Quantum Delta NL

PLAN PHASE 3

Quantum Delta NL

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Summary

This document outlines the proposed plan for phase 3 of the Quantum Delta NL Growth Fund programme. Phase 3 marks a pivotal moment in the QDNL programme in every aspect. Over the past years, the QDNL foundation has worked very hard to establish and grow the QDNL programme. All the planned activities have started and generated results within the programme lines: the Catalyst programmes (hereafter: CATs), the Action Lines (hereafter: ALs) and NanoLabNL, supported by the QDNL Core Team. This has all contributed to the growth of a world-renowned and highly dynamic national quantum ecosystem. As a mission driven programme, the goal of QDNL is to accelerate scientific developments, stimulating commercialisation of quantum technology and thereby growing the quantum economy, to create long-term economic and societal impact for the Netherlands.

Quantum technology is developing fast in a rapidly changing world, where external developments and competition have a strong influence on the QDNL programme. These developments played a significant role in the internal and external reflections which were used to chart the course for phase 3 of the QDNL programme: QDNL conducted a self-assessment, a mid-term review and crafted a new QDNL Vision towards 2035, aligning with these recent advancements. The advice from the mid-term review is integrated into this plan. Additionally, a Taskforce was established to provide guidance on the optimal strategy for phase 3.

All these preparations have led to a revised design of activities and interactions within and between CATs and ALs, emphasising collaborative efforts between the programme lines. This approach aims to foster synergy and enhance executive effectiveness. The long-term objectives of QNDL – sustainable economic and societal impact – remain unchanged and continue to drive the ambitions. To reach maximum economic impact, greater emphasis is placed on engaging end-users and enhancing manufacturing and industry participation in the ecosystem, to ensure that the efforts are strategically aligned with (future) market needs and opportunities. Next to that, a new funding strategy is implemented, characterized by transparency and flexibility. This will contribute to strategic decision making as the programme moves forward.

As quantum technology increasingly becomes applicable in the upcoming years, the technology development and commercialisation will also necessitate constructing manufacturing facilities. This situation will soon give rise to a causality dilemma: whether to invest further in technology development and commercialisation or in manufacturing facilities. Certain investments in facilities can already be undertaken in phase 3, but there will be a need for follow-up after NGF funding concludes to scale up and prepare for international demands and participation in initiatives like the Chips Act and future EU Quantum Act.

Within the CATs, a significant portion of the budget will flow to companies to solidify a Netherlands-based quantum industry. Further strategic choices are anticipated during phase 3, partly driven by the significant increase in global investments in quantum technologies in recent years.

With this comprehensive plan, there is confidence that QDNL is well-prepared to further build and expand the quantum ecosystem in the Netherlands and globally. This plan not only addresses immediate needs and leverages past successes but also sets a clear path towards a sustainable and innovative future, empowering the next generation of quantum technologies and their applications worldwide.

1 Introduction

Quantum Delta NL (hereafter: QDNL) was one of the first projects that was granted from the National Growth Fund (NGF) in 2021, with QDNL being awarded a total funding of €615 million. Over the past four years, QDNL has cultivated a strong ecosystem that includes research, talent and start-up development. This has empowered all stakeholders to sustain a prominent position both within Europe and on the global stage, effectively transforming quantum technology into tangible economic and societal benefits. Consequently, this significant effort strongly contributes to fostering innovation and driving long-term economic impact in the Netherlands – one of the main goals of the NGF.

The funding of QDNL is split into three phases: phase 1, 2022: €54 million, phase 2, 2023-2024: €228 million that have been granted and a reservation for the years 2025-2028 of €333 million, called phase 3.[1] For the third phase to be awarded, the precondition was to conduct an independent midterm review (MTR) and submit an updated plan. The MTR was initially foreseen for 2025. However, after consulting with the Netherlands Enterprise Agency (RVO), the Ministry of Economic Affairs (EZ) and NGF early 2023, we have decided to conduct the MTR already in 2024 to have valuable input for our phase 3 activities.

In recent years, international competition has intensified, underscoring the necessity for a comprehensive MTR to critically evaluate our programme in the context of ongoing developments. The review had a significant impact on shaping our vision, emphasising the importance of making bold decisions and greatly speeding up the advancement of our programme. Phase 3 of the QDNL programme is therefore crucial to reinforce our early industrial position while embracing forward-thinking disruptive innovation. The awarded phase 3 funding of QDNL,[2] coupled with a programme evolution geared towards bolstering economic positioning, will empower the Netherlands to capitalise on the momentum generated in phase 1 and 2 of this programme.

It is thereby important to mention that QDNL is a mission driven programme, with a clear national vision, strategy, and different subgoals.[3] In phase 3 there will still be a focus on R&D and innovation, but to reach our goals we will focus more on productisation and commercialisation. To build and grow the ecosystem, we will keep fostering the development of new companies, to create economic impact for the Netherlands. Now that quantum technology is becoming increasingly more mature and applicable, we need to step up our efforts in the domain of manufacturing and applications. This refocus requires several changes in our programme. Therefore, we have created a new funding strategy (see chapter 4.3), a new vision on end-user engagement and on the necessary shared facilities and cleanroom infrastructure.

The MTR committee considers QDNL to be a globally iconic project that has inspired other nations to invest in quantum technology in its image and spirit. As the QDNL ecosystem, we see this global leadership as a testament to the collective effort of our ecosystem and a sign of the courageous decision of the Dutch government to give us this chance. We very much welcome the opportunity to present in the following pages our plans for the final phase of the QDNL National Growth Fund programme.

This document presents the approach and plans for phase 3. It starts with a brief overview of the QDNL programme of the past few years, highlighting both developments that influenced our programme. After that, we sketch the main findings of the MTR and the taskforce that reviewed the phase 3 plan. Then we translate those

[1] The investment phase will be in 2025-2028, after that there is a continuing management phase until 2031, since activities like open calls and PhD's take longer to execute then 2028.
[2] See: https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken/nieuws/2024/07/12/groen-licht-voor-vervolg-vijf-lopende-projecten-nationaal-groeifonds
[3] See: https://assets.quantum-delta.prod.verveagency.com/assets/proposal-that-was-submitted-to-the-national-growth-fund.pdf and https://assets.quantum-delta.prod.verveagency.com/assets/nationale-agenda-quantum-technologie.pdf

finding in the main changes to our programme for the next phase. This is followed by visions on the important overarching topics: economic and societal impact, user engagement, funding strategy, entrepreneurship, internationalisation, standardisation, shared facilities, chips act and IP. Next, we describe an outlook on the developments of quantum technology in computing, communication and sensing. Then we sketch the strategies for a.o. talent, start-up development, societal aspects and community building. In chapter 7 there is an overview of all the projects per programme line, where the strategies and visions are translated into work packages.

To create this plan, we have undergone a rigorous period of evaluation and planning in collaboration with our ecosystem partners. In accordance with the recommendations from the MTR, we have made challenging yet decisive strategic choices for phase 3, while also achieving alignment with the entire ecosystem. Although this is a plan of only 64 pages, it is the result of hundreds of conversations and the work of hundreds of people. This is a testament to the growth and connectedness of our ecosystem.

Figure 1. The Executive Board members of Quantum Delta NL: Beau Greville, Philippe Bouyer and Pieter de Witte.

2 QDNL 2021-2024

In this chapter we zoom in on three years of QDNL, our governance and the external developments that influence our programme. After that, we sketch our vision and strategy towards the future.

2.1 Governance and Organisation

The QDNL programme is organised and steered along eight programme lines: three catalyst or CAT-programmes, four action lines and a cleanroom programme. Technology development primarily takes place in the three overarching CAT-programmes (quantum computing, quantum networking and quantum sensing). These CATs are supported by the four action lines: research and innovation, ecosystem development, talent development and making societal impact. The cleanroom programme (NanoLabNL) establishes the required cleanroom infrastructure which sets a precondition for the programme as a whole. Together, these programme lines cover all topics relevant for establishing the envisioned ecosystem and realising the economic impact the programme aims at. This comprehensive approach makes the QDNL programme unique in its kind – not only within the Netherlands itself, but also internationally.

The programme is managed and coordinated by the QDNL foundation and most of the work in the different programme lines is carried out by companies, universities and knowledge institutes in our five hubs: Delft, Eindhoven, Leiden, Twente and Amsterdam. Day-to-day management resides with QDNL's Executive Board, which is supported by the QDNL Core Team and supervised by the Supervisory Board. The programme lines are steered by the programme leads (hereafter: leads). QDNL currently has three subsidiaries: House of Quantum BV, QDNL Participations BV and QDNL Manager BV. As an NGF programme, QDNL falls under the responsibility of EZ and RVO. QDNL collaborates closely with both EZ and RVO, covering topics ranging from execution of the programme to policy. For phase 3, we will adhere to the described programme structure, see figure 2. In line with the MTR advice, we recognise the importance of strengthening interaction, alignment and collaboration with neighbouring industries, stakeholders, and policymakers. To meet this challenge, we are considering creating an Expert and Advisory Board (EAB) and commissioning a Quantum Tech Trends (QTT) quarterly report. These initiatives will offer us external insights, fostering industry collaboration and enhancing our alignment with global technological ecosystems.

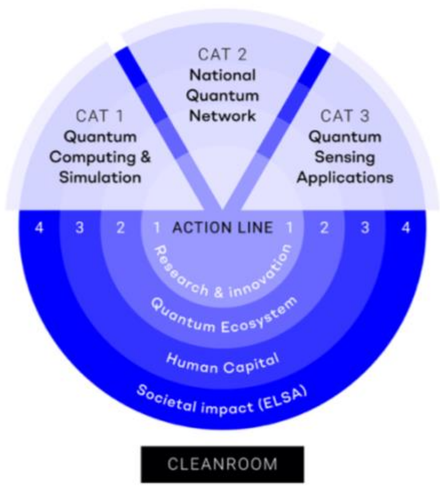

Figure 2. The QDNL programme comprises 8 programme lines: 3 Catalyst programmes (CATs), 4 action lines (ALs), and a national cleanroom programme.

2.2 Three Years of Quantum Delta NL in 10 Highlights

The NGF investment in QDNL has catalysed the development of quantum technology in the Netherlands, fostering a new economic sector that offers innovative solutions and sustainable economic prosperity. Some notable achievements include:

1. **Strong growth in quantum jobs**
   Over a thousand new, full-time jobs have been created, reflecting the thriving quantum sector and the impact of QDNL in fostering innovation and employment opportunities.
2. **Leaders in science**
   The Netherlands has secured a leading scientific position in the quantum field, with QDNL playing a crucial role. Notably, QuTech now ranks first worldwide in the global impact of publications.
3. **International top talent heads to the Netherlands**
   The Netherlands has become a magnet for top international talent in quantum technology, further strengthening its position as a global leader.
4. **Quantum opportunities for every Dutch enterprise**
   QDNL programmes, including the SME Programme, Fieldlab Programme and Quantum Application Lab (QAL), enable Dutch organisations to explore and engage with quantum technology, driving innovation and economic growth.
5. **International leadership**
   QDNL collaborates with other leading quantum countries to build a global community, enhance market access and participate in EU programmes (e.g., QuantEra, EuroQCI, EuroHPC).
6. **Growth programme and investment fund for quantum enterprises**
   QDNL established Infinity and QDNL Participations to support Dutch quantum start-ups, resulting in significant investments such as QphoX's €8 million funding round.
7. **Secondary vocational education, universities and universities of applied sciences join forces**
   Four Quantum Talent & Learning Centres (TLCs) have been building up an employee pool for the future industry. Vocational schools, universities and universities of applied sciences all work together towards the same goal: a national quantum industry, accessible to all. The number of quantum students, nearly 800 in total, in the Netherlands has increased significantly – showcasing QDNL’s success in talent development.
8. **House of Quantum: the physical home of innovation and collaboration**
   QDNL established the world's first 'House of Quantum', facilitating cooperation between local and international stakeholders, providing essential laboratory facilities and attracting interest from other countries.
9. **Quantum for economic prosperity and social well-being**
   Initiatives like the Centre for Quantum & Society (CQS) bridge quantum innovation with wider society, fostering ethical discussions and practical applications.
10. **Core values for effective collaboration and happy people**
    The quantum community in the Netherlands is characterized by core values of excellence, inclusivity, and societal impact, as outlined in the Quantum Delta NL Culture Manifesto. Initiatives such as Quantum Meets foster collaboration and innovation in a supportive environment.

All of these highlights are showcased in our Mid-Term brochure.[4]

Figure 3. Former Minister of Economic Affairs Micky Adriaansens visits the Quantware lab during the opening of House of Quantum.

2.3 Main External Developments

National developments

Quantum technologies (computing, communication and sensing) will become crucial for our economy, our security in the long run, and will enable solutions in sectors such as energy, health and (cyber)security. This is recognised by our Ministry of Economic Affairs and Climate Policy, where quantum is identified as a key enabling technology in the National Technology Strategy (NTS).[5] The strategy mentions that "The Netherlands should keep its forefront position and strengthen it, to continue to be a world-renowned quantum ecosystem in 2035". With our phase 3 plan we gladly contribute to the goals of the NTS. The QDNL programme contains projects and work packages that contribute to a greater or lesser extent to the subgoals. Notable examples are "In 2035, the Netherlands has world-class facilities, education (MBO, HBO, WO) and research (position in top 10 of the world)", which is very well aligned with our action line for talent (AL-3), and "Involving users in research and innovation and market creation", which is a big priority in the next years, see also our vision on user engagement in chapter 4.2. Moreover, QDNL is currently involved in the development of the so-called NTS action agenda for quantum technology,[6] which focuses on industry-oriented innovation programmes that are necessary to stimulate the growth of the Dutch quantum economy in the coming decade. The action agenda is developed in collaboration with leading Dutch quantum companies and knowledge institutes, and will be formally published in January 2026.

While knowledge base and scientific quality of Dutch quantum research is beyond dispute, there are challenges like large-scale private investment and industrialisation. In this, major American companies (and investors) seem to get a head start on the industrial rollout of quantum technologies. The Dutch high-tech industry has proven that it is possible to play a significant role in large and complex value chains. There are many opportunities for the Netherlands to participate in the future quantum economy value chain and capture essential niches within that value chain. We are deploying our organisational capacity and leadership to take a coordinating and strategic role in international partnerships. With both the key quantum hubs in Europe and with like-minded countries. Next to that, national cooperation in R&D and manufacturing with adjacent key technologies (photonics through the PhotonDelta programme, semiconductors and nano) are sought. The Netherlands is also well positioned to accelerate the adoption of quantum technology in various end-user industries. The adoption of digital technology

[4] See: https://issuu.com/quantumdelta.nl/docs/qdnl_mid-term_def_hr
[5] See: https://open.overheid.nl/documenten/67b0a9e1-135b-483f-9ed9-3aade270dbce/file
[6] See: https://www.kia-st.nl/kia-sleuteltechnologieen/actieagenda-s-nts

is well embraced by industry and society and the Netherlands is playing a key role in the digital infrastructure in Europe which is concentrated around Frankfurt a/M, London, Amsterdam and Paris (FLAP). This key position is a great fundament to adopt quantum technology into the current digital infrastructure especially in the domain of (super) computing, cloud, data exchange, connectivity and more.

International developments

At its inception, QDNL was given the mandate to execute one of the first national quantum strategies in the world. However, many other countries have followed this path and launched similar strategies to develop their national quantum ecosystem. National governments and companies have increased their investments immensely. Quantum technology has emerged as a vital strategic asset for global powers like the US, China and the EU, with access to and advancement in this field deemed crucial for safeguarding national and economic security interests. Geopolitical shifts are actively shaping the landscape of quantum technology, with nations vying to maintain their autonomy in key technology domains.

A key example of this is the fact that quantum technology has been selected as one of the EU's most sensitive critical technology areas, as part of its new economic security policy.[7] QDNL has played a pivotal role in contributing to the corresponding risk assessment, which will inform potential new policies aimed at preserving the EU's autonomy in strategic technology sectors.

Tech & science developments

At the start of the QDNL programme, Google's quantum supremacy experiment was still one of the key milestones in the field. This result was largely driven by an academic research group at the University of California and only a handful of companies were actively developing quantum technology. Similarly, the first quantum key distribution pilots were run and some operational tests with quantum sensors were performed. However, in the past years we have seen an impressive acceleration of technology developments that have led to many new scientific milestones and, perhaps more significantly, the rise of a flourishing global private sector.

The quantum technology landscape has witnessed a surge in both public and private investments,[8] sparking a race among companies to develop integrated full-stack technology systems. Meanwhile, other firms focus on providing specialized products and services within specific segments of the value chain. In the Netherlands, numerous start-ups excel in these niche areas, yet they face stiff competition in the global market.

A significant challenge across the EU is the scarcity of private capital needed to scale up these companies further. Despite being home to a quarter of all quantum companies worldwide, the EU receives less than 5% of global funding in this sector. In contrast, the US dominates private funding, with individual companies securing investments that surpass the total seven-year funding for the QDNL programme. Efforts are underway in the EU to attract more private investment through initiatives like the European Investment Bank and the European Innovation Council, but closing this funding gap remains daunting.

In response to this shifting global landscape, we must strategically reposition ourselves. Rather than diversifying into multiple technology areas, we must make decisive choices and focus on key domains where we can excel. This strategic approach will enable us to secure pivotal positions in future value chains and uphold our status as a leading player in the global quantum technology sector.

[7] See: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4735
[8] See: Quantum Technology Monitor April 2024, McKinsey Digital (p. 4)

EU developments

Looking at the EU more broadly, quantum technology developments have been stimulated by multiple parallel activities that each focus on a different domain, and the Dutch ecosystem is deeply involved in many of these. The most important programme is the €1 billion Quantum Flagship, which mostly funds research projects such as the Quantum Internet Alliance, iqClock and OpenSuperQPlus, in which the Netherlands is well-represented and is even leading some of the consortia. In order to further coordinate research and innovation in quantum technologies throughout the EU, QDNL has also become an active member of QuantERA. At the end of 2023, twenty-three member states, including NL, signed the European Declaration on Quantum Technologies, recognizing the strategic importance of quantum technologies for the scientific and industrial competitiveness of the EU.[9] This initiative also aims to further integrate the national quantum strategies of EU member states, which was already spearheaded earlier by the Netherlands through the trilateral programme with Germany and France. In July 2025, the European Commission launched the Quantum Europe Strategy, which aims to position Europe as a global leader in quantum by 2030.[10]

Next to that, QDNL has a board position at the European Quantum Communication Infrastructure (EuroQCI) initiative, which is driving the deployment of a pan-European quantum communication network and forms an integral part of our current and planned CAT-2 activities.[11] In paralel, EuroHPC, the European High Performance Computing Joint Undertaking,[12] focuses on connecting quantum computers to existing supercomputer clusters in Europe which will become the funding vehicle for the next quantum flagship phase, before the initiation of a specific Quantum Act. With EuroHPC, Europe has now launched its first Quantum Centres of Excellence, co-lead by QDNL, accelerating the development of next-generation quantum algorithms and middleware. EuroHPC is also preparing a coordinated grand challenge in quantum computing, and QDNL is actively engaged in these discussions to position the Dutch ecosystem as a leading contributor. This is an integral part of the CAT-1 programme.

As part of the broader European semiconductor strategy, QDNL also supports the establishment and development of three Chips Act pilot lines—including one led by the Netherlands—aimed at strengthening Europe's quantum-hardware and photonics value chain. In the sensing domain, members of the Dutch ecosystem (notably CAT-3) participate in projects funded by the European Defence Fund, such as ADEQUADE, which focuses on disruptive applications of quantum sensors.[13] Defence is also at the heart of ongoing discussion to position our Dutch ecosystem in the value chain for other applications with the Ministry of Defence. CAT-3 furthermore plays a leading role in the Qu-Test and Qu-Pilot programmes, which are creating a European network of testing and pilot-line facilities.[14] QDNL is also a partner to help shape the emerging European quantum-sensing infrastructure for gravimetry, for which it will design EU's first "on-demand" quantum-sensing service for scientific and industrial users. In addition to that, CAT partners are contributing to the creation of the European optical time distribution network within GÉANT SIG-TFN. These efforts embed QDNL and the Dutch ecosystem strongly in the long-term European research-infrastructure landscape.

In a neighbouring domain, the EU has been confronted over the past few years with its relatively weak position in the global semiconductor value chain, which it aims to strengthen with the EU Chips Act launched in 2023. One of the objectives of the first pillar in this initiative is to support the development of design libraries, pilot lines and infrastructure for prototyping and producing quantum chips, as well as fostering the development of facilities for testing and validating advanced quantum chips produced by the pilot lines.[15] In April 2024, four quantum technologies were selected by the EU in the context of the Chips Act for collaborative consortia from EU member

[9] See: https://digital-strategy.ec.europa.eu/en/library/european-declaration-quantum-technologies
[10] See: https://digital-strategy.ec.europa.eu/en/library/quantum-europe-strategy
[11] See: https://quantumdelta.nl/qcined
[12] QDNL is recently also re-elected as member of the EuroHPC JU advisory board.
[13] See: https://defence-industry-space.ec.europa.eu/system/files/2022-07/Factsheet_EDF21_ADEQUADE.pdf
[14] See: https://qu-pilot.eu/
[15] See: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733596/EPRS_BRI(2022)733596_EN.pdf

states to develop world-leading capabilities in chips design and manufacturing.[16] This creates opportunities for the Dutch quantum ecosystem. This can also enable us to further intensify the collaboration between the semiconductor, integrated photonics and quantum technology ecosystems in the Netherlands. On December 1, it was officially announced that the Chips JU Public Authorities Board has approved funding for the quantum pilot lines P4Q, Spins, and SUPREME—marking a major milestone for the 19 Dutch partners involved and a significant advancement for the Dutch quantum ecosystem. The €20 million national investment, including €12 million contributed by QDNL, will unlock an additional €20 million in EU co-funding, further amplifying our collective impact.

As is clear from the developments described above, the quantum technology landscape is rapidly changing, both from a technological as well as a policy perspective. This requires continuous forecasting and flexibility in our operations, which we have incorporated into our plans for phase 3.

2.4 Vision towards 2035

The QDNL board has started the preparations towards phase 3 of the QDNL programme by developing a vision for 2024 – 2035. This vision & accompanying strategy form the underlying framework of the phase 3 plan.

2.4.1 Vision for the Quantum Ecosystem towards 2035

QDNL is established to generate long-term economic impact for the Netherlands. To reach this economic impact, QDNL has formulated a holistic ecosystem approach in the NGF proposal of 2021:

"Quantum Delta NL is the place where the world's top talent is drawn to and where the entrepreneurial climate is so fertile that the quantum hardware and software providers of the future are born here. The ambition is that in ten years Quantum Delta Netherlands will grow into a vibrant and international hotspot where world-leading science, technology and talent come together and emerge."

Now that we are three years underway and have made progress in building this ecosystem, we have reshaped this rather generic and abstract ecosystem mission into a more focused and concrete goal, that more directly relates to the long-term economic impact that our ecosystem needs to realise to be successful.

Our QDNL Goal-2035:
"NL holds unique positions in the future global value chain of QT and its applications by fostering a portfolio of NL based quantum tech companies. By achieving this unique position, we aim to reach an ambitious macroeconomic goal – to be in the top 3 quantum economies in the world, measured by the size of the quantum economy related to the size of the country: Quantum related GDP per capita."

Ecosystem position

A thriving Quantum Economy is the overarching ambition of QDNL and the NGF programme. To reach this goal, our entrepreneurial ecosystem needs to be top-notch and attractive, covering the entire spectrum from talent, science & technology, shared facilities all the way to availability of capital, business, legislation and engagement of end-users and society. The engine of the quantum economy is formed by the businesses that generate impact, value and jobs. Therefore, existing, and yet to be incorporated businesses are the anchor point for QDNL. We focus on what is needed to incorporate the right companies, and how we can help them to scale and succeed, but also, on how we can engage existing industry and end-users in the quantum economy, and most importantly: how we can create the right entrepreneurial culture in the ecosystem, where talent feels challenged to embark in quantum business and where our public infrastructure is accelerating growth.

[16] See: https://www.chips-ju.europa.eu/Pilot-lines/

Unique selling points in the Netherlands

1. **First mover**
   NL was among the first countries with a national quantum strategy, a joint scientific and engineering research centre (QuTech) and a European quantum computer in the cloud. We are also pioneering in executing a national programme, with a dedicated national organisation, a roadmap for making choices, new campus facilities for the ecosystem and an innovative approach to tech transfer and IP.
2. **Leading in science and technology**
   Our R&D position in quantum technologies is world leading, based on an excellent foundation of physical and engineering sciences. In the specific fields of quantum computing and quantum communications, the TU Delft scores within the top 3. Our well organised and cooperative community is an attractive place for scientific and entrepreneurial talent.
3. **Fertile start-up ecosystem**
   With 23 start-ups in 2023, NL is 4th in terms of the number of quantum start-ups, only leaving the US (65), Canada (33) and the UK (26) higher ranked. Adjusted for population size, we have the highest relative prevalence of quantum start-ups worldwide. Yet, the total amount of capital raised by NL start-ups is only 0.8%. We commit to further nurture start-up creation by the entrepreneurial talent pool and pave the way for growth by offering dedicated support, shared facilities and attracting scale up funding.
4. **Gateway to Europe**
   NL is strongly embedded in Europe both geographically and programmatically with close ties to the European Commission, France, Germany and the Nordics. As we follow an 'open strategic autonomy' policy, we also have strong partnerships with like-minded nations including USA, UK, Japan and Switzerland. With excellent physical, social and digital infrastructure, and near 100% English speaking population in the EU, we can rightfully position ourselves as the gateway to Europe.

Ecosystem in 2035

In 2035, the Dutch quantum ecosystem is comprised of an internationally networked group of industrial quantum players and state of the art shared infrastructures that facilitate R&D at the companies. We expect that some of the industrial players will be fully integrated full stack providers and others will take up a significant piece of the supply chain. We also foresee a significant presence of end-users from sectors like agriculture, energy, security, science and digital infrastructure providers by that time.

The business ecosystem will be a combination of several international tech companies and Dutch grown tech scale ups. By nurturing many start-up seeds, attracting international companies and by creating a beneficial environment to grow with a strong ecosystem of suppliers, it is our intent to ultimately create two to four companies that are well positioned to become international leaders and shape the ecosystem. It is too early to paint the picture of the exact focus of the portfolio companies. To become an industry leader, it is crucial to have access to international markets and partners. The Netherlands and even Europe are too small to create independent quantum technology supply chains and end markets. Therefore, we double down on our international presence and partnerships, and sit in the front row when economic policies and standards are defined, ready to protect the interests of our local players. For this we work closely together with EZ and other important stakeholders. We engage international talent to support our ecosystem from the inside and outside. Netherlands should be strongly embedded in the fabric of the international supply chain, at all levels, in all forms.

On the infrastructure part, for the longer term, we foresee crucial synergies between semiconductor, photonics and quantum technologies, and this is an opportunity for us in the NL, as we have strengths in each area. To build a strong and balanced ecosystem we plan a systematic, de-verticalized approach, involving start-ups and scale-ups that cater to specific areas in the value chain – from quantum processors to integrated systems. The goal is to develop a quantum industry roadmap for Europe by focusing on scaling the start-up ecosystem and partnering with leading technology institutes. The Netherlands will take a leading role in these areas, just as other member states will do so for others. To build towards this, QDNL should develop and support a variety of pilot and production facilities for the fabrication, testing and application needs of the quantum ecosystem. This means we will develop facilities and infrastructures: testbeds, networks, differentiating process modules and hetero-integration technology, while also leveraging existing fabs for other process modules (e.g., cryo CMOS, state of the art lithography). Partnerships with established international frontrunners are part of that vision. In addition to that, the integration of quantum computers with high-performance computers (HPC), will accelerate the possibilities of quantum software, the execution of quantum application and quantum algorithms. This will create many new opportunities, in the innovation domain, as well to attract and interact with (future) end-users.

Ecosystem priorities

The timelines of quantum technology extend far beyond the QDNL programme. Currently this is an R&D market, and a fully commercial market is many years away. While NL has a strong scientific base, the industry is hesitant to invest in quantum technology, and the entrepreneurial ecosystem is still in its early stages, requiring acceleration and an influx of talent and capital. The QDNL programme addresses these challenges by stimulating and supporting start-ups, attracting talent, funding R&D, building shared facilities and addressing societal impacts.

However, reaching our goal will require significant additional effort and resources. Currently our companies are small and have limited access to fab or foundry services, creating a bottleneck that needs urgent fixing. QDNL sees this as an opportunity to develop a distributed (international) value chain, leveraging multiple fabs for different key components.

Phase 3 of our programme will focus on positioning ourselves optimally for this goal and developing the necessary facilities. We will focus our activities on four priorities:

1. **Technology acceleration**
   An essential aspect of our unique selling points lies in the excellence of our science and technology (S&T) ecosystem. We aim to leverage this strength by challenging our community to collaborate and compete with international peers, accelerating progress on critical hurdles toward achieving a fully commercial quantum economy. To address these challenges and prioritize technology development, we will establish a challenge-based programme. This programme will foster innovation, collaboration and competition, driving advancements in quantum technology and positioning us as leaders in the field.
2. **Commercialisation & end-user participation**
   A strong emphasis will be placed on technology transfer, industry engagement, and start-up development to facilitate the transition of ideas from (applied) universities and knowledge institutes (e.g., RTOs) to new companies, ultimately scaling these ventures into industry leaders within healthy market conditions. To achieve this, clear strategies for talent acquisition and intellectual property (IP) management will be essential. Additionally, the provision of shared facilities, investment capital and robust start-up support programmes will play pivotal roles in extracting ideas from the academic environment and fostering their growth in the commercial sphere. Lastly, to go from a technology push to a pull, more end-user participation is required, to foster the adoption of quantum technology.
3. **Internationalisation**
   Building international partnerships (with like-minded countries) and attracting talent and companies from outside into our ecosystem creates innovation power, new culture and ideas, and capital as well as an export market for our companies. Also, we believe that securing funding and being recognised as a key hub in Europe in the context of e.g., the Quantum Flagship (with FPA’s like Quantum Internet Alliance) and Chips Act will be a crucial prerequisite for our continued journey.
4. **Fabrication**
   In supporting our start-up ecosystem, one of the biggest challenges we encounter is fab facilities. Specific demands of companies require dedicated solutions for fabrication infrastructure. While the

academic/RTO infrastructure is mainly used for research, development and prototyping and small-scale production, dedicated fabrication facilities are required for pilot lines and mid- and high-volume production. We will develop fab facilities (cleanrooms), including new (private) governance models that make it possible for companies to access them on their terms. To ensure a smooth transition from research, design and innovation, to pilot lines and high-volume production, facilities shared by both NanolabNL and private fabrication are required. This development is in line with the EU Chips Act. We will not look at this in isolation, but with partners in Europe for optimal European synergies, and make the link with adjacent tech fields such as AI, Photonics, Next Generation Internet (Digital Infrastructure) and others.

On top of these priorities, there are three conditions that our programmatic activities will need to meet. This means that all actions we take are benchmarked/aligned on these conditions:

1. **One ecosystem**
   It is vital that the QDNL ecosystem is seen both from within as from the outside as one system, which means that profiling is based on activity, expertise and mandate -not on institutional level. This is vital since changing the perspective from university or hub to the actual programme goals, as described in the CATs, will allow us the make choices and define what expertise is really needed to progress. This network of centres and facilities with a specific focus is what we call the QDNL national campus, that we will connect via the Houses of Quantum in our network.
2. **Quantum for good**

   We work towards technologies that are beneficial for society at large, by understanding the ethical and legal frameworks, by creating broad acceptance in society through a clear communication strategy and by considering ethical choices that need to be made to implement the technology. We will do this in parallel with the translation of the technology into different industry domains and the development of end-user activities. Thereby focusing the technology development towards industrial and societal problems.
3. **Self-sustainability**

   Our ecosystem still heavily relies on (NGF) subsidies and facilities offered by QDNL and knowledge institutes (TNO, NanoLabNL, Mesa+, QuTech, QuSoft and others). As we move towards the end of the NGF funding, we aim to shift our business ecosystem to a healthy mix of other (public and private) funding sources, such as private equity, EC funding sources and other subsidy instruments. Also, we will focus on the set-up self-sustaining public/private facilities that offer shared services to our business ecosystem, such as pilot facilities, field labs and demonstrators. As the aim is to move the technology out of the lab, into the fab and the app, we foresee an increasing part of the budget targeting businesses and outside university or TNO facilities. The foundation will continue to shape and solidify its strategic role as a national ecosystem orchestrator, aligning stakeholders toward shared objectives

3 Midterm Review & Taskforce

In formulating and finalising the plans for phase 3, our aim was to incorporate feedback and insights from external professionals, including the Midterm Review Committee and the Taskforce. This chapter outlines the processes undertaken and presents the advice provided by these entities. The chapter ends by summarising our main changes for phase 3, which shows how we took the strong evaluation into consideration and made strategic choices.

3.1 Midterm Review

As outlined in the grant conditions, QDNL was asked to conduct a MTR of its entire programme halfway phase 2. This review also served as a prerequisite for budget allocations for phase 3. The MTR consisted of a self-evaluation and an independent assessment by an external MTR Committee.

The MTR committee's task was to assess the effectiveness of QDNL in governing and managing the programme, the performance of the eight programme lines, the (draft) strategy and plans for phase 3. The final report has been separately presented to the NGF committee by EZ in April 2024. In this paragraph we will highlight a few of the committee's findings and recommendations and connect them to our plans for phase 3.

The MTR was overall very positive about our programme:

> "The Quantum Delta project is highly ambitious and has gained international recognition for setting a standard and inspiring other countries. The Committee is impressed with QDNL's accomplishments over the past two years, achieved with limited resources, especially in terms of time and personnel. QDNL's pioneering work in new quantum technologies and approaches is internationally recognised. Projects like ELSA and the approach to internationalisation are noted for their innovative thinking and ability to address emerging needs."

The committee gave specific recommendations to further develop the QDNL programme and organisation to progress into phase 3, especially with the challenging goals for the next years and international competition in mind: *"The foundation laid by its initial achievements is solid, yet the path forward demands further professionalism in several key areas.*" Some examples of recommendations are: the development of smarter KPIs, enhancing the value and utility of the cleanrooms by providing access to companies, integrate photonics in the CAT-1 activities, improve cross-collaboration between the CATs and AL's and end-user engagement, create more space for strategic decision making to guide future directions and priorities.

The QDNL board is very grateful for the sound and thorough recommendations and has used them to reorganise the QDNL organisation and programme along these recommendations.

3.2 Main Changes in Phase 3

The feedback from the Taskforce and MTR committee has led us to make significant adjustments to the QDNL programme, compared to phase 1 and phase 2. Next to that, the cancellation of round 4 of the NGF has also led to various changes. This section details these major changes.

Shift focus from academic to industry

As mentioned in chapter 2.4, Vision Towards 2035, one of our biggest challenges is to take the next steps towards creating economic value. Therefore, we must increasingly focus on commercialising and industry participation (both manufacturing and end-users). We need to unlock the market and strongly connect with possible customers. We already took some steps towards that in phase 2, such as the development of Participations Fund 2.0, which we are currently preparing. Another main change in phase 3 is the shift in funding, a larger part of the budget will go towards (new) companies (e.g., start-ups, scaleups and some established companies) and less to the base funding of universities. While (basic) research is obviously still an important part of our programme in the next few years, this shift allows us to contribute more to entrepreneurship and the development of economic activity. We expect that about 50% of the funds in the funding strategy will go towards companies.

Create a new funding strategy

We decided to create a new funding strategy to allow for increased flexibility in the programme and to support industry engagement. Next to that, the challenge-based programme in the funding strategy will allow us to make more strategic choices and act on potential new developments faster. Another important part of our new funding strategy is a greater alignment with the CAT technology roadmap, where the goals of the roadmaps provide essential input for calls like the SME-call. In contrast to phase 1 and 2, where the various funding instruments had their own specific goals, the instruments in the funding strategy will specifically add to the technology roadmaps or industry and end-user goals and be deployed were appropriate. Even though we are making this change, the QDNL programme will stay a missiondriven programme. We will elaborate on the new funding strategy in chapter 4.3.

Improve cleanroom access for economic impact

Both the MTR and taskforce recommended to evaluate the need for new or improved cleanrooms and other shared facilities and further develop possibilities to create economic impact by allowing industry access. We will take an integral approach to the development of pilot lines, cleanrooms and other shared facilities. This also has a close connection to the developments in the EU Chips Act. The details of this analysis can be found in chapter 4.7.

CAT-centric & more alignment

We're aiming for greater integration of activities and stronger connections between different programme lines, fostering a more cohesive and unified approach to enhance cross-collaboration. Next to that, both the TF and MTR committee identified this issue during their assessments and recommended more interlinking and greater collaboration to support the CATs. We're also placing a strong emphasis on engaging with end-users and business development, from a CAT perspective – where the organisation is linked to the capabilities in the action lines. In chapter 4.2 this is explained in more detail.

Other changes

In phase 2 we have decided to convert our ambition of realising a new House of Quantum building into an ambition where we offer lab, office and meeting space by renting and refurbishing existing buildings. This concept, offering these facilities under a visible House of Quantum 'look and feel', will be expanded to all hubs in phase 3.

Additionally, our trilateral programme with France and Germany will be embedded in a new international strategy and the activities, such as the trilateral call and summer schools, will be integrated with phase 3 activities, see chapter 4.5.

3.3 Other relevant developments

3.3.1 National Quantum Campus: House of Quantum

QDNL is developing a national quantum campus for co-creation, in which all actors (scientists, entrepreneurs, students, financiers and companies) can quickly find each other and collaborate without barriers. The campus will be an attractive place for talent and companies from abroad to come and settle in the Netherlands. Central to the campus vision are the House of Quantum community buildings in each of the five QDNL hubs. The first three buildings have already been realised: in Delft (HoQ EW10 and HoQ DT01) and in Leiden (BioPartner 4). Eindhoven, Amsterdam and Twente will follow in phase 3, after which each local hub community will have its own

Figure 4. The newest House of Quantum building was officially opened on May 14 2024.

central ‘quantum’ hotspot. We envision all these facilities to become part of the national House of Quantum concept, in which all will have a recognisable ‘look and feel’. This will be accompanied by a national membership model for partners and companies interested in using or setting up shop in these buildings and spaces.

This will enable growth and innovative collaboration across the country and with international partners. Building on this concept, we aim to lay the foundations for a European Quantum Campus, starting by connecting the Dutch ecosystem with emerging initiatives in France and Germany. This effort will facilitate talent exchange, joint education initiatives, shared access to facilities and increased international visibility for Dutch research and start-ups.

A first framework programme with iXcampus in Saint-Germain-en-Laye and IOGS at Paris-Saclay is already underway, creating a structured platform for collaboration, mobility and co-development—serving as the initial building block of the broader European Quantum Campus vision.

4 Phase 3

This chapter starts by describing the economic and societal impact of the QDNL programme. Following that, descriptions of several key themes identified as crucial for phase 3 (as described in chapters 3.2 – 3.3) ensue. These key themes need to be addressed across all programme lines, thereby also stimulating the collaboration between the various programmes. The visions have been created in cooperation with the ecosystem and impact our choice of investments and priorities.

4.1 Accelerating Economic and Societal Impact

The most important goal of QDNL is creating long term sustainable economic impact – this goal was set when the proposal in 2021 was created, and is still is our centre focus. QDNL does so by making breakthrough technology market-ready and leveraging the collective expertise and resources within our ecosystem. As explained in chapter 2.4, we have finetuned our generic goal, to a more specific focus. QDNL will change the approach to reach these goals, based on internal and external developments and the advice by EZ and independent committees. This was explained in chapter 3, and the main changes were briefly explained in chapter 3.2 (and will be further elaborated in the upcoming paragraphs). Since we adhere to the same goals, the analysis of our long-term economic impact still stands.[17]

Long-term economic impact

Table 1 (below) depicts the long-term economic impact QDNL is expected to make towards 2040, as overarching objective of the programme. The objectives stated in this table were defined based on input from TNO and McKinsey SEO Economisch Onderzoek,[18] [19] knowing that it is inherently difficult to provide numerical substantiation to indicate the long-term earning capacity of an emerging technology like quantum, with still a distance to the market. The KPIs from the original QDNL proposal have been adapted to provide better indicators for the actual status of the programme, also supporting the stronger focus on industry and the Vision towards 2035. This approach was also recommended by the MTR committee. An overview of the new set of KPIs can be found in chapter 9.

[17] In close consultation with the responsible parties at EZ it was not deemed necessary to execute a new analysis or theory of change.
[18] See: https://assets.quantum-delta.prod.verveagency.com/assets/proposal-that-was-submitted-to-the-national-growth-fund.pdf (p. 19)
[19] See: https://www.seo.nl/publicaties/beoordeling-onderbouwing-bbp-effecten-rdi-voorstellen/) and https://www.cpb.nl/sites/default/files/omnidownload/CPB-Analyse-voorstellen-Nationaal-Groeifonds-2021.pdf

2040 Objective	Explanation	Objective
Number of jobs	▪ Total number of Dutch high-quality jobs related to quantum technology	▪ 8,000 – 18,000
Annual GDP contribution	▪ Annual GDP contribution that can be attributed to the QDNL programme	▪ 0.02 – 0.04%, or € 0.23 – € 0.46 billion
Multiplier	▪ Expected return on investment for the NGF-investment in the QDNL programme	▪ 3.3
Added value	▪ Added value in the quantum industry	▪ 47%
Cumulative economic impact	▪ Cumulative economic impact of the QDNL programme	▪ € 1.5 – 2.5 billion

Table 1. Long-term economic impact QDNL is expected to make towards 2040, as overarching objective of the programme.

Current approach towards long-term economic impact

Crucial to fostering long-term economic impact is the establishment of an appealing ecosystem wherein businesses, scientists, talent, investors, engineers and entrepreneurs can thrive. Growing and sustaining the ecosystem is a core focus. To that regard, QDNL has implemented various measures and actions aimed at maximising the likelihood that companies and talent remain in the Netherlands and, more importantly, continue to contribute to our goal as to create a long-term economic impact. This is inherent to our ecosystem approach. These efforts complement the government's policy to establish an appealing environment for industry, including initiatives to foster a favourable business climate, implementing international schemes, and provide opportunities for growth, among others. As a result, QDNL is internationally renowned as a successful innovation cluster, as showcased in the McKinsey Quantum Technology Monitor published in April 2024[20] (see figure 5). A few examples of the measures and actions QDNL has implemented as part of our ecosystem approach, thus ensuring key impact:

- Providing top-notch R&D and production facilities through targeted investments in our programme.
- Having clear IP policies that prioritize keeping IP in the Netherlands as much as possible.
- Establishing a dedicated Netherlands-based quantum investment fund, equipped with relevant expertise and recognised on an international scale. This initiative, among other benefits, creates space for company expansion, thereby enhancing the likelihood that Dutch-based companies can acquire others rather than being acquired themselves.
- Implementing a clear policy for international collaborations in combination with an international strategy.
- Establishing influence at both policy and R&D levels within the EU27.
- Ensuring attractiveness for talent through existing top talent and visitor's programmes.
- Taking on an active role as a facilitator, activator and connector within the entire ecosystem.
- Close alignment with government policies, for example with the ”Bureau Toetsing Investeringen” at EZ, that checks every foreign investment >5%, thereby contributing to economic security.

[20] See: Quantum Technology Monitor April 2024, McKinsey Digital (p. 66).

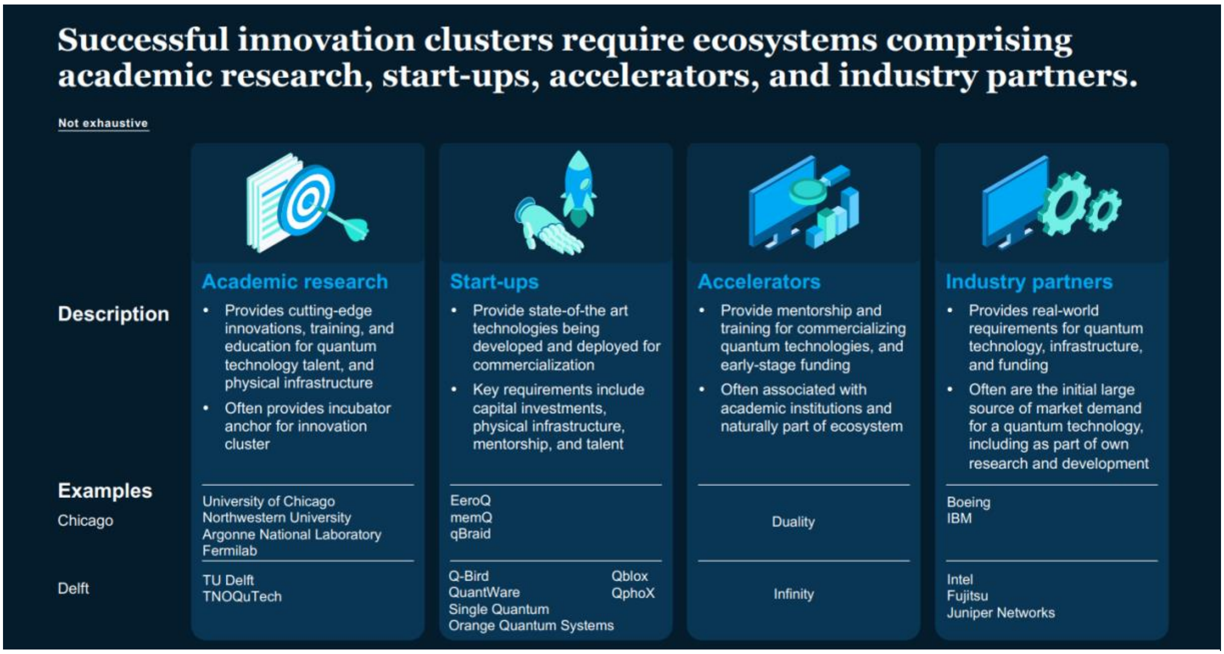

Figure 5. QDNL is internationally renowned as a successful innovation cluster. This slide from the McKinsey Quantum Technology Monitor published in April 2024 mentions Delft and Dutch start-ups as very successful examples.

Further accelerating economic impact in phase 3

To accelerate the economic and societal impact of the QDNL programme, we will direct more of our efforts towards enhancing technology acceleration, end-user engagement, industry support and participation. This shift underscores our commitment to not only advancing scientific research but also translating our findings into real-world applications that create meaningful value for different end-user industries and societies alike. To that end we will:

1. Professionalise manufacturing and industry participation to ensure that our efforts are strategically aligned with market needs and opportunities.
2. Step up (end) user engagement to attract end-users through various initiatives in the programme and connections in the supply chain.
3. Reorganise our funding strategy geared towards industry.

We will allocate greater funds towards procurement endeavours, streamlining tender processes and introducing the challenge-based programme (see chapter 4.3).

International collaboration is another key aspect of accelerating economic impact, therefore we updated our international strategy, to facilitate collaborations and safeguard the strategic autonomy aspects of quantum technologies, including standardisation. Moreover, we will intensify our focus on end-user and industry engagement activities for the ecosystem within the CATs, ensuring that our efforts are strategically aligned with market needs and opportunities. Additionally, we are enhancing our engagement with end-users, fostering collaborative relationships that drive mutual success and innovation adoption.

All the programme lines took various actions in their phase 3 plans, to accelerate the economic impact of their plans. The table below shows examples of such actions and their expected effects (please note that this is not a comprehensive overview). More detailed descriptions can be found in chapter 7.

Programme line	Action taken towards economic impact	Goal
CAT-1: Quantum Computing & Simulation	• Introducing tenders and the challenge-based programme	• Strengthen the Dutch value chain for quantum computing components and modules and make it more competitive on the international market.
CAT-2: National Quantum Network	• Attracting industry and end-users by developing new use cases, establish and foster industry association, develop quantum communication standards.	• Foster a sustainable market for quantum communication technology in existing digital infrastructure.
CAT-3: Quantum Sensing Applications	• Develop practical applications of quantum sensing within specific industries, by market engagement, problem identification and challenge calls.	• Demonstrate at least five industrial use cases in industries such as Defence, Metrology, Semicon, Space and Healthcare.
AL-1 Research and Innovation	• Connect the NWO call to the CAT technology roadmaps.	• CAT programmes can refer to the NWO call for specific tech development questions, thereby accelerating technology developments.
AL-2: Quantum Ecosystem	• Introducing the SME scale-up procurement programme, as a tender-based funding initiative.	• Accelerating the progress of start-ups and companies fostering product development, empowering entrepreneurs to translate innovative ideas into market-ready solutions.
AL-3: Human Capital	• Starting the quantum technology training for professionals and programmes aimed at fostering entrepreneurship.	• Expanding the quantum workforce and readying more talent for an entrepreneurship career.
AL-4: Quantum and Society	• Support the end-user engagement activities by connecting with end-user trough the Centre for Quantum and Society.	• Gain more insight into the societal boundary conditions that must be considered before implementing applications in an ethically and socially responsible manner, therefore safeguarding “quantum for good”.
NanoLabNL	• Add high-TRL facilities to pave the way for alignment with current and future needs from companies.	• Access to cleanrooms for companies to allow for prototyping and small-scale production.

Table 2. An overview of some of the actions taken towards economic impact and expected effects.

Societal impact

It is well known that quantum technologies can potentially revolutionise many aspects of society, from computing and communication to medicine and energy. While the game-changing aspects might still be further away, smaller applications are getting closer by the day. By focusing more on end-user engagement, commercialisation and use cases, this development will go even faster. The sooner there are practical applications, the sooner our society can notice the effects of quantum. “Quantum for good” is a precondition in that development. We work towards technologies that are beneficial for society at large. To mitigate possible negative impact, we focus on understanding the ethical and legal frameworks, and strive to create broad acceptance in society through a clear communication strategy. Lastly, we are considering ethical choices that need to be made to implement the technology. To do so, we perform cutting-edge research on the ethical, legal and societal aspects of these technologies, launch awareness campaigns for the broader public and promote knowledge dissemination, while working on creating practical tools and a Quantum for Good competition. In phase 3, our programme will also explore where and how quantum applications can best be deployed through collaboration with organisations (i.e. within the public, public-private and private sectors). For example, there are projects with the Dutch Ministry of Infrastructure & Water Management, the Dutch Ministry of Finance and Alliander. Most of this work is done via AL-4, which is described in chapters 6.4 and 7.8.

4.2 User Engagement

Quantum technologies have quickly become more and more applicable for different industries and potential end-users. In phase 1 and 2, QDNL has deployed various activities in order to foster participation of each end-user group to use quantum technology for their solutions and processes. One such example is the Quantum Application Lab (QAL), which develops applied quantum algorithms and applications for specific industry end-users. Concrete projects were deployed with companies such as Alliander (Dutch Energy Grid), Toyota Motors Europe, Fujitsu, Bluefors, EquAL-1, Microsoft and others. In phase 3, it is essential to enhance our engagement with end-users, as was also recommended by the MTR committee.

On an international level, the quantum community faces the challenge to accelerate the development of end-user and industry participation in projects. Recently, we visited “Le Lab Quantique” in Paris to exchange insights on these challenges and to learn about France's approach to fostering end-user engagement. They also encounter similar challenges, but with a significant difference: the group of potential industry users with a long-term strategic outlook on technology development and adoption is much larger compared to the Netherlands. To foster the adoption of quantum technology in the Netherlands across various industries and end-user groups, we must accelerate and expand business development activities on a strategic level. This entails connecting the activities of the CATs, innovation hubs within AL-2, Quantum Application Lab activities, Quantum for Business, the Quantum Manufacturing Alliance (see chapter 7.6.2) and the Centre for Quantum and Society.

Several potential user groups are identified as crucial for the Dutch quantum technology ecosystem in adopting the technology. Each group requires a tailored approach in business development activities and ultimately on-barding as true end-users. A brief overview is in the table below:

User group	Examples
End-user industry	Alliander, KLM, Shell, Port of Rotterdam
Manufacturing suppliers	VDL, Demcon, NXP, Eurofiber
European Commission Calls	Horizon, Digital Europe, Connecting Europe Facility, Chips Act
Bilateral projects	France, Germany, US, UK, Japan

Table 3. Identified potential user groups with examples.

In phase 3 we will offer operational stable environments accessible for industry end-uses to develop, test and deploy proof of concepts and applications. For instance, on the different quantum sensing testbeds in CAT-3, the national quantum staging network and operational quantum computers in CAT-1 (this could be through the Quantum Inspire portal or through the new semiconducting quantum computer and HPC hybrid system to be acquired and deployed by SURF in Amsterdam).[21]

We will professionalise the structure around these facilities, i.e. organise better access, professional, technical, and engineering support, and true business development support. These are embedded in the hubs and will be

[21] See: https://www.surf.nl/en/news/surf-hosts-european-quantum-computer

connected more explicitly to the CAT activities targeted towards end-user and industry engagement. These facilities will also serve to expand international public-private collaborations and wider EC projects. End-user engagement will also be supported from AL-4 with foresight capabilities and feasibility studies for appropriate timing of quantum application offerings for wider societal and industry needs.

Additionally, a central unit focused on “End-users & Industry Participation” will be established within the QDNL programme that will strategically align and guide efforts in industry and end-user participation. This unit will contain dedicated business developers acting in strategic industry verticals and with the support of the CAT programmes. The main task of this unit is to bridge the gap to other types of industry. As an illustration, we are on the verge of establishing a quantum network. For this network, we require stakeholders who will utilise the network and advance the application layer. So, this unit will have a strategic focus, to activly identify use cases, reach out to leading parties in various promising sectors and push the developments of proof of concepts. In addition, this unit will align concrete end-user and industry projects in close cooperation with the participants in the different CATs.

4.3 Funding Strategy: How to Adapt to New Challenges

Phase 3 marks a fundamental shift in QDNL’s funding strategy. Building on the lessons of phases 1 and 2, we will move decisively towards a challenge-based, high-risk/high-gain and procurement-driven approach that focuses on real-world use cases, strategic choices and technological breakthroughs.

A key learning is that flexibility alone is not enough. We must also be prepared to make strong, sometimes difficult decisions as technologies mature, bottlenecks become clear, and paths towards market relevance begin to diverge. For example, we continue to explore multiple qubit technology platforms, because committing to a specific one is not desirable. Hence, as technology advances and evidence accumulates on progress to solve technological bottlenecks, we must be ready to concentrate resources where the Netherlands can lead and create differentiated value. This requires a disciplined approach to identifying bottlenecks, backing high-potential breakthroughs and acknowledging where decisive choices need to be made.

Additionally, we recognise the importance of identifying external use cases for quantum technology and how it can contribute to solving real-world problems. Although mature applications of quantum technologies may be years away, it is essential to make efforts now to identify these use cases, raise awareness, train talent, and develop applications. These efforts will ensure that Dutch capabilities are aligned with societal and industrial needs by the time quantum technologies reach deployment readiness.

Collaboration is key. Therefore, we facilitate and foster external (international) partners such as industry, government and society. In the paragraph below, we outline our new funding programme. These efforts will ensure that Dutch capabilities are tightly coupled with societal challenges, economic opportunities and Europe’s strategic interests.

The following paragraphs outline how this challenge-based funding model will be implemented in phase 3.

In 2025, QDNL launched a first pilot of the Quantum Forward Challenge, targeting the Life Sciences & Health sector. This programme embodies our new approach: use case driven, collaborative and built on short timelines that enable agile, high-risk exploration. It supports joint projects between researchers, industry partners and end-users to test whether quantum technologies can address pressing sector-specific challenges. The instrument is intentionally flexible and low-threshold, encouraging dynamic project formation, rapid iteration and early validation of ideas. The programme will be expanded in phase 3 with new Forward Challenges addressing additional real-world problem domains. These challenge calls will help steer the ecosystem towards meaningful applications, strengthen demand-driven innovation and prepare the Netherlands for procurement-based adoption of quantum technologies as they mature.

Three primary funding instruments

In phase 3, we intend to provide considerable budget for our funding approach, which will be accessible for the entire spectrum of universities, RTOs and companies. While in phase 1 and 2 the majority of the projects were executed in the scientific domain, in phase 3 we intend to shift this more towards companies. The funding strategy will revolve around three primary funding instruments, called Quest, Accel and Forward. Each addresses specific needs and opportunities, the first is based on open calls, the second instrument contains various tools to contribute to the CAT and AL roadmaps and the third instrument is focused on SMEs.

1. **QUEST: Open Call programmes with a bottom-up character**
   These programmes expand upon the open calls initiated in phase 1 and phase 2 with AL-1. They aim to strengthen the knowledge base, are open to all stakeholders and offer funding opportunities through collaborative partnerships with universities, as well as national and international partners. With an open and inclusive approach, these programmes aim to make funding more accessible and promote collaboration across different sectors, disciplines and between universities, RTOs, universities of applied science and industry. Thereby bringing the diverse expertise and resources in our ecosystem together.
2. **ACCEL: Flexible Tools integrated with CATs and Als**
   This instrument will expedite project initiation and development within CATs and ALs, based on simple, effective and short procedures, to enable swift responses to emerging opportunities and challenges. Integrating funding resources will ensure focused investments and strong alignment with CATs and ALs. These funds will be accessible to all stakeholders, including universities, RTOs, and companies, with an expected emphasis on the latter, to stimulate collaborative research efforts and amplify the impact of funding on advancing quantum technology innovation. Additionally, we will offer tailored support to nascent start-ups to expedite the translation of research into practical applications.
3. **FORWARD: Forward-Driven and Innovation-Focused Programmes based on procurements**
   This initiative primarily targets SMEs and industrial players, while still allowing universities and RTOs to participate collaboratively. By prioritizing ambitious projects focused market impact, these programmes aim to drive innovation and scale-up efforts, fostering an entrepreneurial and innovative culture. Additionally, we will offer tailored support to SMEs and start-ups to spur economic growth. We intend to focus more on procurement opportunities for SMEs and start-ups, fostering greater engagement and support within these communities.

Accel and Forward are new programmes representing a significant disruption from our current approach and will require careful development. They are intended to generate and accelerate new ideas, featuring a flexible and expedited decision-making processes. We have a clear understanding of the high-level design of the instruments, their alignment with our objectives and the transparent execution timeline. We will draw from existing experiences in Europe. Calls will be administered by QDNL, drawing from our experience in executing calls internally during phases 1 and 2. We also have hired an experienced programme manager. The first forward challenge was published in October: Call for proposals - Feasibility Study in Life Science and Health.

4.4 Entrepreneurship

QDNL’s ambition is to foster entrepreneurship across the Dutch quantum ecosystem, complementing the excellent work already carried out by the regional hubs. Our focus is on cultivating vocations, entrepreneurial mindset and long-term talent pipelines, recognising that successful deep-tech entrepreneurship depends not only on individual projects but on nurturing a community of driven founders. During phases 1 and 2, QDNL developed a series of successful initiatives to stimulate the emergence and early growth of start-up projects. These initiatives were strategically designed to facilitate the inception of start-up projects, bolster their growth trajectory and drive value creation. Programmes such as QDNL Participations and early stage financial instruments like SAFE notes have since evolved into mature, larger scale investment funds. In parallel, the SME programme and the trilateral programme have played instrumental roles in supporting companies through early validation and co-development; these instruments are now fully embedded in QDNL's broader funding strategy. In phase 3, QDNL will build on these successes to place an even stronger emphasis on entrepreneurship—understood in the broadest sense: creating a pool of entrepreneurs, empowering these entrepreneurs and accelerating the growth of quantum technology start-ups by creating opportunities, nurturing business ventures and driving market value.

Create opportunities and vocations

Our first objective is to forge strategic partnerships with key stakeholders, including business development entities and end-users, to identify market needs and opportunities. By collaborating closely with CATs, universities and RTOs, we aim to uncover technological prospects and provide specialized training in Entrepreneurship and Innovation. We will also look into the work done by other entities, for example Techleap, to find synergies. We are also in close contact with the RVO.

Leveraging the Talent & Learning Centers (TLCs),[22] we will instill an entrepreneurial spirit among the younger generation through dynamic open innovation programmes and workshops. Additionally, we will establish platforms such as the Young Innovator Award Programme to incentivise and recognise promising projects and individuals.

Create business ventures

Building on the success of the start-up support programme in phase 1 and phase 2, we propose expanding it into a dedicated national start-up initiatiave that will sustain and complement current activities, especially within universities. The goal is to cultivate entrepreneurial vocations, strengthen mindset and support project teams from the earliest stages. By coordinating initiatives and aligning instruments across the Netherlands and potentially the EU, we aim to provide comprehensive guidance and support to future entrepreneurs and start-up projects. Through tailored coaching, mentorship opportunities and assistance with funding applications, we will empower start-ups to navigate the complexities of intellectual property management and business model development.

Create market and value

To create market opportunities and drive value, we will provide dedicated support to existing start-ups in accessing markets and strengthening their business development capabilities. By incentivising product development through procurement-oriented grants and fostering collaborations with external customers, we aim to accelerate innovation and commercialisation. In addition, we will facilitate fundraising and investment opportunities, including the next phase of QDNL Participations, to fuel the growth and scalability of quantum technology start-ups.

4.5 Internationalisation

QDNL's overall strategic goal from an international perspective is to be the most relevant quantum ecosystem for Europe. This means that engagement with key partners in Europe is essential, while proactively working on a wider community of like-minded countries to secure market access, capital, talent and resilient supply chains. During phase 2, QDNL's international team has successfully built the foundation for fruitful collaboration with partners in Europe and beyond – and will modify this strategy as we enter a new phase of QDNL.

[22] See: https://quantumdelta.nl/talent-learning-centres

For phase 3, QDNL will revise its international strategy along two major axes:

1. **Greater synergies with the technology roadmaps (CATs) within QDNL programme**
   The QDNL organisation will play a proactive support role in linking international partners to the CAT technology roadmaps. This way, we support the CATs in finding and attracting potential partners for R&D projects within their phase 3 plans. Based on the input from the CAT leads, QDNL will review international focus areas. Leads from QDNL's action lines have also provided input to consolidate this new approach.
2. **More focus on attracting relevant international players to NL**
   QDNL has established a standing arrangement with the Netherlands Foreign Investment Agency quantum focus group. This group consists of four regional development agencies (ROMs), NFIA HQ and QDNL and maintains a priority lead list of international companies that are a (potential) attractive addition to the Dutch quantum ecosystem. These can be hard- or software companies, investment outfits or end-user / corporates.

This two-step shift will be reflected in an updated international strategy. QDNL will maintain the way it engages with other national ecosystems, for example with Japan, the United Kingdom and Canada, as well as the trilateral activities (e.g., trilateral call and summer schools). Next to that, we continue to strengthen connections with the leading quantum nations worldwide. This will be done in the form of outreach activities, knowledge exchanges, and selected projects with partner organisations across the globe. This also includes a proactive role in bringing together the 13 nations that are already part of the 'multilateral dialogue on quantum'. These can be seen as a set of trusted nations within the global quantum community that can drive the conversation about global collaboration in today's geopolitical landscape.

QDNL will also invest in constructive relationships with a number of emerging quantum ecosystems such as Singapore, India, South Korea, Austria and Spain. These countries are set to increase their investment in quantum-related hard- and software and represent potential customers and R&D partners for Dutch start-ups. With our efforts mentioned above, we are also actively contributing to the National Technology Strategy ambitions, where the importance of connecting with other quantum ecosystems is underlined.

Figure 6. The fourth session of the 'Multilateral Dialogue on Quantum' with colleagues from 13 different nations.

The EU and its funding programmes play a central role in QDNL's international work facilitating infrastructure in the Netherlands and in Europe. QDNL, its hubs and stakeholders already have a prominent position in core EU Quantum programmes such as the Quantum Flagship. QuTech coordinates the Quantum Internet Alliance initiative, a consortium with a €10 million R&D budget for three years, and the University of Amsterdam is leading a consortium of the same size for quantum clocks. SURF is going to host a Quantum Computer in the Science Park in Amsterdam, procured under EuroHPC JU, connecting to the hybrid infrastructure. The first Quantum Excellence Centre (QEX) was granted to create a one-stop-shop for hybrid quantum applications. QDNL coordinates the consortium with multiple European partners (e.g., LRZ in Munich, University in Southern Denmark SDU, Danish Technical University DTU and CESGA from Galicia, Spain) and national affiliated partners (e.g., SURF, aQA and QuSoft). The National Quantum Key Distribution network project QCINed, which is co-funded by the EU Commission under Digital Europe Programme, will be followed by cross-border project BENELUX starting in 2026 under Connecting Europe Facility coordinated by QDNL. SEEWQCI is focusing on the non-terrestrial satellite network, with TNO as a partner. With EQUIP-G, the procurement of a quantum gravimeter is aiming at multiple use cases with a number of instruments across Europe. The Dutch project involves QDNL and TU Delft. All projects are co-funded by the European Commission. QDNL will invest further into building strategic cooperation with EU member states and facilitate the European infrastructure in a consolidated and approachable way. This is in close collaboration with the CAT technology roadmaps and strategic goals.

Geopolitical developments

During phase 2, QDNL invested in its knowledge position on strategic policy questions, with a focus on six policy themes: global supply chains, export control, knowledge security, IP policy, standardisation and investment screening. The EU's ambitions regarding economic security and open strategic autonomy were central driving forces in this regard. For phase 3, QDNL will build on this foundation and help shape the European industrial policy agenda for deep tech with a focus on quantum. We maintain our position as a thought leader in the fields of protecting strategic Europe's strategic quantum assets. IP policy, standardisation and investment screening will be specifically addressed in chapters 4.6 and 4.10

QDNL works closely together with EZ, specifically with the country contacts at the Innovation & Knowledge directorate and the network of Innovation Advisors all over the globe. A best practice was set by bringing together the IA's from the QDNL priority countries in a bi-monthly quantum update call. For strategic policy questions that often arise within international context, it is especially important to closely align with EZ and other ministries such as the Ministry of Foreign Affairs for export control and the Ministry of Education, Culture and Science for knowledge security.

4.6 Standardisation

Standardisation will become a central key topic in the QDNL phase-3 plans, as it directly relates to industrialisation, internationalisation, export, empowering start-ups and entrepreneurship. Active Dutch participation in quantum technology standardisation assures their access to European and international markets. This is both through direct contact with potential partners and customers in the standardisation arena, but also through standards-based market defragmentation and harmonisation of supply chains relevant to the Dutch players. In particular, the contacts between suppliers, competitors and customers in the standardisation arena supports Dutch parties in their market-oriented professionalisation and scale-up. The latter is an important part of QDNL's third phase, which focuses on realising significant economic impact.

Standardisation does not happen by itself. Markets for quantum technologies are still immature and so are their players. Work is needed to understand and get consensus about the Dutch interests, both macro-economically and micro-economically, and to analyse the relevant supply chains from the Dutch industrial perspective. Education is needed on the topic, along with an understanding of the social, economic, and ethical dimensions of the standardisation process and the ways different actors and stakeholders (co-)operate in this space in Europe and beyond. For this we closely align with key stakeholders like EZ and NEN (Stichting Koninklijk Nederlands Normalisatie Instituut). Finally, Dutch players should be supported to actively contribute to the standardisation arena. Germany, France, United Kingdom, Italy, Spain, as well as USA, China, South-Korea and Japan, are all taking positions in the quantum-technology standardisation arena.

Dutch participants like OrangeQS, QuiX Quantum, Delft Circuits and TNO are already active in for example European committees for standardisation (CEN-CENELEC) via NEN. In phase 3, we will accelerate the developments on two levels when it comes to standardisation. 1) Maximise the involvement of start-ups and technical experts into standardisation activities, with the scope of increasing awareness on the importance of technical standards in the quantum ecosystem and stimulating technical standard developments in the CAT activities (quantum computing, quantum communication and quantum sensing). 2) On an overarching strategic level, -we will deploy a couple of activities to identify key strategic areas of international standard developments for the Dutch ecosystem and to ensure that the Dutch ecosystem will be well positioned internationally on key activities and key positions. This will be done in close collaboration with, for example, EZ and BZK.

4.7 National Shared Quantum Facilities

State of the art facilities are a cornerstone in the QDNL ecosystem as they drive technology development, innovations, business and attract scientific top talent. With facilities we mean shared equipment and tools made available through NanoLab NL, cleanrooms, staging networks, testbeds and pilot lines. In this paragraph we elaborate on these facilities.

Within NanolabNL shared tools are present and accessible to academic and industrial users. In phase 1 and 2 we have laid the foundations for a revision of the national cleanroom equipment through NanoLabNL. In phase 3 we will add high-TRL facilities paving the way for alignment with current and future needs of companies. Such high-TRL facilities enable companies to have access to shared equipment, working on product development, demonstrators and small series productions and prototyping. To support the growing need of companies in our ecosystem we need to have facilities in place in the short term. Investing in dedicated cleanrooms and equipment for a specific technology poses a risk, considering the capital-intensive facilities. Therefore, we will look at flexibility and scalability and fit for purpose. We will pave the way for commercial initiatives to develop cleanroom facilities, in a ‘plug-and-play' setting. Besides, we are offering access to shared facilities in a competitive and dynamic environment. These initiatives can be positioned between the university needs for academic research, and foundries or privately owned cleanrooms owned by more mature companies.

Another key focus in phase 3 will be the development of joint cleanroom facilities in Delft by TNO and TU Delft, replacing the outdated Else Kooi and Van Leeuwenhoek labs. These new facilities will have an academic baseline lab and applied thematic labs. With investments in these cleanrooms, we will service (together with NanoLabNL) both the academic community and the start-ups. At QuTech, where top-level research is being conducted, state-of-the-art facilities play a crucial role in attracting top talent. This also supports the growth of start-ups emerging from QuTech. The new commercial cleanroom described in the former paragraph is complementary to the new joint cleanroom facilities by TNO and TU Delft. The latter focuses on academic research, very early phase start-ups and dedicated R&D services by TNO. The commercial cleanroom focuses on the more mature start-ups that have outgrown the academic environment and are in need of their own cleanroom space, tools and shared tools that provide support for product and process development.

By introducing pilot lines, we will also bridge the ‘gap’ between the academic focused NanoLabNL and large corporate cleanrooms or foundries. This will allow for prototyping and small volume production. We will explore how to best make available the high TRL NanoLabNL tools in such environments and how to speed up the availability of equipment.
The human capital aspect needs special attention. There is a shortage of cleanroom operators and (processing) engineers. The joint cleanrooms will coordinate their training and education to educate cleanroom engineers.

Besides, part of the cleanrooms is used for training HBO and MBO students on topics like vacuum systems, deposition and etching techniques. We will connect these to the TLCs. In this way, technicians are trained that become available to the ecosystem.

The cleanroom infrastructure in the Netherlands encompass other high-tech sectors like nano, semicon, photonics and optics. Suppliers and users from these sectors also have their own cleanroom and pilot lines. In our Quantum Manufacturing Alliance initiative, we will connect to these sectors. We will draw inspiration from Brainport with its extensive network of suppliers. We will also align with PhotonDelta.

Beside the cleanroom facilities there are other shared facilities, described in the CAT programmes, that are accessible to researchers and developers. These are, for example, the quantum sensing testbeds in CAT-3, the roll out of a National Quantum Staging Network in phase 3 and operational quantum computers in CAT-1 (this could be through the Quantum Inspire portal or through SURF in Amsterdam with the introduction of the hybrid quantum computer as described in chapter 4.2). These will be positioned as shared infrastructure, to bridge the technology to end-users, and which will accelerate the development of quantum applications in all three domains (computing, communication and sensing).

Activities in 2025-2028

Next to further investment in NanolabNL, in phase 3 we will also focus on the development of private initiatives with co-funding from QDNL expected for 2024/2025. The high-TRL equipment positioned in NanoLabNL will be available for companies and, if required, some equipment could become part of such private initiatives. The equipment will be developed in 2025-2026.

The shared facilities will become part of our national quantum campus concept “House of Quantum” that we will develop in phase 3, showcasing the facilities together with other facilities we offer to external users, including interested users from outside NL. We will team up with other places in Europe, including the trilateral partners Germany and France. We will align QDNL investments with the EU, including the Chips Act, to optimise European synergy and allow for additional investments.

4.8 Manufacturing Capabilities for Quantum Chips

Although the true value of quantum technologies will depend on the end-user engagement via quantum algorithms, the core of the innovation lies in optimising qubits. Presently, all the existing qubits technologies suffer from inferior performance in one or more metrics (e.g., fidelities, system error rates, long-range interactions, connectivity, decoherence rate), or are hindered by large footprint per qubit (mm size and above) which impacts miniaturisation when the qubit number increases (i.e. scaling). It is therefore of paramount importance to mature manufacturing processes of qubits. This requires stability in process modules and a tight feedback loop with wafer level, device level and “system in package” level testing and metrology.

The instability and lack of scalability of qubits is the reason that the quantum market is predominantly academic at this moment in time. In fact, even the evolution of peripheral components (e.g., interconnects, control electronics, testing and automation equipment) and algorithms (for error correction or noisy-intermediate scale applications) is being hampered by the lack of availability of more than rudimentary qubit processors. This means that the growth of quantum companies addressing such components or even complete systems (many of which are present or emerging in the Netherlands) relies on the availability of qubit processors and/or their roadmaps for expected specifications. An analogy to ASML can be drawn here – its innovation cycle for their lithography and metrology equipment occurs in-tandem with the evolution of the requirements from leading chip manufacturers such as Intel, TSMC or Samsung. Jointly they innovate to enable the next generation technology node.

If the Netherlands intends to create leading industries in quantum, then it must provide production facilities for stable and reliable manufacturing (fabrication) of physical qubits and integrated chips within its own borders, and/or to ensure access and participation in such manufacturing facilities emerging in other EU member states. Academic cleanrooms simply do not offer the facilities and expertise for a systematic approach for stable process development, with tight process control, quality management, contamination control, fast-feedback testing, a guaranteed up-time and a short turnaround time – all of which are crucial to identify and solve the bottlenecks in the fabrication of the highly sensitive qubits and integrated quantum processor chips. Moreover, due to a lack of state-of-the-art production facilities in academia, such as extreme UV lithography, flip-chip bonding or 3D integration, cutting-edge quantum processors designs cannot be built or optimised in academic cleanrooms. Therefore, we must establish industrial pilot lines, with a combination of shared and dedicated equipment for process optimisation, automated testing and metrology. These facilities should employ professional process technology experts who will co-develop the various process modules together with leading users, and then release them to a broader user community via so-called process development kits (PDKs).

Having access to such pilot lines, or even running or coordinating some of these pilot lines, will be a condition sine qua non for maintaining the Netherlands’ leading position in quantum. We are being faced with fierce competition from big tech companies (e.g., Intel, IBM, Microsoft, Google and Amazon) who have large, dedicated teams and investments for the development of qubits. These companies are also acting as talent-magnet. The Netherlands risks losing its strong starting position, both in terms of academic excellence and a promising set of start-ups. Setting up and investing in production facilities for quantum chips will enable us to reap the benefits of the investments we have made in quantum technology in the Netherlands. By establishing these facilities, we can sustain the development of quantum products and solutions, strengthen the Netherlands' position as a leading technology hub in Europe, secure a strategic role in the quantum value chain and create more jobs, thereby driving greater economic impact. We are therefore in need to act.

4.9 From Chips Act to Quantum Act

The impending rise of quantum technologies and their disruptive potential encouraged EU to facilitate the development of quantum chips in conjunction with classical chips, under the Chips Act. Europe also realised that while we lost the most advanced classical chip manufacturing race (with dominant players now in Taiwan, Korea, China and the United States), we still have a chance to build a strong industrial position in quantum chips and systems, based on Europe’s academic leadership in quantum technologies. However, this requires stepping up our manufacturing capabilities for quantum chips and moving from the academic labs to industrial fabs.

We must move beyond technology demonstrators with just a few qubits, to fully functional quantum processor chips for computing and communication applications, which requires a much higher number (beyond a thousand and up to millions) of high-fidelity qubits fabricated using high yield processes. Specifically, we need to accelerate our qubit technology development. For this we need to establish state of the art professionally managed manufacturing facilities in the Netherlands and in Europe. This need was not foreseen in the original QDNL plan but is now of the utmost importance. We developed a strategy to pursue these objectives, in a way that we can leverage the new instruments being rolled out under the EU Chips Act. This will be further explained in chapter 7.12. In addition to that, we are also preparing ourselves for the upcoming Quantum Act, wich will further impact the QDNL programma and offers new opportunities.

4.10 IP & Tech Transfer

The wider objective of QDNL Programme is to increase the economic footprint of quantum technology in the Netherlands. IP strategy and vision have a central role for achieving this objective. The IP strategy aims at enhancing and promoting IP creation in quantum technology at the national ecosystem level while at the same time bringing together the know-how and the IP of the knowledge institutions to take decisions on IP creation and exploitation. The QDNL IP strategy has its legal basis in a collaboration agreement signed by all QDNL main partners in June 2023. The collaboration agreement establishes that the parties participate in a joint knowledge and technology transfer development. The ownership of the IP will remain with the party of the ecosystem that has generated it. However, parties should collaborate to scout IP and facilitate IP technology transfer with the terms agreed in the collaboration agreement.

The collaboration agreement outlines that the parties of the ecosystem participate in a joint knowledge and IP technology transfer development via a quantum technology transfer team (Q3T) whose members represent the knowledge institutions. The IP team is a sub-team of Q3T team and is responsible for creating IP awareness, stimulating IP creation and providing advice on the best way to exploit the IP. Exploitation of IP could take place via transfer of patent(s) to a start-up or through licensing IP to companies that collaborate or bring crucial knowledge to our ecosystem via ‘golden routes’ defined in the collaboration agreement. An IP Council is installed that advises on strategic IP issues on the ecosystem level and on a case-by-case basis the terms and the feasibility of such IP exploitation. Henk van Houten is chair of the IP council.

For phase 3, QDNL will focus on several key areas: executing the IP creation and exploitation strategy to meet the KPI targets; strengthening the IP collaborative effort at CAT programme level in line with the advice from the MTR committee and Taskforce; and providing continued IP creation and exploitation guidance to the whole ecosystem.

5 Quantum Technology: future developments

This chapter introduces the important future developments that QDNL foresees in our programme on quantum computing, quantum networks and quantum sensing.

5.1 Quantum Computing

Quantum computing is a major focus of our QDNL programme, with CAT-1 driving the national effort. During phases 1 and 2, CAT-1 centred on Quantum Inspire, a unique platform accessible to the Dutch ecosystem for both technology development and applications. Three quantum processors; superconducting, electron-spin and neutral-atom; were prepared for integration on the platform, reflecting our commitment to supporting a diversity of promising qubit technologies.

Figure 7. Quantum Inspire will serve as a unique platform accessible to the Dutch ecosystem for both technology and applications. It aims to connect three types of qubits by the end of 2024.

In phase 3, we will significantly expand this scope. CAT-1 will support the development of photonic processors—an area where the Netherlands is internationally recognised as a frontrunner—and colour-centre processors, which are now drawing foreign investment, such as Fujitsu's new Dutch activities. Through challenge-based programmes and targeted support to companies, we will channel resources into the technologies with the clearest potential for scale-up and market relevance. This will position Dutch actors to compete strongly in upcoming procurement calls, including the JU HPC-QC acquisition at SURF.

Current quantum processors operate in the NISQ regime: incredibly valuable for research and talent development, but not yet capable of outperforming classical systems on meaningful industrial problems. Despite these limitations, global roadmaps now point toward feasible routes for achieving fault tolerance. Our ambition in phase 3 is to transition from exploratory component research to integrated, full-stack systems, linking high-quality hardware to control software, compilers, error-mitigation tools and application layers. Reaching this stage requires a concerted effort across the entire value chain, strengthening everything from fabrication and calibration to user interfaces and hybrid HPC integration.

To support this, QDNL will place much stronger emphasis on the software and applications layer. Dutch companies working on algorithms, compilers, hybrid workflows and domain-specific solutions will receive targeted support, enabling them to help define emerging use cases and ensure the Netherlands remains competitive as global adoption accelerates. Strengthening software capability is also essential for real end-user engagement, allowing Dutch corporates and start-ups to experiment, validate workflows and build early competitive advantage.

Our phase 3 roadmap outlines how CAT-1 will guide this evolution from diverse platforms toward increasingly integrated demonstrators. All partners (e.g., universities, research institutes, start-ups, corporates and HPC facilities) will collaborate on system-level challenges, marking a transition from fragmented research to coherent, interoperable architectures. The supply chain will evolve in parallel. Beyond qubit count and fidelity, we will prioritise manufacturability, operations per second, stability, yield, software robustness and user-centred design. Persistent challenges, such as low QPU yield, will receive dedicated investment. End-users will be involved from the outset to shape future procurement specifications and validate technology relevance. This national effort is closely aligned with European initiatives, including EuroHPC, Chips Act pilot lines, Digital Europe and Horizon Europe. This alignment ensures coherence between national priorities and European ambitions. A substantial share of the phase 3 budget will be allocated to a new challenge-based programme that tackles critical bottlenecks in hardware, software and system integration. This high-risk/high-gain model will allow us to take bold decisions, support breakthrough directions and adjust course as evidence accumulates. Mid-term evaluations will ensure that resources flow to the most promising technologies. The programme will culminate in procurement oriented calls for tender for integrated demonstrators. Toward the end of phase 3, we will also explore hybrid approaches, linking CAT-2 capabilities on networking and distributed quantum computing to CAT-1 hardware. Finally, standardisation, interoperability and IP protection will be strengthened through coordinated efforts, including international alignment and the trilateral programme, ensuring that Dutch innovations are secure and globally relevant.

5.2 Quantum (Internet) Networks

The Netherlands is at the forefront of the quantum communication revolution. Maintaining this global leadership position requires us to focus on accelerating developments in quantum communication technology. We have defined three main goals to help us achieve this:

- Deploy and operate the national Quantum Staging Network based on Quantum Key Distribution technology.
- Prepare for the next Generation of Quantum Networks by accelerating Quantum Internet R&D.
- Maximise economic value by scaling up, international leadership and end-user participation

During phase 3, our focus will be on establishing the “National Quantum Staging Network” across the Netherlands. Based on Quantum Key Distribution technology, this network will be designed to connect strategically chosen locations in the Netherlands and allows industry, government and academia to plug into, ensuring seamless integration with Dutch digital infrastructure. The network will also enable synergies with post-quantum cryptography, laser-satcom ground stations and operational high-performance (incl. quantum) computing clusters, lowering barriers for governments and industries to adopt quantum technology. Furthermore, this network will become the Dutch backbone for cross-border quantum networks under the European quantum communication strategy (EuroQCI) by 2030, thus laying the foundation for broader European participation in quantum communication initiatives. The deployment and integration of this network will play a critical role in safeguarding our digital and vital infrastructure in the future.

The operational quantum network is, in turn, essential for paving the way for next-generation quantum networks based on entanglement, commonly referred to as the ‘quantum internet’. To achieve this vision, we aim to have components such as quantum memories, frequency converters and repeaters, as well as the necessary software layers and protocols ready for productization by 2028, necessitating significant advancements in technology development. A pioneering network testbed will showcase these technological advancements, fostering collaborations across the value chain and positioning the EU as a leader in quantum communication technology by 2035.

The recent surge in quantum network technology investments by other non-EU nations underscores the need for us to double down on our R&D initiatives and forge strong alliances, both nationally and internationally. The United States has recently shown a stronger presence in this field by allocating funds towards quantum network technology in the US Chips Act, as well as the rise of Qunnect and the Amazon Web Services (AWS) Centre for Quantum Networking. Major telecom equipment suppliers such as Cisco, Toshiba and Nokia are also increasing their efforts on this front.

To solidify our position as a global leader in quantum network technology, we will furthermore leverage the existing integrated photonics ecosystems in the Netherlands to scale up, manufacture and reduce technology footprints. Establishing strategic partnerships at the EU level will further enhance our position. This also includes maintaining our current strong involvement in EU27 initiatives such as the Quantum Internet Alliance and our strategic contributions to EuroQCI. Additionally, advocating for international standards that align with EU values will be pivotal for increasing network interoperability and market uptake.

Use case development and stimulating industry participation will further help meet end-user needs and ensure a practical application of our network. This includes engaging with a large group of commercial parties that are united in an industry association. Leveraging the National Quantum Staging Network and the Quantum Internet testbed infrastructure, we aim to implement various projects with end-users across sectors such as government, logistics, healthcare, industry and key players in digital/vital infrastructure such as telecom, sea cable infrastructure and datacenter providers.

By establishing a nationwide quantum network and driving advancements in next-generation technology R&D, we will not only keep pace with growing international competition but also position ourselves as a global leader by 2028 in the field of quantum communication technology.

5.3 Quantum Sensing

Sensors are everywhere, from basic thermometers to our own smartphones, quietly shaping the fabric of our daily lives. Quantum sensors, tapping into the intricate workings of quantum systems and offering enhanced measurements, hold promise for transforming various industries, ranging from healthcare to telecommunications. Within the QDNL ecosystem, the Quantum Sensing Applications Programme (CAT-3) positions itself to capitalise on this potential and drive meaningful societal impact. The goals for phase 3 are as follows:

- Deliver open platforms for quantum sensing technologies,
- Demonstrate use case driven proof-of-concept instruments.
- Develop the Quantum Sensing value chain.

CAT-3's primary objectives aim to advance the industrialisation of quantum sensing technologies. The programme seeks to accelerate technology development, foster innovation and the boundaries of what is achievable in terms of sensitivity, precision and functionality. Furthermore, CAT-3 strives to facilitate the commercialisation of these technologies, ensuring that breakthroughs in the lab translate into tangible products and solutions in the market. Lastly, the programme is committed to driving internationalisation and fostering collaborations beyond the Dutch borders to amplify the impact of quantum sensing on a global scale, all while nurturing expertise in fabrication to ensure the scalability and reliability of these technologies.
CAT-3's strategy revolves around making quantum sensors accessible and practical for companies, both established players and emerging start-ups. Through three projects, Testbed Facilities, Application Lines and the New Ideas Accelerator, the programme provides essential resources, infrastructure and funding opportunities to drive the adoption of quantum sensing technologies:

- Testbed Facilities are open environments where quantum sensing technologies can be developed, tested and applied to real-world challenges. These facilities provide access to state-of-the-art equipment and expertise, fostering collaboration and knowledge sharing among participants.
- Challenge Based Calls focus on developing practical applications of quantum sensing technologies within specific domains or industries. By engaging R&D engineers across diverse sectors, CAT-3 aims to demonstrate the potential impact of quantum sensors and facilitate their integration into existing workflows and processes.

CAT-3 focuses on system integration, demonstrators and real-world use cases. Integrating quantum sensors into practical applications facilitates the transition of quantum technology from theoretical promise to tangible solutions. Additionally, we recognise the significance of outreach and multidisciplinary collaboration as critical components of this journey. These elements are essential for educating end-users, attracting talent and ensuring the benefits of quantum sensing are shared across various domains and industries.

By 2028, CAT-3 aims to contribute to creating a thriving Dutch quantum ecosystem where quantum sensing technologies are integrated into daily life. Through open collaboration, shared resources and a focus on practical applications, CAT-3 is prepared to play a pivotal role in accelerating the adoption of quantum sensing, driving innovation and transforming our understanding of the world across a spectrum of industries.

6 Strategy on 6 Key Themes

In this chapter we introduce our vision and strategy for key themes in the QDNL programme. Most of these are covered within the action lines in close collaboration with the CATs.

6.1 Basic Research and Innovation

An important aim of QDNL is to support fundamental research essential to the CAT programmes, acknowledging the critical role of research and innovation in shaping the current quantum technology landscape. This is mainly executed by our AL-1 programme. By expanding the scope of the CAT programmes, i.e. quantum computing, communication, and sensing, AL-1 creates an environment conducive to exploring innovative ideas beyond their traditional scope. Through thematic open calls managed by NWO, all Dutch quantum researchers, including young post-doctoral fellows, are invited to contribute, strengthening, and broadening the foundational basis of the CAT programmes. This will offer essential support to many young and talented researchers, helping them become key contributors to the Dutch quantum ecosystem. These efforts will kick-start their careers and empower them to form novel research groups, thereby enhancing the quantum landscape in the Netherlands.

The projects initiated under AL-1 span a variety of topics, ranging from the design of hybrid analogue-digital quantum computation models to research aimed at enhancing the scalability and speed of atom quantum computers. Additionally, studies focusing on identifying optimal material compositions for quantum memory and sensors.Research also investigates the energy efficiency of quantum computers, contributing to the enrichment of quantum research within the Netherlands.

The budget allotted to AL-1 during phases 1 and 2 enabled the Netherlands to re-engage with the QuantERA funding scheme after a period of inactivity. This strategic move not only established the country's international presence through the QuantERA programme but also through active participation in trilateral initiatives with France and Germany. AL-1 remains committed to forming strong international alliances, bolstering the scientific reputation of the Netherlands. Furthermore, we collaborate with other nations to develop new funding mechanisms and new avenues for collaboration. In phase 3, AL-1 aims to complete two QuantERA calls by 2028. This collaborative approach ensures optimal utilisation of resources by leveraging research conducted globally on similar topics.

In phase 3, we aim to strengthen collaboration between academia and industry, promoting the exchange of ideas and advancing quantum technology. By inviting participation from Universities of Applied Sciences (HBOs), AL-1 seeks to build stronger connections with applied research and with industry partners, facilitating the application of research findings. Moreover, AL-1 provides researchers with essential skills for navigating the quantum technology landscape through training programmes on for example IP, entrepreneurship and ethical and societal aspects. This will ensure that research contributes positively to society. The Principal Investigators (PIs) and researchers in AL-1 projects will become part of the training and education activities of QDNL. We will also identify research results suitable for commercialisation and outreach activities together with the CAT programmes.

In phase 3, AL-1 will be fully integrated into the new funding strategy, serving as the primary operator of the Quest Programme, including the NWO quantum call and QuantERA. It will also participate in specific bi- or tri-national calls and SME-oriented programmes like Eureka, which will be administered by RVO.

6.2 Quantum Business Ecosystem

As explained in chapter 4.1, a vibrant quantum ecosystem is the foundation to achieve our long-term goals. As mentioned in our QDNL Vision 2024-2035, we want to focus more on growing our quantum businesses. This will require us to grow the business ecosystem in the Netherlands in a sustainable way with best chances of securing unique positions in the future global value chain. The activities contributing to this goal are distributed across all our CATs and action lines, with a particular focus on AL-2, which features various activities specifically tailored to reaching this goal.

The core business of AL-2 lies in supporting the creation of start-ups and a focused effort to advance scale-ups:

- QDNL facilitates the creation of start-ups, through entrepreneurial development, IP creation, speeding up the process of starting a company, and providing proof-of-concept funding to kickstart and grow start-ups. Typically, universities and RTOs serve as the source of inventions, IP, and entrepreneurial talent. To accelerate start-up creation, we will focus on entrepreneurship specifically. The IP and Q3T teams and the business developers stationed at the hubs, play crucial roles in identifying and nurturing promising initiatives.
- Together with the hubs, we will professionalise our start-up support activities, using the ecosystem expertise and best practices and jointly overseeing the entire portfolio and opportunities in the hubs. This will entail a joint founders pool and founder support through every stage of entrepreneurship, from lab to exit. The programme will combine extensive entrepreneur and start-up experience with data-driven knowledge tools to impartially serve and connect the Dutch quantum ecosystem. QDNL aims to expand to 70 incorporated start-ups (and attract 30 from abroad) by 2028.
- Securing growth funding will be essential for driving the expansion of our start-ups and scale-ups, maintaining their leading position internationally, and enabling them to pursue acquisitions rather than being acquired. In 2025 QDNL launched the independent QDNL Participations fund, a closed-end VC-fund that started under QDNL's wings as a pre-seed initiative. This transformation leverages QDNL public funds with private capital.

A strategic approach to tech transfer, most notably IP-development and exploitation, is part of our activities to build a business ecosystem. With our way of working (see also chapter 4.10), we facilitate start-up creation and collaboration with (inter)national corporates.

As start-ups scale up, the demand for fabrication and critical facilities increases (see chapter 4.7). To meet this demand, we plan to invest in campus development and facilities in the hubs. This will provide our companies with essential infrastructure for growth. We also envision making agreements on access to facilities in other countries, notably France and Germany through our trilateral collaboration, and to extend the House of Quantum concept to a cross-border initiative.

A significant effort to grow the ecosystem lies in user-engagement, activities connected to this include:

- Develop the national quantum campus. It is our vision that our ecosystem becomes an ecosystem without barriers. The national quantum campus, visible through our House of Quantum look and feel, contributes strongly to that goal. In all hubs we develop Houses of Quantum where organisations and individuals can meet and work. Next to that, the hub provides access to facilities, like cleanrooms, testbeds, pilot lines, TLCs and corporate R&D facilities.
- Attract foreign companies to establish R&D or production facilities in the Netherlands. To achieve this goal, it's essential to have a well-coordinated plan among all hubs to establish a unified national campus. Each hub should prominently feature a House of Quantum, representing our collective presence and strength, alongside the facilities that we offer. Strong coordination between the hubs with the Houses of Quantum and their facilities will be crucial in achieving this goal, next to close alignment with EZ, the NFIA and the ROMs.

- Connect to adjacent sectors like semicon, (integrated) photonics, AI, micro & nanotechnology, trough initiatives like Quantum for Business and the Quantum Manufacturing Alliance. Collaboration with other sectors will enhance resource and expertise access, drive innovation and foster synergies.

> At the end of our programme, we should have established a self-sustaining quantum ecosystem where companies and other initiatives thrive, contributing to the growth and success of the Dutch business landscape.

6.3 Talent

A cornerstone of our programme and an essential prerequisite to reach our goals is the availability and development of talent. Most of the activities connected to this are part of AL-3. The ambition is to help build a knowledge ecosystem of quantum talent at all levels of education, both 'home grown' and attracted from abroad. To realise this ambition, AL-3 is developing an open knowledge ecosystem with attractive conditions for talent. Its target groups are students in higher education at all levels (short-term future workforce), students in secondary and primary education (longer-term future workforce) and professionals from various sectors (industry, government, non-profit) with a need for expanding their knowledge and/or skills in quantum technology (lifelong learning of current workforce). In addition, AL-3 has an international focus: a top talent initiative and a visitor's programme are already in place to facilitate cross-border exchange of talent. In doing so, AL-3 aims to ensure perpetuation of inflow and development of talent in the Dutch quantum ecosystem. We are strengthening our ties within Europe, with dedicated collaborations with France and Germany and within several educational programmes by the EC.

In the past years AL-3 has built a strong network of educational experts in Quantum Technology from (mostly) academic universities, universities of applied sciences, and vocational colleges (WO, HBO and MBO). Together, we have established 4 Talent and Learning Centers (TLCs) and 5 Quantum Laboratories (Qlabs). The concept of a TLC, in which expertise from educational institutes that traditionally operate on their own, is shared and used to design joint projects and connect to industry, is new and unique in The Netherlands. The Qlabs develop and provide educational materials and activities focused on quantum science and technology primarily to secondary and primary school students. This initiative is crucial, particularly considering the decline in the number of Dutch students with a STEM background in recent years. The Qlabs welcome thousands of children annually to their labs to conduct experiments.

In phase 3, the ambition is to follow up on the creation of TLCs and associated Qlabs, bringing these two together in a sustainable national network will help improve their impact in the long run. On a local hub level TLCs and Qlabs closely collaborate and are often situated ‘under one roof’. Another focus in phase 3 will be ‘tailored quantum-technology training for professionals’, which addresses the increasing demand for quantum technology training for professionals from private and public sectors (e.g., companies, government institutions) and we will develop entrepreneurship education to grow the pool of entrepreneurs.

> By the end of 2028, there should be a sustainable national network of Qlabs and TLCs, where the latter should act as the leading centers for coordinating and providing quantum technology training and help foster entrepreneurship among students.

6.4 Societal Impact

Developing quantum for good is another key pillar of our programme. There is a specific programme to accelerate quantum for good developments: the Quantum & Society programme (AL-4). We aim to enhance the positive aspects of quantum technologies and their applications and strive to prevent or mitigate the negative aspects. AL-

4 follows a holistic approach to support the transition of the quantum technologies developed in the CATs into applications that are useful to society at large. To do so, we perform cutting-edge research on the ethical, legal and societal aspects of these technologies, launch awareness campaigns for the broader public, promote knowledge dissemination, develop practical tools and create a Quantum-for-Good competition. This holistic approach is in line with the strategic choice of QDNL to “work towards technologies that are beneficial for society at large, by understanding the ethical and legal frameworks, by creating broad acceptance in society through a clear communication strategy and by considering ethical choices that need to be made to implement the technology”.

Early interaction between science, industry, government and society is required to make emerging technologies beneficial for society, while quantum applications must be ethically sound, legally appropriate and socially desirable. In phase 3, we work towards this via two main pillars: 1) the Centre for Quantum & Society (CQS), 2) supported and guided by excellent scientific research teams, who help to assure scientific quality and rigor and provide validation.

Using the CQS as the co-creation place, tools are developed together with many stakeholders from within the QDNL programme (and particularly with experts from the CATs) and in society (in phase 3 particularly putting more emphasis on collaboration with the public). Along the way, we raise awareness in growing communities, engage with (future) end-users, work on responsible innovation and on the Quantum for Good competition, first nationally, but also beyond our borders.

> By the end of the programme, the Netherlands should be recognised as a thought leader on societal issues around quantum technologies.

6.5 Cleanroom Programme: NanoLabNL

As mentioned before, shared facilities and cleanrooms are integral to reaching our goals. We aim to strengthen the Netherlands' state-of-the-art academic cleanroom capabilities of NanoLabNL through investments in new equipment with improved specifications. In addition to that, we strengthen capabilities to enable new research, development and production and to improve the quality and reproducibility of nanofabrication and characterization. NanoLabNL is a coordinated, distributed and open-access infrastructure and is the national facility for research based on nanofabrication. Cleanrooms are available at five locations (Amsterdam, Delft, Eindhoven, Enschede and Groningen) with equipment and expertise for the manufacture of nanodevices. The available high-end equipment is used for depositing and structuring materials with nanometer resolution and inspecting and analysing the fabricated surfaces and structures. These techniques are widely applicable and are used for quantum, photonics, space, health and semicon. NanoLabNL caters primarily to academic users but also accommodates commercial use up to 20% (bound by EU state-aid regulations) of maximum capacity.

The following two goals are defined:

1. Strengthening the basic infrastructure: renewal of the machinery at the five NanoLabNL locations. This reinforcement of the basic infrastructure by making equipment available with state-of-the-art performance allows to achieve high quality and precision in research and development of nano-devices.
2. High-TRL impulse: extra impulse to make the machinery suitable for developments further down the innovation chain, at higher technology readiness levels (TRL). These include equipment that improves reproducibility and predictability of specific processes, equipment with improved automation, improved uniformity over larger substrate surfaces and higher throughput. High TRL tools will be installed at the TU/e, UT and TU Delft Nanolabs.

In phase 3, we will continue with our investment in basic infrastructure and in high-TRL equipment, in strong connection to the NanoLabNL cleanrooms, and envision in investing in tools that constitute pilot lines within the Chips Act programme, for industrial access.

6.6 Communication & Outreach

QDNL envisions an ecosystem community that fosters collaboration, inclusivity and global recognition. Building upon a broad spectrum of successful national and international efforts, our goal is to establish and communicate an appealing brand and community for the Netherlands in quantum technology, grounded in principles of excellence, cooperation and forward-looking vision. This strategy supports QDNL's long-term goal: positioning the Netherlands among the top three quantum economies worldwide by 2035.

Strategic goals for communication & outreach

- **Raising quantum awareness**
  Raise visibility and awareness of quantum research and innovation in the Netherlands and Europe. Our mission extends beyond the quantum community to inspire the general public about the potential of quantum technology. Through accessible content, storytelling, initiatives and projects we aim to build understanding and enthusiasm for quantum's impact on society.
- **Accelerating adoption of quantum technologies**
  Stimulate interest and proactively involve potential end-users in the co-creation and implementation of quantum applications. By showcasing Dutch leadership and facilitating dialogue at key events and through targeted outreach, we foster partnerships that accelerate adoption and create real-world impact.
- **Attracting global talent and empowering the Dutch community**
  Position the Netherlands as an attractive destination for quantum talent and companies worldwide. Through compelling storytelling, international presence and community-building initiatives, we support talent development and highlight success stories that demonstrate the strength and inclusivity of the Dutch quantum ecosystem.
- **Ensuring consistency & quality in messaging**
  Deliver clear, aligned and audience-driven communication across all channels and partners. We focus on strong narratives around projects in CATs and action lines and around technology impact. This is supported by integrated planning, clear processes and evaluation to ensure visibility, credibility and impact.

Communication and engagement strategy
Our strategy brings together a diverse mix of communication and outreach activities to strengthen engagement and amplify global recognition of the Dutch quantum ecosystem. At the heart of this approach is Quantum Meets, our flagship event that has grown into a dynamic platform for knowledge sharing, networking and collaboration.

Beyond our own events, we maintain a strong international presence by actively participating in leading conferences such as Q2B and The APS Global Physics Summit. These engagements provide Dutch organisations with opportunities to present their work, attract talent and forge strategic partnerships. QDNL plays a key role in facilitating access for start-ups and researchers to these global stages, ensuring that the Netherlands is visible where quantum innovation happens.

Our communication efforts span multiple channels and are driven by compelling storytelling that highlights breakthroughs, applications, and impact. These narratives are shared consistently across LinkedIn, our website and the newsletter, ensuring audience-focused messaging that amplifies visibility and engagement. By providing tools, templates, support, and clear processes, we enable a unified voice that strengthens the collective impact of the Dutch quantum ecosystem.

Through this integrated approach (combining events, international engagement, digital communication and community activation), we position the Netherlands as a robust, collaborative and globally connected leader in quantum technology.

Figure 8. Building upon the success of the previous edition, this year's Quantum Meets will continue to offer inspiring opportunities for networking and showcasing the strength of our vibrant quantum community.

7 Plans per Programme Line

7.1 Introduction

In the next chapter, we introduce the projects and work packages for our programme lines in more detail. The table below shows an overview of all the milestones. We expect that the vast majority of activities have finalised by 2028, however the administrative duration of the QDNL-programme is until 2031. The milestones presented below are towards 2028, because ideally activities are executed sooner rather than later. However, some activities might not be finished yet in 2028, due to their nature, e.g., PhD projects.

	Milestone	Year
CAT-1	• Design and showcase quantum processors with 100 qubits, meeting NISQ application standards, utilising a complete supply chain.	2027
	• Strengthen the Dutch supply chain for quantum computing components and modules.	2028
	• Development & application of quantum algorithms and procedures/methods to optimise the execution of such algorithms for quantum computers.	2028
	• Deliver fully functional quantum computers with enough compute power to use algorithms.	2028
CAT-2	• Establish and manage the operatable 'National Quantum Staging Network' nationwide, utilising QKD technology, operated by new quantum network operator.	2026
	• Setup of Quantum Internet testbed (aligned with the developments in the EU, linked to QIA and/or EDIC).	2028
	• Develop photonically integrated quantum hardware components and critical elements for next-gen quantum hardware and software, essential for building the future global quantum internet while minimizing footprint.	2028
	• Attracting industry and end-users by developing new use cases, establish and foster industry association, develop quantum communication standards.	2028
CAT-3	• Three quantum sensing testbeds operational for external partnerships.	2025
	• >10 non-academic project collaborations using the services of the testbed facilities.	2026
	• >2m budget of co-funding attracted to testbeds from external projects.	2026
	• >100 unique visits to the testbeds.	2027
	• External partnerships and self-sustainability frameworks in place for all three testbeds.	2027
	• Established at least five application lines in Defence, Metrology, Semicon, Space and Healthcare.	2028
AL-1	• NWO call awarded.	2026
	• Participate in QuantERA call and have three projects involving Dutch partners in three projects granted at each call.	2025
	• Participate in QuantERA calls and have three projects involving Dutch partners in three projects granted at each call.	2027
AL-2	• Official launch of Quantum Manufacturing Alliance.	2026
	• CRM system implemented an used by all hubs.	2025

	Milestone	Year
	• Use case catalogue completed with all NL quantum offering.	2026
	• Launch of first pilot call for quantum inventions.	2025
	• Launch of QDNL IP tech transfer program.	2025
	• Launch of new calls suitable for SME's.	2025
	• All five hubs will have their QDNL HoQ community space as part of the national campus.	2028
AL-3	• Establish four Quantum Education and Development Labs; and a digital learning platform.	2026
	• Strengthen national collaboration between regional Qlabs through the Qlab-NL network and launching a shared, publicly accessible digital platform that enables the wide dissemination of educational content, lesson materials, outreach activities and teacher resources.	2026
	• Increase the reach and impact of Qlabs by expanding their capacity to host school groups and educators, aiming for 2000 annual visitors, and broadening outreach to include middle schools (havo/vmbo) and primary education.	2028
	• Each TLC conducts~2 trainings of professionals per hub per year.	2028
	• Two trilateral (with France and Germany) summer schools organised and implemented.	2025
	• Continue international summerschool approach on a yearly basis until 2028.	2026
	• Woman mentorship programme and We in Quantum Development programme further developed.	2028
AL-4	• An international version of the National Quantum Course will be launched in at least three languages.	2026
	• A Quantum Awareness exhibition and a Quantum Escape Room will be launched through the project Quantum & Arts.	2026
	• The co-organisation of an ELSA conference.	2027
	• A second citizen-centric Quantum Gala will be organised.	2028
	• The organisation of an annual Quantum for Good Competition (pilot in 2025 on microplastics).	2028
	• The co-organisation of 4 Quantum for Good events to fulfil our goal of directing quantum applications at major societal problems and challenges, like the SDGs together with organisations like UN agencies, ITU, OQI, GESDA and OECD.	2028
	• The CQS deploys the creation of feasibility maps for quantum technologies per vertical (eg water, health, energy) to enhance end-user engagement and disseminate quantum knowledge.	2028
	• The CQS will be established as a one-stop-shop for awareness, working together with public and private organisations in the Netherlands.	2028
	• The deployment and validation of EQTA in working sessions and develop at least two more tools (a "quantum technologies card set" and our foresight capabilities).	2027
NanoLabNL	• All identified equipment should be acquired.	2028
	• All identified High-TRL equipment should be acquired.	
	• All identified High-TRL equipment should be installed and operational.	2030
	• Give out 10 vouchers per year.	2028

	Milestone	Year
Trilateral	• Trilateral call conducted, projects selected and launched.	2025
	• Projects Eureka call selected and launched.	2025
	• QDNL Participation Fund 2.0 successfully launched.	2025
Infrastructure	• Participation in three Chips Act pilot line calls.	2028
	• Commercial cleanroom Delft.	2026
	• Cleanroom infrastructure TU Delft and TNO start of construction.	2026
	• Cleanroom infrastructure TU Delft and TNO realised.	2030

Table 4. Overview of all the projects and their milestones**.**

7.2 CAT-1: Quantum Computing & Simulation

7.2.1 Project 1: High quality and powerful processors – from lab to fab

Goal: Design and demonstrate functional quantum processors in a relevant environment, with performance required for NISQ applications, supported by a complete supply chain.

We aim to advance quantum processor technology by scaling up to 100 qubits while enhancing device quality. It involves analysing current devices, refining fabrication processes and implementing testing procedures to ensure improved performance. These processors will serve as validation tools for control hardware and software, aiding in error mitigation and providing valuable feedback to application developers. Deliverables include quantum processors operated by control electronics and software for calibration, error mitigation and basic use cases. Leveraging a de-verticalized approach, the project will evaluate systems with at least 25 qubits for mid-term assessment, potentially advancing to 100 qubits with additional funding. Supervised by CAT-1, the project aims to establish a self-sustaining supply chain for quantum processors, supported by EU flagship projects.

7.2.2 Project 2: A strong and viable value chain – enabling a quantum future.

Goal: Strengthen the Dutch supply chain for quantum computing components and modules.

We dedicate this project to enhancing the field of enabling technologies crucial for the operation and validation of quantum computing systems, encompassing signal generators, amplifiers, data processing equipment and control systems. With a focus on strengthening the Dutch supply chain in these critical areas, it tackles challenges related to scalability and defining clear requirements. Through collaborative efforts with end-users to pinpoint their needs and prototype demonstrations, the project endeavours to expedite the commercialisation process. Funding for standardisation activities ensures global compatibility, complemented by open calls for innovative solutions. Managed by consortia and backed by specialised personnel, the initiative encourages international collaboration and seeks to bolster the self-sustainability of the existing supply chain through partnerships within the EU.

7.2.3 Project 3: Best value for end-users – from fab to app

Goal: Development & application of quantum algorithms and procedures/methods to optimise the execution of quantum algorithms.

We will focus on two main activities: developing and applying algorithms to use cases in areas where we excel and creating tools and methods to support the development and implementation of quantum algorithms and applications, mainly focusing on NISQ. Collaborating with leading players like the Quantum Application Lab and academic institutes such as aQa and QuSoft, we aim to advance both fundamental and applied knowledge in optimisation and error mitigation techniques. Integrating these tools into existing devices is crucial to maximising their potential, with a strong emphasis on understanding end-user needs. The project will be executed through grants to consortia and the challenge-based programme, with a focus on practical use cases and enabling tools validated on real hardware. Leveraging international activities like EuroHPC, benchmarking and standardisation efforts will also be pursued through external funding sources.

7.2.4 Project 4: World class quantum computers for NL – demonstrating the Dutch approach.

Goal: Deliver fully functional quantum computers for the Netherlands, with enough computing power to run NISQ algorithms.

Here we aim to build ambitious demonstrators to support the goals of projects 2.1, 2.2 and 2.3. However, it's not yet clear what technology or the full costs needed to achieve this are. This project seeks to provide grants for creating full-stack quantum computers in relevant environments, with specific focus on the SURF facility recently granted by the EU. The exact specifications will depend on technological progress, funding availability and end-user needs, which will be determined during the project. It involves defining top-level requirements, evaluating existing systems and integrating them for end-users. The project also aims to maximise synergy with European initiatives like EuroHPC, with activities supervised by the CAT-1 lead and an external advisory board.

7.3 CAT-2: National Quantum Network

7.3.1 Project 1: Build the NL National Quantum Staging Network

Goal: Establish a nationwide operable Quantum Staging Network primarily utilising Quantum Key Distribution.

We will roll out a "National Quantum Staging Network" (NatQCI) in the Netherlands, with a dedicated activity for the translation to the market and onboarding end-users. This network will enable secure data exchange among governments, institutes, vital industries and businesses, fostering the development and testing of new use cases while validating overall crypto agility. This enables the Netherlands to gain operational experience in operating a nationwide quantum network, positioning itself as a key player in Europe and opening commercial opportunities abroad. The network will also strengthen the national supply chain.

The NatQCI will be a new legal entity responsible for the network's roll-out, maintenance, support and financial sustainability. It will be jointly founded by multiple stakeholders within the existing ecosystem, including telecom fiber operators, network providers and data exchange providers. Initially, the network will connect Utrecht, Amsterdam, Delft/Den Haag and Eindhoven, strategically chosen for their concentration of Quantum Technology developments and existing digital infrastructure. While cross-border connectivity is not initially in scope, the initiative prepares the Netherlands to become a significant quantum network hub within the EU. Funding sources include in-kind contributions from founders, end-user and industry participation, and future initiatives from the European Commission in scope of EuroQCI.

7.3.2 Project 2: Accelerate the next generation Quantum (Internet) Network Developments

Goal: Strengthen the Dutch supply chain for critical components for a full-stack quantum internet and photonically integrated quantum devices.

Advancing next-generation quantum communication technology is pivotal for the development of a global quantum internet. Our project is strategically divided into two distinct work packages, each dedicated to crafting essential components (hardware and software) for a comprehensive quantum internet framework and the seamless integration of photonic quantum devices.

Critical Components for a Full-Stack Quantum Internet aims to develop the necessary hardware and software layers for a quantum internet, integrating them into a testbed network. Activities include scalable qubit hardware development, network timing synchronisation, control protocols and an application stack. A quantum domain controller will orchestrate network services, representing a pioneering achievement in the field. The goal is to accelerate the development of entanglement-based quantum networks, building on Europe's leadership position in quantum communication technology.

Photonically Integrated Quantum Devices focuses on reducing the footprint of quantum communication technology by leveraging integrated photonics technology. Collaboration with Dutch integrated photonics ecosystem partners and international collaborators like IMEC aims to scale quantum repeaters and improve their performance. Success will generate new start-ups and contribute to the EU Chips Act's goals of increasing manufacturing capacities for advanced chips in the EU.

The investments in these initiatives will enable both established entities and start-ups to confront scientific challenges with a clear path to market. Upon completion of phase 3, selected stakeholders will operate autonomously, leveraging revenue streams from additional funding sources and customer engagements

7.3.3 Project 3: Productise Quantum Communication Technology

Goal: Foster a sustainable market for quantum communication technology.

Here, our focus is on attracting industry and end-users through the development of use cases and stimulating industry participation. Our aim is to enhance the commercial appeal of quantum communication networks by developing new use cases for diverse applications. This includes exploring how quantum communication can integrate with existing digital infrastructure, advancing Quantum Position Verification (QPV) technology and piloting new industrial applications in collaboration with commercial end-users. By diversifying beyond security applications, we seek to expand the market potential.

We intend to establish a new industry platform for quantum communication technology, engaging leading digital infrastructure suppliers and operators to facilitate knowledge exchange and awareness. This initiative aims to encourage the adoption of quantum communication technology by existing IT and telecom suppliers, internet and telecom providers and other relevant stakeholders. The industry platform will be financially supported by participating entities, with a possible transition to subscription models for long-term sustainability. Collaboration will extend globally with like-minded nations, as use cases developed in the Netherlands have the potential for international adoption.

Goal: Actively develop Quantum Communication standards.

Developing and deploying Quantum Communication technology on an international level requires standardised devices, components and interfaces, thereby increasing modularity, interoperability, and market accessibility. By establishing common ground in quantum communication technology, these standards accelerate productisation and commercialisation while safeguarding Europe's technological leadership position and foster integration with the existing telecom standards.

7.4 CAT-3: Quantum Sensing Applications

7.4.1 Project 1: Testbed Facilities

Goal: Provide accessible infrastructure and expertise to the industries.

Our strategy recognises the diverse strengths of various quantum sensing technologies, each excelling in different domains. To address this, we have developed a comprehensive programme that emphasizes multiple technologies, based on the NL strengths. Within our testbed facilities, we focus on advancing Quantum Sensing systems with high TRLs, offering accessible infrastructure and expertise tailored for Dutch industries. These testbeds not only foster collaborations but also serve to identify impactful use cases and drive societal and economic progress. Looking ahead to phase 3, we will further advance technological readiness and ensure the self-sustainability of our testbeds beyond 2028.

The Ultracold Atom Quantum Sensing Testbed collaborates with Dutch and EU partners to develop atomic clocks and inertial sensors, aimed at practical societal applications. The testbed focuses on developing robust industrial components and prototypes for these sensors, together with partners like Quix Quantum and Menlo Systems.

Additionally, it supports the Time and Frequency Application Line (see Project 2), paving the way for novel products and highly skilled quantum engineers. Throughout its phases, the testbed aims to produce prototypes, demonstrate innovative schemes, and foster partnerships to advance ultracold atom quantum sensing technologies.

The Mechanical Sensors Testbed aims to create a facility where sensor developers can collaborate and benchmark novel mechanical sensing solutions against existing technologies in various controlled environments, together with industry. By leveraging advancements in quantum optomechanics, the testbed intends to develop high-resolution and high-sensitivity sensors for next-generation applications, particularly in fields like navigation, security, process control and medicine.

The Diamond Sensors Testbed aims to accelerate the industrialisation of quantum sensors utilising color centers in diamonds, particularly NV centers. The testbed, situated in TNO, serves as an open facility housing NV-based sensing instruments, developed by TNO or in collaboration with TU Delft, alongside commercially available options. Beyond technology development, this testbed focuses on demonstrating the capabilities of NV-based sensors by scouting potential use cases, conducting technology demonstrations and engaging with national and international users.

In phase 3, all testbeds aim to attract additional funding from industrial collaborations, user fees, business development, IP exploitation and from EU projects, thereby gaining independence from QDNL funding.

7.4.2 Project 2: Applications of quantum sensing

Goal: Develop practical applications of quantum sensing within specific industries.

The application project serves as a challenge-based programme in CAT-3. Bridging the gap between cutting-edge quantum R&D and real-world challenges, this challenge-based project encourages collaboration among stakeholders, including industry experts, end-users, government agencies and academic researchers. The process involves three phases: market engagement, problem identification and a challenge call, using the challenge programme that will be implemented in phase 3. The goal for 2028 is to establish at least five application areas, covering defense, metrology, semicon, space and healthcare industries.

One example is the Time and Frequency application line at UvA, of which an academic setup is shown below. Key objectives include building a reliable National Quantum Clock by 2027, distributing time and frequency signals to multiple nodes, educating users about the benefits and transitioning maintenance and marketing responsibilities to designated entities post-2027.

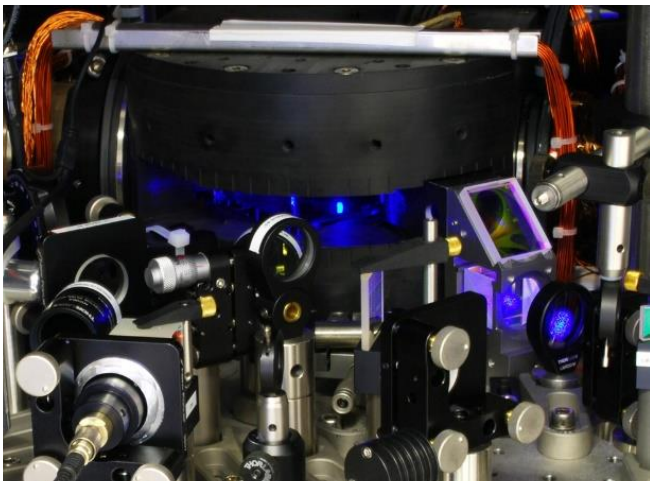

Figure 9. The Time and Frequency Application Line aims to significantly enhance time and frequency references across the Netherlands by providing access to a cutting-edge optical clock via telecom fibers. This advancement eliminates the vulnerability of current timing signals from navigation satellites, offering improved reliability for telecom networks and enabling new services like precise terrestrial navigation and geodetic levelling. Researchers also benefit from longer coherence times in quantum computers and enhanced precision spectroscopy.

7.5 AL-1: Research and Innovation

7.5.1 Project 1: NWO calls for proposals.

Goal: Create new research positions in the quantum field and nurture strong talent in the Netherlands.

NWO will conduct thematic, open calls for proposals allowing for exploring various directions, as many fundamental breakthroughs remain needed in quantum technology development. This call will resemble previous AL-1 calls, allowing applications for PhD and PD positions with a standard runtime of 4 years. However, it will be thematically focused on the three CATs. The themes will be determined by the AL-1 committee, CAT leads and the scientific lead of the QDNL board. We aim for calls with a about 40% granting percentage, aiming to create new PhD and postdoc positions in quantum technologies, attracting talent nationally and internationally, enhancing the Netherlands' scientific impact position in QT and providing a fundamental scientific basis for CATs. NWO will manage these calls in collaboration with the AL-1 programme committee.

7.5.2 Project 2: International calls - QuantERA.

Goal: Stimulating international collaboration on QT, fostering long-term scientific relationships, tech transfer acceleration.

Supporting QuantERA calls is a priority for us. The QuantERA programme plays a crucial role in integrating the Dutch ecosystem into the European QT landscape. Collaboration with other EU countries through these calls has proven invaluable, fostering enduring connections beyond initial projects.
The QuantERA programme, led by NCN Poland, involves QDNL in handling Dutch submissions and participating in the Steering Committee that decides on project grants. QDNL will host the QuantERA midterm meeting in September 2024, strengthening international connections and introducing European colleagues to our established quantum ecosystem. The next QuantERA calls are scheduled for 2025 and 2027. Our ambition is to have three projects involving Dutch partners granted at each call. The QuantERA call 2025 offers co-funding support from the European Commission, making it more appealing.

7.6 AL-2: Quantum Business Ecosystem

7.6.1 Start-up development

Goal: Grow the number and value of quantum start-ups in the NL ecosystem.

Our start-up programme will be developed together with the hubs, where different kinds of professional support are offered. We will focus on the following pillars:

1. Enrich the founder-focused quantum start-up support programme. A community-driven model supported by expert guidance, online tools and industry insights.
2. Build and engage the curated and international network of investors, key player and companies essential to building the quantum industry and positioning The Netherlands as a global player.
3. Promote entrepreneurship.

In phase 3, we will invest in the following activities:

- QDNL will add to the existing expertise in the hubs the right tools, analyse the right insights and engage the right people.

- QDNL will offer data collection, analysis and insights. These insights and tools are inputs for the start-up programme and are also used by founders to discover commercial and investment opportunities, by the community to engage and by new players to become active.
- Facilitating the right players engaging at the right time and in the right way builds the collaborations and connections the quantum industry needs.

7.6.2 Quantum Manufacturing Alliance (QMA)

Goal: Creation of a manufacturing ecosystem that is ready for scaling.

Improve industrialisation in NL through the Quantum Manufacturing Alliance (QMA). QMA is an initiative to enable quantum companies in the Netherlands to access existing expertise in quantum, high-tech systems, semicon, photonics and micro/nano technologies and manufacturing and vice versa. The aim is to increase industrialisation quality, speed and ease, and thus decrease costs, through an open, wall-less manufacturing ecosystem.
Activities in phase 3 are:

- Stakeholders in quantum and enabling technologies are approached to create a knowledge base of relevant Dutch capabilities; rules of collaboration will be standardised; and a legal framework will be created. All set up to best serve the Dutch quantum ecosystem and to collaboratively sell industrialization services worldwide. This will magnify the potential results, as significant national value can be created also from technologies that are commercialized elsewhere in the world.

7.6.3 Quantum for Business (Q4B)

Goal: Engage end-users and encourage their involvement in the quantum technology ecosystem.

The overarching aim of Q4B's activities is to engage end-users and encourage their involvement in the quantum technology ecosystem. Q4B’s goal is to facilitate the adoption and utilisation of quantum technologies by end-users across different sectors by providing them with access to resources, knowledge and support, thereby fostering innovation and driving economic growth.

Activities in phase 3 are:

1. Through regular updates, courses, events, and community building (live and online), Q4B will connect the companies, universities, TLCs and knowledge institutions that develop (new) quantum technologies with the target audience.
2. Promoting quantum technologies via Massive Open Online Courses, information sessions, workshops and at events to attract end-users from different sectors to get acquainted with quantum.
3. Establish a repository of quantum use cases across various industries to showcase the practical applications and benefits of quantum technologies for end-users. This objective aims to provide valuable insights and resources that will inform decision-making and promote the adoption of quantum solutions among target audiences. Support setting up a CRM system for the Dutch quantum ecosystem.
4. Improve industrialisation in the Netherlands through the QMA. The aim is to increase industrialisation quality, speed and ease, and thus decrease costs, through an open, wall-less manufacturing ecosystem. Stakeholders in quantum and enabling technologies are approached to create a knowledge base of relevant Dutch capabilities; rules of collaboration will be standardised; and a legal framework will be created. All set up to best serve the Dutch quantum ecosystem and to collaboratively sell industrialisation services worldwide. This will magnify the potential results, as significant national value can be created also from technologies that are commercialized elsewhere in the world.

7.6.4 IP Strategy

Goal: Enhance IP tech transfer and IP creation at a strategic national level.

The aim is to bring together the know-how and the IP of the knowledge institutions on the national ecosystem level to take decisions on IP exploitation from the national ecosystem perspective. The knowledge institutions are responsible for the actual IP exploitation since they are the owners of the IP. Jointly we are responsible for making the right decisions on an ecosystem level so that the IP can be exploited in the best manner. This means:

- Getting much more invention disclosures out of the research labs of the knowledge institutions. QDNL will focus on increasing IP awareness (courses) and supporting IP creation where needed, especially in the field of technologies which typically have less IP creation and exploitation rates, like, e.g., quantum software.
- Supporting and monitoring quantum technology developments and roadmaps of the three CATs from an IP perspective. A strategic IP overview at CAT programme level can be built for the whole ecosystem.
- Knowledge institutions sometimes must take actions that they would not necessarily have initiated themselves, e.g., submitting patent applications on topics they don't feel fitting their own valorisation goals or maintaining pending patent applications or granted patents for national strategic reasons. QDNL will facilitate this process as much as possible.
- Providing continued IP and exploitation guidance to the ecosystem via the IP team and the IP council.
- Keeping track of the IP landscape and discussing strategies with the IP council.

7.6.5 SME Scale-up Procurement Programme

Goal: A strategic initiative aimed at accelerating the progress of start-ups and companies.

The SME Scale-up Procurement Programme is part of our Forward instrument and will focus on scale-up and procurement. For this, we will redesign the previous SME call and Field Labs as a top-down, call-based funding initiative, following the strategic priorities of QDNL. It will support ambitious projects in phase with end-user and customer demand. Through grants tailored to accelerate proof-of-concept development, the programme empowers entrepreneurs to translate innovative ideas into market-ready solutions, thereby driving economic growth and competitiveness. This programme is also partly merged with the trilateral call. This funding will support projects that demonstrate potential for significant technological advancement, supply chain integration and economic impact.

Figure 10. Winners of the second SME call grant.

7.6.6 House of Quantum & Campus Development

Goal: House of Quantum will focus on creating a valuable membership for its existing and growing community.

The House of Quantum concept aims to create the visible 'look and feel' of our hubs and of the physical meet & work place of QDNL's community. All the real-estate facilities that have been or will be developed with support of

QDNL, will be part of the House of Quantum offering. Within the next phase, House of Quantum will focus on creating a valuable membership for its existing and growing community, while also developing a strong brand and presence throughout the Netherlands and internationally. We will:

1. Enhance existing hubs, through brand-wide events, support and collaborative initiatives, as well as facilitate an interconnected network between existing workspaces and facilities for quantum technology. Our focus is to foster a thriving community as a layer on top of these existing spaces and facilities, creating a cross-hub environment.
2. Attract international companies as residents to set up shop in NL. The House of Quantum concept is unique and resonates internationally and contributes to the overall goal to build the most attractive business ecosystem in the world. Part of the activities in phase 3, is to heighten the House of Quantum experience for members, with the goal of attracting and retaining top quantum companies in the Netherlands. We will scout new partners strategically, together with the NFIA and the Q3T.
3. Extend the House of Quantum concept to all the hubs in NL and in other countries, starting with France and Germany. By doing so, we will lay the groundwork for the continuation of House of Quantum as a commercial entity in the future, after the end of the QDNL programme.

7.6.7 Quantum Tech Transfer Team (Q3T)

Goal: Accelerate the creation and growth of quantum business in NL.

Within the 5 hubs of QDNL, about 10 to 15 scouts and business developers have been appointed to drive building a business ecosystem in the hub. These are funded 50% locally and 50% from QDNL, with the intention of strengthening the wall-less character of the national ecosystem. QDNL brings these people together in the so-called Quantum Tech Transfer Team, or Q3T. The team's purpose is as follows: "Q3T accelerates the creation and growth of quantum business for the Netherlands via partnerships and tech transfer."

The Q3T is chaired by the lead of AL-2 and consists of 4 smaller sub-teams: (1) Spinoffs, start-ups & scaleups, (2) tech-industry & end-users, (3) IP team and (4) international leads. The sub-teams meet frequently to work on concrete leads, to launch joint projects and to share best practices and policy developments. This project will be connected to the new lead for user-engagement and industry participation.

7.6.8 Hub support

Goal: The 5 QDNL Hubs shape the National Quantum Campus.

Together, the 5 QDNL Hubs (Delft, Eindhoven, Leiden, Twente and Amsterdam) shape the National Quantum Campus. For turning the hubs into 5 vibrant communities, QDNL supports the hubs on a 50/50 basis for the following activities:

- Business development (with the purpose of valorising QT, linked to Q3T).
- Community building (with the purpose of creating an attractive (national) campus).
- Community events (with the purpose of creating an attractive (national) campus).
- Visits to international events (with the purpose of internationally positioning QDNL).

This activity is a continuation of the team that has already been built in phases 1 and 2. In other words, all people are in place and the Q3T and hub teams have turned into "performing" teams.

7.7 AL-3: Human Capital

7.7.1 Project 1: Talent & Learning Centers

Goal: Quantum Technology TLCs should facilitate and provide education and training of a workforce towards the commercialisation and fabrication of quantum technology.

In phase 3, emphasis lies on maturing established TLCs, fostering national and international collaborations, and particular attention will be devoted to skills development in quantum device fabrication, integration and operation. Part of this project is establishing five Quantum Educational and Development Labs, aimed at students from applied universities (HBO) and vocational schools (MBO), and providing training for their lecturers, ideally tailored to local contexts (e.g., integrating with photonics in Eindhoven). Additionally, efforts will focus on forming a national TLC network, developing a digital learning platform and organising outreach events and industry-student meetups.

7.7.2 Project 2: Quantum for the youngest generation (<18 years)

Goal: Interest pupils of all levels of education in quantum technology and inspire them to pursue STEM-oriented profiles.

Central to this project is enabling pupils at all levels of education to learn about quantum technology, while also supporting their teachers pedagogically, by creating an extensive, well-embedded educational framework. Our high-level aim is to encourage more students to choose a STEM-oriented profile, motivated by numerous studies indicating that early-age exposure to technology significantly contributes to this choice. The key vehicle for this initiative is the creation of a national network of Qlabs (Qlab-NL), regional laboratories offering and coordinating material and activities on quantum science and technology for secondary and primary school students. In the past few years, Qlabs have been established at each of the five participating hubs. In phase 3, the ambition is to professionalise these activities, seek further collaboration and integration with the TLCs, establish ‘Qlab-NL’ and expand outreach to all levels of secondary education.

7.7.3 Project 3: Quantum technology training for professionals and fostering entrepreneurship

Goal: Develop and provide tailored training in quantum technology for professionals in both the public and private sectors.

As quantum technology becomes increasingly integrated into organisations, ‘reskilling’ and ‘upskilling’ the current workforce is crucial to ensure they effectively navigate and leverage this rapidly evolving field. The TLCs will serve as the primary centres for coordinating and organising these activities. Additionally, in close collaboration with AL-2, project 3 aims to foster entrepreneurship among students through training and education.

7.7.4 Project 4: Internationalisation

Goal: Attract international top talent to the Dutch quantum technology ecosystem.

The Top Talent Initiative was part of the original growth fund proposal and started in 2022. It will be continued as planned. A new goal of this initiative in phase 3 is to offer (co-funded) QDNL scholarships for talented international master students in the master programmes on quantum science and technology in the hubs.

7.7.5 Project 5: Top Talent Initiative & Visitor’s programme

Goal: Attract international top talent to the Dutch quantum technology ecosystem.

The Top Talent initiative was part of the original growth fund proposal and has started in 2022. It will be continued as planned. A new goal of this initiative in phase 3 is to offer (co-funded) QDNL scholarships for talented international master students in the master programmes on quantum science and technology in the hubs.

To further broaden the international appeal of QDNL, we established the Visitor’s programme. This consists of offering sabbatical stays and supporting exchange visits for PhD students, postdocs and other stakeholders across the QDNL network. Also, contributions to workshops and (summer) schools can be applied for. In phase 3, (part of) this programme will be used for targeted calls aimed at filling specific gaps of talent or expertise in the national quantum ecosystem (with specific focus on the CATs and national industry).

7.8 AL-4: Societal Impact

7.8.1 Project 1: Awareness & Communities

Goal: Grow and interact with our communities and create more awareness about quantum technologies in society

We will organise public dialogue sessions, community events, a 2nd Quantum & Society Gala, as well as the first international conference on the societal impact of quantum technologies towards the end of the programme. One example is the Awareness Challenge, where we aim to combine Quantum & Arts to educate the public on quantum phenomena and open a dialogue with the public in the transition towards desirable quantum technologies and applications for society.

7.8.2 Project 2: Quantum for Good beyond borders

Goal: Reach out internationally and make available the societal, educational, end-user and foresight tools developed by the CQS through international collaboration.

This is an integral part of the mission; without this quality, we cannot achieve a balanced interest and deployment of quantum technology. Next to that, the Centre will focus on large societal challenges, like the Societal Development Goals, to create a Quantum-for-Good Competition, building on the experience on the topic of the energy transition. With respect to EU, we see fast-growing interest in policy-making circles across Europe in the way quantum is developed and how it impacts society. With the CQS and its activities, QDNL is widely recognised as a front runner.

7.8.3 Project 3: End-User Engagement

Goal: Support end-user activities in the CATs from a societal perspective.

We also aim to support the end-user activities in the CATs in contribution to the overarching vision on end-user engagement. Our approach involves leveraging expertise from a societal perspective. We will connect to end-users through their participation in awareness campaigns, as part of Quantum-for-Good activities, or as partners in research exploration and research projects, for instance via the sensing testbeds in CAT-3. Through this approach, we aim to gain more insight into the societal boundary conditions that must be considered before implementing applications in an ethically and socially responsible manner, while meeting any legal requirements.

7.8.4 Project 4: Responsible Innovation and Tool development

Goal: Further develop our toolbox with tools to assess the impact of quantum technologies.

We will further expand the EQTA capabilities (Exploratory Quantum Technology Assessment) tool and develop at least two new tools, a “quantum technologies card set” and our foresight capabilities. EQTA is one of the world's first tools that allow organisations and businesses to look at the impact of quantum technologies by considering legal, ethical and societal aspects. The foresight capabilities have gained momentum recently, as organisations struggle with the uncertain timing of quantum possibilities and the anticipated impact. The CQS will coordinate these activities.

7.8.5 Project 5: Research Excellence & Thought Leadership

Goal: Conduct world-leading research on the societal impact of quantum technologies.

With the Quantum & Society programme a bold step was taken to bring together experts in the fields of ethics, law, governance and science communication around the common topic of societal impact of quantum technologies. QDNL is the only national programme in the world committing a dedicated budget to this. In phase 3, we will continue our world-leading research in these fields. Importantly, roughly 20% of the total research time available in this project is dedicated to other activities and projects within QDNL.

7.9 NanoLab NL

7.9.1 Project 1: Reinvestment in Basic Nano Fabrication Infrastructure: Ensuring State-of-the-Art Equipment

Goal: Reinvest in the basic nano fabrication infrastructure, encompassing various essential items crucial for maintaining cutting-edge equipment.

This initiative is born out of the necessity to keep our nano fabrication facilities at the forefront of technological advancements, ensuring that researchers and innovators have access to state-of-the-art tools and capabilities.

The timeline for this reinvestment initiative sets an ambitious target: all identified equipment should be installed and operational by the year 2028. The deliverables, therefore, include the successful installation, calibration and integration of advanced nano fabrication machinery.

7.9.2 Project 2: Impulse Investments in High-TRL Equipment: Advancing Predictability and Manufacturability

Goal: The primary objective of this proposal is to make impulse investments in high-TRL (Technology Readiness Level) equipment, strategically chosen to complement the expert functions of the NanoLab at the 3 Technical Universities (3 TU's).

The investment in cutting-edge equipment is driven by the overarching goal of enhancing predictability and manufacturability in nanotechnology and in particular to serving the quantum agenda.

The proposed timeline for this initiative is to have all identified equipment installed and operational by the year 2028. The deliverables encompass the successful integration of state-of-the-art equipment within the NanoLab facilities at the 3 TU's, ensuring that researchers and industry partners have access to the latest technologies. To oversee the effective implementation and maintenance of the high-TRL equipment, the same governance applies as with the 'basic investments'. Also, the same model for sustainability beyond 2028 applies.

Vouchers

Goal: Stimulate the use of NanoLabs and promote the establishment of spin-off companies.

The "From Voucher to Start-up" initiative is designed to facilitate SME companies and aspiring entrepreneurs in leveraging the resources of NanoLabs to kickstart their innovative projects. The primary goal is to stimulate the use of NanoLabs and promote the establishment of spin-off companies, aligning with the broader quantum agenda.

The voucher programme serves as a catalyst, providing SMEs and entrepreneurs access to NanoLab facilities with each voucher valued at 10K€. With an annual budget of 100K€, which allows the project to offer 10 vouchers per year, the programme is set to run until the end of 2028. Its potential continuation beyond this date is highly likely, contingent on the success it achieves within NanoLab's diverse range of programmes.

By offering financial support and access to cutting-edge nanotechnology infrastructure, the initiative not only fosters a culture of innovation but also contributes to the realisation of quantum-related objectives. International cooperation is not an immediate objective of the voucher programme, but it could help to incentivize foreign companies to join the quantum ecosystem. Co-funding is not applicable in this case.

7.10 Cleanroom Delft

TU Delft and TNO have joined forces to jointly develop a new cleanroom on Campus South. This facility fits into the broader development of Campus South, which also includes the new QuTech building and a TNO facility. The cleanroom is for a wide range of stakeholders, ranging from students, research groups to companies. There are two distinct zones in the new Cleanroom Delft: Campus Baseline Lab (CBL) and Thematic Lab (TL). These areas each have their own governance to ensure that stakeholders have access to the right infrastructure for the right application.

- **Baseline Lab (BL)**
  A micro-, nano- and quantum-technology cleanroom facility for lower TRL research and manufacturing up to TRL levels 0-6. The primary base is a generic Campus Baseline Cleanroom facility with state-of-the-art technology facilities for fabricating a wide range of functional micro and nanostructures.
- **Theme Lab (TL)**
  The cleanroom also houses theme labs in which users from TNO, TU Delft and start-ups, among others, conduct specific research at TRL levels 0 to 6, but in a closed environment with state-of-the-art infrastructure. Stakeholders who cannot share equipment because of the specific applications of that equipment can use TL and set up their own space. An example of this is the TNO laboratories for activities in quantum and nanofabrication to realise demonstrators and small-series production. Again, it is important to further explore how these activities connect to the foreseen pilot lines.

7.11 Standardisation

In phase 3, we will accelerate the following activities or initiate new ones:

CAT-1: Continue the work which is now done in JTC-22.

- Subdividing quantum computing systems into layers with well-defined interfaces and functional descriptions and requirements, accounting for different hardware architectures.
- Specification of requirements and functionalities of hardware and software modules that may fit within a layer or may even cover the full layer or multiple layers.
- Specification of interfaces, interoperability and integration testing of modules and systems from different suppliers, prepare a path to interoperability “plugfests” and certification.
- Benchmarking and hybridisation.
- A vision and solutions towards 10,000+ qubit systems and how to handle such a high volume of interconnections.

CAT-2: Create overview and start interacting.

- Network technology is standardised in different global standardisation bodies, like IEEE, ITU, ETSI, IETF, CEN-CENELEC and more. In the first phase we will create an overview of the quantum network activities in these bodies, and we will define a strategy how to act in the benefit of the quantum communication ecosystem.
- Based on this first phase, we wil further decide on the follow up activities. But depending on the maturity and the strategic link with the existing Digital (Internet) Infrastructure.
- Define and execute a strategy to take a leading position in this domain, to accelerate the quantum communication leadership from the Netherlands. Also, in potential cooperation with NLNET Labs and RIPE NCC.

CAT-3: Follow the activities and in this domain and see how can connect:

- CAT-3 is participating in one of the NEN-NOQT events and there is synchronisation with the Dutch Metrology institute VSL.
- Analysis is needed to understand who the relevant quantum sensing players in the Dutch ecosystem are, as well as coordination with and between them related to standardisation.
- We have allocated budget to do this analysis, and to deploy different activities around quantum sensing standardisation activities, which will focus probably on measurement, metrology and interface standardisation.

Budget: standardisation activities are budgeted within the CAT budgets.

7.12 Chips Act

In phase 3, QDNL will participate in the European Chips Act programme, which has a modest but very important, quantum-related aspect. QDNL has created a national strategy prioritising technologies and focusing on creating broad consortia with public and private partners. On December 1, it was officially announced that the Chips JU Public Authorities Board has approved funding for the quantum pilot lines P4Q, Spins, and SUPREME—marking a major milestone for the 19 Dutch partners involved and a significant advancement for the Dutch quantum ecosystem. The €20 million national investment, including €12 million contributed by QDNL, will unlock an additional €20 million in EU co-funding, further amplifying our collective impact.

During this pre-phase the goal is to accelerate the development of industrial grade process technologies for quantum devices. We expect that the activities in the pilot lines will be on the stabilisation and yield improvement of the most mature process technologies and key chip components. The strategic focus is on three main areas, where we have a strong position and are able to take leadership in Europe:

- **Photonics for Quantum (P4Q)**
  Key technologies for photonic quantum computing, including low-loss waveguide and modulator technology in SiN and AlOx, photon source technology based on four-wave mixing, quantum dot source-waveguide integration using hetero-integration technology and testing of photonic integrated circuits to address neutral atoms and colour centres in diamond. These technologies are key for both quantum computing (CAT-1) and communication (CAT-2).
- **Superconducting quantum devices (SUPREME)**
  Key technologies for fabricating transmon-based quantum processor units, nanowire single photon detection and transduction from MW to optical. This will be augmented by hetero-integration, for example with rapid single flux quantum devices coming from EU partners. The focus here is on quantum computing, as well as on key chip technology allowing linkage to quantum internet via hybrid superconducting-optical devices.
- **Semiconducting technology for qubits (Spins)**

Based on single-electron tunnelling. The focus here is on moving the key concepts and technologies developed out of the lab, by leveraging the state-of-the-art process technology and infrastructure with partners. The application focus is on quantum computing.

In addition, hetero-integration technologies will need to be developed, as well as in-line testing methodologies. This also requires additional funding in a later stage.

7.13 QDNL Core Team

The QDNL core team has a central place in the execution of the programme. The MTR committee noted about the core team: "The dedication and expertise of the staff are crucial for meeting the project's goals. Additionally, the Committee values the innovative and dynamic culture at QDNL, reflected in its organisation and physical space, which contributes to its distinct brand."

The core team consists of approximately 30 people with various tasks and roles (e.g., HR, finance, communication, coordination of action and programme lines, IP policy, international cooperation, ICT, events). People are hired (on secondment or otherwise) or are employed by the foundation. The team has its office in the House of Quantum in Delft and meets weekly, chaired by the QDNL board. Our team includes seven nationalities.

8 Budget

Overall budget

TOTAL QDNL	Phase 3	NWO + Nanolab[23]	Total
AL-1	2.971	10.850	13.821
AL-2	20.570	-	20.570
AL-3	15.300	-	15.300
AL-4	6.750	-	6.750
CAT-1	48.895	-	48.895
CAT-2	48.565	-	48.565
CAT-3	17.360	-	17.360
NanoLabNL	-	70.000	70.000
Cleanroom Delft	35.000		35.000
Strategic budget	9.848	-	9.848
Programme Office	17.058	-	17.058
Total	**222.407**	**80.850**	**303.257**

Table 5. The overall budget of QDNL for phase 3, in €1000.

[23] NWO and NanolabNL request their budget directly to RVO.

9 KPIs

As mentioned before, phase 3 comes with a sharpened focus on building a strong and sustainable quantum industry in the Netherlands. To ensure our efforts are aligned with this goal, we have introduced a renewed set of KPIs that reflect this focus.

The KPIs are directly derived from our objectives and complemented by our rephrased long-term vision (see chapter 2.4). They are designed to be measured in a standardised way, with clear, consitent monitoring, providing a concrete instrument to track progress and to identify where additional focus is needed.

To ensure that the KPI framework fully supports the strategic direction of phase 3, including the themes of commercialisation, internationalisation, fabrication, and technology acceleration, the KPIs are grouped into eight categories:

- Economic value
- Entrepreneurship
- Industry
- Facilities
- International
- R&D
- Society
- Talent

Topic	definition	2025	2028 (phase 3)
Economic Value			
Quantum-related jobs	Cumulative number of quantum-related job in the Dutch ecosystem, including startups, scale-ups, industry, fundamental and applied research	800	3500
Control points	The KPI cannot yet be defined as a single numerical metric. Instead, it will be presented as a narrative approach while continuation to explore its definition in collaboration with TNO and NXTGEN Hightech		
Entrepreneurship			
Startup Investment	Cumulative private investment in startups and scale-ups (all start-ups that have reached series A funding) founded or headquartered in the Netherlands	106M	732M
Startups	Cumulative number of quantum tech start-ups based in the Netherlands	40	100
Industry			
Industry involvement	Annual number of companies in the Netherlands executing quantum-related activities in R&D, fabrication, and development (excluding quantum startups)	30	60

Topic	definition	2025	2028 (phase 3)
Private co-funding	Annual share of (inter)national private co-funding in QDNL activities, derived from private entities and self-generated	0.1	0.25
End-user engagement	Annual number of end-users utilising products (incl. software), services or infrastructure developed through QDNL activities aligned with its focus areas: quantum sensing, computing and communication	10	25
Facilities			
Shared infrastructure	Annual number of (quantum) companies utilising shared infrastructure	20	30
Pilot lines	Cumulative number of pilot lines	0	4
International			
International leads	Cumulative number of international quantum companies that have established operations in the Netherlands	7	30
Participation & leadership	Annual number of participations and leadership/coordinator positions held by Dutch entities in EU projects aligned with QDNL's focus areas: quantum sensing, computing and communication	55	60
R&D			
Scientific impact	Country rank based on highly cited publications based on 'ASPI technology tracker rankings', aligned with QDNL's focus areas: quantum sensing, computing and communication	7.7	7
Valorisation IP	Annual number of patents/patent applications (both QDNL and non-QDNL funded) that have been licensed or transferred to third parties	5	30
Society			
Social value	Annual number of unique participants of CQS activities (e.g. exhibitions, workshops, trainings, digital courses)	1000	2000
Talent			
Graduated student	Annual number of graduated students at wo, hbo and mbo level from quantum relevant educational programs recognised in The Netherlands	850	1400
Training	Cumulative number of unique persons that have received QDNL associated training to work as a professional in quantum sector	120	1000

Table 6. Detailed overview of the new set of KPIs.

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