Sustainability – sectoral challenges

Greg Bodeker

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Quantum Meets Space and Sustainability

Quantum technology applications in sustainability

- **Optimisation problems**, in particular combinatorial optimization problems: quantum annealers → D-wave machine. Quantum Approximate Optimization Algorithm (QAOA).
- **Quantum Machine Learning** (QML) → expedite training of large neural networks → design and optimization of supply chain networks.
- Manufacturing system innovations that respect global ecological boundaries → **Quantum simulator applications** in physics, chemistry (diagnosing chemical equations and spintronics), medicine, electrical and **material science** → new material development for carbon capture.
- **Quantum imaging** using entangled photons to cover the full optical spectrum.
- The use of **quantum sensors** to manipulate the quantum state of atoms and photons → applications in measurement probes.
- Quantum computers can **simulate fluid dynamics** → model 3D turbulent flows in hydraulic engineering.

Quantum technology applications in sustainability

- Solve the advection equation and various quantum computing methods to approximate **Navier-Stokes equations** (climate modelling and NWP modelling) $\longrightarrow$ Navier-Stokes equations are non-linear while the the Schrödinger equation is linear.
- Requires some fundamental research (Marsden Fund) $\longrightarrow$ the number of times a quantum-enabled climate model simulation can be queried is **very** limited.

Quantum technology contributions to the SDGs

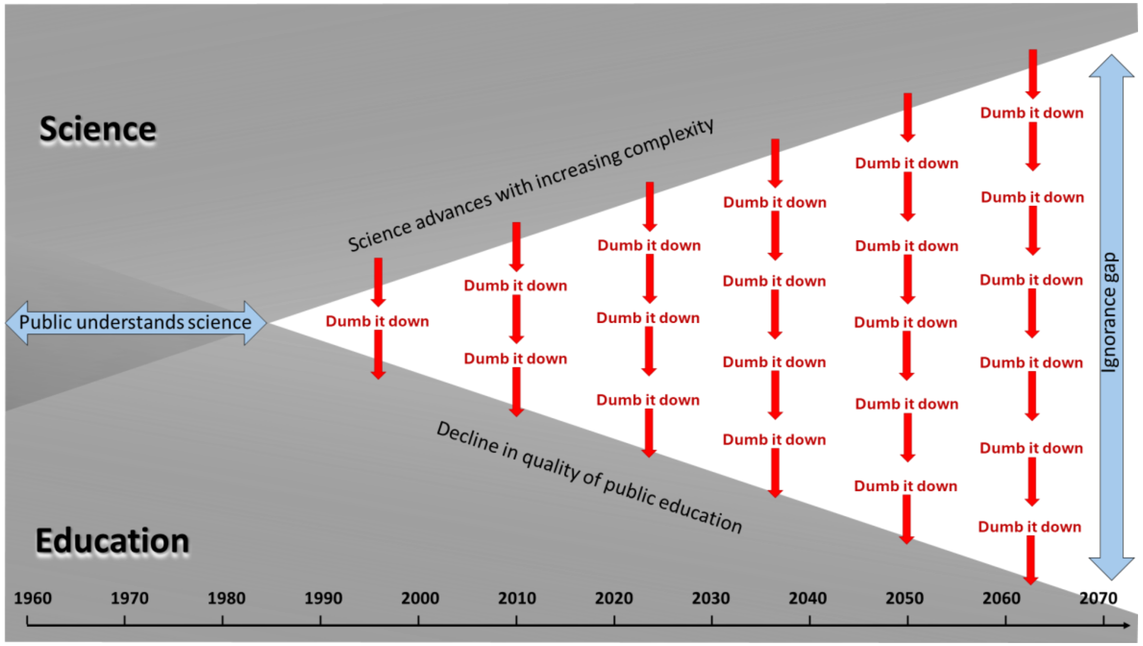
Challenge #1: Lack of understanding = lack of trust

Richard Feynmann in *The Character of Physical Law*: "I think I can safely say that nobody understands quantum mechanics". Customer awareness of what is possible.

Principles of quantum mechanics: superposition, entanglement, and reversibility.

Misconceptions:

- Quantum computers are fast classical computers. The way quantum computers work is profoundly different from the way classical computers work → they can solve very narrow classes of problems, e.g., factoring large numbers, simulating quantum systems, solving nonlinear differential equations exponentially faster than classical algorithms.
- Quantum entanglement allows instant communication.



Asimov: Any sufficiently advanced technology is indistinguishable from magic → people don't trust magic.

Challenge #2: Technical challenges

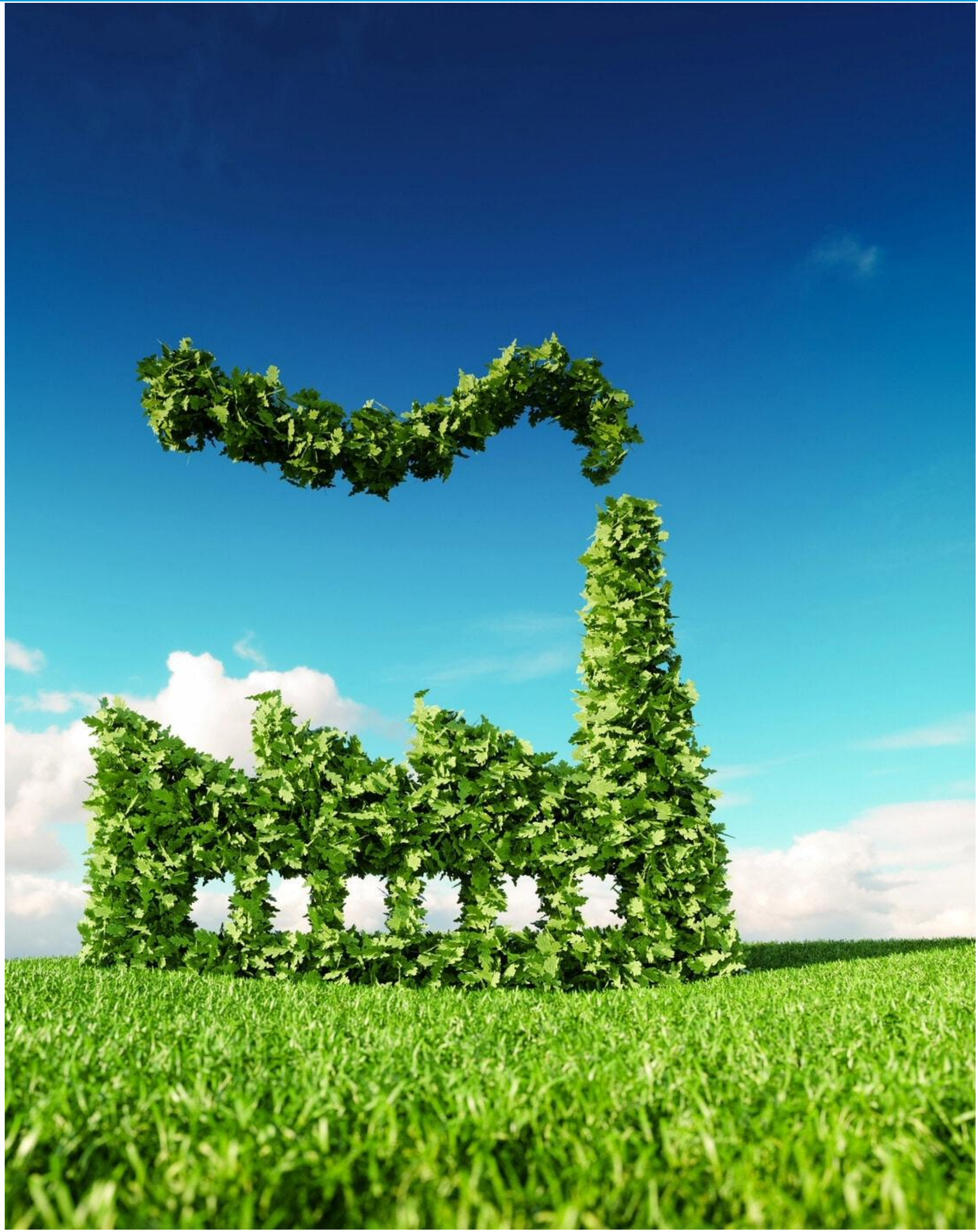
- Quantum computers are not there yet $\longrightarrow$ require a few hundred error corrected qubits to be sufficient for addressing the Lorenz system. Currently available quantum hardware such as IBMQ offers about 100 noisy qubits with plans to achieve about 1000 in the coming years.
- Qubits cannot be copied.
- Accumulation of 'mean field errors' during the course of computation.
- **Marsden question:** Do quantum solvers generate output typical of an ensemble mean of climate model simulations? If so, this would be huge.

Challenge #3: Sustainability growth/degrowth

Definition (David Griggs): **Sustainability** → enough for everyone for ever.

Issues:

- Energy requirements for quantum computers (and AI).
- Increasing resistance to technological solutions to sustainable growth.



Challenge #4: Lack of ‘courageous’ capital

- Too much investment in real estate and too little investment in start-ups → great to see what Bridgewest Ventures is now doing → the need for values-aligned capital.
- Better policy support for companies looking to develop deep tech that supports sustainability initiatives.