

QUANTUM COMPUTING FOR CLIMATE ACTION

Accelerating innovation in quantum computing enables the Sustainability Quantum Working Group to unlock near-term applications to climate change mitigation and adaptation



ADVANCING CLIMATE ACTION AND SUSTAINABILITY

Humanity faces global challenges as climate change intensifies, and six of the nine Planetary Boundaries are breached.¹ Ambitious policies and technological innovation are essential. Quantum computing is maturing rapidly, enabling the investigation of near-term transformational applications in sustainability such as advancing clean energy, resilient cities, and land management.² As decision makers gather at UNFCCC COP 30, the global quantum innovation community stands ready to contribute to achieving climate targets and advance progress towards the Sustainable Development Goals (SDGs).^{3,4}



STATE OF QUANTUM COMPUTING

Quantum computing is making steady progress towards enabling scientific research at a scale where conventional cutting-edge methods alone start to struggle. Hardware manufacturers are delivering on technology roadmaps and predicting the arrival of early fault-tolerant quantum computers as early as 2029.^{2,5,6,7} Rapid advances across both hardware and software are continually reducing the timeline for practical implementations such that now is the time to accelerate the development of quantum applications.

SUSTAINABILITY QUANTUM WORKING GROUP

The Sustainability Quantum Working Group is a worldwide technical community of 55+ quantum and domain experts from academia and industry. It was created in 2024 by IBM, PINQ², Hydro-Québec and Université de Sherbrooke, with a steering committee that includes representatives from Arizona State University, E.ON, IBM, Open Quantum Institute, and the University of Victoria.



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THE QUANTUM COMPUTING AND SUSTAINABILITY WORKING GROUP - EMERGING OPPORTUNITIES

Some critical innovation for climate action demands vast computational resources. Quantum computers provide new, potentially transformative methods to model Nature and design technologies whilst foreseeably requiring less energy than traditional approaches like AI. This expands what's possible digitally, yielding faster, cheaper, and more accurate solutions benefiting the environment, economy, and society. The Sustainability Quantum Working Group, founded in 2024, unites global experts to explore quantum advantages⁸ for sustainability across sectors like energy, climate, semiconductors, forestry, and carbon capture.

HARNESSING QUANTUM COMPUTING FOR THE ENERGY SECTOR

Electrical grids, built over decades, lack native digital infrastructure. As electricity demand may double by 2050, modernization is essential.⁹ Ensuring resilience in energy grids amid renewable energy availability intermittency and other unpredictable events introduces major computational challenges. To mitigate this challenge, we must look beyond traditional computing infrastructures to deliver capabilities that can handle the computational complexity inherent to this digital transformation.

Quantum computing may be such a desired computational powerhouse to solve some of these most complex challenges and thereby aid to deliver cleaner, more reliable, and affordable energy through advanced modeling. Applications include grid optimization, materials analysis, renewable energy characterization, fusion research, and cybersecurity.^{10 11} Furthermore, quantum computing's strength in solving complex optimization supports resource planning, load forecasting, and reliability modeling. Within the Sustainability Quantum Working Group, researchers from Hydro-Québec, E.ON, SaskPower, Technical University of Denmark, University of Calgary, University of Saskatchewan, EPRI, and IBM are addressing grid optimization problems including powerflow calculations, unit commitment, and energy storage.

As these technologies mature, quantum integration will enhance efficiency, resilience, and innovation in the energy sector.



ADVANCING ENERGY STORAGE AND BUILDING MATERIALS

Quantum chemistry underpins sustainability, as challenges like improving batteries, catalysts, fertilizers, and carbon capture depend on accurately modeling molecular interactions. Quantum computers can simulate these systems to chemical accuracy, revealing mechanisms and material properties beyond classical reach.

The chemistry branch of the Sustainability Quantum Working Group focuses on batteries and sustainable concrete—key technologies for reducing greenhouse gas emissions and enabling cleaner energy storage. These involve complex many-body systems requiring simultaneous computation of multiple subsystems. The group applies new quantum algorithms designed to surpass classical methods and unlock previously intractable chemical problems.^{13 14}

By uniting experts in quantum chemistry, condensed matter physics, and toxicology from University of Victoria, Arizona State University, Hydro-Québec, IBM, Université de Sherbrooke, MILA, and USRA/NASA, the team aims to demonstrate quantum advantage in chemical systems, identify benefits for batteries and concrete, and extend these methods to broader sustainable materials.



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BUILDING RESILIENCE TO WILDFIRES AND EXTREME WEATHER EVENTS

Wildfire spread is chaotic and dynamic, driven by shifting winds, uneven fuels, and volatile weather that can turn embers into firestorms. As wildfires grow in frequency and intensity, they're exposing the limits of how we manage forests, protect infrastructure, and monitor carbon. Forecasting their behavior means capturing nonlinear, multi-scale interactions among fuel conditions, weather systems, and regional climate, a computational challenge as unpredictable as the fires themselves.

This interdisciplinary collaboration brings together researchers from Natural Resources Canada, IBM, University of Calgary, University of British Columbia, University of Ottawa, MILA and USRA/ NASA to explore quantum machine-learning techniques for wildfire modeling. The group is evaluating the efficacy of approaches such as quantum reservoir computing, quantum Long Short-Term Memory (LSTM) models, and quantum feature mapping. These approaches leverage the ability of quantum systems to encode complex correlations in high-dimensional spaces, potentially offering greater expressivity and stability for modeling nonlinear processes.

The project focuses on testing these techniques with real wildfire datasets and benchmarking them against established classical models. Future work will examine scalability as larger quantum resources become available, advancing the goal of improving wildfire forecasting accuracy and operational resilience.



CONCLUSION, KEY TAKE AWAYS, INVITATION TO PARTICIPATE

Quantum computing has reached a pivotal stage where its potential to accelerate sustainability innovation can now be studied in depth and applied across multiple sectors. Concrete examples have demonstrated how quantum applications for the SDGs can be developed in collaboration with UN agencies.¹⁵ From optimizing energy systems and advancing sustainable materials to modeling climate adaptation, the technology offers transformative potential for addressing some of humanity's most complex societal and environmental challenges. The Sustainability Quantum Working Group is dedicated to this mission—uniting researchers, industry providers, and domain experts to explore quantum advantages for climate action and the UN SDGs.

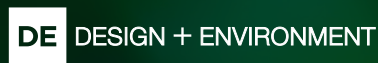
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As the field advances, international collaboration will be essential to unlock the full potential of quantum computing for a sustainable future. The Sustainability Quantum Working Group is constantly evolving, growing, and looking for new ways quantum computing can tackle generational challenges.

Please fill out this form to stay informed about our activities and help shape the next wave of solutions for climate resilience!



CREDITS

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