Australian Government
Office of the Chief Scientist

Quantum Meets Energy Workshop Summary

A workshop led by Australia's Chief Scientist in partnership with the CSIRO

CSIRO

Acknowledgement of Country

The Office of the Chief Scientist acknowledges the traditional owners of the country throughout Australia and their continuing connection to land, sea and community. We pay our respect to them and their cultures and to their elders past and present.

Artwork: Connection to Country, 2021 by Shaenice Allan

Meeting Place icon by DISR employee Amy Huggins

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The purpose of this publication is to summarise the events and outcomes of the Quantum Meets Energy event which occurred in Melbourne on 31 May 2024.

Microsoft Co-Pilot was used in developing this summary.

Workshop overview

Quantum Meets Energy was an in-person workshop led by Australia's Chief Scientist in partnership with the CSIRO at the University of Melbourne on 31 May 2024. Approximately 70 people attended, including representatives from the energy sector, industry, quantum technology companies, universities and government.

The workshop discussed the challenges facing Australia's energy system and the solutions that quantum technologies are expected to provide. Australia's energy system is complex, interconnected and experiencing a significant transition. For example, the large uptake in residential solar is leading to seasonable variability, the main driver of capacity planning. Due to these variabilities, it is necessary to design the entire system to survive the 'worst five minutes of the year', which is the middle of winter when energy demands are at their peak and solar power production is at a minimum.

Another issue involved in the transition to renewable energy is that of how to handle the small buffer in the system as the few large generators (coal-fired power stations) retire and are replaced by multiple small generators. The ability to have real-time optimisation of this new energy grid, which has millions of components, will be possible using quantum computers.

Providing Australia's energy while meeting global commitments to reducing contributions from CO_2 emitting sources will require the planning, modelling and operating of highly complex, interconnected systems – potentially made up of hundreds of millions of connected devices that need to be monitored, optimised and controlled. This is where quantum technologies can play a part.

The workshop focus was aligned with Australia's National Quantum Strategy[1] and a challenge featured in Round 1 of the Critical Technologies Challenge Program, asking applicants to optimise the performance, sustainability and security of energy networks.

[1] https://www.industry.gov.au/publications/national-quantum-strategy

Scene setting

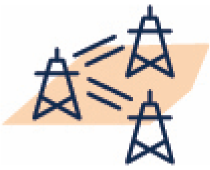
Australia's Chief Scientist, Dr Cathy Foley, described the workshop as part of a broader effort to realise the ambition embodied in Australia's National Quantum Strategy.[Error! Bookmark not defined.] Dr Foley emphasised the opportunity to identify potential applications of quantum technology in the energy sector in Australia. She provided examples of the use of quantum technologies, including for optimised wind farm energy production, wind farm technology fault detection, and new materials design for extreme conditions, such as those needed in fusion reactors. She also discussed how car companies are using quantum computing for advancing effectiveness of next generation batteries and the potential of superconducting transmission lines to reduce losses during distribution.

Dr Foley also highlighted the opening of Round 1 of the Critical Technologies Challenge Program and noted that Challenge 1 related to optimising the performance, sustainability and security of energy networks to help the transition to net zero.

Dr Dietmar Tourbier, Director of the energy business unit at the CSIRO, discussed how energy and quantum sector experts often used different language and scales. He encouraged both sides to be curious and open to learn more about each other with the goal of sparking new ideas. Dr Tourbier gave an overview of Australia's energy challenges and described the potential for quantum technologies in:

- efficient and responsible energy
- grid operation and optimisation
- high-density energy storage, fast charge and discharge
- energy generation from advanced materials.

Areas of industry impact



Grid optimisation and fault detection

Quantum computing could solve complex grid management optimisation problems, and quantum machine learning approaches could be used for fault detection or forecasting. Additionally, quantum metrology could give more frequent and accurate measurements, which are required for modernised power grids.

Quantum technologies may find application in enhancing electricity grid stability and reliability. Quantum sensors could be used to detect minute changes in magnetic fields, enabling early identification of faults and disruptions.

Materials discovery and devices

Quantum computers could simulate complex molecular structures and help discover new materials. These could include more efficient and higher performing materials for high-efficiency photovoltaic solar cells, advanced batteries, thermoelectric devices, hydrogen storage, fuel cell catalysts, carbon capture and transmission lines.

Quantum batteries

Quantum batteries represent a new class of energy storage devices that operate on quantum mechanical principles. They exhibit a surprising feature where the bigger the battery is, the faster it charges. Researchers are working towards an operational prototype in the next few years.

Grid security

Increased use of technology and the distributed nature of the system in smart grids will require stronger cybersecurity. Quantum technologies such as quantum key distribution could potentially provide unhackable security. Quantum sensors could detect minute changes in magnetic fields, allowing early identification of faults and disruptions.

Subsurface exploration

Quantum gravimeters provide highly sensitive measurements of gravitational anomalies, enabling the detection of underground resources like oil, gas and minerals with greater precision. Quantum magnetometers and gradiometers can detect minute magnetic field variations, aiding in the mapping of geological structures, identifying potential drilling sites and identifying subsurface infrastructure. Quantum computing could be used to improve the accuracy of subsurface models and predictions.

Efficient Power Transmission

Quantum wires and systems are in development for near-zero loss superconducting transmission lines. Such a transmission system significantly reduces energy losses over long distances, reducing the required investment in energy capture capability by up to 10%.

Program schedule

Setting the scene

- Dr Cathy Foley, Australia's Chief Scientist
- Dr Dietmar Tourbier, Director of the Energy Business Unit at the CSIRO

Keynote 1 – Critical challenges for the energy sector

- Violette Mouchaileh, Executive General Manager for Emerging Markets and Services at the Australian Energy Market Operator (AEMO)
- Phil Hirschhorn, Managing Director, Senior Partner, and Henderson Institute Fellow at the Boston Consulting Group

Keynote 2 – Meeting the challenge with quantum technologies

- Professor Chris Vale, Professor of Physics and Director of the Quantum Technologies Future Science Platform at the CSIRO
- Professor David Jamieson, Professor of Physics at the University of Melbourne

Panel 1 – Quantum technology for efficient and responsible energy

Chair: Dr Claudia Echeverria Encina, Sustainable Carbon Technologies Group Leader at the CSIRO

- Professor Jared Cole, Professor at RMIT and Director of RMIT Applied Quantum Technologies
- Michael Edwards, Senior Director of Boeing Research and Technology – Asia Pacific
- Gabi Skoff, Research Technician: Quantum Readiness at the CSIRO, PhD Candidate: Responsible Innovation of Quantum Technologies

Panel 2 – Quantum computing for grid operation and optimisation

Chair: Dr Michael Harvey, Translational Research Program Manager at the ARC Centre of Excellence for Engineered Quantum Systems (EQUS)

- Mark Twidell, Industry Professor of Practice at the UNSW Energy Institute, non-Executive Director at AGL
- Roberto Mauro, General Manager at Pasqal
- Dr Chris Bentley, Lead Solutions Engineer at Q-CTRL

Panel 3 – Quantum batteries for energy storage

Chair: Dr Felicity Splatt, Data Scientist and Digital Lead in the Energy Business Unit at the CSIRO

- Josef Tadich, Head of Tesla Energy, Asia Pacific
- Dr Howard Lovatt, Chief Technology Officer at Energy Renaissance
- Dr James Quach, Science Leader in Quantum Science and Technologies and the Team Leader of Quantum Batteries at the CSIRO
- Dr James Hutchinson, Senior Lecturer at the School of Chemistry at the University of Melbourne

Panel 4 – Quantum energy generation from enhanced materials

Chair: Dr Katja Digweed, Research Director in the Manufacturing Business Unit at the CSIRO

- Kallen Cook, Head of New Technology – Asset Development at Origin Energy
- Professor Michael Fuhrer, ARC Laureate Fellow in the School of Physics at Monash University
- Dr Tim van der Laan, Functional Nanosystems team lead at the CSIRO
- Scientia Professor Alexander Hamilton, ARC Industry Laureate Fellow at the UNSW Sydney, Deputy Director of the Australian Research Council Centre for Future Low Energy Electronics

Breakout sessions

- Four breakout sessions explored energy sector challenges where there could be applications for quantum technology

Overview of government funding opportunities

Michele Graham, General Manager of the Quantum Branch, Department of Industry, Science and Resources

Next steps and closing statement

Dr Cathy Foley, Australia's Chief Scientist

Keynotes

Critical challenges for the energy sector

Violette Mouchaileh, Executive General Manager, Emerging Markets and Services, AEMO, spoke to the transitioning energy sector, with key disruptors across weather and climate change, aging infrastructure, cyber security, supply sources, new service models and consumer preferences. She spoke to the opportunity of data and digital as a key enabler in running a highly renewable and distributed eco-system, and of the increasingly complex data processing required for supply and demand, the increasing complexity of system planning, and of the need for real-time planning and management for system security.

Philip Hirschorn, Managing Director, Senior Partner and Henderson Institute Fellow, Boston Consulting Group, spoke of the challenges in the energy transition: planning under uncertainty, optimising the massive proliferation of connected appliances and data, managing fragile infrastructure and dimensioning for the peak (while adding new forms of supply and demand, and with critical constraints in wind energy and gas). He saw opportunities in improving our predictive ability (across weather, supply/demand, system dynamics), optimising physics and markets across millions of active appliances, protecting our grid and household infrastructure, improving our energy efficiency (especially at peaks, including new demand), making the most of scarce raw materials, and anticipating, sensing and responding to community concerns.

Meeting the challenge with quantum technologies

Professor Chris Vale, Director of the Quantum Technologies Future Science Platform, CSIRO, noted that this is the global era of the 'quandemic', and Australia is not immune, with interest and investment in Australia in quantum technologies continuing to rise. Quantum technologies are notoriously fragile, expensive and difficult to work with, but the 'quantum 2.0' era, where technologies can explicitly exploit quantum properties, promises enormous opportunity in quantum sensing, quantum materials and energy, quantum communications and quantum computation.

Professor David Jamieson, Professor of Physics at the University of Melbourne, described the steep road to 2050 and the challenge of matching nanoscale quantum to the gigascale power grid. Professor Jamieson took both a local and a global lens, describing the challenges in Melbourne of meeting our electricity demand (and our historic struggles with electricity supply during heatwaves), and providing an example from the UK and the phenomenal infrastructure growth needed to provide the required sustainable 'platform' to service future electricity needs. He outlined the potential connection between nanoscale quantum technologies and our gigascale power grid and underscored the importance of having a quantum workforce to support this.

Panel composition and discussions

Panel 1 – Quantum technology for efficient and responsible energy

Chair: Dr Claudia Echeverria Encina, Sustainable Carbon Technologies Group Leader at the CSIRO

- Professor Jared Cole, Professor at RMIT and director of RMIT Applied Quantum Technologies
- Michael Edwards, Senior Director of Boeing Research and Technology – Asia Pacific
- Gabi Skoff, Research Technician: Quantum Readiness at the CSIRO, PhD Candidate: Responsible Innovation of Quantum Technologies

Australia's National Quantum Strategy explicitly discusses a 'trusted, ethical and inclusive quantum ecosystem'. Developers and users of quantum technology need to consider the impact of quantum technology both independently and as a synergist for other technologies.

One example of quantum computers facilitating efficient and responsible energy usage is in the aviation industry, where their immense data processing capability could assist in the transition towards electrification. Fossil fuels have been critical in managing long-haul, large-scale machines such as airplanes, however the aviation industry has committed to achieving net-zero carbon emissions by 2050. The global commercial fleet is forecast to nearly double in the next 20 years, which will impact efficiency and zero-emissions targets. This will see traffic optimisation become more challenging. Quantum computers are particularly well-suited for solving traffic optimisation problems because they can explore many possible routes at once, thanks to quantum parallelism.

Quantum-enhanced AI is an example where quantum technology could lead to increased energy use, as well as to broader ethical implications, from increasing AI usage. Quantum computers could be used to create more accurate and sophisticated AI models with their increased speed and efficiency in large-scale data processing. This could increase the use of AI applications and its subsequent energy usage.

Researchers need to continue to explore potential risks and harms to society and the environment from quantum. Australia is a great market for investors, and quantum readiness work can map out use cases for quantum technologies and the benefits for Australia.

Image 1. Panel 1 discussion

Panel 2 – Quantum computing for grid operation and optimisation

Chair: Dr Michael Harvey, Translational Research Program Manager at EQUS

- Mark Twidell, Industry Professor of Practice at the UNSW Energy Institute, Non-Executive Director at AGL
- Roberto Mauro, General Manager at Pasqal
- Dr Chris Bentley, Lead Solutions Engineer at Q-CTRL

The renewable energy transition means we need to replace the current system, which uses large CO_2 emitting energy sources, with smaller decentralised renewable energy sources. This new system will need to control and balance millions of devices while managing grid reliability.

Some energy providers are already exploring the potential of quantum computing for optimising the electricity grid. For example, Aramco, the state-owned petroleum and natural gas company that is the national oil company of Saudi Arabia, has invested in a 200-qubit quantum computer.

Other applications of quantum computers include simulating weather systems, planning and scheduling electric vehicle charging, and assisting with real-time decision making. Quantum sensors can provide more information for measuring and tracking the health of the electricity grid.

Image 2. Panel 2 discussion

Panel 3 – Quantum batteries

Chair: Dr Felicity Splatt, Data Scientist and Digital Lead in the Energy Business Unit at the CSIRO

- Josef Tadich, Head of Tesla Energy Asia Pacific
- Dr Howard Lovatt, Chief Technology Officer at Energy Renaissance
- Dr James Quach, Science Leader in Quantum Science and Technologies and the Team Leader of Quantum Batteries at the CSIRO
- Dr James Hutchinson, Senior Lecturer at the School of Chemistry at the University of Melbourne

The emerging field of quantum batteries presents new opportunities for energy storage in the energy transition. Current battery technologies have challenges: each type of battery has strengths and weaknesses. Quantum batteries are energy storage devices that use quantum mechanical properties to enhance storage and capability. They exhibit super extensive charging, where the larger the battery is, the faster it charges.

Scaling up quantum battery technology will be challenging. Researchers in the field are aiming for a commercial product in 5 years. Technological challenges include very high temperatures or large sizes. Research into energy conversion is showing the possibility of photo energy being more efficiently delivered through fibre optics rather than current infrastructure.

The capability of technology can move quickly: tiny increments in technological advancements can become improvements in orders of magnitude very quickly.

Image 3. Panel 3 discussion

Panel 4 – Quantum energy generation from enhanced materials

Chair: Dr Katja Digweed, Research Director in the Manufacturing Business Unit at the CSIRO

- Kallen Cook, Head of New Technology – Asset Development at Origin Energy
- Professor Michael Fuhrer, ARC Laureate Fellow in the School of Physics at Monash University
- Dr Tim van der Laan, Functional Nanosystems team lead at the CSIRO
- Scientia Professor Alexander Hamilton, ARC Industry Laureate Fellow at the UNSW Sydney, Deputy Director of the Australian Research Council Centre for Future Low Energy Electronics

The panel agreed that the potential for quantum computers to design new materials is enormous. Quantum computers can encompass all the ways atoms interact, which makes them very good at modelling the properties of materials. This capability is useful in designing new materials for specific purposes. For example, an advanced material to be used in containing substances at extremely high temperatures.

Quantum technologies could be used to reduce computing energy use and the energy sector could help to accelerate quantum technology research in the right areas by sharing information on current challenges without solutions. The breakout opportunities for new quantum technologies could be to deliver solar power that works at night or designing more efficient building materials to reduce energy demand.

Image 4. Panel 4 discussion

Breakout sessions

Breakout sessions focused on specific issues for the energy sector. Ideas explored during these smaller group discussions were:

- grid optimisation using quantum computing
- advanced materials using quantum technologies
- sensing and devices for grid optimisation and generation management
- quantum-enhanced photovoltaics.

These topics are the foundation of the case studies in the appendix, which show the opportunities to understand and capture market value by leveraging existing national strengths, infrastructure and expertise.

Attendees explored challenges in the energy sector including:

- designing for year-round performance, stability and efficiency amid seasonal variability
- increased frequency of power measurement, such as moving from meter reading every three months to smart meters and the internet-of-things with real-time responses
- maintaining frequency and phase as the distribution system evolves
- the progressive loss of inertia in the system, such as from large base-load generators
- uncertainty across timeframes – from controlling the grid at the millisecond level to decadal planning for national and ageing infrastructure.

Attendees noted that quantum technologies have the potential to bring benefits to the energy industry, such as:

- increasing storage capacity in the system through quantum batteries
- using cybersecurity enhanced with quantum key distribution
- early identification of faults through quantum sensors.

There were also potential applications for quantum computer modelling and simulations including:

- optimising grid stability and reliability
- anticipating consumer preferences and behaviours
- building resilience to dynamic pressures such as weather
- materials discovery for more efficient energy generation and transmission.

Next steps and closing

Dr Foley closed by highlighting three themes:

- The intense scale and speed necessitated by the pressure of climate change, and the commitment to decarbonisation in the 2050 net-zero targets.
- The challenges in achieving a successful transition to renewable energy sources, including variable climate, extreme weather events, the mix of electrical generation sources and the threat of cyber-attacks.
- Increasing needs for energy storage, which could lead to a scenario with less constant baseload power generation.

Dr Foley also referred to the 2nd International Conference on Quantum Energy in 2025 in Genoa, Italy, which would explore quantum's role in addressing global energy challenges and transforming the energy landscape for the future. The first of these conferences had been held in Melbourne.

She referred to Round 1 of the Critical Technologies Challenge Program as an opportunity to encourage quantum solutions to market-led challenges, including optimising the performance, sustainability and security of energy networks. This program was designed to drive private-sector demand, demonstrate Australian capability and de-risk adoption of quantum technology across the economy.

Appendix: Case studies

Case study 1: Advanced materials using quantum technologies

Big picture problem

The topic 'advanced materials using quantum technologies' is very broad, and the group focussed on materials used in energy production, particularly, when the active material is heating in a vessel or container, and this process is limited by break down of the active or containment material. Better materials may result in more efficient energy production.

Breaking the problem down

- Can we get materials to work at higher temperatures where heat engines are more efficient?
- How can we use quantum technologies to improve materials?

How could quantum technology help?

- Quantum simulations to understand the parameters and narrow down the parameter space
- Materials discovery using quantum technologies can be applied across a wide range of use cases.

Next steps or questions/projects

Advanced materials' discovery is computationally demanding, even when using quantum computers. The full power of this type of research will only be unlocked with the advent to fault tolerant quantum computers, which are yet to be practically realised.

Case study 2: Grid optimisation using quantum computing

Big picture problem:

The move towards a decarbonised economy is driving a more complex grid system.

Breaking the problem down:

- How do we identify smaller, more specific and immediate problems that can be solved?
- How do we determine the right order, extent and nature of investment required?
- How do we deal with multiple inputs to optimise load distribution?
- Alongside optimisation of the grid, we also need to ensure security and cybersecurity of our grid.

How could quantum technology help?

- Quantum algorithms and software can change the nature of the problems we can address in an increasingly uncertain environment.

Next steps or questions/projects:

Breakout session participants were highly engaged, and the obvious next step is to convene a workshop bringing together energy sector and quantum computing experts, to better understand the opportunity and identify specific examples and test cases.

Case study 3: Sensing and devices for grid optimisation and generation management

Big picture problem:

Compliance is a big problem in grid services assets and generation. Some information is in front of the meter and some behind. The energy sector doesn't know a lot about quantum technologies.

Breaking the problem down:

Three main pillars:

- visibility of the grid, including issues with compliance, and information out of the control of distributed network service provides (DNSPs)
- optimisation of forecasting of resourcing required for grid
- various forms of sensing required to gather better grid information

How could quantum technology help?

- quantum clocks are small and cheap
- magnetometry for detecting precursor inverter defect
- quantum computing applications for optimising accommodation of weather forecasting and AEMO market forecasting
- quantum-insured information exchange for users.

Next steps or questions/projects:

The problem space and potential quantum solution spaces are both extensive in scope – therefore, we need to further refine understanding of specific challenges. Strong potential for a follow-on workshop around this topic.

Case study 4: Quantum-enhanced photovoltaics

Big picture problem:

Australia has formidable solar resources, but capacity factor is a big problem. How do we solve the intermittency problem of generation from solar in winter, or on cloudy days? The energy transition is harder than everyone thinks – it's harder to build, and to transmit – people are reluctant to have renewable energy sources in their backyard.

Breaking the problem down:

- There are limits to how far enhancement of organic solar can take you.
- How can we have enhanced solar that generates on cloudy days?
- How do we generate locally, so we don't have transmit over large distances? The current efficiency of photovoltaics mean that we require a lot of land and pay-off periods are currently 30-50 years – we need to reduce this.

How could quantum technology help?

- Development of quantum-enhanced photovoltaics are still at the fundamental and research and development level
- A lot of materials science and engineering work is begin carried out, for example through ARENA projects, however, the quantum 'flavour' of these projects could be enhanced
- We have the quantum capability in Australia, but need a step change in how we approach this, including incentives to operate in this space
- At the moment, we cannot identify any breakthrough technology with clear advantage.

Next steps or questions/projects:

Is it even worth converting photons to electrons, or should we shift to thinking about what else light energy can be used for?