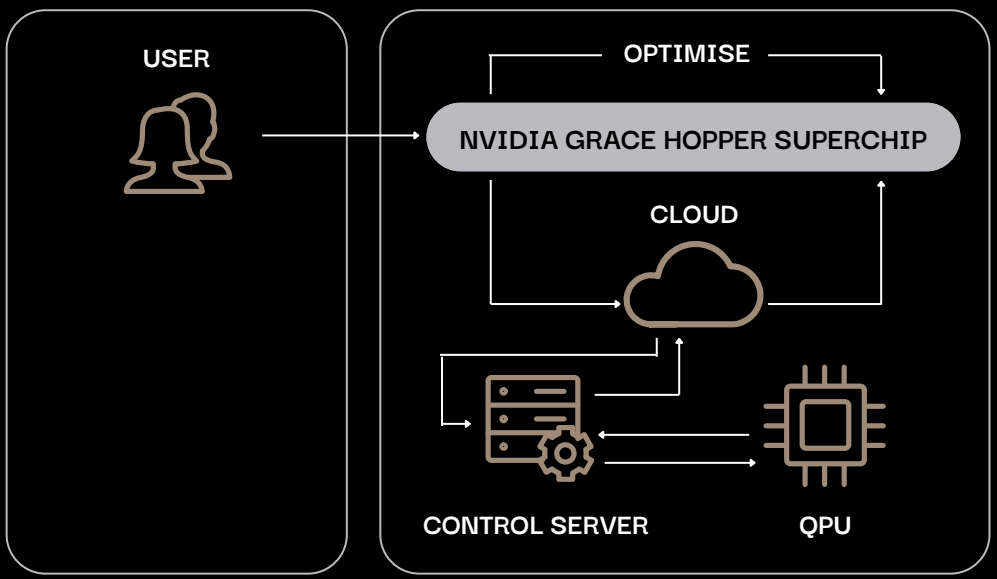
There are many examples of near-term hybrid algorithms that will similarly require classical compute when scaled up to the fault-tolerant regime. This includes quantum machine learning, for which it is useful to leverage classical computers for the optimisation of the parameter space. Hybrid computing can also be important for applications which work solely in a fault-tolerant regime. For instance, factorization using Shor's algorithm requires computing the "greatest common divisor" at the start and end of the computation. Classical computers can compute this incredibly efficiently and quickly.

Once we reach the fault-tolerant era, we will need to introduce error correction to reduce errors in computations. A vast quantity of classical computing will be required to do the error correction decoding, although this will likely need to be bespoke classical hardware. Due to the complex behaviour of physical quantum computers, these error reduction schemes can take many forms.

PREVIOUS FLOW OF DATA FOR A SINGLE ITERATION OF A HYBRID PROBLEM



OQC & NVIDIA PROCESS FLOW



Quantum and energy applications

Once integrated, on top of the natural energy efficiency benefits they bring, quantum computers can also be applied to key energy industry applications.

Their ability to be in a superposition means that quantum algorithms can use a group of qubits in a superposition to shortcut through calculations, giving them their innate capacity to work faster. However, it is important to note that the connectivity of the qubits play a pivotal role in determining their time-to-solution.

The energy sector has already begun shifting towards renewables like solar, hydro, geothermal, and wind to meet global climate targets, with energy giants such as BP developing, constructing and operating fixed-bottom offshore wind projects, with grid connection targeted by end-2030. This transition presents challenges for the industry as they adapt to new energy sources and distribution methods. Quantum computers offer potential solutions to these challenges by enabling advanced simulations in chemistry and materials development, promising breakthroughs in battery technology and alternative fuel optimisation.

WIND AND SOLAR ARE PREDICTED TO SUPPLY 50% OF THE WORLD'S ENERGY CONSUMPTION BY 2050. APPROXIMATELY 10 TRILLIONS OF NEW INVESTMENT IS EXPECTED TO GO TO RENEWABLE ENERGY BETWEEN NOW AND 2050.

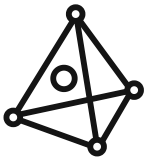
[SOURCE: BLOOMBERG NEW ENERGY FINANCE]

GLOBAL QUANTUM COMPUTING WITHIN THE ENERGY MARKET IS PROJECTED TO GROW AT A CAGR VALUE OF 30.8% FROM 2022 TO 2027, WITH THE UNITED STATES EXPECTED TO BE THE DOMINANT FORCE IN THE MARKET.



A key area of interest for quantum application to the energy sector is carbon capture. By utilising quantum capabilities such as simulation to study chemical reactions related to carbon capture could support researchers discovering new carbon-capture reactions and ways to predict reaction efficiencies. For this use case, both quantum simulations using VQEs and quantum machine learning (QML) approaches are currently being investigated as they could help to predict the performance of carbon capture materials, and accelerate the design of novel compounds which are also practical to produce at scale.

The possibilities are endless with how quantum compute can contribute to sustainability with a report by Deloitte (2023) outline the following potential areas:

SIMULATION	OPTIMISATION	MACHINE LEARNING
 CATALYSTS	 ELECTRICAL GRID	 EARTH SYSTEM MODELLING
 BATTERIES	 VEHICLE ROUTING	 MATERIALS DISCOVERY
 CARBON CAPTURE MATERIALS	 TRANSPORTATION SPACE USAGE	 POLICY DECISION SUPPORT

Continuing the journey

At OQC our team and emerging technology will endeavour to support the implementation of customer and partner sustainability goals, and address the world's urgent sustainability challenges by working to enable:



The reduction in the energy use of data centres and servers as critical national infrastructure



The reduction in energy required for complex computations even as demand continues to rise



The acceleration of the development of new applications to address global sustainability



The reduction of quantum computing's own potential environmental impact

We continue to build with sustainability in mind so we can scale effortlessly and through accomplishments such as our world-first integration into a colocation data centre and providing access to our Quantum Compute-as-a-Service (QCaaS) capabilities, we are empowering businesses to begin their quantum exploration journey.