



Visions of quantum computing: An ethical assessment

Eline de Jong^{a,*}, Armin Grunwald^b

^a Institute for Logic, Language and Computation, Institute of Physics, QuSoft, University of Amsterdam, Science Park 107, Amsterdam, the Netherlands

^b Institut für Technikfolgenabschätzung und Systemanalyse (ITAS), Karlsruhe Institute of Technology (KIT), Karlstrasse 11, Karlsruhe, Germany

ARTICLE INFO

Keywords:

Ethics of technology
Technological visions
Ethical vision assessment
Responsible innovation
Quantum computing

ABSTRACT

Visions of future technologies shape their development trajectories, making them important objects of ethical analysis. This paper examines contemporary visions of quantum computing and the futures they project. First, we analyse vision statements by key actors in the field, focusing on anticipated technical affordances, the applications these give rise to, their associated domains, and the value-laden terms used to describe these projections. Drawing on these insights, we distil four main visions of quantum computing, each framing its societal relevance differently: as a contributor to the public good, a scientific tool, an economic asset, or a geopolitical advantage. Second, we highlight ethically salient patterns and presuppositions embedded within these visions, including a pervasive techno-optimism paired with techno-solutionist reasoning; the prevalence of promissory language used to legitimise innovation agendas; and a morally ambivalent discourse shaped by the interests of a narrow group of powerful actors. Taken together, these features form a figurative heatmap of potential ethical concerns in contemporary visions of quantum computing that warrant closer ethical scrutiny and point to avenues for further research.

1. Introduction

Emerging technologies often come with grand promises. These promises are wildest in their earliest stages: when their full potential is still unknown, they are frequently framed as promising “transformative forces” that could reshape society—for better or worse. These early visions are expansive because the technology itself is still open-ended. When everything is still possible, well, everything is still possible. Quantum technologies exemplify this dynamic.

While first-generation quantum technologies—such as MRI, lasers, and transistors—are already embedded in society, a second generation is now being developed. Among these innovations, quantum computing has emerged as the principal focus of attention. The core idea is to exploit principles of quantum mechanics—such as entanglement, superposition, and tunnelling—to perform certain computational tasks more efficiently than classical machines. In particular, quantum computing promises exponential speedups for a specific type of problems: problems whose complexity scales exponentially with size (Hidary, 2019). Tasks that would take classical computers years—or much longer—could, in principle, be solved in practical time frames.

This potential has generated high hopes for applications across diverse domains, from accelerating drug discovery and improving climate modelling, to revolutionising artificial intelligence and challenging existing cybersecurity systems. Since the first experimental steps towards building quantum computers in the late 1990s and early 2000s, major technology firms—including Google, IBM, and

* Corresponding author.

E-mail address: e.l.dejong@uva.nl (E. de Jong).

Microsoft—are now investing heavily in this field. Estimates place the potential economic value of quantum computing between \$900 billion, and \$2000 billion by 2035 (McKinsey, April 2024). Government interest has also surged, with national strategies fuelling a global race to develop practical quantum computers. More recently, alongside commercially and strategically driven efforts, socially motivated initiatives have emerged—seeking to harness quantum computing to address grand societal challenges (Open Quantum Institute, n.d; Quantum for Good, n.d).

These high expectations bring quantum computing into the realm of ethics and responsible innovation¹: How can this technology be guided toward societally desirable outcomes? How can we ensure “the right impact”? (Von Schomberg, 2013) Since Vermaas’ special issue on the societal impact of emerging quantum technologies (Vermaas, 2017), an ethical discourse around quantum computing has begun to take shape. A growing body of literature highlights the potential societal consequences of this technology and emphasises the need to guide its development responsibly (De Jong, 2022; De Wolf, 2017; Gasser et al., 2024; Inglesant et al., 2021; Kop et al., 2024; Kop et al., 2024; Possati, 2023; Seskir et al., 2023; Ten Holter et al., 2023).

Despite abundant ambitions, high expectations, and efforts to anticipate its societal impact, a practically relevant quantum computer—capable of solving real-world problems more effectively than classical alternatives—remains elusive at present. Paradoxically, what is currently technically possible holds little societal significance, while what is societally significant remains technically out of reach.² At present, quantum computing exists primarily as a projection: a (scientifically grounded) technological promise.

This promissory status of quantum computing has implications for its ethical analysis. Much of the current ethical discourse centres on assessing quantum computing’s anticipated impacts—considering the benefits and risks that might arise once the technology is realised. However, this tends to involve engaging with highly hypothetical futures, speculating about what the technology *might* become and what it *might* do. Such “speculative ethics” has been widely criticised for potentially diverting intellectual resources toward a mirage (Grunwald, 2010; Nordmann & Rip, 2009; Nordmann, 2007).

To avoid speculative overreach, ethical inquiry into early-stage technologies like quantum computing should shift the focus from the future technology itself, to *how it is being envisioned* (de Jong, 2025): How is the societal relevance of quantum computing imagined? By whom? And under what assumptions? These are ethically salient questions. Long before a technology materialises, the meanings projected onto it—through ambitions, expectations, hopes, and fears—can have tangible effects in the present (Borup et al., 2006; Dignum et al., 2018; Ferrari et al., 2012; Michael, 2000; Pyrrho, 2011; Schneider et al., 2021). In other words, prior to analysing technological artefacts themselves, we can examine the ways in which they are imagined and prospectively endowed with meaning (Wynne, 2007; Ferrari, 2013).

Among such anticipatory imaginaries, *visions* play a particularly important role. Technological visions are active, strategic narratives that frame the future of a technology and define its supposed societal relevance (Grunwald, 2018; Schneider et al., 2021). Visions are never neutral: they are inherently normative because they outline futures considered worth pursuing.³ In articulating such ‘desirable futures’, visions give the technologies involved *meaning*; visions ‘make sense’ of technologies in specific ways (cf. Kudina, 2021), assigning them roles and significance in relation to what valued in those futures. This value-ladenness, in combination with their capacity to shape technological trajectories, makes visions important objects of ethical analysis.

Yet, despite this significance, visions of quantum computing have received limited ethical scrutiny (cf. Alleblas, 2026: p.6). Notable exceptions include Roberson (2021) and Possati (2024), who examine societal meanings in projections of quantum technologies more broadly, and Inglesant et al. (2021), who explore expectations around technical capabilities and timelines. Yet a systematic study of the societal meanings specifically attributed to quantum computing, and an ethical assessment of those meaning-attributions, remains lacking.

This gap provides the rationale for the present study. We ask: In what ways is quantum computing envisioned? How is its societal significance constructed, and what are the underlying presuppositions? To address these questions, we critically examine contemporary visions of quantum computing and highlight the ethical questions they raise at this formative stage. After outlining our approach of *ethical vision assessment* (Section 2), we undertake a two-stage analysis. First, we analyse vision statements from across key actors in the field and distil from them four main visions of quantum computing and its societal relevance (Section 3). Second, we analyse these visions from an ethical perspective, highlighting patterns and presuppositions embedded within these visions that (can) give rise to ethical concerns (Section 4). We present these findings as a figurative heatmap of ethically salient issues that warrant closer scrutiny (Section 5).

The paper thus offers an empirical analysis of how the future of quantum computing is currently being envisioned by those driving its development, and an ethical analysis of these visions, revealing continuities with broader patterns and issues in the ethics of new and emerging science and technology (NEST-ethics).

2. Method: ethical vision assessment

To scrutinise contemporary visions of quantum computing, this study adopts—and adapts—the approach of vision assessment.

¹ Here understood as anticipating the ethical, legal, and social implications of technological innovation.

² For example: Google’s demonstration of quantum advantage, while a milestone in computational capability, has no immediate practical applications; while cryptographically relevant quantum computers—those powerful enough to break existing encryption or enable other transformative applications—would require a vastly greater number of stable qubits than any system currently available.

³ This understanding of visions also accommodates “dissident visions”, that is, imaginaries of undesirable futures and the pathways proposed to prevent them.

Originally introduced by Grunwald (2018), this evolving approach aims to uncover the underlying premises, presuppositions, and normative commitments embedded in technological visions. As a hermeneutic method, it examines how technologies come to matter by analysing the visions through which their significance is constructed (Grunwald, 2020; Nordmann & Grunwald, 2023).

In this paper, we further develop and extend vision assessment by making its ethical dimension explicit, focusing on the ethical issues raised by emerging visions of quantum computing. To operationalise this “ethical vision assessment”, we adopt a two-stage analytical strategy, combining elements of reflexive thematic analysis, discourse analysis, and critical hermeneutics. First, we map contemporary visions through a thematic analysis of a corpus of “vision statements”. Second, we interrogate their ethical dimensions: Who is shaping these visions? Whose interests do they serve? What values do they promote? And what assumptions do they make about what is desirable, inevitable, or urgent in the imagined future of quantum computing?

We elaborate on each of these stages below.

2.1. Stage one: Identification of visions

2.1.1. Materials selection

To identify and analyse contemporary visions of quantum computing and its societal significance, we examined publicly available texts—such as reports, policy documents, and other web-based publications—that articulate expectations about the future of quantum computing and, taken together, reflect the contemporary discourse.

The selection of texts was guided by two criteria. First, we deliberately focused on actor groups that are currently and actively shaping the development of quantum computing and its surrounding discourse. We distinguished five such groups: governments, coordinating organisations, companies, research institutes, and thought leaders (prominent individuals). Within each group, we selected specific actors as follows:

- **Governments:** Countries and supranational unions with published national or regional quantum strategies.
- **Industry:** The five largest tech firms active in quantum computing and five prominent companies specialising exclusively in quantum technologies.
- **Coordinating organisations:** Organisations that do not develop quantum computing technologies themselves but play a key role in shaping strategic direction, aligning actors, and influencing innovation and policy landscapes.
- **Research institutes:** Research centres with an explicit focus on quantum computing.
- **Thought leaders:** Individual researchers widely recognised as prominent voices in international debates about the future of quantum computing.⁴

Looking through a lens of the quadruple helix, an expectable additional actor group would be “society”, as represented, for example, by civil society or the broader public. We deliberately chose to focus on the five actor groups above, primarily because of their influence: their visions do not merely express desired futures, but also set agendas and mobilise resources to pursue these futures. This makes their visions particularly ethically salient, not because they are exhaustive, but because they are performative and influential in setting agendas and expectations.

We recognise that focusing on such “vanguard visions” promoted by elite actors has been criticised for sidelining alternative voices (Sand, 2019). At present, however, these alternative voices have not yet fully developed within the discourse on quantum computing. Quantum computing remains a very early-stage technology that has not yet convincingly entered public debate or civil-society agendas. Empirical studies indicate that public discussion of the societal impacts of quantum computing remains limited (Meinsma et al., 2025; Van de Merbel et al., 2024). References to quantum computing in (news) media often report on scientific developments rather than reflecting an emerging public discussion. While a small number of scholars have adopted more critical perspectives, they do not yet form a coherent actor group shaping the technology’s development. Where appropriate, we engage with such critical work in our ethical analysis of the identified visions. We thus see our focus on vanguard visions justified not only by their performative power, but also by the current empirical absence of broader societal imaginaries. We further reflect on this absence in Section 4.

The second criterion for the selection of our corpus, was to select for each actor textual material that most elaborately articulated claims about what quantum computing⁵ is expected to be, what it will do, and why this matters. We refer to these texts as the actor’s *vision statements*: public statements about the imagined future of quantum computing and its meaning for society.⁶

The corpus was assembled through an extensive desktop search conducted in May 2025⁷ and resulted in a corpus of 64 actors and their vision statements (see Appendix). It includes national strategies, action plans, roadmaps, agendas and initiatives in the case of governments; reports, papers, and web-based publications in the case of coordinating organisations; website texts, mission statements,

⁴ We based this selection on our experience in the field.

⁵ In our analysis, we included ‘quantum simulation’ in our understanding of ‘quantum computing’.

⁶ We take ‘society’ as an overarching term, including also the economy and the environment.

⁷ The corpus necessarily reflects a time-bound snapshot of discourse.

and organisation descriptions in the case of companies and research institutes; and blogs and interviews in the case of thought leaders.⁸ We treat this corpus as reflecting the current discourse among prominent actors about the significance of quantum computing and its meaning for society.

2.1.2. Thematic analysis

In the first analytical step, we conducted a qualitative content analysis aimed at identifying recurring themes across the vision statements. We chose not to study the visions per actor group, but instead to focus on patterns across the corpus. This choice was motivated by the aim of this study, which is to map the discursive landscape shaping quantum computing's trajectory as a whole, and not to evaluate or compare specific actors' positions. For that purpose, what matters most is which framings and issues are prevalent across the discourse; an actor-by-actor breakdown would answer a different question than the one our analysis is designed to address. Additionally, we wished to avoid essentialising actor groups—treating categories such as ‘government’ or ‘industry’ as internally coherent and externally distinct—when in practice there is likely to be considerable heterogeneity within, and overlap between, these categories. This also would require a different methodological set-up. A corpus-level analysis avoids this kind of overattribution, while still allowing us to identify which framings and issues are prevalent within the discourse as a whole.

The analysis was inspired by the approach of thematic analysis (Braun & Clarke, 2006). After an initial close reading of the selected materials, we selected text excerpts that articulated ideas about quantum computing and the future it enables. Depending on the document, this resulted in the selection of multiple paragraphs or, in some cases, only a few sentences.

From this initial reading, we inductively defined four thematic categories that naturally structure the material: (1) quantum computings perceived *technical affordances*; (2) its practical *applications*; (3) the *domain* of application; and (4) the *value-oriented language* used to frame these possibilities:

- 1) **Technical affordances:** The perceived capabilities or functions of quantum computing (e.g. "modelling complex molecules", "enhanced computational abilities", "optimisation"). This category helps isolate the technical narrative from broader societal framing.
- 2) **Application:** This captures the immediate practical goal associated with the technology, such as "designing novel batteries" or "improving encryption methods". It serves as a bridge between technical capabilities and societal domains.
- 3) **Domain:** The sector or societal field in which the applications are situated, linking the technology to particular ‘problem spaces’, like “health”, “energy”, or “defence”. This provides context for how actors imagine the societal significance of quantum computing.
- 4) **Value-oriented language:** Evaluative and normative framings through which quantum computing is presented—as desirable, necessary, risky, or consequential. Such language, implicitly or explicitly appealing to values, expresses judgments about what ought to be pursued, prioritised, or avoided. In some sources, value-oriented language is explicit (e.g., “sustainable”, “improve”, “revolutionise”), directly framing quantum computing as serving social or ethical aims. In other cases, explicit value language is absent, but underlying values can still be inferred from the way applications or societal impacts are framed. For example, references to using quantum computing for better battery design may implicitly invoke the value of sustainability, given its association with clean energy. We therefore coded value-oriented language using the subcodes “explicit” and “implicit”.

These categories or themes are analytically useful as they help distinguish between what quantum computing is *imagined to be*; what it is *imagined to do*; and what it is *imagined to do good for*. For each selected excerpt, we highlighted substantive phrases, and coded these across the four themes.

Initial qualitative analysis of the coded material revealed that quantum computing was almost universally envisioned as bringing about some kind of “change”. As we deemed this characterisation meaningful for a deeper understanding of visions of quantum computing, we subsequently added *change* as an additional code.

Table 1 gives an overview of the complete coding scheme, illustrated by examples.

Section 3.1 presents the analytical results per theme. Qualitatively analysing and interpreting these results, we distilled four main contemporary visions of quantum computing and its societal relevance (Section 3.2). These visions reflect interpretative choices made in this study, particularly our choice to focus on quantum computing as a driver of change and to look at projections *across* different actor groups rather than per actor category (see also footnote 8 and p.6). We thus do not claim that these four visions are the only possible ones; different analytical choices could plausibly produce a different mapping.

2.2. Stage two: Ethical analysis

In the second step of our analysis, we subject the identified visions to an ethical analysis or “assessment”. We adopt a critical hermeneutic approach (cf. (Timmermans & Blok, 2018), aiming to develop an understanding of the meaning assigned to quantum computing and to uncover recurring patterns, presuppositions and assumptions embedded in these visions. Drawing on tools from hermeneutic analysis of visions (Grunwald, 2018; Sand, 2023), we structure our analysis across three analytic levels:

⁸ We recognise the difficulty of reliably attributing documents to a single actor or actor group: strategic documents, for instance, are often produced collaboratively and may reflect input from multiple types of actors. This does not pose a problem for our analysis, however, since we focus on patterns across the discourse rather than on specific actors or actor groups. Where we refer to documents as associated with a particular actor group, this denotes the document's institutional origin rather than a claim about its individual authorship.

Table 1

Overview of themes (codes), their description and illustrative examples from the corpus.

Theme (code)	Description	Example
Technical affordances	Claims about the anticipated technological capabilities of quantum computing	"We expect that [quantum computers] will be able to solve some problems exponentially faster than classical computers can." (25). "It promises problem-solving capabilities far beyond classical computing, particularly for complex simulations and optimisation." (37). "The three types of problems where quantum computing will have a transformational impact are: the simulation and modelling of quantum systems and processes occurring in nature; search for the ideal or "optimal" solution to a given problem with multiple existing answers; and algebraic problems such as factorization." (41).
Applications	Claims about how quantum computing is expected to be applied	"Material design (e.g., new battery materials), pharmaceutical development, climate change modelling and environmental monitoring may be areas where progress will be made." (8) "Applications include the development of new sources of clean energy, monitoring climate change on the planet, developing new vaccines more quickly and accurately, and secure data communication." (3). "The anticipated applications for this technology range from drug discovery, new materials and new ways to tackle climate change to financial services, cybersecurity and a quantum internet." (22). "Some applications where quantum computers can provide a speed boost include machine learning (ML), optimization, and simulation of physical systems." (28). "Quantum computing promises to enable breakthroughs in materials, chemicals and drug design, financial and climate modeling, and cryptography." (29). "For many scientists, the most exciting quantum computing application is the opportunity to study quantum physics itself in a way that wasn't possible before." (50) "Quantum computers are expected to challenge current cryptography methods and to introduce new possibilities for completely private communication." (58).
Domain	Claims about the domains in which anticipated applications are situated	"Quantum technology holds enormous potential for science, the economy, and society." (11). "The development of quantum computers [can] create opportunities for all sectors of the economy." (15). "We foresee a significant presence of end-users from sectors like agriculture, energy, security, science, and digital infrastructure." (38). "The long-term goal is to develop fault-tolerant quantum computers which [...] are of broad use for both the economy and society." (43). "Quantum technology is [...] considered a potential game-changer in many social and economic sectors, including health, agriculture, climate, and safety." (56).
Value-oriented language	Evaluative and normative terms or phrases that qualitatively appraise the anticipated impacts of quantum computing.	<i>See below</i>
Explicit	Explicitly stated qualitative appraisals (e.g. clear reference to values or normativity)	"[T]his transformation will: modernise our economy, improve our society, support national interests." (1) "[We must] recognise the strategic importance of quantum technologies for the scientific and industrial competitiveness of the EU." (7). "Quantum technologies have the potential to benefit society and almost all industries." (18). "To accelerate scientific discoveries for a better future." (27). "[Our mission is] to accelerate quantum computing and use its power to positively transform the world." (33). "[Quantum computing] promises to bring transformative benefits to several industries and have a considerable impact on improving the state of the world in the coming years." (41). "Quantum computer as a research tool [...] whose results benefit humankind." (44).
Implicit	Implicit or indirectly expressed qualitative appraisals (e.g. adjectives or framings).	"The future is quantum." (44). "Quantum is going to change the world." (34). "Now we have another opportunity to be among the world's leading forces in a new technological revolution." (8). "Once we master quantum technology, it will transform our world." (15). "We need way more [computational] power." (30). "We believe that quantum technologies can be a game changer in many societal and economic sectors, including health, agriculture, energy and safety." (45). "Although we don't know when we will build a quantum computer that will threaten current public-key ciphers, it will happen one day." (64).
Change	Characterisation of quantum computing as a force of change	"The paradigm-shifting computational differences of quantum computing give rise to extraordinary transformational opportunities." (41). "Quantum technologies will make a difference improving economic and national wellbeing." (1). "This emerging field will transform how we develop and design everything from life-saving drugs to next-generation batteries." (4). "With new tools and new ways of thinking, quantum computing will forever change the way we solve problems across industries." (31)

1) Content (substantive level)

This level focuses on presuppositions and assumptions about desirable futures and the role assigned to quantum computing in attaining them. The central ethical question is: *Why is quantum computing mobilised in these visions?*

2) Framing (discursive level)

This level examines how visions are rhetorically constructed and morally legitimised. The central ethical question is: *How are these visions framed as normatively compelling?*

3) Author (agential level)

This level considers who produces and promotes these visions and which interests or stakes may underlie them. The central ethical question is: *Who advances these visions, and why?*

Using these levels as our analytical lense, we identify issues that constitute, or may develop into, ethical concerns warranting further scrutiny. The results of this analysis are presented in [Section 4](#) (“Ethical assessment of quantum computing visions”). Throughout this analysis, we relate our findings to existing literature in the emerging field of quantum ethics and, more broadly, ethics of technology.

3. Visions of quantum computing

This section presents the results of the first stage of our analysis. [Section 3.1](#) discusses the findings for each analytical dimension—value-oriented language, domains, applications, and technical affordances—and highlight some meta-level observations. Section 3.2 then synthesises these findings to identify four dominant visions of quantum computing.

3.1. Findings: value-oriented language, domains, applications, and technical affordances

3.1.1. Value-oriented language – Projected progress of a transformative technology

A key characteristic of value-related language surrounding quantum computing that we identified is its strong *orientation toward the future*. Across the material, quantum technologies are frequently associated with promissory terms such as “potential”, and expressions like “unlocking” or “realising potential”. These formulations present the value of quantum computing as largely deferred, that is, not located in present capacities, but expected to emerge through continued technological development. The following quotes are illustrative:

“Quantum technology is an exciting and rapidly evolving field of scientific research and innovation with tremendous disruptive potential in the medium to long term. [...] Quantum computing may unlock solutions and new responses to specific challenges across many sectors and in turn may accelerate progress towards several of the United Nations Sustainable Development Goals.” (22)

“[Denmark has] a unique opportunity to unlock the immense potential of quantum technologies, not only in the realm of research but also in translating this knowledge into solutions that can benefit society, businesses, and national security, ultimately improving the lives of individuals worldwide.” (6)

Secondly, this anticipated value is often described in terms of *significant change*. Common terms include “transformation”, “revolutionise”, “game-changer”, “paradigm shift”, and “disruption”, even “changing people’s everyday lives”, framing quantum computing as a “frontier technology” that does not merely contribute to existing trajectories but rather alters or reshapes them. The areas associated with such change include the economy, science, national security, geopolitics, and society at large:

“Quantum computing has the potential to revolutionize the way we solve problems that are impossible to solve using classical computers. It is therefore expected to have a significant impact on a great number of fields, from cybersecurity and chemistry to finance and climate science.” (9)

“Quantum computing is recognized as one of the most critical breakthrough technologies, with the potential to radically alter society.” (23)

“By applying the laws of quantum physics to computing, we will achieve unprecedented breakthroughs in drug discovery, healthcare, materials science, cybersecurity, energy transformation, and more.” (33)

“The paradigm-shifting computational differences of quantum computing give rise to extraordinary transformational opportunities.” (42)

Third, the projected change is largely cast in terms of positive development, indicated by the ubiquity of terms like “advancing”, “enhancing”, “accelerating”, “improving”, and “benefitting” and “breakthrough”. In this way, quantum computing is frequently framed as an “opportunity”, an “advantage”, an “enabler” or “key” to reaching desirable goals across multiple sectors:

“If we are successful, quantum innovation could be a positive disruptive power that leads to improved lives, a richer, more sustainable economy, a healthier planet – and an even deeper understanding of our universe.” (38)

“Society and almost all industries [...] stand to benefit from quantum technologies due to the exponential increase in computational power and secure communication capabilities.” (18)

“Quantum computing [...] promises to bring transformative benefits to several industries and have a considerable impact on improving the state of the world in the coming years.” (41)

“Quantum technologies already offer possible solutions to some of our greatest societal challenges and, perhaps most excitingly, offer future capabilities that are yet to be explored. They will improve lives, drive economic growth and create jobs, and make us more secure.” (17)

A notable exception to the mostly positive projections of a quantum-enabled future is the flagging of the potential “risks” of quantum computing for security, in particular its “threat” to currently widely used encryption schemes that keep digital data secure:

“Quantum computing [has] the potential to radically alter society - affecting [...] the nature of threats to national and personal security, and governance systems.” (23).

“Quantum technologies have a double-edged impact on cyber security and defence, benefitting both the defensive as well as the offensive side.” (42).

“Quantum technologies will very likely change our approach to digital security. [...] So current encryption methods need to be changed.” (64).

Fourth, references to progress are often linked to a *wide range of value domains and societal goals*. These include security, health, sustainability, economic growth, scientific advancement, curiosity, efficiency, and social well-being. The desirable futures associated with quantum computing are thus ‘multi-driven’, incorporating both instrumental goals (e.g. efficiency, competitiveness) and broader societal aims (e.g. sustainability, well-being):

“Quantum computing can help develop solutions to major societal challenges, such as health care, energy production and climate change research.” (8)

“The broad field of quantum science and technology holds tremendous potential for science, the economy and society.” (12)

“Quantum computers are a revolutionizing technology — they have the potential to transform business, society, and the planet for the better,” (32)

“The first companies to use quantum computing to realize improvements in cost, speed, or accuracy [...] could see significant changes to their bottom line, save years of development time bringing new products to market, or break ground in new industries yet to be imagined.” (31)

Finally, and closely related, quantum computing is often framed in terms of strategic importance. It is portrayed as a key asset in national competitiveness and international leadership, with references to a “global race,” “technological sovereignty,” and efforts to “position” countries or regions at the forefront of scientific and technological power. This framing adds a sense of urgency to the broader value discourse, reinforcing the perception that securing quantum capabilities is vital for maintaining strategic advantage and addressing national interests. This is illustrated by the following quotes:

“Quantum technology is one of Finland’s future industries. We have every opportunity to be global leaders in this area.” (8)

“It is therefore obvious that quantum technology is closely tied to immense momentum in the global innovation race. [...] How we deal with the topic of quantum computing is indeed also a question of technological sovereignty in global competition with strong rivals.” (11)

“To remain competitive on the global stage, Lithuania needs to actively engage in the development and application of QT.” (23)

3.1.2. Domains – Everything, everywhere, all at once

We also found that, at a high level, quantum computing is projected as a technology of wide societal relevance, with *anticipated impact across almost every major domain in society*, and “a wide range of application fields” spanning the entire economy. Based on recurring themes and framings, we can distinguish four main domains where quantum computing is imagined playing a significant role: society, the economy, science, and national security.

Society – First, quantum computing is frequently envisioned as a transformative tool for addressing *societal challenges* and achieving shared goals. It is associated with a wide range of application areas, including healthcare, energy systems, environmental sustainability, agriculture, cybersecurity, and defence. Frequently, its potential is explicitly connected to the United Nations Sustainable Development Goals (UN SDGs), with the technology framed as a contributor—sometimes even a key enabler—of progress on global health, clean energy, and environmental protection. This societal framing tends to emphasise both public benefit and the pursuit of long-term sustainability. The following quote is illustrative here:

“[Our mission is] to promote global and inclusive access to quantum computing, developing applications that benefit humanity and support the United Nations Sustainable Development Goals (SDGs).” (36)

Economy – Second, in the economic domain, quantum computing is commonly positioned as a driver of *national and industrial competitiveness*. It is linked to job creation—particularly in high-skill sectors—economic growth, and innovation across diverse industries such as logistics, manufacturing, AI, and finance. This includes both enhancing existing capabilities and enabling new ones (see the next two subsections), with quantum computing often described as a foundation for a future digital or “quantum” economy. The following quotes illustrates this:

“Quantum technologies will make a difference improving economic and national wellbeing. [...] Commercialising quantum technologies could create an Australian quantum industry worth \$2.2 billion and directly employing 8700 people by 2030. This could reach approximately \$6 billion and 19,400 jobs by 2045. These technologies are expected to add billions of dollars of value to related industries in that timeframe.” (1)

Science – Third, quantum computing is expected to *advance scientific discovery*. It is projected to open up new frontiers in research areas such as chemistry, physics, materials science, and biology. In this context, quantum computing is imagined as a tool for overcoming limitations of research tools based on classical physics, enabling breakthroughs that are currently out of reach:

“Our mission [is] to accelerate scientific discoveries for a better future.” (27)

“Well, remember I’m a scientist, so I like to think of computers as tools for advancing science, for scientific discovery. We use computers to illuminate how nature works in a variety of ways. [...] Quantum computers will be good for solving problems like that.” (6)

National security – Fourth, *national security* emerges as a distinct and prominent domain where quantum computing is expected to have significant impact. At one level, it introduces a strategic and geopolitical dimension to the technology’s anticipated economic value, with quantum computing portrayed as a critical asset in securing technological sovereignty and positioning within global competition. At another level, it is expected to influence (inter)national security more directly—particularly through applications in defence and cybersecurity—where it is viewed both as an opportunity (e.g. enabling advanced encryption and secure communication) and as a threat (e.g. the potential to undermine existing cryptographic systems):

“Quantum computers [...] could also have far-reaching implications for national and international security, as they enable new defence capabilities and threaten current data protection systems.” (35)

3.1.3. Applications – quantum (r)evolution

Before detailing specific applications, one overarching pattern that clearly emerges in how quantum computing is envisioned is the tension between *evolution* and *revolution*. On the one hand, applications are framed as the next step in a continuum of technological progress—incremental enhancements of existing processes. On the other hand, quantum computing is also positioned as a fundamentally disruptive technology, imagined unlocking capabilities beyond the limits of classical computing—sometimes described in almost aspirational terms, as “making the impossible possible”.

Zooming in on specific areas of envisioned application, several clusters emerge as the most frequently mentioned and substantively developed:

- *Healthcare and life sciences*: Quantum computing is anticipated to revolutionise drug discovery, accelerate medical research, and improve diagnostics and personalised treatments. Envisioned applications include molecular simulation, protein folding analysis, pharmacokinetic modelling, and advanced medical imaging—thus framing quantum computing as a key enabler of faster, more targeted healthcare innovation:

“The exponential increase in computing power from quantum computers could revolutionise our healthcare system - from dramatically improved drug discovery techniques to providing personalised treatment to an individual based on genetic and environmental factors.” (17)

- *Environmental and energy solutions*: Quantum computing is expected to support climate and environmental goals through improved modelling, monitoring, and optimisation. Key applications include energy-efficient systems, clean battery and catalyst design, smart grid management, emissions reduction, reduction of ‘forever chemicals’, precision agriculture by enhanced weather forecasting and crop management, and the development of sustainable fertilizers and pesticides. This quote is illustrative:

“Anticipated benefits [include] improved weather and climate modelling, pollution remediation, climate-friendly industrial processes.” (37)

- *Finance and business analytics*: In financial services, quantum computing is expected to be useful (“enhance”) risk management, fraud detection, scenario planning, and portfolio optimisation. It is also linked to advances in AI acceleration, big data analytics, and transaction security—envisioned to improve efficiency and resilience in business operations and financial markets:

“With new tools and new ways of thinking, quantum computing will forever change the way we solve problems across industries. [For example,] optimizing returns and risks for large financial portfolios.” (31)

- *Logistics, mobility, and infrastructure optimisation*: Quantum computing is envisioned as a solution for complex optimisation problems in transport, logistics, and infrastructure planning. Proposed applications include traffic flow management, route optimisation for freight and emergency services, smart city design, and improved supply chain efficiency and resilience across sectors:

“By harnessing these capabilities, quantum computers could [...] optimise logistics to deliver our parcels faster and more accurately.” (1)

- **Manufacturing and materials development:** In manufacturing, quantum computing is expected to optimise production processes and enable the design of novel materials. Applications include the development of new batteries, catalysts, and corrosion-resistant components, thus positioning quantum computing as a driver of more efficient, sustainable industrial innovation:

“By enabling the simulation of new materials and chemical reactions, quantum computing can contribute to the creation of better batteries and more efficient energy systems.” (15)

- **Scientific discovery:** Quantum computing is framed as a transformative research tool in fundamental science. It is projected to accelerate discoveries in physics, chemistry, biology, and materials science through powerful simulation capabilities—thus opening up new avenues for exploring quantum systems, molecular interactions, and theoretical problems previously beyond reach:

“Quantum computers will help us learn about, model, and manipulate other quantum systems. That ability will improve our understanding of physics.” (58)

- **National security and cybersecurity:** In security domains, quantum computing is depicted as both a strategic asset and a disruptive threat. Envisioned applications include quantum-enhanced encryption, secure communications, cyber operations, and military planning, as well as concerns about breaking existing cryptographic systems and undermining digital infrastructures:

“If fully adopted, functional quantum technologies would allow private and public actors in the Alliance to better protect their data and communications in a way that is fast and reliable. [...] A functional quantum computer would also have the ability to break current cryptographic protocols.” (42)

- **Risk, forecasting, and emergency management:** A cross-cutting cluster highlights quantum computing’s role in anticipating and responding to systemic risks. Envisioned applications include climate and weather forecasting, flood and seismic risk assessment, emergency response modelling, and food security prediction—which suggests potential for enhanced preparedness and resilience in crisis management. The following quote is illustrative:

“Applications of quantum computing explored at OQI focus on [...] food security - last mile delivery [...], resilient global food supply [...], weather and climate forecasting.” (36)

These envisioned applications hinge on the specific technical capabilities that are attributed to quantum computing, which we discuss next.

3.1.4. Technical affordances – transcending classical capacities

Our analysis reveals that the anticipated technical capabilities—or *affordances*—of quantum computing are commonly framed around four central functions: *simulation*, *optimisation*, *modelling*, and *solving computationally intractable problems*. These affordances are often attributed to the inherent affinity between quantum computers and natural quantum systems, as well as their anticipated ability to process vast and complex datasets more efficiently than classical systems. This is illustrated by the following quotes:

“Quantum computational technologies present the opportunity to tackle many practical problems that are currently infeasible to solve, even with the most powerful classical supercomputers.” (41)

“Because quantum computers use quantum physics to access new computational abilities that are inaccessible to classical computers, we expect that they will be able to solve some problems exponentially faster than classical computers can.” (26)

These perceived are often framed as *quantum-specific*, which underpins the portrayal of quantum computing as a “key enabling technology,” capable of transcending classical limitations and providing solutions to problems previously deemed unsolvable. Quantum simulation, in particular, is frequently cited as a distinctive capacity—whether for modelling molecular interactions, physical systems, or complex environmental processes.

When it comes to the feasibility of these affordances, some ‘vision authors’ are more cautious or modest than others. The majority portrays quantum computing as a paradigm-shifting force, capable of exponentially accelerating problem-solving and enabling ‘entirely new possibilities’:

“Quantum research opens up entirely new possibilities that will eclipse anything previously possible. Major leaps in innovation are on the horizon.” (2)

On the other hand, more measured assessments point to the speculative nature of these claims. They note the absence of a clear empirical basis for some of the stronger expectations, the lack of practical demonstrations of quantum advantage in most real-world applications, and the risk of overhyping what remains a nascent and highly experimental field:

“It’s important to understand that it’s still an open question where quantum computers will find their niche. Potential applications to drug development and logistics optimization are possible and understandably exciting, but we’re still in the early days of this computing revolution. [...] Scientists have come up with a handful of killer apps, but for the most part no one yet has a clear picture of the full capabilities of quantum computers.” (50)

Indeed, while quantum computing is often presented as inherently “superior to traditional methods,” this superiority is frequently restricted to a narrow class of problems for which specific quantum algorithms may yield a speed-up, and whose practical significance

is still under debate.

3.1.5. Change

While the framing of quantum computing as “a force of change” was a clearly recurring pattern, we noticed differences in the way this change is framed. This observation is reminiscent of the familiar phenomenon of “ambivalence” that has often been noted in relation to promising technologies (Shelley-Egan, 2010; Swierstra & Rip, 2007): the coexistence of competing framings of the same technology. Applied to change, this means that the change a technology is expected to bring may be framed in different—sometimes contradictory—ways, for example as “revolutionary” or as “business as usual” (Swierstra & Rip, 2007: p.9). We inductively distinguished three modes of change associated with quantum computing. Rather than standing in direct opposition to one another, these modes reflect different framings of the same technology.

The first is *revolutionary change*, signalled by terms such as “disruption”, “transformation”, and “game-changer”. In this mode, quantum-induced change is characterised as fundamentally transforming existing systems and fields such as security and materials science:

“While quantum computing is still in its infancy, it has the potential to revolutionize industries such as finance, healthcare, and logistics.” (9)

“Quantum technologies have potentially revolutionary and disruptive implications, which can degrade the Alliance’s ability to deter and defend.” (42)

“We are creating the quantum future, because we believe that quantum technologies can be a game changer in many societal and economic sectors.” (45)

“Quantum technologies are not just an incremental step. They are a transformational step — a revolution that will impact our world.” (46).

Second, we distinguish *augmentative change*, signalled by terms such as “enhancing” and “improving”. Here, the change associated with the arrival of quantum computers is characterised as scaling existing capabilities or making operations more efficient:

“In machine learning, quantum computing enhances the processing of large training materials.” (8)

“Quantum computing has the potential to revolutionise healthcare and medical science [through] accelerating drug discovery.” (23)

“Quantum computing could help make hospital systems more efficient, improving delivery and reducing costs.” (17)

“Making research in chemistry and materials science faster, easier, and more productive.” (27).

“Quantum computers will improve the accuracy of long-term climate models.” (39)

A third mode of change is *catalytic*, signalled by terms such as “enabling” and “unlocking”, and portrays quantum computing as enabling previously infeasible possibilities:

“Quantum technology offers a promise to make the impossible possible.” (8).

“Quantum research opens up entirely new possibilities that will eclipse anything previously possible.” (2).

“Quantum computational technologies present the opportunity to tackle many practical problems that are currently infeasible to solve, even with the most powerful classical supercomputers.” (41)

“Quantum technologies will make it possible to do things that simply cannot be done today.” (7)

These different modes of change indicate that the scope and depth of quantum-induced change is framed in different ways across the discourse: projections range from incremental improvements to more speculative accounts of fundamentally transforming existing systems. We account for these differences when we synthesise the analytic results of this section into four main visions of quantum computing.

3.2. Four visions of quantum computing

Building on the findings presented in Section 3.1, we identify four visions of quantum computing that emerge from across key actors in the field. Our starting point is the overarching observation that quantum computing is consistently envisioned as bringing about change, often framed positively in terms of progress. We use the four societal domains in which this change is imagined as a structuring principle for identifying different visions of the societal significance of that change. We dub these domains the *social*, *economic*, *scientific*, and *geopolitical sphere*. Within each domain, the change-making capacity of quantum computing is framed in a particular way—respectively, as a contributor to the public good, a scientific tool, an economic asset, and a geopolitical advantage. These framings constitute the four visions of the future of quantum computing that we identify.

Each vision is anchored in a “value vocabulary”—the implicitly or explicitly value-laden terms that actors use to frame quantum computing (e.g. as a scientific tool). As noted in the previous section, there is variation in the ambitions and scope of quantum-induced change. We account for this by distinguishing between narrower, more modest articulations of each vision and broader, more

speculative forms. Table 2 summarises this framework.

We emphasise once more that these visions are *synthetic*: they result from aggregating patterns across actors and cannot be attributed to any single actor or actor group. They are also not mutually exclusive. They represent recurring ways in which the future of quantum computing is imagined across actors. We describe each of them below.

3.2.1. Quantum computing for the public good

This mission-driven vision situates quantum computing within the social sphere, portraying it as a tool for addressing collective challenges—from healthcare and food security to sustainable energy and inequality. It frames quantum computing as a ‘force for the public good’, significantly contributing to societal goals and solving the grand challenges of society. The value vocabulary it appeals to includes terms such as “societal benefit,” “wellbeing,” “improvement,” and “progress.” In its more modest articulation, the technology is expected to contribute targeted solutions to specific societal goals. In its more expansive form, it is envisioned as a disruptive, general-purpose technology that is essential for navigating complex global problems and with the potential to radically alter society at large. The quotes below are paradigmatic for this vision:

“We believe that quantum computers will be uniquely capable of solving some of the world's most pressing issues.” (26)

“We're on a mission to build the world's most powerful computers to help solve humanity's most important and pressing problems” (31)

“Our vision is to enable the UK to solve some of the most complex and challenging problems facing society by harnessing the potential of quantum computing.” (40)

3.2.2. Quantum computing as scientific tool

Projected onto the scientific sphere, quantum computing is primarily envisioned as an epistemic instrument, extending or surpassing the capabilities of tools grounded in classical physics. It reflects a framing in which quantum computing serves the advancement of science—in particular physics, chemistry, and materials science—and the pursuit of fundamental knowledge. This vision is underpinned by value-laden terms such as “curiosity”, “breakthrough”, “discovery”, and “progress”. In the modest variant, quantum computing is portrayed as a new research apparatus; in more speculative variants, it is imagined as enabling paradigm-shifting discoveries. This vision is illustrated by the following quotes:

“A critical driver for further advancement of the field and a top priority for Switzerland is curiosity driven research and innovation.” (12)

“Quantum computers will help us to get a better grasp of [quantum mechanics] by allowing us to simulate quantum phenomena that would otherwise just be too hard to study. [...] These simulations could lead to advancements in chemistry, materials science, and fundamental physics.” (60)

3.2.3. Quantum computing as economic asset

In a third vision, quantum computing is envisioned as driving change within the economic sphere. This vision frames quantum computing as a business opportunity, a key driver of economic growth and industrial competitiveness. It is portrayed as both a catalyst for innovation and a platform for new business models, with applications across a wide range of sectors. This vision appeals to term like “growth,” “innovation,” “value creation,” “competitiveness,” and “opportunity.” In its more modest version, the focus is on incremental innovation and process optimisation, while in its more speculative form it anticipates a technological revolution underpinning a new economic paradigm. The following quotes are illustrative for this vision:

“[The goal is] achieving a fully commercial quantum economy.” (38)

“Quantum computing is seen as a transformative paradigm for digital economies and societies.” (37)

“With the first paradigm-shifting advance since the integrated circuit, quantum computing is poised to transform every global market. [...] The first companies to use quantum computing to realize improvements in cost, speed, or accuracy over the best possible classical solutions could see significant changes to their bottom line, save years of development time bringing new products to market, or break ground in new industries yet to be imagined.” (31)

3.2.4. Quantum computing as geopolitical advantage

In the geopolitical sphere, quantum computing is framed both as an opportunity to be seized and as a threat to be managed. More than the other visions, this one foregrounds the dual-use character of quantum computing, combining expectations of economic and military advantage with awareness of significant cybersecurity risks. Quantum computing is thereby positioned as a strategic asset tied to security, influence, and international competitiveness, conferring geopolitical advantage on those who possess it. Its value vocabulary spans terms such as “sovereignty,” “leadership,” and “opportunity,” alongside “risk,” “threat,” and “security.” In narrower articulations, the focus lies on cybersecurity threats; in its broader shape, the vision is embedded in narratives of a global race for technological dominance. Illustrative quotes include:

Table 2

Four visions of quantum computing and its societal significance.

Vision	Sphere	Dominant framing	Scope	Value vocabulary
“Quantum computing for the public good”	Social	Quantum computing is framed as a <i>contributor to societal goals</i>	<i>Narrow:</i> targeted, niche solutions <i>Wide:</i> general-purpose enabler	Societal benefit; wellbeing; improvement; progress
“Quantum computing as a scientific tool”	Scientific	Quantum computing is framed as an <i>epistemic instrument</i>	<i>Narrow:</i> new research instrument <i>Wide:</i> paradigm-shifting discoveries	Curiosity; breakthrough; understanding; discovery
“Quantum computing as an economic asset”	Economic	Quantum computing is framed as <i>innovation driver and business enabler</i>	<i>Narrow:</i> incremental innovation <i>Wide:</i> economic revolution	Growth; innovation; value creation; competitiveness; opportunity
“Quantum computing as a geopolitical advantage”	Geopolitical	Quantum computing is framed as <i>strategic and security asset</i>	<i>Narrow:</i> cybersecurity threat <i>Wide:</i> global race for leadership	Sovereignty; leadership; opportunity; security; dual-use; threat

“For Austria as a business location, it is important that companies invest early in future technologies and score points with innovative products ‘made in Austria’. This applies in particular to quantum technologies, which hold enormous potential.” (2)

“Now we have another opportunity to be among the world’s leading forces in a new technological revolution: quantum technology. [...] Quantum technology can also strengthen Finland’s national security in several ways in both cyber security and defence.” (8)

“[Q]uantum technology is closely tied to immense momentum in the global innovation race. Germany and Europe are challenged to significantly intensify their efforts in the coming years. How we deal with the topic of quantum computing is indeed also a question of technological sovereignty in global competition with strong rivals, especially in Asia and the USA.” (11)

“Quantum technologies have potentially revolutionary and disruptive implications, which can degrade the Alliance’s ability to deter and defend. Quantum technologies are therefore an element of strategic competition.” (42)

4. Ethical analysis of quantum computer visions

In this section, we analyse the ethical dimensions of the visions of quantum computing outlined above. We seek to uncover patterns and presuppositions embedded within and appearing across these visions, and reflect on their ethical significance. Rather than assessing each vision in isolation, we analyse them collectively as expressions of the contemporary discourse on quantum computing. This involves interrogating how these visions frame desirable futures, delineate problems in need of resolution, and orient trajectories of technological development.

Before proceeding to the analysis, two points are worth noting. First, our analysis is exploratory in character. It seeks to flag ethically salient aspects of current visions of quantum computing, identifying where ethical concerns already arise or may emerge. The resulting “ethical heatmap” thus serves as an agenda outlining issues that warrant closer scrutiny, rather than as a comprehensive normative assessment.

Second, the aspects we highlight are not claimed to be unique to quantum computing. Rather, most of them are familiar issues resurfacing from previous NEST-ethics discourses. We contend that issues need not be specific to quantum to be relevant to quantum (see also (Grunwald, 2005), for a similar argumentation in the context of nano-technology). Following Shelley-Egan and De Jong (2025), we take seriously the importance of continuities in ethical discussions about new and emerging technologies, as attending to them serves as a useful heuristic for ethics and allows us to learn from previous debates rather than treating each new technology as ethically unprecedented. By identifying how recurring issues manifest in the new technological context of quantum computing, we locate its emerging ethical discourse within the broader tradition of NEST-ethics.

As outlined in Section 2, we structure this analysis across three analytic levels: the substantive level (content), the discursive level (framing), and the agential level (authors).

4.1. Content (substantive level): Techno-optimism and techno-solutionism

4.1.1. Techno-optimism

As the discussion of the value-oriented language mobilised in the visions shows, a pervasive *techno-optimism* characterises the contemporary discourse. One might be tempted to see such optimism as implicit in the notion of a vision, understood as a desirable and pursue-worthy future. However, this would be too simplistic. Visions of the future can also include negative imaginaries, articulating outcomes to be avoided and developments that should be prevented. Our analysis nonetheless shows that optimism strongly dominates the discourse. When left largely unquestioned, this can give rise to an overly confident, unreflexive or outright naïve understanding of quantum computing's future. We return to this concern of an imbalanced discourse in the next section.

The techno-optimism in visions of quantum computing take two forms: optimism about its positive impact on the world (impact optimism), and optimism about the feasibility of realising this impact (feasibility optimism). We begin with the latter.

Feasibility optimism cuts across all four visions. It reflects a dual confidence in both the technical and social feasibility of quantum computing. The innovation process is often portrayed as linear and inevitable, with the realisation of practical quantum computing framed as merely “a matter of time”:

“It is no longer ‘if’ but ‘when’.” (1)

This optimistic, at times even deterministic frame rarely displays epistemic humility or engage seriously with the profound uncertainties⁹ surrounding the development trajectory of quantum computing. Instead, these are treated as practical hurdles that will be overcome in time. Such neglect is facilitated by the abstract, often vague language used to articulate projections; language that can obscure complexity, downplay substantial scientific and technical challenges, and risk fuelling hype and inflated expectations.

The social feasibility of quantum computing—that is, its capacity to function effectively within real-world social, economic, and regulatory contexts—likewise tends to be taken for granted. Although some visions acknowledge enabling conditions such as education, skills development, or infrastructure, these are typically framed as items to be addressed. The underlying assumption remains that, *once* the right conditions are in place, quantum computing *will* deliver on its promises.

This assumption warrants ethical scrutiny. Without denying the technology's potential, it is ethically important to recognise profound uncertainties involved, not least because they are relevant for responsible decisions about investment, policy, and precaution (cf. Nordmann & Rip, 2009). Yet across all four visions—albeit to different degrees depending on their speculative scope—such uncertainties are seldom mentioned, let alone meaningfully acknowledged. This raises questions about the justification of substantial financial and intellectual commitments to a technological future that remains fundamentally uncertain.

When it comes to impact optimism, the visions display a strongly positive view of the change associated with future quantum computers. Quantum computing is frequently cast as playing a key role in realising desirable futures. On this basis, the visions can be characterised as techno-optimistic (cf. Danaher, 2022; Königs, 2022). While modest forms of optimism are not necessarily problematic, stronger forms that frame a technology as necessary or sufficient for achieving desirable futures invite ethical scrutiny (Danaher, 2022).

A critique of such future-oriented impact optimism is articulated by Wilson (2017), who argues that techno-optimism becomes contestable in the absence of reliable probability estimates. He writes:

“It is fine to be optimistic when probabilities are explicitly known to be in our favor. But when they are not known, and cannot possibly be, as in the case of our evaluation of the techno-scientific future, does reason not call on us to remain neutral?” (p. 349)

Given the substantial uncertainties surrounding the development of quantum computing, and the historically ‘bumpy’ and unpredictable nature of technological trajectories and their societal impacts (Grunwald, 2024), the prevalence of techno-optimism in contemporary quantum computing discourse warrants critical examination. It becomes ethically concerning in particular where it informs or steers decision-making about the technology.

Beyond this epistemic critique, impact optimism can also be questioned on substantive grounds; namely, with respect to the ethical defensibility of the optimistic claims about positive societal impact themselves. This brings us to the notion of technosolutionism.

4.1.2. Technosolutionism

Closely linked to this optimism is a pronounced tendency toward *techno-solutionism*, understood here as the belief that technology offers effective solutions to complex societal problems (Sætra, 2023). Across the identified visions, quantum computing is repeatedly framed as a solution-generating technology, capable of—and often presented as key to—addressing not only technical challenges but also broader social and economic problems. This is consistent with other analyses in the literature, especially around the concept of “quantum for good” (Shelley-Egan, 2025; de Jong & Shelley-Egan, 2026).

Techno-solutionism has been widely critiqued for reducing complex, multidimensional social problems to narrowly defined technical issues (Broussard, 2019; Morozov, 2013; Siffels & Sharon, 2024). It risks sidelining structural, political, or moral dimensions in favour of quick ‘technofixes’, not seldom generating new problems (Nydal et al., 2023; Grunwald, 2024). At the same time, framing

⁹ At present, the feasibility of large-scale quantum computers is the “million-dollar question” in the field. Expert forecasts indicate a broad consensus that large-scale quantum computers are likely to emerge within the next thirty years (Mosca and Piani, 2024). However, these projections have remained relatively stable in recent years, which suggests that, despite progress, the gap between current capabilities and practically relevant quantum computing remains substantial.

a technology as contributing to the solution of a problem is not in itself ethically problematic; doing so would deny a core aspect of how technologies function in society. The ethical concern is more nuanced and context-dependent (Ruser & Machin, 2016; Nydal et al., 2023; Sætra & Selinger, 2024).

Beyond concerns about technology-first approaches that privilege technical interventions over normative and political considerations, and about effectiveness, given that technosolutions may leave the roots of the problems they purport to address untouched (Grunwald, 2024), Nydal et al. (2023) highlight the risk of *de-moralisation*: technological solutions may obscure or displace the moral issues underlying the problems they aim to address. It is this problem of moral opacity that can render technosolutionist framings ethically problematic.

Viewed through this lens, the vision of quantum computing as serving the public good becomes particularly salient, especially in its stronger forms that present the technology as essential for addressing societal “grand challenges.” By emphasising quantum computing’s contribution primarily in terms of increased computational power, this vision tends to tacitly reframe “society’s hardest problems” as computational problems. Such framing is ethically consequential: it shapes what is recognised as a problem in the first place and narrows the range of responses considered appropriate—echoing that ‘for those with a hammer, every problem appears as a nail’ (de Jong & Shelley-Egan, 2026).

Whether such framings are ethically problematic depends on context and, ultimately, on how they shape concrete interventions and their consequences. We therefore flag technosolutionism as an ethically salient pattern in contemporary quantum computing discourse that warrants further scrutiny, in particular with regard to how it consolidates and translates into practice (cf. Nydal et al., 2023).

4.2. Framing (discursive level): The good lies in the future and justifies innovation

Shifting the analytic focus from the ‘what’ to the ‘how’, it stands out that the visions of quantum computing are consistently framed through *future-oriented discourse*: the future is presented as the primary site in which societal prosperity will be realised. Within this framing, quantum computing is positioned as a key enabler of that desirable future.

At first glance, this is unsurprising: if visions are understood as projections of how the future might or should look, they are inherently future-oriented. Yet the strongly instrumental framing of quantum computing—as a means to clearly desirable ends—warrants closer scrutiny. When such a direct link between a technology and promised benefits comes to dominate the discourse, other ethically relevant dimensions risk being obscured, including potential downsides, the possibility of unintended consequences, value conflicts, and opportunity costs. If innovation is prefigured as inherently beneficial, then ethical reflection may be limited to questions of *how* to steer its development responsibly—rather than whether the innovation itself is desirable.

Moreover, locating “the good” primarily in a distant future may shift ethical attention away from the present. It can defer responsibility and distract from more immediate interventions or alternative courses of action. While this concern overlaps with critiques of techno-optimism and technosolutionism, it highlights a distinct temporal dimension: technology is not only framed as an effective problem-solver, but its promised solutions are consistently projected into a speculative future.

The prevalence of such promissory futurism in contemporary quantum computing discourse—where beneficial impacts are largely presupposed and framed as something that merely needs to be unlocked—warrants attention. Not only may it indicate an imbalanced discourse, but also raises ethical concerns about speculative overreach (Nordmann, 2007), which may undermine the quality of public and ethical debate (de Jong, 2026).

Closely related to promissory futurism is a discursive pattern of *morally legitimising innovation through anticipated social and economic benefits*. Projected contributions of quantum computing—to society, the economy, science, and national positioning—are mobilised to justify continued financial and intellectual investment. Such a logic is characteristic of innovation contexts and is not inherently problematic. However, like other recurring patterns and presuppositions, it becomes contestable beyond a certain point.

Ethical concerns arise when desirability frames are mobilised whose plausibility is uncertain or insufficiently substantiated—with ‘sufficiently substantiated’ being subject to debate. In other words, promising ‘rose gardens’ becomes problematic when such promises cannot be made plausible, yet still serve to attract or justify the allocation of substantial resources. In such cases, a form of spurious or *pseudo-legitimation* may occur, which is ethically problematic. Whether this dynamic is at play around quantum computing requires closer examination of individual claims.

This issue of legitimization is strongly tied to questions of discursive agency—namely, *who* articulates these promises. We take up this question in the next section.

4.3. Authors (agential level): Interest shaped narratives

Crucial to the ethical significance of the patterns and presuppositions discussed at the previous levels is the question of authorship. Who articulates visions of quantum computing matters, because discursive power can translate into agenda-setting and action, whether directly or indirectly. It makes the difference between techno-optimism being merely naïve or potentially harmful. In other words, the ethical relevance of visions cannot be separated from their authors.

As discussed in Section 3, we did not examine how societal actors such as civil society organisations or citizens imagine the future of quantum computing, for reasons explained there. Instead, we focused on actor groups that actively articulate visions of what the future of quantum computing will or should look like, and thereby currently shape the dominant discourse. These actors are not only discursively visible but also institutionally powerful, and their visions play an active role in steering the development of quantum computing. This performative power renders their visions particularly ethically salient. We here reflect on two features of this discursive landscape and their potential ethical implications.

First, the visions we identified are largely authored by actors with *direct institutional or strategic stakes* in the advancement of quantum computing. For example, while the ‘quantum for good’ vision rhetorically centres on benefits for “humanity,” its principal authors—national governments—also emphasise the geopolitical and strategic value of maintaining leadership in quantum technologies. Similarly, the economy- and science-oriented visions are shaped by institutions whose legitimacy, funding, or influence may depend on projecting quantum computing as a major opportunity. These overlapping stakes reinforce a strong desirability frame and contribute to a discourse in which more critical questions—such as those concerning energy use, reliance on scarce materials, or the need for non-technological forms of change—tend to receive limited attention.

That visions are shaped by interests is not in itself surprising. Ideas about how the future should (or should not) look are closely tied to what different actors consider desirable, often from their own perspective. However, if the discourse remains largely shaped by a narrow set of elite actors, a relatively narrow set of interests disproportionately shapes the discourse, and the ethical concern arises that broader societal stakes are sidelined in setting innovation agendas. From an ethical perspective, a more plural and inclusive discourse would therefore be preferable.

A related but more implicit issue concerns the value tensions embedded within these visions—most notably between sustainability and economic growth (cf. [Atladóttir et al., 2025](#)). Economic growth is often framed both as a goal and as a justification for quantum innovation, yet this may stand in tension with sustainability considerations, particularly in light of the material and energy demands associated with the technology. The different values mobilised in the visions and the tensions between them raise questions not only about the compatibility of different visions, but also about internal inconsistencies within individual visions.

Such ambiguity or moral ambivalence is common in discussions of new and emerging technologies (Shelley-Egan & De Jong, 2025). While Shelley-Egan and De Jong explain this ambivalence in terms of framing a technology as novel versus business as usual, our findings suggest that it also manifests in the simultaneous appeal to potentially competing values in visions of quantum computing. This is not ethically problematic in itself. However, when such value tensions remain implicit or unaddressed, they obscure underlying trade-offs and normative choices. Making these tensions visible therefore matters ethically, as it opens space for explicit reflection and contestation over what kind of progress is being pursued, and for whom. ([Table 3](#)).

To a high extent, this analysis reveals similarities with previous debates about system technologies such as nanotechnology and artificial intelligence ([Swierstra & Rip, 2007](#); [WRR, 2021](#)). This provides openings for transferring insights from these previous debates to the contemporary discourse on quantum computing (see also ; [Shelley-Egan & De Jong, 2025](#)).

5. Conclusion and discussion

Visions of technology do not merely reflect anticipated futures—they are value-laden narratives that actively shape technological trajectories. For this reason, projections of the future of quantum computing warrant ethical scrutiny. Moreover, studying these visions allows for early-stage ethical engagement without relying on speculative or potentially contested assumptions about how the technology will develop.

In this study, we identified four main visions sourced from across key actors in the field. Each of these visions casts the societal relevance of quantum computing in a distinct role: as a contributor to the public good, a scientific tool, an economic asset, or a geopolitical advantage. Taken together, these visions form a powerful discursive force that shapes how quantum computing is framed and developed.

Analysing these visions through an ethical lens brings several observations and concerns to the fore. First, we noted the pervasive techno-optimism embedded in these projections, which tends to obscure the uncertainties and challenges inherent to quantum computing’s development. This optimism is closely tied to a technosolutionist logic—one that positions quantum computing as a key enabler of diverse societal goals, potentially backgrounding the sociopolitical dimensions of these goals and the ethical implications of pursuing them through technology.

Second, we highlighted the promissory language through which these visions justify current innovation efforts by appealing to speculative future benefits. While this is a familiar feature of innovation discourse, it becomes ethically significant in the context of quantum computing’s early stage and the considerable technical and conceptual hurdles that remain before such promises can be

Table 3
summarises the ethical analysis.

Level of analysis	Feature	Potential concern
Content (substantive level)	1a. Techno-optimism	1a. Downplaying uncertainties around the development of practically relevant quantum computers may compromise responsible decision-making
	1b. Techno-solutionism	1b. Presenting quantum computing as a solution to social problems may obscure the social complexity of those problems and their sociopolitical and ethical aspects.
Framing (discursive level)	2a. Promissory futurism	2a. Framing quantum computing as enabling “the good in the future” risks speculative overreach, which may negatively affect the quality of public and ethical debate.
	2b. Moral legitimization	2b. Legitimising innovation agendas by appealing to future benefits of quantum computing without substantiated plausibility risks pseudo-legitimation
Authors (agential level)	3a. Stakeholder bias	3a. Visions of quantum computing shaped by a narrow set of powerful actors may sideline broader societal interests.
	3b. Moral ambivalence	3b. Unacknowledged tensions between values in different visions of quantum computing obscure ethical trade-offs and keep the ethical debate about what counts as progress implicit

realised, potentially collapsing into pseudo legitimization.

Third, we observed that the authors of contemporary visions of quantum computing all have direct stakes in its development. While this is not surprising in itself, the fact that the discourse is currently dominated by a small, powerful elite raises concerns that broader societal interests may be neglected. Moreover, different authors appeal to different values in their visions, which sometimes come into tension with one another. This moral ambivalence highlights potential conflicts between visions and raises questions about their compatibility and practical feasibility.

These aspects are not necessarily unique to quantum computing; rather, they reflect recurring patterns in ethical discussions about new and emerging technologies. By identifying whether and how these issues resurface in the context of quantum computing, our analysis sets an agenda for more focused ethical inquiry into each of them. It also underscores the value of attending to continuities with previous debates—such as those on nanotechnology—which allows us to draw on, and learn from, earlier ethical discussions (Shelley-Egan & De Jong, 2025).

With this ethical vision assessment, we aim to make a threefold contribution. First, to the emerging field of quantum ethics and the broader discussion of responsible innovation in the quantum realm. Our analysis functions as an ethical heatmap of potential concerns arising from how the future of quantum computing is currently envisioned. Rather than providing an exhaustive ethical evaluation of each vision, we highlight patterns and presuppositions that warrant closer scrutiny, thereby identifying entry points for further ethical inquiry and public reflection. These concerns should be seen in light of the largely absent broader societal perspectives in current discourse. A key avenue for future research is therefore to explore public perspectives on quantum computing in relation to the ‘vanguard visions’ examined here.

Second, this study contributes to methodological discussions on applying a hermeneutic or meaning-oriented approach to ethics, especially for technologies still in an early, conceptual stage. We propose a structured method for identifying technological visions from textual materials, and for interrogating their ethical dimensions. By explicitly incorporating ethical analysis as a distinct stage of vision assessment, we foreground technological visions as ethically salient phenomena.

Third, our findings allow embedding the current visionary communication around quantum into the recent waves of other technosciences and, by reminding a notion frequently related with the nano and the human enhancement debate, of other NEST (Swierstra & Rip, 2007). These and further ones like synthetic biology, gene editing, and artificial intelligence (AI) were, respectively are, characterised by visionary communication with ethical aspects, partially reaching the dimension of powerful hypes, as currently in the field of AI. They also included aspects like technosolutionism, the legitimization of investments and efforts today by promising bright futures, and stakes and interests of researchers and research managers. Hence, we argue that in-depth comparative studies of the techno-visionary communications and their ethical aspects will be promising for better understanding commonalities and differences of the various NEST waves.

Finally, having argued that the uncertainties surrounding quantum computing development are relevant for ethical analysis, we must also apply this insight to our own study. How can we justify engaging with visions of a technology whose feasibility remains deeply uncertain? As Nordmann and Rip (2009) point out, the relevance of ethical analysis partly depends on the plausibility of the projections it addresses. While this holds for consequentialist approaches focused on technological impacts, the ethical relevance of engaging with visions depends less directly on their plausibility. Since visions mobilise resources, shape expectations, and influence what eventually becomes possible, they merit ethical scrutiny regardless of the current state of technical feasibility. In this sense, our method of ethical vision assessment may offer one of the most anticipatory forms of ethical engagement with emerging technologies.

CRedit authorship contribution statement

Eline de Jong: Writing – review & editing, Writing – original draft, Conceptualization. **Armin Grunwald :** Supervision.

Funding

This publication is a result of the project *Quantum Impact on Societal Security* (project number NWA.1436.20.002), funded by the Dutch Research Council (NWO) under the Quantum/Nanorevolution programme, and made possible with funding from the Quantum Delta Netherlands Growth Gund programme.

Declaration of Competing Interest

All authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to thank Dr Sebastian De Haro and Dr Clare Shelley-Egan and for their thoughtful feedback on earlier drafts of this article.

Appendix A. Overview of selected actors and materials (“vision statements”)

	Actor	Actor type	Vision document	Document type
(1)	Australia	Government	National Quantum Strategy	National strategy
(2)	Austria	Government	Quantum Austria	Research agenda
(3)	Brazil	Government	Competence Center in Quantum Technologies	National action plan
(4)	Canada	Government	National Quantum Strategy	National strategy
(5)	China	Government	China's 14th Five-Year Plan	National strategy
(6)	Denmark	Government	National Strategy for Quantum Technology	National strategy
(7)	European Union	Government	Digital strategy	Supranational strategy
(8)	Finland	Government	Quantum Technology Strategy	National strategy
(9)	France	Government	National Quantum Strategy	National strategy
(10)	Germany	Government	Quantum Technologies Conceptual Framework Programme	National action plan
(11)	Germany	Government	Roadmap for quantum computing	National road map
(12)	Switzerland	Government	Swiss Quantum Initiative	National initiative
(13)	Israel	Government	Israel National Quantum Initiative	National initiative
(14)	India	Government	National Quantum Mission	National strategy
(15)	Netherlands	Government	National Agenda on Quantum Technology	National strategy
(16)	United States	Government	National Quantum Initiative	National strategy
(17)	United Kingdom	Government	National Quantum Strategy	National strategy
(18)	Sweden	Government	Swedish Quantum Agenda	National strategy
(19)	Japan	Government	Strategy of Quantum Future Industry Development	National strategy
(20)	South Korea	Government	National Strategic Plan for Quantum Science and Technology	National strategy
(21)	Italy	Government	Quantum Technologies: Italian Strategy Document	National strategy
(22)	Ireland	Government	Quantum 2030-A national quantum strategy for Ireland	National strategy
(23)	Lithuania	Government	Lithuanian Quantum Agenda	National agenda
(24)	Spain	Government	Quantum Spain	National strategy
(25)	IBM Quantum (IBM)	Industry	ibm.com	Roadmap
(26)	Google Quantum AI (Alphabet Inc.)	Industry	quantumai.google	Website
(27)	Microsoft Azure	Industry	quantum.microsoft.cin	Website / roadmap
(28)	Amazon Braket (AWS)	Industry	aws.amazon.com	Website
(29)	Intel Labs (Intel)	Industry	intel.com	Website
(30)	D-Wave	Industry	dwavequantum.com	Website / e-book
(31)	Rigetti	Industry	rigetti.com	Website
(32)	IonQ	Industry	ionq.com	Website
(33)	Quantinuum	Industry	quantinuum.com	Website
(34)	Infleqtion	Industry	infleqtion.com	Website
(35)	G7	Coordinator	g7.canada.ca	Website
(36)	Open Quantum Institute	Coordinator	open-quantum-institute.cern	Website
(37)	OECD	Coordinator	oecd.org	Paper
(38)	Quantum Delta NL	Coordinator	quantumdelta.nl	Website
(39)	United Nations	Coordinator	quantum2025.org	Website
(40)	National Quantum Computing Centre UK	Coordinator	nqcc.ac.uk	Website
(41)	World Economic Forum	Coordinator	weforum.org	Report
(42)	NATO	Coordinator	nato.int	Website
(43)	Munich Quantum Valley	Coordinator	munich-quantum-valley.de	Website
(44)	EU Quantum Flagship	Coordinator	qt.eu	Website
(45)	QuTech (TU Delft, The Netherlands)	Research	qutech.nl	Website
(46)	IQC (University of Waterloo, Canada)	Research	uwaterloo.ca	Website
(47)	Harvard Quantum Initiative (Harvard University, USA)	Research	quantum.harvard.edu	Website
(48)	ETH Zurich – Quantum Center (Switzerland)	Research	qc.ethz.ch	Website
(49)	Oxford Quantum Institute (Oxford University, UK)	Research	oqi.ox.ac.uk	Website
(50)	JQI (University of Maryland & NIST, USA)	Research	jqi.umd.edu	Website
(51)	Hefei Institutes for Physical Science (Chines Academy of Sciences, China)	Research	hf.cas.cn	Website
(52)	Quantum Physics and Quantum Information dep. (University of Science and Technology, China)	Research	quantum.ustc.edu.cn	Website
(53)	Centre for Quantum Technologies (National University of Singapore, Singapore)	Research	cqt.sg	Website
(54)	RIKEN Center for Quantum Computing (Japan)	Research	riken.jp	Website
(55)	Institut Quantique (Canada)	Research	usherbrooke.ca	Website
(56)	QuSoft (University of Amsterdam, The Netherlands)	Research	qusoft.org	Website
(57)	Simons Institute (Berkeley University, USA)	Research	simons.berkeley.edu	Website
(58)	IQIM (CalTech, USA)	Research	iqim.caltech.edu	Website

(continued on next page)

(continued)

	Actor	Actor type	Vision document	Document type
(59)	Scott Aaronson (Quantum Information Center, University of Texas)	Thought leader	scottaaronson.blog	Blog
(60)	John Preskill (California Institute of Technology)	Thought leader	scienceexchange.caltech.edu	Interview
(61)	Michele Mosca (Institute for Quantum Computing, University of Waterloo)	Thought leader	ieeexplore.ieee.org	Paper
(62)	Peter Shor (Massachusetts Institute of Technology)	Thought leader	ep-news.cern.ch	Interview
(63)	Aram Harrow (MIT's Center for Theoretical Physics)	Thought leader	medium.com	Interview
(64)	Artur Eckert (Mathematical Institute, University of Oxford)	Thought leader	executivemagazine.pl	Interview

Data availability

Data will be made available on request.

References

- Alleblas, J. (2026). *Moralized Visions and Technological Design*. [Doctoral dissertation]. ISBN/EAN: 978-94-6384-902-9.
- Atladóttir, D., Roch, N., Leese, M., et al. (2025). A quantum of responsibility? A comparison of national quantum governance frameworks and expert views. *Digital Society*, 4, 54. <https://doi.org/10.1007/s44206-025-00205-7>
- Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology Analysis & Strategic Management*, 18(3–4), 285–298.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
- Broussard, M. (2019). Artificial unintelligence. *How Computers Misunderstand the World*.
- Danaher, J. (2022). Techno-optimism: An analysis, an evaluation and a modest defence. *Philosophy & Technology*, 35(2), 54.
- De Jong, E. (2022). Own the unknown: an anticipatory approach to prepare society for the quantum age. *Digital Society*, 1(2), 15.
- de Jong, E. (2025). Ethics readiness of technology: The case for aligning ethical approaches with technological maturity. *Science and Engineering Ethics*, 31(30). <https://doi.org/10.1007/s11948-025-00556-x>.
- de Jong, Eline (2026). Functional Understanding of Quantum Technologies is Essential to the Ethical Debate About Their Impact. *NanoEthics*, 20(1), Article 12. <https://doi.org/10.1007/s11569-026-00501-7>. <https://link.springer.com/10.1007/s11569-026-00501-7>. (Accessed 6 March 2026)
- de Jong, Eline, & Shelley-Egan, Clare (2026). Quantum for good through a lens of technosolutionism: A critical-constructive view. *Journal of Responsible Technology*, 25, Article 100157. <https://doi.org/10.1016/j.jrt.2026>. <https://linkinghub.elsevier.com/retrieve/pii/S2666659626000107>.
- De Wolf, R. (2017). The potential impact of quantum computers on society. *Ethics and Information Technology*, 19(4), 271–276.
- Dignum, M., Correljé, A., Groenleer, M., & Scholten, D. (2018). Governing through visions: Evaluating the performativity of the European gas target models. *Energy Research & Social Science*, 35, 193–204.
- Ferrari, A. (2013). From nanoethics to the normativity of technological visions. *Etica & Politica*, 15(1), 220–235.
- Ferrari, A., Coenen, C., & Grunwald, A. (2012). Visions and ethics in current discourse on human enhancement. *Nanoethics*, 6(3), 215–229. <https://doi.org/10.1007/s11569-012-0155-1>
- Gasser, U., De Jong, E., & Kop, M. (2024). A call for responsible quantum technology. *Nature Physics*, 1–3.
- Grunwald, A. (2005). Nanotechnology—A new field of ethical inquiry? *Science and Engineering Ethics*, 11(2), 187–201. <https://doi.org/10.1007/s11948-005-0041-0>.
- Grunwald, A. (2010). From speculative nanoethics to explorative philosophy of nanotechnology. *NanoEthics*, 4, 91–101.
- Grunwald, A. (2018). *Technology assessment in practice and theory*. Routledge.
- Grunwald, A. (2020). The objects of technology assessment. Hermeneutic extension of consequentialist reasoning. *Journal of Responsible Innovation*, 7(1), 96–112.
- Grunwald, A. (2024). Technology assessment for a 'good' Anthropocene. *Handbook of Technology Assessment* (pp. 441–450). Edward Elgar Publishing.
- Hidary, J. D. (2019). A brief history of quantum computing. *Quantum Computing: An Applied Approach*. Cham: Springer. https://doi.org/10.1007/978-3-030-23922-0_2.
- Inglesant, P., Ten Holter, C., Jirotko, M., & Williams, R. (2021). Asleep at the wheel? Responsible Innovation in quantum computing. *Technology Analysis & Strategic Management*, 33(11), 1364–1376.
- Königs, P. (2022). What is techno-optimism? *Philosophy & Technology*, 35(3), 63.
- Kop, M., Aboy, M., De Jong, E., Gasser, U., Minssen, T., Cohen, I. G., Brongersma, M., Quintel, T., Floridi, L., & Laflamme, R. (2024). Ten principles for responsible quantum innovation. *Quantum Science and Technology*, 9(3), Article 035013.
- Kop, M., Aboy, M., De Jong, E., Gasser, U., Minssen, T., Cohen, I. G., Brongersma, M., Quintel, T., Floridi, L., & Laflamme, R. (2024). Towards responsible quantum technology. *Harvard Berkman Klein Center for Internet & Society Research Publication Series*, 1.
- Kudina, O. (2021). Alexa, who am I?": voice assistants and hermeneutic lemniscate as the technologically mediated sense-making. *Human Studies*, 44(2), 233–253.
- Meinsma, A., Rothe, T., Reijnierse, W., Smeets, I., & Cramer, J. (2025). Quantum in the media: A content analysis of Dutch newspapers. *Science Communication*, 48(1), 128–147.
- Michael, M. (2000). Futures of the present: From performativity to prehension. In N. Brown, B. Rappert, & A. Webster (Eds.), *Contested futures: A sociology of prospective techno-science*. Aldershot: Ashgate.
- Morozov, E. (2013). *To save everything click here: Technology, solutionism, and the urge to fix problems that don't exist*. New York: PublicAffairs.
- Mosca, M., & Piani, M. (2023). *Quantum threat timeline report 2024*. Toronto, Canada: Global Risk Institute & evolutionQ.
- Nordmann, A. (2007). If and then: A critique of speculative nanoethics. *Nanoethics*, 1, 31–46.
- Nordmann, A., & Grunwald, A. (2023). Hermeneutic technology assessment – Why it is needed and what it might be. In A. Grunwald, A. Nordmann, & M. Sand (Eds.), *Hermeneutics, History, and Technology: The call of the future* (pp. 37–41). Routledge.
- Nordmann, A., & Rip, A. (2009). Mind the gap revisited. *Nature Nanotechnology*, 4(5), 273–274.
- Nydal, R., De Grandis, G., & Ursin, L. (2023). When is a techno-fix legitimate? The case of viticultural climate resilience. *Journal of Agricultural and Environmental Ethics*, 36(1), 3.
- Open Quantum Institute (n.d.). The Open Quantum Institute [Web page]. Retrieved from: <https://open-quantum-institute.cern/>.
- Possati, L. M. (2023). Ethics of quantum computing: an outline. *Philosophy & Technology*, 36(3), 48.

- Possati, L. M. (2024). Quantum technologies: A hermeneutic technology assessment approach. *NanoEthics*, 18(1), 2.
- Pyrho, M. (2011). Nanotechnology and ethics: Assessing the unforeseeable. *Bioethics in the 21st Century Londres: Intech*, 121–138.
- Quantum for Good (n.d.). Leveraging quantum for good: A global collaborative movement [Web page]. Retrieved from: <https://quantumforgood.eu/#introduction>.
- Roberson, T. M. (2021). On the social shaping of quantum technologies: an analysis of emerging expectations through grant proposals from 2002–2020. *Minerva*, 59(3), 379–397.
- Ruser, A., & Machin, A. (2016). In *Proceedings of the international conference "Technology + Society = Future* (pp. 437–447).
- Sætra, Henrik Skaug, & Selinger, Evan (2024). Technological Remedies for Social Problems: Defining and Demarcating Techno-Fixes and Techno-Solutionism. *Science and Engineering Ethics*, 30(6), Article 60. <https://doi.org/10.1007/s11948-024-00524-x>. <https://link.springer.com/10.1007/s11948-024-00524-x>. (Accessed 2 December 2024)
- Sætra, H. S. (2023). Introduction: The promise and pitfalls of techno-solutionism. *Technology and sustainable development* (pp. 1–9). Routledge.
- Sand, M. (2019). On “not having a future”. *Futures*, 107, 98–106. <https://doi.org/10.1016/j.futures.2019.01.002>
- Sand, M. (2023). The questions of hermeneutic TA: Towards a toolbox. *Hermeneutics, History, and Technology: The Call of the Future* (pp. 73–88). Routledge - Taylor & Francis Group. <https://doi.org/10.4324/9781003322290-5>. Article 10.4324/9781003322290-4.
- Schneider, C., Roßmann, M., Lösch, A., & Grunwald, A. (2021). Transformative vision assessment and 3-D printing futures: a new approach of technology assessment to address grand societal challenges. *IEEE Transactions on Engineering Management*, 70(3), 1089–1098.
- Seskir, Z. C., Umbrello, S., Coenen, C., & Vermaas, P. E. (2023). Democratization of quantum technologies. *Quantum Science and Technology*, 8(2), Article 024005.
- Shelley-Egan, C. (2010). The ambivalence of promising technology. *Nanoethics*, 4(2), 183–189.
- Shelley-Egan, C. (2025). The Risk of Ethicalisation in Ethical Engagement with Quantum Technologies: Some Brief Considerations. *NanoEthics*, 19(2), 7.
- Shelley-Egan, Clare, & De Jong, Eline (2025). From Nano to Quantum: Ethics Through a Lens of Continuity. *Science and Engineering Ethics*, 31(5), Article 31. <https://doi.org/10.1007/s11948-025-00557-w>. <https://link.springer.com/10.1007/s11948-025-00557-w>. (Accessed 13 October 2025)
- Siffels, L., & Sharon, T. (2024). Where technology leads, the problems follow. Technosolutionism and the Dutch contact tracing app. *Philosophy & Technology*, 37(4), 125.
- Swierstra, T., & Rip, A. (2007). Nano-ethics as NEST-ethics: patterns of moral argumentation about new and emerging science and technology. *Nanoethics*, 1, 3–20.
- Swierstra, T., & Rip, A. (2007). Nano-ethics as NEST-ethics: Patterns of moral argumentation about new and emerging science and technology. *Nanoethics*, 1, 3–20. <https://doi.org/10.1007/s11569-007-0005-8>.
- Ten Holter, C., Inglesant, P., & Jirotko, M. (2023). Reading the road: Challenges and opportunities on the path to responsible innovation in quantum computing. *Technology Analysis & Strategic Management*, 35(7), 844–856.
- Timmermans, Job, & Blok, Vincent (2018). A critical hermeneutic reflection on the paradigm-level assumptions underlying responsible innovation. *Synthese*, 198(S19), 4635–4666. <https://doi.org/10.1007/s11229-018-1839-z>. <https://link.springer.com/10.1007/s11229-018-1839-z>. (Accessed 9 June 2018)
- Van de Merbel, A., Peer, J., Willems, S. J., & Cramer, J. (2024). Quantum technology will change my life. 'Citizens' attitudes and knowledge of quantum science and technology. *Journal of Physics Communications*, 8(7), Article 075005.
- Vermaas, P. E. (2017). The societal impact of the emerging quantum technologies: a renewed urgency to make quantum theory understandable. *Ethics and Information Technology*, 19, 241–246. <https://doi.org/10.1007/s10676-017-9429-1>
- Von Schomberg, R. (2013). A vision of responsible research and innovation. *Responsible innovation: Managing the responsible emergence of science and innovation in society*, 51–74.
- Wilson, A. (2017). Techno-optimism and rational superstition. *Techné: Research in Philosophy & Technology*, 21, 342–362. <https://doi.org/10.5840/techné201711977>
- WRR. (2021). *Opgave AI. De nieuwe systeemtechnologie*. The Hague: WRR.
- Wynne, B. (2007). Public participation in science and technology: Performing and obscuring a political-conceptual category mistake. *East Asian Science, Technology and Society: An International Journal*, 1(1), 99–110. <https://doi.org/10.1215/s12280-007-9004-7>