White paper

High-tech industry in 2040

New challenges for achieving long-term earning power and impact for the Netherlands

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TNO innovation for life

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Preface
Towards a National High-Tech Strategy

The high-tech industry is vital to the Netherlands. The sector drives growth in the economy and is an innovator when it comes to our greatest societal challenges. High-tech is innovative and constantly evolving.

Around 2000, the sector focused mainly on consumer electronics, whereas now the emphasis is on equipment for the semiconductor industry. This transformation of the sector will accelerate in the coming years towards disruptive technologies such as AI, quantum, and photonics. The Dutch high-tech industry is positioning itself in these technologies, which will have an unprecedented impact on the global value chains in which they operate. An increasing need for strategic autonomy, the fragmentation of global markets, and transitions to sustainability will further accelerate the transformation.

Until around 2030, the Netherlands will be investing heavily in the transformation of the high-tech industry, especially through National Growth Fund programmes such as NXTGEN HIGHTECH, Quantum Delta NL, and PhotonDelta. But how do we ensure that Dutch high-tech continues to generate innovations that define the future, as well as economic growth and high-quality jobs beyond that point? This question was the basis for a study conducted by TNO in 2022 and the first half of 2023. We spoke to a wide range of experts, entrepreneurs, and policymakers. This paper stems from that research and presents a new vision of the high-tech industry for 2040. The key insight: in 2040, a successful Dutch high-tech industry will generate around 50% of its revenue from newly created value chains. The sector will also have to be 100% sustainable, 150% more productive, and significantly more resilient.

This presents the sector with challenges that require coordinated efforts from all stakeholders in the innovation and research ecosystems. We advocate drafting a National High-Tech Strategy that builds on the KIA Key Enabling Technologies and the National Technology Strategy. A consistent long-term agenda that creates the essential conditions for robust investments. TNO is committed to helping address these challenges for the Dutch high-tech sector. We invite high-tech companies, knowledge institutions, and the government to join forces in working towards a future-proof high-tech industry that will also be an example to the world in 2040. This paper aims to be a first step towards that goal.

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Managing Director TNO High Tech Industry

Chapter 1
Dutch high-tech

The high-tech industry is of great importance to the Netherlands. High-tech makes a significant and growing contribution to the Dutch economy, with 784,000 FTEs in 2021, or 10% of total employment in the Netherlands. Gross added value was estimated at 80.2 billion euro in 2021. While the share of the manufacturing industry in the Dutch economy has declined over the past 25 years, the share of the high-tech industry has actually increased.

The Dutch high-tech industry is R&D-intensive and characterised by the design and manufacture of complex products produced in small volumes. It often involves complex systems engineering and uses complex partnerships, value chains, and value networks.

The high-tech industry's products and services are used as inputs for the manufacturing of semiconductors, medical instruments, and data communications, among other things.

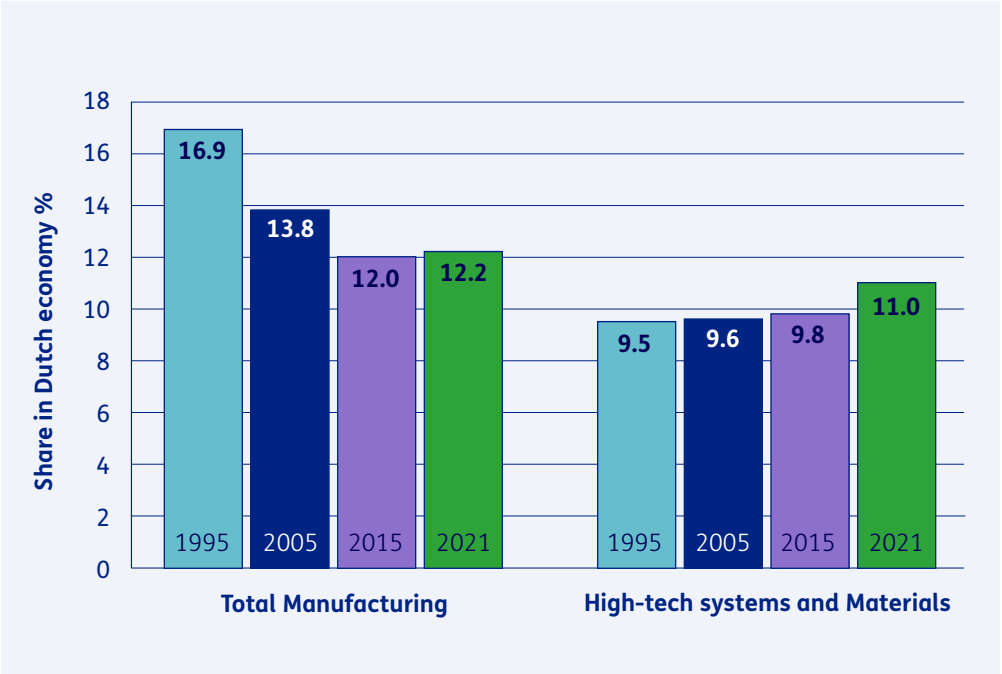
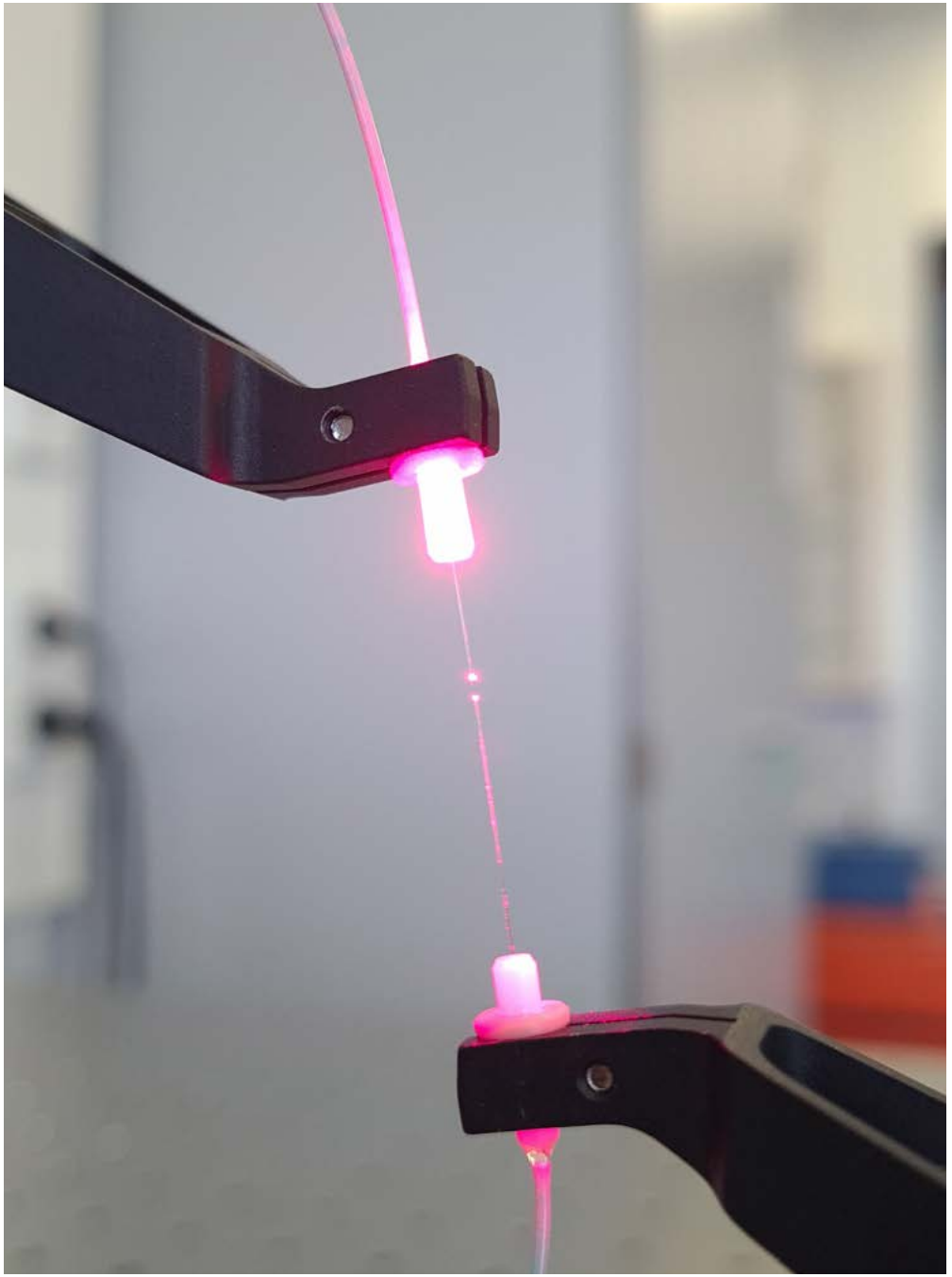


Figure 1. Share of the Dutch economy in terms of gross added value (Source: CBS, TNO calculations).

The three main subsectors within Dutch high-tech are:

- **Machinery**
  With companies such as ASML, ASMI, and BESI, the Netherlands is a world leader in the production of machinery used to manufacture chips and semiconductors. Other important activities within the Dutch machinery industry include making machinery for weighing, lifting, and handling, as well as for food processing and agricultural activities.
- **Electrical appliances**
  The electrical equipment industry produces a wide range of equipment and devices. In the Netherlands, the main activities include the production of lighting equipment; electrical household appliances; electric engines, generators, and transformers; electricity distribution and control equipment; and the production of electronic and electrical wires and cables. Companies in the industry include Signify, Philips Domestic Appliances, and Prodrive.
- **Computers, electronics & optics**
  Within the Dutch computer, electronic, and optical industries, the manufacture of instruments and devices for measuring, testing and navigation accounts for the largest share. Other important activities include the production of electronic components, capacitors, resistors, and microprocessors, as well as medical and electromedical equipment, and communication equipment. Companies include Philips, NXP, and Thermo Fisher Scientific.

Although most high-tech industry subsectors have grown in recent years, it is not the case that all have seen strong productivity growth (Figure 2). The machinery subsector in particular stands out, thanks to a strong rise in gross added value of 7.3% per year on average. At the same time, it showed one of the highest growth rates in labour productivity (4.8%), second only to electrical equipment (5%).



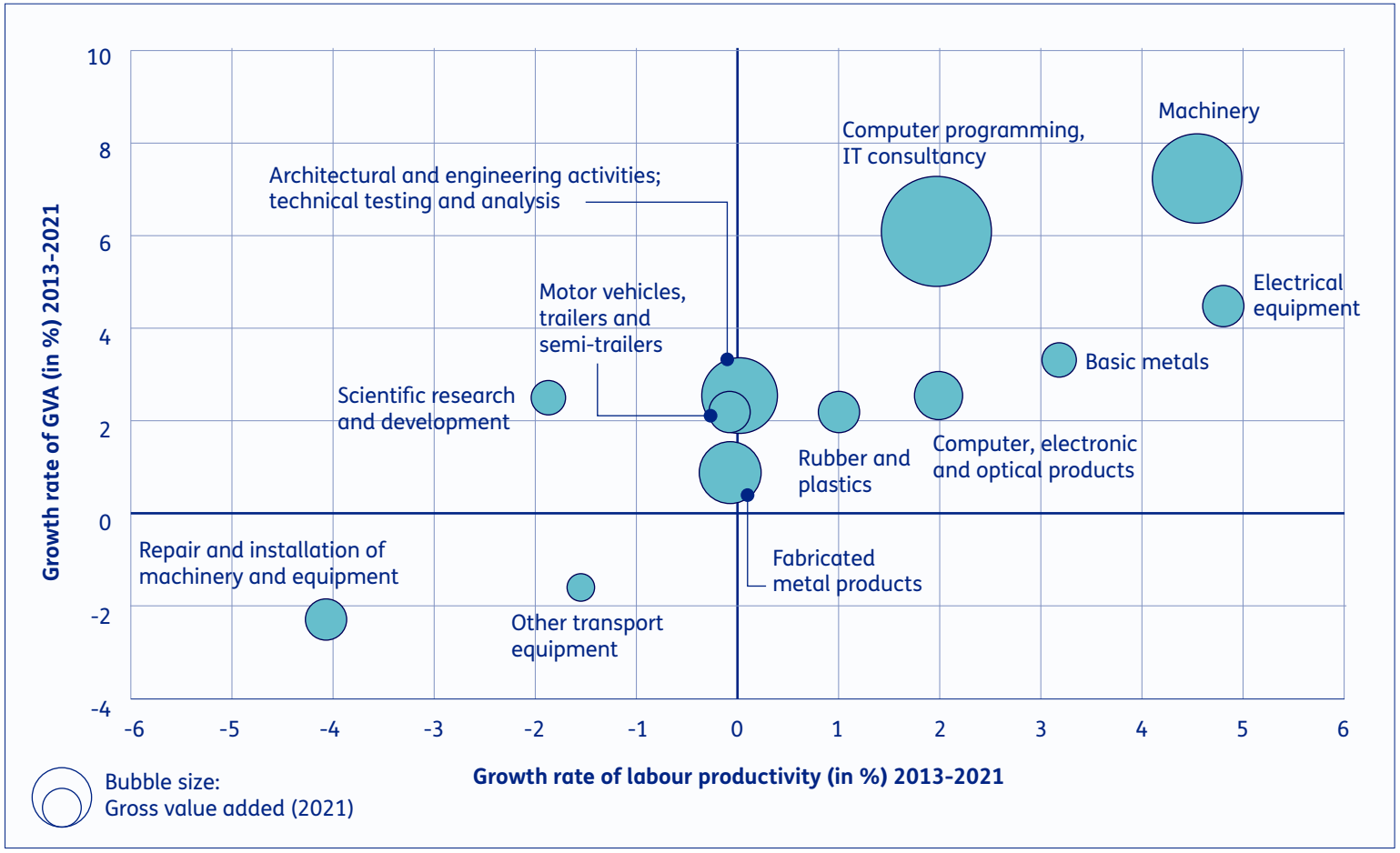


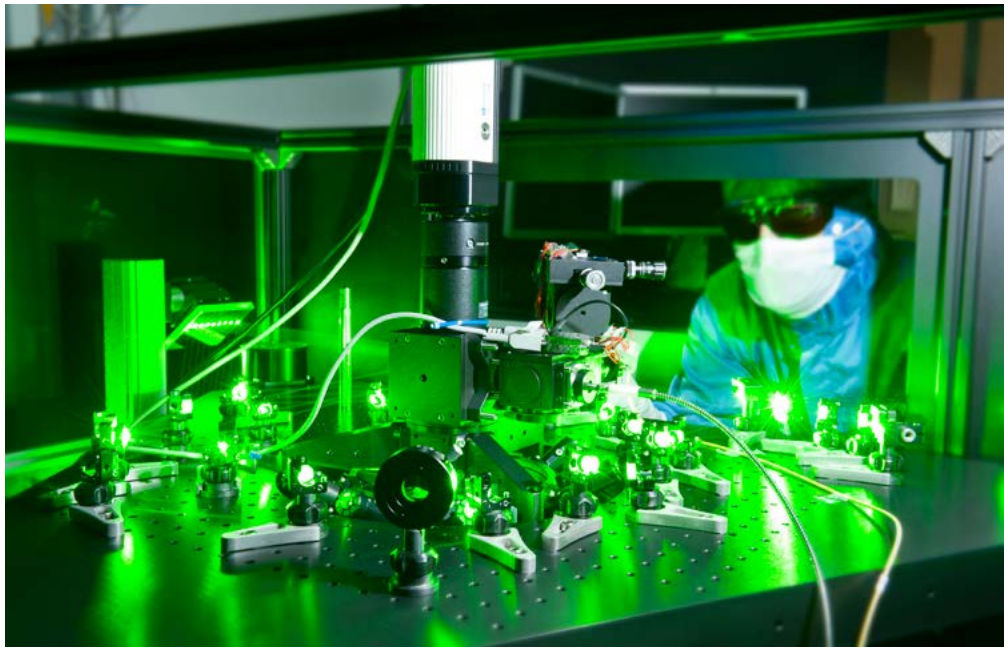
Figure 2. Comparison between growth in gross added value and labour productivity for the subsectors within the high-tech industry (2015 price level).

1.1 TNO

TNO supports Dutch high-tech in aspects where it can make the greatest societal and economic impact with applied research. Together with partners, TNO works on innovations that define the future, for example in aerospace, quantum technology, semiconductors, and photonics. It works to tackle societal challenges and create a strong economy. And a business community that contributes to solving these societal challenges also ensures economic earning power and employment. TNO's ambition is to support the high-tech industry with groundbreaking technological and system innovations.

Chapter 2
Changing balance of forces

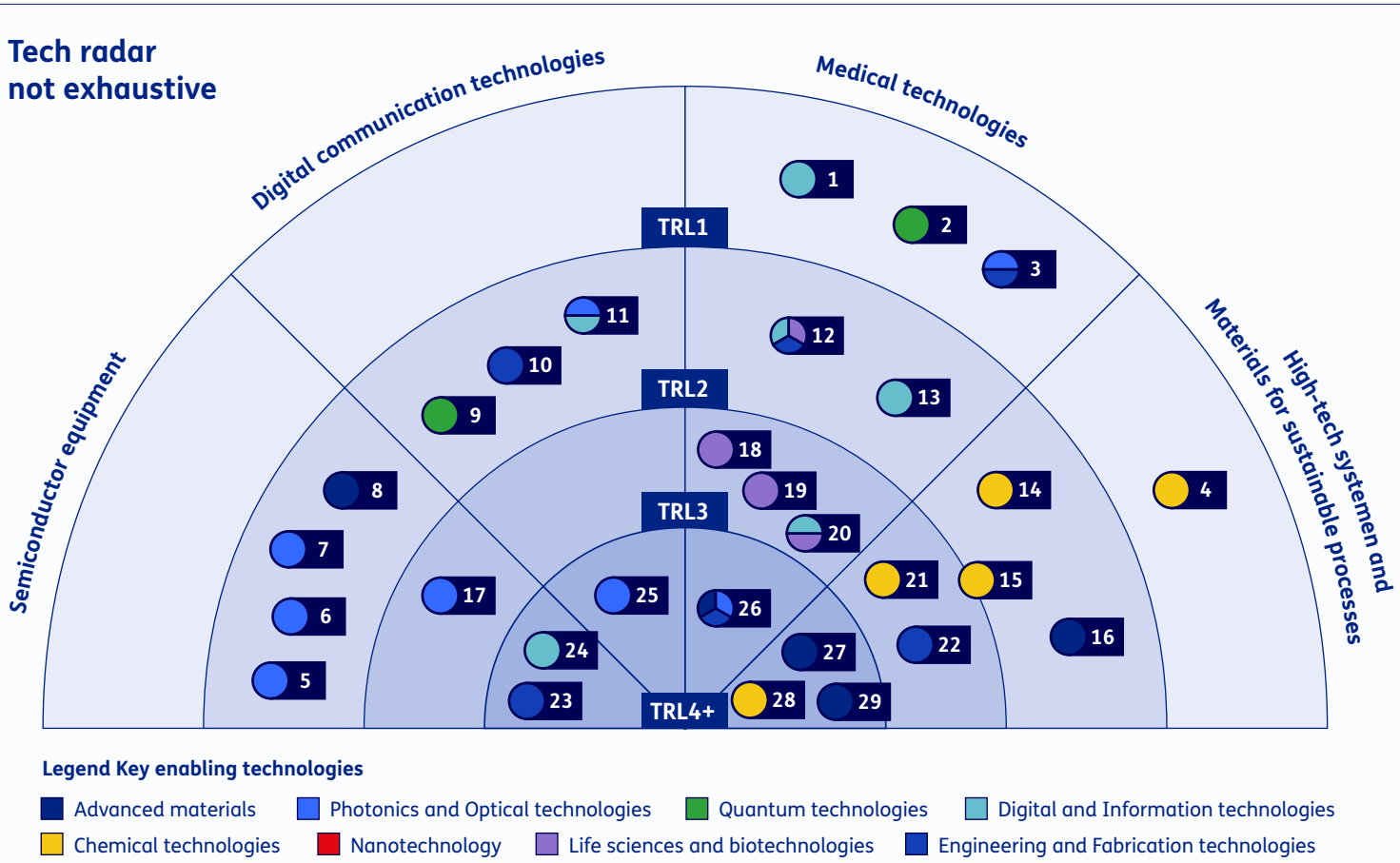
Innovation is the most important constant in the Dutch high-tech industry. The high rate of innovation that characterises the sector means that value in the industry is constantly being shifted into new areas.



Thirty years ago, IBM, then mainly active in computer systems, was the largest technology company worldwide in terms of market capitalisation, whereas 20 years ago, it was the software company Microsoft and 10 years ago, it became Apple, mainly active in consumer electronics. The Dutch high-tech industry has also been transformed in the last three decades: 30 years ago, the broadly diversified Philips was the largest company and now it is the strongly focused ASML.

ASML's market value is 30 times higher than it was 20 years ago, making it currently Europe's most valuable technology company. This high rate of innovation means that by 2040, the Dutch high-tech industry will look completely different, for which it will largely have to reinvent itself.

That innovation will largely come through the adoption of new technologies that we already see climbing the TRL ladder. Disruptive technologies, such as AI, quantum, photonics, biotech, and autonomous systems, are going to lead to new high-tech devices in a large number of markets. In the semiconductor domain, we are seeing, for example, the integration of optical and electronic chips, new multimodal metrology, and the application of new materials. In digital communications, there are technologies in the pipeline relating to quantum internet, integrated photonics for laser satellite communications, and green data centres. In the medical field, there are high expectations for quantum computing for pharmaceutical applications, neurostimulation, 3D printing of organs, and personalised medicine. And on the sustainability front, high-tech is coming in the areas of energy storage and conversion, photoelectrochemical systems, and hydrogen (hydrogen leakage) measurement systems.



1. Hybrid intelligence
2. Quantum computing for pharma
3. Empathic robots
4. Next gen nuclear waste managment
5. PIC wafer scale / high throughput metrology tools
6. Hybrid integration / new chip architecture
7. Co-design electronic and optical chips
8. New materials for semicon
9. Quantum internet
10. Next gen sensor technology
11. Green data centers
12. Neuro stimulation
13. Personalised medicine
14. Modular massive parallel reactors
15. Solar to fuel
16. Photo-electrode materials
17. Multi-modal metrology
18. Artificial tissue / organoids
19. Regenerative medicine
20. 3D printing of organs
21. Transparant flow reactors
22. Integration concepts for PV and electrolysis
23. 3D stacking
24. Neuromorphic computing
25. Integrated optics in laser satcom
26. Point of care systems
27. Hydrogen (leak) measurement
28. Photo-electro-chemical systems
29. Energy storage and conversion

Figure 3. Examples of new technologies relevant to high-tech.

2.1 Opportunities in a changing world

A number of global trends are having a major impact on the high-tech playing field, creating new opportunities for the Dutch high-tech industry. Our social environment is fundamentally changing with the ongoing ageing of the population, which will bring healthcare challenges and acute labour shortages in a growing number of countries.

On the ecological front, we face the essential transition to sustainable systems in relation to energy and raw materials. As regards the economy, we see global value chains becoming increasingly regional and governments choosing a more initiating and intervening role. Politically, major societal challenges are high on the agenda. Investment in sustainability and health is rising sharply, as is investment in defence, due to the rapidly deteriorating security situation.

This leads to a series of promising opportunities to create new high-tech value chains for markets that are emerging in high-tech for sustainability, health, digital transformation, and defence. Moreover, the desire to pursue strategic autonomy and far-reaching automation and robotisation offers the chance to build production in Europe or the Netherlands.

2.2 Existential threats

The changing world also means that the high-tech industry has to consider threats that in some cases could be existential. The sustainability transitions will result in increasingly stringent regulations, which could jeopardise the existence of companies unable to keep pace. Competitiveness is also under pressure due to decreasing access to critical materials and a diminishing supply of labour, combined with stagnating labour productivity.

Finally, there are significant threats concerning the long-term resilience of the industry. Will the value chains that have been so carefully optimised withstand shocks such as wars, natural disasters, or a shifting political balance? And do our knowledge positions offer sufficient guarantees that we can continue to hold leading positions in the high-tech industry in the near and not-so-near future?

2.3 Facing the future

The Dutch high-tech industry has a strong hand with regard to building positions in the area of high-tech for societal challenges. It is a leader in designing, developing, and producing high-tech equipment and components with three key characteristics: highly intelligent (embedded systems, software, sensors), highly precise (nanoelectronics, high-precision manufacturing), and highly efficient (mechatronics).

High-tech is also strong in translating knowledge into industrial solutions. There are well-developed ecosystems of specialised companies and knowledge institutions that have collaboration and knowledge exchange in their DNA. Finally, the Netherlands has a strong knowledge base with regard to key enabling technologies and a favourable business climate.

Chapter 3
Success factors and transformations

The changing balance of forces poses tough challenges for the Dutch high-tech industry. Four critical success factors are decisive for continuing to be strong, healthy and leading in particular areas in 2040. Each of these success factors requires transformations.

3.1 Success factors

It is important for the high-tech industry to be capable of continuing to operate within the rules that will apply in the Netherlands and the EU in 20 years' time. This right to exist (licence to operate) must be secured, which will require major changes in view of the ever-increasing demands. Examples are the necessary reduction in carbon emissions and the growing number of restrictions in countries to which high-tech products may be exported.

Competitiveness is the second critical success factor. Operating in global and highly competitive markets requires continuous investment in competitiveness – and therefore in innovation. An additional challenge here is the growing scarcity of qualified staff.

Long-term resilience is a factor that has been on the agenda since Covid-19, the war in Ukraine, and rising tensions with China. It has become clear that companies have optimised their supply chains too much in the direction of low cost, at the expense of resilience to shocks.

It also appears that the relevant knowledge and technology positions are under pressure due to unprecedented investments by China and the United States in topical fields such as AI, quantum, and knowledge leakage, for example through espionage.

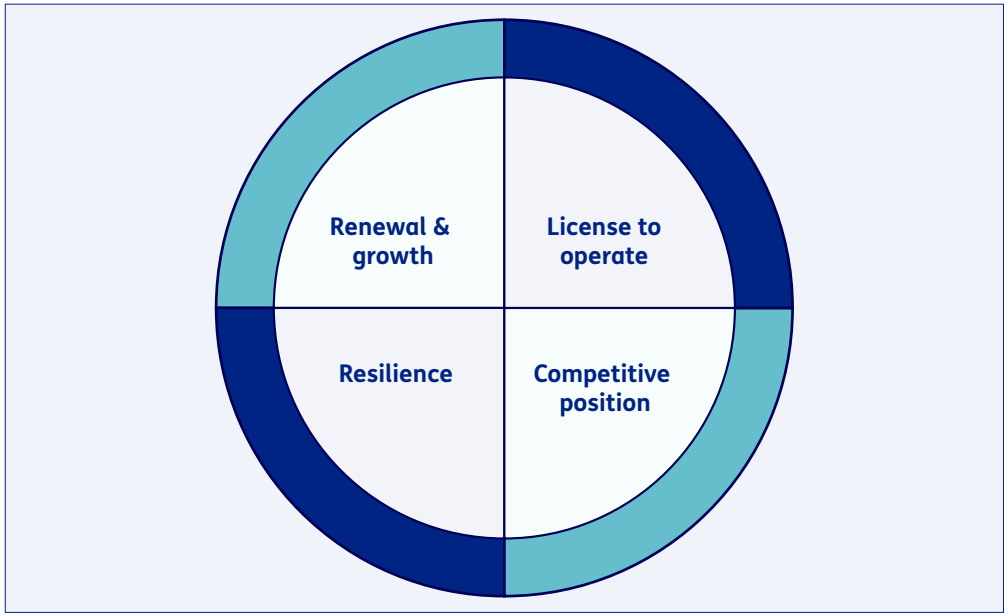


Figure 4. Success factors for Dutch high-tech.

Finally, achieving innovation and growth is crucial for success. This begins with building on and further developing positions in existing value chains. In addition, it is necessary to keep innovating, in the knowledge that a large part of revenue from high-tech in 2040 will come from value chains that do not yet exist today. Those value chains will emerge from the convergence of demand arising from societal challenges such as sustainability and health, on the one hand, and the technological innovation that is coming our way in areas such as AI, quantum, and photonics, on the other.

3.2 Transformations

A successful route to 2040 consists primarily of a wide variety of companies, from startups to multinationals, doing what they do best: business.

Developing new products, setting up efficient production, building partnerships, and all the other activities crucial to a constantly evolving business. But at system level, the level of the high-tech industry as a whole, a number of necessary transformations are emerging that all these companies have to deal with and in which government and knowledge institutions play an important facilitating role. The word 'transformation', a fundamental change of state, is used here to indicate that these are changes that parties cannot achieve separately. Eight transformations are needed to set the stage for a successful future as a high-tech industry.

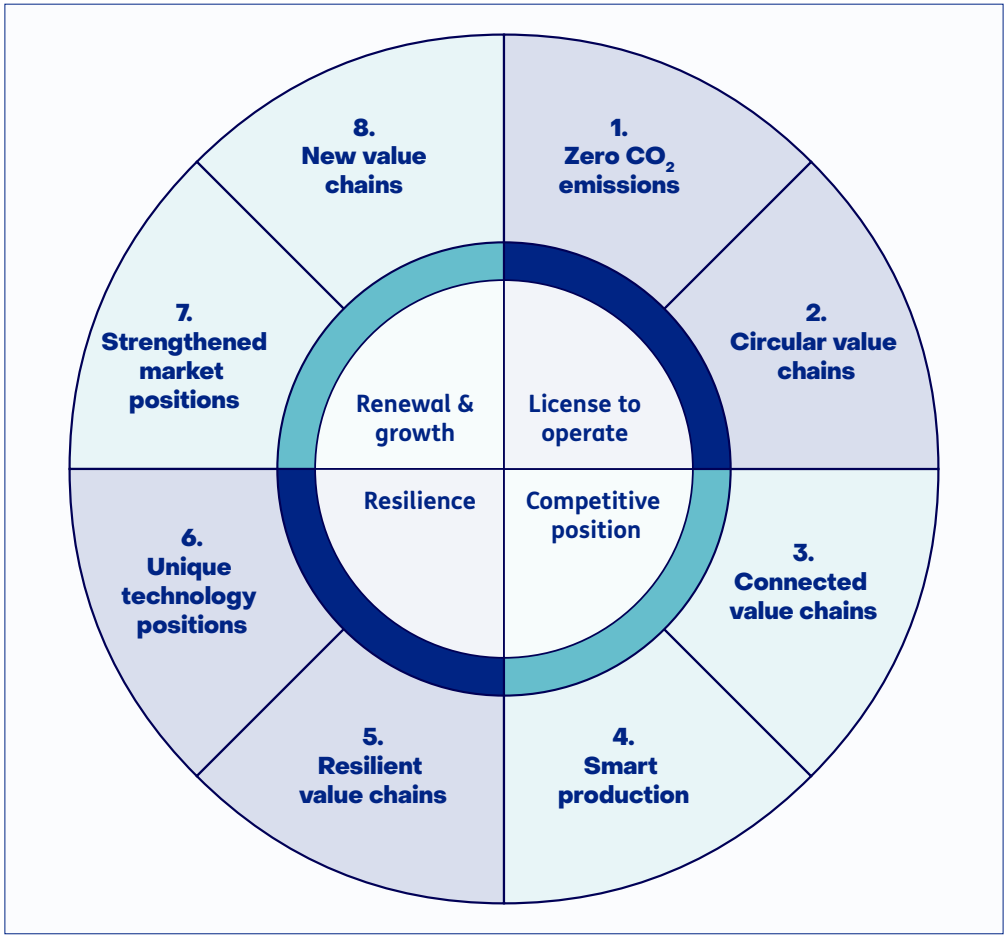


Figure 5. Transformations in Dutch high-tech.

1. Net-zero carbon emissions
The goal for 2040 is clear: no high-tech company should produce carbon emissions by 2040. This involves a company's own operations, its supply chain (upstream), and the effect of its products at customers' locations (downstream). Important levers to achieve this goal are lower energy consumption in production and the switch to green energy. Products at customers' locations will also have to become more energy-efficient and facilities will have to be created to recycle discarded products, thus reusing the CO^2 invested. The inhibiting factor here is that national legislation on CO^2 is still in development and may create an uneven playing field internationally.

Stable government regulations to encourage the shift to net-zero emissions, while ensuring a level playing field, are therefore crucial. Once such regulations are in place, coalitions can emerge that will make the transition to net-zero emissions within the value chain where they operate. Dominant players in the value chain play a key role in driving this development and technological innovations will be needed in the areas of the energy consumption of the product, the production process (e.g., Industry 4.0), and the recording of CO^2 consumption (e.g., the product passport and digital twins).

2. Circular value chains
Value chains managed by Dutch high-tech companies will adopt a circular business model with near-100% resource efficiency by 2040. 'Re-x' processes (e.g., rethink, repair, remanufacture, recycle) will have become a standard part of the production landscape. Products and processes will be designed and redesigned to minimise material use and maximise reuse.

The service life of products will be extended through design, redesign, and new 'servitised' business models where the producer has ownership of the product in the use phase. Inhibiting factors here are uncertainty regarding legislation, a lack of remanufacturing and demanufacturing capacity close to the end customer, and a lack of understanding of the reuse potential of products and components when they are presented for recycling. Moreover, producers face a trade-off between performance and reuse potential. From a business point of view, performance currently still wins out over reuse potential.

Here, too, we need stable regulations, coalitions of willing parties, and a product passport (for demanufacturing information). In addition, systems engineering of value chains is required to incorporate demanufacturing, remanufacturing, and recycling capabilities. New technological breakthroughs are needed, for example to improve product longevity and recyclability, and enable highly automated and autonomous demanufacturing processes.

3. Connected value chains
Further connecting and integrating the players in the Dutch high-tech value chains is crucial to perpetuating and developing competitiveness. We want to move towards a Dutch high-tech industry that operates the best digitally connected and protected production network in Europe by 2040. This will enable a high degree of integration between partners in the value chain, with unprecedented flexibility and efficiency. This integration will be achieved partly through further digitalisation and standardisation, allowing companies to use real-time information in their own order-fulfilment process, as well as that of their suppliers and customers.

However, there are several barriers: low digitalisation rates in the factory environment, a lack of digitalisation expertise among SMEs, standardisation that is still being developed, and the need to protect proprietary data. Innovation is needed to create international platforms and standards that allow data to be shared securely and efficiently across company boundaries, while parties retain sovereignty over data. Standardisation is also needed in the factory environment – a digital connector (Distributed Technical Intelligence Operating System, or DTI-OS) to enable apps to perform a production or product service operation on top of a standard interface within a production environment.

4. Smart production
A labour shortage is already one of the main bottlenecks in the Dutch high-tech industry and this problem will become even more acute as the population continues to age. To remain competitive, we therefore need to give new impetus to stagnant productivity through extensive automation and smart production.
To achieve this, the Dutch high-tech industry will need to ensure that it has the most automated and autonomous production capacity in Europe by 2040, enabling single-piece production at the cost price of mass production.

Manufacturers will have a ‘Digital Factory’, where everything is digitally linked by standardised digital connectors and where a digital twin is available for all products, processes, and equipment. Within this environment, smart applications with decision-making and remote-control functions operate to ensure productivity and efficiency on the shop floor.

This will enable production lines to adapt automatically to changing products without human intervention. Furthermore, production lines will automatically correct themselves in case of quality problems, disruptions, or changing conditions.

Accelerating the move to smart production requires a common solution strategy, knowledge base, and definition of building blocks for flexible and autonomous manufacturing. Policies are also needed to help high-tech SMEs prepare for automated and autonomous manufacturing.
Technological development will be needed both in the field of Operational Technology, especially industrial robotics, and Information Technology. Examples of developments include a standardised digital connector and applications for self-configuration, automatic programming, distributed intelligence and generative algorithms, recipe-based techniques and production configurators, and autonomous agents and digital twins.

5. Resilient value chains
The aftermath of COVID-19 and other disruptions have highlighted the need for the high-tech industry to find a new balance between resilience and efficiency in supply chains. Maintaining access to scarce resources has emerged as an additional factor. This means a movement towards shorter supply chains, diversification of suppliers, running multiple production sites, such as local production on each continent, and building more surplus into the chain. In addition, greater flexibility will be built into the chain through further digitalisation. The associated costs will increasingly be seen as the costs of doing business rather than inefficiency.

This shift will not come naturally to individual companies. There are also arguments against bringing production back home, for example, due to the strained labour market in both the Netherlands and other key parts of Europe. Moreover, companies often focus strongly on labour costs, without considering other relevant factors (uncertainty, risk of IP theft).

The situation described above requires public policy in the Netherlands and Europe. This policy should result in the high-tech industry achieving strategic autonomy based on a thorough understanding of its own vulnerabilities. Technologically, there is a need for flexible and automated supply chain processes and solutions to reduce dependence on critical and scarce raw materials. The high-tech sector will therefore have to focus on more efficient production, recycling, and substitution by less scarce raw materials.

6. Unique technology positions
Dutch high-tech builds on leading technology positions, parts of which are under pressure from huge investments by large countries such as the United States and China, and knowledge leakage (e.g., through espionage, students, or knowledge workers).

A successful high-tech industry in 2040 will largely be built on the unique knowledge positions for new technologies that will be developed in the Netherlands in the coming years and in which the country will therefore have to continue investing. The EU Chips Act is beginning to bring more strength and coherence to the high-tech-focused innovation programme at European level, although we will have to see how this develops as the Act is elaborated and implemented.

In addition, there are bottlenecks with regard to the inflow of technological talent, partly due to the continuing sub-optimal image of technical studies and jobs, as well as entry barriers for international technical graduates, which include a shortage of housing.

Building unique technology positions for high-tech requires an integrated (EU and NL), long-term, high-tech-oriented technology strategy, pursuing the aim of strategic autonomy (required technology, industry, capacity positions). To this end, we need to carry out groundbreaking fundamental and applied research in high-tech key enabling technologies: advanced materials, photonics and optical technologies, quantum technologies, digital and information technologies, chemical technologies, nanotechnology, life sciences and biotechnologies, and engineering and manufacturing technologies. And this requires policies, so that there will be enough knowledge workers in the Netherlands in science, technology, design, and applied mathematics.

7. Strengthened market positions
The current strong market positions are the basis for our earning power in 2040. We must therefore defend these positions and, where possible, build on them. This calls for new technology, in order to further develop existing positions in semiconductors (e.g., metrology, pick-and-place, heterogeneous integration, advanced packaging, production for Ångström Era, and domain-specific chips), electronic instruments and devices (e.g., Systems Engineering and Cyberphysical), equipment for weighing, lifting, and handling (e.g., AI and soft robotics), and equipment for agriculture & food processing (e.g., AI, robotics, and sensors), among others.

8. New value chains
Our existing strong market positions also ensure that the mass and innovative strength are in place, so that we can diversify into new value chains. A significant part of Dutch high-tech revenue in 2040 will have to come from new value chains that do not yet exist on a large scale in 2023. By then, Dutch high-tech companies will have strengthened their market positions by further developing their products, innovating their business models, entering adjacent market segments, and improving their R&D success rate. Since these companies are part of a relatively highly integrated local value chain, it is important that the whole chain can join in this development. In this context, the relatively low R&D intensity of SMEs is a concern and this calls for targeted support to improve the success rate of innovation.

Chapter 4
New value chains

The transformations for the high-tech industry described above are often clearly connected to the immediate interests of the individual players. The last transformation – building new value chains – requires additional impetus for system innovation and public-private partnerships. This often involves new markets and new technologies that are currently not on the radar of existing players.

The most important new value chains in which the Dutch high-tech industry can achieve sustainable earning power and societal impact are:

A. High-tech for a healthy society
B. High-tech for sustainable processes
C. High-tech for transformational digital technologies
D. High-tech for defence and security

4.1 High-tech for a healthy society

The progressive ageing of the population is increasing demand for high-tech devices and production equipment that provide solutions to health and care challenges.

Solutions in which such equipment will play an important role are:

- Prevention. Preventing people from becoming ill and ensuring that they live longer and in good health.
- Diagnosis. Ensuring early detection of diseases.
- Healthcare. Ensuring that overall healthcare costs are reduced and the burden on healthcare staff is eased.

Innovation in the healthcare system is extremely difficult for individual players. The implementation of new technologies often founders early on and regulations make innovation in healthcare difficult. In addition, many applications require both standardisation and volume, while healthcare is very personal and therefore not standardised.

This reinforces the need for system-level coordination and regulation:

- Encouraging a system transition in healthcare. This requires impetus through public-private partnerships with the participation of all the necessary ecosystem partners.
- Improving regulations to enable innovation in healthcare (e.g., framework for data sharing).
- Developing standard digital platforms that suppliers can join.
- Establishing an open ecosystem that enables healthcare providers and health technology companies to collaborate on building patient pathways that combine various technologies.

Technology development will need to focus on potential game changers in healthcare, such as:

- Being treated in one's own living environment/home monitoring (wearable technologies).
- Prevention and early diagnosis (lab-on-a-chip).
- Personalised medicine (organ-on-a-chip).
- Improved drug production and delivery systems (under the skin, smart 3D-printed pill, electroceuticals).
- Robotics.
- Mobility of devices.
- In-house sensors.

4.2 High-tech for sustainable processes

The increased understanding of the environment and climate has resulted in a number of far-reaching transitions being initiated. Ambitious targets have been set for energy and materials transitions that cannot be met without substantial investment. These transitions are facilitated by high-tech devices and production equipment that enable, for example, sustainable energy production, distribution, and storage. This provides substantial opportunities to capture positions in the new value chains that are already emerging.

For many sustainability technologies, the challenge is to achieve sufficient critical mass. Momentum and the most important market players (e.g., system integrators for electrolysers) often have to be sought abroad. A complicating factor in achieving mass is that there are frequently multiple competing technologies.

At the same time, there is tension between gaining momentum and building a position in the Netherlands. Established companies have an interest in not adopting new technology too quickly, while founding startups carries the risk of being taken over by foreign players.

Needs at system level

- National (NXTGEN) development programmes with top-down coordination to gain control points in the new value chains
- Partnerships with key EU countries to connect Dutch high-tech to their value chains for sustainable high-tech (e.g., batteries in Germany)

Promising priority areas in technology development

- Technology for the energy transition:
  - Next-generation rechargeable batteries and thermal batteries
  - Electrolysers
  - Reactors (plasma, small core)
  - Devices for smart grids (e.g., smart sensor and monitoring devices, next-gen power electronics)
- Technology for the transition to a circular economy:
  - Equipment for solar-powered chemical processes (Sunlight-to-chemicals).
  - Equipment for power2chemicals.
  - o Sustainable devices (batteries, electronics, electrolysers) with high recyclability and related production equipment.
  - Disassembly equipment (e.g., photonic detachment).
- Technology and processes to produce this equipment on a large scale.

4.3 High-tech for transformational digital technologies

Digitalisation is having a profound effect on society and offers opportunities for creating well-being and prosperity. It is changing the ways in which people live, work, and learn. A number of disruptive technologies, such as AI, quantum, photonics, and autonomous systems, could transform society even more radically.

This offers the high-tech industry new opportunities for devices and production equipment that take digital technologies to the next level:

- More powerful: e.g., more powerful computer chips, sensors.
- Faster: e.g., faster digital communications.
- Safer: e.g., more secure digital communications.
- More sustainable: e.g., lower energy consumption by data centres.

It is not a foregone conclusion that existing Dutch industry or startups will automatically gain control points in the new value chains that will emerge in relation to these new technologies. Developing such technology is capital-intensive. However, there is less investment power in the Netherlands than in a number of large countries and regions. In addition, most Dutch OEMs are highly focused and less willing to invest in diversification early on.

At the system level, coordination is needed to ensure:

- Connection with – and influence on – European initiatives (e.g., the Chips Act and the Net-Zero Industry Act).
- Bases (technology, market, experts) for new domains that Dutch companies can then develop further.
- Pilot environments.

In the area of technology development, focus and volume are needed with regard to game changers, such as:

- Quantum technology (computers, communication, sensing).
- Optical wireless communications (laser-satellite communications, data centres, LIFI).
- Integrated photonics.
- Advanced packaging of chiplets and heterogeneous integration to combine multiple functions in one package, such as sensing, processing, or wireless communications.
- 6G components and systems.
- Edge computing and neuromorphic technologies.

4.4 High-tech for defence and security

The geopolitical developments of recent years make it clear that our security cannot be taken for granted. The war in Ukraine is the most tangible example of this but the underlying trend has been pointing in that direction for some time. The unipolar world order with the US as the dominant superpower is becoming a multipolar world order. This is putting geopolitical pressure on the traditional multilateral systems (UN, EU, NATO), creating new security threats. Europe and the Netherlands have become more vulnerable and are having to secure their own interests and guard their strategic autonomy. They also increasingly have to be self-reliant with regard to security.

Investment in defence is now rising sharply. This is triggering new European business activity, with value chains that will produce high-tech devices and production equipment. These products will play a crucial role in meeting defence and security challenges in the second quarter of the 21st century. For the Dutch high-tech industry, this creates opportunities to develop pioneering equipment at the interface of defence and security. Examples are satellites (laser satellite communications, nanosatellites), next-gen sensors (advanced radar, acoustic sensors, sensors for UAV, nanosensors), robots and autonomous systems (for operational and/or logistics applications), integrated information systems (sensor, weapon, command), and weapons (missiles, high-energy weapons).

It is essential to think and operate internationally to gain a good position in this field. There is no level playing field in defence. Much of the defence industry is driven by national interests and the Dutch armed forces are small. In addition, the Netherlands does not have any major relevant OEMs, apart from Thales, Airbus D&S, and Damen. It is therefore necessary to take part in European programmes or join forces with major European players.

At the system level, coordination is needed to ensure:

- Maximum alignment with European defence plans, organisations, and funds (EDF, PESCO, EDA) that help open up the European defence market.
- Beachheads (technology, market, experts) for new fields (see laser satellite communications) that Dutch companies can develop further, especially in the area of dual-use technology.
- The Dutch armed forces as investor and launching customer for key enabling technologies.

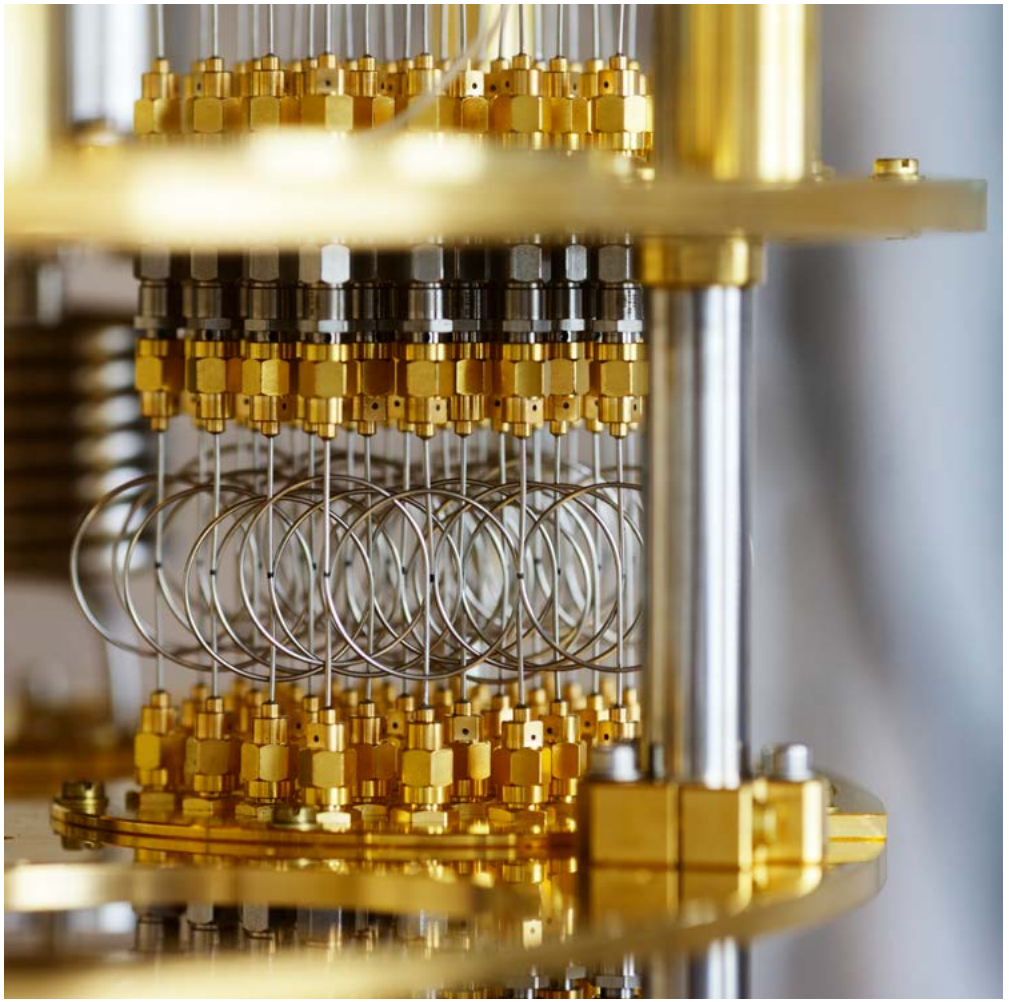
Promising technological developments include:

- AI.
- Quantum technology.
- Sensors (incl. quantum and nano sensors).
- Human-system integration.
- Aerospace and satellites.
- 3D printing and new materials.
- Simulation and virtualisation.
- Human enhancement.
- Robotics and autonomous systems.
- Semiconductors suitable for defence applications (trusted, quality).

Chapter 5
New challenges

The Dutch high-tech industry creates significant wealth in the Netherlands. To continue delivering this value to society in 2040, the industry will have to:

- **renew itself by generating 50% of revenue from new value chains in equipment for meeting societal challenges.**
- **secure its licence to operate by transforming to a 100% sustainable business through net-zero emissions and a circular model.**
- **secure its competitive position by becoming 150% more productive with the help of digitalisation, automation, and further chain integration.**
- **achieve maximum resilience and perseverance through robust supply chains and unique technology positions.**



"The high-tech industry in 2040: 50% of revenue from new value chains, 100% sustainable, 150% more productive and highly resilient."

This leads to new challenges for the high-tech industry in three areas: a system task, a valorisation task, and an R&D task:

1. System challenge. Provide the basic conditions for the 8 transformations.
2. Valorisation challenge. Accelerate the translation of new application areas into new activity.
3. R&D-challenge. Achieve technology breakthroughs to drive the 8 transformations.

5.1 System challenge

At system level, the basic conditions must be created to successfully shape the eight transformations.

Policy and regulations

We need measures to give direction, promote consistency, and ensure the basic conditions are met. For example, a stable long-term strategy for the high-tech industry is required, which is translated into effective policy. There has to be structural, consistent, and long-term investment in innovation. A key challenge here is to turn the very positive momentum created with the establishment of the National Growth Fund into a structural tool. Additional policies are also needed to boost the availability of talent and create infrastructure. With regard to regulations, such as the licence to operate, there should be a constant focus on achieving a level playing field for the Dutch high-tech industry.

Talent

The high-tech industry must have sufficient well-trained talent available. This means that targeted study programmes are needed, especially in the technical field. It is also important to attract international talent where national recruitment is not sufficient.

Mobilisation

For players in the high-tech industry, there is a shared interest in doing what is required throughout the value chain. Initially, we need coalitions of the willing to initiate the necessary transformations and thus secure the licence to operate. Value chains also have to be redesigned on the basis of systems thinking to make them more future-proof. Multiple transformations require the introduction of standards, such as a product passport and standardised digital connectors in the factory.

Finally, the high-tech industry will have to develop a human capital agenda in which recruitment will be much more skills-based than education-based.

5.2 Valorisation challenge

A valorisation agenda encompasses the activities that help convert new application areas into new business activity. Public-private applied research programmes with sufficient focus and mass should ensure that the high-tech industry is put to work to help solve societal challenges. These are programmes focused on 'High-tech for x' (Health, Sustainable, Digital, Defence) that develop new applications, from initial design through to demonstrators and pilot lines.

In addition, programmes are needed to ensure that the knowledge, products, and market positions developed have the best possible chance of success and take root in the Netherlands:

- Smart Industry: developing building blocks and rolling out solutions to produce equipment at industrial scale and competitive costs.
- Startup and scale-up programmes: driving startup activity and successful upscaling.
- International collaboration programmes: establishing high-tech collaboration programmes with regions that have momentum.

5.3 R&D challenge

We need an R&D agenda to achieve those technology breakthroughs that will ensure the high-tech industry stays in the lead over the next 20 years. Unique technology positions will need to be achieved in the following key enabling technologies:

- Advanced Materials (Optical, electronic, magnetic, and nanomaterials; Thin films; Energy materials).
- Photonics and Optical Technologies (Optical systems & integrated photonics; Photonic/optical detection and processing; Photon generation techniques).
- Quantum Technologies (quantum computing; quantum communication; quantum sensing).
- Digital and Information Technologies (AI; Digital connectivity; Digital twinning).
- Chemical Technologies (catalysis; Electricity-driven chemical reaction techniques).
- Nanotechnology (Nanomanufacturing incl. metrology, thermal management, contamination control; Nanomaterials; Functional devices and structures; Micro- & nanofluidics).
- Engineering and Fabrication Technologies (Sensor and actuator technologies; Imaging technologies; mechatronics and optomechatronics; Additive manufacturing; Digital manufacturing technologies; Robotics; Microelectronics; Systems engineering).

This list could provide more focus and identify which technologies require additional impetus.

Chapter 6
National High-Tech Strategy

The continuous transformation of the Dutch high-tech industry is a necessary process that affects all high-tech companies and in which individual interests largely coincide.

TNO therefore advocates two mutually reinforcing actions:

1. Formulate a National High-Tech Strategy
A national strategy is needed to facilitate the high-tech industry in tackling the new challenges, building on the National Technology Strategy and the KIA Key Enabling Technologies, among others. This includes a role for companies, knowledge institutions, and government.

2. Create a structural funding instrument
The positive impetus of the National Growth Fund should be turned into a long-term strategic innovation policy. In terms of design, this could build on the successful form of joint programming that has now been established in the Dutch high-tech ecosystem with the National Growth Fund.

TNO is committed to helping address these challenges for the Dutch high-tech sector. It has the competences in-house to play a decisive role in key areas, for example in the development of new technologies, applications, and business activity for the four major new value chains.

TNO also has a role in coordinating system innovation. We invite high-tech companies, knowledge institutions, and government to join forces in working towards a future-proof high-tech industry that will continue to be an example to the world in 2040 and offer jobs and a future to many people living in the Netherlands.

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