CONNECTING
CHANGING
ACCELERATING

TNO innovation for life

TNO STRATEGY 2022 - 2025

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IN TIMES OF **TRANSITION**, **NEW NEEDS** EMERGE, AND WITH THEM, **NEW OPPORTUNITIES** TO **INNOVATE**

INTRODUCTION

The world is changing – that is nothing new. But what is new is the speed and complexity of those changes. People are worried about whether their jobs will still exist in a few years' time as a consequence of further digitalisation and robotisation. They worry about data that is being collected about them without their knowledge. And about algorithms that make choices for them, which they can neither influence nor understand. The digital public space has become a platform that people sometimes use to disrupt society. The security situation is worsening in the world outside Europe and we face new threats, such as daily cyber-attacks. Growth in labour productivity has been feeble for years. The COVID-19 pandemic has exposed the vulnerability of our healthcare and logistics chains around the world. And how do we make sure that the climate crisis and the energy transition are tackled effectively? That we will be able to travel safely and sustainably in the future? The complexity of these challenges to society has increased enormously and reflects changes in technology, behaviour, business and government regulations. So, more than enough challenges...

…but a wide range of solutions, too. If the COVID-19 crisis has shown us anything, it is that when we are really up against it, we can achieve rapid breakthroughs in the development of knowledge and technology. The Dutch Advisory Council for Science, Technology and Innovation (AWTI) said in February 2020: 'In times of transition, new needs emerge, and with them, new opportunities to innovate. There are many examples of this. During the digital transition, millions of new jobs were created worldwide. New ways of working, doing business and engaging in science emerged; other lifestyles became possible. The transitions of the future will also provide opportunities. Increasing demand for sustainable products, services and lifestyles is already producing new areas of science, innovation and new employment opportunities[1].' The costs of a wide variety of products and services are falling extremely fast, as are the costs of generating sustainable energy. Since 2017, R&D investment by OECD countries has again been increasing in real terms. Few people still doubt the profitability of such investments. Solutions are being developed to use data on a large scale without violating privacy (privacy as an opportunity!) and to make algorithms transparent. Digital technologies provide opportunities to bring production back to Europe. Increasing dependency on digitalisation is accompanied by a growing need for robust cyber resilience. With the Green Deal, the countries of Europe are showing that they want to tackle the climate and energy challenges together as a matter of urgency. A circular economy is becoming more attainable through technological development that enables the economically viable reuse of raw materials and resources. And who would have thought that within just one year there would be vaccines on the market to combat COVID-19? There is every reason to assume that now is the time to expect more rapid technological breakthroughs.

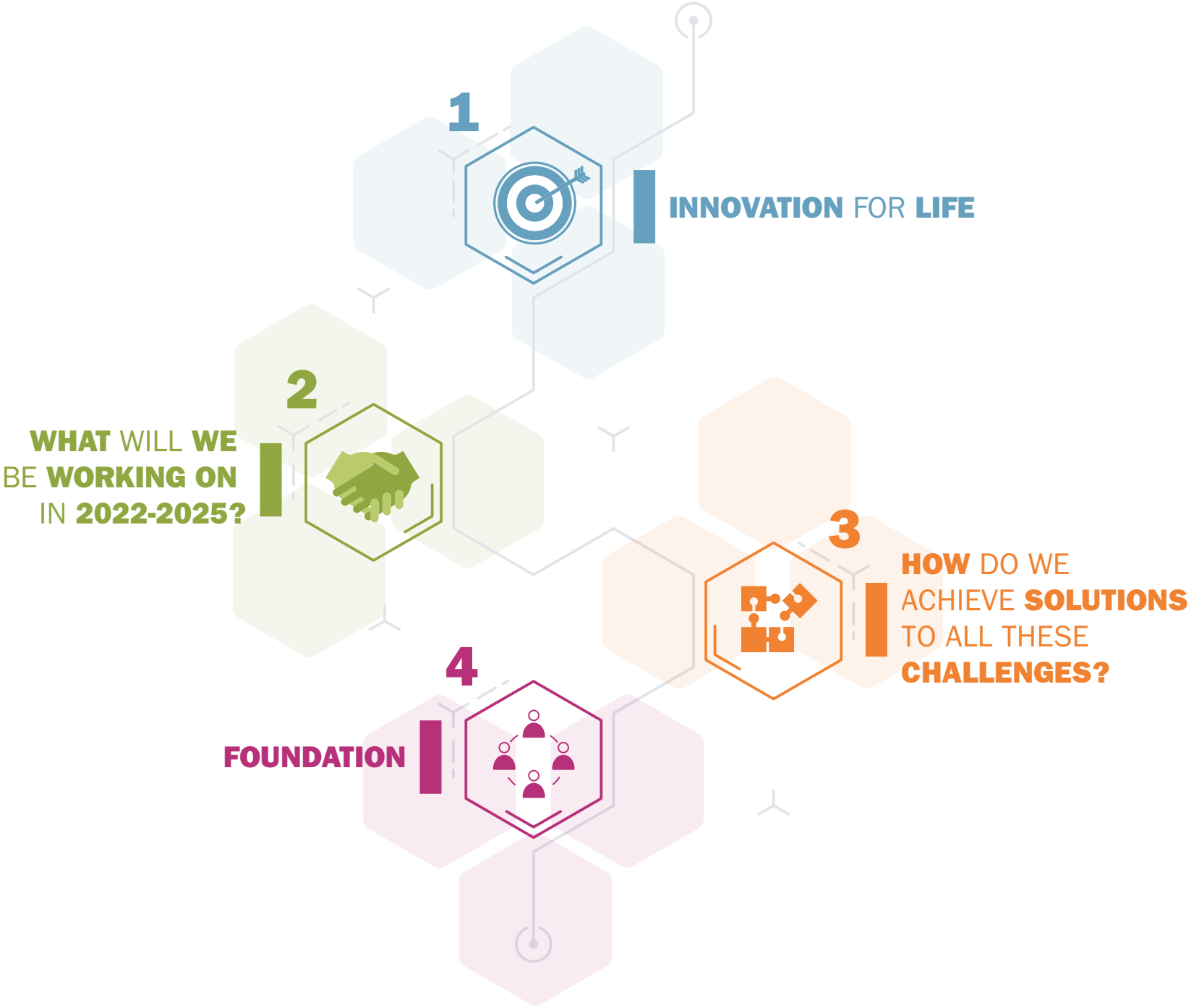
1. AWTI, Strengthen the role of science, technology and innovation in societal transitions, February 2020

TNO wants to be in the forefront of these developments. This strategic plan embeds this ambition in the organisation and defines what is needed to achieve it. But at the same time, we must modestly acknowledge that without the aspirations, commitment and trust of our partners and clients, we cannot do our work. Only a firmly anchored and broadly supported TNO has a 'right to play' and is able to deliver the added value that society and TNO's partners and clients are calling for. You can expect TNO to continue being proactive in providing you with high-quality knowledge, advice and smart, unique and surprising solutions. Honest, independent, professional and socially committed: innovation for life!

We are well aware that the world will not stand still after this strategic plan has been finalised. Therefore we invite you to continue sending TNO your comments, suggestions and ideas. Only by being open to external developments at all times and being quick to adapt can TNO continue to offer you the recommendations and solutions that you are really looking for. Only in this way can TNO realise its ambition of being the prime agent of change in the Netherlands.

Finally, TNO realises that a strategy is all very well in theory, but it is of no use if it remains on paper. The real challenge is of course for every employee to implement and give meaning to the strategy. In that regard, TNO sees this plan as the kick-off for the exciting and challenging years that lie ahead. TNO hopes that you are with us in finding inspiration in this plan and that you recognise and endorse the ambitions described here and the course that we aim to follow.

On behalf of the Executive Board
Paul de Krom, chairman and CEO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ONLY A FIRMLY **ANCHORED** AND BROADLY **SUPPORTED** **TNO** HAS A **'RIGHT TO PLAY'**

ACCOUNTABILITY AND STRUCTURE OF THE PLAN

TO2 strategic framework

The strategic framework of the Dutch national Federation of Applied Research Organisations (TO2 federation) is the overarching structure for the strategic plan of TNO and the other TO2 institutions. The two documents should be read in conjunction.

External consultation

Our ambition is to look at TNO 'from the outside in' – in other words, to determine our research portfolio and programming in close cooperation with our clients and partners. The strategy is therefore also based on extensive consultation with our most important partners and clients. We held discussions with, among others, the Ministry of Economic Affairs and Climate Policy, the Ministry of Defence (in the Council for Defence Research), other relevant ministries, TNO's own Strategic Advisory Councils (and their chairs in particular), representatives of various national 'top sectors' and 'top teams', as well as representatives of our partners and clients. Naturally, we have also considered the recommendations of the Evaluation Committee for Applied Research Organisations [TO2 Evaluatiecommissie] in its sub-report on TNO.

Internal consultation

Internally, too, the plan has been developed in an intensive process of coordination and creativity, with contributions from various working groups. A group of nearly 100 employees, brought together in the 'Strategy & Change Panel', collaborated actively in the process. The Central Works Council and the Supervisory Board were also heavily involved.

The authors would like to express sincere thanks to everyone, both within and outside TNO, who invested valuable time to help with this exercise. The strength and effectiveness of TNO's innovation lie precisely in the continuous search for dialogue, self-reflection and making connections.

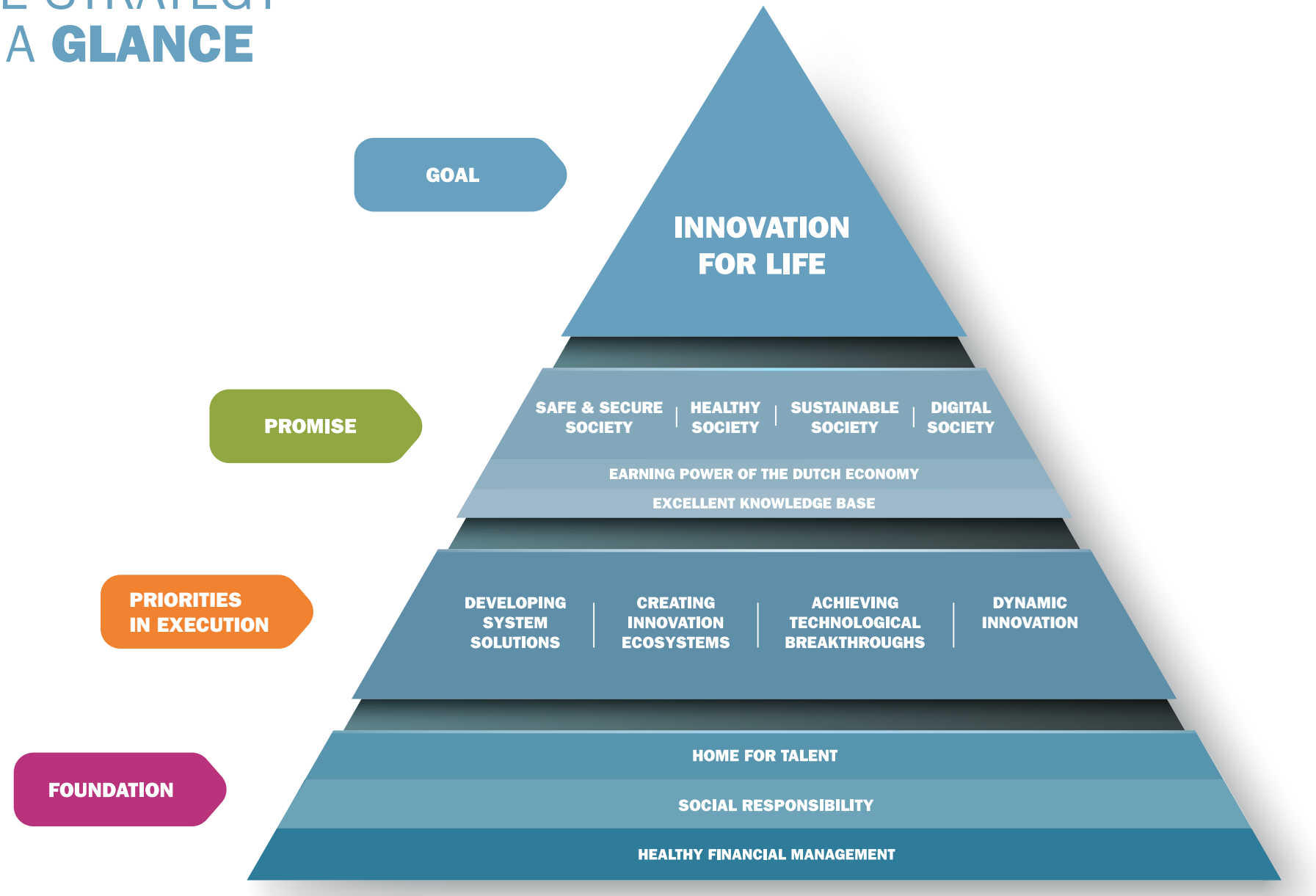
Structure of the plan

This strategic plan comprises four parts:

1) A description of TNO's goal, including its mission, vision on innovation and working method;
2) A description of TNO's promise, containing an overview of the challenges that TNO is prioritising and TNO's contribution to the related solutions, the choices that TNO makes in the knowledge base and the way in which TNO ensures that its impact is demonstrable;
3) A description of four priorities in execution for the coming period.
4) A description of the foundation of TNO, focusing on our talent and the organisational and financial prerequisites.

The first part is preceded by a summary and the document ends with a number of appendices that elaborate further on the ambitions.

THE STRATEGY AT A **GLANCE**



PROFILE OF TNO

ROLES

1) Researcher
2) Systems Integrator
3) Innovator
4) Orchestrator
5) Independent Advisor
6) 'Home laboratory'

VISION ON INNOVATION

T- Shape: In-depth knowledge combined with broad innovative skills and linking in networks with results for the overall environment.

FORMS OF RESEARCH

1) Early Research Programs
2) Shared Research
3) Contract Research
4) Technology Transfer

MAIN TASKS

1) Developing, applying and disseminating knowledge for the purpose of resolving societal issues and supporting governmental (statutory) tasks and policy.

2) Developing, applying and disseminating knowledge to enhance the innovative strength and competitive position of the Netherlands, in particular for the 'top sectors'.

3) Managing strategic research facilities, some of which are unique in the Netherlands or even internationally.

THE STRATEGY AT A GLANCE

The TNO strategy 2022-2025 continues the course TNO has pursued over recent years, but it focuses more strongly on a number of subjects:

- The strategy is more strongly driven by TNO's goal and mission;
- It centres on four societal challenges: Safe & Secure Society, Healthy Society, Sustainable Society and Digital Society. The theme of the 'Sustainable Society' is addressed more broadly and more comprehensively than in the past and the 'Digital Society' is explicitly included, given the huge impact of digitalisation and its power to bring about change.
- Explicitly linking these four societal challenges to the strengthening of the Dutch economy, based on the conviction that they will reinforce each other.
- As a basis for everything that TNO does – and in particular its national advisory function and statutory duties – the maintenance of an excellent knowledge base.

TNO's specific distinctive ability to address these challenges lies in:

- Developing system solutions: addressing together the issues of technology, earning power, government regulation and the role of citizens; strengthening competences such as a systems approach, integration and multidisciplinarity; and expanding international partnerships based on complementary technology.
- Creating innovation ecosystems: with a focus on competences in the area of orchestrating innovation and social innovation, and a strong, stakeholder-oriented approach (stakeholder intimacy).
- Achieving technological breakthroughs: scouting for new technology, doing excellent research, more explicitly identifying the importance of Key Enabling Methodologies in addition to Key Enabling Technologies, and intensifying collaboration with universities.
- Dynamic innovation: examples are different business models for different clients, accelerated development of business intelligence based on internal and external data, and – if opportune – more short-cycle innovation.

In relation to the foundation underlying our organisation, the most important addition is that we have greatly strengthened the importance of diversity, inclusiveness and Corporate Social Responsibility. An important consideration continues to be healthy financial management.

1. SUMMARY

TNO innovation for life

1.1 THE STORY OF TNO

INNOVATION FOR LIFE

We are TNO, an independent research organisation. We have been applying knowledge to serve the public interest since 1932. It is our task to give the right answers – and to ask the right questions. For a life that is safer and more secure, healthier, and more sustainable. For a digitally connected society. For a strong economy. We think ahead. About cars that clear up traffic jams and algorithms that detect diseases. About the beginning of the quantum era and the end of fossil energy. We are front-runners in a world that is changing ever faster. By combining disciplines and domains, we can take on the most complex questions. TNO is the flywheel of innovation. We bring together ideas and ideals. As we work towards solutions, we connect policymakers, entrepreneurs, scientists and citizens. We share amazement and ingenuity. We are driven to push the boundaries. Because with every innovation, we contribute to a better life.

CONTRIBUTING TO SOCIETY, THE ECONOMY AND THE KNOWLEDGE BASE

The Netherlands is facing major and urgent societal challenges. These include challenges in the area of safety & security, such as safeguarding our sovereignty and security – including cyber-security – in a multipolar world order; challenges in the area of health, such as the transition from treatment-based to preventive healthcare; challenges in the area of sustainability, including sustainable energy provision, the circular use of materials and natural resources, and zero-emission mobility; and challenges in the area of digitalisation, such as ICT technology that respects public values and fundamental rights, creates a global level playing field and safeguards national security.

The complexity of these four major challenges – and therefore also the complexity of the possible solutions – is increasing. Solutions require technological feasibility, affordability, government regulation and acceptance by the general public, all at the same time. New Key Enabling Technologies and Methodologies are needed to deal with this complexity and tackle the societal challenges effectively. TNO takes the view that the earning power of the Dutch economy is inextricably linked with – and focused on – these challenges. After all, with their products and services, companies help to create a safe, secure, healthy, sustainable and digitally connected society.

Thanks to its unique and distinctive knowledge base, TNO makes its crucial contribution. In a number of key areas of public research, such as Defence and the Geological Survey of the Netherlands, TNO has the (statutory) duty to maintain, strengthen and/or renew the knowledge base for the government.

THE ORGANISATION WANTS TO **EXCEL** BY PUTTING FORWARD **EFFECTIVE SOLUTIONS** TO **SOCIETAL** CHALLENGES

COOPERATION IN EUROPE

Major societal challenges such as the energy transition and climate change go beyond national borders and can only be faced effectively through European policy and cooperation. Therefore, it is also essential for applied knowledge institutions in Europe to join forces in order to create maximum impact. In addition, companies that operate internationally need innovation platforms that work across borders. To respond rapidly to the EU's agenda and strengthen its position at the heart of the European knowledge and innovation system, TNO needs to be firmly committed to international cooperation. In the light of Brexit, the relationship with France and Germany is especially important. Although TNO's strategic focus is on the Netherlands and Europe, relationships with the United States and with innovative countries such as South Korea continue to be of great value. In recent times, the foundations have been laid for partnerships, for example in the area of defence, with Canada, Sweden, the United Kingdom, Norway and the US.

CREATING IMPACT

Creating impact: this is what drives TNO. TNO must put its ideas and concepts into practice, visibly and demonstrably. The organisation wants to excel by putting forward effective solutions to societal challenges. For example, a rapid coronavirus test, applying Artificial Intelligence in tracking down hard-to-find offenders or developing instruments that can measure air quality from space. An enterprising government that gives direction is needed if we are to create the solutions to complex societal problems. TNO has played an active role in drawing up the Mission-driven Top sectors and Innovation Policy [Missiegedreven Topsectoren- en Innovatiebeleid] (MTIB). At the same time, TNO wants to strengthen the economy and the earning power of the Netherlands by working with the business community to develop innovations that support the MTIB and speed up its progress. This can be achieved by setting up new companies or making existing companies more competitive. In TNO's vision, close cooperation with the business community is crucial for dealing with the challenges that society is facing.

1.2 PRIORITIES IN EXECUTION: AGENT OF CHANGE IN THE NETHERLANDS

DEVELOPING SYSTEM SOLUTIONS

The complexity of challenges in society today calls for integrated solutions at the system level. The energy transition requires not only technologies that have to be incorporated into the energy system, but also changes in raw material supply chains, new business models and societal integration. And today's solutions for the energy transition must not be allowed to create new challenges in the future, for example affecting people's quality of life. The ingredients for successful solutions are factual information, models that identify consequences, creativity and good connections with all stakeholders, including individual citizens. These should all be developed as a coherent whole, which calls for a new and different type of change agent: systems thinkers, people who take a systems approach.

Such thinkers are able to combine and integrate relevant scientific disciplines, build national and international partnerships, and bring relevant public and private players together in new partnerships and value chains. In this way, societal interests and earning power are linked together, and well-being and prosperity are aligned with each other. TNO is uniquely positioned and uniquely equipped to be the key systems thinker of the Netherlands. Like no other organisation, it has the independence, multidisciplinary research talent, breadth of its fields of activity, versatile facilities and solution-driven culture to achieve that position. With its focus on systems innovation, TNO is the obvious partner for public authorities, industry and knowledge institutions.

At the core of the strategy is the ambition to implement this systems approach in every fibre of TNO, developing from product innovation to systems innovation, from multidisciplinary to transdisciplinary, and from research to thought leadership. TNO aspires to be the agent of change of the Netherlands.

CREATING INNOVATION ECOSYSTEMS

Innovation requires more than just knowledge development. It takes place in innovation ecosystems: clusters of companies, public authorities, organisations and knowledge institutions that collaborate to develop knowledge and to create new products and processes. Together with public authorities, companies and knowledge institutions, TNO aims to offer a solid base of experts with access to unique research facilities and relevant international networks.

IN ADDITION TO **TECHNOLOGICAL INNOVATION**, INNOVATION IN **METHODS** AND **PRACTICES**, AS WELL AS UNDERSTANDING **BEHAVIOUR** AND **SOCIAL CONTEXT**, ARE OF INCREASING **IMPORTANCE**

In this context, there will be particular emphasis on Small and Medium-sized Enterprises (SMEs) over the next few years. As the bulk of private R&D in the Netherlands is currently being carried out by a limited number of large companies, in particular in the high-tech sector, the necessary additional growth in private R&D spending will have to come mainly from SMEs or from new industrial activity and new sectors.

TNO's ambition is to increase its contribution to the innovative and competitive ability of SMEs. With the cutting-edge proposition 'TNO-SME Innovation Engine' [TNO-mkb Innovatiemotor], TNO wishes to serve a larger proportion of SMEs.

ACHIEVING TECHNOLOGICAL BREAKTHROUGHS

The Netherlands holds a strong position in the area of Key Enabling Technologies and it should therefore focus on all such technologies. At the level of underlying technologies, there are choices to be made between technologies that differ as to the amount of value that can potentially be created.

TNO also makes these choices, based on innovations that are necessary to address societal challenges effectively and to respond accurately to the needs of its partners and clients. In the strategy period, there will be a particular focus on the further development and application of: photonics; quantum technologies; digital, nano, chemical and life science technologies; engineering and manufacturing technologies; advanced materials and the nine Research & Technology areas that are described in the Strategic Knowledge and Innovation Agenda of the Dutch Ministry of Defence.

In addition to technological innovation, innovation in methods and practices, as well as understanding behaviour and social context, are of increasing importance. The way in which innovations are introduced into society is decisive for their success. In the 2022-2025 strategy period, the development of these Key Enabling Methodologies will be deepened, expanded and accelerated. Focus areas are technology forecasting, data-driven road mapping, impact assessments (economic, social, legal and/or ethical) and integrated models that take into account both the technological and the social and behavioural aspects of societal challenges. In addition, methodological knowledge in the area of orchestrating innovation will be developed, which is necessary to achieve the ambition of building effective innovation ecosystems.

Access to state-of-the-art facilities is essential in order to stay at the forefront of research. TNO will draw up a long-term facilities agenda to secure its position over the coming years. Where possible, facilities will be shared with partners. A condition for creating state-of-the-art facilities is the availability of structural funding from the government. The Evaluation Committee for Applied Research Organisations recommends that a fund be established for this purpose. TNO will make a case for this with the next government.

DYNAMIC INNOVATION

Innovation is traditionally seen as a linear process, from fundamental research, through applied research, to the actual development of products, services and policy. That world no longer exists. Innovation now often takes place in networks and ecosystems in which a number of players from the value chain are involved. An idea has to be developed, launched on the market and then further developed through experimenting, learning and adjusting. More than ever before, this calls for speed and entrepreneurship, new business models, and different ways of managing projects and organising. Operational processes, management and learning are becoming data-driven and further digitalised.

1.3 A SOLID FOUNDATION

TALENT TAKES CENTRE STAGE

TNO is as good as the sum of all the talents on its team. To achieve its ambitions, TNO first of all needs highly talented employees who are not satisfied with taking a back seat. It needs people who, together with partners and clients, want to determine the direction of research and decide on solutions. People who unerringly know which way the wind is blowing and who spot opportunities and seize them. People who want to have a visible and demonstrable impact and who are given all the space and resources they need to achieve this. These are people who think and act internationally, and focus on collaboration. They are given freedom to operate and they take responsibility. TNO aims to have a diverse and inclusive workforce. Not because it is politically desirable, but because it is the right thing to do, it makes the organisation better and also simply because it is much more enjoyable and informative to work in an environment with people from different backgrounds. Over the years to come, TNO will make additional efforts to promote diversity and inclusion.

A **SAFE**, **HEALTHY** AND **SUSTAINABLE** WORK ENVIRONMENT IS AN **ESSENTIAL** PREREQUISITE

SOCIAL RESPONSIBILITY

TNO's mission is to help create a better society through research and innovation. And of course, TNO is also pursuing this goal in its internal operational management ('practice what you preach'). In the 2022-2025 strategy period, TNO will take a further step in the area of Corporate Social Responsibility (CSR). As an important milestone in this ambition, TNO signed the United Nations' Global Compact (UNGC) in 2020. It will report annually on its progress in accordance with the UNGC guidelines.

A safe, healthy and sustainable work environment is an essential prerequisite for TNO's employees to perform to the best of their ability. In addition, TNO's partners and clients think it is important for the organisation to perform well with respect to safety, health and the environment (SHE). TNO's goal for the coming years is to reduce the number of safety-related incidents and increase significantly the number of preventive reports, with a higher percentage of incidents that are acted on correctly.

HEALTHY FINANCIAL MANAGEMENT

TNO's legal duty is to ensure the maintenance of an appropriate knowledge base infrastructure. This is only possible with a structurally healthy financial base and through effective operational management. In recent years, there has been a successful financial recovery from the 2008-2009 financial crisis. Additional funding from the national government played an important role in this from 2017. For the coming years, our ambition to obtain additional investment and ensure healthy operational management will be as strong as ever, with the aim of accelerating the progress of societal transitions.


We are **TNO**
and since 1932 it has
been our task to give the right
answers and to ask the right
questions. In this way we work to
create well-being and prosperity. For today
and the future. By combining disciplines and
domains, we can take on the most complex
questions. Our quest for solutions brings together
scientists, policymakers, entrepreneurs, individuals
and society as a whole to contribute to a better life
and a more attractive future.
DEVELOPING SYSTEM SOLUTIONS
CREATING INNOVATION ECOSYSTEMS
ACHIEVING TECHNOLOGICAL BREAKTHROUGHS
DYNAMIC INNOVATION
HOME FOR TALENT
SOCIAL RESPONSIBILITY

PART I

GOAL:
INNOVATION FOR LIFE

2.
THIS IS **TNO**

MISSION OF TNO

TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way.

2.1 SPIDER AT THE CENTRE OF THE INNOVATION WEB

TNO is the leading independent applied research organisation for the Netherlands. It is TNO's duty to develop solutions to major problems in society by translating knowledge into practical applications, while at the same time creating new employment and stimulating the economy.

TNO has the task of giving the right answers – and of asking the right questions: questions about the beginning of the quantum era as well as the end of fossil energy. By combining disciplines and domains, but also by involving policymakers, entrepreneurs, scientists, professionals and society, TNO can tackle the most complex questions.

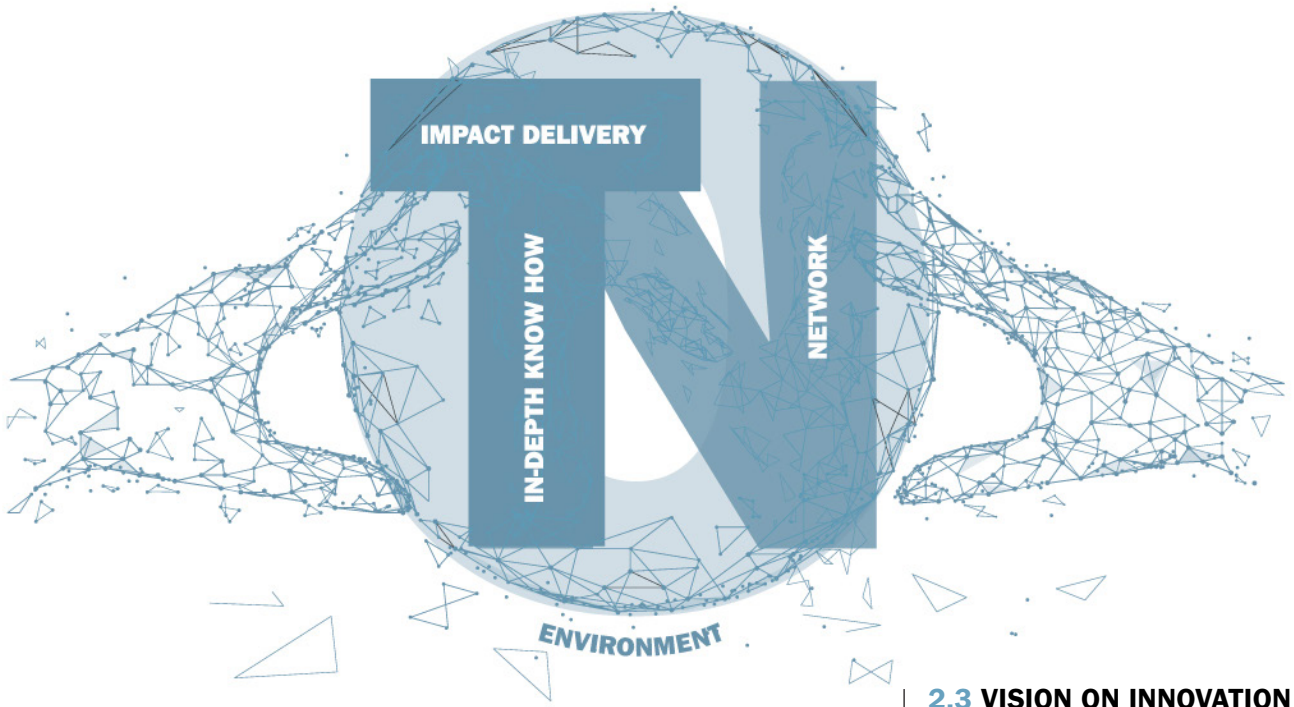
For the purpose of developing and applying knowledge, TNO receives government funding and carries out assignments for public and private parties.

2.2 SOCIETAL CHALLENGES AND THE EARNING POWER OF THE NETHERLANDS

TNO's agenda and programming are drawn up on the basis of national and international (European) policy; they result from close coordination with partners and clients or are based on statutory duties such as Defence Research and the Geological Survey of the Netherlands.

Working on societal challenges and strengthening the earning power of the Netherlands are often two sides of the same coin: sensors, models or tools that contribute to resolving societal issues can at the same time put Dutch industry in a position to commercialise products and services.

Part II of this strategic plan gives further details on the challenges that TNO is working on.



2.3 VISION ON INNOVATION

Innovation involves developing new products, processes and services that improve the quality of people's lives and create value for society and the economy. Dealing with the major societal challenges requires innovations that can only be achieved through collaboration in research and innovation ecosystems. There are roles in these ecosystems for public authorities, business and knowledge institutions (applied knowledge institutions, universities and universities of applied sciences). TNO brings parties together to tackle a specific challenge, with the aim of creating solutions by working together in an ecosystem ('orchestrating innovation'). To produce these solutions, connections need to be made between the different types of extensive specialist knowledge held by partners, as well as that of TNO itself. Major technological developments, for example in Key Enabling Technologies, social innovations and system transitions, take place contemporaneously and influence each other. This raises questions that TNO can look into from various perspectives, thanks to its multidisciplinary character. A systems approach and the integration of different applications at system level are becoming increasingly important[2].

TNO visualises its unique positioning using the letters that form its name. In the 'T', the vertical line stands for its deep knowledge and the horizontal bar for TNO's innovative skills and ability to link internal and external know-how and parties. Because innovation mostly takes place in networks (symbolised by the letter 'N') and must ultimately have an impact on the overall environment (the letter 'O'), TNO summarises its vision on innovation with the letters 'TNO'.

2. Systems integration can be described as the process of integration between links and players in value chains, between different technologies, between actors in the value chain and related sectors in the system, resolving bottlenecks and creating opportunities for new business models, products and services.

The three main tasks of an applied knowledge institution, as described in the Government Vision Document on Applied Research (2013)

1. **Developing, applying and disseminating knowledge for the purpose of resolving societal issues and supporting government tasks and policy. A proportion of this research comes under statutory tasks.**
2. **Developing, applying and disseminating knowledge to enhance the innovative strength and competitive position of the Netherlands, in particular for the 'top sectors'.**
3. **Managing strategic research facilities, some of which are unique in the Netherlands or even internationally.**

2.4 FORMS OF RESEARCH AND ROLES INVOLVED

TNO's role and position are embedded in the TNO Act[3]] and the Dutch Government's Vision Document on Applied Research[4]. The TNO Act stipulates that TNO has the task of deploying applied research for the public interest. The Government Vision Document on Applied Research lists three main tasks for applied knowledge institutions (see box).

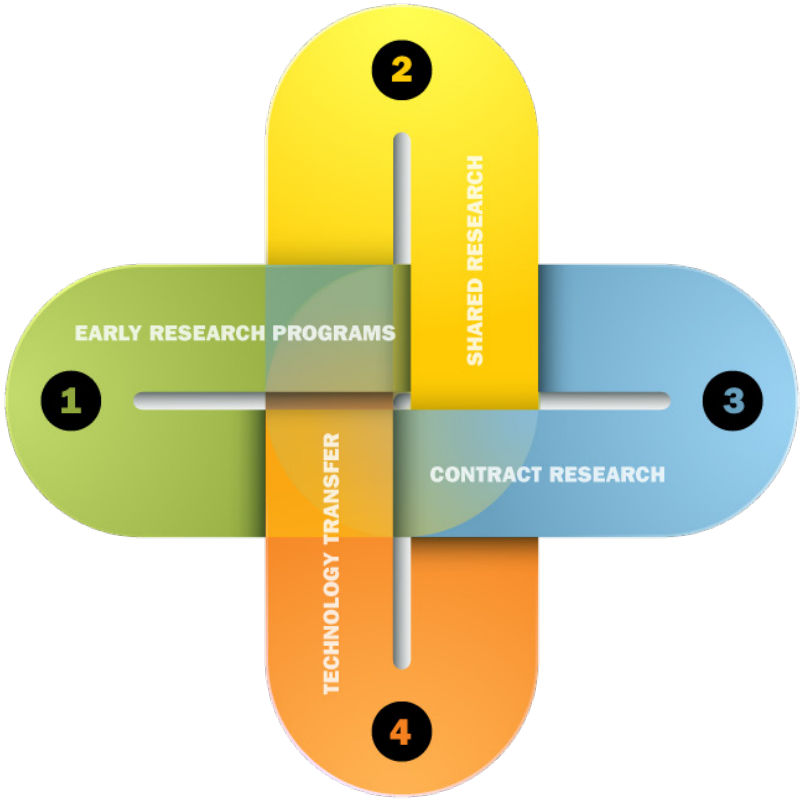
FUNDING

In order to carry out the main tasks listed above, TNO receives and seeks out funding from various sources:

- Institutional funding: funds made available by the national government (through the Ministry of Economic Affairs and Climate Policy as intermediating ministry) for developing, applying and disseminating knowledge for the purpose of resolving societal issues, giving support in relation to government tasks and policy, and enhancing the innovative strength and competitive position of the Netherlands.
- Programme funding: earmarked funds from various ministries. Each ministry involved indicates the topic or subject for which these funds should be used. An important and special part of this is the task-related funding for carrying out delegated knowledge-intensive, (statutory) public tasks for Defence and the Geological Survey of the Netherlands.
- Competitive funding: contributions from partners in collaborative projects that TNO wins on a competitive basis, such as EU projects and large-scale public-private collaborations. TNO matches these contributions with institutional funding and programme funding.
- Contract funding: fully external public or private funding for research, which TNO obtains by drafting proposals and winning contracts. The content of the contract is tailored to the customer, but with TNO remaining alert to the uniqueness of its contribution.

There is as yet no funding for the third main task (see text box) – managing strategic research facilities. TNO is lobbying for this funding, partly on the advice of the Evaluation Committee for Applied Research Organisations[5] and in close cooperation with its partners.

3. TNO Act, 19 December 1985.
4. Ministry of Economic Affairs and Climate Policy, Vision Document on Applied Research, 5 July 2013.
5. Evaluation Committee for Applied Research Organisations, final report on the partial evaluation of TNO, 2021, TNO Evaluation subcommittee TNO, led by A. Lundqvist.



PRINCIPAL FORMS OF RESEARCH

To carry out its tasks, TNO engages in four principal forms of research, which differ as to their objective, management, funding and legal form. The four principal forms are:

1) Early Research Programs (ERP): fundamental knowledge development to strengthen TNO's own knowledge base, funded from of a specific part of institutional funding;
2) Shared Research (public-private and public-public cooperation): knowledge development together with partners, funded from institutional and/or programme funding, as well as the competitive funding from partners[6];
3) Contract Research: research under contract to public or private clients and funded by those clients;
4) Technology Transfer: the transfer of technology to the market by granting licences and starting up new companies.

With these sources of funding – of which an average of 55% is obtained in competition – TNO is in a position to maintain and continually upgrade a high-quality public knowledge base for the Netherlands.

ROLES OF TNO

When carrying out the principal forms of research, TNO plays a number of different roles in the innovation landscape. TNO is a/an:

- Researcher and makes new discoveries;
- Systems Integrator, which combines various types of expertise within and outside TNO to produce a system solution;
- Innovator, which is able to match a client's problem to a technological solution;
- Orchestrator, which brings together parties and ambitions (such as missions) to produce innovations jointly;
- Independent Adviser, which advises public and private clients, drawing on in-depth knowledge;
- 'Home laboratory', in which the knowledge base is maintained, expanded and/or upgraded for the government in a number of important areas of public research.

6. Knowledge development in the context of the previously mentioned statutory public tasks is also classified as 'shared research'

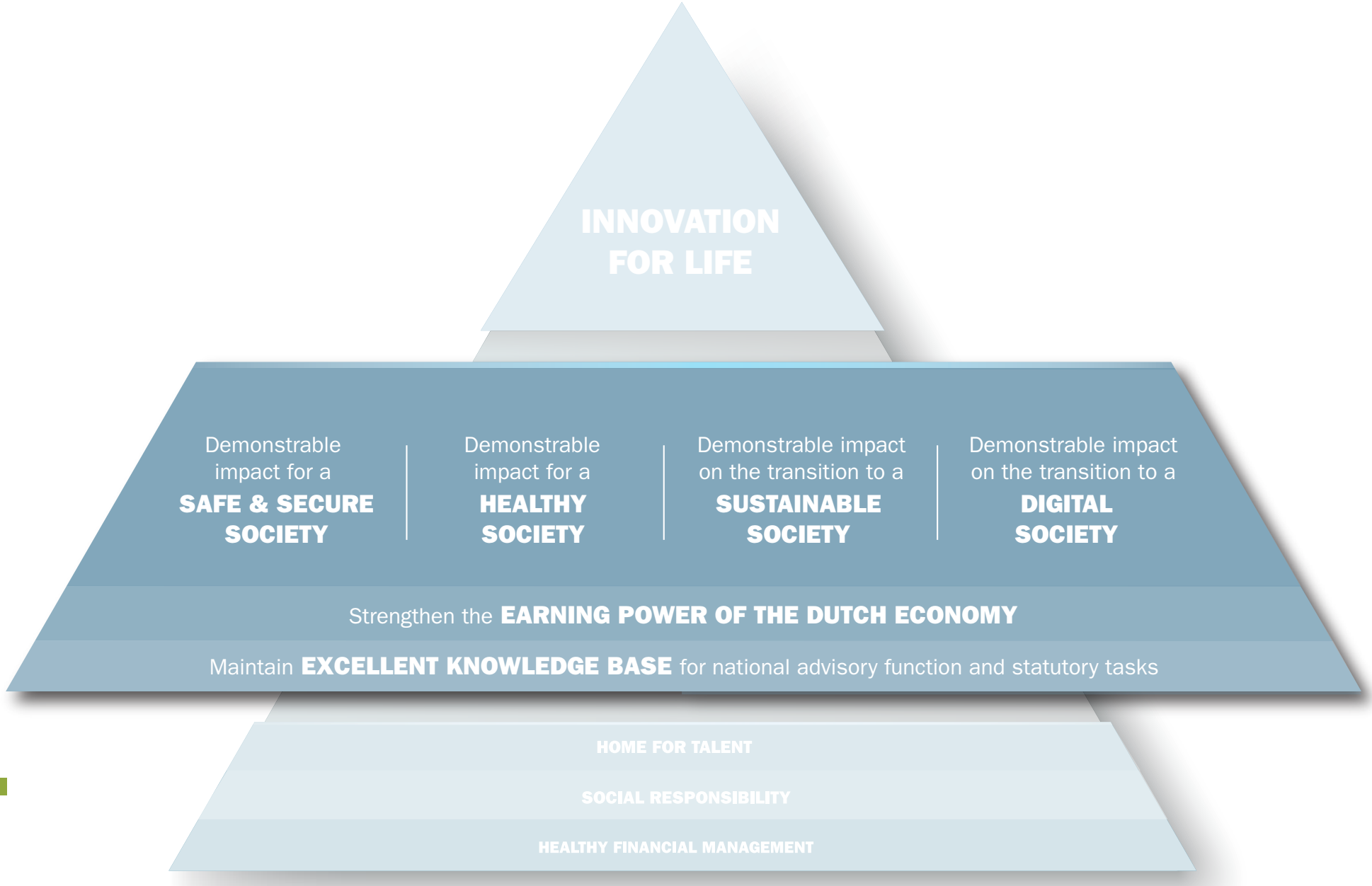
2.5 CORE VALUES OF TNO

There are four core values that determine how TNO employees should do their work. Integrity: e.g., all decision-making is based on information that is as accurate as possible. Independence: results are achieved without any inappropriate influence from commercial or other interests. Professionalism: professional conduct through the application of clearly-defined working processes within the limits set by time and money. And social commitment: TNO employees are aware of the role of their work in society. These four core values are further laid out in the 'TNO code'.

2.6 THE ORGANISATION

TNO is organised in nine units that correspond to different segments of the public and private sectors. It combines know-how from different units to arrive at integrated solutions for partners and clients.

The special strategic relationship with the Dutch Ministry of Defence and the Council for Defence Research's role in the governance of TNO's Defence, Safety & Security unit are enshrined in the TNO Act. The defence research at the Defence, Safety & Security unit is an integral part of TNO, but it has its own system for planning, budgeting and accountability.


INNOVATION FOR LIFE
Demonstrable impact for a SAFE & SECURE SOCIETY
Demonstrable impact for a HEALTHY SOCIETY
Demonstrable impact on the transition to a SUSTAINABLE SOCIETY
Demonstrable impact on the transition to a DIGITAL SOCIETY
Strengthen the EARNING POWER OF THE DUTCH ECONOMY
Maintain EXCELLENT KNOWLEDGE BASE for national advisory function and statutory tasks
HOME FOR TALENT
SOCIAL RESPONSIBILITY
HEALTHY FINANCIAL MANAGEMENT

PART II

PROMISE:
CONTRIBUTION TO **SOCIETY**, **ECONOMY** AND **KNOWLEDGE BASE**

3. BACKGROUND: CHALLENGES FACING THE NETHERLANDS

CREATING **LINKS** BETWEEN THE **INTERNATIONAL, NATIONAL** AND **REGIONAL** RESEARCH AGENDAS

3.1 CHALLENGES THAT TNO IS PRIORITISING

TNO staff work on today's challenges and tomorrow's solutions. The greatest challenges facing the world are described in the United Nations' Sustainable Development Goals (SDGs), the European Green and Digital ('Twin') Transition, Horizon Europe and agreements within NATO.

Since 2020, the national innovation agenda for the Netherlands, together with the specific policy agendas of the ministries, has been shaped in the Mission-driven Top sectors and Innovation Policy (MTIB). This builds on the experiences of top sector policy and – with the involvement of the ministries – it focuses on the economic opportunities presented by societal challenges and Key Enabling Technologies. Over the next strategy period, too, TNO wants to be a major player in the MTIB. Based on its portfolio, TNO will contribute to achieving its missions, further developing Key Enabling Technologies and creating links between the international, national and regional research agendas. TNO is highlighting four challenges in its research and innovation agenda:

1) A safe & secure society (section 4)
2) A healthy society (section 5)
3) A sustainable society (section 6)
4) A digital society (section 7)

Wherever possible, TNO relates these challenges to the earning power of the Dutch economy (section 8). TNO takes the view that the earning power of the Dutch economy is inextricably linked with – and focused on – these challenges. After all, with their products and services, companies help to create a safe & secure, healthy, sustainable and digitally connected society.

TNO is in a strong position to work on solutions to the major societal challenges, given its multidisciplinary composition, its unique expertise and experience (knowledge base, section 9), its position in the field of applied research in the Netherlands and the statutory duties that it performs for various ministries in a number of areas.

OUR **PORTFOLIO** IS IN CONTINUOUS **DEVELOPMENT**

3.2 TNO'S RESEARCH PROGRAMMING

TNO manages the strategic programming of its research through a portfolio of roadmaps. Roadmaps show the knowledge (technological and methodological) that is being developed, the impact that TNO expects to achieve with that knowledge and the mix of funding sources necessary for this work.

Each of the challenges described in 3.1 is the subject of a section in this part of the document. Each section describes the nature of the challenge, TNO's ambition, the substance of the solutions that TNO is working on and the roadmaps on which these efforts are based. The roadmaps are described in more detail in the appendix.

External dynamics mean that TNO's roadmaps also have to be sufficiently dynamic. This means our portfolio is in continuous development. Over the next few years, TNO will intensify its efforts on a number of topics by investing more of its government funding in those areas (within the existing possibilities). These topics are:

- The new Transitions & Transformations roadmap: focus on solutions to dependencies between various societal transitions. The various societal transitions influence each other. Developing know-how for dealing with this is an essential condition for addressing these transitions effectively.
- The growth of the Environment & Sustainability roadmap: focus on solutions for creating a circular economy and support for government and the business community. Circularity is key to making society more sustainable. TNO wants to expand its contribution on this point, in line with growing interest from outside.
- Strengthening Smart Industry: digitalisation of the Dutch manufacturing industry (including SMEs). Digitalisation of the manufacturing industry is a key element in ensuring that the economy remains strong into the future. TNO is organising its existing activities in this area in a separate roadmap and intensifying them.

In addition, TNO is using its own financial reserves to invest in a number of topics, beyond the various roadmaps. These topics are:

- TNO SME Innovation Engine [TNO mkb Innovatiemotor]: building networks and jointly developing and transferring knowledge, with a specific focus on SMEs. The further growth that is needed in private investment in research and innovation in the Netherlands has to come from the 'robust mid-market sector' of small and medium-sized enterprises. TNO is making a contribution to this through extra investment in cooperation with the SME sector.
- Brains4X: short-cycle innovation targeting urgent societal issues, such as the COVID-19 crisis and the nitrogen problem. In 2020, TNO implemented the Brains4corona programme, in which it used the breadth of its knowledge to develop, together with external partners, concrete, immediately applicable solutions such as the LAMP test, to help provide solutions to the COVID-19 crisis. TNO will pursue this approach further in the coming years, focused on other urgent societal problems.
- International collaboration, with the focus on Europe, for example collaboration with Fraunhofer and CEA. The challenges that the Netherlands is facing do not stop at its borders and the know-how needed to find the necessary solutions could come from anywhere in the world. For this reason, over the next strategy period TNO will be concentrating more strongly on international collaboration, in particular with institutes in our neighbouring countries, to develop the solutions of the future together.

4.
SAFE & SECURE SOCIETY

PRESERVING OUR **SAFETY** AND **SECURITY** IS **ESSENTIAL** TO OUR **FREEDOM**, **WELFARE**, **WELL-BEING** AND **DEMOCRACY**

LONG-TERM GOAL

TNO makes a demonstrable contribution to preserving, protecting and developing strategic knowledge, technology and capabilities, to protect what we hold dear and ensure that people can live together in freedom and security.

The Netherlands is a safe and secure country. Preserving our safety and security is essential to our freedom, welfare, well-being and democracy. It is clear from current geopolitical developments that security cannot be taken for granted. The centre of power – economic and otherwise – is shifting from the West to Asia and 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), giving rise to new threats to security.

Europe and the Netherlands have become more vulnerable; they have to secure their own interests and guard their strategic autonomy. They increasingly have to rely on themselves for their security. There are a number of actors trying to undermine our Western democracy, both militarily and in the areas of the economy, politics, the judiciary and information. Threats to our security are growing in complexity, because everything is interconnected through technology. Dependence on high-performance technology is increasing, including dependence on non-Dutch suppliers.

Countries such as China and Russia are becoming more assertive, building up and modernising their armed forces and challenging the existing world order. In cyberspace, we are seeing a race between countries, but also between governments and non-state actors, including criminal organisations, private military companies and religious groups. Non-state actors are taking on an ever-greater role on the international stage, partly due to their links to state actors.

In addition to the changing geopolitical situation, we are living in a world that is increasingly interconnected, which brings risks on various levels. The changing climate will threaten the stability of our society with increasing frequency, through extreme weather in our own country or due to environmental damage and growing scarcity elsewhere in the world. The COVID-19 pandemic has shown that health risks from other countries can spread with lightning speed to become a national threat here.

All these dangers generally first affect defence, the police and other public justice and security organisations, as well as the professionals who work there. TNO's primary aim is to give military and security professionals a head start by developing and applying relevant know-how and technology.

TNO'S AMBITION

Together with its partners, TNO creates solutions to the complex safety & security challenges of today – and of the future.

DEFENCE

New threats in our environment, combined with the emergence of cutting-edge technologies, force us to make a continuous effort to stay ahead of our current and potential adversaries. For this reason, TNO carries out internationally distinguished applied scientific research in the field of defence and is the strategic knowledge and innovation partner of the Ministry of Defence. TNO has the statutory task of maintaining the Ministry of Defence's defence-specific knowledge base, which it does on the basis of demand management. TNO's unique combination of varied expertise, state-of-the-art facilities and its knowledge and market network enable military forces and judicial and security professionals to excel on the frontline. A separate TNO task is to represent the Ministry of Defence in international Science & Technology cooperation. This takes place in bilateral and trilateral cooperative partnerships, for example with Germany, Norway and the US, as well as in the joint defence research programme of the NATO member states.

By performing its statutory task and carrying out assignments, TNO supports the Dutch Ministry of Defence with activities that are developed in three roadmaps that focus specifically on defence: Operations & Human Factors, Information & Sensor Systems and Protection, Munitions & Weapons. Additionally, significant contributions are made to defence research on the basis of various other roadmaps, such as National Security, Digital Innovations, Space & Scientific Instrumentation, Prevention & Productivity and Renewable Electricity.

In the context of a long-lasting strategic relationship with TNO, the Ministry of Defence invests substantially in research for knowledge-building (research) and technology development (technology), as well as in knowledge application and use, for example in equipment-related projects. Knowledge is accumulated through multi-annual research programmes and the funding of research facilities. TNO maintains a large part of the defence-specific knowledge base for the Ministry of Defence. This knowledge base comprises nine areas of research and technology,[7] and focuses on knowledge that cannot be obtained on the market due to market failure or secrecy and that is essential for organising defence and carrying out defence tasks. Knowledge is necessary:

- For developing and acquiring capabilities and services, including the assessment of the quality and applicability of products and services to be purchased elsewhere;
- To be able to integrate new components into the military capability portfolio;
- To be able to support military doctrine, together with deployments and exercises, and the evaluation thereof;
- To gain access at international level to knowledge accumulated elsewhere.

7. The nine areas of research & technology of the Ministry of Defence are: 1. Cyber & Electronic Warfare; 2. Sensors; 3. Weapons systems; 4. Platform systems; 5. Command & Control (C2); 6. Protection; 7. Human performance, people & training; 8. Autonomous & unmanned systems; 9. Key Enabling Technologies.

NATIONAL **SECURITY** AND A CERTAIN DEGREE OF STRATEGIC **AUTONOMY** ARE CLOSELY **LINKED** TO **PROTECTING** AND DEVELOPING **CRITICAL TECHNOLOGIES**

This is essential for retaining technologically high-quality and operationally relevant armed forces over the long term. Even with the increasing use of civilian innovations for military applications ('dual-use' and short-cycle innovation), the emergence of 'open' innovation and stronger international collaboration, defence-specific knowledge remains indispensable. And its importance is increasing under the pressure of the geopolitical developments outlined above. National security and a certain degree of strategic autonomy are closely linked to protecting and developing critical technologies.

Guidance for the 2022-2025 period is provided by the Defence Vision 2035, the Defence Industry Strategy (DIS) and the Strategic Knowledge and Innovation Agenda (SKIA) 2021-2025 of the Dutch Ministry of Defence. The Medium-term Plan approved by the Council for Defence Research describes the policy for defence research carried out within TNO. The ambition, objectives and milestones of the Medium-term Plan are reflected in the roadmaps of the Defence, Safety & Security unit and the defence research carried out in other units. Based on international agreements, we can observe an increased political willingness to invest in defence. TNO takes into account the fact that it will be providing extra support to the Ministry of Defence in view of this expected growth.

The defence research and technological development at TNO also contribute to the economic earning power of the Netherlands. In many cases, defence firms (OEMs and SMEs) benefit from knowledge and technology that TNO has developed for the Ministry of Defence. Furthermore, the Ministry of Defence and TNO collaborate within the Defence Industry Strategy, the Mission-driven top sectors and Innovation Policy (the Knowledge and Innovation Agenda for Security), the National Growth Fund and the European Defence Fund, often with the involvement of other public and private parties. TNO actively seeks synergy between knowledge development for the Ministry of Defence and knowledge development that is covered by other government funding. TNO is also taking into account growth in defence over the next few years and corresponding growth in the demand for support from the Ministry of Defence.

TNO WANTS TO **BECOME** THE **LEADING INSTITUTE** FOR APPLIED **TECHNOLOGICAL INNOVATION** IN THE FIELD OF **JUSTICE** AND **SECURITY** IN THE NETHERLANDS

JUSTICE AND SECURITY

Justice and security are an essential prerequisite for a healthy and sustainable society and a flourishing economy. TNO therefore works together with justice and security organisations for a just, safe and secure society. They develop and use scientific knowledge and technology to enhance security – both physical and digital.

TNO wants to become the leading institute for applied technological innovation in the field of justice and security in the Netherlands. To this end, TNO engages in strategic collaboration with the Ministry of Justice and Security, the National Police and related organisations, including executive organisations such as the Custodial Institutions Agency, the Safety Regions and the Public Prosecution Service. The National Security roadmap is primarily focused on this work. In addition, various other units contribute to research in the area of national security, based specifically on the Digital Innovations roadmap.

Research in the national security domain focuses specifically on combating subversive activities with undermining effects and cybercrime; controlling the borders and limiting the threat of terrorism; preparing for and managing major crises that disrupt society, such as the COVID-19 pandemic; strengthening the intelligence function; and supporting and improving security professionals, so that their work can be done better and more efficiently, with fewer people.

In the 2022-2025 period, TNO will be guided by the National Security Strategy, the Strategic Environment 2020 [Strategisch Omgevingsbeeld 2020] of the Dutch Ministry of Justice and Security, the strategic compass of the National Police and their Innovation Agenda. Also of importance are the missions based on the ‘security’ topic of the Dutch Mission-driven Top sectors and Innovation Policy.

WORKING FOR THIRD PARTIES IN THE AREA OF SECURITY

In addition to the close collaboration with the above-mentioned strategic partners, TNO, in consultation with those partners, works closely with the national and international defence and security industry, foreign governments and international organisations, as well as with knowledge institutions, government laboratories and universities.

5. HEALTHY SOCIETY

LONG-TERM GOAL

TNO wants to contribute demonstrably to reaching the goal that by 2040, all residents of the Netherlands will live a healthy life for at least five years longer, while the health gap between the lowest and highest economic groups will have been reduced by 30%. (Source: MTIB)

Nearly 20% of forty-year-olds and 90% of 80-year-olds in the Netherlands[8] have a chronic condition. This is a major cause of constantly rising healthcare costs, which already account for 13% of GDP. Fighting chronic diseases requires innovation and a rapid transition to a fundamentally innovative approach to health and healthcare. At the same time, there is a need to emphasise maintaining health and preventing the disease burden and associated costs. And there should be a focus on the living environment – a factor that has a significant influence on our health. The World Health Organisation states that healthier living environments can prevent nearly a quarter of the disease burden worldwide.

The challenges require urgent action. In recent years, problems relating to health and a healthy living environment have resulted in parts of the economy stagnating. To address these challenges, the Dutch government – with the Ministry of Health, Welfare and Sport, and the Ministry of Social Affairs and Employment playing a leading role – has formulated a number of missions. The aim is that by 2040, all residents of the Netherlands will live a healthy life for at least five years longer, while the health gap between the lowest and highest economic groups will have been reduced by 30%. The missions focus on a healthy start for everyone, among other themes. Key priorities are lifestyle, the living environment, the right – possibly personalised – care in the right place, and participation by people with a chronic condition.

8. Vektis, Fact Sheet on Chronic conditions in people aged over forty, 2019 . Examples are cardiovascular diseases, cancer, diabetes, COPD/asthma and dementia/Parkinson.

TNO'S AMBITION

TNO aims to improve the physical and mental health of individuals and to organise the work and living environment in a way that promotes good health. Priorities are:

- Effective prevention and behavioural intervention: Disease prevention has to start early in life (even before birth) and continue until death in order to obtain maximum health benefits, limit the rising costs of healthcare and sustainably promote well-being and participation, including economic participation. TNO's intended impact is to make a demonstrable contribution to maintaining health and halving the burden on society and the economy of chronic and non-chronic diseases related to a person's lifestyle and working style.
- Personalised (possibly digital) health and lifestyle interventions: Personalised prevention, treatments and support, including digital support, must become the norm. Every individual is unique as regards their physiological and genetic background, mental health and social context. TNO develops customised technological solutions and frameworks that bridge the gap between medical care data and health data generated by the individual (e.g., the exposome and 'digital health twins'). TNO additionally focuses on AI and other models for bringing together data from these sources to produce personal and comprehensible recommendations. This enables companies to offer health-promoting products and services directly to consumers, with a view to ethics and privacy.
- Faster, better and cheaper drug development: Drugs need to be developed faster, better and more cheaply, to guarantee all people access to treatment, while at the same time keeping healthcare affordable. For this purpose, TNO develops technologies and models – both preclinical and clinical – and ensures that these bring added value to pharmaceutical and biotechnology companies. TNO also develops methods for performing clinical trials in a home setting, which has become even more relevant due to the COVID-19 crisis.

TNO HELPS TO CREATE A **HEALTHY** WORK ENVIRONMENT WITH **'SAFE-BY-DESIGN' SOLUTIONS, INNOVATIONS** FOR **PREDICTING** AND **REGULATING** THE INDOOR CLIMATE ('PREDICTIVE TWINS'), **BEHAVIOURAL INTERVENTIONS** AND THE MODELLING OF **EFFECTS** ON **HEALTH**

- Healthy innovative work environment: Working for longer requires a work environment that helps employees to stay healthy and in which they can continue to develop during their working lives. A flexible labour market is also important, so as to meet the rapidly changing demand for new skills. TNO helps to create a healthy work environment with 'safe-by-design' solutions, innovations for predicting and regulating the indoor climate ('predictive twins'), behavioural interventions and the modelling of effects on health (exposome). Because there is a reciprocal relationship between health and participation, TNO is working towards an inclusive, sustainable and adaptive labour market. Inclusive technology that everyone can use plays an important role in this.
- A healthy living environment: Clean air and limited noise pollution are preconditions for good health. TNO contributes to improving conditions, for example with research on the indoor climate (healthy buildings); emission measurements and emission dispersion models; monitoring air quality from space; determining exposure; and interpreting the effect of exposure (exposome). TNO works with field labs where toxic substances are monitored and modelled to create a living environment that promotes good health.

The priority areas above primarily belong to the roadmaps Environment & Sustainability, Prevention & Productivity, Biomedical & Digital Health, Flexible & Free-form Products, Sustainable Traffic & Transport and Transitions & Transformations.

6. SUSTAINABLE SOCIETY

LONG-TERM GOAL

TNO contributes demonstrably to the objective of cutting Dutch greenhouse gas emissions by 49% by 2030, on the way to a 95% reduction in emissions by 2050 in relation to 1990 levels. (Source: MTIB)

Over the past century, the welfare and well-being of the population has increased substantially. However, this now has consequences for the human living environment and the wider environment. Consequences such as climate change, the depletion of natural resources, soil subsidence, threats to biodiversity and the negative effects of these consequences on health. This produces complex challenges where different interests may be at odds with each other. Take, for example, land claims of industry, agriculture and mobility versus cutting nitrogen emissions; sustainable energy generation and house-building versus the preservation of the landscape; and the application of circular raw materials versus a competitive, 'low-cost' industry.

In a sustainable society, there is a balance between these interests. National and international priorities for creating a sustainable society are 1) reducing emissions of substances that harm humans and the environment, set out in – among others – the climate objectives of the Paris Agreement; 2) building a circular economy in order to make balanced choices about the use of raw materials; and 3) climate adaptation in order to be prepared for changes to our climate. These three priorities are linked. Solutions in sub-areas may reinforce each other, but may also be in conflict. The Dutch Ministries of Economic Affairs and Climate Policy, the Interior and Kingdom Relations, and Infrastructure and Water Management lead the way in setting the agenda for the Netherlands in this area.

TNO'S AMBITION

In the 2022-2025 strategy period, TNO will intensify its efforts and it wants to play a key role in the transition to a sustainable society – a transition that addresses the three priorities mentioned above. The guiding vision of the future is a society in which living, working, energy generation, industry, mobility and recreation are optimally integrated into the available space and resilient in the face of the changing climate. In the future, mobility systems will be reliable, safe, smart and sustainable. Buildings will have a sustainable energy supply and manageable maintenance. The energy system will be robust, accessible to all and sustainable. We will live in a world without waste, where material chains are closed to avoid the depletion of primary raw materials. Industrial processes will be climate-neutral, without any greenhouse gas emissions. Finally, new business activities will emerge, which are for the benefit of 'people, planet and prosperity'.

In order to make real progress in dealing with this complex set of problems, it is crucial to search for integrated solutions at the system level: solutions that balance the changing needs of society, the environment and the economy.

KNOWLEDGE CENTRE FOR THE ENERGY TRANSITION

The plan to establish a 'Knowledge Centre for the Energy Transition' is an example of how TNO wants to use knowledge at the system level to meet the needs of policymakers and decision-makers for integrated know-how on the energy transition, by developing and sharing knowledge on the subject. The role of the knowledge centre is to identify, collect, integrate and provide access to knowledge and information that are needed to make well-founded choices in relation to the energy transition in the Netherlands.

TNO focuses on:

- Sustainable industry: In 2050, raw materials, products and processes in industry will be climate-neutral and at least 80% circular. Factories will use sustainably produced electricity, green gas and hydrogen to meet their energy needs.

  TNO develops technologies for producing this sustainable energy, which makes industrial production more energy-efficient, resulting in lower greenhouse gas emissions. For the chemical industry, TNO focuses on the use of renewable energy to produce heat, hydrogen and chemicals. TNO also works on the use of renewable raw materials, such as recycled products, biomass and CO2. TNO designs products that are easy to recycle and materials with a lower environmental footprint.

  The roadmaps CO2 Neutral Industry, Environment & Sustainability, Sustainable Chemical Industry, Maritime & Offshore and Transitions & Transformations concentrate on this topic.

- A sustainable living environment: In our living environment, demands related to living, working and mobility compete with each other and also with the environment, biodiversity and the economy. TNO's ambition is to improve liveability, now and in the future, anticipating the effects of climate change.

  TNO develops smart, sustainable technologies aimed at creating safe, secure and efficient mobility and logistics, without CO2 emissions. It also studies how material chains in the living environment (regions) can be closed as much as possible and the use of primary raw materials can be avoided. In addition, TNO develops concepts for energy-neutral, healthy, safe and secure buildings with sustainable heating (geothermal energy and heat networks). TNO also creates monitoring systems and models for pre dicting pressure on the road network in various scenarios: for circular, safe and secure infrastructure with manageable maintenance and for identifying current and future pressures on the environment and the climate. TNO studies the possible effects of climate change on buildings, infrastructure and existing and planned facilities.

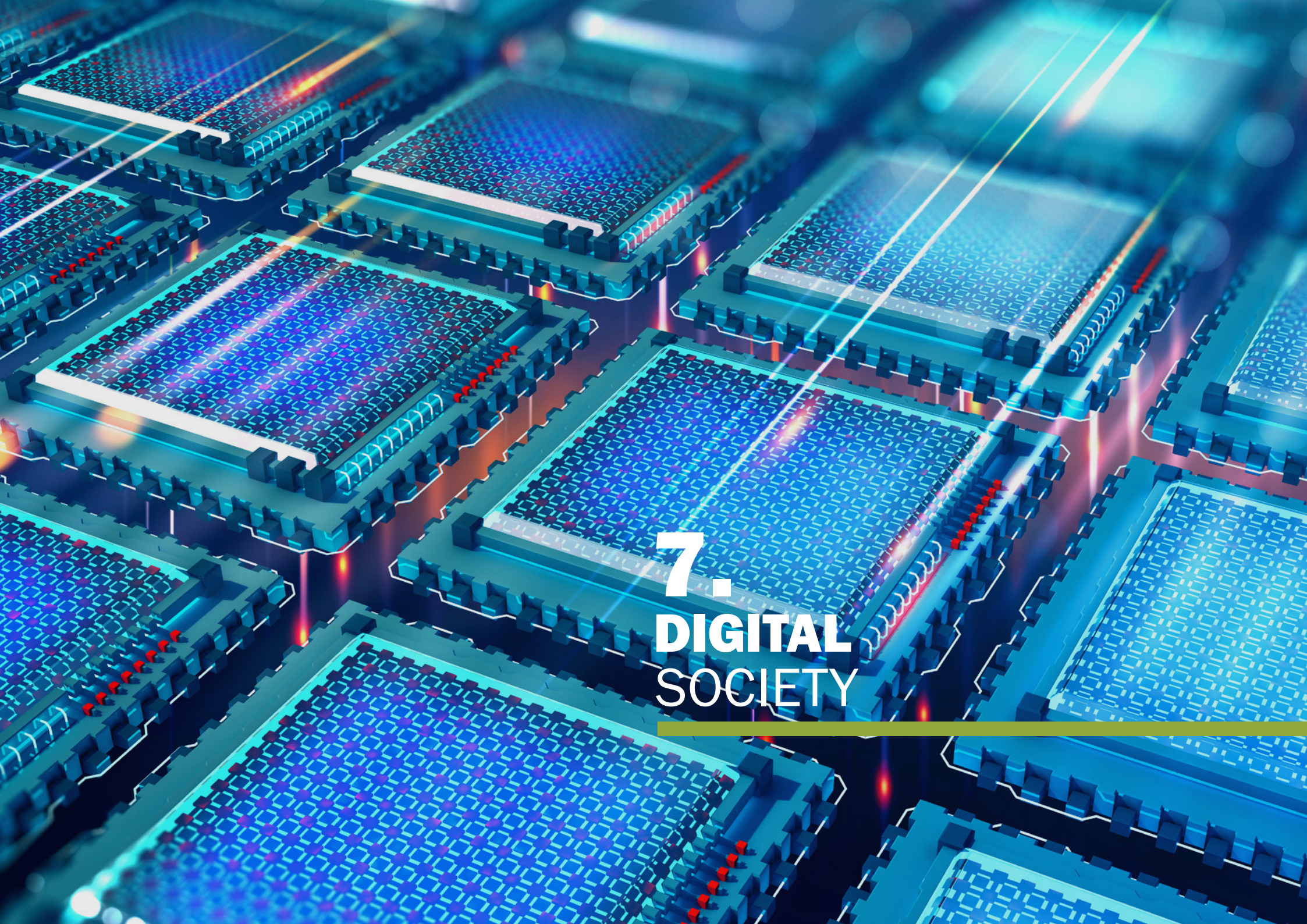
  The roadmaps Environment & Sustainability, Buildings & Infrastructure, Space & Scientific Instrumentation, Sustainable Subsurface, Transitions & Transformations, Renewable Electricity, Smart and Safe Traffic & Transport and Sustainable Traffic & Transport focus on this area.

TNO AIMS FOR **SOLUTIONS** THAT **BALANCE** THE **CHANGING NEEDS** OF **SOCIETY,** THE **ENVIRONMENT** AND THE **ECONOMY**

- Sustainable energy supply: To curb further climate change, it is crucial to accelerate the transition to an emission-free energy supply. TNO focuses on the innovative mix of technological solutions that make this possible. This includes generating energy from the sun, the wind, biomass and geothermal technology, but also developing clean energy carriers, such as green hydrogen. Technologies for energy storage and a reliable energy infrastructure are also of great interest. TNO also develops concepts for a reliable, accessible and sustainable energy system.

  The roadmaps Renewable Electricity, Sustainable Subsurface and System Transition focus on this area of expertise.

TNO carries out socio-economic and behavioural science research on the three focus areas above. Knowledge of the needs and interests of current and future users is crucial to developing technology and support for the transition to a sustainable society. TNO creates new business models and decision-supporting knowledge and systems models to facilitate decision-making on competing demands in the living environment, for example in the area of spatial planning. In addition, TNO works on innovation in the labour market, to ensure that there will continue to be enough well-trained professionals to make the energy transition a reality.



7. DIGITAL SOCIETY

DIGITALISATION PROVIDES OPPORTUNITIES FOR IMPROVING **WELL-BEING** AND **INCREASING PROSPERITY**, BUT IT IS ALSO A SOURCE OF **CHALLENGES**

LONG-TERM GOAL

TNO contributes demonstrably to the ambition of making the Netherlands the digital leader of Europe. (Source: Nederland Digitaal, Ministry of Economic Affairs and Climate Policy)

Digitalisation is having a profound effect on society. Developments such as the emergence of artificial intelligence or the robotisation of industry are changing the way people live, work and learn. Digitalisation also has an impact on societal issues such as social inequality, security or the way the country is run.

It provides opportunities for improving well-being and increasing prosperity, but it is also a source of challenges. The Netherlands faces the task of facilitating the opportunities and tackling the challenges. The priorities in the Netherlands, as formulated in the 'Dutch Digitalisation Strategy 2020',[9] concern:

1) The responsible use of data and systems, and the safeguarding of European and Dutch fundamental rights and public values, such as privacy, digital security and care in the use of new digital technologies;
2) Inclusivity: everyone must be able to participate;
3) Fair competition, digital sovereignty and digital security, healthy competition – a level playing field of large and small companies in a global arena – and the development of a leading position in innovation.

In addition, the Netherlands occupies a key position in the worldwide high-tech and semiconductor industry. Dutch multinationals and SMEs are among the leaders in their areas of expertise. These companies and the ecosystems around them are a major driver for the Dutch economy. Similar ecosystems are formed around technologies such as artificial intelligence and the quantum computer. Here too, larger and smaller companies collaborate with knowledge institutions and the Dutch government, developing high-quality know-how that can be applied in many fields and used to deal with societal challenges. The Ministry of Economic Affairs and Climate Policy plays an important role as part of the Dutch government administration, but there is also overlap with the policy areas of the other ministries, such as Defence, Justice and Security, and the Interior and Kingdom Relations.

9. Ministry of Economic Affairs and Climate Policy, Dutch Digitalisation Strategy 2020, June 2020.

TNO'S AMBITION

TNO wants to contribute demonstrably to making the Netherlands the digital leader of Europe. This is important, because digital technology supports and accelerates all efforts to meet major innovation challenges and because the last decade has seen digital sovereignty become increasingly important for Europe and the Netherlands.

TNO develops ICT technology that respects public values and fundamental rights, creates a global level playing field and safeguards national security. TNO contributes to cyber security for public and private parties in the Netherlands. This will put the Netherlands in a position to achieve its societal goals while remaining competitive and prosperous.

TNO also wants to support its partners and clients in dealing with the digitalisation challenge by developing generic methods, techniques and tools that can be deployed in multiple domains and across sectors. This includes creating smart industry, digitalising SMEs, smart mobility, digital health technologies and support in developing the next generation of semiconductors and quantum computers.

It is precisely the combination of ICT technologies that ensures innovation. Fast, open infrastructures, combined with data sharing and AI-driven analyses – developed and applied in a secure and responsible manner – call for an approach that can cope with the ever-increasing complexity. TNO does this by developing and integrating the most important supporting ICT technologies from the Dutch and European digitalisation agendas.

DIGITAL TECHNOLOGY **SUPPORTS** AND **ACCELERATES** ALL **EFFORTS** TO MEET MAJOR **INNOVATION CHALLENGES**

Here, TNO focuses on five main topics:

- Fast, open infrastructures: The Netherlands has a strong ICT infrastructure that is used intensively. The hyper-connected society of the future depends on this strength. Further integration of ICT infrastructures and connections between and across domains will increase. An open and secure infrastructure, in which cloud services, for example, are made interoperable in a secure manner, is crucial for taking this next step.
- Data sharing: On the one hand, sharing data must be an autonomous process and secure, and on the other hand, everyone must be able to have control over his or her data. There are challenges concerning the multiple use of data, the quality of data, data reliability and data security.
- Trusted ICT: ICT services and infrastructure must be safe and reliable automatically, without human intervention. Examples are systems that can withstand cyber-attacks, but that also take account of privacy.
- Systems engineering: TNO is the most important supplier of structured methodologies and technology that enable its clients in high-tech and IT systems development to design and operate increasingly complex systems efficiently and effectively.
- Artificial intelligence: The goal is to use AI to tackle societal and economic challenges while complying with legislation – such as privacy laws – and ethics.

The roadmaps Digital Innovations, Semiconductor Equipment, Smart Industry and Smart and Safe Traffic & Transport focus on the above topics.

8. EARNING POWER OF THE DUTCH ECONOMY

It is crucial to strengthen the earning power of the Dutch economy in order to safeguard prosperity and well-being for future generations. Climate change, recovery from the COVID-19 crisis, the aging population, increasing instability around the world and other issues will require considerable investment in the coming years. At the same time, economic growth forecasts[10] for the Netherlands show that, in spite of a post-pandemic recovery, the economy is unlikely to grow at the same pace as in past years.

In its Growth strategy for the Netherlands over the long term[11], the Dutch government outlines a broad agenda aimed at strengthening the Dutch economy over the long term. Boosting productivity is at the top of this agenda. The government sees an important role for industry and its industrial policy focuses on 1) investing in growth markets; 2) digitalisation; 3) human capital; 4) raw materials and improving sustainability; and 5) conditions for attracting and retaining talent and business activity.

The applied research can make a major contribution to the Dutch growth strategy by developing and transferring technologies that help companies to boost their productivity, retain their licence to operate and contribute to overcoming societal challenges.

TNO'S AMBITION

TNO wants to be the top innovation partner for companies which, through their portfolio, help to deal with the major societal challenges by:

- Linking companies to societal challenges. On the one hand, by using companies' capabilities to develop and implement solutions. On the other hand, by helping companies to identify and seize opportunities and new markets that result from these solutions.
- Developing and applying Key Enabling Technologies and Methodologies, to boost labour productivity and enhance the competitiveness of companies based in the Netherlands.
- Developing innovations to strengthen the adaptive ability of the Dutch labour market, such as creating a uniform language of skills, or skills ontology, so that major transitions are better facilitated, labour market potential is optimally used and innovations find their way to market more quickly.
- Building and working in ecosystems (e.g., 'quantum valley', 'space valley') where knowledge parties, public authorities, and companies create innovations that will have an impact.

10. See, for example: CPB Netherlands Bureau for Economic Policy Analysis, Update of medium-term study 2022-2025, November 2020
11. Ministry of Economic Affairs and Climate Policy, Growth strategy for the Netherlands over the long term, 13 December 2019

TNO WANTS TO DELIVER PRACTICAL **SOLUTIONS** BOTH **FOR** AND **WITH SMES** MORE **QUICKLY**

- Together with SMEs, start-ups and scale-ups, developing concrete solutions based on the latest technologies and methodologies, helping them to digitalise their activities and supply chains, to become more efficient, more flexible and more resilient, as well as positioning them in large European programmes and emerging supply chains. Over the last period, TNO has set up 28 spin-offs, which currently have a cumulative value of more than 80 million euros and have created more than 200 new jobs. TNO will continue with this work. Furthermore, TNO wants to participate in investment funds, with the aim of tapping into additional investment capital for TNO spin-offs and by co-investing in spin-offs, thus making them more attractive to private investors.
- Developing knowledge and technology to increase the strategic autonomy of the Netherlands and Europe. Examples are European or Dutch alternatives in the areas of energy generation or reusing materials, or making value chains more flexible through automation and standards.

The activities mentioned above also require TNO and its partners and clients to innovate in their own ways of working. For example, TNO will apply other business models to work with start-ups and scale-ups, use various Key Enabling Methodologies to work in ecosystems and adopt a systems approach to involve the appropriate parties in the area of societal challenges.

SMALL AND MEDIUM-SIZED ENTERPRISES

Specifically for Small and Medium-sized Enterprises (SMEs), TNO will make additional efforts over the next few years to ease their access to TNO's high-quality expertise and thus increase the innovative strength of SMEs. TNO wants to deliver practical solutions both for and with SMEs more quickly. With a cutting-edge proposition – 'TNO-SME Innovation Engine' – TNO wishes to serve a larger proportion of SMEs. TNO's proposition comprises:

- Network building: TNO helps SMEs to forge links with innovation ecosystems and consortiums, and to make connections with large companies.
- Knowledge transfer: TNO helps SMEs to grow and to speed up the creation of new activities.
- Joint knowledge development: SMEs and TNO as partners in the joint development of innovations, for example in Top Consortia for Knowledge and Innovation (TKI) projects, by supplying use cases and as partners in field labs and pilot environments.

9.
EXCELLENT
KNOWLEDGE BASE

9.1 KNOWLEDGE BASE FOR STATUTORY AND OTHER PUBLIC TASKS

TNO is responsible for maintaining, enhancing and updating the knowledge base for the government in a number of important areas of public research. This task is partly laid down in law and concerns the following areas:

- Under the TNO Act, TNO is tasked with maintaining a defence-specific knowledge base for the Ministry of Defence.
- The Geological Survey of the Netherlands (part of TNO) is the knowledge centre for the subsurface of the Netherlands. It gathers data on the subsurface and publishes the resulting information in innovative ways for the benefit of society[12]. TNO's Geological Survey of the Netherlands performs this task on behalf of the Ministry of the Interior and Kingdom Relations and the Ministry of Economic Affairs and Climate Policy.

For the Ministry of Social Affairs and Employment, TNO uses programme funding to manage the MAPA working conditions programme, the Knowledge Programme for the Social Affairs and Employment Inspectorate and the Knowledge Programme for Employer Interventions in the Labour Market.

TNO works with the ministries mentioned to increase the added value of task-related funding in these areas by strengthening the synergy with TNO's other activities. An additional aim is to expand our supporting tasks for ministries, in line with the recommendation of the Evaluation Committee for Applied Research Organisations[13], This would be in the form of a statutory task or other structural agreements.

9.2 KEY ENABLING TECHNOLOGIES

Innovation based on new technologies and methods is still the key to solving societal challenges and creating opportunities for the economy. TNO is constantly making choices in its portfolio of technologies and methodologies. For the Netherlands and for TNO, the choices to be made are not between but within the clusters of Key Enabling Technologies (KETs), as they are referred to the Mission-driven Top sectors and Innovation Policy. The fact is that all these clusters create great societal and economic value. It is at the underlying level, the level of specific sub-technologies, that there are choices to be made between technologies that differ as to the amount of value that can potentially be created.

For the 2022-2025 period, TNO, in consultation with partners and clients and based in part on the Knowledge and Innovation Agenda for Key Enabling Technologies (KIA-ST), is making the choices set out below with regard to technology, grouped according to the taxonomy developed for the Ministry of Economic Affairs and Climate Policy[14].

12. General tasks, such as developing knowledge, managing and maintaining infrastructure, and representing the Geological Survey of the Netherlands in national and international partnerships, are administered in consultation with the Ministry of the Interior and Kingdom Relations, the Ministry of Economic Affairs and Climate Policy, and the Ministry of Infrastructure and Water Management.
13. Evaluation Committee for Applied Research Organisations (TO2), final report on the partial evaluation of TNO, 2021, Evaluation subcommittee TNO, led by A. Lundqvist
14. TNO, The potential contribution of technology to societal challenges (2018 R11465), November 2018.

ADVANCED MATERIALS

In this area of technology, TNO is focusing in the first place on circularity (reuse). In construction, for example, this involves circular and sustainable building materials, and in industry, TNO's focus is on plastics.

Second, TNO is focusing on materials for energy storage, such as circular energy carriers to prevent depletion of and dependence on critical materials.

Third, TNO is expanding its knowledge of composites and metamaterials (engineered materials with special characteristics) for high-tech and defence applications.

Fourth, TNO is developing knowledge relating to biocompatible materials, which include 'organ-on-chip' applications that can accelerate drug development.

Focus technologies: Circularity (construction, plastics), metamaterials

PHOTONICS

TNO is expanding its knowledge about long-distance laser communication (e.g., between ground stations and satellites). In addition, TNO is focusing on upscaling and applying integrated photonic circuits (e.g., for sensors). TNO is also working on next generation solar cells (e.g., perovskite solar cells) and the reliability and lifespan of solar cells. The fourth priority area is medical photonics for diagnostics and patient monitoring.

Focus technologies: Laser satcom, upscaling integrated photonics

QUANTUM TECHNOLOGIES

TNO and Delft University of Technology have joined together with a growing number of other parties in QuTech. This research is in full swing and focuses on quantum computers and quantum communication. Quantum sensors and applications is a new topic within this Key Enabling Technology.

Focus technologies: Quantum sensors and applications

DIGITAL TECHNOLOGIES

This is the broadest of the Key Enabling Technologies, including at TNO. The priority area is artificial intelligence (AI): the integration of model and data-driven AI (Hybrid AI), self-aware and context-aware systems, the interaction between people and AI systems, and transparently reasoning AI. There are numerous applications: automated driving, flying and sailing; robots in healthcare and defence; monitoring health; air quality; and the condition of civil engineering structures. Cooperation between various AI systems (swarm intelligence) and the use of AI as a design tool (generative design) are at an earlier stage.

In some fields (ultrasonic sound, glass fibre-based sensors, radar front-end technology), TNO is developing sensors. However, the emphasis is on the application of sensors: signal processing and pattern recognition, integration of information from various sensors (sensor fusion, big data).

Security in the digital domain remains a priority. This concerns, for example, automated protection from cyber-attacks and secure data exchanges (post-quantum and distributed cryptology, multiparty computation). With this, TNO is opening the doors to new business models, for example in the transport sector (Mobility as a Service).

Digital twinning is also of increasing importance to TNO: making models of complex physical systems, with sensors linked to physical reality. This technology is applied in monitoring the living environment (emissions), bridges, buildings, ships and other constructions, but also in monitoring energy systems and networks, and chemical processes.

Other important technologies are future networks, federated cloud systems and distributed IT systems.

Focus technologies: Swarm intelligence, self-aware / context-aware systems, generative design, automated cyber security, post-quantum cryptology, digital twinning, future networks, federated cloud systems and distributed IT systems

NANOTECHNOLOGIES

TNO focuses mainly on nanometrology, the measuring of structures at the nanoscale. A new priority area is measuring in three dimensions. Chip structures will eventually be designed in ‘3D’, which means that it must be possible to measure below the surface and also to identify material compositions.

Focus technologies: 3D nanometrology

CHEMICAL TECHNOLOGIES

TNO priority areas are electrochemistry and photochemistry (combined with catalysis). This research results in circular production processes (e.g., for ammonia), which reduce the chemical industry's dependence on fossil sources and cause no CO2 emissions or even 'negative' emissions (BECCS, DAC, CCUS, mineralisation options). Among other products, TNO is focusing on sustainable fuels (for road vehicles, aircraft and water vessels, as well as stationary applications). A new venture is the use of plasma technology for the high-quality reuse of plastics.

Focus technologies: Chemical processes for circularity, electrochemistry and photochemistry

LIFE SCIENCE TECHNOLOGIES

TNO is focusing on models of human health (quantified self, body-brain interactions, microbiome), with the aim of developing personalised therapies, for example. TNO generates the data needed using digital technologies such as wearables and biochips. Although the emphasis is on modelling, TNO also develops sensor technology in specific areas (ultrasound, optics). TNO is expanding its 'organ-on-chip' know-how to speed up drug development and reduce the number of animal and human experiments. TNO also invests in knowledge about human exposure to harmful influences (toxicology, exposome), dispersion and protection. A new focus area is the impact of microplastics on humans and animals.

Focus technologies: Exposome, body-brain interactions, ultrasound arrays, personalised medicine, microplastics.

INNOVATION REQUIRES ALSO **INNOVATIVE METHODS** AND WAYS OF **WORKING**

ENGINEERING AND MANUFACTURING TECHNOLOGY

In the coming years, TNO will invest more in smart industry, a topic that lies at the intersection with the 'Digital Technologies' cluster and is in line with the characteristics of the Dutch manufacturing industry (comparatively small numbers of products of greater complexity). Important areas of smart industry are: the interplay between human and robot (flexible manufacturing), digital linking in supply chains, product platforms, parametric / generative design, topology optimisation and smart measuring methods with associated data processing.

With the development of new methods and techniques for system design and engineering, TNO is creating order in the complex array of systems in the high-tech industry. TNO's extensive research programme, 'Embedded Systems Innovation' (ESI), aims to support the high-tech industry in improving throughput times and the effectiveness of product innovation processes, as well as the functionality, quality and social impact of high-tech products.

In addition, TNO is focusing on manufacturing processes such as atomic layer deposition, as well as manufacturing processes for large area electronics and carbon nanotubes (and products using carbon nanotubes). With the energy transition in mind, TNO is working on production processes for electrodes for use in reactors and batteries, among other things.

Focus technologies: Flexible manufacturing, carbon nanotubes, components for the energy transition

9.3 KEY ENABLING METHODOLOGIES

Innovation requires not only distinctive technological know-how ('what'), but also innovative methods and ways of working ('how'): Key Enabling Methodologies (KEMs). TNO wants to apply these Key Enabling Methodologies and help to develop them further. Over the next few years, TNO will concentrate on further developing methodologies in the following two clusters:

VISION, IMAGINATION AND IMPACT

TNO develops methods that enable a better understanding of how technology, world views, behaviour and systems will develop, what innovations can be expected and what impact this will have on society. These methods include technology foresight; estimating the socio-economic and societal impact of innovations; drawing up future scenarios; and determining possible policy choices in the domains in which TNO is active.

TNO invests in modelling societal and economic systems in order to achieve better forecasts of effects, better policy and continual adjustments. Models of the use of space, for example, make it possible to weigh up the various interests linked to the quality of the living environment, the economy, mobility and housing.

The behaviour of stakeholders plays a key role in many societal challenges and transitions. TNO is strengthening its methods in order to assess and influence behaviour (e.g., through effective forms of communication and training).

Focus technologies: Technology foresight, data-driven roadmapping, socio-economic impact assessment, integrated models for use in major societal challenges and transitions

JOINT INNOVATION, VALUE CREATION AND UPSCALING IN EXPERIMENTAL ENVIRONMENTS

Major innovations are no longer achieved within one single organisation: collaboration is essential, both at the early stages and when the time is ripe for upscaling. In recent years, 'orchestrating innovation' has gained a prominent place on the TNO agenda. TNO is expanding its knowledge and skill set in relation to this topic.

New 'collaborative' business models are needed, for example in construction, in order to address major building and maintenance tasks. New methods of participation should involve stakeholders in policy, design and the implementation of solutions (citizen involvement and co-creation, participatory system dynamics, serious gaming).

Innovation is accelerated by bringing different parties together: (Digital) Innovation Hubs and Field Labs are proven 'tools of innovation'. Success over the coming strategy period depends on TNO expanding its knowledge of setting up and managing such experimental environments.

Focus technologies: Collaborative business models, stakeholder involvement, innovation hubs and field labs.

All the developments above have two features in common. First, they all involve transdisciplinarity: combining knowledge from various disciplines is the key to success. Second, they concern responsible innovation: the aim is always to find the right balance between the various interests in society, and to do this in a transparent fashion.

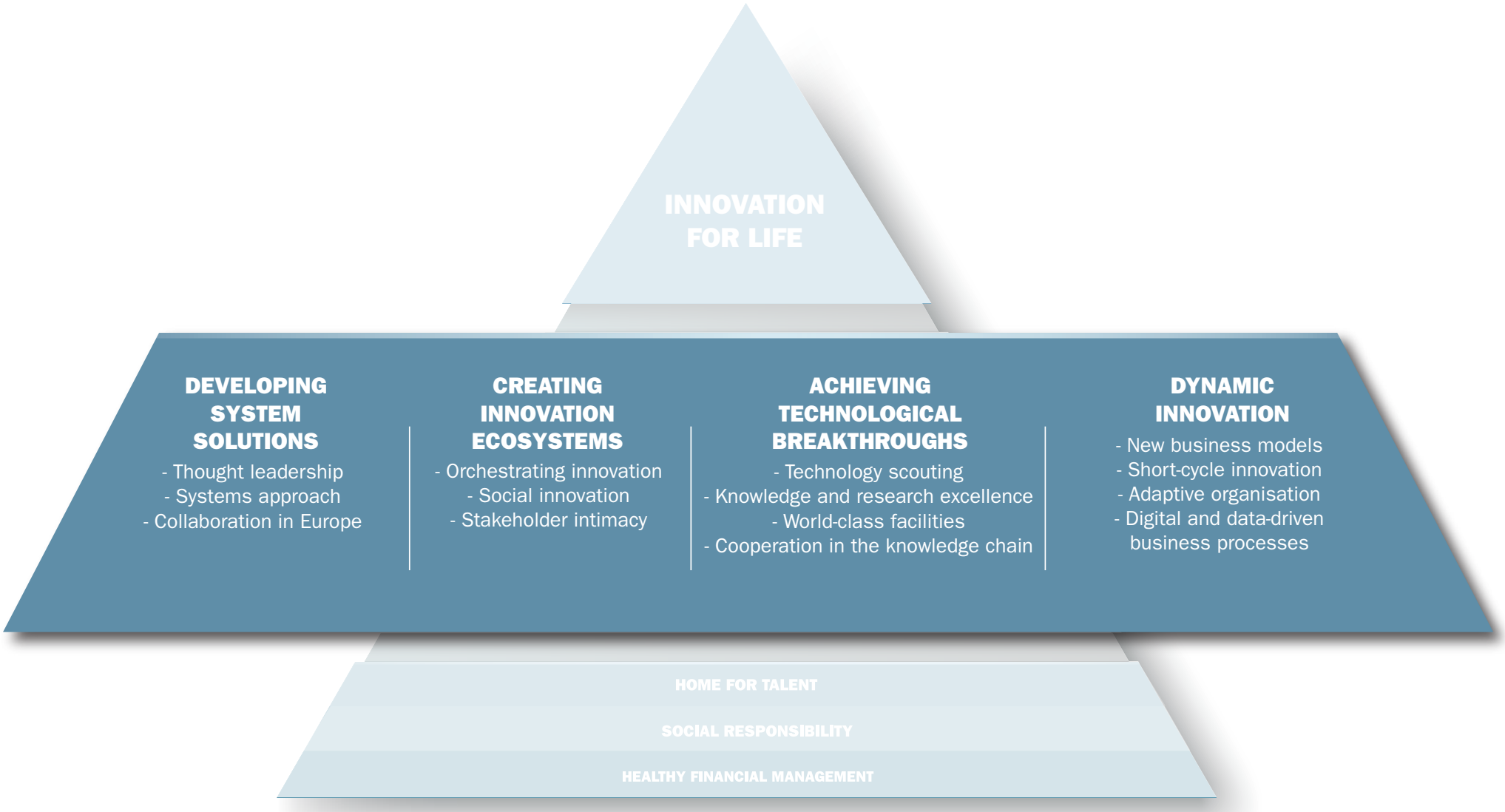
10. DEFINITION OF SUCCES: DEMONSTRABLE IMPACT

CONTRIBUTE **DEMONSTRABLY** AND **PRACTICALLY**

TNO wants to contribute demonstrably and practically to finding solutions for public authorities and companies. The ultimate impact is what counts and that is what will be pursued through the roadmaps. In practice, this means that impact is identified by means of:

1) Monitoring of the achievement of defined milestones
   Milestones are defined annually for each of the roadmaps and are important interim results on the way to achieving the ambition of the roadmap. Reaching these milestones is a measure of TNO's impact.
2) Score on quantitative impact indicators
   The quality and relevance of TNO research is measured using a set of quantitative indicators in five different categories: Science, Collaboration, Entrepreneurship & Economy, Policy & Politics, and Communication.
3) Impact cases
   The impact of a roadmap is illustrated through the structured analysis of impact cases.
4) Annual evaluation with most important partners and clients
   For every roadmap, an annual discussion is held with the most important public and private partners and clients to evaluate the extent to which TNO's work has contributed to achieving their objectives.

METHODS	TODAY	TOMORROW
Monitor achievement of milestones	1) Agendas are coordinated annually 2) Qualitative roadmap reports 3) Milestones are monitored and form part of the company score card (CSC).	1) Continue 2) Standardised and integrated into the methodology for Portfolio management 3) Continue
Impact indicators	· Measurement of quantitative impact indicators	· Continue
Impact cases	· No structured case study library available	· Make a collection of case studies for each unit/ roadmap as evidence/ example of outcome delivered.
Evaluation with stakeholders	· There are project evaluations (a limited number), discussions take place with directors about SMO allocation and results.	· Annual meeting with stakeholders about TNO's contribution, review and preview (resp. previous and coming years)


INNOVATION FOR LIFE
DEVELOPING SYSTEM SOLUTIONS
- Thought leadership
- Systems approach
- Collaboration in Europe
CREATING INNOVATION ECOSYSTEMS
- Orchestrating innovation
- Social innovation
- Stakeholder intimacy
ACHIEVING TECHNOLOGICAL BREAKTHROUGHS
- Technology scouting
- Knowledge and research excellence
- World-class facilities
- Cooperation in the knowledge chain
DYNAMIC INNOVATION
- New business models
- Short-cycle innovation
- Adaptive organisation
- Digital and data-driven business processes
HOME FOR TALENT
SOCIAL RESPONSIBILITY
HEALTHY FINANCIAL MANAGEMENT

PART III

PRIORITIES IN EXECUTION

11.

BACKGROUND: A CHANGING KNOWLEDGE AND INNOVATION LANDSCAPE

ACTIVELY **CHANGING ROLE, PROPOSITION, ORGANISATION** AND **WORKING METHOD**

The knowledge and innovation landscape in which TNO operates is constantly evolving. Therefore, TNO also has to be active in changing its role, proposition, organisation and working methods.

Key developments in the knowledge and innovation landscape:

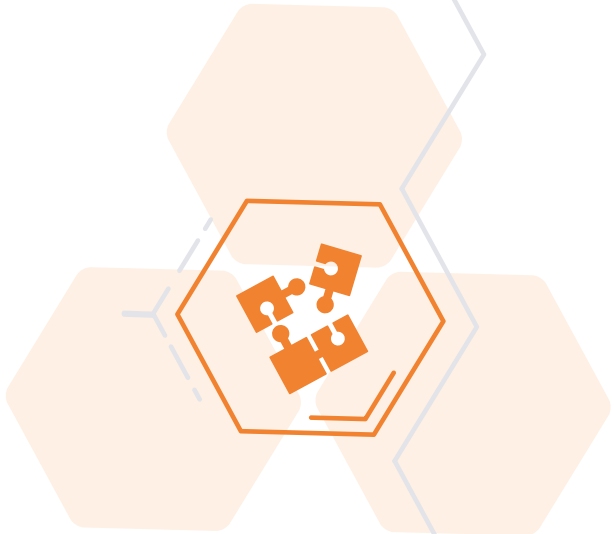
- Complex societal challenges at the centre – changing role of government
  Societal challenges are growing in complexity and affect a great many actors, and a public stimulus is often needed in order to tackle them. The role of government with regard to innovation is changing and is becoming mission-driven and managerial in both the Netherlands and Europe. The boundaries between public and private responsibilities and innovation chains are shifting and blurring. This means that – even more than in the past – different parties, both public and private, need to collaborate earlier in the development chain.
- Changing ways of innovating by business
  In addition to their own and outsourced R&D, companies also apply other forms of innovation. Large companies are making increasing use of corporate venturing (investing in start-ups) to gain access to innovations. They are also becoming ever more international in their innovation methods, with R&D investment increasingly being optimised worldwide. .
- Increasing complexity and impact of new technologies
  The speed with which new technologies are developing is continuing to increase. This is being helped by growing internationalisation and global competition, easy access to knowledge and the availability of ever-improving development tools, techniques and methods. Technology is growing in complexity and requires increasing resources in order to be and remain world-class. New game-changing technologies have a great impact on people and on society, but those same people and that same society have to meet ever-greater demands in order to cope with such developments.
- A changing knowledge and innovation system
  The knowledge and innovation system is also changing. Complex national and international innovation systems and ecosystems are emerging, in which government, knowledge institutions and companies work together. Furthermore, universities are focusing more on the second and third flow of funds,[15] and foreign research institutes are occasionally active in the Netherlands with temporary or regional funding.

15. In addition to government funding (the first flow of funds), universities receive funding from the Netherlands Organisation for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW) for specific research projects (the second flow of funds). The third flow of funds consists of other income, such as EU funding, contract teaching or research funds and money from national private funding organisations.

- Changing social debate – knowledge democratises
  With social media, both facts and ‘alternative facts’ spread quickly. With the help of open data, more people than ever before have access to research material. In consequence, the authority of knowledge institutions can no longer be taken for granted. The independence of institutions is more likely to be called into question, especially when they make an important contribution to policy choices. This underlines the need for knowledge institutions to supply top-quality knowledge that has been developed independently and objectively.
- Impact of COVID-19
  The impact of the COVID-19 pandemic can be felt in many ways. As well as the direct consequence in the form of economic contraction, there is a growing awareness of our dependence on other continents – for example for medicine production – and the risks that this involves. Another effect is the acceleration of digitalisation. The current economic contraction is putting pressure on private investment in R&D, resulting in increasing dependence on the government.

TNO is responding to these developments by setting four priorities for the next strategy period:

1) Developing system solutions (Section 12)
2) Creating innovation ecosystems (Section 13)
3) Achieving technological breakthroughs (Section 14)
4) Dynamic innovation (Section 15)



12.
DEVELOPING **SYSTEM SOLUTIONS**

BY **FACILITATING** THE **REALISATION** OF **SYSTEM SOLUTIONS** **TNO** WANTS TO BE THE **PRIME AGENT** OF **CHANGE** IN THE NETHERLANDS

The challenges facing society require solutions at the system level, consisting of technological breakthroughs, but also changes – possibly radical changes – in government regulations, citizen participation and new, collaborative, business models for industry. Consider, for example, the use of wind energy as part of the energy transition. This necessitates technological system solutions on the one hand: the development of diverse technological breakthroughs to arrive at higher-capacity wind turbines. On the other hand, it also requires societal system solutions at the ecosystem level: how do we create support in society for wind farms, taking account of our core values? And how can we align demand for electricity as closely as possible with the fluctuating supply of sustainably generated power? The core of the strategy is that, in addition to the technological system solutions, TNO is developing a framework for action at the ecosystem level to achieve real innovation. With these efforts, TNO wants to be the prime agent of change in the Netherlands. For this purpose, TNO is building up its resources in a number of areas:

1) Thought leadership
   TNO is committed to providing a perspective for action on major societal challenges at the ecosystem level and in this way, it wants to encourage public debate and help form opinions, with a sound scientific base at all times. To this end, TNO develops what are called 'Novel Points of View': an innovative perspective for action on relevant societal issues that are important to our partners and clients, and to the broader public. Ideally, this innovative perspective should provoke, inspire and mobilise.
2) Systems approach
   TNO is strengthening the systems approach in order to create solutions that reach beyond the borders of individual disciplines. This means investing in competences of lead scientists as well as of consultants and project managers.
   For innovation at the ecosystem level (complex systems of users, providers and public authorities), a transdisciplinary approach is chosen for the research question and how to address it, as well as team composition. This approach integrates knowledge of the natural sciences, social sciences, health sciences and humanities, but also knowledge in the area of engineering and non-academic knowledge (domain and region-related value chains, cooperation models and policy areas).
3) Collaboration in Europe
   Major societal challenges such as the energy transition and climate change go beyond national borders and can only be faced effectively through European policy and cooperation. To participate fully at an international level, respond rapidly to the EU agenda and strengthen our position at the heart of the European knowledge and innovation system, we need to focus strongly on Europe and pursue strategic collaborations with other Research and Technology Organisations in our neighbouring countries, such as Fraunhofer in Germany and CEA in France.

13. CREATING INNOVATION ECOSYSTEMS

INNOVATION INCREASINGLY TAKES PLACE IN **ECOSYSTEMS**

Innovation increasingly takes place in ecosystems[16]. This is especially the case for system innovations that address the major challenges facing society. Real change requires the participation of many different parties: private individuals, public authorities, the business community, knowledge institutions and educational institutions. These kinds of innovative ecosystems do not emerge by themselves. One party is needed to bring together the other participants, ensure a common strategy and consistently push for that strategy to be implemented. TNO is in an ideal position to play such a role, being independent, impact-oriented and multidisciplinary.

In order to play this role even more emphatically over the coming years, TNO is strengthening the following areas:

1) Orchestrating innovation competences
   Orchestrating innovation is a method for creating a sustainable ecosystem in which all the relevant parties contribute to developing and implementing one or more innovations in the pursuit of a common (possibly societal) goal.
2) Social innovation
   Mastering, applying and disseminating knowledge of the 'human factor' in innovation (how people adopt innovations). In addition, involving citizens more fully in TNO research.
3) Stakeholder intimacy
   Further deepening the strategic relationships with TNO's key partners and clients; knowing and helping to shape their strategic agendas; and anticipating current and potential needs.

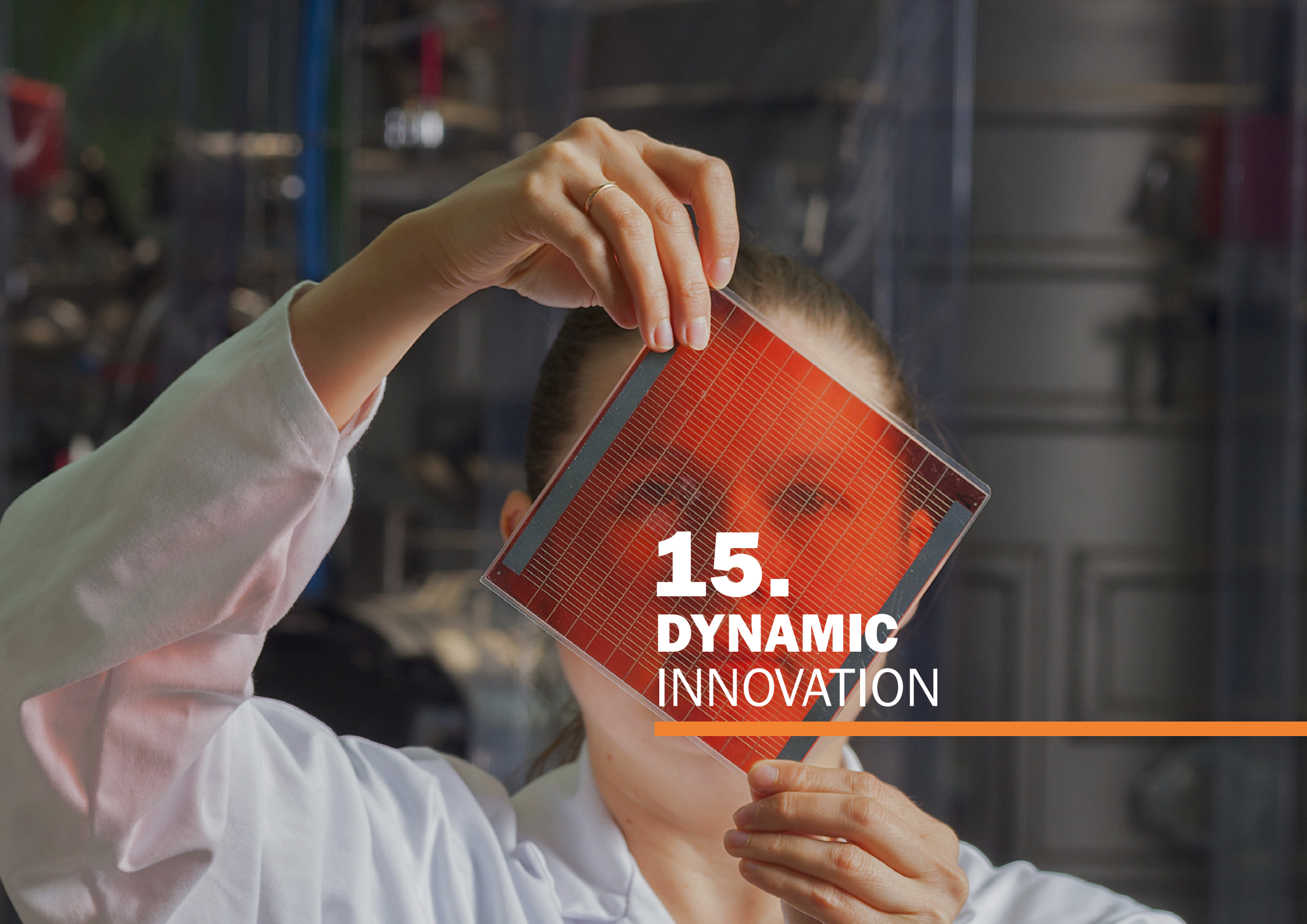
16. An ecosystem for research and innovation contains a dynamic set of interconnected actors, activities, facilities and rules that are important for the research and innovative ability of individual actors and groups of actors, and therefore also for value creation (Dialogic, 2020).

14.
ACHIEVING TECHNOLOGICAL BREAKTHROUGHS

TECHNOLOGICAL BREAKTHROUGHS ARE A PREREQUISITE FOR ARRIVING AT SURPRISING SYSTEM SOLUTIONS

In-depth technological knowledge of selected sub-areas is one of TNO's strong points. Technological breakthroughs are a prerequisite for arriving at surprising system solutions. To be able to continue drawing on a sound knowledge base in future, TNO wants to strengthen its organisation in a number of areas:

1) Technology scouting
   Actively and systematically exploring what the technologies of the future will be and translating these into TNO's own activities and collaborations with partners and clients: what does TNO do itself and in which areas does the organisation collaborate with others?
2) Knowledge and research excellence
   Knowledge excellence and applied research remain the basis for TNO's work. Maintaining this knowledge base is therefore essential to TNO's 'right to play'. Collaboration with others and connecting TNO's knowledge with that of partners and clients is of crucial importance, in particular for creating system solutions.
3) World-class facilities
   High-quality research facilities are essential for TNO to continue playing a leading role. TNO prioritises the implementation of a long-term facilities agenda. Where possible, facilities will be shared with partners in the relevant ecosystems. A condition for creating prestigious facilities is the availability of structural funding from the government. TNO makes a strong case for such funding, in close cooperation with its partners.
4) Cooperation in the knowledge chain
   TNO will strengthen its cooperation with universities, to obtain knowledge from fundamental research and new, highly qualified talent, and to find partners in research and innovation ecosystems. Cooperation with universities of applied sciences will also be developed, with a view to the practical application of innovations and regional cooperation, including with SMEs. This cooperation will, for example, take the form of TNO employees who work as part-time professors or lecturers, as well as the involvement of TNO with PhD students.

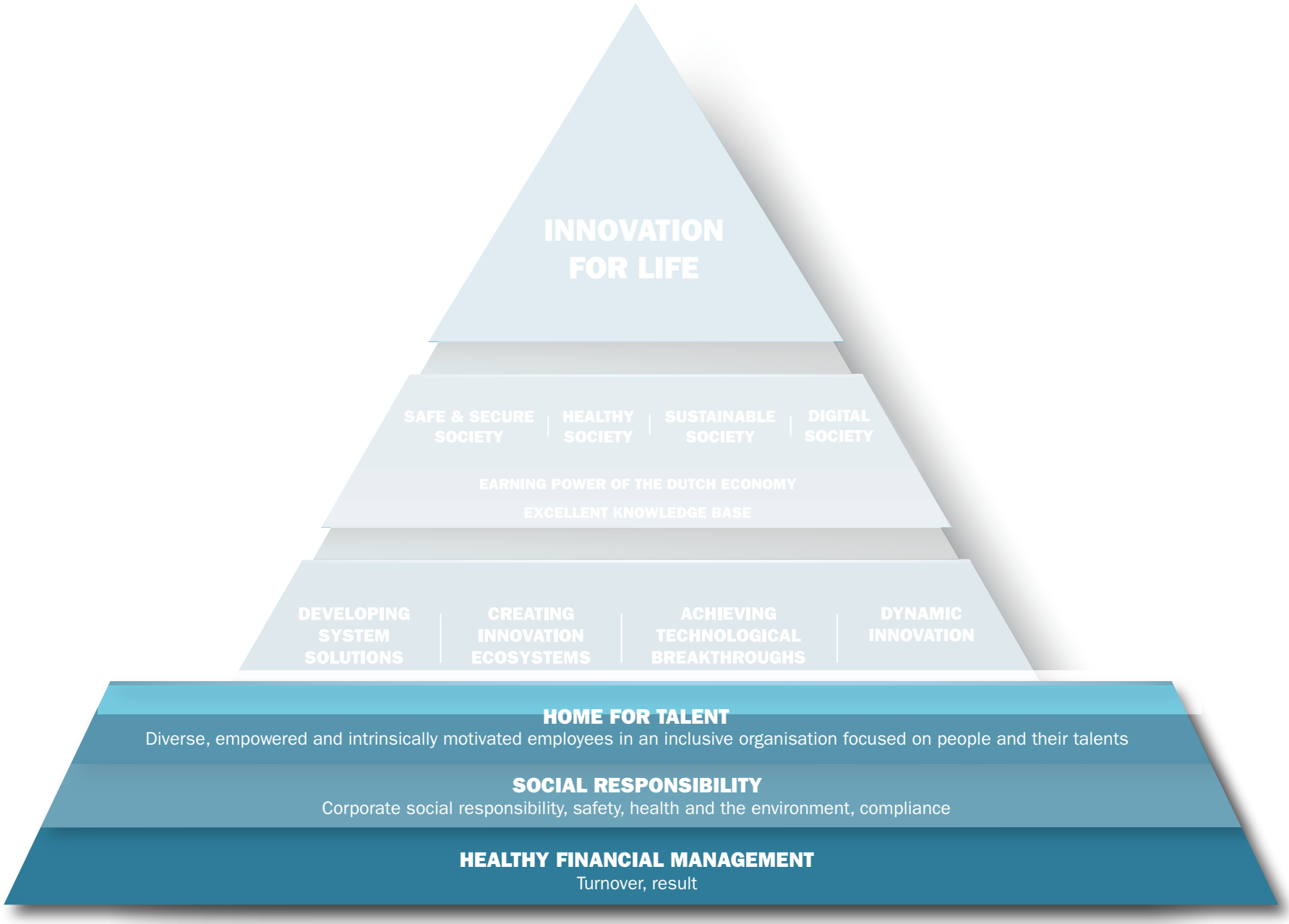


15.
DYNAMIC INNOVATION

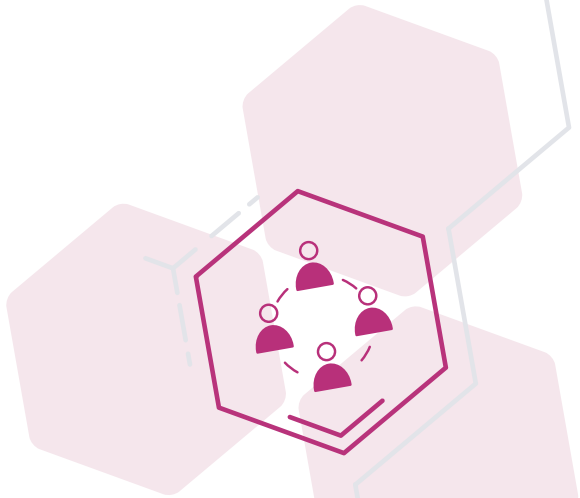
A CONTINUOUSLY **DEVELOPING ORGANISATION** IS A **PREREQUISITE** FOR **SUCCESS**

The world in which TNO operates is changing, partners and clients are asking new questions and staff members are coming up with ground-breaking ideas. To have a chance of success, an organisation must be involved in development and move with the times in this rapidly changing external environment, and also give employees the opportunity to realise their full potential. Over the coming years, TNO plans to develop in the following areas:

1) New business models
   The expansion of the successful TNO Technology Transfer programme, which creates spin-off companies based on knowledge developed by TNO. Participation in external investment funds, to be able to invest in innovation through start-ups, together with partners and within the legal framework.
2) Short-cycle innovation
   The ability to carry out short-cycle research projects, tailored to an urgent need. This depends on TNO – in consultation with partners and clients – using part of its financial resources for such short-cycle work, TNO staff having the competences needed to work in this way, and the organisation and management facilitating this working method. An example of this is 'Brains4X', the programme in which TNO deploys its innovative strength to help tackle urgent societal problems, such as the COVID-19 crisis and the nitrogen problem.
3) An agile/adaptive organisation
   Enabling the organisation to adapt more quickly to changing circumstances by reducing bureaucracy and being committed to empowering staff (putting them in a position to take more responsibility).
4) Digitalisation & data-driven business processes
   More extensive digitalisation of the research domain – in laboratories, project implementation and Research Data Management (RDM) – and of the supporting business processes. Strengthening data-driven decision-making, among other things by expanding the Business Intelligence Competence Center.


INNOVATION FOR LIFE
SAFE & SECURE SOCIETY
HEALTHY SOCIETY
SUSTAINABLE SOCIETY
DIGITAL SOCIETY
EARNING POWER OF THE DUTCH ECONOMY
EXCELLENT KNOWLEDGE BASE
DEVELOPING SYSTEM SOLUTIONS
CREATING INNOVATION ECOSYSTEMS
ACHIEVING TECHNOLOGICAL BREAKTHROUGHS
DYNAMIC INNOVATION
HOME FOR TALENT
Diverse, empowered and intrinsically motivated employees in an inclusive organisation focused on people and their talents
SOCIAL RESPONSIBILITY
Corporate social responsibility, safety, health and the environment, compliance
HEALTHY FINANCIAL MANAGEMENT
Turnover, result

PART IV



FOUNDATION:
BASIC CONDITIONS FOR **SUCCESS**

16.
HOME FOR TALENT

TNO GIVES **PRIORITY** TO **DIVERSITY** AND **INCLUSION**

The knowledge in the heads of TNO's employees is the organisation's most important asset. TNO's policy and practices must make it easier for them to do their work and enable them to realise their full potential.

With a people-oriented way of working, employees are not seen merely as 'human resources' or as 'cogs in a complex machine', but as individuals. Important principles for this way of working, which all emphasise the personal characteristics of employees, are:

- Intrinsic motivation: aligning with what motivates and inspires the employee;
- Focus on talent and job crafting: discovering, developing and making use of talent;
- Reciprocal added value: equal relationship between the employee and TNO, with added value for both sides;
- Joint responsibility: facilitated by management, employees have control over their careers, of which their time at TNO is a part;
- Sustainably employable: employees are encouraged to engage in continuous professional development and to maintain a healthy balance between the pressure of work and pleasure of work;
- Inclusive culture: a culture in which everyone feels valued and respected, and has access to the same opportunities.

TNO gives priority to Diversity and Inclusion (D&I). It recognises the value of diversity and is committed to ensuring an inclusive work environment in which all employees have the same opportunities, regardless of background, gender, sexual orientation, nationality, etc. In the TNO organisation, employees can develop to the best of their ability. At the end of 2020, a D&I officer was appointed to underline the importance of this issue. The aim is to professionalise D&I further within TNO and a focus on inclusive leadership will help to achieve this aim.

People with a natural sciences background will continue to make up a large proportion of TNO staff. Over the coming years, however, the need for a comprehensive approach and social innovation will lead to an increasing demand for knowledge from the social sciences.

17. SOCIAL RESPONSIBILITY

PRACTICE WHAT WE **PREACH**

The socially responsible operations of the TNO organisation, the safety of its processes and compliance with relevant legislation and regulations form TNO's 'licence to operate'.

CORPORATE SOCIAL RESPONSIBILITY

Partners and clients are asking TNO to shape the major transitions in such a way that there is a move towards a sustainable society. Based on its mission, TNO contributes to this goal through its research and innovation. It also wants its own operations to reflect social responsibility ('practice what we preach'). In the next strategy period, TNO will take a further step in the area of Corporate Social Responsibility (CSR) and to underline its intentions, it signed the United Nations' Global Compact (UNGC) in 2020. TNO intends to make an improvement each year, to measure these changes and report on the results in accordance with the UNGC guidelines.

TNO has drawn up the following CSR objectives:

- Recognising and shaping TNO's chain responsibility, both 'upstream' (purchasing) and 'downstream' (clients) by pursuing policies on socially responsible purchasing and customer acceptance.
- Prioritising the focus areas integrity, energy and sustainability, and working conditions and diversity, with 'practice what we preach' as a guiding principle.
- Further reducing TNO's CO2 footprint, with the target of being climate-neutral in 2040.

In addition, TNO has an 'innovation for development' programme, funded out of its government grant, with which it wants to increase opportunities for vulnerable groups in low and middle-income countries and reduce inequality in the world. With 'innovation for development', TNO aims to improve the lives of 1 million people. In this programme, too, it works closely together with national and international partners from the public and private sectors on ground-breaking multidisciplinary innovations through a sound business model.

HEALTH, SAFETY AND THE ENVIRONMENT

A safe and healthy work environment, and minimising the effect of our work on the environment, are important preconditions for TNO in all the work that it does. In addition, partners and clients think it is important for TNO to perform well with respect to health, safety and the environment (HSE).

A comprehensive package of HSE processes and working methods has been introduced to ensure that TNO continues to perform well in this regard and continuously improves.

TNO's goal in the area of health, safety and the environment is to increase significantly the number of preventive reports, reduce the number of incidents and increase the percentage of incidents that are acted on correctly.

COMPLIANCE

TNO operates in the arena of public and private interests. The relevant legal frameworks and ethical standards are becoming even more complex and TNO's partners and clients are setting stronger requirements with regard to compliance. As a result, compliance is growing in importance. Efficient and effective work processes are important for proper compliance. The most important objectives over the next few years are:

1) Embedding compliance more firmly, in order (using a risk-based approach) to comply demonstrably with relevant legislation and regulations, internal rules and the TNO code.
2) Client acceptance: introducing and automating an improved process for screening and assessing new and existing clients across TNO.
3) Developing a compliance workflow to ensure that the administrative burden of complying with legislation and regulations remains manageable.

18. HEALTHY FINANCIAL MANAGEMENT

HEALTHY FINANCIAL **MANAGEMENT** IS AN **ESSENTIAL CONDITION** FOR **TNO**

Turnover and results are not an end in themselves for TNO. However, healthy financial management is an essential condition for TNO to achieve its aims and maintain its basic knowledge infrastructure, including facilities. In addition, turnover is an indicator for our contribution in relation to a specific issue in society. A positive operating profit is a requirement for healthy financial management, on the one hand to provide a buffer for setbacks and on the other to create room for investment in innovation.

18.1 TURNOVER

The basis for this strategic plan is that government funding in the next four years will at least be maintained at the 2021 level (€252 million) excluding adjustment for inflation.

To complement the above-mentioned funding, TNO obtains contributions from third parties for research. This is often done in collaboration with partners and clients (public and private) that co-finance or fully finance the research.

TNO has the duty to use the funding it receives as effectively as possible and to achieve the right balance between this income and contributions from third parties[17]. The relationship between these two income sources is expressed by what is called the 'multiplier': total turnover divided by the government funding. TNO strives for a multiplier of between 2 and 3. Too low a multiplier would mean that public and private partners, as well as clients, do not find TNO research relevant enough to invest in it. However, too high a multiplier means that the activities in the portfolio have now 'matured' and can partly or wholly be left to other (possibly commercial) parties.

Achieving a multiplier of between 2 and 3 will be challenging over the coming years, because private investment in research and innovation is under pressure as a result of the economic fall-out from the COVID-19 pandemic. For this reason, TNO will further intensify its efforts to involve the business community in its research, to maintain the private share of competitive funding and contract funding.

Based on the above assumptions, in the 2022-2025 period, TNO will work to maintain annual turnover at the current level of approximately €540 million.

17. The second part of this duty does not apply to those parts of government funding that relate to the previously mentioned statutory and other public tasks.

18.2 FINANCIAL PERFORMANCE

A positive result is necessary in order to maintain a healthy financial position. The objective is to achieve a long-term positive net result of 1-2% of turnover on average. This provides scope to maintain equity as a foundation for operations and as a buffer against setbacks. This result is also necessary for investing in upgrading knowledge and in facilities. This model offers no scope for large-scale investments, which would require additional government funding.

TNO records its results – positive and negative – through capacity results (deviations in staffing levels and efficiency in relation to the budget), project results (margin obtained on the contract research that makes up about 25% of total turnover) and the Intellectual Property (IP) balance. TNO's research enables it to create a valuable IP portfolio. This is used as the basis for new research, while the granting of licences based on IP provides an additional revenue stream. The objective is for the balance of IP income and IP costs to make a positive contribution to the result.

In TNO's Technology Transfer programme, spin-offs are established on the basis of technology developed at TNO. This is a way for TNO to valorise its knowledge. The goal is for the Tech Transfer programme to become 'revolving' over time, with proceeds from the sale of the equity interest in TNO spin-offs at least covering the costs of the Tech Transfer programme. It will then be possible for the Tech Transfer 'flywheel' to be considered self-sustaining and it can continue turning in the future.

FINANCIAL STABILITY OF TNO

Over the last strategy period, the financial stability of TNO has greatly improved. Increased government funding enabled growth and this growth – combined with good operational management of the organisation – resulted in a positive financial performance. In addition, equity capital has grown as a result of the proceeds from the sale of technology developed in the past and launched on the market during the strategy period. These financial resources will be used for strategic activities, such as continuing and further expanding the successful Technology Transfer programme.

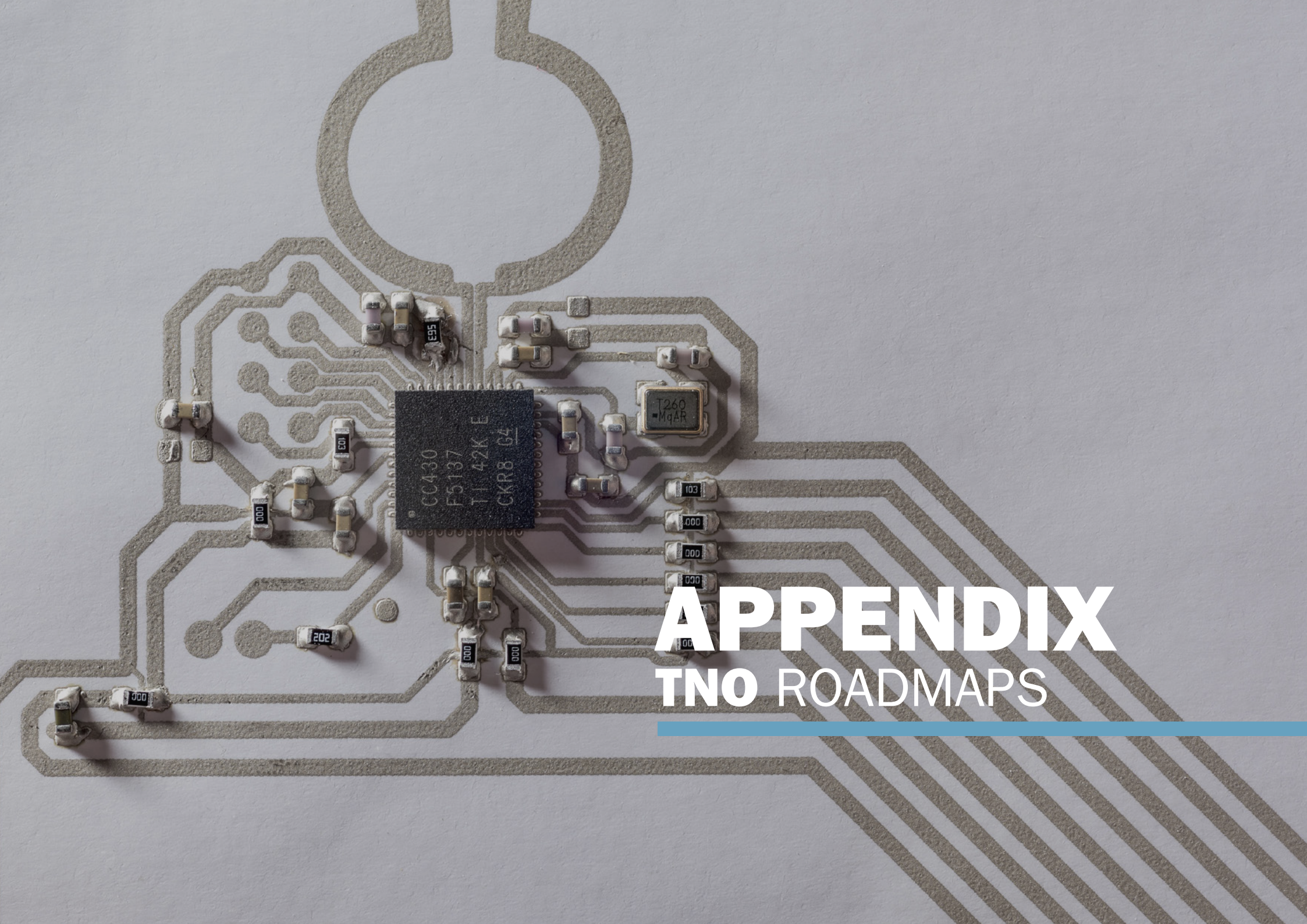
TNO ADVOCATES INCREASING INVESTMENT IN RESEARCH AND INNOVATION TO 3% OF GDP

18.3 ADDITIONAL IMPACT IS POSSIBLE

Increasing labour productivity in the period following the COVID-19 pandemic by means of targeted investment in research and development is the best recipe for economic growth in the Netherlands[18]. Since 2008, Germany has shown how an economy can grow its way out of a crisis through consistent investment in R&D. TNO advocates increasing investment in research and innovation to 3% of GDP. It hopes that the government will decide, in line with the report 'Innovative society: Broad Societal Reappraisal', [19] to invest more in the applied knowledge institutions.

Together with the other applied knowledge institutions, TNO is also calling for structural funds for research facilities, to bolster the ambitions related to the Mission-driven Top sectors and Innovation Policy. Finally, facilitating a rise in the private contribution to R&D would make it possible to achieve additional impact. In this context, TNO supports SMEs in their desire for their growth to be further facilitated, by making innovation together with applied knowledge institutions easier and more accessible for the SME sector. These additional public efforts will accelerate the development of solutions to increase well-being and prosperity in the Netherlands that have a greater impact and are economically attractive.

18. See the white paper: 'The economy after the coronavirus vaccine: how the Netherlands can innovate its way out of the crisis (TNO, 2020).
19. Innovatieve samenleving, brede maatschappelijke heroverweging, 20 April 2020, Government Finance Inspectorate. The Broad Societal Reappraisals (BMH) provide insight into possible policy choices for the long-term future of the Netherlands.



APPENDIX

TNO ROADMAPS

TNO ROADMAPS

TNO has organised its research in a portfolio of roadmaps. Roadmaps show the results that TNO is aiming for, how knowledge (technological and methodological) is being developed and used for this purpose, and the mix of funding sources that is being drawn on. The diversity and dynamics of the external challenges are reflected in diversity and dynamics in TNO's roadmaps: the portfolio is constantly developing.

Individual roadmaps frequently make contributions to tackling several challenges. The overview on the next page indicates the primary (■) focus and the secondary (■) focus.

ROADMAP	UNIT	SAFE & SECURE SOCIETY	HEALTHY SOCIETY	SUSTAINABLE SOCIETY	DIGITAL SOCIETY	EARNING POWER[20]	STATUTORY TASK
Buildings & Infrastructure	BIM						
Maritime & Offshore	BIM						
Environment & Sustainability	CEE						
National Security	DSS						
Operations & Human Factors	DSS						
Information & Sensor Systems	DSS						
Protection, Munitions & Weapons	DSS						
Renewable Electricity	ET						
CO2 Neutral Industry	ET						
Sustainable Subsurface	ET						
System Transition	ET						
Prevention & Productivity	HL						
Biomedical & Digital Health	HL						
Digital Innovations[21]	ICT						
Space & Scientific Instrumentation	IND						
Semiconductor Equipment	IND						
Flexible & Free-form Products	IND						
Sustainable Chemical Industry	IND						
Smart Industry	IND						
Transitions & Transformations	SAP						
Smart and Safe Traffic & Transport	T&T						
Sustainable Traffic & Transport	T&T						

primary focus

secondary focus

20. Earning power also includes the Key Enabling Technologies in line with the MTIB and the KIA for Key Enabling Technologies..
21. This roadmap creates the conditions for tackling all the challenges.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

SAFE & SECURE SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
SAFE & SECURE SOCIETY 'Science and innovation at the frontline'	**DEFENCE** - **High-quality Technology** - **Information-driven**	Operations & Human Factors	Guide and support Ministry of Defence with knowledge of military operations, technology and human factors, to arrive at the best solution for our armed forces.	- Support the Ministry of Defence and the three branches of the armed forces in transforming to meet future conditions in an unstable and uncertain world. - Resolve the operational and technical shortcomings of the military through analyses and direct support.
		Protection, Munitions & Weapons	Provide innovative solutions for optimal, affordable protection for those who protect us (e.g., protection concepts, detection systems, smart ammunition, laser weapons).	- Technology for saving and improving the lives of soldiers after regular armed conflict or IED attack. - Improve the safety of the use, transport and storage of regular ammunition by the armed forces, also to protect civilians against consequential damage. - Support the defence industry in jointly developing new, safer, effective and sustainable products (ammunition or protection systems) and create new economic activities. - Support the Ministry of Defence in the energy transition and the reduction of fossil fuels and CO2.
		Information & Sensor Systems	Create information dominance in the pursuit of information-driven achieve-ments and help our armed forces to excel in their use of information and misinformation as weapon, means and target.	- Ensure access to the best military technology in existence, which is years ahead of the technology available on the market. - Enable our military to realise its ambition by developing and applying new and existing technology. - Knowledge development with partners (industry, universities, international institutes and SMEs) to develop new technologies and new ecosystems and start-ups that will benefit our armed forces. - Support the Dutch defence industry in its development of advanced and new technology. - Disseminate knowledge in the Netherlands by creating spin-offs to the other sectors of the economy.
		Space & Scientific Instrumentation	Contribution to defence, for ex. via Laser Satellite Communication.	More information about this roadmap can be found in 'Sustainable society'.
		Prevention & Productivity	Contribution to defence, for ex. dealing with stress.	More information about this roadmap can be found in 'Healthy society'.
		Renewable Electricity	Contribution to the energy transition of defence.	More information about this roadmap can be found in 'Sustainable society'.
		Digital Innovations	TNO invests in technology that is relevant for defence as well as justice and security.	- Blueprints and infrastructure in the areas of cybersecurity, network technology and data sharing. - More information about this roadmap can be found in 'Digital society'.
	JUSTICE & SECURITY - **Effective** - **Affordable**	National Security	Create innovations that enhance the effectiveness of national security organisations (government and business community), among other things by organising collaboration in consortiums..	- Advanced data and data-analysis toolbox containing a risk assessment, selection and advisory instrument for all national security organisations. - Predictive analytical tool for detecting and countering criminality, public order disturbances, radicalisation and terrorism. - Knowledge development with partners (universities and international institutes) to develop new technologies and new ecosystems and start-ups that can benefit national security. - Do research on new cryptocurrencies, advising on their use and protecting Dutch society against negative effects. - Resilience monitor and dashboard for the national security forces to improve performance and resilience. - Strengthen physical and mental condition and resilience of security professionals using technology and innovation.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

HEALTHY SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
HEALTHY SOCIETY 'After a healthy start, self-managing a life in good health for longer'	**EFFECTIVE PREVENTION, PERSONALISED CARE AND FASTER DRUG DEVELOPMENT**	Biomedical & Digital Health	Develop pioneering and life-changing biomedical and digital interventions to improve health in society and boost economic growth. Personalised interventions consisting of lifestyle changes and medicines that are developed faster, better and more cheaply.	- Halve the societal and economic burden of lifestyle-related diseases over the next 10 years, by developing lifestyle interventions that both prevent and heal. - Contribute to lowering costs of drug development by 10% by introducing innovative technologies and models that eliminate steps that slow down the development process. - Develop solutions and frameworks to bridge the gap between medical care data and health data generated by the individual.
		Prevention & Productivity	Enable children and young people to grow up safe and healthy, to have the same opportunities and to become healthy and productive adults.	- Reduce health disparities between different socio-economic groups from 30% to 20% by developing electronic and other interventions that give the lower SES groups equal opportunities to grow into healthy, involved and productive citizens.
		Flexible and Free Form Products	Create world-leading technologies for health, as well as flexible electronics, to make it possible to develop a new portfolio of products, together with and on behalf of industrial partners.	Thanks to TNO technology: - The time that patients spend in hospital has been reduced by 30% in specific cases. - The availability of medical staff for patient care has been increased by 100%. - Over the next five years, at least five start-ups will be established to commercialise these technologies.
		Semiconductor Equipment	Among other things, position the Dutch high-tech industry to deliver crucial enabling technologies to the healthcare ecosystem.	This roadmap contributes to medical technology and thus to physical health. More information on the primary focus of this roadmap can be found in 'Digital society'.
		Digital Innovations	Design and develop ICT blueprints for major Dutch 'smart' innovation challenges.	This roadmap works on various digital technologies that contribute to personalised healthcare. More information on the primary focus of this roadmap can be found in 'Digital society'.
		Operations & Human Factors	Apply knowledge on effective performance of people and human-machine interaction.	This roadmap uses knowledge to contribute to prevention & personalised care. More information on the primary focus of this roadmap can be found in 'Safe & Secure society'.
	HEALTHY WORK AND LIVING ENVIRONMENT - **Clean** - **Protected** - **Safe & Secure** - **Health-promoting** - **Lifelong development** - **Socially innovative**	Prevention & Productivity	Make social and technological innovations possible in order to achieve inclusive and sustainable labour participation. Contribute to strengthening the mental health and well-being of working people. Give working people the opportunity to stay healthy and enjoy lifelong development.	- Make a demonstrable contribution to a 2% productivity gain by supporting employees and companies in effectively applying innovations and organising their processes in such a way that humans and technology work together optimally (industry 5.0). - Reverse the trend of increasing numbers of working people with burnout complaints to reach at least a stabilisation of the situation. - Reduce disruption to 1.1 million employees as a result of the major societal transitions by ensuring that 50% of working people are optimally qualified for the work of the future, through a skills-based approach. Increase the contribution by working people to the innovative capability of the Netherlands by 5%. - Reduce the burden of work-related illness by 5%, so that working people nearing the pensionable age are just as active as younger workers. - Increase the development opportunities of working people by 10%, so that they can engage in lifelong development.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

HEALTHY SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
HEALTHY SOCIETY 'After a healthy start, self-managing a life in good health for longer'	**HEALTHY WORK AND LIVING ENVIRONMENT** **- Clean** **- Protected** **- Safe & Secure** **- Health-promoting** **- Lifelong development** **- Socially innovative**	Environment & Sustainability	Reduce emissions of gases that are harmful to the environment, the climate and health, and optimise the socio-economic impact.	- TNO is working to minimise the avoidable proportion of the loss of human lives due to air pollution and noise, and to improve the quality of life and productivity. - TNO offers open emissions data and modelling tools to support the development of strategies for improving air quality worldwide. This roadmap contributes to a healthy and sustainable society. See 'Sustainable society' for more details.
		Sustainable Traffic & Transport	Make traffic and transport sustainable, with very low to zero emissions of air pollutants, noise and CO2, driven by renewable energy.	- Ensure that clean combustion engines and zero-emission electric and fuel cell propulsion systems are available for heavy and niche applications. - Act as a knowledge centre for real-world emissions for the source/air quality policies of European, national and local governments. Emissions monitoring provides fact-based information on real-world emissions of road traffic, shipping and mobile machinery. - Make the urban mobility and transport system more sustainable, taking account of wishes, opportunities, limitations and basic conditions for end users; accessibility and transport infrastructure; spatial integration; and other societal and economic dimensions. This roadmap contributes to a healthy and sustainable society. See 'Sustainable society' for more details.
		Buildings & Infrastructure	TNO contributes to safe, comfortable and healthy buildings in which to live and work.	This roadmap helps create a safe and healthy built environment and a good indoor climate – thus promoting good health. More information about this roadmap can be found in 'Sustainable society'.
		Space & Scientific Instrumentation	Among other things, to be a globally recognised developer of technology for space and scientific instrumentation.	This roadmap contributes to monitoring atmospheric pollution and thus to a healthy living environment. More information about this roadmap can be found in 'Sustainable society'.
		Smart and Safe Traffic & Transport	Contribute to the creation of a safe traffic and transport system	- Ensure that smart, safe and efficient logistics and mobility systems contribute to liveable cities by developing and deploying monitoring and evaluation methodologies and simulation methods. - Ensure that road safety is increased, in spite of (and thanks to) the growth in new forms of mobility, such as 'connected automatic driving', light electric vehicles and the further automation and digitalisation of transport and logistics. - Act as a knowledge centre for safe and effective mobility for public authorities as well as national and international industry, by providing knowledge and physical and virtual test methods for vehicles and traffic. SMRC is the primary national research centre in this area. This roadmap contributes to a healthy and sustainable society. See 'Sustainable society' for more details.
		Transitions & Transformations	TNO's ambition is to contribute to achieving maximum long-term prosperity by ensuring that government, business and individuals are able to deal with technological changes and societal challenges.	This roadmap contributes to long-term prosperity and thus to a healthy work and living environment.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

SUSTAINABLE SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
SUSTAINABLE SOCIETY "Preserving a healthy planet"	**SUSTAINABLE INDUSTRY**	CO2 Neutral Industry	TNO supports and facilitates the flexible, safe and efficient transition of Dutch and European industry to become carbon-free in 2050. In 2050, Dutch industry, including energy-intensive industry, is flourishing and climate-neutral. The industrial transformation in the Netherlands is seen as a good example in other EU countries.	- TNO develops technology and supports its implementation in industry in order to use bio-based fuels and raw materials on a large scale in the Netherlands. - TNO supports Dutch industry in playing a major role in the broad commercial implementation of the production of green hydrogen and its applications, such as synthetic fuels and chemicals. TNO contributes to a substantial reduction in the costs of electrolyser technology. - TNO supports the development of the North Sea as a renewable energy hub. TNO is developing a vision and helps to make the transport of CO2 and H2 possible in a north-west European context. - Implementation of Carbon Capture & Storage (CCS) in sectors where CO2 reduction is harder to achieve, such as the waste sector, refineries, the cement industry and the steel industry. - Offer of CO2-neutral heat, efficient consumption and solutions for reuse in industry. - TNO innovations support the EPC and technology companies of the Netherlands in reaching a competitive position in the world market.
		Environment & Sustainability	Optimise value chains and improve the ecological footprint of production and the use of materials.	- TNO is working to achieve a reduction of 1 MT CO2 by closing the plastic value chain and improving resource efficiency. - We offer a framework for action by quantifying and modelling the economic and ecological impact of circular value chains.
		Sustainable Chemical Industry	TNO wants to contribute to a sustainable chemical industry that makes a sustainable society possible.	- By making green chemistry and smart materials possible, TNO makes a significant contribution to the sustainability of the chemical industry.
		Maritime & Offshore	A competitive maritime sector with a strong innovation ecosystem; offers solutions for sustainable and safe development of the North Sea.	The maritime and offshore sector faces a huge sustainability challenge. This provides opportunities for this sector in the Netherlands. TNO supports shipbuilders, ship operators and companies active in developing products and services for this growing market. With activities in the maritime sector, TNO contributes to the cost-effectiveness of the offshore wind industry. TNO does this by, among other things, developing technology for underwater inspection, monitoring, reliability of structures and failure mechanisms under extreme conditions. It also enables ship owners to meet acoustic environmental impact requirements, allowing them to continue their maritime activities.
		Transitions & Transformations	TNO's ambition is to contribute to achieving maximum long-term prosperity by ensuring that government, business and individuals are able to deal with technological changes and societal challenges.	- In line with the Green Deal, we will provide the energy-intensive industry in the Netherlands with new value chains and business models. - We identify the socio-economic consequences of artificial intelligence, so that public partners and clients can formulate conditions under which further development can take place. - We support the government in drawing up effective regulations to enable responsible and accountable application of AI. - In order to achieve transitions and remove obstacles to scaling up, we are working on new national assessment frameworks based on a regional integrated approach. - We contribute to the optimal use of limited space, deploying the power of the regions.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

SUSTAINABLE SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
SUSTAINABLE SOCIETY "Preserving a healthy planet"	**SUSTAINABLE LIVING ENVIRONMENT**	Smart and Safe Traffic & Transport	Contribute to the creation of a sustainable traffic and transport system through the development of smart mobility systems.	- This roadmap contributes to a healthy and sustainable society. See 'Healthy society' for more details.
		Environment & Sustainability	Reduction in use of primary raw materials and optimisation of socio-economic impact.	- We make it possible to supply 10 to 20% (~ 6 to 12 million tonnes) of the materials required by the building sector with recycled materials and for the infra / civil-engineering sector, TNO aims for a CO2 reduction of 30% through an 80% reduction in the need for primary materials. - TNO quantifies and models the economic and ecological impact of circular value chains, with which TNO provides action frameworks and policy insights.
		Buildings & Infrastructure	Contribute to a sustainable built environment where people live and work in comfortable and healthy buildings, and where the civil infrastructure is well maintained at acceptable costs.	- There is no longer any possibly risky unplanned maintenance; the infrastructure is completely circular and there is autonomous assessment of the status of civil infrastructure. - All existing buildings are carbon neutral and new and renovated buildings are net producers of clean energy (electricity and heat) and building materials used are circular. - Guaranteed and lifelong optimal performance and constructional safety of buildings. - The Netherlands is the leader in the high-tech greenhouse growing sector.
		Space & Scientific Instrumentation	To be a globally recognised developer of technology for space and scientific instrumentation based on our legacy in optics, optomechatronics and radar system design and technology.	- Great impact regarding a sustainable economy by making a gradual change in detecting and understanding pollution, which is crucial to reducing emissions. - Scientific impact by providing more accurate, reliable and capable instruments for scientific research. - Enable fast and secure communication networks. Increase jobs and economic earning power by Dutch companies by positioning companies, build an ecosystem and enable series production of high-tech instruments, terminals and components.
		Sustainable Subsurface	Develop and manage independent knowledge of the deep and shallow subsurface in order to accelerate the energy transition and answer current and future societal questions about the subsurface as a world-leading geological service.	- Support the decarbonisation of the Dutch economy. - Support for studies and recommendations which should ensure that the Dutch delta continues to be habitable over the long term. - The prediction and mitigation of the effects of mining. - The development of a digital twin of the Earth in order to support sustainable management of the subsurface. - Realisation of the ambitions from the climate agreement: extra connections to collective heat networks so that 1.1 million buildings will be connected to heat networks in 2030 (= 750,000 extra), making heat sources for collective heat networks more sustainable. TNO is working on an average CO2 reduction of 70% by 2030 compared with a current gas central heating boiler (2018). In concrete terms, this objective means that the CO2 intensity of the heat supplied by district and other heating networks will be reduced to 18.9 kg CO2/GJ and a cost reduction of 1.5% per year.
		Transitions & Transformations	(see P98)	(see P98)

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

SUSTAINABLE SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
SUSTAINABLE SOCIETY "Preserving a healthy planet"	**SUSTAINABLE LIVING ENVIRONMENT**	Renewable Electricity	Together with partners in business and science, TNO develops knowledge and technologies that enable solar and wind energy to make major contributions to the energy system. In this work, TNO focuses on reducing costs, removing barriers, increasing the economic, societal and ecological value, boosting performance, and improving the competitiveness and effectiveness of public and private parties involved.	TNO's innovations aim to: - Increase and accelerate the application of renewable electricity generation in the Netherlands, Europe and worldwide, with major contributions to the Dutch economy; - Make renewable electricity generation (solar energy systems and wind farms) even more reliable and cost-effective; - Support the integration of large amounts of sustainable electricity into the energy system; - Integrate renewable electricity generation into our living environment and the ecosystem, including the multifunctional use of space; - Increase acceptance by society and the involvement of individuals; - Make renewable electricity generation (solar systems and wind farms) circular: from renewable to fully sustainable.
		Sustainable Traffic & Transport	Make traffic and transport sustainable, with very low to no emissions of air pollutants, noise and CO2, and driven by renewable energy.	- Demonstration of hybrid, electric and hydrogen-based propulsion with low Total Cost of Ownership and efficient internal combustion engines using renewable fuels with almost zero emissions. - Efficient logistics and mobility systems that contribute to sustainable traffic and transport. - Fact-based tooling in support of policy for monitoring and reducing real-world emissions of vehicles, water vessels, and machines. - Optimisation of the entire transport system in terms of minimising energy use and emissions, taking account of the end user and economic and policy requirements. - An impact assessment method for developments in mobility and logistics, and developments of technical, behavioural and policy measures to improve the sustainability of traffic and transport.
	DUURZAME ENERGIEVOORZIENING	Renewable Electricity	(see above)	(see above)
		Sustainable Subsurface	(see above)	(see above)
		System Transition	TNO develops knowledge and tools for policymakers and professionals who work on the energy transition, so that they can deal with the societal, economic and behavioural issues associated with the energy transition.	- The goal for 2050 is a reliable and inclusive energy system without CO2 emissions. There are key interim goals for 2030, which are being translated into a policy agenda. - The energy transition is currently in full swing: sun and wind are replacing coal and gas; heat provision is becoming gas-free. The goal is to speed up the energy transition and make the energy system sustainable, reliable, affordable and inclusive. - Achieving the goals will require a transition of the energy system, which, in addition to technology for energy generation, storage and use in all sectors, will also include policy, funding and markets. But above all, the energy system consists of people: policymakers, inhabitants, consumers, investors and local residents. - Our goal is to help those people to make the energy system more sustainable. TNO does this by contributing to effective policy, targeted investment decisions, social involvement and sustainable lifestyles for residents and companies.

OVERVIEW OF ROAD-MAPS' CONTRIBUTION BY CHALLENGE

DIGITAL SOCIETY

CHALLENGE	SUB-QUESTION	ROADMAP	AMBITION	LONG-TERM GOALS
DIGITAL SOCIETY 'The Netherlands is becoming digital leader'	**ONTWIKKELEN VAN VEILIGE EN VERTROUWDE SYSTEMEN**	Digital Innovations	Design and develop ICT blueprints for major Dutch 'smart' innovation challenges.	- Blueprints and infrastructure in the area of fast open infrastructures, data sharing, trusted ICT, system implementations and AI implemented in practice. - An economic boost of 15% growth in added value at organisations with which TNO collaborates.
		Space & Scientific instrumentation	To be a globally recognised developer of technology for space and scientific instrumentation.	- Scientific impact by providing more accurate, reliable and competent instruments for scientific research. - Enable fast and secure communication networks. - Increase jobs and economic earning power by Dutch companies by positioning companies in large programmes, build an ecosystem and enable series production of high-tech instruments, terminals and components. More information about this roadmap can be found in 'Sustainable society'.
	DIGITALISEREN VAN DE MAAKINDUSTRIE	Smart Industry	Guiding and supporting the Dutch manufacturing industry (including SMEs) in its transition to the most flexible, resilient and digitally connected production network in Europe for the design, manufacture and supply of high-tech products and related services.	- High-mix, low-volume manufacturing of complex products at the cost level of mass production. - The high-tech industry is able to make its supply chain 20% more efficient thanks to better data sharing. Innovation is stimulated by the fact that manufacturing companies retain sovereignty over their data..
	STERKE ICT/ SEMICONDUCTORS INDUSTRIE	Semiconductor Equipment	Position the Dutch high-tech industry to deliver crucial enabling technologies to the information-led society and the healthcare ecosystem. At the same time, create sustainable jobs and growth in Dutch GDP now (semiconductor industry) and in the future (quantum technologies).	- Turnover of the Dutch semiconductor equipment industry passes the 16-billion-euro mark. - Dutch quantum technology industry with 30,000 jobs, 2-3 billion euros of GDP and 100 start-ups by 2040.
	SLIMME MOBILITEITSSYSTEMEN	Smart & Safe Traffic & Transport	Contribute to achieving a sustainable traffic and transport system by creating smart mobility systems. Digitalisation, connectivity and automation are central to this and will dramatically change our traffic system over the coming years.	- Ensure that smart, safe and efficient logistics and mobility systems contribute to the sustainability objectives by: - Contributing to the development and optimisation of new forms of mobility, such as Mobility as a Service, Hyperloop, Light Electric Vehicles, Self-organising Logistics and connected Automated Transport. - Optimising smart algorithms (AI), digital platforms and applications to achieve a smoother traffic flow with these new forms of mobility.
	DIGITALE TECHNIEKEN VOOR EEN GEZONDE SAMENLEVING	Biomedical & Digital Health	Contribute to the use of ICT and AI for the renewal of the health and care system.	- The roadmap 'Biological and Digital Health' focuses, among other things, on health data management that respects privacy, such as innovative health trains, health measurement, digital and AI-assisted diagnostics. including early detection of biomarkers, digital interventions and digital behaviour change technologies.

ROADMAPS AND THE KEY ENABLING TECHNOLOGIES AND KEY ENABLING METHODOLOGIES

The table below shows the relevance of the Key Enabling Technologies and Key Enabling Methodologies to TNO's roadmaps.

ROADMAP	UNIT	TECHNOLOGIES								METHODOLOGIES	
		ADVANCED MATERIALS	PHOTONICS	QUANTUM TECHNOLOGIES	DIGITAL TECHNOLOGIES	NANO TECHNOLOGIES	CHEMICAL TECHNOLOGIES	LIFE SCIENCE TECHNOLOGIES	ENGINEERING & MANUFACTURING TECHNOLOGIES	VISION, IMAGINATION AND IMPACT ASSESSMENT	VALUE CREATION, UPSCALING AND EXPERIMENTAL ENVIRONMENTS
Buildings & Infrastructure	BIM	■			■				■	■	■
Maritime & Offshore	BIM	■			■				■	▪	▪
Environment & Sustainability	CEE	■			■		■		■		
National Security	DSS			▪	■			▪		▪	▪
Operations & Human Factors	DSS			▪	■			■		■	▪
Information & Sensor Systems	DSS	■	■	■	■	▪			▪		▪
Protection, Munitions & Weapons	DSS	■			▪		■	■	■		▪
Renewable Electricity	ET	■	■		■		■		■		
CO2 Neutral Industry	ET	■			■		■		■		
Sustainable Subsurface	ET	■			■				■		
System Transition	ET				■			■			
Prevention & Productivity	HL				▪	▪			▪	■	■
Biomedical & Digital Health	HL				■			■			▪
Digital Innovations	ICT			■	■				■		
Space & Scientific Instrumentation	IND		■		■	■			■		
Semiconductor Equipment	IND		■	■	■	■			■		
Flexible & Free-form Products	IND	■	■		■	■			■		
Sustainable Chemical Industry	IND	■					■		■		
Smart Industry	IND				■				■		
Transitions & Transformations	SAP				▪					■	■
Smart and Safe Traffic & Transport	T&T				■				■	■	■
Sustainable Traffic & Transport	T&T	■			■		■		■	■	■

■ work is being done in the roadmap on the technology or methodology to develop it further

▪ the technology or methodology is being used in the roadmap

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