QUANTUM FUTURES

QUANTUM DELTA NL (2023)

“Quantum technology has a ‘systemic’ impact on society and is therefore a technology that enables all sorts of innovation, in all kinds of fields.”

QUANTUM FUTURES GAME
THE POLICY GAME TO ENGAGE WITH THE DISCOURSE OF QUANTUM TECHNOLOGIES

PROGRAM
Design for Interaction, Industrial Design Engineering
Delft University of Technology

GRADUATION
February 2025

MASTER THESIS
Juwe van Vliet

IN COLLABORATION WITH
Centre for Quantum and Society

SUPERVISORY TEAM
Prof. Ir. Deborah Nas (chair)
Ir. Maurizio Filippi (mentor)

"Quantum is everywhere!"
(Policy Trainee, 2025)

I can't unsee it anymore. Quantum concepts appear in Interstellar, the 2024 series of Dune, and the book AI 2041: Ten Visions for Our Future. Throughout my master's in Design for Interaction at Delft University of Technology, I have explored how design can shape interactions between people, technology, and systems. This thesis brings these elements together, applying my knowledge and skills to an emerging field: quantum technologies.

Over the past seven months, I have worked closely with the Centre for Quantum and Society, focusing on engaging policymakers in the discourse of quantum technologies through policy games. This research and communication report serves as a support document for the Quantum Futures Game, with the goal of creating a game that helps policymakers engage with and better understand the systemic impact of quantum technologies.

A common call to action in the quantum field is: "We need other expertises to join." This project reinforced for me that curiosity alone can drive meaningful engagement. Coming into the quantum industry with no prior knowledge, I never expected to leave with a policy game featuring 90+ quantum applications that highlight the far-reaching societal implications of the technology. I welcomed the freedom to explore diverse sources, shaping the game in a way that maximized engagement, and I had a lot of fun embracing this broad and exploratory process. I particularly enjoyed interacting with experts from both the quantum industry and government, learning to empathize with their work and perspectives. It was a truly unique experience.

This thesis is the result of that journey, and I could not have done it without the support of so many people.:
First and foremost, thank you, Deborah, for introducing me to this inspiring field. You truly opened my eyes to the possibilities of current and future innovations, and I'm deeply grateful for the fun collaboration, endless support, and many cool recommendations. Thank you, Maurizio, for enthusiastically joining the quantum exploration. Thankyou for the funny meetings, your patience during elaborate explenations and all the graphic design references.

I am grateful to all early playtesters at the Quantum Policy Academy, Alliander, DesignerxPolicymakers test afternoon, Industrial Design Engineering faculty, Centre for Quantum and Society team day, Centre for Future Generations Flagship Event, the Government Trainees Programme Day, and everyone else who helped refine the earliest versions of the game. A special thank you to all the contributors who helped bring this game to life.

Thankyou to all policymakers I spoke to during this project. The passion for your jobs was inspiring to experience.

To my colleagues at the Centre for Quantum and Society, thank you for the warm welcome. Because of you I truly enjoyed the team days and quantum events.

Lastly, a big thank you to my friends and family, who provided feedback and report inspirations, joined game prototype tests, and forever supported me throughout this process.

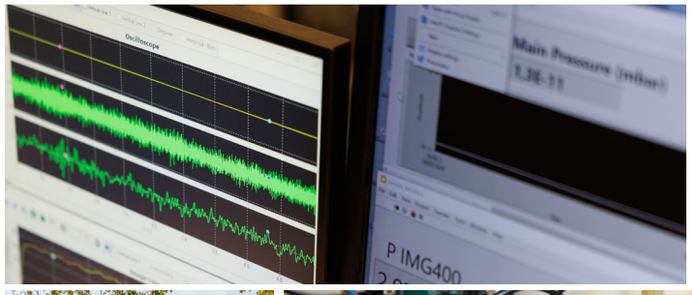
During my years at Industrial Design Engineering, I was drilled to see users as experts and in the case of quantum technologies, society, policymakers, and each of us will be users of these innovations. We are experts in how we want to interact with quantum innovations and the systems around them. So my call to action is: stay curious, even towards (maybe intimidating) tech.

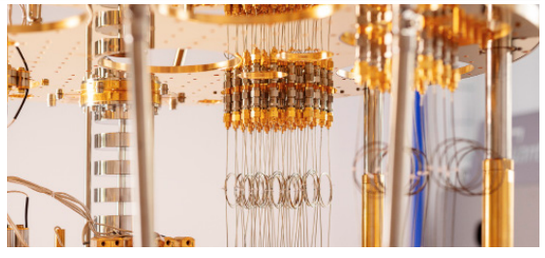
I'm looking forward to the quantum future!
Enjoy reading!

JUWE VAN VLIET

TABLE OF CONTENTS




This graduation thesis for the master's program Design for Interaction at the Delft University of Technology is written as a research and communication report as a support document for the Quantum Futures Game. The report answers the following question:"How to engage policy-makers in the discourse of quantum technologies via a future-scenario game?"

The Dutch government has begun integrating quantum strategists into its technology departments, initiating collaborations with external organizations to explore quantum technology's implications. However, these efforts remain largely contained within technology-focused departments or limited to policymakers already interested in the field. The Quantum Futures Game was developed to expand this engagement by addressing the fundamental question: "What can quantum technologies do for my area of expertise?" To provide policy-makers with an effective way to engage with quantum technologies, the game highlights the systemic nature of quantum technologies and raises awareness of their potential impact on society.

The current stage of quantum development, known as the Noisy Intermediate-Scale Quantum (NISQ) era, is marked by instability and a gap between academic research and industry applications (Groenland, 2024). While businesses promote quantum's revolutionary potential, the discourse remains highly technical, making it inaccessible to non-experts. Although quantum applications in healthcare, material science, and cybersecurity illustrate its role in broader technological ecosystems, the current level of quantum literacy in governance is diverse. It has as a result that quantum technology discourse potential impacts are being confined to specialized circles, limiting its adoption in governance.

A central barrier to engaging policymakers is the complex image of policy design for quantum technology development and the needed interdisciplinairy approach. Currently, existing laws may not fully address quantum's interdisciplinary nature leadin to regulatory gaps and overlap. The complexity of risk assesments and unclear accountability are hard to adress due to quantum convergence with other emerging technologies. Also, the rapid technological evolution creates difficulties for policymaking to keep pace with quantum advancements, leading to outdated or misaligned policies.

As quantum technologies may disrupt markets it benefits best from anticipatory governance strategies and global coordination to balance innovation and ensure the public trust.

To offer a proactive governance tool, the Quantum Futures Game was designed as an interactive tool that helps policymakers make informed decisions during the quantum technology discourse.
The game followed an iterative design approach, resulting in five prototypes tested with over 150 stakeholders from policy, innovation, and quantum domains. The final outcome of this process is the Quantum Futures Game. The Quantum Futures Game introduces several key mechanics to dive into quantum policymaking, including:

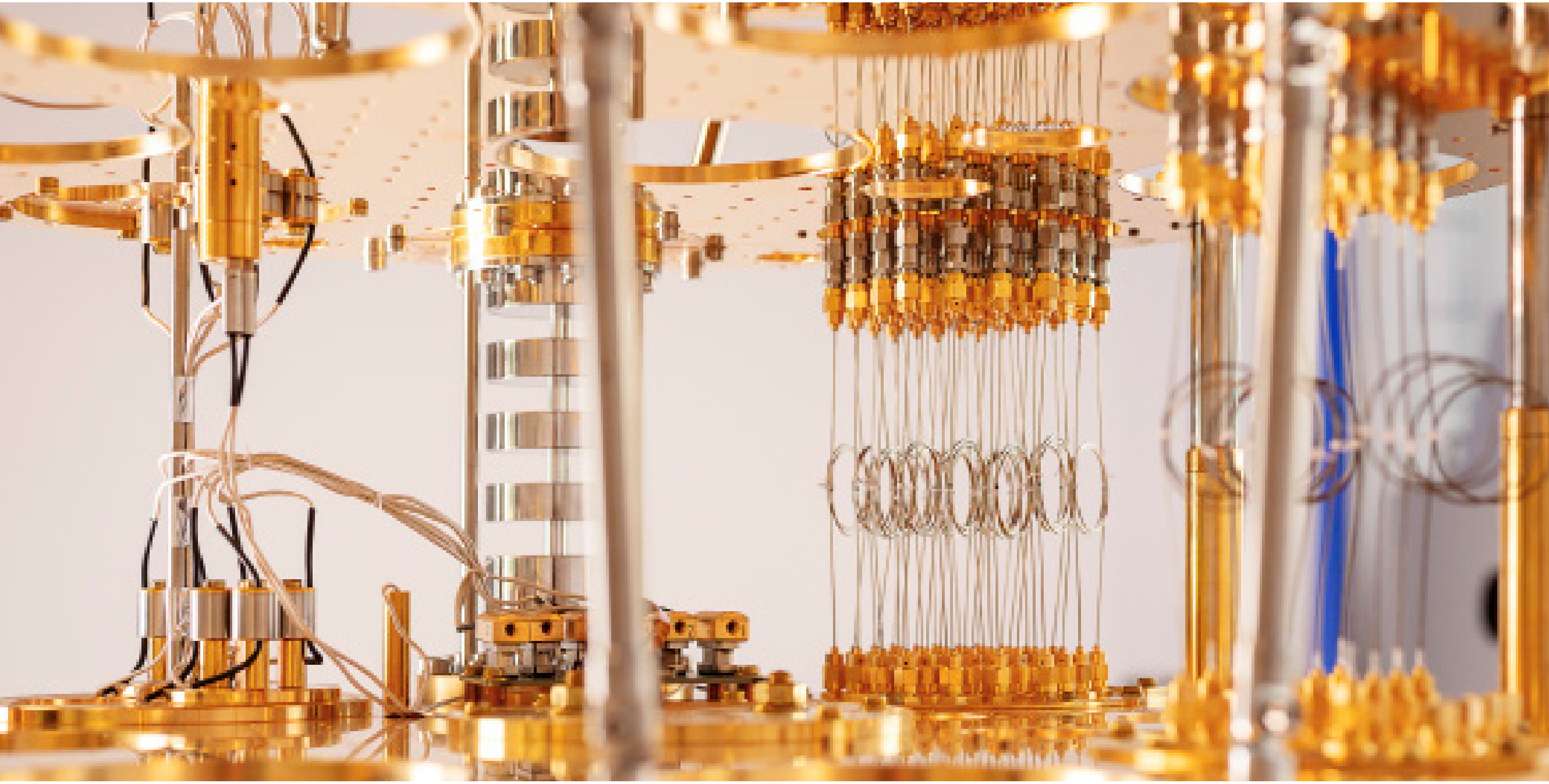
Strategic Agendas: Each team is immersed in a quantum future scenario of 2050 with a quantum strategy.
Quantum Technology Cards: Covering quantum for infrastructure, energy, water, healthcare and military applications to show the systemic impact of quantum technology.
Critical Materials: Highlighting the role of scarce resources essential for quantum technology development
Policy Instruments: Leveraging regulatory strategies, international collaborations, and acceleration mechanisms to increase the chance on winning the game.
Discussion Structures: Encouraging exploration into the stakeholder ecosystem around quantum applications and the pro-active role of governments for the emerging technology.

By implementing gamification as an engagement tool, CQS has an extra opportunity to raise awareness around quantum technology for policymaking contexts. The Quantum Futures Game serves as a interactive engagement format to (re)initiate interest in quantum policymaking.

It shows quantum applications to facilitate dialogue and help making informed decisions. Through structured gameplay, policymakers will gain an understanding of quantum's systemic impact, ideally shaping a future where quantum technologies are governed proactively.
By embedding interactive tools into policymaking, the Centre for Quantum and Society gains an additional means to support the adoption of responsible quantum governance frameworks, ensuring a proactive and resilient approach to quantum's societal impact.

THESIS **GLOSSARY**

CENTRE FOR QUANTUM AND SOCIETY (CQS)	A knowledge and co-creation centre launched in 2022 to maximize the positive impact and mitigate the risks of quantum technologies on society.
QUANTUM DELTA NEDERLAND (QDNL)	A Dutch quantum ecosystem accelerating technology development through collaborative partnerships between government, industry, and research institutions.
FUTURE SCENARIOS	CQS developed four future quantum scenarios, Collapse, Transformation, Growth and Discipline, based on strategic foresight methodologies anticipating long-term quantum technology impacts by envisioning possible societal and technological outcomes by 2050.
QUANTUM TECHNOLOGIES	Emerging innovations based on quantum mechanics, including quantum computing, sensing, and communication.
POLICYMAKERS	Government officials creating and shaping policies, developing laws and governance frameworks for responsible quantum technology adoption.
QUANTUM FUTURES GAME	An interactive game for policymakers to explore potential impacts of quantum technology through quantum technology applications, critical materials, policy instruments and role-playing stakeholders in discussion structures.
QUANTUM LITERACY	Foundational knowledge required to understand and engage with quantum technologies in policy or governance contexts.
POLICY INSTRUMENTS	Regulatory and strategic tools managing quantum technology adoption and building on society readiness.
CRITICAL MATERIALS FOR QUANTUM	Strategic and critical materials essential for building and maintaining quantum development.
STRATEGIC AGENDAS	Future scenarios in the Quantum Futures Game enholding policy strategies in a quantum-driven future.
QUANTUM GOVERNANCE FRAMEWORKS	Guidelines and policies ensuring responsible, ethical, and societal integration of quantum technologies.



Quantum technology is poised to have a transformative, systemic impact on society, enabling innovation across diverse fields (Quantum Delta NL, 2023). Quantum Delta NL (QDNL), of which the Center for Quantum Scenarios (CQS) is a part, is committed to establishing a robust quantum ecosystem in the Netherlands. This ecosystem is aimed at delivering significant societal benefits as the quantum industry continues its rapid evolution.

The current stage of quantum technology development, referred to as the Noisy Intermediate-Scale Quantum (NISQ) era, is characterized by its nascent, receptive, yet unstable nature (Groenland, 2024). This state creates a paradoxical relationship between academia and industry. While businesses eagerly promote the revolutionary potential of quantum technology, experts present findings in highly technical terms that are largely inaccessible without specialized knowledge. Groenland (2024) identifies four primary application domains: (1) simulating complex chemical and material processes, (2) breaking cryptographic codes, (3) deploying quantum networks for secure cryptographic key distribution, and (4) solving large-scale optimization and AI challenges. These applications underscore the convergence of quantum technologies with a broader technological landscape.

THE FUTURE WITH HANNAH FRY DOCUMENTARY (2024)

"Rather than a zero-sum game, quantum technology represents a universal scientific tool that could enable humanity to probe the atomic and subatomic realms like never before."

Quantum technologies have implications far beyond technical domains. As Groenland (2024) notes, organizations across sectors, particularly those reliant on IT, must prepare for the profound disruptions quantum computing may bring. In the Bloomberg Originals documentary, Hannah Fry dives into the race to harness Quantum Computing's mind-bending power. She concludes scientists anticipate breakthroughs in discovery, while governments and financial institutions recognize both the risks and the economic opportunities (see Figure 1.1 for an image of a quantum computer) . "However, this quantum "race" differs from historical rivalries like the space or nuclear arms races, as multiple entities can emerge as beneficiaries."

Amid these possibilities, stakeholders are exploring how to translate the theoretical potential of quantum technology into tangible societal benefits. IBM educator Olivia Lanes articulated the challenge succinctly in The Quantum Era podcast (2024): "The hardest part is not the final step, but the first step—identifying the problems that quantum technology can uniquely solve." Consequently, a multidisciplinary approach is vital to responsibly guide the quantum discourse. This requires the involvement of industry leaders, policymakers, educational institutions, and the quantum research community (Quantum Delta NL, 2022). A collaborative mindset is essential to shape the trajectory of quantum technologies (Bharosa & Janowski, 2024).

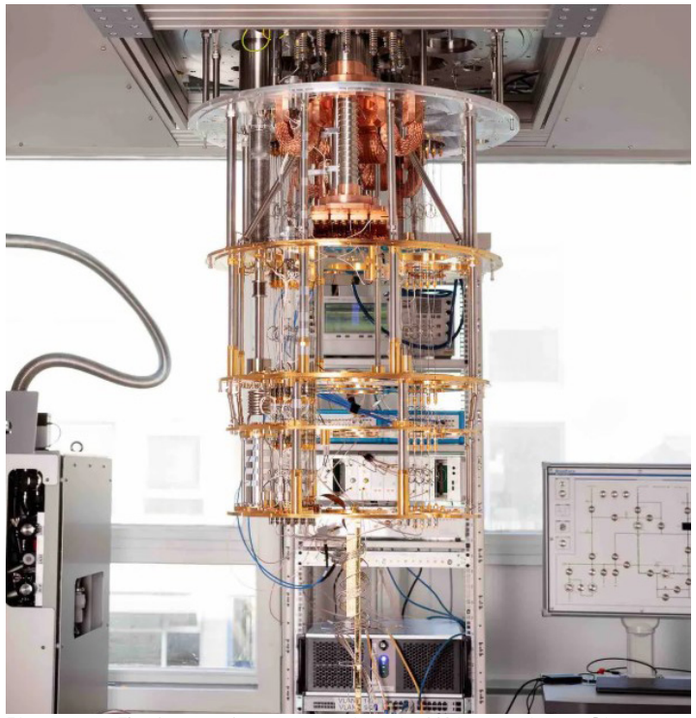


Figure 1.1: The Quantum Computer requires in 2024 extensive cooling systems to maintain its operational stability (QuantumInspire, 2024).

So, as part of fostering quantum literacy collaboratively, this graduation project builts upon the Futures Scenarios Project, which developed exploratory scenarios envisioning the state of quantum technologies by 2050.

FUTURE SCENARIOS

The Futures Scenarios Project employs Strategic Foresight, a non-predictive approach within Future Studies, to map potential developments in quantum networks. This initiative involves diverse stakeholders and emphasizes ethical, legal, and societal aspects (ELSA) in its methodology (D. Nas, April 26, 2024). Through a series of workshops, the project follows a structured methodology: (1) horizon scanning to identify "Seeds of the Future," (2) evaluating these seeds to pinpoint critical uncertainties, and (3) co-creating exploratory scenarios with an ELSA focus (see Figure 1.2) (Quantum Delta NL, 2023).

This graduation project addresses next to quantum networks also related advancements in quantum computing and sensing. This incorporation makes it possible to explore their intersections with emerging technologies such as advanced AI, climate interventions, biotechnology, neurotechnology, and nanotechnology. At the convergence, interesting applications appear which should be taken into account too when working with quantum future scenarios.

The organization has developed successful engagement tools, including research publications, keynote presentations, educational games, and tailored workshops. Building on these initiatives, the Futures Scenarios Project introduces an interactive element—a game—to translate complex quantum futures into engaging, reflective experiences. Games are uniquely suited to explore, examine, and reflect on speculative futures, particularly those involving quantum technologies (Bontoux et al., 2020). Participation in such a game allows stakeholders to consider ethical, legal, and societal implications while fostering collaboration across diverse perspectives (Morishita et al., 2024; Vervoort, 2022).

Figure 1.2: The four quantum scenarios allow to imagine possible extreme futures (Centre for Quantum and Society, 2024).

INITIATION OF THE PROJECT

The project originated from a question posed by Deborah Nas, innovation lead at the Centre for Quantum and Society: What type of game can engage a multidisciplinary team in quantum future scenarios? With this question, she identified a gap in the current quantum discourse. While many resources focus on explaining quantum principles or technical advancements, few explore why these developments matter. Existing tools, such as discussion frameworks, often rely on participants' ability to share domain-specific insights—a challenging expectation given the nascent understanding of quantum technologies among most stakeholders.

This project narrows its scope to a target group of policymakers.

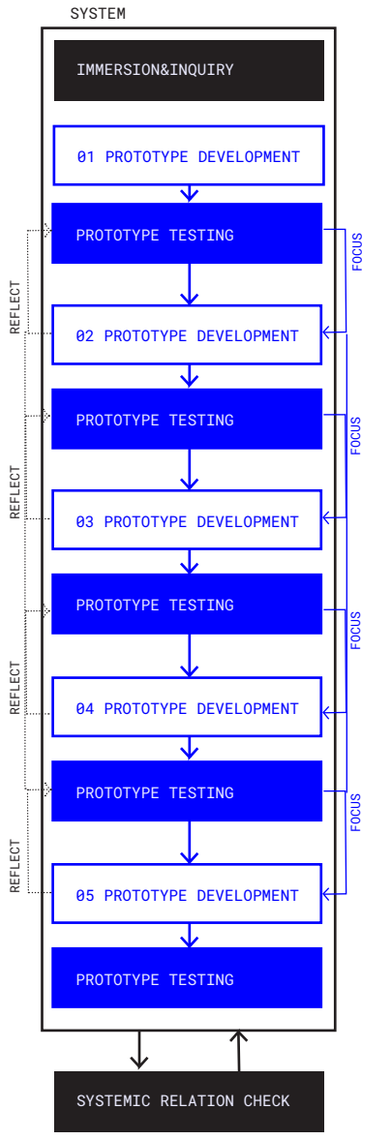


Figure 1.3: Personal persuasive game design approach.

Policymakers play a critical role in shaping the societal impact of quantum technologies by crafting regulatory frameworks and incentives to guide responsible adoption (Kong et al., 2024). Like Kong, researchers Bharosa and Janowski (2024) argue for clear policy guidance to bridge the disconnect between expert knowledge and organizational actions. Before formulating such policies, policymakers must first achieve a foundational understanding of quantum technologies' systemic implications.
This leads to the project's central inquiry: What do policymakers need to build quantum literacy? The following chapter examines this question in detail.

APPROACH

Given the complexity and rapidly evolving nature of quantum technologies, this project adopts a persuasive game design (PGD) methodology. PGD aims to immerse users in a meaningful, game-based exploration of real-world challenges, creating engaging experiences that parallel actual scenarios (Siriaraya et al., 2018; Visch et al., 2013). This approach aligns with the objectives of the Futures Scenarios Project.

The design process incorporates several critical considerations. First, the game must balance accessibility with the intricacies of quantum technology to ensure policymakers can engage meaningfully. Second, the game must adapt to the rapid pace of technological advancement, necessitating iterative updates. Third, the project integrates a systemic relation check to make sure the end result fits its intented policy and societal context (Dorst, 2018; Schaminée, 2021; Visch et al., 2013). Figure 1.3 illustrates the project's adapted methodological framework.

To evaluate the game's impact, the project employs reflection methods inspired by Woolrych et al. (2011), Jaskiewicz & Helm (2017), and Schön & DeSanctis (1986). These methods allow for systematic review of design assumptions, uncovering blind spots and refining intuitive insights.

Throughout the project, the following practices guided the process:

- Examining the quantum technology ecosystem and its systemic relationships.
- Validating concepts with experts in quantum technology, policymaking, and game design.
- Reflecting on personal and professional development
- Maintaining flexibility to accommodate the system's inherent complexity and rapid evolution.

Detailed explanations of data collection and validation processes can be found in Appendix A-E.

REPORT STRUCTURE

Although the iterative game design approach in Figure 1.2 provides the approach for this project, the report is structured slightly differently. This is to increase readability and provide better understanding of the end product.
The report consists of ten parts (see Figure 1.4)

1. **Chapter 1** provides the necessary context to understand the remainder of the report.
2. Chapter 2 frames the general problem space. Here I will provide findings from literature to substantiate the problem.
3. **Chapter 3** dives a bit deeper into the observations during the development of the technology game. It overviews underlying difficulties for policy design with converging technologies.
4. Chapter 4 overviews the iterative process towards the end product and how the iterations connect to the eachother and project assignment.
5. **Chapter 5** formulates the end product: The Quantum Game. I provide the general steps and recommendations for answer the question posed in part 1.
6. **Chapter 6** provides a possible product intergration strategy guide the implementation of the end product in chapter four. A purpose, vision and proposition statements are proposed next to a product timeline and marketing inspiration
7. **Chapter 7** includes limitations of current the Quantum Futures ame and how they could be overcome for future editions.
8. **Chapter 8** provides an addition to the Quantum Futures Game which plays into the difficulties posed in chapter three.
9. **Chapter 9** discusses the limitations of this research.
10. **Chapter 10** provides some essential extra information as a bibliography and appendices.

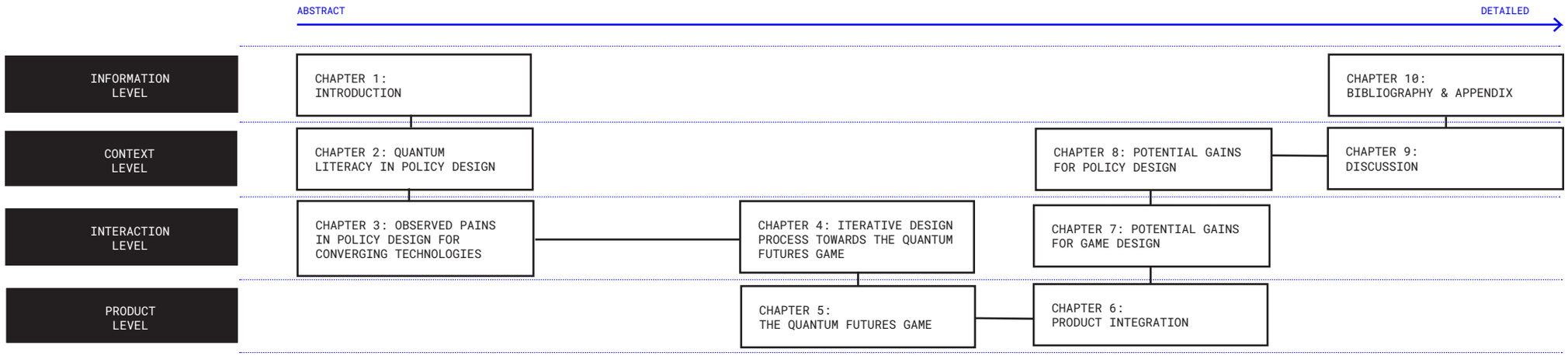


Figure 1.4: Report structure consists of ten chapters.

To address the question posed in Chapter 1 this section explores the tools available to policy-makers for strengthening quantum literacy and integrating quantum technologies into governance frameworks. While gamified discussion tools, commercial games, and scenario planning guides exist, their effectiveness in promoting structured collaboration and technological literacy in government contexts varies.

Prior research by Bontoux et al. (2020) and Vervoort et al. (2022) provides critical insights into the potential of serious games as interventions for fostering cross-sectoral dialogue and decision-making within ministries. Interviews with policy-makers from the Dutch Ministry of the Interior and Kingdom Relations (BZK), Municipality of Amsterdam, Ministry of Justice and Security (JenV) and Ministry of Infrastructure and Water Management (n=5) further emphasize the applicability of gamification in this context.

PROBLEM STATEMENT

To foster quantum literacy among policy-makers, two fundamental questions must be addressed: What can quantum technologies do for my area of expertise? Why is it necessary to prioritize planning for quantum adoption now? To provide policy-makers a fruitful engagement with a game on quantum technologies, these questions must be answered to enabe them to start a follow up project or refer the topic to colleagues who should investigate.

QUANTUM TECHNOLOGY AWARENESS

The game falls under the CQS strategy of increasing awareness. Groenland (2024) gives an approach for building awareness of quantum technology and to inform decision-makers and stakeholders of its transformative potential. The strategic action he structured are visualized in Figure 2.1.

The CQS product portfolio already successfully supports key strategic actions like engaging stakeholders, showcasing practical use cases, and keeping track of technological advancements, making the game a valuable addition (see Figure 2.1). However, it is important to take into account that public engagement into new technologies could start with high enthusiasm fueled by speculative media, moving into disappointment as early expectations are not met (Gartner's Hype Cycle, 1995). The researchers Linden and Fenn (2003) highlight that stakeholders should not invest in tech because its a hype nor ignore it because its not living up to early over-expectations. This is why a fifth quantum awareness strategy is introduced based on AIDA marketing: '(re)initiate interest'. As stated in Chapter 1 quantum technology should not end up in the impact category of 'another technology'.

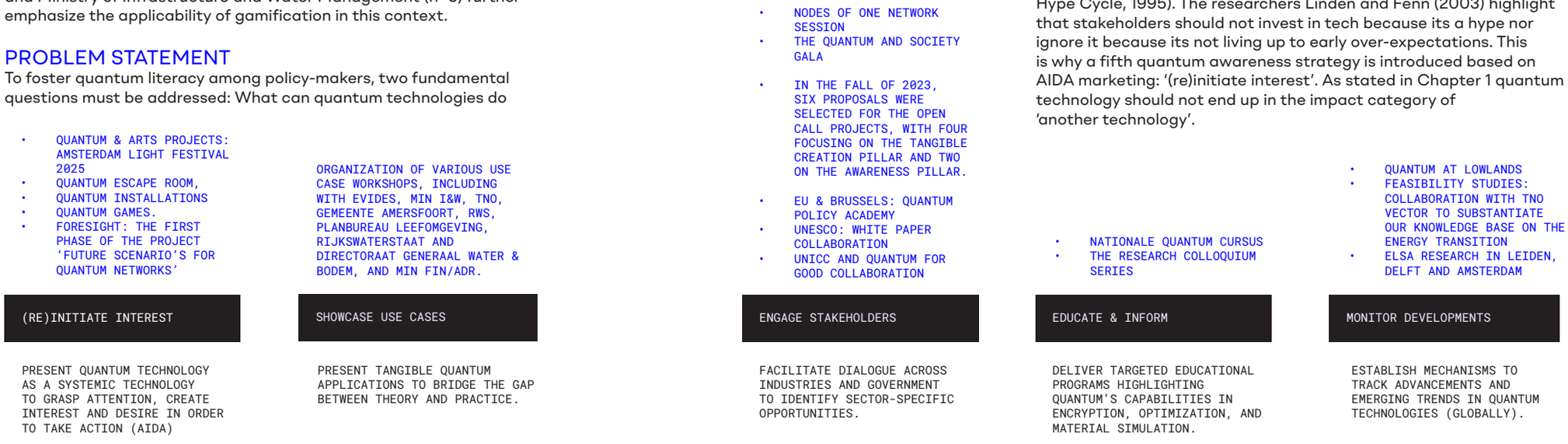


Figure 2.1: Quantum technology awareness strategies are linked to the CQS product portfolio.

POLICYMAKER (2024)

"Regarding your question about serious gaming, I haven't experienced that even once yet. Although I have come across it in my studies (Technology, Policy and Management), and it can truly be a useful tool."

EMAIL OF POLICYMAKER (2024)

"That game also sounds good; who knows, maybe we can do something with it."

GAMIFICATION AS A TOOL FOR STRUCTURED COLLABORATION

Gamification, particularly in the form of scenario games, has emerged as an innovative tool for fostering collaboration in governance. These games allow participants to adopt specific roles and simulate policy challenges in a controlled, risk-free environment. This approach encourages multi-perspective understanding and collaborative problem-solving (n=2; Interviews 1, 4) (Vervoort et al., 2022). Unlike traditional data-driven policy-making tools, scenario games emphasize creativity and innovation, allowing policy-makers to engage in forward-thinking discussions on complex technologies like quantum.

Despite their effectiveness, scenario games remain niche compared to mainstream commercial games. Their limited adoption stems from resource intensity and a lack of broader recognition as a governance tool (Bontoux et al., 2020; Vervoort et al., 2022). Although researchers Mayer et al. (2014) Hassan & Hamari (2020) and Ampatzidou et al. (2018) discuss the potential of gamefication for policymakers, however, no research was found poliycmakers were interested to partake. On the otherhand, all interviewees (n=5) mentioned they would be interested to join a session with games for policymaking.

To increase the possibility policymakers will become interested, four semi-structured interviews explored: How do policy-makers currently interact with emerging technologies, such as quantum, within departmental and broader ministry ecosystems? The challenges and opportunities presented by these interactions are analysed across four domains: staying informed, internal development, collaboration with knowledge institutions, and partnerships with market actors.

CURRENT INTERACTIONS WITH EMERGING TECHNOLOGIES

Policy-makers interact with new technologies through structured and informal mechanisms, enabling knowledge-sharing and strategic alignment within their departments. These interactions occur across four key domains. However, reliance on external expertise can lead to dependencies that may complicate the integration of these innovations into policy frameworks (Figure 2.2).

STAYING INFORMED IN THEIR PROFESSIONAL FIELD

Policy-makers remain updated on technological trends through trade fairs, industry events, and conferences, which offer opportunities to network and observe public sector-relevant innovations (n=1; Interview 4). Internal updates, such as policy memos and briefings, supplement these efforts (n=1; Interview 1). However, industry vendors often employ a "tech-push" approach, promoting technologies without aligning them to public sector priorities. This disconnect can overwhelm policy-makers with irrelevant solutions, creating tension between staying informed and maintaining focus on practical, policy-relevant innovations.

01 STAYING INFORMED IN THEIR PROFESSIONAL FIELD

02 INTERNAL DEVELOPMENT AT MINISTRIES

03 COLLABORATING WITH THE MARKET THROUGH CONSORTIUMS

04 COLLABORATING WITH EXTERNAL KNOWLEDGE INSTITUTIONS OR PARTIES

Figure 2.2: The four identified ways policymakers interact with (emerging) technologies.

INTERNAL DEVELOPMENT AT MINISTRIES

Internal collaboration within ministries is a critical mechanism for exploring the application of emerging technologies. Specialized colleagues with niche expertise provide depth in areas such as mobility, digital architecture, or climate policy (n=2; Interviews 1, 4). While this specialization fosters targeted innovation, it can also create silos that hinder broader adaptability across the ministry (n=1; Interview 2). Balancing specialization with interdepartmental collaboration remains a key challenge for ensuring both depth and breadth in technology integration.

COLLABORATIONS WITH KNOWLEDGE INSTITUTIONS

Partnerships with universities, research institutions, and other knowledge-based organizations enable policy-makers to access cutting-edge insights and methodologies. Municipalities often fund pilot projects in collaboration with these institutions, such as smart waste bins or quantum-safe encryption systems (n=3; Interviews 1, 2, 4). These partnerships provide a testing ground for evaluating the societal and operational viability of emerging technologies. However, reliance on external expertise can lead to dependencies that may complicate the integration of these innovations into policy frameworks.

COLLABORATING WITH THE MARKET THROUGH CONSORTIUMS

Policymakers engage with private-sector actors through consortiums and public-private partnerships. These collaborations bring state-of-the-art solutions into the public sector, leveraging market innovation and technical expertise (n=2; Interviews 2, 4). For example, multiple municipalities may work with technology vendors to develop shared data platforms or quantum-secure communication networks. While these partnerships enhance innovation, they require strategic oversight to align commercial objectives with public sector values and avoid overreliance on market-driven priorities.

This outlines the opportunity for the game to '(re)initiate interest'. It is key to integrate the game into the current interaction domains and to play into the need to stay informed in their professional domain or personal interest. During industry events and conferences where CQS is present, the game provides an additional way to engage with quantum technology collaboratively.

Policy design for converging technologies is difficult because it requires addressing regulatory overlap, managing new risks, ensuring accountability, keeping up with rapid evolution, and balancing global coordination, all while promoting innovation and maintaining public trust.

REGULATORY OVERLAP AND GAPS

When technologies from different fields converge (e.g., quantum and biotechnology), existing regulations may no longer be sufficient. The laws governing one technology might conflict with or not apply to the other, leading to regulatory overlap or gaps (F. Braza, R. Cordier & L. Quattrucci, Converged Technologies Expert Workshop, September 12 2024) (Policymaker at Ministry, personal communication, October 30 2024) (Belkom, 2024).

Overlap happens when multiple regulatory bodies might have jurisdiction over the converging technologies, leading to conflicting or redundant rules (Policymaker at Ministry, personal communication, October 30 2024).
For example, biotechnology, quantum technology, and data privacy regulators may be involved in overseeing reading and writing to the brain (F. Braza, R. Cordier & L. Quattrucci, Converged Technologies Expert Workshop, September 12 2024).
Gaps occur when existing regulations may not cover new intersections between technologies, creating a policy vacuum where neither technology is fully regulated (Policymaker, personal communication, October 30 2024). Another example, raises profound ethical questions about human enhancement, fairness, and the rights of individuals, when quantum and AI will be use in genetic editing. These innovations will not fully be addressed by traditional bioethics(F. Braza & R. Cordier, Converged Technologies Experts Workshop, September 12 2024).

UNCLEAR ACCOUNTABILITY

Convergence often makes it difficult to determine who is responsible for different aspects of the technology's regulation, use, and impact (Export Control Group, Quantum Policy Academy, October 10 2024)(Policymaker Ministry, personal communication, October 30 2024). Policymakers struggle with creating frameworks that clearly delineate accountability across multiple industries or stakeholders (Quantum Delta NL, 2021)(Schaminée, 2019).

For example, as technologies like AI and IoT merge, it becomes harder to attribute responsibility for things like data breaches, malfunctions, or ethical concerns. In autonomous vehicles, if AI algorithms (software) interact with physical vehicle components (hardware), it can be unclear whether the fault lies with the AI developer, the vehicle manufacturer, or the user when an accident occurs (Lee & Qiufan, 2024). When quantum computing is able to optimise traffic through real-time traffic flow analysis it adds anther factor to the accountability decisions.

RAPID TECHNOLOGICAL EVOLUTION

Technologies that converge often evolve quickly, making it hard for policy to keep pace (n=5; Interview 1, 2, 3, 4)(Schaminée, 2019). By the time regulations are drafted, the technological landscape may have already shifted, rendering the policies outdated or misaligned with current advancements and societal needs (Kong et al., 2024) (Schaminée, 2019). This lag creates challenges in ensuring responsible adoption, fostering innovation, and mitigating risks associated with emerging technologies (Hollanek, 2024).

For example, has the convergence of quantum, AI and big data analytics shifted the privacy and data protection landscape. It is outpacing many existing regulations like the General Data Protection Regulation (GDPR),a comprehensive data protection law enacted by the European Union (EU), or national privacy laws (B. Pataki, Converged Technologies Experts Workshop, September 12 2024).

COMPLEX RISK ASSESSMENT

Each technology on its own might pose specific risks, but when technologies converge, new risks emerge that may not have been anticipated (Kong et al., 2024)(The AI Risk Repository, 2024).
These new risks are often complex, involving interactions between both technologies (Goudsmit et al., 2022)(Schaminée, 2019). The combination creates new, unpredictable risks that are difficult to fully understand and regulate (Hollanek, 2024).

ECONOMIC AND MARKET DISRUPTION

Convergence often disrupts existing markets, business models, and economic sectors, creating challenges for policymakers who must balance supporting innovation with protecting existing industries (Feng et al., 2021)(Bharosa & Janowski, 2024). It requires policymakers to develop strategies to mitigate the economic disruption (Kong et al. 2024).

Materials will play a critical and strategic role in the emerging industry of quantum (D.Nas, personal communication, December 6 2024). Researchers mention that the critical component suppliers for quantum sensors are well-represented in the EU. However, increased foreign competition may change this picture as we move towards commercialising quantum sensors (Osorio Tamayo et al., 2024).

For example, an economic and market disruption will happen with the convergence of AI and autonomous robotics. It could lead to widespread job displacement in manufacturing and logistics, requiring a rethinking of labor policies, job training, and social safety nets (Lee & Qiufan, 2024).

GLOBAL COORDINATION AND STANDARDS

Converging technologies often operate across borders and sectors, making international coordination necessary (CJW Quantum Consultancy, Quantum Policy Academy, October 10 2024)(Quantum Delta NL, 2021) (Sitra, 2023). However, different countries have different regulatory frameworks, and coordinating policies on a global scale becomes a challenge (TNO, Quantum Policy Academy, October 10 2024). Additionally, converging technologies often require the development of new technical standards, which can be difficult to establish when industries and countries have differing priorities (CQS, Converged Technologies Workshop, September 4 2024) (CEN-CENELEC Focus Group on Quantum Technologies, 2023).

For example, autonomous vehicles rely on AI and telecommunications (5G), which require global coordination in terms of safety standards and data-sharing regulations. Countries with different approaches to data privacy, such as the EU and the US, can face challenges in aligning policies (Lee & Qiufan, 2024).

BALANCING INNOVATION WITH REGULATION

Converging technologies often push the boundaries of innovation, and policymakers need to strike a balance between fostering technological progress and ensuring safety, privacy, and fairness (Schaminée, 2019)(Policymaker Ministry, personal communication, October 30 2024)(Kong et al.,2024). Too much regulation could stifle innovation, while too little could lead to harm or misuse of the technology (Bharosa & Janowski, 2024). Policymakers must find the right level of intervention, which becomes more difficult when two or more rapidly evolving technologies are involved.

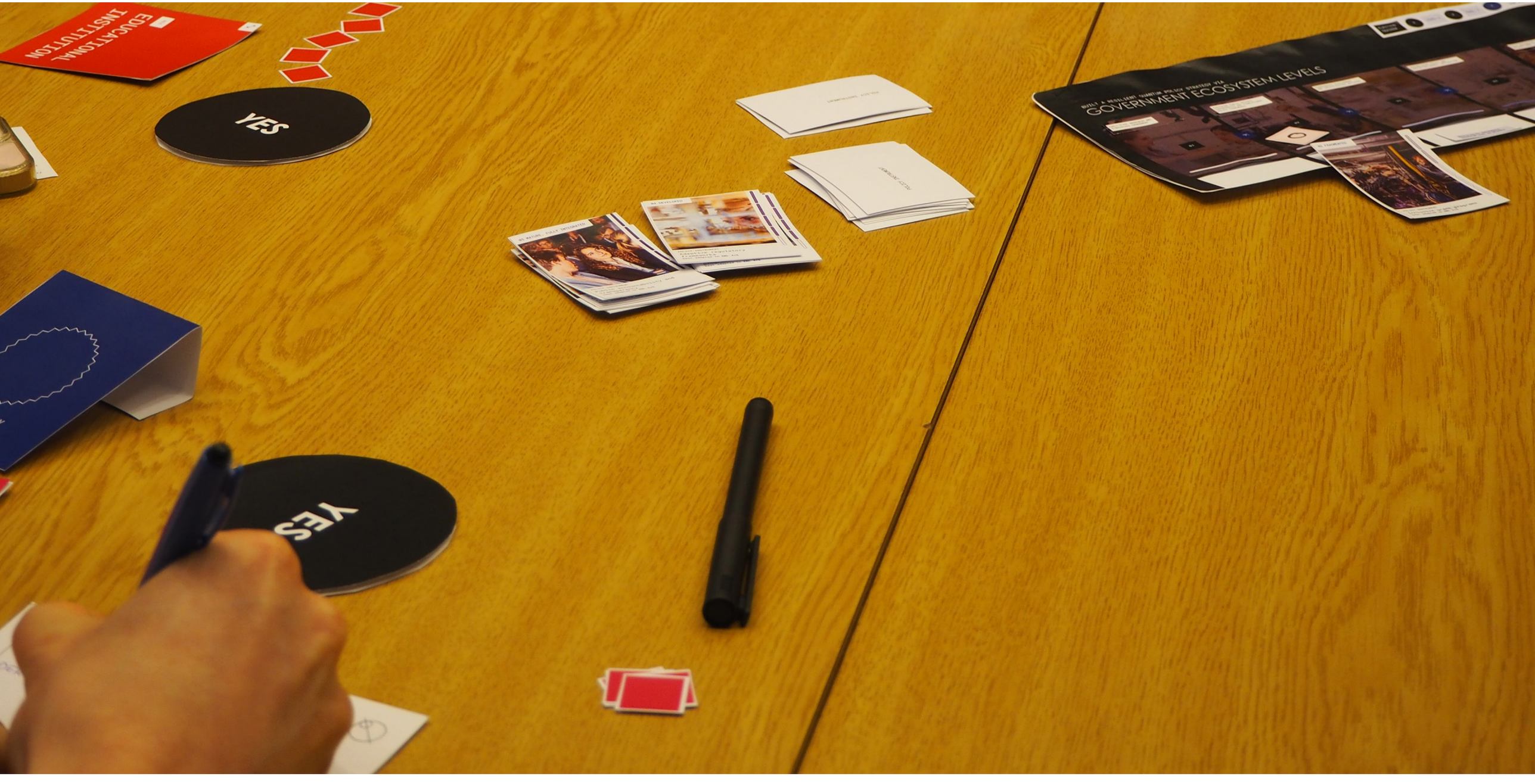
For example, overregulation could hinder innovation in decentralized finance with blockchain converging with AI. However, underregulation could lead to increased risks of fraud or market instability (Sitra, 2023) (Bank of Italy, Quantum Policy Academy, October 10 2024) (Groenland, 2024)(Lee & Qiufan, 2024).

PUBLIC TRUST AND PERCEPTION

Convergence of emerging technologies often leads to public concerns and scepticism, especially when the impact on privacy, jobs, or safety is unclear. Policymakers need to craft regulations that build public trust while allowing for innovation (Kong et al., 2024) (Schaminée, 2023) (Bharosa & Janowski, 2024). This is particularly challenging when the public may not fully understand how converging technologies work or what risks they pose (Quantum Delta NL, 2021) (Feng et al., 2021).

For example, the use of quantum-powered AI systems with personal data collection, raises significant privacy concerns (Lee & Qiufan, 2024). If policies are not designed in a way that addresses these concerns transparently, public trust may erode, hindering adoption (Ethiqual, Quantum Policy Academy, October 10 2024).

CHAPTER 4 **ITERATIVE DESIGN PROCESS TOWARDS THE QUANTUM FUTURES GAME**



This chapter overviews the design process of five game prototypes from low to high fidelity. The game evolved iteratively in order to find a fitting engagement for policmakers with varying levels of quantum literacy.

As posed in Chapter 1 the project's central inquiry is 'What do policymakers need to build quantum literacy?' More precisely: What do they need during an interactive activity at a quantum oriented event? Next to context immersion and inquiry of chapter 2 and 3, these needs were explored through interactive sessions at quantum events where the developed game materials were tried out and evaluated. Throuh the iterative process along side the quantum keynotes, it was also possible to indicate needs of CQS for better integration into the portfolio and convenient interaction for the session facilitator. Figure 4.1 shows an overview of the game prototypes and when needs were explored and turned into design requirements.

The evaluations were gathered via personal and session leaders' observations, open ended interviews and short questionnaires. The evaluation approach was based on the three Persuasive Game Design reflection categories: User Effect Level, Knowledge Level and Commercial Level (see Appendix A-E for detailed results). The data was reflected on in a conversations with Deborah Nas to stay in line with the aspirations of the Centre for Quantum and Society.

NOTE OF AUTHOR

The search for the amount and forms of information that could be converged into an iterative format depended largely on which excisted games were taken as inspiration. The first prototypes were, unintendedly, more focussing on stakeholder engagement via gamified facilitation of dialogue, although reaching for '(re)initiating interest'. The quest became to make the game mechanisms as simple as possible and the information in depth if 'searched for' by the policymaker.

Furtermore, a personal reflection was categorised in Gained knowledge about the people, the technology, the organisation and the design context. This led to the realisation of the postion of the prototypes on the awareness strategy overview created in Chapter 2 (see Figure 4.2) and the evolvement of narrative focus of the game prototypes (see Figure 4.3).

CONTEXT IMMERSION & INQUIRY

N=24

N=12

N=06

N=30

N=48

EXPLORATION OF

ENGAGEMENT REQUIREMENTS

01
CURIOSITY FOR QUANTUM SCENARIOS
CREATE CURIOSITY FOR POSSIBLE QUANTUM SCENARIOS.

02
DECISION-MAKING SUPPORT 1/2
INFORM DECISION-MAKING PROCESSES ON POTENTIAL IMPACTS OF QUANTUM TECHNOLOGIES

03
STRATEGIC POLICY ALIGNMENT
ALIGN GAME ELEMENTS WITH STRATEGIC POLICY GOALS.

04
PROFESSIONAL ENVIRONMENT RELEVANCE
ENSURE RELEVANCE TO PROFESSIONAL ENVIRONMENTS.

05
LONG-TERM VISION SUPPORT
SUPPORT LONG-TERM VISION BUILDING.

06
POLICYMAKERS INTEREST 1/2
ENCOURAGE TEAM-BASED ENGAGEMENT.

07
STRATEGIC POLICY ALIGNMENT
ALIGN GAMEPLAY WITH REAL-WORLD POLICIES.

08
COMPELLING NARRATIVE
INTEGRATE ENGAGING STORYTELLING ELEMENTS.

09
CQS USAGE SUPPORT 1/2
ENSURE AN ADAPTABLE GAME FRAMEWORK.

10
CQS USAGE SUPPORT 2/2
ENSURE A SCALABLE GAME FRAMEWORK.

11
(EVENT) CONTEXT INTEGRATION 1/2
PROMOTE STRUCTURED YET FLEXIBLE GAME FLOW.

12
GAMEPLAY DEVELOPMENT 1/3
SUPPORT EVOLVING GAMEPLAY, INTEGRATE QUANTUM ADVANCEMENTS.

13
POLICYMAKERS INTEREST 2/2
MAINTAIN BALANCE BETWEEN COMPLEXITY AND ENGAGEMENT.

14
DIVERSE LITERACY SUPPORT
ENSURE EASE OF UNDERSTANDING AND PARTICIPATION.

15
DECISION-MAKING SUPPORT 2/2
ENCOURAGE STRATEGIC THINKING, EXPLORE OUTCOMES TO PRIORITISATION OF VALUES.

16
GAMEPLAY DEVELOPMENT 2/3
SUPPORT DYNAMIC GAMEPLAY,ADD CONSEQUENCE OR PROGRESS INDICATORS

17
SOLUTIONS FOR TOMORROW
ENCOURAGE ACTIONABLE SOLUTIONS.

18
SYSTEMIC IMPACT OF QUANTUM
OFFER FULL DIVERSITY OF QUANTUM TECHNOLOGY APPLICATIONS (TO ACCELERATE AND MITIGATE).

19
(EVENT) CONTEXT INTEGRATION 2/2
MAINTAIN CLARITY IN GAME MECHANICS.

20
INFORMATION DEVELOPMENT 2/2
GIVE TIME TO UNDERSTAND THE GAME RULES

21
ITERATION ON SCENARIOS SUPPORT
SUPPORT SCENARIO FLEXIBILITY FOR FUTURE ITERATIONS.

21
INFORMATION DEVELOPMENT 1/2
ENSURE RELEVANCE YET TECHNICAL DEPTH IN QUANTUM TECHNOLOGY APPLICATIONS

22
GAMEPLAY DEVELOPMENT 3/3
SUPPORT DYNAMIC GAMEPLAY, PROVIDE VARIED EXPERIENCES EACH TIME THE GAME IS PLAYED

23
QUANTUM STAKEHOLDERS
OFFER FULL SPECTRUM OF QUANTUM TECHNOLOGIES' SOCIETY NEEDS, PERSPECTIVES AND ROLES.

Figure 4.1: The overview shows where policymakers, CQS portfolio and session facilitator needs turned into design requirements.

POSITIONING OF

PROTOTYPE AWARENESS STRATEGY

PROTOTYPE 01
HOW DID THE GAME RAISE AWARENESS?
MAKE POLICY LITERACY TANGIBLE, ENABLING STAKEHOLDERS TO ALIGN GOVERNANCE STRATEGIES WITH SOCIETAL AND TECHNOLOGICAL NEEDS

PROTOTYPE 02
HOW DID THE GAME RAISE AWARENESS?
USES A GLOBAL POWER STRUGGLE TO EDUCATE EMPLOYEES ABOUT FUTURE SOCIETAL IMPACTS OF QUANTUM TECHNOLOGY.

PROTOTYPE 03
HOW DID THE GAME RAISE AWARENESS?
INTEGRATING UNKNOWN SCENARIO DRIVEN PLAY WITH POLICY TOOLS, PARTICIPANTS COLLABORATIVELY IDENTIFY QUANTUM OPPORTUNITIES AND TEST GOVERNANCE FRAMEWORKS.

PROTOTYPE 04
HOW DID THE GAME RAISE AWARENESS?
HIGHLIGHT THE SYSTEMIC IMPACT OF QUANTUM TECHNOLOGIES VIA QUANTUM APPLICATIONS AND ITS CRITICAL MATERIALS, AND THE LINK WITH POLICY INSTRUMENTS

PROTOTYPE 05
HOW DID THE GAME RAISE AWARENESS?
HIGHLIGHT THE SYSTEMIC IMPACT OF QUANTUM TECHNOLOGIES VIA QUANTUM APPLICATIONS AND ITS CRITICAL MATERIALS, SHOW THE ROLE POLICY INSTRUMENTS COULD HAVE AND THE QUANTUM STAKEHOLDER ECOSYSTEM AROUND EACH APPLICATION

IT WAS NOT THE GOAL TO POSITION THE GAME HERE (SEE CHAPTER 1)

(RE)INITIATE INTEREST	SHOWCASE USE CASES	ENGAGE STAKEHOLDERS	EDUCATE & INFORM	MONITOR DEVELOPMENTS
PRESENT QUANTUM TECHNOLOGY AS A SYSTEMIC TECHNOLOGY TO GRASP ATTENTION, CREATE INTEREST AND DESIRE IN ORDER TO TAKE ACTION (AIDA)	PRESENT TANGIBLE QUANTUM APPLICATIONS TO BRIDGE THE GAP BETWEEN THEORY AND PRACTICE.	FACILITATE DIALOGUE ACROSS INDUSTRIES AND GOVERNMENT TO IDENTIFY SECTOR-SPECIFIC OPPORTUNITIES.	DELIVER TARGETED EDUCATIONAL PROGRAMS HIGHLIGHTING QUANTUM'S CAPABILITIES IN ENCRYPTION, OPTIMIZATION, AND MATERIAL SIMULATION.	ESTABLISH MECHANISMS TO TRACK ADVANCEMENTS AND EMERGING TRENDS IN QUANTUM TECHNOLOGIES (GLOBALLY).

Figure 4.2: The game prototypes are mapped on the quantum technology awareness strategy overview.

POSITIONING OF

PROTOTYPE NARRATIVE

PROTOTYPE 01
WHAT DID PARTICIPANTS HAD TO DO?
ASSUME STAKEHOLDERS ROLES, DEBATE STRATEGIES, AND USE POLICY INSTRUMENTS TO NAVIGATE QUANTUM-RELATED GOVERNANCE CHALLENGES

PROTOTYPE 02
WHAT DID PARTICIPANTS HAD TO DO?
ASSUME DEMOCRATIC OR AUTHORITARIAN STAKEHOLDERS, LEVERAGE POLICY TOOLS LINKED TO ECOSYSTEM READINESS LEVELS TO ACHIEVE THEIR QUANTUM SCENARIOS

MOVE THROUGH DISCOURSE OVER TIME

PROTOTYPE 03
WHAT DID PARTICIPANTS HAD TO DO?
EXPLORE THE SYSTEMIC IMPACTS OF QUANTUM TECHNOLOGIES WHILST REACTING TO THE THE DEVELOPMENTS BY BUILDING A GOVERNANCE ECOSYSTEM WITH POLICY INSTRUMENTS

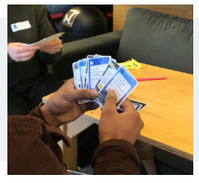
MOVE THROUGH DISCOURSE OVER TIME

PROTOTYPE 04
WHAT DID PARTICIPANTS HAD TO DO?
CARRY OUT A SECRET AGENDA TIED TO A FUTURE SCENARIO, DEPLOY QUANTUM TECHNOLOGY APPLICATIONS AND CRAFT POLICIES, SHOW ROLE MATERIALS PLAY WITHIN THE FUTURE DISCOURSE

PROTOTYPE 05
WHAT DID PARTICIPANTS HAD TO DO?
CARRY OUT A SECRET AGENDA TIED TO A FUTURE SCENARIO, DEPLOY QUANTUM TECHNOLOGY APPLICATIONS AND CRAFT POLICIES, SHOW ROLE MATERIALS PLAY WITHIN THE FUTURE DISCOURSE, REFLECT ON STAKEHOLDER RELATIONS AROUND THE QUANTUM APPLICATIONS

END WITH AN ACTIONABLE OUTCOME

BEGIN FROM 2050 NARRATIVE



CURRENT GOVERNMENT

QUANTUM DISCOURSE

FUTURE GOVERNMENT

Figure X: Quantum technology awareness strategies are linked to the CQS product portfolio.


Training
and Educatio
Programmes
Protecting
Critical
Infrastructure

The Quantum Futures Game combines strategic gameplay, policy engagement, and technological foresight to provide players with an interactive learning experience. This chapter explaines the game elements and dynamics.

The Quantum Futures Game challenges players to shape the future by crafting policies and deploying cutting-edge quantum technology applications. Each player carries a secret agenda tied to a future scenario: securing control, empowering communities, fostering innovation, or reshaping global dynamics. The game invites players to explore the transformative potential of quantum technologies.

The game operates on a multi-round structure where players win by strategically collecting and playing cards that align with their secret agenda. They accumulate the most points by forming high-scoring combinations and using key quantum technologies and policy instruments to shift the quantum trajectory towards their strategy (see Figure 5.1). The gameplay engages players into quantum computing, quantum sensing, networks, and key sector applications, as well as the policy mechanisms that influence technological adoption (see examples of the game cards in Figure 5.1).

GOVERNMENT TRAINEE 6 (2025)
"Quantum is everywhere!"

GAME STRUCTURE AND COMPONENTS

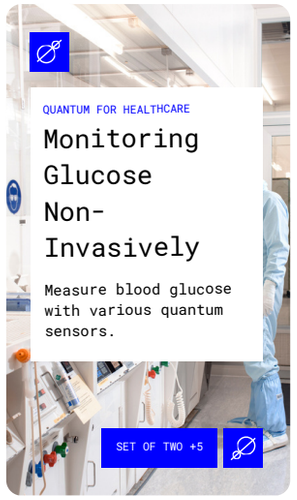
The game accommodates 2 to 4 players per team, with a recommended duration of 60-75 minutes. The following components shape the core mechanics:

Game Cards with quantum applications (Total: 112):

- Quantum for Infrastructure, Water Management, Energy Transition: 20 cards
- Quantum for Healthcare: 14 cards
- Quantum for Military: 14 cards
- Quantum Sensing: 26 cards
- Quantum Computing: 14 cards
- Critical Materials for Quantum: 10 cards

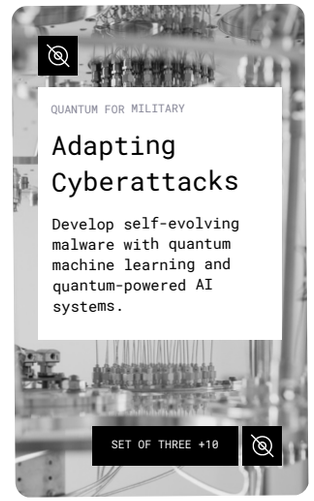
- Policy - Acceleration Factors: 6 cards
- Policy - Collaborations: 4 cards
- Policy - Strategies for Alignment: 4 cards

- Secret Agendas: 4 cards
- Leverage/Mitigate card and True card: 2 cards

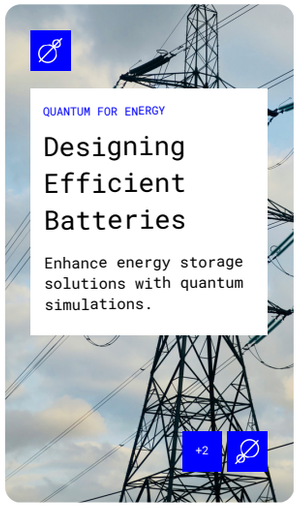


QUANTUM FOR HEALTHCARE
Set of two: **+5 points**
Less than two: **0 points**
Points can be doubled by using a Policy Card.

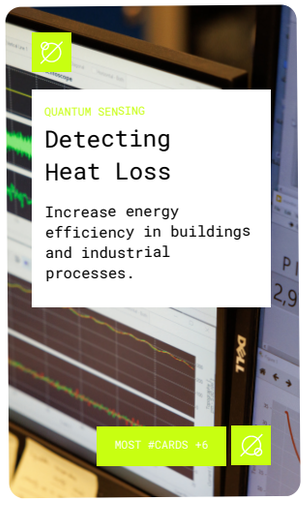
POLICY | ACCELERATION FACTORS
Doubles points of the card on top, only in combination with Quantum for Infrastructure, Energy, Water Management, Healthcare



QAUNTUM FOR MILITARY
Set of three: **+10 points**
Less than three: **0 points**
No special card combination.



QUANTUM FOR ENERGY
Per card **+2 points**
Points can be doubled by using a Policy Card.



QUANTUM SENSING
Most #cards: **+6 points**
Second most #cards: **+3 points**
Points can be doubled by using a Policy Card.

POLICY | STRATEGIES FOR ALIGNMENT
Doubles points of the card selection on top, only in combination with Quantum Sensing.

Figure X: The quantum application cards and policy cards a distincted and linked through colour and icon design.

GAMEPLAY MECHANICS

SETUP

Secret Agenda Distribution: Players receive one hidden Secret Agenda that defines their long-term strategy.
Card Dealing: Players receive eight cards from a shuffled deck, forming their initial hand.

GAME ROUNDS

The game is played over two structured rounds, with the following sequence:

- Card selection | Each player chooses one card from their hand and places it face-down.
- Revealing and sharing | The selected cards are revealed, and their effects are discussed.
- Card passing | Remaining cards are passed to the next player, following a predefined sequence.
- End of Round Evaluation | Players assess the impact of their played cards and adjust strategies.

SCORING AND WINNING CONDITIONS

The game concludes when all rounds are completed, and points are tallied based on the following criteria:

- Quantum Technology Cards | Different applications contribute varying point values.
- Policy Cards | Certain policies double point values of related technology cards.
- Critical Materials for Quantum | Scored at the end of the game, rewarding those with the majority.
- Secret Agenda completion | Players achieving their secret agenda gain an additional score boost.
- Tiebreaker Rules | If multiple players fulfill their Secret Agenda, the highest total points determine the winner.

Game set up is explained via printed game rules and guiding videos on how to play, how to count the points and how to structure the discussion (see Appendix E). applications and policy measures. The

GOVERNMENT TRAINEE 20 (2025)

"Be more aware of the different paths the world can take regarding the future of quantum."

PERCEIVING THE SYSTEMIC POTENTIAL APPLICATIONS OF QUANTUM TECHNOLOGIES

QUANTUM TECHNOLOGIES IN GAMEPLAY

The Quantum Futures Game integrates a range of quantum applications through a card-based strategy. Players collect and combine technology cards to achieve their Secret Agenda. This approach encourages players to recognize how different quantum innovations interact with broader technological ecosystems.

BUILDING QUANTUM SYSTEMS THROUGH CARD COLLECTION

Players accumulate cards that represent key quantum applications, such as:

- Quantum Computing for data encryption, financial modelling, and optimization challenges.
- Quantum Sensing for precision medical diagnostics and environmental monitoring.
- Quantum for Infrastructure supporting secure communications and optimized transportation networks.

By engaging with these mechanics, players develop an understanding of the systemic role of quantum technologies, reinforcing the game's educational objectives.

STRATEGIC COMBINATIONS & TECHNOLOGICAL IMPACT

Certain card combinations unlock additional strategic advantages, reflecting real-world quantum applications' cumulative effects. Through these interactions, the game models how quantum technologies contribute to system-wide transformations. For example:

- Pairing Policy Collaborations with Quantum Computing Cards can simulate advancements in early disease or company advancements detection.
- Combining Policy Acceleration Factor Cards with Infrastructure Cards represents how governments can accelerate quantum adoption.

GOVERNMENT TRAINEE 37 (2025)

"I was pleasantly surprised by the practical applications."

Figure X: Government trainees tested the Quantum Futures Game which was an interactive element during a quantum and innovation trainee day.

ENCOURAGING DECISION-MAKING WITH A FUTURE-ORIENTED MINDSET

ADAPTIVE STRATEGY DEVELOPMENT

Players must continuously adapt their decision-making as they navigate the game, reflecting the unpredictability of technological evolution. The game employs:

- Scenario-based Secret Agendas drive player objectives and reinforce long-term strategic choices.
- Dynamic card exchanges simulate the competition for quantum resources.

RISK ASSESSMENT & REINFORCEMENT LOOPS

The game includes positive and negative reinforcement mechanisms, encouraging players to assess risk while making strategic decisions:

- Positive Reinforcement | Successful technology combinations result in bonus points, reinforcing optimal decision-making patterns.
- Negative Reinforcement | Failing to complete a technology set penalizes players, driving adaptive risk-taking strategies
- Variable Rewards | The randomization of available quantum cards ensures that players remain engaged with shifting strategic landscapes.

GOVERNMENT TRAINEE 42 (2025)

"In policymaking about quantum, you have to consider the long term a lot can change."

Figure X: Participants had to collect quantum applications, policy instruments and critical materials in order to reach their Strategic Agendas.

Figure X: Government trainees tested the Quantum Futures Game which was an interactive element during a quantum and innovation trainee day.

ENGAGING IN POLICY DISCUSSIONS ABOUT QUANTUM AND SOCIETY

DISCUSSION-BASED LEARNING & SOCIAL INFLUENCE

The Quantum Futures Game incorporates structured discussion rounds, where players debate and negotiate their strategies in response to shifting technological landscapes. These discussions allow players to:

- Explain and refine strategic choices for the different future scenarios.
- Adapt to stakeholder perspectives.
  Consider ethical and governance challenges related to quantum technologies.

ROLE OF STAKEHOLDERS & POLICY INTEGRATION

Players engage with a variety of stakeholders in quantum governance, such as:

- Corporations are driving the commercialization of quantum technologies.
- Educational institutions contributing to quantum advancements.

Including policy cards shows the possible influence governance can have on quantum innovations. In the game, players can use policy instruments in governance structures to double the points of quantum application collections.

NEGOTIATION & DECISION-MAKING IN A QUANTUM FUTURE

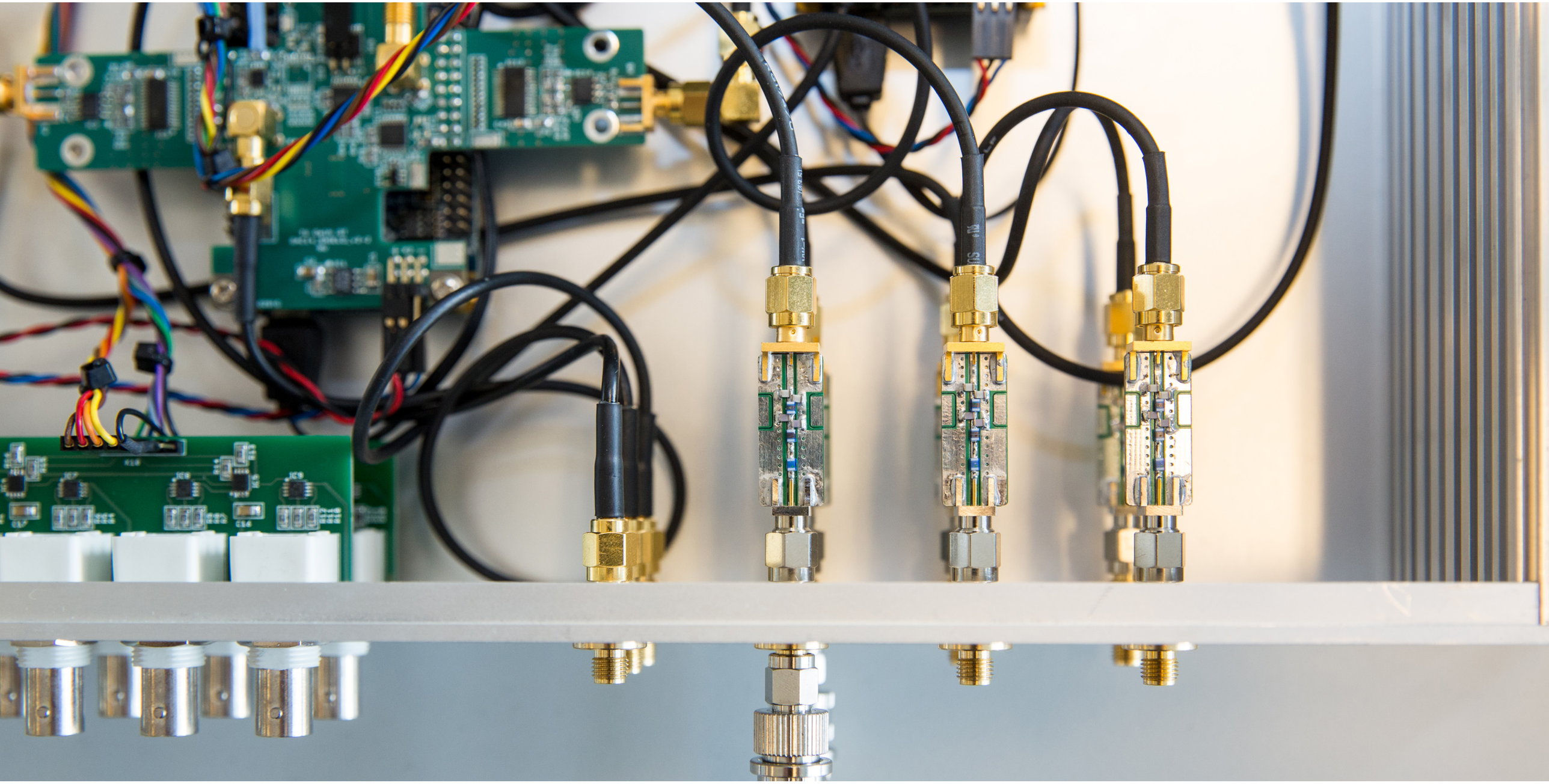
As the game progresses, players must negotiate competing technological priorities and align their strategies with long-term quantum governance goals. These discussions would ideally lead to topics such as:

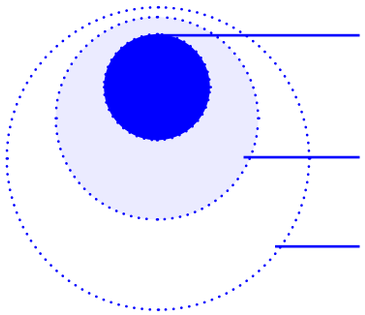
- Trade-offs between security and innovation.
- Balancing economic incentives with ethical concerns.
- Global collaboration versus national competition in quantum research.

Through these discussions, the game encourages players to engage in meaningful debates on the societal impact of quantum technologies.

GOVERNMENT TRAINEE 51 (2025)

"Discussions about quantum need to happen now, especially for policymakers who tend to lag behind the commercial companies."





This chapter outlines the strategic foundation of the product, covering its core contribution, impact, audience, engagement strategies, and market positioning. Through interactive engagement and systemic thinking, the product enables policymakers to make informed, forward-looking decisions on quantum governance.

PRODUCT'S CORE PURPOSE

The core purpose of the product is to gamify the relationship between quantum applications and policy instruments, ensuring systemic understanding and practical application for policymakers. See Figure 5.1 for the why, how and what of the Quantum Futures Game.

WHY?
THE PRODUCT IS DESIGNED TO:
ENCOURAGE CONVERSATIONS ABOUT THE POSSIBLE IMPACTS OF QUANTUM TECHNOLOGY.
SUPPORT POLICYMAKERS IN EXPLORING: WHAT CAN QUANTUM TECHNOLOGY CONTRIBUTE TO MY AREA OF EXPERTISE?

HOW?
BY FOCUSING ON TWO KEY ASPECTS:
- UNDERSTANDING THE SYSTEMIC IMPACT OF QUANTUM TECHNOLOGY.
- EXAMINING THE ROLE OF GOVERNMENTS IN SHAPING QUANTUM DISCOURSE.

WHAT?
THE PRODUCT FACILITATES ENGAGEMENT THROUGH:
- QUANTUM TECHNOLOGY APPLICATIONS, HELPING POLICYMAKERS CONSIDER QUANTUM'S ROLE IN BROADER SYSTEMS.
- POLICY INSTRUMENTS, HIGHLIGHTING HOW GOVERNMENT DECISIONS INFLUENCE QUANTUM INNOVATION.
- DISCUSSION ROUNDS, SIMULATING STAKEHOLDER INTERACTIONS THROUGH ROLE-PLAYING.
- FUTURE SCENARIOS (2050 VISION), PROVIDING STRATEGIC AGENDA CARDS THAT CONNECT QUANTUM ADVANCEMENTS TO POLICY STRATEGIES.

Figure 5.1: The why, how and what of the Quantum Futures Game

PURPOSE AND VISION STATEMENTS

The purpose statement outlines the intended impact:
Gamify the link between quantum applications and policy instruments so that the systemic applicability of quantum is approachable for varying quantum literacy levels.

The vision statement sets the long-term goal:
Strengthening engagement among policymakers to support informed decision-making on the societal and economic impacts of quantum technologies.

VISION STATEMENT
Gamify the link between quantum applications and policy instruments so that the systemic applicability of quantum is approachable for varying quantum literacy levels.

VISION STATEMENT (LONG TERM)
Support informed decision-making on the ethical, legal and societal impacts of quantum technologies.

By combining interactive learning, strategic foresight, and applied policymaking, the product ensures that quantum technologies are integrated into future governance strategies with clarity and confidence.

FUTURE MPLEMENTATION

The product is designed to enhance visibility, increase engagement, and prepare policymakers for long-term governance strategies. The structured implementation follows a phased approach, ensuring iterative improvements:

Aspirations are to expand visibility through game and tool development. Secod, encourage policymakers to examine short- and long-term governance challenges related to quantum technologies. Third, enable engagement by showcasing what quantum technology can achieve beyond how it functions.

- Now the Quantum Futures Game could be integrate into keynote events as an interactive activity.
- In the near future beter targeted discussion rounds are developed to create in depth workshop tools for different policymaking audiences.
- Mid-Term real-world case markers could be introduced to show which quantum applications are in practical use and which impacts are identified.
- Long-Term the content can be extended by incorporating new quantum application cards and tailoring workshop materials to other market stakeholders such as water, healthcare, and infrastructure coorporations.

PRODUCT VALUE AND TARGET AUDIENCE

The product is grounded in five core values:
- Collaboration – Encouraging multi-stakeholder engagement and knowledge-sharing.
- Curiosity – Inspiring policymakers to explore emerging opportunities in quantum.
- Learning – Increasing quantum literacy across different policymaking levels.
- Reflective Thinking – Encouraging critical examination of quantum's potential risks and benefits.
- Society-Driven – Ensuring quantum technology aligns with public interest and ethical governance.

The primary audience consists of government policymakers, with a focus on building resilient governance structures for quantum technology.

KEY CHALLANGES QUANTUM POLICY DESIGN

Policymakers face significant challenges in quantum governance, including regulatory inconsistencies, legal gaps, complex risk assessments, and security concerns. The need for global coordination and standardization further complicates decision-making, while unclear accountability and ethical dilemmas raise concerns about responsibility in quantum development. Balancing rapid technological innovation with stable regulation presents an ongoing struggle, as does managing economic and societal disruptions caused by emerging quantum applications. Additionally, public trust and perception challenges must be addressed to ensure acceptance and responsible adoption.

To navigate these complexities, policymakers require structured tools that enable them to make well-informed decisions about quantum adoption, seeing quantum technology as an enabler rather than a predefined solution. A clear understanding of sector-specific applications is crucial for developing policies that align with both technological advancements and societal needs. Without proactive engagement, there is a significant risk of uninformed adoption, leading to reactive governance and missed strategic opportunities in quantum policymaking.

MARKET ANALYSIS

The market analysis identifies two major opportunities for differentiation (see Figure X). leading to a positioning statement.

We help governments that want to make informed decisions by providing a context-adaptable and audience-specific format that allows policymakers to experience the systemic impact of quantum technology.

Our solution invites policymakers to participate in society's preparation for quantum technology discourse through an interactive, strategic, and engaging experience.

This positioning ensures the product is practical, relevant, and valuable for policymakers facing complex governance challenges.

Opportunity 1: Quantum Engagement as a Strategic Discussion Tool
The X-axis represents the focus of quantum conversations, ranging from personal quests for knowledge to group exploration, while the Y-axis contrasts technical insights with societal impact. The key benefit lies in presenting quantum as a systemic technology, leveraging interactive engagement to generate interest and actionable insights within policymaking networks.

POSITIONING STATEMENT

We help governments that want to make informed decisions by providing a context-adaptable and audience-specific format that allows policymakers to experience the systemic impact of quantum technology.

Opportunity 2: Gamification vs. Discussion-Based Engagement
X-Axis: Type of engagement tool (Discussion-based vs. Game-based).
Y-Axis: Purpose of engagement (Mutual understanding vs. Technology impact analysis).
Key Benefit: Unlike traditional policy-making tools, this product integrates scenario-driven learning and creative problem-solving, helping policymakers develop future-proof quantum strategies.

ENGAGEMENT & COMMUNICATION STRATEGY

A multi-channel communication plan ensures visibility and ongoing engagement of digital presence, social media, video content, promotional content or relational gifts at events.

The landing page provides PDF Print & Play game materials and game rules supported by explenation videos for easy adoption, reinforcing re-engagement through the message, "Want the same experience? Let's do it again!" (see Figure 5.2). To launch its presence, LinkedIn updates are scheduled every two weeks, while a promotional video featuring event highlights and expert interviews showcases the product's impact.

Strategic distribution includes using game materials as discussion aids at policy summits and diplomatic events, complemented by relational gifts to strengthen engagement. Key events include World Quantum Day (April), Quantum Meets: Public Interest Technologies (May), Quantum4Good UNICC (May), and Quantum4Good UN (September-October). Future initiatives involve a finance-focused quantum event (TBD) and an expert interview series exploring quantum's role in policymaking.

Figure 5.2: The landingpage provided a downloadable PDF of the game materials, game rules and discussion structures.

MARKETING AESTHETICS

Quantum Delta NL's marketing aesthetics emphasize a clean, modern design that reflects the cutting-edge nature of quantum technology. The use of bold typography, vibrant imagery, and structured layouts effectively conveys their commitment to innovation and collaboration within the quantum ecosystem. As these marketing aesthetics are also used for the game development, is for the communication materials an inspiration board is creating to derive a tagline and tone of voice for further implementation (see Figure 5.3).

Figure 5.3: Inspiration board for marketing purposes of the Qauntum Futures Game

In this chapter, the Quantum Futures Game is assessed on the qualification as Persuasive Game Design (PGD) and the design requirements stated in Chapter 4 to see where potential lies for improvement of the game.

The analyses reviews the design requirements linked to game design and stakeholder engagement and suggest potential gains based on Hooked Model strategies of Nir Eyal and Persuasive Game Design strategies.

NOTE FROM AUTHOR
Persuasion is a core theme in Persuasion Game Design, however, within the government context it is more an 'image towards technology' problem (as stated in Chapter 1). This asks for other strategies than 'persuasion'. In order to stay with the intended approach, the potential gains contain inspiration from the theory.

SCENARIO GAMES

The game incorporates scenario-based narrative, role-playing, and stakeholder engagement, all techniques used in persuasive game design. The game subtly nudges players toward understanding quantum's systemic impact by assigning Secret Agendas and requiring them to craft policies to increase collected points.

POTENTIAL GAIN
While the game encourages awareness and discussion, its primary function appears to be quantum technology exploration rather than direct scenario exploration with its potential behavioural benefits (see Chapter 2). Unlike scenario games that aim for specific attitude shifts, this game leans more towards quantum literacy rather than active scenario immersion. Here still lies an opportunity to add to the CQS portfolio.

HOOKED-MODEL AND GAME PERSUASION STRATEGIES

The game is explicitly designed to engage policymakers in discussions about quantum technologies and their societal impact. Its goal is to initiate interest, encourage strategic reflective thinking, and promote understanding of quantum-related governance challenges. 60% of the participants at the traineesday (n=29, 100 procent of all reflections) named 'quantum technology' in a positive sense as their main insight after the activity.

POTENTIAL GAINS
The game's core interest triggers are more focused on education rather than game persuasion. 44% of the participants (n=21, 70% of all reflections) noted improvements for the game structure, materials and explanation of the rules. More iterations are needed to optimize game mechanisms.

Enhance variable rewards by implemention of a system of unpredictable rewards to increase engagement. This could include surprise bonuses, random challenges, or hidden achievements that players can discover throughout the game (Eyal, 2025). This aligns with the Variable Reward step of the Hook Model, which creates intrigue and desire to continue playing (Matthiopoulos, 2023).

Enhance user experience by focussing on creating a more immersive and enjoyable game world experience (De la Hera et al., 2021). This could involve improving graphics, sound design, or narrative elements to make the game more captivating.

Personalize the experience by implementing adaptive difficulty levels or personalized content based on player performance and preferences. This can help maintain the balance between challenge and skill, keeping players in a state of flow (Visch et al., 2013).

ROLE OF POLICY CARDS

The game gamifies policy discussions by integrating:
Quantum Policy Cards and the different point strategies for collecting Quantum Applications that influence strategic thinking. Future Scenarios that create a sense of consequence. These mechanics simulate real-world decision-making, which aligns with persuasive game design. Secret Agendas that subtly push players toward certain decision-making paths.

POTENTIAL GAIN
While the game models policy consequences, it does not appear to reward or penalize specific real-world behaviors, as adopting certain policies in their actual roles. Without explicit feedback loops, its persuasive effect may be limited.

BEHAVIORAL IMPACT MEASUREMENT

The game incorporates survey-based impact assessment to measure changes in players' understanding of quantum technologies post-game. This approach aligns with the 'Investment' phase of the Hooked Model, encouraging players to reflect on their learning experience. However, to fully leverage persuasive game design principles, the assessment could be expanded to include more

interactive and immersive evaluation methods (Visch et al., 2013) (Eyal, 2025).

POTENTIAL GAINS

Implement a longitudinal tracking system to monitor how policymakers apply learned insights in their real-world decision-making. This aligns with the 'Trigger' phase of the Hooked Model, creating external cues that prompt players to revisit and apply game concepts.

Introduce in-game challenges or scenarios that simulate real-world policy decisions, allowing for immediate behavioral assessment. This ties into the 'Action' phase of the Hooked Model and reinforces procedural rhetoric in persuasive game design.

Develop a system of variable rewards based on players' real-world application of game concepts. This could include recognition, additional resources, or advanced game features, tapping into the 'Variable Reward' phase of the Hooked Model.

RECEIVE REAL-TIME FEEDBACK

Unlike straight-forward gamification, which mostly adds points and rewards, this game involves role-playing, decision-making, and scenario-building, which are hallmarks of persuasive game design.

POTENTIAL GAIN

The game's current design lacks structured reinforcement mechanisms, such as variable rewards or repeated triggers, to ensure lessons translate into sustained real-world behaviour. While it effectively sparks short-term discussion, integrating elements from the Hooked Model, could enhance its long-term persuasive impact by encouraging habitual engagement. By applying the strategy of reinforcement loops, players could receive real-time feedback on their decisions' potential impact on real-world scenarios (Visch et al. 2013).

NOTE FROM AUTHOR

During this project, validating outcomes were received eventhough it was still in its development phase. A re-invitation to host an interactive session at the Centre for Future Generations Flagship event after the Quantum Policy Academy session. Second, interest at Alliander to investigate broader cybersecurity impacts with CQS. Important to note is that a main part of this success is also due to the convincing and inspiring quantum innovation keynotes and the link with CQS as an organisation open to further collaboration.


WELCOME TO THE Q-EXPO
AMIRES
QBLOX
Control The Quantum Future
Fully-integrated Quantum Control Stacks
All-to-all connectivity Fast Scalable Feedback
QU-PILOT
QU-TEST
MULTIVERSE COMPUTING
kiutra
Q·bird
quantum connectivity
Is your Data really Safe?
Personal touch in patents

This chapter starts with a suggestion called ‘ecosystem readiness levels’, as a systems-oriented approach for discussions. This suggestion bundles a series of discussion structures as addition to the Quantum Futures Game. These could help unfold the main challenges mentioned in chapter three.

The discussion structures were reviewed via semi-structured interview with a colleague from the legal PhD team of CQS, a policymaker from the interview in the beginning of this research, a data governance trainee and a Nationale Nederlanden trainee.

A SYSTEMS-ORIENTED APPROACH

Emerging technologies often require a systems-oriented approach, as illustrated by the S-T-A-M model, which highlights how technologies transition from scientific discovery to market application (Phaal et al., 2011). This phased understanding into a governance structure, enables navigation of industrial emergence challenges such as changing in perspective towards technology and stakeholder interest. (Adner &Kapoor, 2011). The quantum internet ecosystem strategy for the Port of Rotterdam proves that analysing the industrial emergence of a technology could help with creating ecosystem strategies. .. (2024) suggests: “Transferring this approach to different settings could be interesting to see if it is indeed a valid strategy.”

Applying ecosystem theory strategies to the government context aligns with the vision of QDNL of creating a quantum ecosystem and makes it particularly effective in fostering cross-sectoral collaboration and encouraging stakeholders to actively engage with systemic challenges (QDNL, 2024).

ACTIONABILITY IN TACKLING GOVERNANCE CHALLENGES

The observed pains in chapter three could be categorised as ‘wicked problems’. A wicked problem is defined as complex issue are difficult or impossible to solve because of incomplete, contradictory, or changing requirements (Rittel & Weber, 1973). These problems often involve multiple stakeholders with conflicting interests and have no clear or definitive solution (Buchanan,2015; Norman & Stappers, 2015). For example Ministry of Justice and Security (JenV) feel increasing urgency for tackling these wicked problems and have a vision with a focus on actionability (Çakir, 2022).

TECHNOLOGY READINESS LEVELS (TRL) AND MARKET READINESS LEVELS (MRL)

NASA introduced Technology Readiness Level (TRL) to compare and indicate how technologies are evolving in order to create technology strategies (Straub, 2015). Likely inspired, CloudWATCH2 introduced Market Readiness Level (MRL). Starbridge Venture Capital has also developed a similar concept for evaluating commercial viability of technologies and companies. Innovation Fund Denmark created the Societal Readiness Levels (SRL) scale, which is related to market readiness and public acceptability of technologies. The U.S. Department of Defense has used Manufacturing Readiness Levels, which are sometimes also referred to as Market Readiness Levels.

TRL is a scale from 1 to 9, where TRL 1 represents basic principles observed and reported, while TRL 9 indicates a system ready for full-scale deployment. MRL and SRL use a scale from 0 to 9.

These actionable tools as TRL, MRL and SRL help decision-making because of a clear metric to place a technological innovation. Interestingly, this technology-push or market-push perspective aren’t the only two perspectives governments take on (n=1, Interview 5). Decision are made bases on ethical (justified by moral responsibility), political (aligns with excisting laws and regulations), legal (chosen through political decision-making) and societal(citizens perceive it as legitimate) dimensions (Bruggenbouwer, 2024).

INTRODUCTION OF ECOSYSTEM READINESS LEVELS (ERL)

For governments it is important to prepare society before technology is widely adopted. From their perspective it is about how the governance ecosystem is evolving and if society is ready or resilient enough to sustain and support technological innovations (Bruggenbouwers, 2024). An systems-oriented or ecosystem approach could suit this need.

Based on the ecosystem theories used for the Port of Rotteram quantum network strategy, figure X shows a proposal for an ecosystem strategy for governments. It is partly set up by conversationally iterating with ChatGPT with the goal to categorize the different policy instruments and find a way to see them as a usefull governance tool in guiding the quantum technology disccourse.

The conversation included questions about the link between policy design and TRLs. Also, questioning what makes policy design

difficult when two technologies converge over time? What role can anticipatory governance and foward-thinking regulations play? Which led to the question: Do ecosystem readiness levels exist? The answer was ‘not really’.

Accoring to the policymaker and governance trainee such a structure could help policymakers ensure better alignment between the envisioned governance ecosystem and the actual paths being taken (visualised in Figure 6.1).

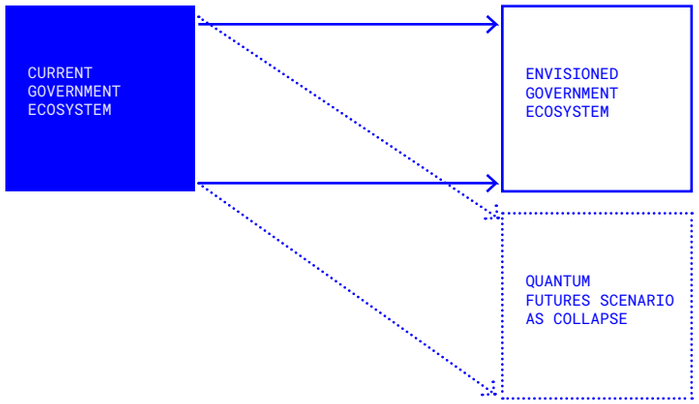


Figure 6.1: Not anticipated futures scenarios as Collapse Scenario could be on the horizon without realising.

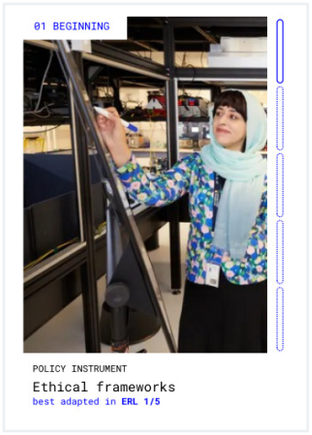


Figure 6.2: An example policy instrument of prototype 3 was used to built an ecosystem governance.

PROPOSAL FOR ECOSYSTEM READINESS LEVEL (ERL)USE

Staying in line with the function of TRL and MRL, an Ecosystem Readiness Level framework can be set up as a matrix to evaluate how prepared a broader ecosystem is for the successful adoption and scaling of new technologies, innovations, or industries. The prototype tests at Alliander (prototype 2) and Ministry of BZK (prototype 3, see example policy instrument in Figure 6.2) led to the choice of first four to later five levels due to practicallity reasons as desired duration of the game (see Figure 6.3 for an example of how an ecosystem readiness level framework could look like).

This Ecosystem Readiness Level framework fits a certain type of governance called anticipatory governcance which employs

PER ERL ECOSYSTEM PHASE ADAPTED

POLICY INSTRUMENTS

POLICY INSTRUMENTS	GOVERNANCE ECOSYSTEM LEVEL
• PUBLIC AND STAKEHOLDER CONSULTATIONS • AWARENESS CAMPAIGNS • ETHICAL FRAMEWORKS • INITIAL RESEARCH FUNDING	01 EARLY-STAGE AWARENESS AND STAKEHOLDER ENGAGEMENT UNDERDEVELOPED ECOSYSTEM WITH LIMITED INFRASTRUCTURE, LOW COORDINATION, MINIMAL REGULATORY FRAMEWORKS, AND LOW AWARENESS. EFFORTS ARE MAINLY ACADEMIC OR NICHE, WITH QUANTUM START-UPS RARE OR NONEXISTENT AND COMMERCIAL COMPANIES LARGELY UNINVOLVED.
• PUBLIC-PRIVATE COLLABORATION: • PILOT PROJECTS AND SANDBOX PROGRAMS • INCLUSIVE GRANT PROGRAMS • EARLY-STAGE REGULATIONS AND STANDARDS	02 PUBLIC-PRIVATE PARTNERSHIPS AND FOUNDATIONAL POLICY FRAMEWORKS SCATTERED STAKEHOLDER EFFORTS WITH BASIC INFRASTRUCTURE BUT LACKING SUFFICIENT FUNDING, COLLABORATION, AND PUBLIC AWARENESS. QUANTUM START-UPS BEGIN TO EMERGE BUT OPERATE IN ISOLATION, WHILE COMMERCIAL COMPANIES SHOW INITIAL INTEREST BUT LACK STRATEGIC COORDINATION.
• INFRASTRUCTURE DEVELOPMENT WITH PUBLIC INPUT • CROSS-SECTOR PARTNERSHIPS • ETHICAL AND SOCIETAL IMPACT ASSESSMENTS • FORMALISED PUBLIC ENGAGEMENT	03 COORDINATED DEVELOPMENT AND INFRASTRUCTURE BUILDING STAKEHOLDER COORDINATION BEGINS WITH EARLY-STAGE POLICIES, FUNDING MECHANISMS, AND INFRASTRUCTURE. QUANTUM START-UPS INCREASE COLLABORATION WITH ACADEMIA AND INDUSTRY, BECOMING KEY INNOVATORS. COMMERCIAL COMPANIES INVEST MORE IN QUANTUM TECHNOLOGIES, POSSIBLY ESTABLISHING DEDICATED R&D DIVISIONS. PUBLIC AND INDUSTRY INTEREST GROW, BUT SCALABILITY REMAINS A CHALLENGE.INTEREST GROW, BUT SCALABILITY REMAINS A CHALLENGE.
• HARMONIZATION OF REGULATIONS • PUBLIC-PRIVATE INCENTIVES • ADAPTIVE REGULATORY FRAMEWORKS • TRAINING AND EDUCATION PROGRAMS	04 STREAMLINED POLICY AND SUPPORTING MARKET INTEGRATION WELL-DEVELOPED INFRASTRUCTURE WITH GROWING PUBLIC AND PRIVATE INVESTMENT, AND EMERGING MARKET MECHANISMS. QUANTUM START-UPS MATURE INTO ESTABLISHED ENTERPRISES CONTRIBUTING SIGNIFICANTLY TO COMMERCIALIZATION. COMMERCIAL COMPANIES ACTIVELY INTEGRATE QUANTUM TECHNOLOGIES INTO PRODUCTS AND SERVICES, SOMETIMES ACQUIRING START-UPS. TECHNOLOGIES GAIN LARGER-SCALE ADOPTION, THOUGH MATURITY AND INTEGRATION CONTINUE TO EVOLVE.
• PUBLIC ACCOUNTABILITY AND TRANSPARENCY • CONTINUOUS ECOSYSTEM REVIEW AND ADAPTATION • ETHICAL LEADERSHIP AND GLOBAL EXPORT OF BEST PRACTICES • GLOBAL COLLABORATION ON STANDARDS	05 FULLY INTEGRATED ECOSYSTEM WITH INTERNATIONAL COLLABORATIONS BROAD COLLABORATION AMONG STAKEHOLDERS WITH ROBUST REGULATORY FRAMEWORKS AND EXTENSIVE PUBLIC AND PRIVATE INVESTMENT. QUANTUM START-UPS AND COMMERCIAL COMPANIES ARE FULLY INTEGRATED INTO THE ECONOMY, DRIVING CONTINUOUS INNOVATION AND WIDESPREAD MARKET ADOPTION. THE ECOSYSTEM DEMONSTRATES RESILIENCE AND ADAPTS TO TECHNOLOGICAL ADVANCES.

Figure 6.3: A governance Ecosystem Readiness Level proposal which still need some critical iterations to be usefull.

forward-thinking and scenario-based regulations. A forward-thinking regulation aims to guide innovation while protecting public interests, anticipating future challenges, and enabling stakeholder collaboration (source). It is a proactive, flexible, and adaptive aproach to governing the evolving technologies and industries (Schaminée, 2017).

NOTE FROM AUTHOR:
This proposal needs more critical iteration and validation to become usefull. Which is going to happen as I have to belief a LinkedIn post from January 27st 2025. A new PhD at the Governance and Ethics Lab of Technoloy, Business and Management Faculty of TU Delft has started with one of the goals to 'create actionable governance tools and strategies that prioritize societal good alongsie technological an economic advancements.' She is also linked to the Centre for Quantum and Society, so I'm curious to see what's next!

SERIES OF DISCUSSION STRUCTURES AS ADDITION TO THE QUANTUM FUTURES GAME

The quantum applications, policy instruments and stakeholders cards are designed for a game structure based on 'Sushi Go!' rules. However they can fit more purposes depending on the needs of the policymakers, event location or call to action of the event. As the content of the game included a broad scala of applications, as it was designed to show the systemic impact of quantum, they can facilitate a systems-oriented approach for discussions. The proposal of an Ecosystem-Readiness Level framework bundles a series of discussion structures as addition to the Quantum Futures Game. These could help unpack the main challenges, the wicked problem boxes mentioned in chapter three.

EXPLORE REGULATION OVERLAP AND GAPS

Discussion Structure: Map 'holistically' excisting and planned regulatios for a chosen quantum application. See what is needed for improvement for a governmental adoption.
Goal: create awarenes around possible creation of overlaps and gaps in existing regulations when technologies converge.
Value proposition: Encouraging critical reflection, instead of offering fixed solutions, it could prompt participants to question policy-quantum systems, their motivations, and their broader societal impacts.

In order to identify critical regulatory intersections it is neccesary to align regulations across domains, mentions policymaker BZK. Forward-thinking regulations tackle this problem and focus on principles and outcomes rather than prescriptive measures. However, they require proactive, flexible, and adaptive frameworks to address the challenges posed by rapidly converging technologies (Schaminée, 2017). An ecosystem-approach could serve as as framework for forwards thinking regulations to structure the proposed regulations on a politcal dimension to explore if it aligns with excisting laws and regulations.

CLARIFY ACCOUNTABILITY

Discussion Structure: Look at all stakeholders of a quantum applications and by which legal documents (IP, patents, spin-off deal terms) they are bound at the moment and in the future.
Goal: Projecting future legal connections as quantum technologies evolve with a stakeholder-centric approach (Kop, 2021) (Johnson, 2023) and assessing how different levels of ecosystem maturity require specific legal documents (Regulatory Horizons Council, 2024) .
Value proposition: Thought-exercise for emerging legal frameworks for quantum applications.

When applying an ecosystem approach it identifies stakeholder engagements with the policy, innovation or systemic problem of topic (Youngblood & Chesluk, 2020). The different ecosystem levels could be linked to which policy instruments are best adopted in that ecosystem (Department for Science, Innovation and Technology, 2024). By relating stakeholders to each other through legal obligations rather than community ties, the structure helps clarify accountability within the ecosystem (n=1, validation interview) (Agarwal, 2023).

NOTE FROM AUTHOR:
This Disucssion Structure is theoratically possible according to however as this is far from my knowledge area and only one person has validated the idea, this requiires more research to see if it is a valuable direction.

PREPARE FOR RAPID TECHNOLOGICAL EVOLUTION

Discussion Structure: Shift from "regulate and forget" to responsive, iterative methods what policy instruments are at place for a quantum technology applications and do they encourage the desired innovation?

Goal: Integrate expansive thinking and a time-aware overview
Value proposition: Policymakers can create more resilient, forward-looking regulatory approaches that anticipate and adapt to technological advancements.

Traditional, static regulatory models struggle to keep up with rapidly evolving technologies (Schaminée, 2019)(Volk, 2022). Which is linked to the recurring issue in governance is the tendency to approach emerging technologies with delayed prioritization(n=1, validation interview). By incorporating the concept of time into decision-making discussions it could enable policymakers to foresee the long-term impacts of their decisions (Bason & Skibsted, 2022). It can serve as a discussion tool to link strategy with execustion and vice versa.

EXPERIENCE COMPLEX RISKS OF POLICY CHOICES

Discussion Structure: Map out the risks for a quantum application if it would be mitigate or accelerated with different value prioritised.
Goal: Help policymakers map out 2nd, 3rd order effects (complex risks) of the mitigation or acceleration of a quantum technology application.
Value proposition: Enhance policymakers' ability to make informed decisions.

Embedding technologies like quantum into structured simulations, can facilitate value-centred decision-making which prioritises technology but also societal good (Morishita et al., 2024) Certain policy choices could have the CQS' qauntum scenarios as extreme outcomes and show which values are prioritised. "Policymakers could explore the effects of their policy choices via simulations of the scenarios," proposed as an idea by two participants of the prototype test at the Ministry of BZK.

NOTE FROM AUTHOR:
This Disucssion Structure should include a multidisciplinairy group of stakeholders as this was quite a hard exercise during the Converged Technology Workshops in September 2024. It could be interesting to see if it different within polictmakers as (should be?) trained to think about 2nd and 3rd order effects.

DISCOVER ETHICAL AND SOCIAL IMPLICATIONS THROUGH REGULATORY SANDBOXES

Discussion Structure: Take a soft regulation that needs to be tested , place it in the corresponding Ecosystem Level and explore what other policy instruments are needed to reach full potential of the intended soft regulation.
Goal: develop a broad strategy for implementing a soft regulation to balance innovation with ethical considerations from a society perspective.
Value proposition: Enables policymakers to proactively identify and address potential ethical and social challenges associated with new technologies before full-scale implementation.

Forward-thinking governance integrates regulatory sandboxes which are controlled environments where emerging technologies are tested with soft regulations. By creating a legal experimentation room it increases the positive effect on securing livelihoods of citizens(De Bruggenbouwers, 2024). "An ecosystem framework could serve as a thought experiment to test and assess the societal impact of a policy instrument in combination with a technological innovation," mentions a participant from the prototype test at the Ministry of BZK.

MAP OUT EXCISTING REGULATION LANDSCAPE

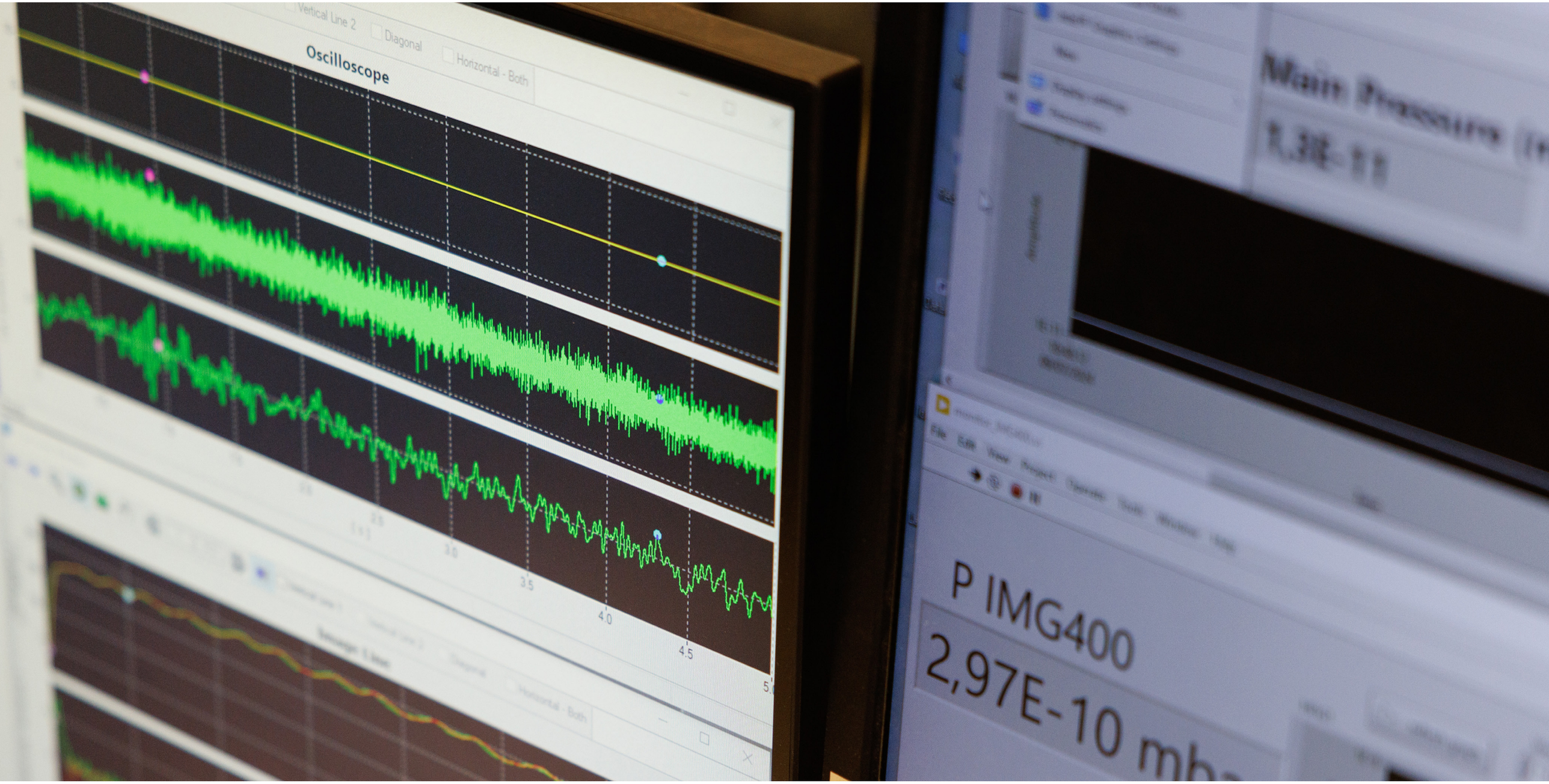
Discussion Structure: Map out how a regulatory landscape could look like for a whole group of quantum applications, for example Quantum for Healthcare. Test the current holistic strategy and what is needed when moving to another ecosystem level.
Goal: Develop a holistic view of existing policy instruments and regulations affecting technological innovations acrossa sector.
Value Proposition: Provides policymakers with a meta-level or 'holistic' exploration for a regulation landscape for emerging technologies (Valenzuela, 2024).

An ecosystem approach uses an holistic lense and leaves room for an organic trajectory with a legal timeline as the basis (n=1, validation interview). It gives a macro-level perspective on the policy instruments as guidelines (soft law), export controls (hard law), (ethical) frameworks already at play for the technology innovations. This could provoke a thought experiment to map out a broader timeframe for technological innovations to navigate them through the excisting policy landscape.

SHOW SOCIETAL COMMITMENT FOR PUBLIC TRUST AND PERCEPTION

Discussion Structure: If the above Discussion Structures are used, it could be a validation tool to discuss with the potential end-users of the quantum application to gather feedback.
Goal: Include perspectives outside the governmental body.
Value proposition: Provides a tool for citizen participation.

These regulatory sandboxes with scenarios simulations allow policymakers to transparently demonstrate their commitment to balancing innovation with public safety and ethical considerations. This could help citizens to perceive policy choices as legitimate which strengthens the societal dimension of government legitamicy (De Bruggenbouwers,2024).


Vertical Line 2
Diagonal
Horizontal - Both
Oscilloscope
3.5
4.0
4.5
Main Pressure
P IMG400
2,97E-10 mb

This chapter enholds challenges, biases and limitations in designing a quantum policy engagement game within a seven months designer project.

MERGING THREE (COMPLEX) FIELDS AS A DESIGNER: AI TOOLS ARE THE BEST!

The Quantum Futures Game required the integration of three distinct fields, game design, policymaking, and quantum technology, each with its own terminology, frameworks, and conceptual models. AI-assisted tools, including ChatGPT and Perplexity, played a crucial role in synthesizing information, structuring jargon-heavy content, and bridging conceptual gaps between disciplines.

While these tools significantly improved efficiency, they also introduced new challenges. ChatGPT excelled in generating prototype texts, identifying conceptual relationships, and drafting stakeholder communications. However, it struggled with specialized terminology, occasionally producing vague or misleading information when reliable sources were scarce. Perplexity, on the other hand, acted as an efficient search tool (sort of Google 2.0), verifying references and streamlining fact-checking processes. However, its inability to retain previously provided content required repeated prompting, making it less useful for iterative refinements.

A key challenge was ensuring that AI-generated content was not taken at face value. The ability to critically assess AI outputs became essential, especially when translating complex policy concepts into game mechanics. As quantum technology is still an emerging field, AI models struggled when no prior literature existed, often generating ambiguous or speculative responses. This highlighted the importance of expert validation to ensure accuracy and relevance in the game's design. The iterative process benefited from AI's rapid content structuring. AI tools provided efficiency, but they did not replace the need for human judgment in contextualizing information.

SYSTEMIC TECHNOLOGIES REQUIRE A BROADER UNDERSTANDING OF GLOBAL DYNAMICS

Quantum technology is a systemic innovation, meaning its impact extends far beyond a single sector. Developing an engagement tool for policymakers required an understanding of broader societal trends. Documentaries such as The Future with Hannah Fry and Huge if True by Cleo Abrams and AI:Ten Visions for 2041 provided a crash course into how technologies integrate into society.

One of the most rewarding aspects of the project was the ability to explore a wide range of interdisciplinary sources, making connections between seemingly unrelated fields. This approach ensured that quantum policymaking was not viewed in isolation but as part of a larger technological and societal landscape. Important to note that is could have resulted in more 'hallucinating AI' kind of outcomes, of which some need better grounding to see if they the same value as is stated in this report.

LANGUAGES OF QUANTUM, POLICY AND DESIGN: JARGONS COMBINED

One of the biggest communication challenges in this project was following the abstraction level of discussions between policymakers, and quantum experts. The game itself served as a bridge, providing a tangible, visual representation of concepts that were otherwise difficult to articulate in words. This approach reduced the risk of oversimplification or misinterpretation, as physical game elements created a shared reference point.

However, this also meant that some conclusions drawn during the project may have been oversimplified. The complexity of quantum policymaking asks for many iterations or more experience to capture all nuances within a game format, meaning some prototype discussions may have lacked the depth necessary to critically adress content specific feedback.

DESIGNER FREEDOM IN ACADEMIC CONTEXT

The project benefited from a broad exploration, incorporating sources from documentaries, podcasts (and short Notebook LM checks for the hunt on interesting scientific papers) and gamification studies. Having the freedom to utilize diverse sources expanded the design perspective, ensuring the Quantum Futures Game was not confined to a single discipline's limitations. This was particularly relevant when structuring current quantum communication products and understanding potential stakeholder interactions.

However, balancing creative freedom with structured validation remained a challenge. While this openness led to a richer, more engaging product, the project could benefit from a defined engagement framework for communication purposes.

CONTEXT IMMERSION: NETWORK LUCKY

Immersing into the quantum policymaking landscape takes 'landing' period. The project took place over seven months, which is a relative short period to fully adapt to quantum concept and next to it deeply understand how government systems influence technology adoption.

Conversations with experts proved essential, offering rapid insights and domain-specific perspectives. The quantum community is highly open to collaboration, eager to think along, experiment, and support initiatives, as this emerging field attracts pioneers. Regular invitations to join quantum events, particularly with the Centre for Quantum and Society, created sustainable interactions and helped others to position the project's goals.

In the government context, prior connections, whether from previous projects, fellow designers, or TU Delft graduates who have transitioned into policymaking, proved valuable. While government networks are highly interconnected, policymakers are generally willing to help and make relevant referrals.

Longer context immersion in the governmentIt will help to grasp policymaking constraints and internal decision-making processes. Engaging with larger governmental dynamics (as discussed in Chapter 2) could benefit from a more strategic approach rather than relying solely on an interaction-driven method.

LIMITATIONS OF HIGH-PACED ITERATIVE GAME DESIGN: INTUITION CAN TAKE THE OVERHAND

The iterative game design process provided valuable flexibility, allowing continuous refinement of the Quantum Futures Game. Without a structured review process or multiple perspectives, intuition could take over the systematic decision-making, leading to biases in design choices. While this intuitive approach enabled quick adjustments, it also meant that certain assumptions remained unvalidated until later stages of testing.

While, this helped maintain focus, iterative processes encourage fast decision-making, which sometimes led to overlooking deeper systemic insights. Collaboration with Deborah Nas and immersion in real-world events played a crucial role in balancing intuition with external input. Attending these events provided first-hand exposure to stakeholder interactions and policy discussions, ensuring the game remained grounded in real-world policymaking rather than theoretical assumptions. Product reflection cards and incorporating aspects of frame innovation seem examples of necessary methods to bring structure into context research and the game development process.

The iterative process refined stakeholder interactions and highlighted the importance of switching between a "closed kitchen" design approach (a more politically attuned strategy) and an "open kitchen" design approach (an experimental, transparent method) to enhance the concept's potential for adoption.

EXPLAINING UNFINISHED GAMES REQUIRES PATIENCE AND FULL IMMERSION

Explaining a finished game is already difficult, but explaining an unfinished or evolving prototype adds another layer of complexity. It became clear why game explanation videos on platforms like YouTube are widely used, because game mechanics are inherently difficult to communicate verbally (at least for me). The desire is to graps it fast but its new information, so it asks for patience and attention.

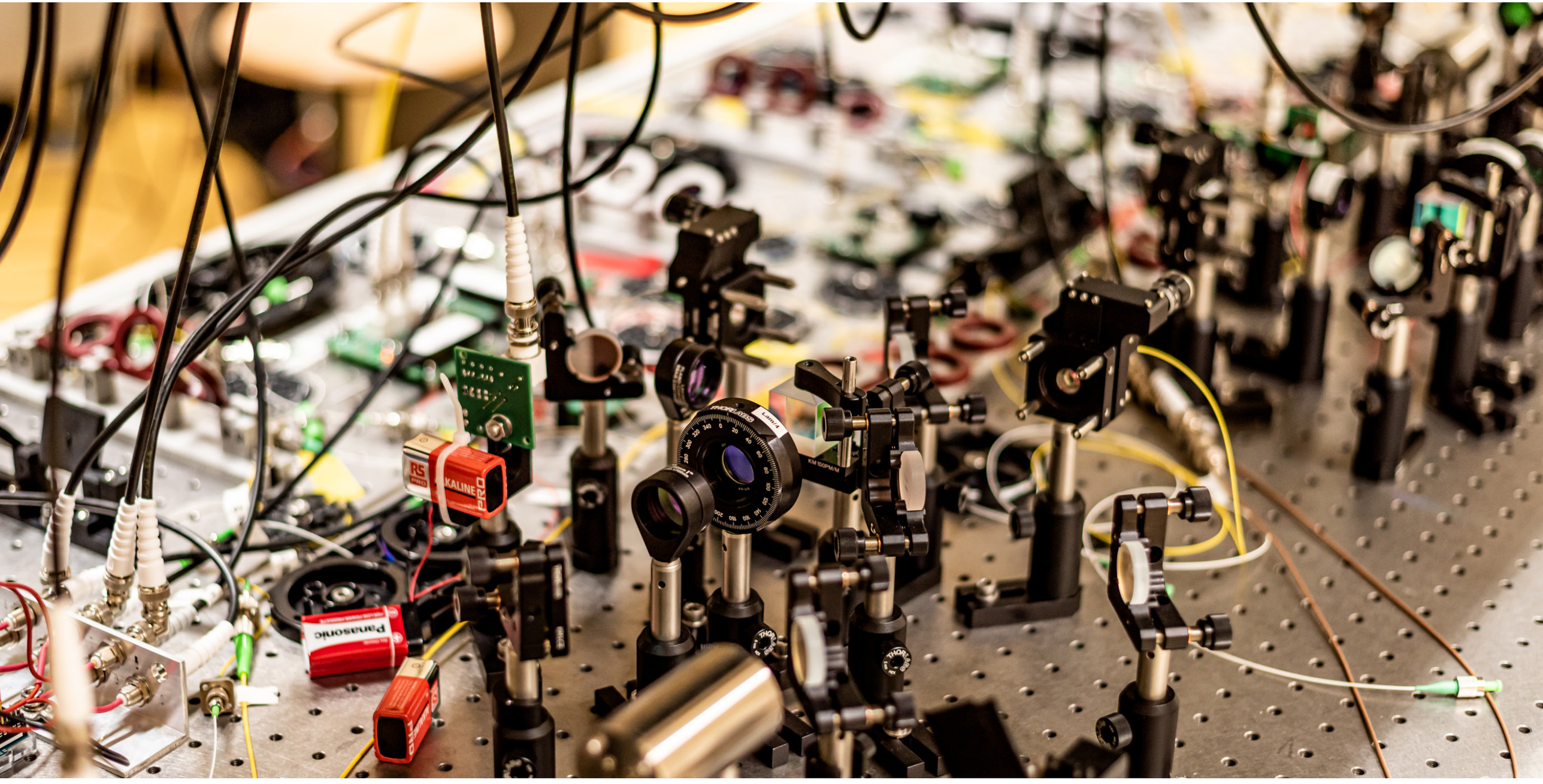
The fast-paced nature of iterative design made it easier to build on existing game mechanisms rather than invent entirely new ones. While this was efficient, it also highlighted that developing original game mechanics is an innovation process in itself, requiring extensive testing and refinement.

USER TESTING: THE IMPORTANCE OF WELL-DESIGNED SURVEY QUESTIONS

User testing was essential for refining the Quantum Futures Game, but the quality of survey questions directly influenced the usefulness of feedback. If questions were too ambiguous, no meaningful conclusions could be drawn.

Design research, particularly in an iterative process, requires a balance between structured data collection and open-ended stakeholder input. Surveys that asked "What improvements do you suggest?" provided valuable insights, but they were also shaped by stakeholder priorities, meaning the game evolved in a way that aligned with their expectations rather than exploring alternative directions.

A structured, multi-phase user testing approach would have further strengthened the validation process, ensuring that stakeholder diversity was fully accounted for in the final design.


KALINE PRO
Panasonic
THORLABS
KM100PM/M

All references are added to provide an overview for other quantum technology. The main references are categorised per topic. It is a combination of scientific papers and various media as newsitems, podcasts and explenation videos. The personal communication documents mentioned in the report are listed as well as a list of the conducted open interviews.

IMMERSION AND INQUIRY: INTERVIEWS

In the case of this project, this inquiry was done by qualitative interviews with policymakers from Netherlands Environmental Assessment Agency (PBL), the Ministry of Infrastructure and Water Management (I&W), the Ministry of Economic Affairs and Climate Policy (EZK), the Ministry of Justice and Security (JenV), the Ministry of the Interior and Kingdom Relations (BZK), and the Municipality of Amsterdam.

A series of semi-structured and unstructured interviews provided me with notes and information that, together, explain the context, the problem and the scope of this project. Via the attended events I was thankfull to speak to:

- Colleagues from the Centre for Quantum and Society team during teamdays and separate meetings.
- Current quantum industry contributors at Quantum Meets, Quantum Policy Academy and Quantum for Good Event
- Energy Transition experts at Alliander
- Game designers during the quantum playtest afternoon in Leiden, at Alliander
- Interaction designers and poliymakers during the prototype test at the Ministry of BZK
- Innovation, technology and policy experts at the Centre for Future Generations Flagship event and Qauntum for Good event
- Second year trainees from the ICT, data and cyber traineeship

To not miss out on any important information, I recorded audio of the qualitative interviews. During each interview, I actively listened and posed follow-up questions to clarify responses. After the interviews, I reviewed the recordings, documented key points, conclusions and insights. For further details, please feel free to contact me.

PERSONAL COMMUNCIATION

- Bank of Italy, Quantum Policy Academy, October 10 2024
- CEN-CENELEC Focus Group on Quantum Technologies, 2023
  CJW Quantum Consultancy, Quantum Policy Academy, October 10 2024
- CQS, Converged Technologies Workshop, September 4 2024
- D. Nas, personal communication, December 6 2024
- Ethiqual, Quantum Policy Academy, October 10 2024
  Export Control Group, Quantum Policy Academy, October 10 2024
- F. Braza, R. Cordier & L. Quattrucci, Converged Technologies
- Expert Workshop, September 12 2024
- Future Scenarios Project. (2023). Quantum Delta NL. https://quantumdelta.nl/news/future-scenarios-project-a-pioneering-leap-into-the-quantum-future
- Participatie Diner (M. Roggeveen, Redesigned Participatory Municipality meeting, September 11 2024)
- Policymaker Ministry, personal communication, October 30 2024
  Quantum Application Values (D. Nas, Quantum Application Values, September 10 2024)
- Quantum applications cheatsheets by the Centre for Quantum and Society (D. Nas, Quantum Application Cheatsheets, September 10 2024)
- TNO, Quantum Policy Academy, October 10 2024
- Workshop Looking at the Bigger Picture (D. Nas, workshop, February 28, 2024)
- Workshop materials provided for the convergence of technology workshops (D. Nas and L. Quatrucci, workshop preparation documents, September 4 and 12 2024)
- B. Pataki, Converged Technologies Experts Workshop, September 12 2024

Originally created by George Profitiliotis, Phd

- (D. Nas, Comparative Table, April 26, 2024).
- (D. Nas, Desirable QT Vision NL, April 16, 2024)
- (D. Nas, ELSA, April 26, 2024).

For the Excel overview with the 30 (reviewed) games and tools, please feel free to contact me.

POLICY AND POLICYMAKERS

Ampatzidou, C., Bouw, M., van de Klundert, F., de Lange, M., & de Waal, M. (2018). The hackable city: A research manifesto and design toolkit. Amsterdam Creative Industries Publishing.

Bemelmans-Videc, M. R. R. C. A. V. E. (2003). Carrots, Sticks and Sermons: Policy Instruments and Their Evaluation. https://openlibrary.org/books/OL698045M/Carrots_sticks_sermons

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the 'policy mix' for innovation. Research Policy, 40(5), 702–713. https://doi.org/10.1016/j.respol.2011.02.005

Hassan, L., & Hamari, J. (2020). Gamification of e-participation: A literature review. Proceedings of the 53rd Hawaii International

Conference on System Sciences, 2020, 3-6.

Hollanek, T. (2024). The ethico-politics of design toolkits: Responsible AI tools, from big tech guidelines to feminist ideation cards. AI and Ethics. https://doi.org/10.1007/s43681-024-00545-z

Lascoumes, P., & Gales, P. L. (2007). Introduction: Understanding Public Policy through Its Instruments—From the Nature of Instruments to the Sociology of Public Policy Instrumentation. Governance, 20(1), 1–21. https://doi.org/10.1111/j.1468-0491.2007.00342.x

Mayer, I., Bekebrede, G., Harteveld, C., Warmelink, H., Zhou, Q., van Ruijven, T., Lo, J., Kortmann, R., & Wenzler, I. (2014). The research and evaluation of serious games: Toward a comprehensive methodology. British Journal of Educational Technology, 45(3), 502-527.

CENTRE FOR QUANTUM AND SOCIETY

Centre for Quantum and Society | Quantum Delta NL. (2024). Quantum Delta NL. https://quantumdelta.nl/centre-for-quantum-and-society

Future Scenarios Project. (2023). Quantum Delta NL. https://quantumdelta.nl/news/future-scenarios-project-a-pioneering-leap-into-the-quantum-future

Ministry of Economic Affairs and Climate, Quantum Delta Netherland, Centre for Quantum and Society. (2023). Exploratory Quantum Technology Assessment. https://assets.quantum-delta.prod.verveagency.com/assets/exploratory-quantum-technology-assessment---engels.pdf

POLICY DESIGN AND THE CONVERGED TECHNOLOGICAL LANDSCAPE

Bharosa, N., & Janowski, T. (2024). The GovTech Challenge: GovTech and Public Value Creation. Digital Government Research (DGO 2024), 1043–1045. https://doi.org/10.1145/3657054.3659125

Kong, I., Janssen, M., & Bharosa, N. (2024). Deriving Government Roles for Directing and Supporting Quantum-safe Transitions. 25th Annual International Conference on Digital Government Research, 201, 507–514. https://doi.org/10.1145/3657054.3657114

Nail, R. (2018). The Global Grand Challenges | Singularity. https://www.su.org/resources/singularity-university-the-global-grand-challenges

Schaminée, A. (2019). Designing With and Within Public Organizations: Building Bridges between Public Sector Innovators and Designers. BIS Publishers.

Straub, J. (2015). In search of technology readiness level (TRL) 10. Aerospace Science and Technology, 46, 312–320. https://doi.org/10.1016/j.ast.2015.07.007

CONVERGED TECHNOLOGY WORKSHOP

ICFG. (2024, 16 juli). Our programs - ICFG. https://icfg.eu/what-we-do/our-programs/

GAMIFICIATION AND GOVERNANCE

Belkom, R. (2024). Stippen op de Horizon: Toekomstbeeld biotechnologie 2030-2050. [Report]. Stichting Toekomstbeeld der Techniek. https://stt.nl/media/pages/toekomstverkenningen/toekomstbeeld-biotechnologie-2030-2050/stippen-op-de-horizon-toekomstbeeld-biotechnologie-2030-2050/b022d9cfbb-1727698264/stt_stippenopdehorizon_final.pdf

Bontoux, L., Sweeney, J. A., Rosa, A. B., Bauer, A., Bengtsson, D., Bock, A., Caspar, B., Charter, M., Christophilopoulos, E., Kupper, F., Macharis, C., Matti, C., Matrisciano, M., Schuijer, J., Szczepanikova, A., Van Criekinge, T., & Watson, R. (2020). A Game for All Seasons: Lessons and Learnings from the JRC's Scenario Exploration System. World Futures Review, 12(1), 81–103. https://doi.org/10.1177/1946756719890524

Morishita, S., Nagato, Y., Higo, K., Teramoto, K., Nagayama, S., Center for Regional Creation and Alliance, Yamanashi Prefectural University, Japan, Research Center on Ethical, Legal, and Social Issues, Osaka University, Japan, Mercari R4D, Mercari, Inc., Japan, & Graduate School of Media and Governance, Keio University, Japan. (2024). "Quantum Quest": Dialogue and Exploration of Quantum Governance Through a Card Game [Conference proceeding].

Vervoort, J. M., Mangnus, A., McGreevy, S., Ota, K., Copernicus Institute of Sustainable Development, Urban Futures Studio, Environmental Change Institute, & FEAST Project. (2022). Unlocking the Potential of Gaming for Anticipatory Governance. Earth System Governance, 11, 100130. https://doi.org/10.1016/j.esg.2021.100130

PUBLIC COMMUNICATION OF (QUANTUM) TECHNOLOGIES

Abram, C. (2023, April 4). Quantum Computers, explained with MKBHD [Video]. YouTube. https://www.youtube.com/watch?v=e3fz3dqhN44

Domain of Science. (2021, December 3). The Map of Quantum Computing - Quantum Computing Explained [Video]. YouTube. https://www.youtube.com/watch?v=-UlxHPIEVqA

Genkina, D. (2024, March 21). Here Are 6 Actual Uses for Near-Term Quantum Computers. IEEE Spectrum. https://spectrum.ieee.org/what-are-quantum-computers-used-for

Lee, K., & Qiufan, C. (2024). AI 2041: Ten Visions for Our Future (2nd ed.). Penguin Random House UK.

StarTalk. (2024, June 4). The Future of Quantum Computing with Michio Kaku, Neil deGrasse Tyson & More [Video]. YouTube. https://www.youtube.com/watch?v=lum6rdKr4To

GAMES AND TOOLS

For further details and an Excel overview of the reviewed games and tools, please feel free to contact me.

QUANTUM TECHNOLOGY DISCOURSE

CEN-CENELEC Focus Group on Quantum Technologies. (2023). Standardization Roadmap on Quantum Technologies. https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN-CENELEC_Topics/Quantum%20technologies/Documentation%20and%20Materials/fgqt_q04_standardizationroadmapquantumtechnologies_release1.pdf

Feng, L., Cramer, J., & Mans, U. (2021). Lessons from AI: Communication [White paper] (pp. 1–13). Quantum Delta NL. https://assets.quantum-delta.prod.verveagency.com/assets/lessons-from-ai_white-paper-2_communication.pdf

Goings, J. J., White, A., Lee, J., Tautermann, C. S., Degroote, M., Gidney, C., Shiozaki, T., Babbush, R., & Rubin, N. C. (2022). Reliably assessing the electronic structure of cytochrome P450 on today's classical computers and tomorrow's quantum computers. Proceedings of the National Academy of Sciences, 119(38). https://doi.org/10.1073/pnas.2203533119

Goudsmit, J., Possati, L., Challis, L., & Mans, U. (2022). Lessons from AI: Risk Management (pp. 1–15). Quantum Delta NL. https://assets.quantum-delta.prod.verveagency.com/assets/lessons-from-ai_white-paper-3_risk-management.pdf

Groenland, K. (2024). Introduction to Quantum Computing for Business. Introduction to Quantum Computing for Business. https://quantumcomputingforbusiness.com/

Huang, H., Broughton, M., Cotler, J., Chen, S., Li, J., Mohseni, M., Neven, H., Babbush, R., Kueng, R., Preskill, J., & McClean, J. R. (2022). Quantum advantage in learning from experiments. Science, 376(6598), 1182–1186. https://doi.org/10.1126/science.abn7293

Nguyen, M. T., Lee, Y., Alfonso, D., Shao, Q., & Duan, Y. (2023). Description of reaction and vibrational energetics of CO–N H interaction using quantum computing algorithms. AVS Quantum Science, 5(1). https://doi.org/10.1116/5.0137750

Osorio Tamayo, C., Rabbie, J., Ellen, F., Quantum Delta NL, & TNO. (2024). Critical Components and Market Dynamics of Quantum Sensors. https://assets.quantum-delta.prod.verveagency.com/assets/quantum-delta-nl-white-paper-quantum-sensing-supply-chains.pdf

Quantum Delta NL. (2021). Lessons from AI: Stakeholder Engagement [White Paper] (pp. 1–14). https://assets.quantum-delta.prod.verveagency.com/assets/lessons-from-ai_white-paper-1_stakeholder-engagement.pdf

Reiher, M., Wiebe, N., Svore, K. M., Wecker, D., & Troyer, M. (2017). Elucidating reaction mechanisms on quantum computers. Proceedings of the National Academy of Sciences, 114(29), 7555–7560. https://doi.org/10.1073/pnas.1619152114

Rubin, N. C., Berry, D. W., Kononov, A., Malone, F. D., Khattar, T., White, A., Lee, J., Neven, H., Babbush, R., & Baczewski, A. D. (2024). Quantum computation of stopping power for inertial fusion target design. Proceedings of the National Academy of Sciences, 121(23). https://doi.org/10.1073/pnas.2317772121

Rubin, N. C., Berry, D. W., Malone, F. D., White, A. F., Khattar, T., DePrince, A. E., Sicolo, S., Küehn, M., Kaicher, M., Lee, J., & Babbush, R. (2023). Fault-Tolerant Quantum Simulation of Materials Using Bloch Orbitals. PRX Quantum, 4(4). https://doi.org/10.1103/prxquantum.4.040303

DESIGN APPROACH

Dorst, K. (2006). Design Problems and Design Paradoxes. Design Issues (Nummer 3). Massachusetts Institute of Technology. http://direct.mit.edu/desi/article-pdf/22/3/4/1714101/desi.2006.22.3.4.pdf

Dorst, K. (2011). The core of 'design thinking' and its application. Design Studies, 32(6), 521–532. https://doi.org/10.1016/j.destud.2011.07.006

Green, M. C., Brock, T. C., & Kaufman, G. F. (2004). Understanding Media Enjoyment: The Role of Transportation Into Narrative Worlds. Communication Theory, 14(4), 311–327. https://doi.org/10.1111/j.1468-2885.2004.tb00317.x

Jaskiewicz, T., & van der Helm, A. (2017). Progress Cards as a Tool for Supporting Reflection, Management and Analysis of Design Studio Progresses. In Proceedings of the Conference: Engineering and Product Design Education, Norway.

Schon, D. A., & DeSanctis, V. (1986). The Reflective Practitioner: How Professionals Think in Action. The Journal of Continuing Higher Education, 34(3), 29–30. https://doi.org/10.1080/07377366.1986.10401080

Siriaraya, P., Visch, V., Vermeeren, A., & Bas, M. (2018). A Cookbook Method for Persuasive Game Design. International Journal of Serious Games, 5(1). https://doi.org/10.17083/ijsg.v5i1.159

Visch, V., Vegt, N., Anderiesen, H., & Van Der Kooij, K. (2013). Persuasive Game Design: A Model and Its Definitions. CHI2013: Workshop Designing Gamification: Creating Gameful and Playful Experiences, Paris, France.

Woolrych, A., Hornbæk, K., Frøkjær, E., & Cockton, G. (2011). Ingredients and Meals Rather Than Recipes: A Proposal for Research That Does Not Treat Usability Evaluation Methods as Indivisible Wholes. International Journal of Human-Computer Interaction, 27(10), 940–970. https://doi.org/10.1080/10447318.2011.555314pdf/22/3/4/1714101/desi.2006.22.3.4.pdf

DISCUSSion stRUCTURES
Agarwal, A. (2023). Probing the production of quantum technologies to imagine its legal framework. Research Directions in Quantum Technologies, 1, e9. https://doi.org/10.1017/qrd.2023.9

Çakir, N. (2022). Designing for a pro-active Ministry of Justice and Security: A strategy to move towards actionability in response to harmful and immoral online behaviour [Master's thesis, Delft University of Technology]. TU Delft Repository. https://repository.tudelft.nl/record/uuid:28c8fdf1-3044-4b23-b240-1822694d1d30

De Bruggenbouwers. (2024). Lessen uit de Wasstraat: Proactieve gegevensdeling als voorwaarde voor bestaanszekerheid [Essay]. https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/43979612/d6d29235-01d7-49fe-8f24-259efdf733dc/Essay-Wasstraat-voor-Gegevensdeling-1.pdf

Department for Science, Innovation and Technology. (2024). Regulating quantum technology applications: Government response to recommendations made by the Regulatory Horizons Council. UK Government.

Johnson, M. (2023). A roadmap for navigating the uncharted legal design landscape towards a bright quantum future. Harvard Journal of Law & Technology Digest.

Kop, M. (2021). Quantum computing and intellectual property law. Musica Juridica.

Peña Valenzuela, D. (2024, November 15). Regulatory Sandboxes: fostering innovation in emerging technologies. Universidad Externado de Colombia. https://dernegocios.uexternado.edu.co/comercio-electronico/regulatory-sandboxes-fostering-innovation-in-emerging-technologies/

Regulatory Horizons Council. (2024). Regulation of quantum technology applications. UK Government.

IMAGE CREDITS AND QUANTUM FUTURES GAME CREDITS
The images used in the Quantum Futures Game and in this report were created by Guus Meinema, Marieke de Lorijn, Willem van Aken (CSIRO), QDNL, QDNL website, Quantum Inspire Lab, Rose Galloway Green, Deborah Nas, Juliette Metz and Juwe van Vliet.

The game rules are inspired by the game mechanisms of the card game Sushi Go! and the board game Secret Hitler. The excel which provides a full game overview can be provided if needed. Inspiration was found in their games and discussion tools, credits to their creators and in depth work.

The report set up is inspired by the master thesis of Maartje Roggeveen and Martijn Nieuwehuijse, see the TU Delft Repository.

AI-ASSISTED TOOLS
AI-assisted tools, including ChatGPT and Perplexity, played a crucial role in synthesizing information, structuring jargon-heavy content, and bridging conceptual gaps between disciplines. ChatGPT and Perplexity were used for research purposes and have been checked with scientific content, resources or validation interviews. In prototope 1, images have been generated to visualise converging technology applications.

While these tools significantly improved efficiency, they also introduced new challenges. ChatGPT excelled in generating prototype texts, identifying conceptual relationships, and drafting stakeholder communications. However, it struggled with specialized terminology, occasionally producing vague or misleading information when reliable sources were scarce. Perplexity, on the other hand, acted as an efficient search tool (sort of Google 2.0), verifying references and streamlining fact-checking processes. However, its inability to retain previously provided content required repeated prompting, making it less useful for iterative refinements.

Adding onto the main findings in this report, these appendices offer some additional information as a background. Appendix A-E show the iterative steps taken during the design process and provide information on the results and reflections after the prototypes at events.

APPENDIX A **QUANTUM POLICY ACADEMY**

Context

The Quantum Policy Academy, held on 10 October 2024 in Brussels by Quantum Delta NL's Center for Quantum and Society (CQS) and the International Centre for Future Generations (ICFG), is designed to equip quantum stakeholders with essential policy insights.

A.1.1 Method: Scenario Game for policy literacy
The scenario game at the Quantum Policy Academy utilises persuasive game design to engage participants with complex policy issues relevant to quantum technology. By simulating real-world decision-making, participants actively explore how geopolitics influences quantum strategy, particularly in areas like strategic autonomy and global supply chains. This design ensures a hands-on learning experience, making policy literacy tangible and relevant through interactive debate and scenario analysis.

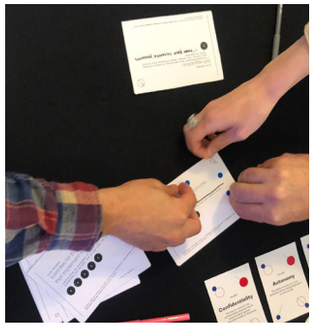
A.1.2 Participant Selection: Preferences, Needs, Values, and Capabilities
Participants are selected for their involvement in the quantum sector, comprising 8–10 individuals or 4–5 teams (up to 30 participants). The selection focuses on those whose needs align with policy training that addresses the evolving geopolitical landscape and its impact on the quantum industry. Each participant's potential to benefit from insights into emerging export controls, industrial policy, and quantum's integration with other disruptive fields (like AI and biotech) is prioritised.

A.1.3 Procedure: Setup in Context
The game will be conducted on 10 October 2024, during the Quantum Policy Academy in Brussels. Participants, organized into teams, will debate the central question: "How does geopolitics impact your quantum business strategy?" in a structured 20-minute round format, repeatable to explore different policy angles. This setting, mirroring real-world dynamics, allows stakeholders to assess strategic options around export controls, the global quantum economy, and interdisciplinary innovation, preparing them for tangible action in their fields.

–

Concept

Prototype



A.2.2 what (user's world)
The QPA's Game is a structured role-playing exercise in which participants assume the roles of key decision-makers with various value perspectives. They can become an educational institution, opinion maker, quantum tech company, economic-oriented or a digital environment regulatory body.

From the perspective of the roles, the teams explore the intersection of quantum technology with other emerging fields to understand their societal impacts. The different roles react to converging technology topics during policy debates, where policy instruments are used as tools to build a resilient regulation strategy.

A.2.3 How (narrative of the game design)
When faced with a public problem, policymakers have a choice of policy instruments to implement and strategies for how to mix them (Bemelmans-Videc, 2003) (Flanagan et al., 2011)(Lascoumes & Gales, 2007). The chosen policy instruments are categorised under the following four policy strategies:

1) Minimal interference instruments allow market forces to influence outcomes without direct government intervention
2) Information instruments are involved in creating voluntary programs or frameworks that individuals can choose to use based on their preferences.
3) Economic means as a policy instrument involves using incentives or disincentives to steer individual behaviour towards desired policy outcomes.
4) Laws and standard-setting involve implementing legal frameworks that set mandatory standards for developing and using technologies.

–
The QPA prototype aims to test the effectiveness of the game components to engage participants in policy understanding of emerging technologies.

A3..1 Why (the purpose of the test)
The prototype test will determine how well the scenario game conveys the interconnected implications of converged technologies like biotech, neurotech, and advanced AI on society, ethics, and governance. After the debate rounds, the effectiveness of illustrating policy possibilities and the ability to engage in strategic policy thinking were evaluated. The test results will inform further iterations of the game, focusing on building future literacy to better align with policy design that navigates the quantum discourse responsibly.

4.2.2 What (the game experience and user stories)
The resilient regulation strategy differs per assigned roles based on their adopted values and created quantum missions. In multiple rounds of policy debates, the roles use policy instruments (e.g., economic incentives, laws, and standards) to address hypothetical but plausible scenarios related to converged technology applications.

The policy response applies to applications that reflect real-world challenges, such as information weaves, extremely powerful products,

participants in Group 2 (P9) wanted all policy instruments and values accessible for strategic choice-making. At the same time, Group 1 (P2) noted a mismatch between policy options and roles, suggesting that roles should have more specific mandates (n=2, Groups 1 and 2).

Mission and Role Alignment
Group 1 participants (P4, P5) felt the mission and roles were somewhat disconnected from the gameplay, indicating the mission was too predefined and didn't reappear meaningfully throughout the game (n=2, Group 1). A clearer integration of roles and mission would support a more cohesive policy debate experience.

A.4.3 Commercial Level:
Participants noted that the game's realism, simulating a regulatory environment without investors, was accurate to European contexts and engaging (Group 2), which could strengthen its appeal to real-world users (n=2, Group 2). Group 3 echoed this sentiment, pointing out that including funding for startups and adding investor roles could increase appeal for broader applications (P11).

Results

Suggestions for making the game more dramatic or idealistic (Group 2) could appeal to a broader market by allowing for customisable, high-stakes scenarios that reflect user preferences. A more dramatic or visionary setup might enhance different sectors looking for a "sandbox" environment to test strategy.

_
4.3.1 Knowledge gained about people
Insights indicated that participants found the roles, values, and mission elements essential for initiating discussions, yet some found role definitions unclear (n=3, Groups 1, 2, and 3). The learning curve for the game rules was steep, as participants reported faster gameplay in the second round (n=2, Groups 2 and 3). This indicates that while role-playing elements facilitated engagement, role definitions and clarity about values need refinement.

4.3.2 Knowledge gained about technology
Feedback highlighted a gap in participants' understanding of ELSA (Ethical, Legal, and Societal Aspects) and its relevance to quantum policy, with a preference expressed for using a more inclusive concept like "Quantum Humanities" (n=1, Group 2). Additionally, converged technology cards, which had contrasting interpretations (e.g., "atomic bomb vs. light bulb"), indicated a need to ensure hese cards have clearer goals to avoid misinterpretation (n=2, Groups 2 and 3).

4.3.2 Knowledge gained about organisation
Participants felt that certain roles, like investors and journalists, were missing and suggested that including these could make the game reflect a more realistic policy-making ecosystem (n=2, Groups 1 and 2). Some noted that specific roles, such as "Opinion Maker," needed to be more precisely defined, and suggested think tanks or lobbyists as more fitting roles (n=1, Group 2).

Discussion

4.3.4 Obtained insights on design context, know-how, and new ideas
The feedback identified motivational incentives for voting dynamics which indicated some . The nuanced converged technology and policy cards were appreciated, as they led to more thorough reasoning among participants on policy choices, suggesting that nuanced elements contribute to the game's effectiveness (n=2, Groups 1 and 2).

The test highlighted the importance of integrating networking activities before lunch to promote familiarity and ease the discussion process (n=1, Group 2). Participants also began writing on policy cards to track their thoughts, indicating that incorporating writable areas on the cards could enhance usability.

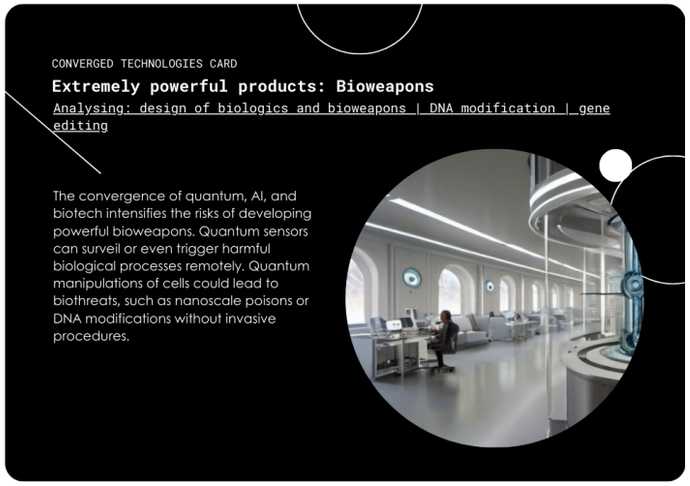
Participants suggested adding a foreign policy angle and lobbying roles to increase relevance. Additionally, they recommended a final tiebreaker mechanism (e.g., extra voting or one final sentence pitch) to address equal voting outcomes, which would add depth to decision-making and conclude debates more effectively (n=2, Groups 2 and 3).

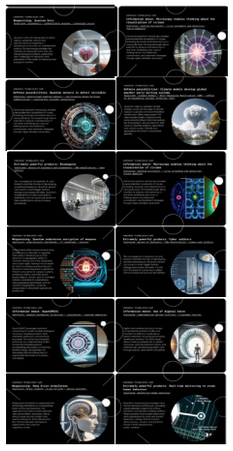
4.3.5 Knowledge Gained About the Design Process
Feedback on the design process revealed that while the game's layered structure effectively encouraged strategic thinking, a clearer structure for role, value, and mission components is essential to streamline gameplay (n=3, Groups 1, 2, and 3). Participants noted that learning the game rules required time, suggesting a need for a quicker on-ramp or tutorial to facilitate early engagement (n=2, Groups 2 and 3). Additionally, the varied pace of team pitches indicated that time management elements, such as assigning timekeepers, would optimize the gameplay experience (n=1, Group 2).

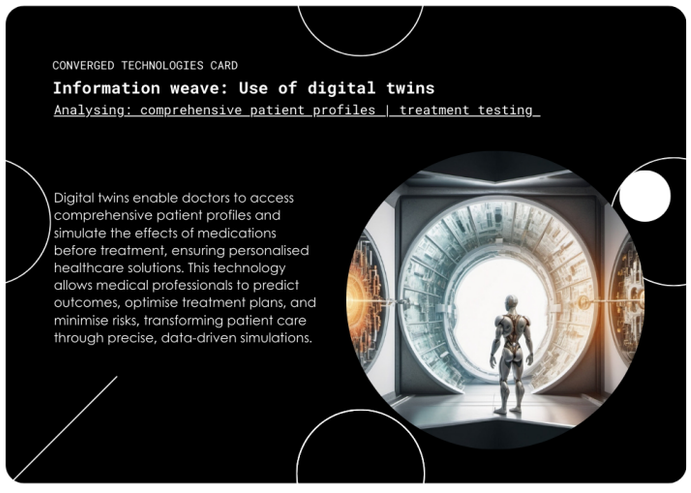
4.3.5 New questions
How can role motivations, especially for "evil" or controversial stances, be more effectively supported to reflect realistic stakeholder incentives?
What mechanisms can be added to make the winning process more meaningful, encouraging alignment with values and missions?
How can the converged technology cards be adjusted to balance innovative and cautionary approaches without overly dark or idealised interpretations?

CONVERGED TECHNOLOGY CARDS
[TECH TRANSFORMS WARFARE / HEALTHCARE]

> Weaponisation [x3]
> Extremely powerfull products [x3]
> Information weave [x3]
> Defence possibilities [x3]







POLICY INSTRUMENT CARDS
[PER STRATEGY]
> Minimal interference instruments
> Information instruments
> Economic means
> Laws and standard-setting

FIX COLOURS

ROLES, MISSION AND VALUES
[PER DUO]
> Opinion Maker
> Economic-Oriented Regulator
> Digital Environment Regulator
> Quantum Tech Company
> Educational Institution

POLICY INSTRUMENT

Enforcing regulations that mandate ethical assessments for applications

- Prohibiting the use of tech application A for developing harmful applications.

€ € €

Laws and standard-setting involves implementing legal frameworks that set mandatory standards for the development and use of technologies.

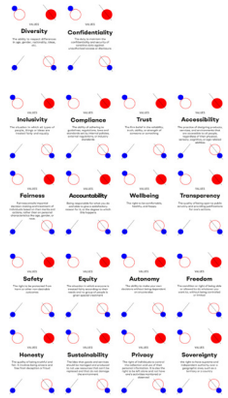
POLICY INSTRUMENT

Subsidised Education Programs

- Government-sponsored training courses or scholarships that individuals can freely apply for encourage upskilling or lifelong learning.

€ € € €

Information instruments involve in **creating voluntary programs or frameworks** that individuals can choose to use based on their preferences.



VALUES

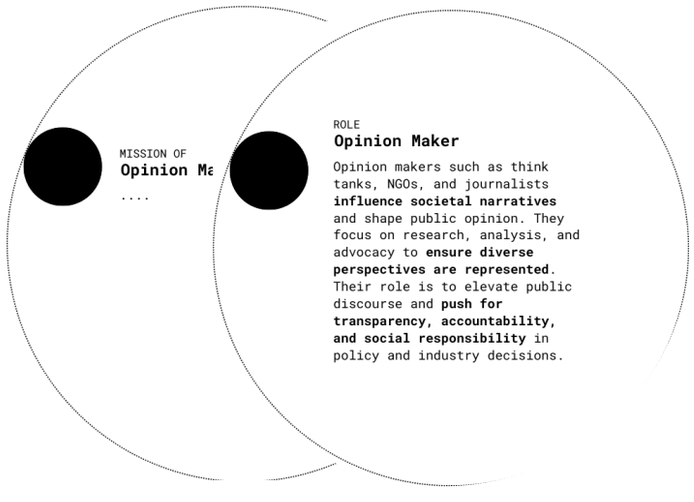
Trust

The firm belief in the reliability, truth, ability, or strength of someone or something

VALUES

Safety

The right to be protected from harm or other non-desirable outcomes



ROLE

Opinion Maker

Opinion makers such as think tanks, NGOs, and journalists **influence societal narratives** and shape public opinion. They focus on research, analysis, and advocacy to **ensure diverse perspectives are represented**. Their role is to elevate public discourse and **push for transparency, accountability, and social responsibility** in policy and industry decisions.

APPENDIX B **ALLIANDER**

Context

The Alliander Quantum Awareness Event, hosted twice a year by Alliander's R&D team, aims to increase company-wide understanding of quantum technology, providing employees with insights into current advancements and future societal implications.

5.1.1 Method: Scenario Game for quantum and future literacy
During the event incorporates a persuasive game design approach to engage non-expert employees in exploring quantum concepts and their potential impacts. Through a combination of lectures and interactive scenario games, participants gain hands-on experience with quantum technology applications, fostering a practical understanding of its ethical, legal, and societal dimensions.

5.1.2 Preferences, Needs, Values, and Capabilities
Participants are invited based on their interest in technology. Typically, around 80 employees attend the initial lecture, with an estimated 40–50 expected to stay for the interactive quantum games. This structure accommodates a range of familiarity levels, allowing all attendees to benefit from foundational awareness and insight into quantum advancements.

5.1.3 Procedure: Contextual Setup
The event begins with a keynote covering quantum technology fundamentals, followed by a split into interactive groups. One group participates in a specially designed game exploring quantum's role in societal and technological contexts, while another engages in a scenario game that delves into potential future applications and implications. This setting provides a comprehensive introduction to quantum technology, enhancing awareness and prompting consideration of its broader impacts.

_
The game concept define the aim to be delivered by the game experience and what this means for the user's role in the game. As well as how this is reflected in the game components.

.2.1 Why (transfer effect)
The Quantum Scenario Game allows participants to explore the strategic governance complexities of opposite global powers, Democratic and Authoritarian, in shaping global futures influenced by quantum innovation. By immersing players in a simulated power struggle, this game encourages thinking about how different policy instruments play a role moving towards future quantum scenarios as Transformation, Growth, Discipline, or Collapse.

Concept

5.2.2 what (user's world)
In the Quantum Scenario Game, 6-8 players are split into two hidden-identity teams, representing either Democratic or Authoritarian global powers. The Democratic team aims to achieve either Transformation or Growth, while the Authoritarian team seeks Discipline or Collapse as their end goals.

Prototype

5.2.2 How (narrative of the game design)
Through rounds of role-playing, policy selection, and strategic interactions, players work together or in opposition, leveraging Ecosystem Readiness Levels (ERLs) to advance towards their team's objectives. The ERL system measures whether critical players and environmental components are aligned to support each team's strategic innovation.

_
The Alliander prototype aims to test the effectiveness of the game components to engage participants in future quantum scenarios through a global power race.

5.3.1 Why (the purpose of the test)
This engaging, policy-driven scenario encourages discourse on the role of governance in innovation, helping players understand the nuanced requirements for successfully implementing large-scale, technological change within different sector frameworks.

5.3.2 What (the game experience and user stories)
This experience of opposite dynamics helps participants recognize the governing struggles, as policy overlap and gaps, and that you can use policies in a global strategy to achieve goals aligned with different governance models in the context of quantum technology.

.3.3 How (interaction with the game design; components)
Setup and Roles: Players are assigned hidden identities as part of either the Democratic or Authoritarian team. The initial Quantum Leader, chosen by dice roll, selects an ally for strategic support.
Rounds of Play: In each round, the Quantum Leader proposes an ally, after which players discuss and vote on the proposal. If the alliance is approved, the Quantum Leader and ally work together to select policies from a pre-determined deck to advance their strategy.
Policy Selection and Board Progression: The Quantum Leader and ally place selected policies on the board, impacting ERLs and contributing to their team's global objective. Successful placement depends on the alignment of ERLs with policy location and the broader team strategy.
Winning the Game: Teams win by advancing their specific world goal (Transformation, Growth, Discipline, or Collapse) using well-aligned policies and strategic alliances, shaped by ongoing discourse about quantum technology's societal impact.

Results

_
The prototype results of the Alliander test were tested through gameplay sessions and an written and spoken evaluation.

5.4.1 User-Effect Level:
Policy Literacy and Debate: Some participants reported that the debate aspect and the use of voting (yes/no) were engaging, providing an opportunity to explore different perspectives on quantum policy (n=5; P4, P5, P6, P7, P10). However, others indicated that voting's impact was unclear or that winning was less important than understanding the policy dynamics (n=3; P4, P5, P12).
Quantum Literacy Through Technology Cards: Quantum technology cards were noted as interesting but secondary to the gameplay, often skipped due to time constraints. This suggests that while the

cards add value, they do not sufficiently enhance quantum literacy as intended (n=3; P3, P7, P8).

End of game: The transfer effect of policy literacy is somewhat successful, especially through voting and debate mechanics, but the impact of quantum literacy could be strengthened by simplifying technology card usage, possibly through structured readings or shorter summaries during gameplay.

.4.2 Knowledge Level:
The game elements could be made more effective by simplifying the cards (e.g., reduced text, clearer indicators) and improving visual aids to support the debate and learning process, which several participants felt was hindered by the current card design and complexity.

Policy Cards Clarity and Design: Many participants noted that policy cards were difficult to read or understand due to unclear information and small font size, which affected engagement in policy discussions (n=6; P1, P2, P3, P7, P9, P12).

Quantum Technology Cards Usage: Quantum tech cards were interesting to participants but often overlooked due to time constraints and complexity, which may have limited deeper engagement in policy debates (n=4; P3, P7, P8, P12).

Scenario and Goal Clarity: Players suggested that clearer visuals for Ecosystem Readiness Levels (ERLs) and a more structured voting system would enhance game flow and purpose, making it easier to connect game actions to strategic goals (n=5; P3, P4, P5, P6, P7).

5.4.3 Commercial Level:
Complexity and Accessibility: Several participants noted that the game's complexity, information overload, and language (currently not in Dutch) posed barriers to entry, which could limit its appeal in a commercial context if not simplified (n=5; P1, P3, P8, P10, P12).

Engagement Value: Participants appreciated the game's tactical and strategic depth, mentioning elements like the "poker element" and the potential for "epic goals," which could be appealing to users interested in complex strategic games (n=3; P4, P7, P8).

Market-Specific Interest: One participant expressed interest in the game's relevance to the energy sector, suggesting that sector-specific themes could enhance its appeal in professional or educational markets (n=1; P10).

Conclusion: The game has potential commercial viability, particularly among users interested in strategic, policy-oriented gameplay. However, simplifying the setup, reducing complexity, and possibly localizing it to the Dutch language could improve accessibility and broaden its market appeal.

–

Discussion

In this chapter, insights in the categories 'people' 'technology' and 'organisation' and further development directions are listed.

4.3.1 Knowledge gained about people
Participants showed a need for clarity and direct impact in gameplay, seeking immediate feedback on their actions and an immersive experience that allows them to feel actively involved in world-building (n=4; groups: P1, P2, P6, P7). Feedback indicated that participants desired a cooperative aspect, suggesting that a shift toward shared goals rather than competitive objectives might enhance engagement and group dynamics (n=3; groups: P4, P5, P7).

4.3.2 Knowledge gained about technology
The quantum technology cards were seen as useful for introducing players to new technological concepts but were considered underutilized due to time constraints and information overload (n=3; groups: P3, P7, P12). However, the Ecosystem Readiness Level (ERL) framework was well-received, with players perceiving it as realistic and intuitive, adding depth to the governance scenarios and enhancing technological awareness (n=2; groups: P6, P8).

4.3.2 Knowledge gained about organisation
Feedback suggested that the game might benefit from a structured focus on different governance scales—national, European, international, or global—which could allow participants to explore organizational strategies on a broader or more tailored scale (n=2; groups: P10, P12). Additionally, the idea of customized goal paths per governance model was suggested to make the scenarios more relevant to specific organizational needs (n=1; group: P8).

Feedback revealed that literal overlap and gaps in policy cards created confusion, highlighting the importance of clear gameplay mechanics for effective policy simulations (n=1; group: P2).

Participants gained experience in testing strategic governance scenarios and evaluating policy impacts within a simulated environment, gaining insight into the complexities of ecosystem readiness and policy alignment in a quantum future (n=2; groups: P5, P6).

Adding cooperative elements or a shared final objective could increase the game's appeal, encouraging players to work towards a common agreement rather than solely pursuing individual objectives (n=2; groups: P5, P7).

Allowing for varying scales of play (national, European, global) could make the game more applicable across different contexts, enhancing its flexibility and relevance to organizational settings (n=2; groups: P10, P12).

Participants desired a grander end goal, suggesting that the game's final outcome should culminate in a shared vision or policy agreement rather than each player simply adhering to their own world policy (n=1; group: P8).

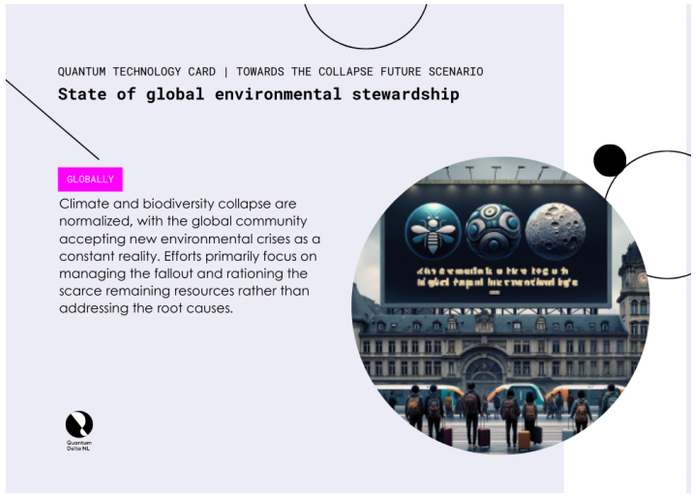
4.3.6 Knowledge Gained About the Design Process
The design process insights reflect the necessity of balancing complexity with accessibility. The feedback highlighted:

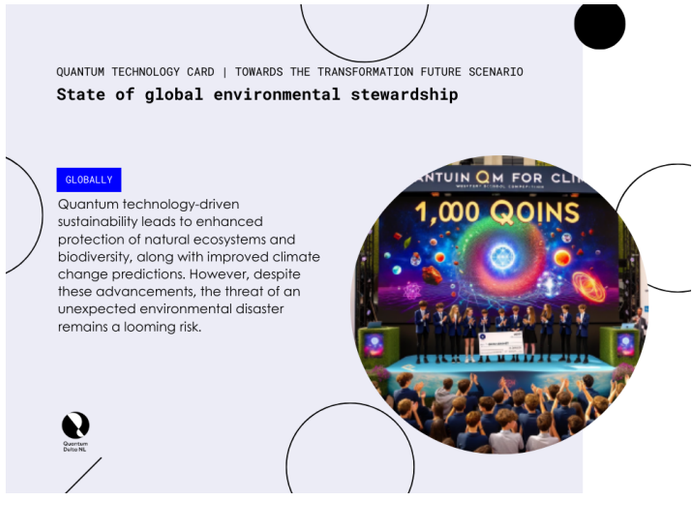
Simplifying Information Presentation: Too much information on cards and the board created an “information overload,” indicating a need to streamline visual and textual elements to maintain player engagement within limited timeframes (n=3; groups: P2, P7, P12).

Design Flexibility: The suggestion to incorporate varying scales of governance and customizable goal paths underscores the benefit of flexible game design that can adapt to different organizational needs and objectives (n=2; groups: P8, P12).

4.3.5 New questions
A remaining question centres on how to design individual objectives that intersect meaningfully with a shared goal. Specifically, participants asked: How can individual objectives coexist within a game structure while converging toward a unified outcome? This question remains open as it directly impacts the game’s capacity to balance individual agency with collective achievement.

QUANTUM TECHNOLOGY CARDS
[INFORMATION PER COLLAPSE, DISCIPLINE, TRANSFORMATION, GROWTH SCENARIO]
> Actors who control QT and their relations
> Public discourse of tech & QT
> State of global environmental stewardship
> Acces to human talent in QT





POLICY INSTRUMENT CARDS
[PER ERL AND GLOBAL POWER]
> Ecosystem Readiness Level 1 Low - 4 High
> Democratic Policies and Authoritarian Policies

POLICY INSTRUMENT

Awareness campaigns

Public campaigns raise awareness of the potential benefits and risks of the new technology, engaging with media, educational institutions, and community organizations.

ERL **1/4** LOW

Ecosystem Readiness Level (ERL) looks at whether all of the key players and components of the broader environment are prepared to support and sustain the innovation.

POLICY INSTRUMENT

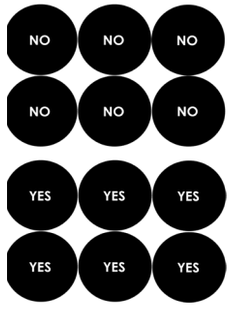
Censorship and information control

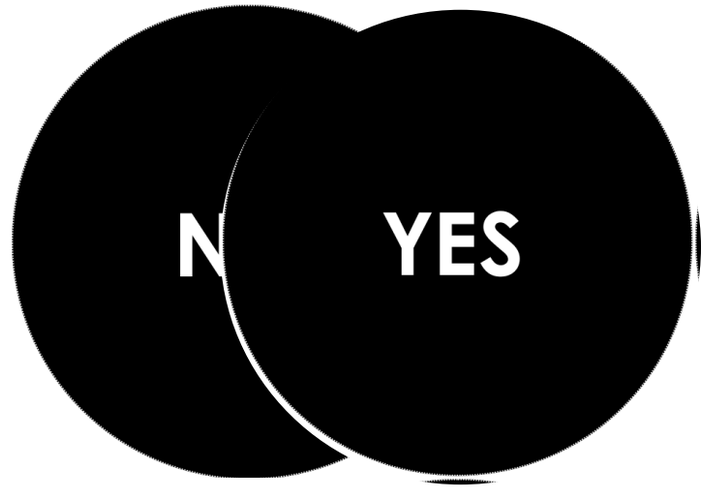
The state exerts strict control over information flows within and outside the ecosystem, suppressing dissent and shaping global discourse on its technological dominance.

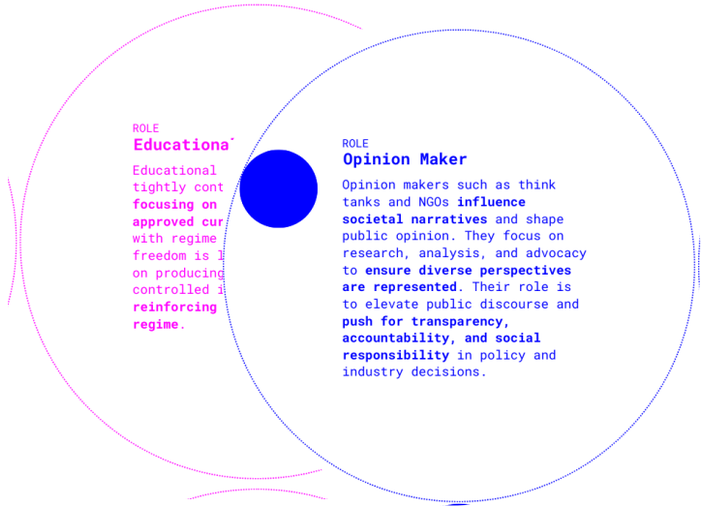
ERL **4/4** HIGH

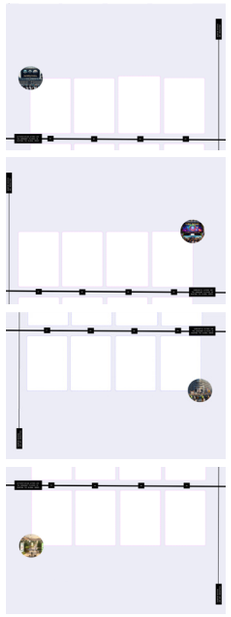
Ecosystem Readiness Level (ERL) looks at whether all of the key players and components of the broader environment are prepared to support and sustain the innovation.

ROLES & VOTES
[PER PERSON]
> Opinion Maker
> Economic-Oriented Regulator
> Digital Environment Regulator
> Quantum Tech Company
> Educational Institution
> Grid Operator

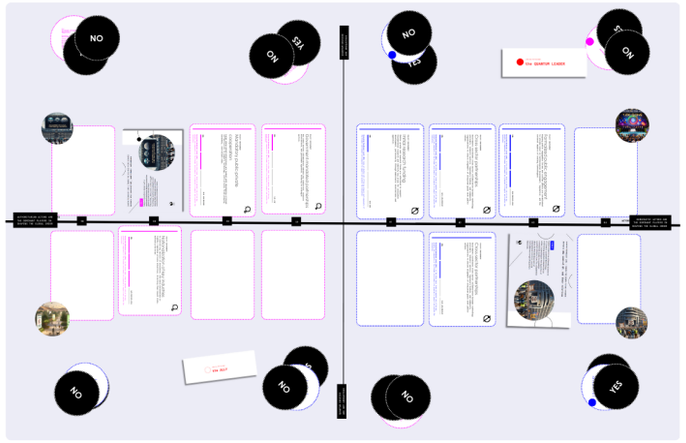




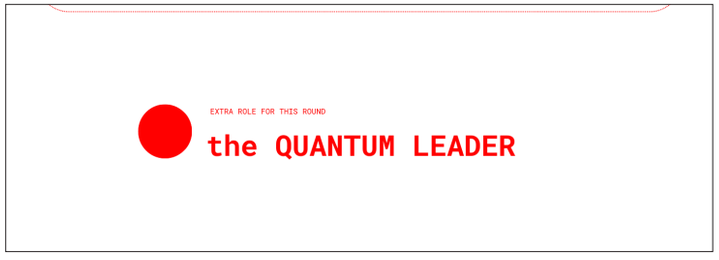


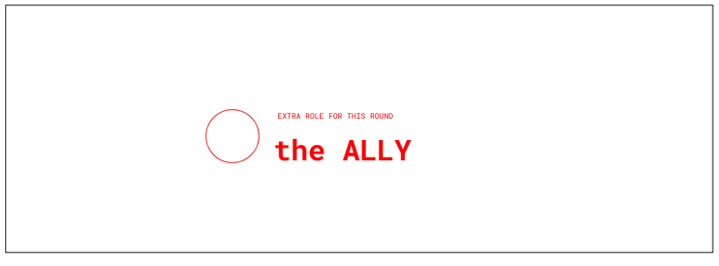


GAMEBOARD
[WITH ALL FOUR QUANTUM SCENARIOS]
> Collapse and Discipline Scenario under the Authoritarian Power
> Transformation and Growth under the Democratic Power



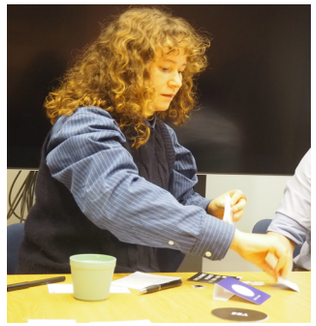
QUANTUM LEADER & ALLY
[CHANGES PER ROUND]
> The Quantum Leader moves clockwise
> The Quantum Ally is elected per round





APPENDIX C **MINISTRY BZK**

Context



Concept

The prototype was tested by assigning participants roles with distinct values and missions in a simulated policy-making environment. Participants interacted with policy and converged technology cards, engaging in debates and strategic decision-making. The purpose of the test was to evaluate the effectiveness of the game in teaching quantum policy concepts, fostering collaboration, and encouraging strategic thinking from diverse perspectives. Participants provided feedback on clarity, usability, and the ability to meet the game's educational and experiential objectives.

5.1.1 Method: Scenario Game for quantum and future literacy
The Scenario Game is designed as a strategic and interactive role-playing experience to engage participants in quantum and future literacy. By introducing roles, policy instruments, and simulated ecosystem readiness levels (ERLs), participants gain a deeper understanding of technological change and its ethical, societal, and governance impacts. The game fosters strategic thinking and collaborative decision-making, helping users contextualize quantum technology's role in shaping potential futures.

5.1.2 Preferences, Needs, Values, and Capabilities
Participants aim for accessible, dynamic gameplay with clear objectives and strategic depth. Simplified terminology, a guided introduction to policy instruments, and role-specific goals were identified as critical to engagement. The roles encourage prioritization of values such as innovation, privacy, competition, and societal impact. The game is designed to enable non-experts on quantum to participate effectively, however no introduction or cheat sheets are shared to test the graspability of the simplified game elements compared to previous tests

5.1.3 Procedure: Contextual Setup
Teams receive detailed cards explaining their roles, missions, and objectives. Gameplay progresses through rounds where participants select policy instruments, discuss strategies, and vote on alliances to advance ecosystem readiness levels (ERLs). The final session evaluates team performance, ecosystem progress, and alignment with overarching objectives such as quantum growth, transformation, or societal balance.

_
The game concept define the aim to be delivered by the game experience and what this means for the user's role in the game. As well as how this is reflected in the game components.

.2.1 Why (transfer effect)
The Scenario Game facilitates the transfer of complex quantum governance concepts into tangible, interactive experiences. By simulating a power race between governance frameworks, participants develop insights into the strategic dynamics of policy-making, exploring how different governance models shape quantum futures. The game enables participants to understand policy overlaps, trade-offs, and the need for collaborative frameworks to advance toward shared or opposing objectives. This transfer effect makes quantum and policy literacy actionable and relevant, particularly for stakeholders in the governance ecosystem.

Prototype

C.2.2 what (User's World)
The gameplay reflects real-world dynamics, encouraging participants to assess policy impacts, values, and strategic priorities within a structured environment. Players interact with policy instruments and evolving scenarios that mirror real-world quantum innovations and governance challenges.

5.2.2 How (narrative of the game design)
Role Assignment and Policy Selection: Participants assume hidden roles and use policy instruments to advance their strategies.
Ecosystem Readiness Progression (ERLs): Policies are strategically placed to improve ecosystem readiness, aligning with team objectives.
Strategic Interactions: Teams collaborate or compete to influence global outcomes, driven by policy gaps, overlaps, and dynamic alliances.
Endgame Scenarios: The culmination of gameplay reveals how policy choices have shaped the simulated world, reflecting outcomes like technological growth, societal equity, or collapse.

_

5.3.1 Why (the purpose of the test)
The prototype aims to test the effectiveness of the game's components in engaging participants with quantum and policy literacy. Specifically, it evaluates how the roles, policy instruments, and ecosystem readiness levels foster strategic decision-making, role commitment, and collaboration.

5.3.2 What (the game experience and user stories)
Participants experience role immersion, strategic collaboration, and decision-making under time constraints. Key user stories include:
Role Dynamics: Participants struggled initially with understanding roles but became more engaged as they connected their values to strategies (Participant 6).
Strategic Decision-Making: Teams recognized policy overlaps and gaps, leading to discussions on trade-offs and role incentives (Participants 3, 5).
Learning by Doing: Participants appreciated the realistic urgency of advancing quantum policies, noting the need for clearer consequences of neglected values (Participants 2, 3).

.3.3 How (interaction with the game design; components)
Setup and Roles: Participants are assigned predefined roles, missions, and policy instruments. Teams strategize to influence ecosystem readiness while aligning decisions with their roles' objectives.
Rounds of Play:
The Quantum Leader proposes alliances and selects policies to progress ERLs.
Players negotiate, vote, and apply selected policies to achieve their goals.
Policy Selection and Impact: Policies are placed on a board, impacting ERLs. Participants observe how policies interact, creating both synergies and conflicts.
Progress Indicators: The ERL system tracks ecosystem readiness,

Results

revealing advancements or setbacks based on team decisions.
Endgame Scenarios: The game concludes with teams evaluating their strategic outcomes against predefined goals, such as growth, transformation, or societal collapse.

_
The prototype results of the Ministry BZK test were tested through gameplay sessions and an written and spoken evaluation.

5.4.1 User-Effect Level:
Policy Literacy and Debate: Some participants reported that the debate aspect and the use of voting (yes/no) were engaging, providing an opportunity to explore different perspectives on quantum policy (n=5; P4, P5, P6, P7, P10). However, others indicated that voting's impact was unclear or that winning was less important than understanding the policy dynamics (n=3; P4, P5, P12).
Quantum Literacy Through Technology Cards: Quantum technology cards were noted as interesting but secondary to the gameplay, often skipped due to time constraints. This suggests that while the cards add value, they do not sufficiently enhance quantum literacy as intended (n=3; P3, P7, P8).

End of game: The transfer effect of policy literacy is somewhat successful, especially through voting and debate mechanics, but the impact of quantum literacy could be strengthened by simplifying technology card usage, possibly through structured readings or shorter summaries during gameplay.

.4.2 Knowledge Level:
The game elements could be made more effective by simplifying the cards (e.g., reduced text, clearer indicators) and improving visual aids to support the debate and learning process, which several participants felt was hindered by the current card design and complexity.

Policy Cards Clarity and Design: Many participants noted that policy cards were difficult to read or understand due to unclear information and small font size, which affected engagement in policy discussions (n=6; P1, P2, P3, P7, P9, P12).

Quantum Technology Cards Usage: Quantum tech cards were interesting to participants but often overlooked due to time constraints and complexity, which may have limited deeper engagement in policy debates (n=4; P3, P7, P8, P12).

Scenario and Goal Clarity: Players suggested that clearer visuals for Ecosystem Readiness Levels (ERLs) and a more structured voting system would enhance game flow and purpose, making it easier to connect game actions to strategic goals (n=5; P3, P4, P5, P6, P7).

5.4.3 Commercial Level:
Complexity and Accessibility: Several participants noted that the game's complexity, information overload, and language (currently not in Dutch) posed barriers to entry, which could limit its appeal in a commercial context if not simplified (n=5; P1, P3, P8, P10, P12).

Discussion

Engagement Value: Participants appreciated the game's tactical and strategic depth, mentioning elements like the "poker element" and the potential for "epic goals," which could be appealing to users interested in complex strategic games (n=3; P4, P7, P8).

Market-Specific Interest: One participant expressed interest in the game's relevance to the energy sector, suggesting that sector-specific themes could enhance its appeal in professional or educational markets (n=1; P10).

Conclusion: The game has potential commercial viability, particularly among users interested in strategic, policy-oriented gameplay. However, simplifying the setup, reducing complexity, and possibly localizing it to the Dutch language could improve accessibility and broaden its market appeal.

_
In this chapter, insights in the categories 'people' 'technology' and 'organisation' and further development directions are listed.

4.3.1 Knowledge gained about people
Participants highlighted the importance of role clarity and alignment with values. Many found roles intriguing but struggled with their implications, which limited initial engagement (n=4, Participants 1, 3, 6, 5).
Terminology was a significant barrier, with several participants (n=3, Participants 1, 2, 6) stating they felt excluded or disengaged due to complex language on cards. Participants noted the game could create a safe environment to learn by simplifying terminology and increasing role alignment, fostering collaboration across knowledge levels (n=2, Participants 6, 3).
Some participants wanted greater awareness of how their roles contributed to the outcomes, which would enhance their ability to commit to strategic decisions (n=3, Participants 5, 6, 3).

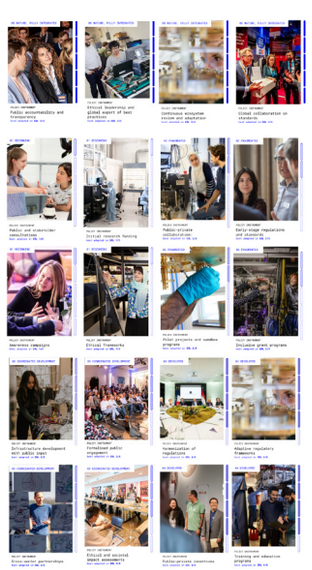
4.3.2 Knowledge gained about technology
Participants expressed difficulty understanding connections between quantum sensing, internet, and computers, suggesting a need for clearer explanations of technological concepts (n=3, Participants 1, 2, 3). The game lacked negative scenarios or counteracting forces to show risks and consequences, limiting engagement with realistic technological challenges (n=2, Participants 3, 4).
The urgency of quantum developments was acknowledged but lacked mechanisms to simulate delays or accelerated advancements due to specific policies (n=2, Participants 2, 3).

4.3.2 Knowledge gained about organisation
The game revealed blind spots in understanding how values link to organizational outcomes, especially the effects of prioritizing or neglecting specific values (n=3, Participants 3, 5, 6).
Participants suggested more alignment between policy cards and the real-world incentives of roles, such as showing how certain policies benefit or hinder roles like big tech or regulatory bodies (n=3, Participants 5, 2, 3).

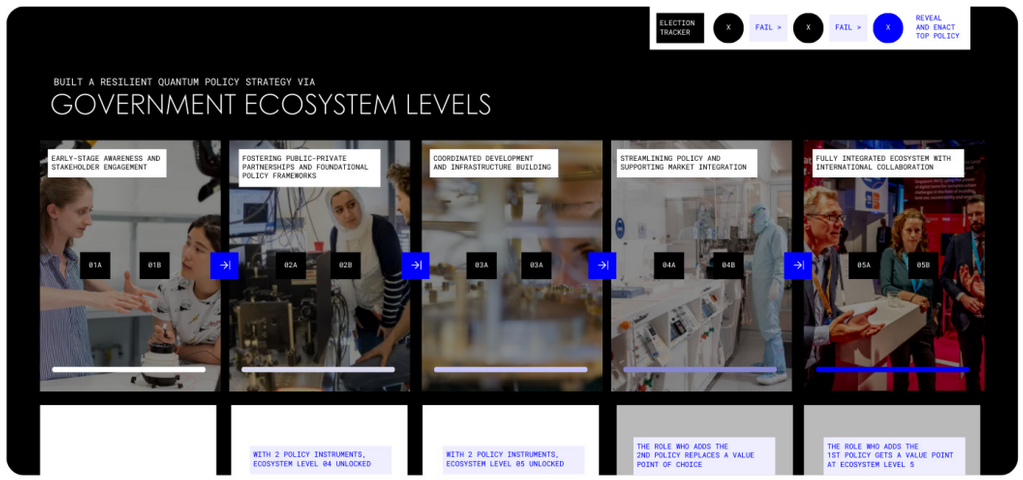
4.3.6 Knowledge Gained About the Design Process
Complexity and Information Overload: While participants appreciated the learning aspect, many struggled with the volume of information. Simplified cards or cheat sheets could improve usability (n=3, Participants 1, 2, 6).
The lack of explicit linkages between policies, values, and their effects hindered the ability to strategize and understand outcomes (n=3, Participants 5, 3, 6).
Adding progress indicators (e.g., stages of development or scenario progress) could help players make informed decisions (n=2, Participants 1, 6).
The learning curve of the game was steep; participants suggested playing multiple rounds or using a video tutorial to reduce the onboarding time (n=2, Participants 5, 3).

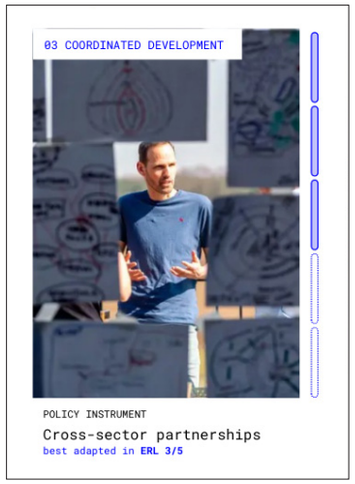
4.3.5 New questions
Introduce negative consequences or counteracting forces for poor decisions to make the game more dynamic and realistic (n=2, Participants 3, 4).
Include interactive progress tracking mechanisms, such as a dashboard showing how policies affect values and technological advancements (n=2, Participants 5, 3). How can the game better represent the trade-offs between values, such as privacy versus innovation, to encourage meaningful decision-making?
What mechanisms can simulate the real-world consequences of neglecting certain values, such as inequality or slowed innovation?
How can the game ensure participants feel their roles and contributions impact the outcomes meaningfully, even when collaboration is emphasized?

PER GOVERNMENT ECOSYSTEM LEVEL
[POLICY INSTRUMENTS]
> EL 1
[Public and stakeholder consultations] [Initial research funding] [Ethical frameworks] [Awareness campaigns]
> EL 2
[Public-private collaboration] [Pilot projects and sandbox programs] [Early-stage regulations and standards] [Inclusive grant programs]
> EL 3
[Infrastructure development with public input] [Cross-sector partnerships] [Formalised public engagement] [Ethical and societal impact assessments]
> EL 4
[Harmonization of regulations] [Public-private incentives] [Adaptive regulatory frameworks] [Training and education programs]
> EL 5
[Continuous ecosystem review and adaptation] [Public accountability and transparency] [Global collaboration on standards] [Ethical leadership and global export of best practices]



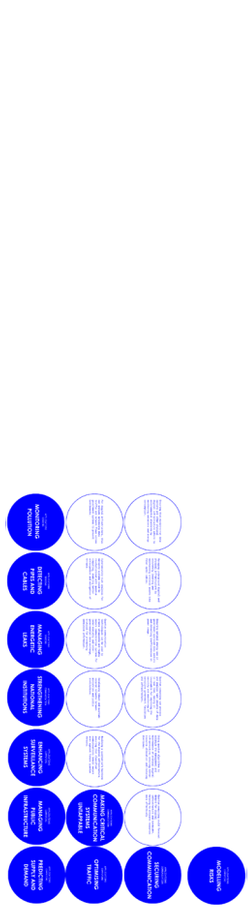
GAME BOARD
[GOVERNMENT ECOSYSTEM LEVELS LINKED TO POLICY INSTRUMENT]
> EL 1 Early-Stage Awareness and Stakeholder Engagement
> EL 2 Public-Private Partnerships and Foundational Policy Frameworks
> EL 3 Coordinated Development and Infrastructure Building
> EL 4 Streamlining Policy and Supporting Market Integration
> EL 5 Fully Integrated Ecosystem with International Collaboration





QUANTUM TECHNOLOGY APPLICATIONS
[SELECTED FOR MINISTRY BZK]

> Quantum Sensors
[monitoring pollution, detecting pipes and cables, managing energetic leaks]
> Quantum Computer
[optimising traffic, predicting supply and demand, managing public infrastructure, enhancing surveillance systems, modelling risks]
> Quantum Communication
[securing communnication, making critical communication systems untappable, strengthening national institutions]



APPLICATIONS
SENSING

DETECTING PIPES AND CABLES

Managing underground digital and physical infrastructure by accurately locating and maintaining critical assets like fiber optic cables.

APPLICATIONS
COMPUTING

MANAGING PUBLIC INFRASTRUCTURE

Using quantum algorithms to optimize the management and maintenance of critical digital infrastructure, ensuring better resource allocation and reducing downtimes.

APPLICATIONS
COMMUNICATION

MAKING CRITICAL COMMUNICATION SYSTEMS UNTAPPABLE

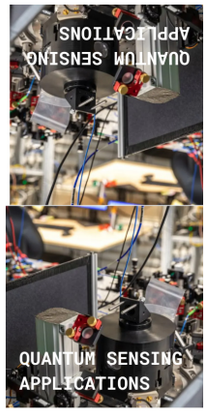
Building a quantum-safe backbone for the digital infrastructure, ensuring that classified communications remain secure even against future quantum threats.

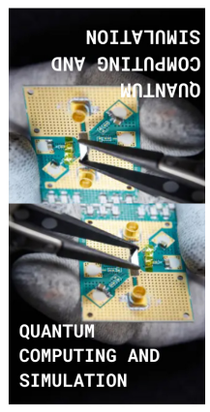
OVERVIEW WHERE APPLICATIONS GET LAUNCHED IN 30 MINUTES
[3D CATEGORIES]

> Quantum Sensing applications
> Quantum Computing and Simulation
> Quantum Networks

UNLOCKING THE POWER OF THE QUANTUM WORLD

QUANTUM SENSING APPLICATION | QUANTUM NETWORKS | QUANTUM COMPUTING AND SIMULATION

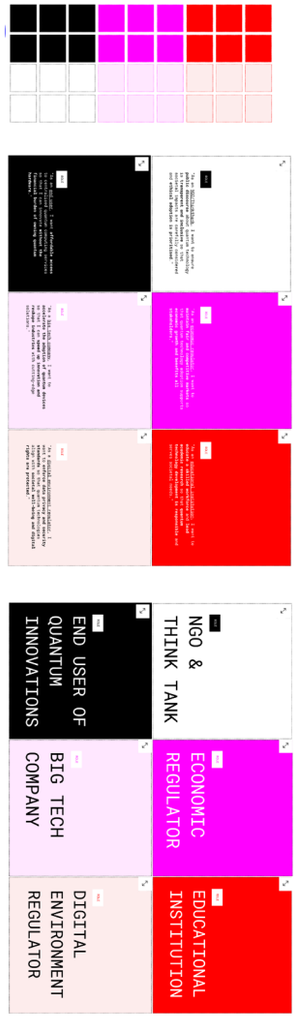


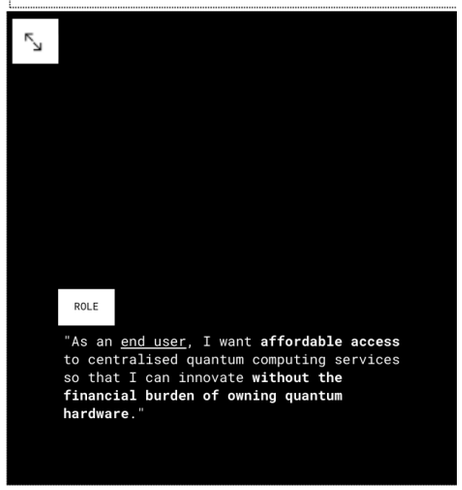


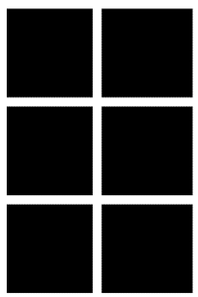
ROLES & VOTES
[PER PERSON]
>
> Economic-Oriented Regulator
> Digital Environment Regulator

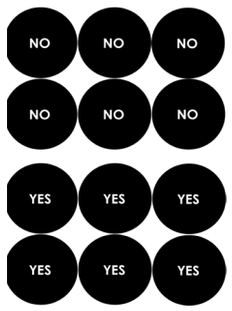
> Quantum Tech Company
> Educational Institution
> End User Of Quantum Innovations

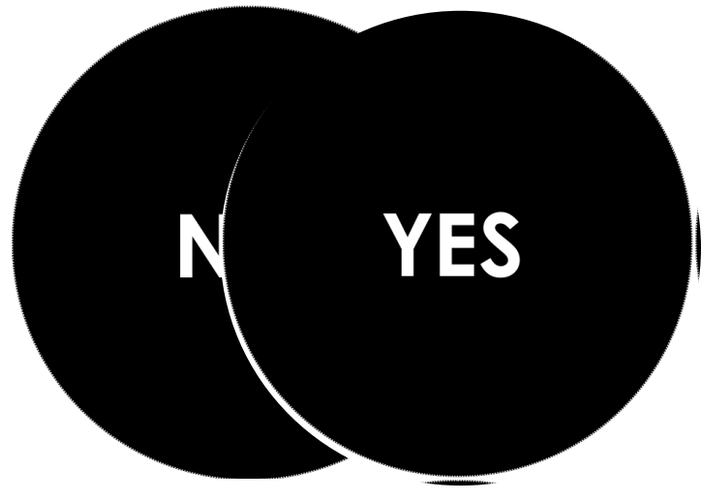
QUANTUM LEADER & ALLY
[CHANGES PER ROUND]
> The Quantum Leader moves clockwise
> The Quantum Ally is elected per round

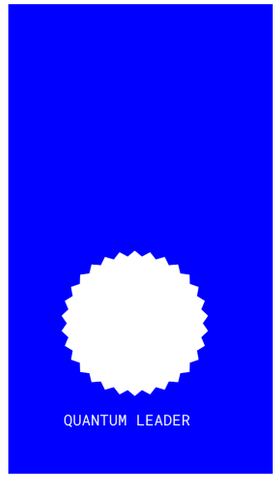


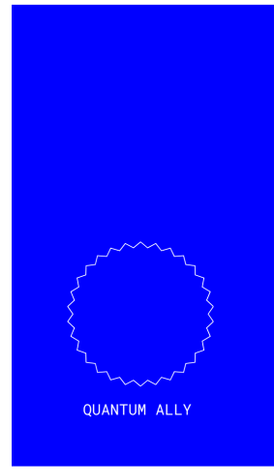












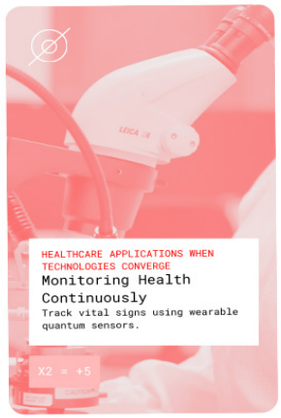
APPENDIX D **CENTRE FOR FUTURE GENERATIONS FLAGSHIP**

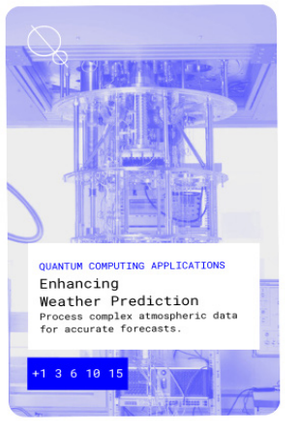
QUANTUM TECHNOLOGY APPLICATION CARDS
[CATEGORIES WITH EXAMPLES ON THE CARDS]

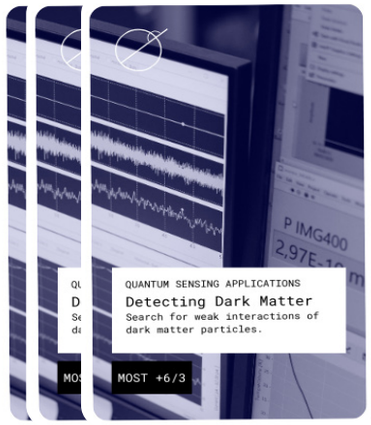
> Quantum for Good Applications: 20 cards
> Quantum Sensing Applications: 26 cards
> Quantum Computing Applications: 14 cards
> Military Applications When Technologies Converge: 14 cards
> Healthcare Applications When Technologies Converge: 14 cards

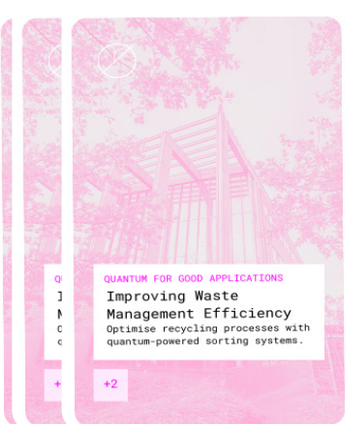
> Critical Materials for Quantum Technologies: 10 cards

> Policy Instruments - Acceleration Factors: 6 cards
> Policy Instruments - Collaborations: 4 cards
> Policy Instruments - Strategies for Alignment: 4 cards









APPENDIX D **CENTRE FOR FUTURE GENERATIONS FLAGSHIP**

SECRET AGENDAS
[QT SCENARIOS WITH DESCRIPTIONS ON CITIZEN- AND INTERNATIONAL PERSPECTIVE]
> Collapse Scenario
> Discipline Scenario
> Transformation Scenario
> Growth scenario

MITIGATE AND ACCELERATE COINS
[FOR DISCUSSION ON SECRET AGENDA COLLECTED APPLICATIONS]
> Mitigate coins (3x every participant duo)
> Leverage coins (3x every participant duo)

COLLAPSE SCENARIO

AUTHORITARIAN POWERS SHAPE THE WORLD ORDER AND QUANTUM DEVICES ARE UBIQUITOUS

Most citizens live sedentary, conformist lives in monitored urban centres; off-grid communities reject oppressive regimes for simpler, tech-free lifestyles. Quantum talent flocks to authoritarian countries.

International collaborations vanish under authoritarian dominance; resource control by regimes marginalises dissenting nations, deepening inequality and limiting global problem-solving.

STRATEGY

- Maximise Military Applications (x3=10)
- Collect Quantum Computing Applications (+1 3 6 10 15)
- Invest Heavily in Critical Materials (End of Game: +6/-6)

TRANSFORMATION SCENARIO

DEMOCRATIC POWERS SHAPE THE WORLD ORDER AND QUANTUM DEVICES ARE UBIQUITOUS

People enjoy authentic, customisable experiences; digital nomads thrive on seamless urban transit systems, while traditionalists embrace off-grid, nature-focused living.

Democratic alliances ensure global quantum governance; equitable tech-sharing improves healthcare, climate resilience, and innovation, enhancing quality of life worldwide.

STRATEGY

- Focus on Quantum Computing Applications (+1 3 6 10 15)
- Leverage Quantum for Good Applications for Quality Education (+3)
- Invest in Healthcare Applications when technologies converge (x2=5)

DISCIPLINE SCENARIO

AUTHORITARIAN POWERS SHAPE THE WORLD ORDER AND QUANTUM DEVICES ARE ONLY AVAILABLE AT SPECIALISED LOCATIONS.

Governments enforce conformity through surveillance; escapist spirituality dominates, while underground hacktivists rebel using advanced, secure quantum tools.

Isolationist policies stifle global collaboration; resource scarcity and trade barriers exacerbate local hardships, but underground networks strive to counteract authoritarianism.

STRATEGY

- Prioritise Military Applications (x3=+10)
- Use Policy | Strategies For Alignment (Most types of cards +4)
- Employ Quantum for Good Applications for Infrastructure (+2)

GROWTH SCENARIO

DEMOCRATIC POWERS SHAPE THE WORLD ORDER AND QUANTUM DEVICES ARE ONLY AVAILABLE AT SPECIALISED LOCATIONS

Societies value personal freedom and cultural progress; collaborative governance fosters environmental and technological advancements, but inequality persists globally.

Balanced international cooperation in quantum regulation fosters peace and technological access; uneven development leaves developing nations struggling with systemic inequalities.

STRATEGY

- Maximise Military Applications when Technologies Converge (x3=10p)
- Collect Quantum Computing Applications (+1 3 6 10 15)
- Invest Heavily in Critical Materials (End of Game +6/-6)

GOVERNMENT ECOSYSTEM LEVELS
[WITH LINKED POLICY INTRUMENTS]
> Ecosystem Level 1
> Ecosystem Level 2
> Ecosystem Level 3
> Ecosystem Level 4
> Ecosystem Level 5

BUILT A RESILIENT QUANTUM POLICY STRATEGY VIA

GOVERNMENT ECOSYSTEM LEVELS

01

EARLY-STAGE AWARENESS AND STAKEHOLDER ENGAGEMENT

Underdeveloped ecosystem with limited infrastructure, low coordination, minimal regulatory frameworks, and low awareness. Efforts are mainly academic or niche, with quantum start-ups rare or nonexistent and commercial companies largely uninvolved.

GOVERNANCE ECOSYSTEM LEVEL

02

PUBLIC-PRIVATE PARTNERSHIPS AND FOUNDATIONAL POLICY FRAMEWORKS

Scattered stakeholder efforts with basic infrastructure but lacking sufficient funding, collaboration, and public awareness. Quantum start-ups begin to emerge but operate in isolation, while commercial companies show initial interest but lack strategic coordination.

GOVERNANCE ECOSYSTEM LEVEL

03

COORDINATED DEVELOPMENT AND INFRASTRUCTURE BUILDING

Stakeholder coordination begins with early-stage policies, funding mechanisms, and infrastructure. Quantum start-ups increase collaboration with academia and industry, becoming key innovators. Commercial companies invest more in quantum technologies, possibly establishing dedicated R&D divisions. Public and industry interest grow, but scalability remains a challenge.

GOVERNANCE ECOSYSTEM LEVEL

04

STREAMLINING POLICY AND SUPPORTING MARKET INTEGRATION

Well-developed infrastructure with growing public and private investment, and emerging market mechanisms. Quantum start-ups mature into established enterprises contributing significantly to commercialization. Commercial companies actively integrate quantum technologies into products and services, sometimes acquiring start-ups. Technologies gain larger-scale adoption, though maturity and integration continue to evolve.

GOVERNANCE ECOSYSTEM LEVEL

05

FULLY INTEGRATED ECOSYSTEM WITH INTERNATIONAL COLLABORATION

Broad collaboration among stakeholders with robust regulatory frameworks and extensive public and private investment. Quantum start-ups and commercial companies are fully integrated into the economy, driving continuous innovation and widespread market adoption. The ecosystem demonstrates resilience and adapts to technological advances.

GOVERNANCE ECOSYSTEM LEVEL

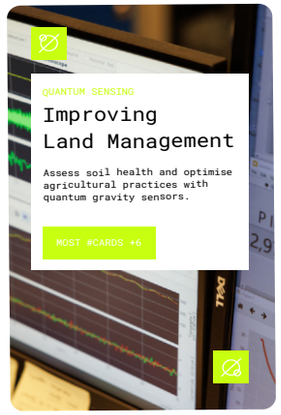
APPENDIX D **CENTRE FOR FUTURE GENERATIONS FLAGSHIP**

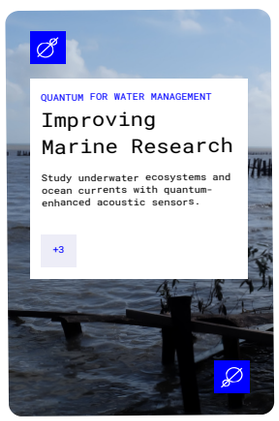
QUANTUM TECHNOLOGY APPLICATION CARDS
[CATEGORIES WITH EXAMPLES ON THE CARDS]

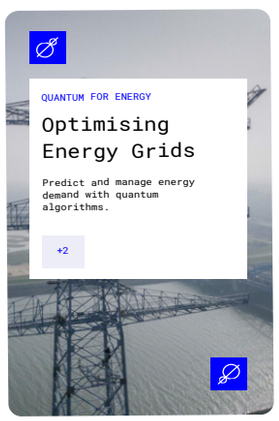
> Quantum for Infrastructure 6 cards
> Quantum for Water Management 4 cards
> Quantum for Energy 10 cards
> Quantum for Healthcare 14 cards
> Quantum for Military 14 cards
> Quantum Sensing 26 cards
> Quantum Computing 14 cards

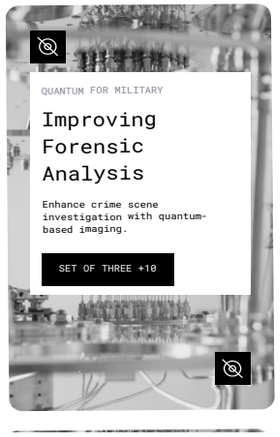
> Critical Materials for Quantum 10 cards

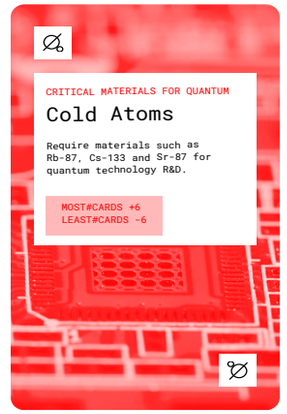
> Policy - Acceleration Factors 6 cards
> Policy - Collaborations 4 cards
> Policy - Strategies for Alignment 4 cards

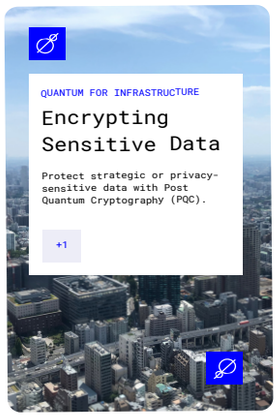


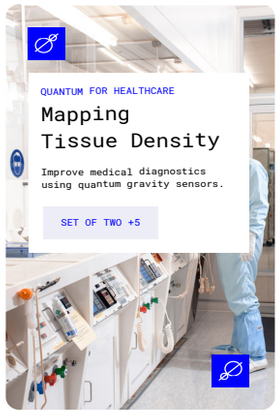








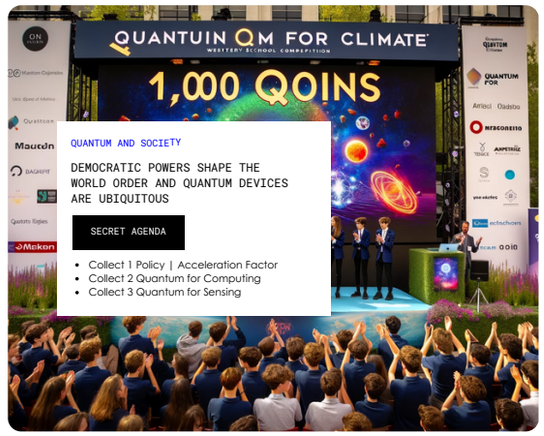


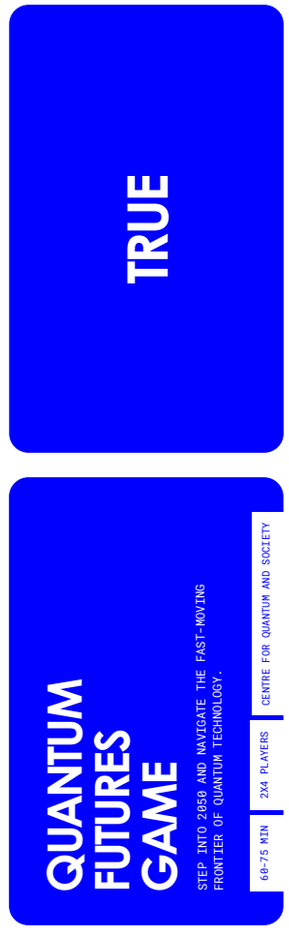


APPENDIX D **CENTRE FOR FUTURE GENERATIONS FLAGSHIP**

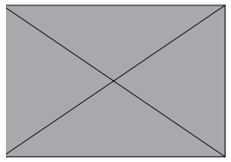
SECRET AGENDAS
[QT SCENARIOS WITH DESCRIPTIONS ON CITIZEN- AND INTERNATIONAL PERSPECTIVE]
> Collapse Scenario
> Discipline Scenario
> Transformation Scenario
> Growth scenario

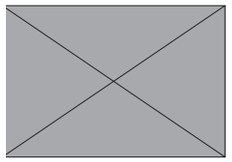
MITIGATE AND ACCELERATE COINS
[FOR DISCUSSION ON SECRET AGENDA COLLECTED APPLICATIONS]
> Mitigate card
> Leverage card
> True card

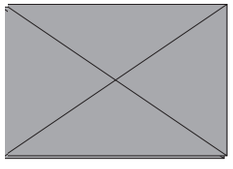


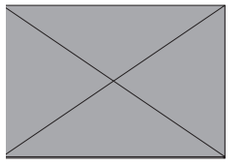


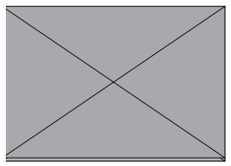
APPENDIX E **QUANTUM FUTURES GAME**

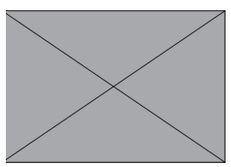


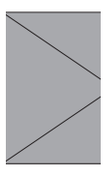










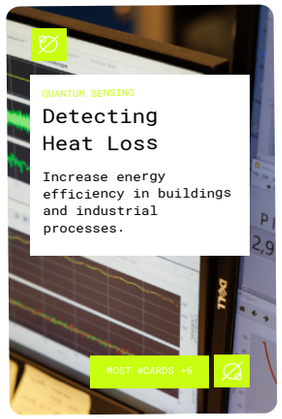


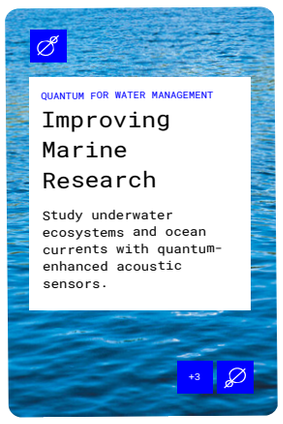
QUANTUM TECHNOLOGY APPLICATION CARDS
[CATEGORIES WITH EXAMPLES ON THE CARDS]

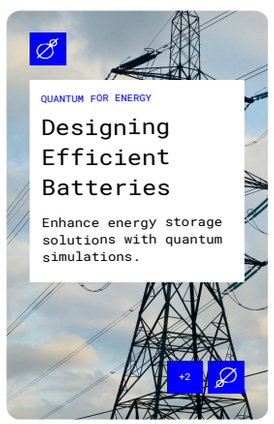
> Quantum for Infrastructure 6 cards
> Quantum for Water Management 4 cards
> Quantum for Energy 10 cards
> Quantum for Healthcare 14 cards
> Quantum for Military 14 cards
> Quantum Sensing 26 cards
> Quantum Computing 14 cards

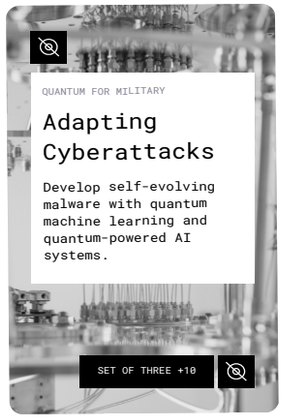
> Critical Materials for Quantum 10 cards

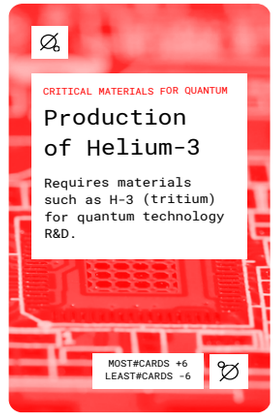
> Policy - Acceleration Factors 6 cards
> Policy - Collaborations 4 cards
> Policy - Strategies for Alignment 4 cards

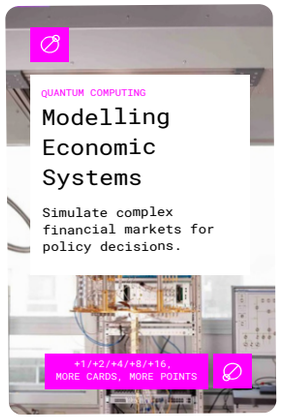


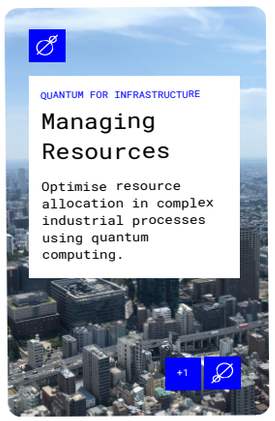


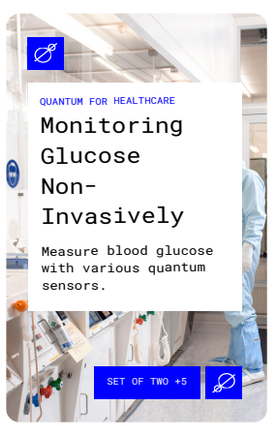






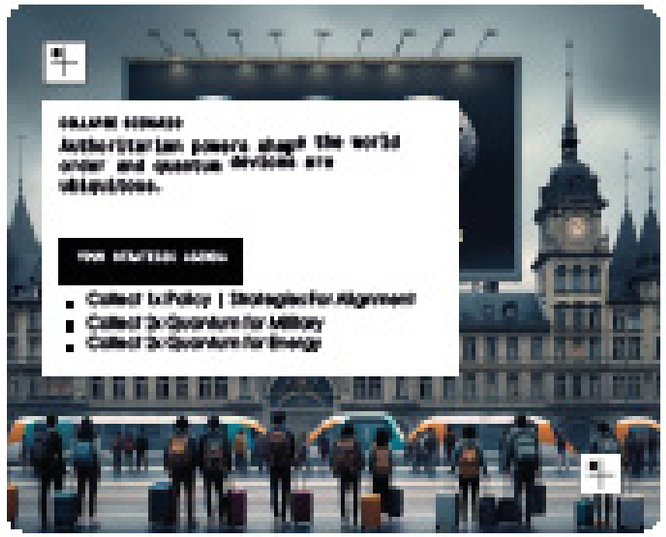


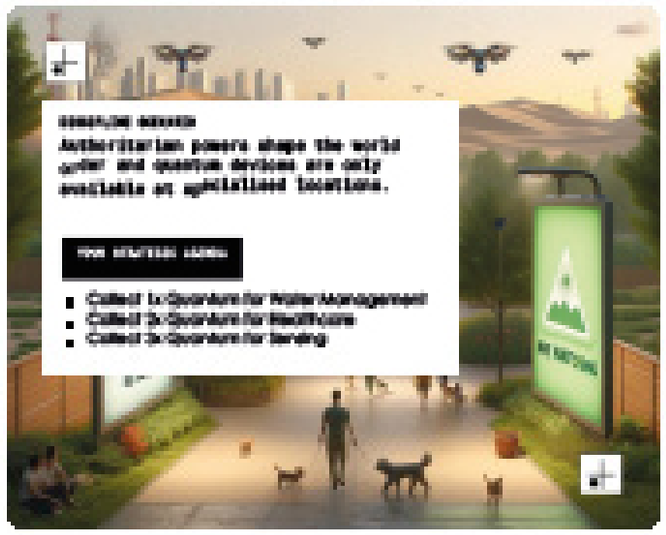


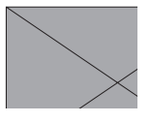


APPENDIX E **QUANTUM FUTURES GAME**

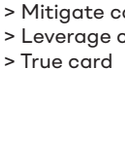
SECRET AGENDAS
[QT SCENARIOS WITH DESCRIPTIONS ON CITIZEN- AND INTERNATIONAL PERSPECTIVE]
> Collapse Scenario
> Discipline Scenario
> Transformation Scenario
> Growth scenario

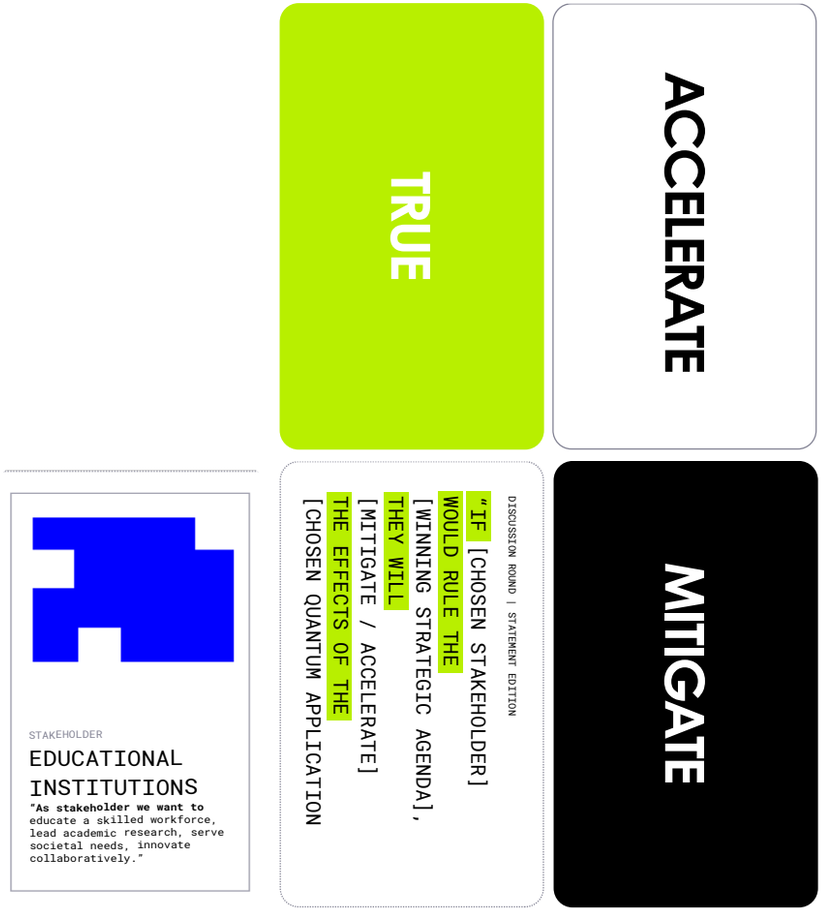






MITIGATE AND ACCELERATE COINS
[FOR DISCUSSION ON SECRET AGENDA COLLECTED APPLICATIONS]
> Mitigate card
> Leverage card
> True card





Personal Project Brief – IDE Master Graduation Project

Name student Juwe van Vliet **Student number** 4674103

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Quantum Scenario Game: engage in the discourse of quantum technologies

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Quantum technology has a 'systemic' impact on society and is therefore a technology that enables all sorts of innovation, in all kinds of fields (Quantum Delta NL, 2023). Currently, the level of engagement with the discourse of this technology varies among stakeholders as it's still in the NISQ area, reciptive and unstable. In 2024 IEEE Spectrum writes about several actual uses for quantum computers, an application of quantum technologies. They mention ongoing research into areas as 1. drug metabolism (Goings et al., 2024) 2. CO_2 sequestration (Nguyen et al., 2023) and 3. agricultural fertilization (Reiher et al., 2017). A multidisciplinary approach is needed in order to explore the discourse of quantum technologies with parties like industry innovators, policy-makers, industry influencers as NGO's or think tanks, educational stakeholders and the quantum community (see Figure 1).

Opportunities:

A. Enhanced Decision-Making: an envisioned environment where decision-makers can explore various scenarios could help them to understand the potential impacts of quantum technologies before they occur. This proactive approach supports in crafting better policies and strategies.

B. Multidisciplinary Collaboration: a varied stakeholder group encouraging a multidisciplinary approach to understanding and managing quantum technology impacts.

C. Public Awareness and Education: by simulating future scenarios and implications of quantum technologies it promotes awareness and understanding of socio-technological advancements.

Limitations:

A. Complexity of Scenarios: Quantum technologies are complex and its future impact is uncertain (see Figure 2). To remain engagement the collaboration must balance between oversimplification and overwhelming complexity.

B. Diverse Stakeholder Perspectives: Different stakeholders have varying levels of understanding and interests. The need to serve these diverse perspectives at the same time can be challenging to design for and to implement effectively.

C. Rapid Technological Advancement: The pace at which quantum technologies are evolving may outrun the game's ability to envision future scenarios accurately, requiring frequent updates to remain relevant.

➔ *space available for images / figures on next page*

introduction (continued): space for images

click to add picture

image / figure 1 The decision-making in the quantum technology discourse demands a multidisciplinary approach.

image / figure 2 The Centre for Quantum and Society co-created future scenarios of quantum-enabled worlds.

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

"We cannot raise each new generation in the fear of the future. While we are correct not to ignore dangerous elements of artificial intelligence and to take action, we must place them in proportion and consider the good that will be achieved in harnessing these technologies," wrote Kai Fu Lee in 2023. This quote underscores the necessity of balanced foresight in technological advancements. However, engaging in the discourse of quantum technologies requires understanding their potential applications. It requires a willingness to take on complex scientific concepts while considering their broader societal implications. Moreover, it requires consideration of the expectations, promises, and potential impacts of the technology on various sectors of society. Therefore, a collaborative mindset helps with shaping the future of quantum technologies.

A serious game can serve as a tool to explore, examine and reflect on future worlds where quantum technologies play a central role. Participation in a serious game could help industry stakeholders foresee ethical, legal and societal aspects. It also enables collaboration between diverse perspectives by involving a multidisciplinary stakeholder group. For the Centre for Quantum and Society, the serious game supports its goal to contribute to a more informed and nuanced understanding of quantum technologies and their potential impact on society.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Create a future-scenario [how] serious game [what] for multidisciplinary teams (including policy-makers, educational stakeholders, industry innovators, industry influencers and the quantum community) [who] to engage in the discourse of quantum technologies [why].

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The Frame Innovation method applied to public organisation creates for me a structured approach for the design research within the decision-making context of the public sector (see Figure 3). It also provides insights on change management, coalition roles, stakeholder management and power dynamics with belonging collaboration styles.
Whilst building on the Centre of Quantum and Society's Future Scenarios project, it gives methodological steps to combine selected literature on user engagement, generational interaction with innovations, quantum technologies, and policy design. Additionally, the persuasive game design (PGD) approach is interesting for the prototyping phase to enhance user engagement and effectiveness (see Figure 4). This will include iterative development and testing of three prototypes: 1. visitors of the Policy Academy and participants of a quantum event at Alliander 2. IDE students role-playing the context stakeholders and/or the Centre for Quantum and Society colleagues 3. The defined multidisciplinary stakeholder group: trainees from the Ministry of Foreign Affairs. All in order to ensure a comprehensive evaluation and refinement of the prototypes and final scenario game.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting***, ***mid-term evaluation meeting***, ***green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	6 sept 2024
Mid-term evaluation	8 nov 2024 13:30
Green light meeting	19 dec 2024 11:00
Graduation ceremony	30 jan 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

This project provides an opportunity to dive into a, for me, new technological topic. I'm interested to learn about transition engagement, how varied stakeholders adapt and evolve in response to technological advancements. I'm looking foward to design a setting for collaborational future thinking and discover how multidisciplinarity works within speculative contexts.

Moreover, I am looking forward to develop storytelling skills, focusing on how to effectively communicate complex ideas. Understanding what to tell, to whom, and when is a usefull skill for engagement of decision-makers, public or topic-experts. This project will challenge me to communicate narratives that resonate with diverse audiences, leading to critical yet open understanding.

Additionally, this project aligns with my interest in systems thinking. Investigating the multifaceted impacts of quantum technologies seems exciting. Engaging with this topic for at least half a year will allow me to delve deeply into its complexities. By conducting conversations with stakeholders, other designers and coaches, I can incorporate the bigger picture into the projects analyses and outcomes. This approach enables me to act as a facilitating designer, integrating diverse perspectives to encourage bold thinking.