How will quantum technologies (QT) change the digital world?

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Abstract

Quantum technologies (QT) have been becoming an important candidate for discussion on their potential societal impact among the new and emerging science and technologies (NEST). It is estimated that globally over 20B€ of public funding is going to be allocated towards QT before 2030. Additionally, there are more than 400 start-ups that emerged in the field, more than 90% of them founded in the last decade. Similarly, companies such as IBM, Google, and Microsoft approximately spent the order of billion dollars on this set of emerging technologies. In this regard, we believe that QT is a suitable topic to be taken as a research subject in the field of technology assessment. In this work, we aim to present the current state of quantum technologies via a series of conducted landscaping studies on academic publications, patent families, start-ups, and public funding. Furthermore, we identify several topics for further inquiry into the field of QT via TA such as; (i) what is the object of TA in QT, (ii) is QT mature enough for applications of TA methods, and (iii) what is the current state of the literature on QT in terms of ELSI/RRI/TA research.

A Brief Overview of Quantum Technologies

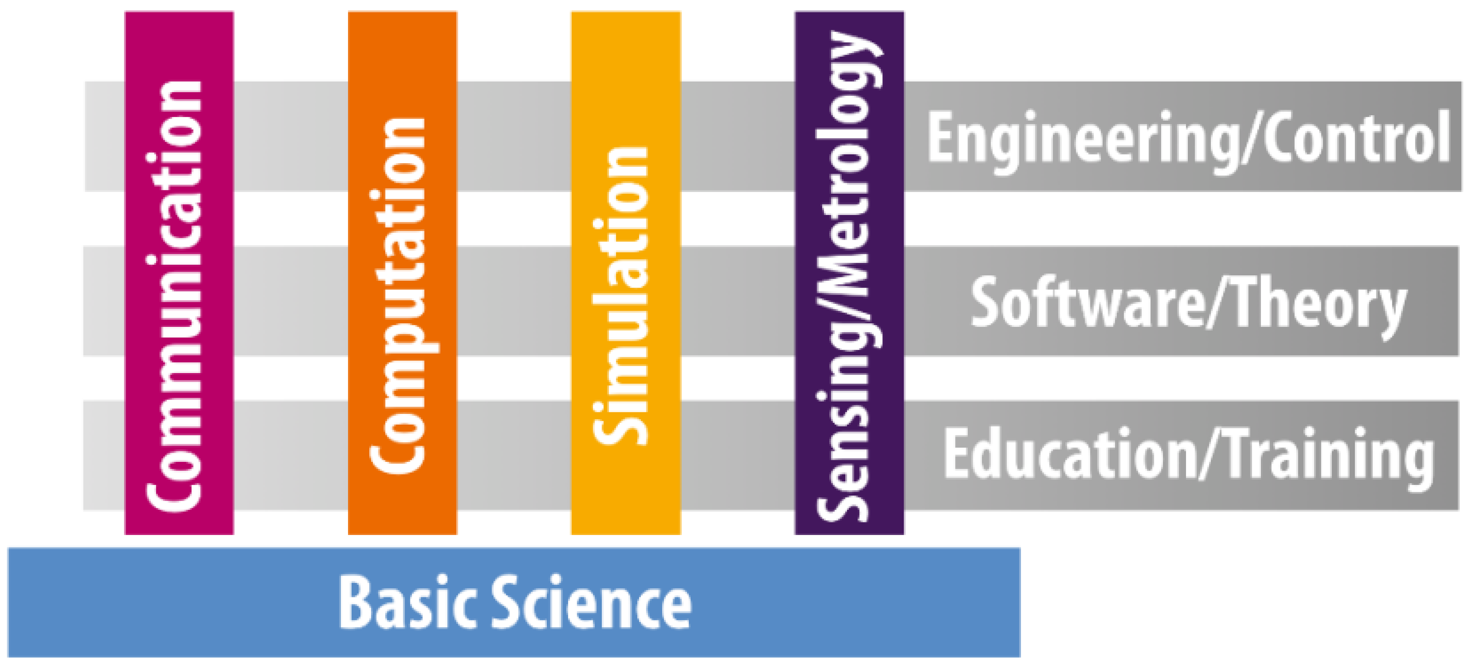


Figure 1: Structure of the Strategic Research Agenda (HLSC, 2017, p. 9)

Quantum technology allows us to organize and control the components of a complex system governed by the laws of quantum physics (Milburn, 1996). This enables the manipulation of physical phenomena that were previously not possible, which can be utilized for building quantum bits (qubits) for information processing, high precision sensors (especially gravitometers and magnetometers), simulating molecular and solid-state systems, and developing quantum networks for distribution of quantum states (i.e., a quantum internet).

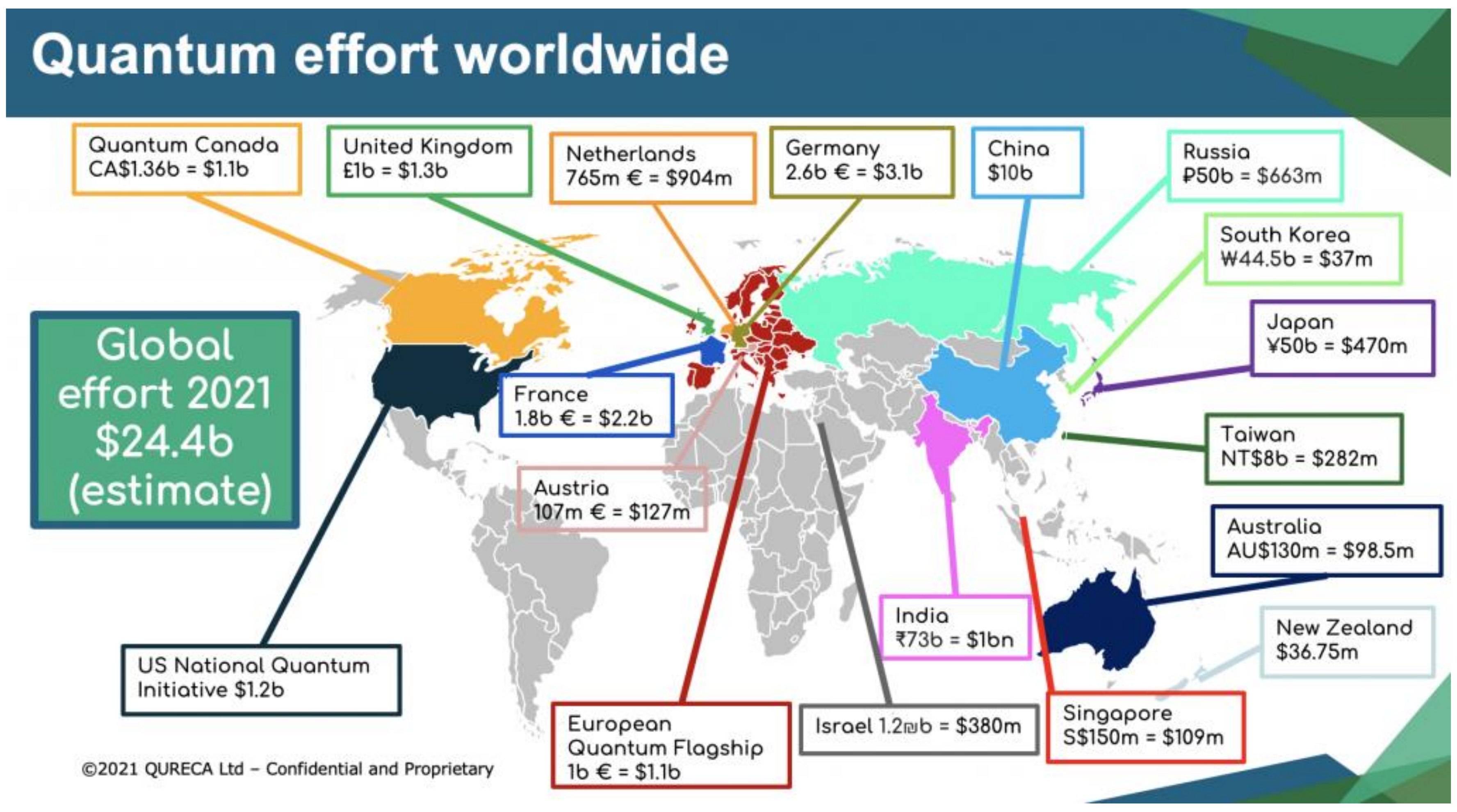


Figure 2: Overview on quantum initiatives worldwide (QURECA, 2021)

Total planned global public investment in QT before 2030 is around $25b, there is also strong interest from private actors and big tech companies (such as IBM, Google, Amazon, Microsoft, etc.). There are more than 400 start-ups founded in QT (Seskir, Korkmaz, & Aydinoglu, 2022). The expected mode of operation in the sector is B2B. This indicates that a shift to QT might happen without public involvement since most commercial uses will involve in-house processes of companies, and not their final products. Meanwhile, there are some end products such as the smartphone Samsung Galaxy Quantum 2.

What may be an object to be assessed in QT?

The obvious answer is the technology itself, but it is not here yet, nor any of its consequences.

Two potential approaches:

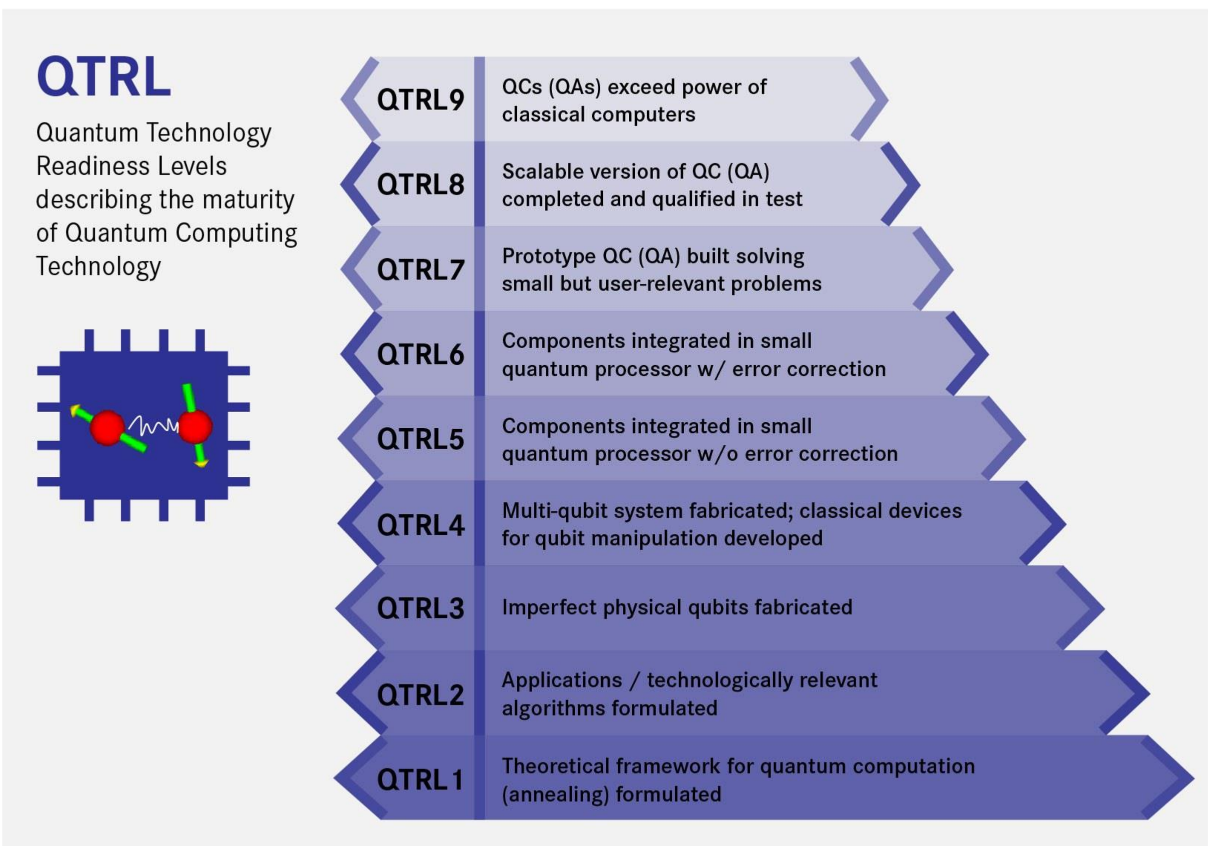
- **Consequentialist approach**; forming scenarios, inferring potential consequences, investigating the dependencies and path trajectories of scenarios to identify the relationships between the development path of QT and its potential consequences.

- **Hermeneutical approach**; consider visions of QT as study objects of today, investigate how (and why) the narratives around these visions are constructed and identify storylines in visionary communication practices.

Resources:

- Roadmaps from national initiatives, companies that are developing quantum hardware (such as IBM, Google, IonQ, D-Wave, and others), market reports, focus groups, media analysis, etc.
- Expert interviews with the scientists, lab researchers, representatives of the application field, companies, regulatory bodies, etc.

Is QT mature enough for applications of TA methods?



There have been some efforts. As an example; QTRL scale is developed by a team at Forschungszentrum Jülich.

Similar QTRL scales are being developed for fields such as quantum sensing, communication, and simulation.

What is the current state of the literature on QT in terms of ELSI/RRI/TA research?

The size of the literature on QT in ELSI/RRI/TA is somewhere between 10-20 articles (Wolbring, 2022). This finding is also supported by searches on Scopus and WoS, which returns 19 and 11 scholarly articles, respectively.

However, a similar number of preprints are located on arXiv, a preprint server mainly used by the Physics community. This indicates further interest in this line of research. However, comparatively to the 50.000+ literature in QT, the lack of ELSI/RRI/TA research represents a lag between studying the technical and societal aspects.

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