TNO Onderzoeksplannen 2026 - Overzicht Vraaggestuurde Programma's

Unit	Vraaggestuurde Programma's (VPs)	MTIB Thema
EMT	1. P325 System Transition	
	2. P330 Vorming NMO (CRM)	
	3. P307 Geo-energy	
	4. P310 Karakterisering Grondwater	
	5. P321 Renewable Electricity	
	6. P510 Luchtkwaliteit	
	7. P515 Circulaire Economie	
	8. P340 Sustainable Industry	
	9. P341 Energy and Infrastructure	
MBE	10. P502 Duurzaam bouwen	
	11. P407 Smart and Sustainable Mobility	
HW	12. P204 Future of Work	
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	15. P102 Veilige maatschappij	
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	18. P706 ICT en AI	
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HTI	21. P607 Space & Scientific instrument.	
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	P604 EZK Algemeen	
	P605 MKB	
	CSO	
		Totaal

MTIB Legenda	
Klimaat & Energie	Gezondheid en Zorg
Circulaire Economie	Veiligheid
Mobiliteit	Sleutel-technologie
Landbouw & Water	
	Publiek
	Publiek / Privaat

Korte Samenvatting (AI ondersteuning).

TNO's 2026 research and innovation plans encompass a broad range of demand-driven programs aimed at tackling major societal challenges such as climate change, energy transition, circular economy, health, safety, digitalization, and strategic autonomy. The programs focus on generating knowledge, developing technologies, and supporting policy to foster sustainable development, security, and economic competitiveness in the Netherlands and Europe.

Energy and Climate Transition Programs

System Transition

Aiming to support the Dutch goal of net zero CO2 emissions by 2050, this program focuses on transforming the fossil-fuel-based energy system into a sustainable one. It addresses complex societal and technological challenges, including spatial conflicts, technology integration, and market readiness. In 2026, TNO plans to develop methods for justice and support of energy communities, model local transitions to sustainable heating and cooling, and analyze mineral and storage needs nationally and internationally. The program also supports policy through scenario studies on fossil-free industry and lifestyle changes.

Geo-energy

This program advances sustainable heat supply and industrial decarbonization by developing geothermal energy, heat storage, and CO2 and hydrogen storage technologies. Safety and cost-effectiveness are priorities, with goals for 2026 including demonstration of seasonal heat storage with dynamic pricing, test drillings for shallow geothermal projects, and AI workflows for subsurface modeling. Collaboration with industry and knowledge institutions is integral to reducing geological risks and enhancing monitoring.

Renewable Electricity

Targeting a climate-neutral, reliable, and affordable energy system with 70 GW offshore wind and 200 GWp solar energy by 2050, this program supports EU manufacturing capabilities and system flexibility. For 2026, efforts include expanding offshore wind measurement locations, modeling wind farm cluster wake effects, validating offshore electricity storage, and advancing solar-on-water projects such as floating photovoltaic farms. The program also focuses on tandem solar cell efficiencies and mass customization manufacturing approaches.

Circular Economy

The program accelerates the circular economy to reduce raw material depletion and environmental impacts. From 2026, it focuses on Circular Strategies & Critical Raw Materials, developing sustainable recycling technologies, integrated assessment models, and electro-leaching for battery recycling. Key goals include extending assessment frameworks, launching a recycling strategy tool, and upscaling patented recycling technologies.

Sustainable Industry: Feedstock Conversion and Sustainable Materials

Supporting the industrial transition to climate neutrality and circularity by 2050, this program develops technologies for plastic recycling, sustainable fuels and chemicals, and industrial carbon capture. It also advances energy-saving materials, alternatives for toxic and critical materials, and circular design principles. Milestones for 2026 include industrial demonstrations of solvent-based recycling, fuel-grade DME production from CO2, and PFAS-free membranes for PEM electrolysis. The program

is structured around two propositions: Feedstock Conversion and Sustainable Materials, each with targeted sub-propositions.

Energy and Infrastructure

This program aims to drive the industrial sector toward carbon neutrality through sustainable industrial heat, Power-to-X technologies (including hydrogen and electrochemistry), process efficiency, and flexible infrastructure development. In 2026, TNO plans to pilot renewable-driven industrial processes and develop resilient energy infrastructure to support electrification and fossil fuel reduction.

Sustainable Building

Focused on optimizing sustainability in buildings and maritime/offshore constructions, this program addresses CO2 reduction, gas dependency, affordability, circularity, safety, and digitalization. It consists of five subprograms covering infrastructure renewal, construction innovation, energy transition acceleration in buildings, maritime/offshore structures, and climate adaptation. Highlights for 2026 include safety guidelines for new concrete types, biobased materials assessments, digital tools for building energy flexibility, and climate impact models for infrastructure.

Mobility and Health

Smart and Sustainable Mobility

This program aims for zero calamities, emissions, and loss by advancing safety, sustainability, and efficiency in mobility and logistics. It focuses on livable cities, safe transport innovations, sustainable propulsion, and green maritime performance. Priorities for 2026 include developing spatial assessment frameworks, multi-fleet logistics solutions, safety assessment for automated vehicles, rapid battery prototyping, emission measurements for maritime vessels, and carbon capture pilots onboard ships.

Future of Work

Addressing productivity, labor market mismatches, and healthy work environments, this program focuses on AI adoption, skills-based labor markets, occupational safety, and chemical risk assessment. Goals for 2026 include preparing sectoral skill passports, developing labor market impact models, accelerating innovation adoption, and building AI-supported occupational health tools.

Biomedical and Digital Health: Future of Health

Supporting the Dutch health mission to extend healthy life years and reduce disparities, this program develops lifestyle interventions, digital health technologies, and drug development platforms. Short-term goals include studying age-related health issues, advancing metabolic flux analyses, digital mental health innovations, and implementing obesity reduction programs.

Safety and Security

Defence Technology Industrial Base

This program strengthens Dutch defence capabilities and industrial competitiveness through innovations in air and missile defense, future fires, autonomous capabilities, maritime security, and military space use. It emphasizes accelerating technology readiness and supporting European rearmament efforts.

Safe Society

Addressing threats such as cyberattacks, disinformation, and personnel shortages, this program develops solutions for digital transformation, organized crime, national security, and workforce resilience. In 2026, it plans to integrate generative AI for workforce coaching, develop interoperable AI decision support frameworks, and enhance sensor technologies for inspection and surveillance.

Resilience

Focusing on societal resilience against military and hybrid threats, this program supports protection of critical infrastructure, counters influence operations, and develops strategic foresight and crisis management tools. Goals for 2026 include integrated safety visualization for infrastructure, simulation environments for influence mitigation, and early warning tools.

Cyber Risk Management and System Resilience

This program aims to embed cyber resilience proactively across products and infrastructures. It advances secure-by-design practices, quantum-safe communications, and autonomous incident response tools. Deliverables for 2026 include launching a Product Security Innovation Radar, new post-quantum cryptography methodologies, and autonomous attack response demonstrations in the energy sector.

Key Enabling Technologies and Digitalization

Digital Systems

Focusing on the digital transition of cyber-physical systems, this program develops systems engineering methodologies to manage complexity in energy, mobility, and high-tech industries. The vision for 2035 is to double engineering productivity through digital assistants. In 2026, the program supports innovations in system architecture, AI integration, and lifecycle engineering.

Semiconductors & Quantum Technologies

This program supports Dutch and European industry in semiconductor and quantum technology leadership, focusing on lithography improvements, PFAS-free materials, quantum photonic integrated circuits, and medical device innovations. Planned 2026 activities include advancing metrology concepts, quantum chip metrology, and AI-driven sensor design.

Flexible and Freeform Products

Centered on thin film and hybrid printed electronics, this program drives innovations in sustainable manufacturing, healthcare wearables, energy storage, advanced packaging, and integrated photonics. Key 2026 deliverables include tools for laser transfer in photonics, ultrasound wearable platforms, pilot lines for batteries, and prototypes for power electronics packaging.

Smart Industry

This program advances smart manufacturing to enhance productivity, flexibility, and strategic autonomy in the high-tech industry. It focuses on data and AI, mechatronics, optical systems, imaging, and cybersecurity. By 2030, it aims for widespread adoption of smart industry practices. In 2026, priorities include integrating smart manufacturing in defense, developing autonomous manufacturing demos, launching fiber-optic sensor networks, and scaling digital twin frameworks.

Space and Scientific Instrumentation

This program supports climate monitoring, secure connectivity, and scientific discovery by developing instruments for Earth observation, satellite communication, ground and space-based astronomy,

fusion diagnostics, and in-orbit servicing. In 2026, goals include launching a new Dutch small satellite instrument for emissions measurement, advancing optical satellite communication terminals, developing deformable mirrors for telescopes, and contributing to gravitational wave detection missions.

Societal Transitions and Innovation Methodologies

This program addresses systemic societal challenges by developing innovation systems, digital value-driven society strategies, spatial-economic governance, and green strategic industry knowledge. It supports agenda setting, ecosystem orchestration, value chain design, impact assessment, governance, and policy advice. The 2026 focus includes enhancing knowledge on strategic control points, AI governance, societal impact evaluation, and chain development to accelerate sustainable transitions.

This integrated approach across multiple domains demonstrates TNO's commitment to fostering sustainable development, enhancing security and resilience, and driving technological leadership in the Netherlands and Europe throughout 2026 and beyond.

Titel	VP System Transition (P325)
MTIB-thema	Klimaat en Energie
Contactpersonen TNO	Erlend Deckers (VP-manager), Patrick Punte (Directeur Divisie EMT System Solutions & Environment)
Contactpersonen Overheid	Timon Vervoorn en Debby Joosen (Ministerie van Klimaat & Groene Groei), Marjolein Bot, Maarten de Vries, Robert-Jan van Egmond, Guus Mulder (Missies)

Programma jaar 2026 - Samenvatting

Nederland heeft zich gecommitteerd aan het reduceren van de CO_2-uitstoot naar nul in 2050[1]. Daaruit volgt de ambitie om het huidige energiesysteem - dat vooral op fossiele brandstoffen is gebaseerd – om te vormen tot een duurzaam energiesysteem: de energietransitie. De opgave van de energietransitie is groot: het energiesysteem vormt het fundament onder de economie en onder onze welvaart en welzijn. De energietransitie heeft een grote impact op onze samenleving, op hoe we onze huizen verwarmen, hoe we werken, reizen en produceren.

De transitie blijkt complex voor beleidsmakers op alle niveaus die werken aan effectief beleid, voor bedrijven die toekomstbestendige strategieën willen ontwikkelen, voor burgers en collectieven: voor de samenleving als geheel. Voorbeelden van complexiteiten zijn: conflicten in het ruimtegebruik, inpassing van nieuwe technologieën, lage technologie- en marktrijpheidsniveaus van diverse belangrijke waardeketens, gecombineerd met de noodzaak om deze snel op te schalen, interactieeffecten (zoals ecologie, economie), financiering en gedragsaspecten. Zeker nu het klimaat- en energiebeleid in de praktijk gerealiseerd moet worden, komen allerlei uitvoeringsproblemen aan het licht, zoals netcongestie en vertragingen in de realisatie. En met de nieuwe geopolitieke realiteit komt de nadruk veel meer te liggen op leveringszekerheid en betaalbaarheid. Met gerichte kennisopbouw wil TNO publieke en private actoren onafhankelijke en feitelijke kennis en inzichten bieden die hen in staat stellen onderbouwde beslissingen te nemen, de voortgang van de energietransitie integraal te monitoren en de uitvoeringsproblemen aan te pakken.

Het *Vraaggestuurd programma System Transition* onderhoudt en ontwikkelt een brede kennisbasis en draagt bij aan de Integrale Kennis en Innovatie Agenda (IKIA) en de missies; met name aan de missie Systeemintegratie van de topsector Energie. De belangrijkste doelgroepen van de ontwikkelde kennis zijn bedrijven in de energietransitie, zoals de netwerkbedrijven, MKB en industrie, overheden (van Europees tot lokaal) en energie-consultants. Een voorbeeld van kennisopbouw in dit kader zijn de scenariostudies ADAPT en TRANSFORM, waarin we bijvoorbeeld laten zien hoe bepalend de ontwikkeling van de energie-intensieve industrie is voor de energietransitie. In 2026 zullen we onder andere investeren in de ontwikkeling van methoden voor rechtvaardigheid en ondersteuning van energiegemeenschappen. Ook zullen we onze modelontwikkeling richten op de lokale transitie naar duurzame warmte-en koudesystemen, in samenhang met de elektriciteitstransitie. Op (inter)nationale schaal zullen we onder andere aandacht besteden aan de *mineralenbehoeften* en *opslagbehoeftes* van de energietransitie.

Naast het VP System Transition loopt het gerelateerde *onderzoeksprogramma Kennis voor Energiebeleid (KVE)* waarin TNO onderzoek doet ter ondersteuning van het energie- en klimaatbeleid van KGG. Dit programma wordt gefinancierd door een programmasubsidie van het ministerie van Klimaat en Groene Groei (KGG). Een voorbeeld hiervan is de KVE-studie naar een fossielvrije industrie met behulp van scenariomodellering. Deze studie ondersteunt het ministerie bij het verkennen van de haalbaarheid om af te stappen van fossiele brandstoffen. Het rapport zal in september 2025 bij een brief van het ministerie KGG naar het parlement worden gestuurd. Een ander voorbeeld is het onderzoek 'Het potentieel van leefstijlveranderingen in de Nederlandse klimaattransitie' dat in juni werd gepubliceerd. De prioriteiten voor onderzoek in het KVE programma 2026 worden pas in Q4 van 2025 samen met KGG vastgesteld. Dit VP-plan gaat daarom met name in op de boogde kennisontwikkeling in 2026 door TNO in het VP System Transition dat wordt gefinancierd uit de Rijksbijdrage die TNO ontvangt.

De twee programma's leveren toepasbare kennis op in de vorm van whitepapers, rapportages, webtools en software (onder andere rekenmodellen), die hun weg vinden naar beleidsmakers, analisten, strategen en politiek. Dit laatste met name in de vorm van bijlagen bij kamerbrieven, zoals de reflectie op de betekenis van de Clean Industry Deal voor Nederland en technische briefings, zoals rond de Wet Collectieve Warmte, energiearmoede en het Interdepartementale BeleidsOnderzoek (IBO)

[1] Parijs COP 21

over netkosten. Met deze kennis kan effectief beleid worden vormgegeven, en kunnen onderbouwde besluiten worden genomen om de energietransitie te doen slagen. Veel van de resultaten worden gepubliceerd op de website www.energy.nl en op www.tno.nl.

Titel	VP Geo-energie (P307)
MTIB Thema	Klimaat en Energie / MMIP4: Duurzame warmte en koude in de gebouwde omgeving (individueel en collectief), MMIP 6,7 (Verduurzaming warmtevraag Industrie, CO2 opslag, grootschalige energieopslag)
Contactpersonen TNO	Maurice Hanegraaf (VPM), Holger Cremer, Jan Diederik van Wees
Contactpersoon Regie-voerder	Robert Jan van Egmond, Jorg Gigler. TKI Urban Energy, TKI Nieuw Gas, TKI Deltatechnologie.

Programma jaar 2026 - Samenvatting

De energietransitie vereist een betrouwbare en betaalbare warmtevoorziening met minder afhankelijkheid van aardgas. Warmtenetten, geothermie, bodemenergie en warmte-koude opslag spelen hierbij een belangrijke rol, terwijl CO_2-opslag en waterstof essentieel zijn voor de verduurzaming van de industrie. Deze ambities zijn verankerd in het Klimaatakkoord en worden ondersteund door de overheid, onder meer via de SDE++-regeling. Veiligheid blijft een cruciaal aandachtspunt: naar aanleiding van de Parlementaire Enquête Aardgaswinning benadrukt de overheid het belang van zorgvuldig risicobeheer en verantwoord gebruik van de (diepe) ondergrond. Daarnaast ondersteunt Nederland haar energievoorziening en klimaatdoelen via de geplande bouw van vier nieuwe kerncentrales. Het TNO onderzoeksprogramma VP307 Geo-energie draagt bij aan een betrouwbaar, betaalbaar en veilig energiesysteem door:

- **Risicoreductie:** vermindering van geologische en technische risico's bij geothermie en warmteopslag door betere data-analyse methoden, AI-toepassingen en publiek toegankelijke informatiesystemen.
- **Productieverhoging:** verhoging van productie en efficiëntie van geothermie- en opslag door ontwikkeling van innovatieve boorconcepten en levensduurverlenging van installaties door predictive maintenance.
- **Veiligheid en duurzaamheid:** verbeteren van putintegriteit, monitoringsystemen en mitigatie van risico's voor geïnduceerde seismiciteit, inclusief abandonnering van putten met natuurlijke materialen.
- **Kosteneffectieve warmtenetten:** doorontwikkeling van de publieke Design Toolkit door optimalisatie van vraag-aanbod matching, integratie van lage temperatuur warmtenetten (inclusief koude levering), verminderen van netcongestie (power2heat) en integratie van duurzame warmte- en koude bronnen.
- **Veilige energieopslag:** ontwikkelen van betrouwbare modellen en workflows voor CO_2-opslag en waterstofopslag, inclusief geomechanische modellering en well integrity.

Beoogde resultaten 2026

- Demonstratie van en businesscase voor seizoensopslag van warmte met dynamische prijzen (power2heat).
- Uitvoeren van proefboringen en evaluaties in het kader van ondiepe geothermieprojecten.
- Opzetten van grootschalige monitoringprojecten gericht op geïnduceerde seismiciteit voor Porthos (CCS) en geothermie.
- Reduceren van geologische risico's door de ontwikkeling van geavanceerde voorwaartse modellen.
- Ontwikkelen van AI-workflows voor ondergrondmodellering en seismische risicoanalyse.
- Doorontwikkeling van modellen ter bevordering van putintegriteit (CREST) en geomechanica (MOLE) voor CO_2- en waterstofopslag projecten.
- Uitwerken van een gedetailleerd ontwerp en safetycase voor opslag van nucleair afval in diepe boorgaten.
- Ontwikkeling van radial drilling technologie voor ontwikkeling van marginale reservoirs voor geothermie.

Samenwerking en innovatie.

De uitvoering van het onderzoek gebeurt samen met industriepartners, kennisinstellingen (o.a. Deltares, KNMI, KWR, UU en TUD) en via nationale en internationale programma's (MOOI, WarmingUP GOO, Geo4ALL).De resultaten versnellen de ontwikkeling van duurzame warmte, vergroten de veiligheid en betrouwbaarheid van ondergrondse activiteiten en verlagen de maatschappelijke kosten van de energietransitie.

Titel	**VP Karakterisering en Dynamiek Samenstelling Grondwater (P310)**
MTIB Thema	Topsector Water. IKIA B,E
Contactpersonen TNO	Maurice Hanegraaf (VP Manager) Tirza van Daalen (Division Director, Geological Survey of the Netherlands)
Contactpersoon Regie-voerder	Wilbert van Zeventer (Min. I&W), Katja Portegies (RWS); programmaraden TKI Watertechnologie, TKI Deltatechnologie

Programma jaar 2026 - Samenvatting

Het Vraaggestuurd Programma **Groundwater Stewardship (VP310)** richt zich op de kennisbasis en instrumenten die nodig zijn voor duurzaam beheer van het Nederlandse grondwater. Grondwater is essentieel voor drinkwatervoorziening, landbouw, natuur, industrie en bodemenergie en energieopslag. Tegelijkertijd neemt de druk op het grondwatersysteem toe door klimaatverandering, verstedelijking, verzilting, nieuwe verontreinigingen (zoals PFAS) en de energietransitie.

Het programma heeft drie hoofddoelen voor de periode tot 2029:

1. Het bieden van een actueel en betrouwbaar beeld van de **beschikbaarheid en kwaliteit** van grondwater in Nederland.
2. Het ontwikkelen van **voorspellende modellen en scenario's** die laten zien hoe klimaatverandering, beleid en menselijk gebruik het grondwater beïnvloeden.
3. Het ondersteunen van **duurzaam, meervoudig gebruik van de ondergrond**, zodat drinkwater, landbouw, natuur en energietoepassingen naast elkaar kunnen bestaan.

In 2026 levert VP310 tastbare resultaten die direct toepasbaar zijn voor beleid en beheer:

- Nieuwe **modelleringstrategieën voor PFAS en andere complexe stoffen**, zodat saneringsbeleid beter kan worden onderbouwd.
- **Veldonderzoek** naar uitloging van secundaire bouwstoffen om risico's voor grond- en oppervlaktewater in beeld te brengen.
- Verbeterde schattingen van de **hydraulische weerstand van dekafzettingen**, cruciaal voor waterbeheer in polders en KRW-rapportages.
- Een eerste prototype van **4D-mapping van grondwaterkwaliteit**, waarmee ruimtelijke en temporele trends zichtbaar worden voor drinkwaterbescherming.
- Doorontwikkeling van **grondwatertools.nl** met actuele droogte-indicatoren en voorspellingen, en een voorstel voor een **nationaal netwerk voor droogtemonitoring**.
- Ontwikkeling van een **blauwdruk voor aquitard-karakterisering** en verbeterde methoden voor lange-termijn modellering van grondwatertrends.
- Demonstratie van **digital twins** en optimalisatiesoftware (EVEREST) om meervoudig ruimtegebruik in de ondergrond efficiënt te plannen.

TNO voert dit programma uit in nauwe samenwerking met ministeries (IenW, LNV, BZK), waterschappen, provincies, drinkwaterbedrijven, RIVM, gemeenten en kennisinstellingen. De kennis en producten ondersteunen beleidsdoelen uit het beleidsprogramma bodem en wagter sturend , Deltaprogramma, Klimaatakkoord en de Kaderrichtlijn Water en dragen bij aan een klimaatbestendige en leefbare delta.

- Door onafhankelijk onderzoek te combineren met een sterke data-infrastructuur (BRO, REGIS-II) en innovatieve analysetechnieken, draagt VP310 bij aan waterzekerheid, klimaatadaptatie en de duurzame energietransitie. Zo blijft Nederland voorbereid op de uitdagingen van de toekomst en worden keuzes over het gebruik van grondwater en ondergrond beter onderbouwd en maatschappelijk gedragen.
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Titel	VP Renewable Electricity (P321)
MTIB Thema	Klimaat en Energie, MMIP1, MMIP2, MMIP 13
Contactpersonen TNO	Mark Overwijk (Division Director Energy Supply), Jan Willem Wagenaar (VP-manager Wind Energy), Kahya Engler (Program Manager Solar Energy)

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	  ○ Robin Quax (Program Manager Renewable Electricity)
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	  ○ Albert Polman (Amolf)

Programma jaar 2026 - Samenvatting

Without question, our sustainable future will require a climate-neutral, reliable and affordable energy system. It is our mission to realize an abundance of offshore and onshore renewable energy, which is fed into the energy system in a reliable, viable, affordable and sustainable way. For 2050, we foresee an installed capacity of 70 GW offshore wind and 200 GWp solar energy. This means for this ‘Vraaggestuurd Programma’ Renewable Electricity a focus on efficiency and cost reduction. In recent years, geopolitical developments put more and more emphasis on energy independence and energy security with direct impact on and the demand for manufacturing capabilities in EU and NL. Secondly, increasing amounts of renewable energy with a highly intermittent character need to be fed into the energy system and matched with demand. So, flexibility in the system is necessary. This can be achieved through flexible generation or demand, coupling generation to storage or other assets and improvement of the energy infrastructure. Further, societal developments are such that we require the renewable energy generation to be both circular and in perfect harmony with nature. With these challenges in mind, the long term goals of this VP are:

1. Support the EU manufacturing of renewable energy technology.
2. Improve the reliability and affordability of the energy system.
3. Increase flexibility in the energy system and enhance storage and conversion methods.
4. Make renewable energy generation more sustainable.

With these long term goals in mind, we define specific goals for 2026. For instance, TNO supports the government in their offshore wind ambitions with a long-term measurement programme providing government and offshore wind developers with high quality information about the wind conditions at various platforms across the North Sea. TNO will commission a fifth Lidar measurement location, i.e. the F2-A-Hanze platform, close to wind farm zone ‘Doordewind’ and search area 6/7 and throughout 2026, the first measurements of this platform are expected. As the North Sea is getting more and more occupied with offshore wind farms, their mutual interaction through wind farm cluster wake effects become more dominant impacting wind farm’s yield. Therefore, TNO has combined the aforementioned long-term offshore wind measurements with mesoscale model data using the Weather Research & Forecasting Model (WRF) and couple this to the more detailed, in-house simulation software

FarmFlow for more accurate farm effects modelling. Following, TNO proposes to add these modelling effort to the 'Wind op Zee' program and to develop a dedicated atlas complementing the offshore wind measurements and representing cluster wake effects. From 2026 onwards, TNO aims to provide the sector with this wind atlas comprising highly accurate wind farm cluster effects.

In order to increase the flexibility in the energy system, TNO explore the coupling of offshore wind to hydrogen production and to energy storage. With main partners RWE and Vattenfall, we research the coupling of offshore wind to various storage techniques with the aim to mature, de-risk, and validate innovative offshore electricity storage solutions from technological, economic, environmental, and societal perspectives. The technologies under evaluation range from short-term (batteries), medium-term (compressed air, pumped hydro) and long-term (pressurized alkaline electrolyser) storage options collocated to offshore wind. Preliminary Front-End Engineering Designs (FEED) and prototype components will be developed to validate these hybrid systems. Digital twins virtual representations of the hybrid system to reflect the physical operations accurately, will be employed to simulate system performance and optimize grid operations at gigawatt scale. In 2026, the validation experiments, to be carried out in the TNO Switch laboratory, will be prepared.

Reaching high power conversion efficiencies is a crucial parameter to reduce the solar PV surface area needs, to improve the environmental profile, and to enhance electrical integration options. Tandem solar cells have the capabilities of reaching high efficiencies, because they consist of two or more sub-cells, where each subcell converts energy of a part the solar spectrum. TNO is well positioned in this field as we can combine our expertise and infrastructure to make state-of the-art hybrid tandems. We focus on scaling the tandem technology towards a scale that is relevant for industry, typically full wafer size. In 2026, we aim to advance the performance and/or power output such to a relevant industrial format size, i.e typically 30%. Further, we will explore additional materials to achieve a fullerene free architecture to reduce the materials costs, CAPEX and OPEX.

The reduction of the cost price of PV is of utmost importance to be able to seamlessly integrate PV on every surface. The Mass Customisation approach using flexible foils, pick-and-place equipment and roll lamination is an essential asset in this quest. TNO has already shown that laminates pass dedicated tests (damp heat, humidity freeze and wet leakage) and now the Mass Customisation line is upgraded to be able to work with back contact silicium cells, as a second technology. The feasibility of the manufacturing of semi-fabricates with silicium is expected at the end of 2025 and preparations have started to show the feasibility of handling perovskite minimodules. 2026 will mark the start of the comprehensive development of roll to roll encapsulation for perovskite solar cell manufacturing, where we aim to have the first minimodules demonstrated. This is key for a robust and industrialisable technology for solar foils.

In order to achieve the abundance of solar power, TNO works with key industrial partners to develop solar on water. For instance, with TNO's support Oceans of Energy has recently completed a 0.5 MWp offshore solar floating farm in Amsterdam's harbor, for installation within CrossWind's HKN offshore wind farm. In this same project (DEI+ NS2), TNO and partners issued a whitepaper describing the effects of slamming wave on floating platforms, following from the wave flume experiments at Deltares. Also, TNO is working with SolarDuck on their OFPV platform in the DEI+ Merganser project. Within this project, TNO has recently published a peer reviewed paper on the effects of various risk management policies on the performance of OFPV installation campaigns. In 2026, TNO will work with CrossWind and Oceans of Energy within the HKN Offshore PV project on (1) monitoring and analysing electrical and mechanical data from the PV system to validate yield models, which will lead to published journal articles, and (2) developing streamlined O&M strategies for multi-MW hybrid farms, providing recommendations for optimising OFPV operations and maintenance using high-fidelity analysis and the UWise O&M tool; a report is due by the end of 2026. On a policy level, the Platform Offshore Solar with TNO as chairman, will collaborate with the Ministry of EZK to define a realistic longer term roadmap for the large scale deployment of Offshore Solar.

Titel	VP Luchtkwaliteit (P510)
MTIB Thema	
Contactpersonen TNO (SD en VPM)	Yana Gon (VPM), Patrick Punte (Directeur Divisie EMT System Solutions & Environment)
Contactpersoon Regie-voerder	Maarten van der Geest (Min. IenW)

Programma jaar 2026 - Samenvatting

The Netherlands continues to face urgent environmental challenges related to air pollution, climate change, and biodiversity loss. Air pollution contributes to approximately 11,000 premature deaths annually and climate change increase the risk of extreme weather events and sea level rise. Biodiversity loss, due to excessive nitrogen deposition, disrupts the natural ecosystem balance.

The Dutch government has committed itself to ambitious targets through the Clean Air Agreement (SLA) and the Climate Act. These agreements aim to improve air quality by 50% in 2030 and reduce greenhouse gas emissions by 55% in 2030. For nitrogen deposition, a new committee (MCEN) is working on a new legal and policy framework for nitrogen reduction that will replace the old WSN[2].

The VP Air Quality program focuses on developing science-based solutions for monitoring and verifying atmospheric emissions, concentrations, and depositions. The program is demand-driven and aligned with the needs of ministries (IenW, LVVN, KGG), provinces, municipalities, and European frameworks. TNO works with partners like RIVM, KNMI and universities to combine measurements, models, and data to create practical insights that support better decisions in policy and society.

Key results for 2026:

- Demonstration of airborne environmental DNA (**eDNA**) sampling for biodiversity monitoring. In combination with atmospheric transport modelling, this enables tracking of large variations in the number and types of species over space and time.
- **Climate Vulnerability:** Light-to-use access to climate and greenhouse gas monitoring and modelling capacity, enabling faster responses to environmental challenges. A first case study will be performed for an African country.
- Integration of real-time particle monitoring, chemical analysis, and policy advice within the Particle Expertise Centre (**PEC**), supporting emission reduction in industry, transport, and circular sectors. For example, broader use of non-target screening (**NTS**) with high-resolution mass spectrometry and cheminformatics to detect unknown and emerging air and process pollutants.
- New releases of national maps of ultrafine particle (**UFP**) map and health-relevant indicators such as oxidative potential (**OP**). These maps are based on mobile and stationary measurements, novel source-specific emissions and models.
- Improved **source attribution of nitrogen deposition** with approaches that can be extended to other pollutants such as PFAS and ozone through a combination of mobile sensing, remote sensing, company-specific monitoring, and fine-scale modelling (DALES, LOTOS-EUROS).

Development of a national top-down inversion system for **greenhouse gas (GHG) budgets**, including CH_4, N_2O, and CO_2, and integration of hydrogen (H_2) emissions into inventories and scenario tools.

[2] MCEN = Ministeriële Commissie Economie en Natuurherstel. WSN = Wet Stikstof en Natuur, which had the goal to have 74% of the Dutch Nature reserves below the critical nitrogen deposition value in 2030.

Titel	**VP Circulaire Economie (P515)**
MTIB Thema	Circulaire Economie
Contactpersonen TNO (DM/SD en VPM)	Erlend Deckers (VPM/MM), Patrick Punte (Directeur Divisie EMT System Solutions & Environment)
Contactpersoon Regie-voerder	Bas Warmenhoven, Wilma van Hunnik (IenW)

Programma jaar 2026 - Samenvatting

The Circular Economy is a key enabler for achieving climate goals, securing strategic autonomy, and reducing dependency on virgin (critical) raw materials. A circular economy greatly reduces the use & depletion of exhaustible raw materials by optimally re-using materials, components, and products, and by substituting with renewable raw materials. In doing so, the circular economy contributes to prevention of climate change, environmental pollution, and loss of biodiversity. It also has positive socio-economic effects (see “Mogelijke doelen voor een circulaire economie”, Policy Brief, PBL, July 2021).

Until 2025, VP515 was structured around two program lines: Circular Strategies & Critical Raw Materials (CS&CRM), and Circular Plastics. Per January 1st, the TNO Unit Energy & Materials Transition (EMT) is reorganized into a division structure with four divisions. The board of director introduced this division structure in order to keep the growing EMT unit manageable. The VP515 program line Circular Plastics has been transferred to the EMT division Industry, and therefore will be integrated in the VPs of this division. From 2026 onwards, VP515 will consist of the Circular Strategies & Critical Raw Materials program line.

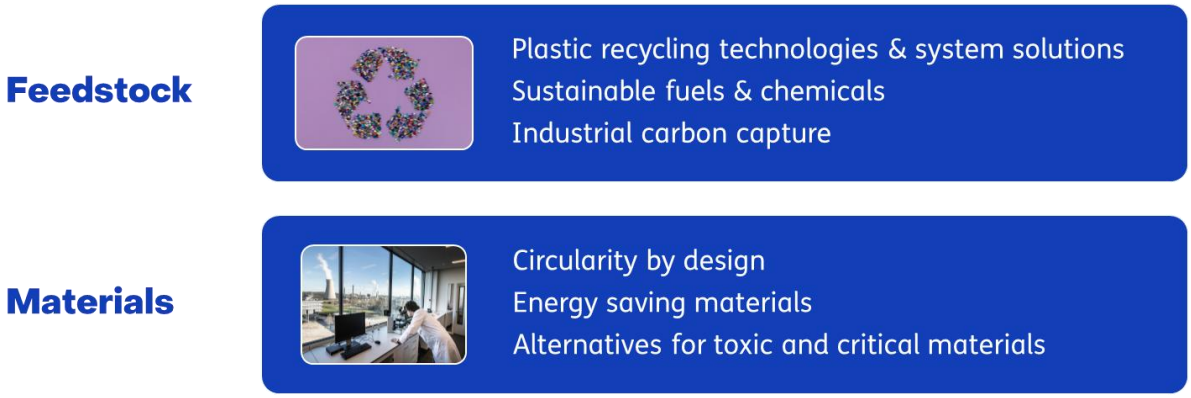
The activities within Circular Strategies & Critical Raw Materials aim to accelerate the transition to a more circular economy, support the energy transition, and to support the materials transition. This VP relates to the high-level policy and goals such as: Circular Economy goals for 2050 & 2030, increasing strategic autonomy (Grondstoffenstrategie 2022, EU CRMA), supporting maximizing raw material efficiency, Design for Recycling, Circular materials & processes (KIA CE), and supporting prioritized value chains (build environment, manufacturing industry, batteries / electronic devices (ICER 2023, NPCE 2023)).

For the long term, CS&CRM aims to enable a circular economy and strategic autonomy by developing sustainable recycling technologies for critical raw materials, an integrated assessment model for full value chains, and by orchestrating end-of-life value chains to support CRMA benchmarks and circularity goals. For 2026, our goal is to extend our integrated assessment framework towards product criticality, environmental assessment of low RTL technologies and second order system effects. Also, we will launch the first version of the recycling strategy tool. Finally, we will start upscaling the patented electro-leaching technology for Li-ion battery recycling, further develop a chemical recycling process for CRM recovery from PV waste and extend our prospective industrial analysis for CRM recycling in the Netherlands.

Titel	VP Sustainable Industry: Feedstock Conversion and Sustainable Materials (P340)
MTIB Thema	Energie en Duurzaamheid / Sleuteltechnologie. Topsector Energy, Topsector Chemistry, Topsector HTSM, Mission C, MMIP 6 and 8, KIA CE MMIP 1, 2 and 3
Contactpersonen TNO	Esther van den Beuken
Contactpersoon Regie-voerder	Peter Besseling, Mark Schmets, Paul Verbraak, & Roy Dekker (KGG) Rob Kreiter (TKI-E&I), Jörg Gigler (TKI-Nieuw Gas), Peter Berben (TKI GC&C)

Programma jaar 2026 - Samenvatting

The demand driven program “Sustainable Industry: Feedstock Conversion and Sustainable Materials” articulates TNO’s comprehensive strategy to support the transition of the Dutch industrial sector toward circular and sustainable materials, aiming at climate neutrality (net zero emissions) and 100% circularity by 2050 – fully in line with the Dutch Climate Agreement (DCA) and the National Program Circular Economy (NPCE), respectively. This plan is structured around two propositions: “Feedstock Conversion” and “Sustainable Materials”. Within these propositions, six targeted sub-propositions serve as focal points for collaboration, innovation and development. The figure below provides an overview of these (sub)propositions.



Overview of relevant propositions (Feedstock & Materials) and their respective sub-propositions for the VP “Sustainable Industry: Feedstock Conversion & Sustainable Materials” 2026-2029.

Feedstock Conversion

Our main objective for the proposition ‘Feedstock Conversion’ is the development of sustainable & efficient processes for the following topics:

- Plastics recycling technologies and system solutions: We develop new recycling technologies, such as thermal cracking, dissolution and depolymerization, applicable to various (complex) plastic waste streams. In addition, we develop system models to make future scenarios to guide authorities, industry and other stakeholder to make the right decisions for the circular transition;
- Sustainable fuels & chemicals: We develop innovative biomass and CO_2 conversion technologies, like thermochemical processes to convert biobased waste streams into syngas and high value chemicals, or catalytic processes to convert biomass into specialty chemicals, or separation-enhanced technologies to convert CO_2 into syngas and fuels (e.g. for shipping and aviation);
- Industrial Carbon Capture (ICC): We develop new process-integrated precombustion capture technologies, including our proprietary sorption-enhanced water-gas shift (SEWGS) capture technology for e.g. the steel industry. We enable the industrial implementation of post-combustion ICC using absorption technology by performing pilot campaigns at industrial sites with real flue gases, and by developing proprietary technologies to decrease solvent degradation and emissions. Finally, we develop new cost-effective technologies for CO_2-purification.

To arrive at these long-term goals, the following main results are intended for 2026:

Plastic Recycling Technologies & System Solutions:

- Industrial demonstration of solvent-based recycling technology at TRL6 through integration in a circular plastics value chain.
- Proof-of-concept at TRL4 of feedstock versatility of thermal cracking through conversion of textile waste into high-value chemicals.
- Our CITS (Circular Industrial Transformation System) model operational for plastics beyond polyolefins, with prospective life cycle analysis in place for energy production and other processes, connected to a macro-economic model.

Sustainable Fuels & Chemicals:

- Proof-of-concept for SAF production from syngas at TRL4.
- Fuel-grade production of DME from CO_2 at TRL6 (up to 500 kilogram).
- Proof-of-principle of three novel bio-based polyols for application in adhesives and coatings.

Industrial Carbon Capture:

- DORA (Dissolved Oxygen Removal Apparatus)successfully demonstrated at TRL6-8 in three pilots with performance on solvent lifetime extension and improved CO_2 purity demonstrated.
- Demonstration of electrified regeneration of CO_2 capture solvent at a cement plant.
- Complete concept definition (basic design) and secure location for the First-of-a-Kind (FoaK) SEWGS plant in the iron & steel sector in collaboration with licensee.

Sustainable Materials

Our main objective for “Sustainable Materials” in the period 2026 – 2029 is the development and validation of novel sustainable materials within the scope of following sub-propositions:

Energy Saving Materials:

Within Energy Saving Materials, we develop and demonstrate novel sustainable materials that facilitate energy saving in the built environment and in mobility applications. For the built environment, we develop and validate innovative optical materials for sustainable buildings. These materials are either coatings or polymer films with specific solar control functionalities, which are applied in windows and building-integrated photovoltaics. Additionally, from 2024 we focus on re-use of old flat glass from windows and solar panels. For mobility applications, we develop and implement circular and lightweight, structural thermoplastic composite (TPC) materials in automotive and other mobility applications. The ability to use these materials in a wide range of products and components will enable accelerating the energy transition by lowering fuel consumption and extending range of electric vehicles, resulting in reduction of CO_2 emissions. These activities are part of Brightlands Materials Center's programs Sustainable Buildings and Sustainable Mobility.

Alternatives for Toxic & Critical Materials:

Within Alternatives for Toxic & Critical Materials, we focus on the development of safe, sustainable, and economically viable alternatives to critical and toxic materials. Furthermore, it focuses on increasing supply chain robustness for materials of high economic and strategic value via novel recycling processes, establishing alternative sources, and developing sustainable production processes. The sub-proposition started in 2025 with the main goal to develop a multi-year technology roadmap for novel materials development related to the above-mentioned topics. The developed roadmap has the PEM electrolyzer at its core, focusing on developing safe and sustainable PFAS-free alternatives for the Nafion membrane and increasing supply chain robustness for critical raw materials (CRMs) used in the PEM electrolyzer, such as Iridium and Platinum, via new recycling processes, alternative sourcing via waste streams and development of alternative catalyst materials.

Circularity by Design:

Within Circularity by Design, we focus on (1) development of products with improved circularity, including recyclability, (2) microplastic and environment system analyses, mitigating microplastics through process design, product design and exposure reduction, and (3) experimental understanding of polymer quality in the life cycle of design, production, use and recycling.

To arrive at this long-term goal, the following main results are intended for 2026:

Energy Saving Materials:

- Thermochromic coatings and laminates: Monitoring of functional performance of thermochromic windows in test and office building. Study the switching behavior in test building, assess the impact of lower temperature and improved thermal comfort by the thermochromic window on health of occupants of non-climatized offices.
- Energy efficient triggered debonding of laminated glass for windows and PV: optimize the composition of the polyolefin laminate for triggered release and establish a lab scale process demonstrator (incl. inductive heating equipment) for triggered release using inductive heating. Assess applicability of this concept for other industrially applied laminate materials, viz. PVB and EVA. Assess applicability of this concept for re-use of glass from old PV panels.
- Heat blocking (BI)PV: Produce demonstrator solar panels and study the impact of heat blocking coatings and polymer front sheets on the temperature of PV panels.
- Demonstration of consistent quality reTPC from mixed production waste streams at 40-60 kg/h and quantified technical and economical assessment for post-industrial waste TPC (technology positioning, cost model, material efficiency).
- Demonstration of TPC products manufactured by CFAM and/or by fused granulate fabrication using recycled materials, meeting the mechanical requirements for selected mobility applications.

Alternatives for Toxic & Critical Materials:

- At least 1 PFAS free membrane for PEM electrolysis developed and tested on lab scale.
- At least 1 circularity concept for PEM electrolyzers established on lab scale, e.g., reduced leaching /recovery of leached CRMs, component designs for easy recycling, use of waste sources as feedstock, etc.
- At least 1 new material (catalyst or anti-corrosion coating) for CRM replacement developed and tested on lab scale.

Circularity by Design:

- An innovative business model and supply chain for re-usable and recyclable E-commerce packaging and for contaminated single-use flexible medical & pharmaceutical packaging waste that is profitable and has a positive environmental impact.
- A demo product that integrates the use of recycled PP by using novel processing techniques, with the aim to expand the current rPP market.
- Design of a method for the measurement of the composition of sorted plastics in a recycling facility, intended as an exit control to enhance its value.
- Development of mitigation strategies for reducing exposure to microplastics via indoor air based on cohort measurements.
- Development of prototype high-temperature reversible adhesive system or composite material + evaluation and validation of recycling principle with industry partners (TRL 3-5).

This plan is heavily supported by strategic collaborations with industry leaders, academic institutions, and government bodies, ensuring that the Dutch industrial sector not only meets its climate and circularity targets but also remains a competitive and sustainable force in the global market.

Titel	VP Energy and Infrastructure (P341)
MTIB Thema	Energie en Duurzaamheid / Sleuteltechnologie. Topsector Energy; MISSION C; MMIP 6, 7 & 8
Contactpersonen TNO	Stephan Janbroers
Contactpersoon Regie-voerder	Peter Besseling, Paul Verbraak, Roy Dekker (EZK) Rob Kreiter (TKI-E&I), Jörg Gigler (TKI-Nieuw Gas)

Programma jaar 2026 - Samenvatting

The demand-driven program “Energy & Infrastructure” articulates TNO’s comprehensive strategy to drive both the Dutch and international industrial sectors toward carbon neutrality by 2050, in alignment with the Dutch National Climate Agreement and the Clean Industrial Deal for EU competitiveness and decarbonisation. By fostering innovation and strengthening the international position of Dutch technology suppliers, the program enhances earning power and global impact for the Netherlands. This program is structured around two critical pillars: **Energy** transformation and **Infrastructure** development, each designed to enable the efficient roll-out of clean energy, to accelerate electrification, and to reduce the dependence on fossil fuels. Within these pillars, six targeted sub-propositions serve as focal points for innovation and development. For Energy, these include (1) Sustainable Industrial Heat, (2) Power-to-X Technologies (including hydrogen, electrochemistry, and photochemistry), and (3) Process Efficiency and Flexibility. In Infrastructure, sub-propositions include (1) Safe and reliable infrastructure development, (2) Flexible energy systems, and (3) North West European energy infrastructure.

By 2026, TNO aims to deliver measurable impact by piloting and licensing renewable-driven industrial technologies, strengthening the international market position of Dutch technology suppliers, and enabling the development of resilient, future-proof energy infrastructure—thereby accelerating both decarbonisation and earning power for the Netherlands. In alignment with recent developments around offshore energy, we plan for more focus on the role of ports and import of renewable molecules, in contrast to the domestic production of hydrogen offshore. For the latter, it is essential to maintain the knowledge position for the Netherlands achieved so far. The plan is heavily supported by strategic collaborations with industry leaders, academic institutions, and government bodies, ensuring that the Dutch industrial sector not only meets its climate targets but also remains a competitive and sustainable force in the global market.

Energy

Sustainable Industrial Heat

Power-to-X Technologies

Process Efficiency and Flexibility

Infrastructure

Safe and reliable infrastructure development

Flexible energy systems

North West European energy infrastructure

Short overview of relevant sub-propositions in the VP Energy & Infrastructure 2025 / 2026.

Titel	VP Duurzaam Bouwen (P502)
MTIB Thema	Energie en Duurzaamheid
Contactpersonen TNO	Arjen Adriaanse (DM) en IJsbrand van Straalen (VPM)
Contactpersoon Regie-voerder	Programmacommissie Deltatechnologie (PCDT), Thematisch overleg via het Afsprakenkader TNO-RWS-IenW, Jelle Bluemink en Hans Weijers (VRO), Bart Brink (TKI Bouw & Techniek), David van der Woude (VRO), Debby Joosen (KGG), Hester Dijkstra (KGG), Josephine Ris (KGG), Veerle Heijnen (KGG), Sabine Jansen (VRO), Marjolein van Splunder (KGG), Frank Klinckenberg (VRO), Casper van Mourik (KGG), Kasper Baarends (VRO), Guus Mulder (TKI Urban Energy), Robert Jan van Egmond (TKI Urban Energy), Robin Quax (TKI Urban Energy), Hans van der Weijde (TKI HTSM, M2i), Bas Buchner (TKI Maritiem) en Bob Meijer (TKI Offshore Energy)

Programma jaar 2026 - Samenvatting

VP Duurzaam Bouwen richt zich op het optimaal verduurzamen van de gebouwde omgeving en van maritieme en offshore constructies. Dit betreft met name windturbines op zee, bruggen, viaducten, gebouwen en schepen. Maatschappelijk relevante thema's zijn daarbij CO2-reductie, verminderen van de gasafhankelijkheid, betaalbaarheid, circulariteit, veiligheid, (voorspelbaarheid van) onderhoud en VP Duurzaam Bouwen richt zich op het optimaal verduurzamen van de gebouwde omgeving en van maritieme en offshore constructies. Dit betreft met name gebouwen, droge en natte kunstwerken, lijninfrastructuur, windturbines op zee en schepen. Maatschappelijk relevante thema's zijn daarbij CO_2-reductie, oplossen woningnood, verminderen van de gasafhankelijkheid, betaalbaarheid, circulariteit, veiligheid, (voorspelbaarheid van) onderhoud en vervanging, en digitalisering. VP Duurzaam Bouwen bestaat uit vijf deelprogramma's: Infrastructuur, Bouwinnovatie, Versnelling energietransitie gebouwde omgeving, Maritieme en offshore constructies en Klimaatadaptatie.

Infrastructuur

Het deelprogramma *Infrastructuur* richt zich op het optimaliseren van het beheer en duurzaam vernieuwen van verouderende infrastructuur. Dit wordt bereikt door middel van levensduurverlenging, beheersing en reductie van risico's voor veiligheid en bruikbaarheid, en het stimuleren van duurzaam materiaalgebruik. De impact komt tot uiting in een beter beheersbare en betaalbare vervangings- en renovatieopgave, een effectievere planning en prioritering van ingrepen met minimale hinder voor bereikbaarheid, een versnelling van de transitie naar circulaire en klimaatneutrale infrastructuur, en een hogere productiviteit in de hele keten — zowel technisch als organisatorisch.

De kennis die TNO hiervoor ontwikkelt, zorgt ervoor dat assetmanagers de beschikking krijgen over modellen en ontwerp- en beoordelingskaders voor wegen, van circulaire en milieuvriendelijke materialen en voor diverse constructies (nieuw en bestaand, beton en staal, droog en nat). In 2026 worden onder andere de richtlijnen omtrent de veiligheidsfilosofie voor bewegingswerken vastgesteld en wordt ingezet op betere voorspellingsmodellen voor de toepassing van wapening in nieuwe betonsoorten zoals geopolymeerbeton. Voor asfalt wordt in 2026 ingezet op een demonstrator met biobased bindmiddelen en op betere voorspellingsmodellen voor duurzamere productietechnieken voor het hergebruik van warm asfalt. Het onderzoek zal leiden tot veiligheidseisen voor constructies van circulaire materialen en constructies met hergebruikte elementen.

Bouwinnovatie

Het deelprogramma *Bouwinnovatie* versnelt de transitie naar een circulaire bouweconomie, bevordert industrialisatie en garandeert veiligheid door innovaties te ontwikkelen voor bouwproducten, bouwelementen en gebouwen. Duurzaamheid, betaalbaarheid en grootschalige toepassing binnen de woning- en utiliteitsbouw centraal staan daarbij centraal. In het kader van een circulaire bouweconomie worden nieuwe processen ontwikkeld voor hergebruik van secundair hout op basis van automatische scan technieken en mechanische bewerking van hout die opschaalbaar zijn in de praktijk. Van veelbelovende biobased materialen op basis van natuurlijke vezels zal de levensduur en veiligheid in hun toepassing worden vastgesteld. Tevens zal TNO zich vanaf 2026 gaan richten op het beoordelen van natuurvezel versterkte biobased composieten. Om industrialisatie in de bouw te bevorderen zal een minimum viable product worden ontwikkeld om digitalisering van de woningproductie mogelijk te maken. Tevens zal een demoversie van een geautomatiseerd voortgangsmonitoringsysteem voor assemblage en productieprocessen beschikbaar komen op basis waarvan kennis zal worden opgebouwd over deze processen in de huidige praktijk. In het kader van de verduurzaming van zorgvastgoed wordt een tool ontwikkeld gericht op

toestandsafhankelijk onderhoud van installaties. Daarnaast neemt de belangstelling in de markt voor gezondheidsgericht ontwerpen toe; TNO zal in 2026 de eerste stappen zetten voor de ontwikkeling van een integrale aanpak om de gezondheidsvoordelen van biobased materialen me te nemen in het ontwerp. In het kader van het blijven garanderen van de veiligheid wordt een systematiek uitgewerkt voor het bepalen van schaderisico's ten gevolge van bodemdaling. Daarnaast wordt nagegaan welke mogelijkheden er zijn om het materiaalgebruik in constructieve ontwerpen terug te dringen en welke opties er zijn van demontabele verbindingen in betonconstructies.

Versnelling energietransitie gebouwde omgeving

Het deelprogramma *Versnelling energietransitie gebouwde omgeving* streeft naar een energiepositieve gebouwde omgeving in 2050. Dit wordt gerealiseerd door de ontwikkeling van kennis en innovaties die de verduurzaming van woningen en utiliteitsgebouwen versnellen, met aandacht voor kwaliteit en betaalbaarheid en waarbij de gebruiker centraal staat. Op het gebied van *datagedreven diensten* wordt in 2026 een eerste publiek toegankelijke basistool voor een gestandaardiseerd landelijk datasysteem voor woningdata ontwikkeld, wordt het potentieel van een Rijksbrede contingentenaanpak[3] verkend en wordt een proof of concept voorzien voor een zelfinregelende warmtepomp. Ten aanzien van het *optimaliseren van flexibiliteitsruimte* op het elektriciteitsnet wordt in 2026 een model voor het voorspellen van de flexibiliteitsruimte in een utiliteitsgebouw geïmplementeerd in een platform voor gebouwbeheerders, zodat zij op basis hiervan passende maatregelen kunnen nemen. Voor woningen wordt een model predictive controller ontwikkeld om de warmtepomp, PV en batterij aan te sturen, inclusief een gebruiksvriendelijke interface. Tot slot worden binnen het *ontwikkelingscentrum voor verwarmings-, koel- en tapwatersystemen* de eerste gestandaardiseerde testpakketten ontwikkeld en geïntroduceerd in de markt. Hiermee kan TNO productontwikkelaars ondersteunen bij het beperken van systeemrisico's om zo de time to market van duurzame innovaties te versnellen.

Maritieme en offshore constructies

Het deelprogramma *Maritieme en offshore constructies* richt zich op het ontwikkelen van veilige, circulaire en kostenefficiënte oplossingen voor scheeps- en offshore constructies onder extreme omstandigheden.

TNO focust in 2026 op een geharmoniseerde aanpak via lab, praktijk, en rekenmodellen om de veiligheid en (kosten)effectiviteit van (nieuwe) technische oplossingen aan te tonen voor de groeiende vloot op alternatieve brandstoffen. De opgedane kennis wordt omgezet in onder andere globale regelgeving via de International Maritime Organisation (IMO). In 2026 leggen we daarbij extra focus op (vloeibare) waterstof testen, mede ingebed in het op te richten Safe Energy Transition (SET) programma en het delen van de lopende inzichten rondom methanol en nucleair. TNO verkend voor nucleair op zee in 2026 een geharmoniseerde aanpak voor de benodigde veiligheidscasussen en onderzoek naar materiaalgedrag aan boord onder nucleaire invloed (hoge temperaturen), als onderdeel van een TNO brede aanpak.

Verder focust TNO op het monitoren en de circulariteit van maritieme en offshore constructies. In 2026 ontwikkelt TNO, in samenwerking met de offshore windindustrie, een eerste 'minimum viable concept' voor levensduurvoorspelling en monitoring van windturbines met rekenkracht-efficiënte modellen en grootschalige tests. TNO definieert daarnaast in 2026 complementaire KPI's voor circulair staalgebruik en levensduurvoorspelling van grote drijvende constructies en PV-panelen. Ook hier wordt gebruik gemaakt van een combinatie van lab- en praktijkdata en modellen. Afsluitend, richt TNO zich in 2026 op co-development van het eerste monitoring en levensduurvoorspellingsmodel voor dynamische (stroom)kabels, die onder belasting staan van extreme (zeegaande) bewegingen.

Klimaatadaptatie

Het deelprogramma *Klimaatadaptatie* richt zich op een klimaatadaptieve gebouwde omgeving. Methoden en oplossingen worden ontwikkeld om de effecten van klimaatverandering op onze leefomgeving te beoordelen en zorg te dragen dat gebouwen, infrastructuur en de gebruikers ervan bestand zijn tegen extreme omstandigheden in de toekomst. Door TNO wordt ingezet op een klimaatrobuuste kritieke infrastructuur, een bebouwde omgeving waarin schade als gevolg van veranderingen in grondwater en ondergrond wordt voorkomen en aan het voorkomen van een ongezond binnenmilieu als gevolg van veranderingen in het klimaat. Voor 2026 zijn de belangrijkste doelen: een eerste versie van een impactmodel van

[3] Contingentenaanpak bewijst effectiviteit van energierenovaties

klimaatverandering op de weginfrastructuur, een eerste versie van een risicobeoordelingsgereedschap voor de effecten van grondwater en ondergrond onder meer via extern gefinancierde projecten, en een simulatiemodel om hittestress en vocht in gebouwen te beoordelen met als doel om maatregelen door te rekenen.

Titel	**VP Smart and Sustainable Mobility (P407)**
MTIB Thema	Mobiliteit / Missie D+ (MMIP 9 & 10; deel-KIA Toekomstbestendige Mobiliteitssystemen)
Contactpersonen TNO (DS en VPM)	Arjen Adriaanse (Director of Science & Technology); Marika Hoedemaeker (VP-manager)
Contactpersoon Regie-voerder	Topsector HTSM: Leo Warmerdam; Topsector Logistiek: Niels Agatz; Topsector Water & Maritiem: Thecla Bodewes; Ministry of IenW: Michel Duinmayer (IenW-DGMO/Unit Strategie) and Marieke Smit (IenW-DGMO/Unit Strategie); Ministry of VRO: Arie Versluis (VRO/Geo-informatie)

Programma jaar 2026 - Samenvatting

The demand driven programme (VP) Smart and Sustainable Mobility is dedicated to advance innovation and knowledge in smart technology and policy solutions. Its primary goal is to enhance the safety, sustainability, and efficiency of the mobility and logistics sector. This is in line with the unit plan of the unit Mobility and Built Environment, where we strive to achieve 'the three zeroes': zero calamities, zero emissions and zero loss. This involves the significant challenge of improving road safety and the efficiency of mobility and logistics, while simultaneously innovating for a sustainable and climate neutral mobility system. The aim is to achieve very low to zero emissions in traffic and transport, powered by renewable energy. We do this by dividing our work into four focus areas: Liveable and resilient cities and regions, Safe and Efficient Mobility, Sustainable Mobility and Green Maritime Performance. 2026 is the first year of a new strategic 4-year period in which we make clear choices in our focus. We will discontinue certain activities and initiate new ones.

The focus area of **Liveable and Resilient Cities and Regions** carries out research aimed at providing tools and methods for better and faster decision making for more sustainable, robust, safe and accessible cities and regions for all, where residents, visitors and businesses function optimally. Cities and regions today face a complex set of interrelated challenges, and to address their challenges our research focuses on three main technology and method lines. In the first line, *Understanding and interpreting the mobility and spatial system*, research in 2026 addresses 1) the development of a spatial assessment framework to evaluate trade-offs of broad prosperity aspects, 2) an analysis of EV infrastructure gaps and shared mobility potential in low-income areas, and 3) practical tools for reshaping policy narratives to support coherent decision-making. In the second line, *Modelling (Predictive Digital Twins)*, we continue to develop concepts for predictive and prescriptive digital twins of cities and regions, capable of fast, large scale, integral assessment. Spatial modelling will focus on linking spatial decisions to policy ambitions and developing indicators to visualise their impacts. Further work includes 1) developing tools for setting up agent and activity-based models with less effort, 2) operationalizing broad prosperity indicators, and 3) quantifying resilience in road network planning. In the third line, *AI-based design and optimisation incl. scenario generation (prescriptive DTs)*, we are advancing AI-based methods to generate and optimise promising scenarios for mobility interventions, based on stakeholders' criteria. These will be supported by fast models to assess and optimise scenario impacts and identify trade-offs between impact areas. This is a first step towards a full, comprehensive design and optimisation methodology.

All our research is grounded in reliable data, robust models and digital twinning technologies, and we use a broad prosperity ('brede welvaart') perspective, with particular attention to vulnerable groups.

The goal of focus area **Safe and Efficient Mobility** is to realise new technologies and methodologies to improve the safety, intelligence, and efficiency of passenger and freight transport in NL. The research focuses on three areas. In area 'Self-organizing logistics', we develop alternative supply chain management forms and provide insights into their technical and business impacts. The main long-term goal is to develop a multi-company, multi-fleet decentralized solution, addressing challenges in collaborative business models, data sharing solutions, and planning algorithms for asset sharing. Integrating these elements will create effective, efficient, resilient, and sustainable logistics solutions, while tackling urgent issues like emissions, supply chain security, and resource scarcity. In 2026 our focus is on developing and testing a multi-party, multi-fleet solution with two trusted logistics companies. Further we will investigate the extension of the application areas by examining other logistics segments, electric truck fleets and automated trucks. For the area 'Safe introduction of new transport innovations', the goal is to extend the earlier developed safety assessment framework that aims to establish a safety case for Level 4 automation systems before road deployment. This is done by: a) assessing context awareness for AI-based systems, b) modelling and

quantifying driving competency, c) quantifying safety at the traffic system level, and d) providing efficient safety assessment methods. These efforts will support the safe introduction of new transport innovations by developing metrics, validating approaches, and ensuring practical application. The objective of area 'Development of solutions for automated vehicles', is to develop core technologies that support safe and reliable vehicle automation and gaining an essential knowledge base for developing the safety assessment framework. These developments will enable higher levels of automation and connected, safe vehicle operations. The initiative aims to deliver resilient and scalable solutions for automated driving, including improved vehicle-to-tower interfaces and simulation frameworks for further algorithm development. Our efforts are concentrated in three primary domains: a) sensor fusion, estimation, and modelling; b) decision-making and context-aware planning; and c) system-centric architecture design methodologies.

For the area of **Sustainable Mobility**, there is a clear urgency for action. Road transport contributes to 24% of total CO_2 emissions. Achieving both international and national climate change objectives will require a fundamental transition of the mobility system. TNO is dedicated to supporting the development of a climate-neutral mobility system by 2050, while also advancing improvements in public health, air quality, nature conservation, and economic growth. This mobility system—covering road, rail, and water transport—must also be accessible for everyone, regardless of income, location, or mobility needs. Our efforts are focused on improving the performance of low to zero-emission powertrains and reducing emissions through policy legislations. Our work encompasses two key areas: policy and technology. Towards 2030 we a) develop and assess sustainable propulsion (battery electric and combustion engines using hydrogen or other carbon-based sustainable fuels) and aftertreatment technologies, b) monitor real world emissions from tailpipe and tyre-wear, and c) develop modular and life-aware energy management strategies that will shorten the time to market of sustainable vehicles. By 2026, in our technology line we aim to have realised a Rapid Battery Prototyping (RBP) methodology, enabling quick and professional realisation of battery prototypes for technology and innovation demonstration. Furthermore, we will show a proof-of-concept demonstration of using water recovered from exhaust gasses to reduce NOx emissions of a H2-ICE engine. This makes expensive after-treatment systems unnecessary. We will also realise TNO's MEMS with predictive functionality for improved system performance on a heavy-duty electrically driven reefer trailer equipped with a solar panel system, electric cooler and auxiliaries to reduce CO2 emissions of existing diesel reefer fleets. In our policy line we will prepare the adaption of our policy support skills to new emerging policy themes, e.g., the Roadworthiness Package, real world performance of electric vehicles, mobile machinery and ships and grid-congestion. In 2026 we will measure 500 vehicles on public roads to demonstrate that plume chase measurement setup is validated for identifying high-NOx-emitting vehicles. We will also determine the real-world energy consumption reduction potential of electric vehicles.

In the area of **Green Maritime Performance**, we aim to remove technical and policy barriers that hold back the maritime energy transition by creating and validating sustainable solutions. To enable the national and global IMO ambition towards climate neutral shipping by 2050, towards 2030 we focus on four key areas: a) development of a validated emission model for Europe wide implementation and scenario building; b) co-development of hybrid methanol ICE powertrain, including energy management approach to optimize the use of batteries onboard based upon maritime energy operational profile; c) development of a full scale carbon capture pilot system towards a first real life permanent installation on board; and d) the development of qualitative and quantitative transition monitor to assess the impact of technology and policy development.

In 2026 we focus on a) measurement of emissions on current vessels (e.g., NOx emissions on diesel fuelled ships and methane slip (CH_4) on LNG ships) and development of standards for measuring emissions from alternative fuels while co-developing regulation. b) enabling full scale engine tests by using TNO's maritime 1-cylinder engine, and the operationalisation of test facilities towards 1.4MW engine size. c) continuing tests for carbon capture system applied to different fuels (MGO/HFO). Finally, d) we will initiate the co-development of transition monitoring methodology with the ministry of Infrastructure and water management as part of the 'Kennisagenda Duurzame Scheepvaart'.

Titel	VP Future of Work (P204)
MTIB Thema	Gezondheid en Zorg
Contactpersonen TNO	Marjoleine van der Zwan (Managing Director TNO H&W), Jeffrey Vermeer (Market Director a.i. H&W), Seth van den Bossche (VP Manager)
Contactpersoon Regie-voerder	-Ministry of Social Affairs and Employment: Marieke Maas Ministry of Economic Affairs: Sarah-Lee Tilly Top Sector HTSM/Nanotech: Ronny van 't Oever

Programma jaar 2026 - Samenvatting

VP Future of Work addresses the challenges of slowing productivity growth and structural labour market mismatch/shortages in Europe and The Netherlands. The programme focusses on innovations for boosting sustainable labour productivity, accelerating innovation-adoption (AI in particular), improving labour market adaptability and creating healthy and high quality work environments. A strong, productive and adaptable labour market with high-quality jobs is key to raising competitiveness, prosperity and tackling major societal transitions in The Netherlands and EU.

The target group of the programme includes the (potential) workforce, employers, government and HR/OSH professionals. The programme consists of the following knowledge lines and objectives:

Main research lines are:
- Adaptive & productive organizations
- Labour market innovations
- Healthy & sustainable work
- Safe & sustainable by design / safe chemical innovation

Strategic objectives (2026–2029) of the programme are:
- Accelerate adoption of human-centric AI and digital work augmentation technologies.
- Development of data-infrastructure, modelling and tooling enabling a Skills Based Labour Market.
- Development AI-assisted occupational exposome modelling and Occupational Safety & Health monitoring & intervention support systems.
- Accelerate development of (socio-technological) workplace innovations for reducing heavy work.
- Development of Safe & Sustainable by Design methodologies and Nextgen Risk Assessment (NGRA) strategies to mitigate potential health & environment risks of new chemicals and materials.

Main goals for 2026 are:
- Preparing CompetentNL data for market application & implementation of sectoral skills-passports.
- Build model using new skills-related data-infrastructure to predict regional and national labour market impact of transitions or sudden shocks.
- Development of (scalable) solutions for accelerating innovation-adoption.
- Develop knowledge on reducing high burden work & shared innovation programs with sectors.
- Build knowledge base for AI-support in OSH-interventions. Start development of exposome passport.
- Development of heat-stress algorithm.
- Build an integrated, multidisciplinary in vitro and in silico facility to assist industry to perform risk-benefit analyses for chemicals and pharmaceuticals (IMFRA).
- Development of AI-assisted data-driven hazards and risk assessments methodologies to support industry in decision making for chemical design and substance substitution.

The VP Future of Work directly addresses the following societal transitions, key technologies and strategic agenda's:

Major Societal Transitions	Key Technologies[4]
Digital Transition Energy Transition Health Transition	**Digital and information technologies**: • AI • Data science, data analytics and dataspaces • Digital Twinning and Immersive technologies **Engineering and fabrication technologies:** • Sensor and actuator technologies • Robotics • Digital Manufacturing technologies
National Technology Strategy[5]	**Thematic KIA**
Artificial Intelligence and Data Productivity enhancement	Health and Care & Public Earning Capacity Digitalization Climate and Energy Safety and security
(Inter)national Agendas and Roadmaps	**Strategic Program Plans TKI**
European Commission-The future of European competitiveness EU Quality Jobs Roadmap European Commission-European Skills Agenda Strategic knowledge Agenda SZW Mission Health & Care / Strategic knowledge agenda VWS / AZWA Productivity agenda NL Human Capital Agenda Top sectors Action plan green & digital jobs	TKI-LSH TKI-HTSM TKI-CT

4 https://www.tno.nl/publish/pages/8843/tno_herijking_sleuteltechnologie_2023_v4.pdf

5 De Nationale Technologiestrategie | Titel uitgave (overheid.nl)

Titel	VP Biomedical and Digital Health: Future of Health (P203)
MTIB Thema	Gezondheid en Zorg
Contactpersonen TNO	Jasper Kieboom (VPM), Marjoleine van der Zwan (MD)
Contactpersoon Regie-voerder	Nico van Meeteren (Topsector LSH)

Programma jaar 2026 - Samenvatting

The research program Future of Health supports the mission driven innovation approach of the Dutch Ministry of Health, Wellbeing and Sports ('VWS'). It supports **the central mission: aiming for Dutch citizens living 5 years longer in good health and reducing the health differences between socioeconomical positions**. TNO research contributes to **reducing health issues that are the consequence of an unhealthy lifestyle or exposure to unhealthy environment.** Our research will also **contribute to preventing chronic diseases and increase the proportion of people with a chronic illness or lifelong disability so that they can participate in society as desired**.

We do this by reducing the risk of disease development (prevention) and by helping to manage disease by developing ground-breaking technologies and approaches such as lifestyle interventions, digital health technologies and drug development. The research program Future of Health significantly contributes to the three moonshots of TNO illustrated below:

To help achieve the moonshots, newly developed technologies and knowledge will be implemented in the context of the quadruple helix that includes collaborations with other research programs, academic and industrial partners, health professionals in field labs, healthcare insurance companies, governmental and local policy makers, and citizens to provide systems solutions. The research is conducted in public-private consortia and used in projects with industry (e.g. in services for industry and growth fund projects).

To contribute to above missions and moonshots some examples of short-term results for 2026 are:

- Investigate age and sex-related health issues, specifically those associated with muscle health and diabetic complications in relation to development of liver and kidney disease. Based on this we aim to create efficacy platforms that can be used for development of therapeutic or preventive interventions.
- Further development of use-cases for sensitive and specific metabolic flux analyses in humans, using accelerated mass spectrometry technology, focusing on disease subtyping, diagnostics and therapeutic efficacy studies. This will allow further understanding of interindividual differences in disease development, progression and treatment response, which is relevant for differentiating between low-risk and at-risk individuals.
- Demo-case showing the relevance of adequate timing of lifestyle interventions to improve health in shift workers.
- Investigate and develop digital innovations that support the mental health care sector (GGZ) in terms of patient triaging/waiting list reduction, treatment options and aftercare.
- Further strengthening of TNOs position in digital biomarkers by developing and valorising digital biomarkers in clinical trials and establishing development of a digital biomarker joint innovation centre together with stakeholders.
- Setting up affordable health care programs focusing on diminishing obesity by means of multimodal treatments that also including social activities and exercise.
- Implementation and scaling of the use of the D-score at the individual level by Youth Health Care and daycare organisations.

Titel	VP Defence Technology Industrial Base (P104)
MTIB Thema	Veiligheid
Contactpersonen TNO	Marcel van der Graaf (VPM), Christa Hooijer (Director S&T)
Contactpersoon Regie-voerder	Fenna Leijten (Mindef/HDB), Leo Warmerdam, Lucas Roffel (HTSM)

Programma jaar 2026 - Samenvatting

The Netherlands must remain a secure and safe country for its citizens to work and live in. Developments like climate change, migration and changing geopolitics pose serious challenges to our society and to our defence and security organisations. The Netherlands and Europe are taking actions to become strategically less dependent, both economically and for its defence. Investments in new defensive capabilities (or their renewal) is the daily news and industry is stepping up its R&D and production. Consequently we foresee an increasing and long-term demand for all innovations in Vraaggestuurd Programma P104.

The propositions of TNO DSS towards the ministry of Defence and defence industry

Of the twelve strategic TNO Defence Safety and Security propositions towards the Ministry of Defence and defence industry, the following are actively supported through P104: (1) Integrated Air and Missile Defence; (2) Future Fires; (3) Surviving on the battle field of the future; (4) Effective Autonomous Capabilities; (5) Maritime Security & Defence; (6) Military Use of Space.

Following the TNO-wide portfolio review, and in light of European rearmament, the topics "High-Tech for Defence" and "Munitions Production" will be added to the portfolio starting in 2026, including the associated impulse funding. These topics are strategically focused on accelerating the transition of defence innovations toward higher Technology Readiness Levels (TRLs) and are embedded in the propositions (1) Integrated Air and Missile Defence and (2) Future Fire Solutions.

P104 forms a crucial part of a mature financing mix, where this programme boosts the exploration of industrial and ecosystem participation in technology development as well as the subsidised investment in highly potential but low-TRL developments. We help maintain and further strengthen the global leadership and competitiveness of our national industrial defence and security ecosystem in specific niches through industry-relevant R&D with an emphasis on the speed of innovation. We do this through a revolving set of approximately 40 running projects and a comparable number of opportunities in various stages of acquisition.

The international defence and security market is by no means a level playing field and national boundaries play an important role. We keep striving for lasting impact, international collaboration, and growth. We continue to support our units propositions. We will bring Science and Innovation at the Frontline.

Titel	VP Veilige Maatschappij (P102)
MTIB Thema	Veiligheid
Contactpersonen TNO	Gwen Jansen-Ferdinandus (VPM), Christa Hooijer (DS&T)
Contactpersoon Regie-voerder	Ron Hanoeman en Bas ter Luun, Directie Innovatie, Kennis en Strategie (Min JenV), Kirsten Hehemann en Sven Hamelink (politie)

Programma jaar 2026 - Samenvatting

De veiligheid en stabiliteit van de Nederlandse samenleving staan onder druk door een reeks complexe en grensoverschrijdende dreigingen. Cyberaanvallen, statelijke inmenging, maatschappelijke polarisatie en afnemend vertrouwen in instituties vormen een directe bedreiging voor onze rechtsstaat. Geopolitieke spanningen, zoals de oorlogen in Oekraïne en Gaza, hebben een voelbare impact op onze nationale veiligheid. Tegelijkertijd ontwikkelen technologieën zoals generatieve AI en autonome systemen zich razendsnel, en zijn ze ook voor kwaadwillenden eenvoudig toegankelijk. Daarnaast kampen justitie- en veiligheidsorganisaties met personeelstekorten door vergrijzing, toenemende werkdruk en concurrentie.

Uit deze ontwikkelingen vloeien maatschappelijke opgaven voort. Het Vraaggestuurd Programma Veilige Maatschappij (VPVM) richt zich op: digitale transformatie en veiligheid, bestrijden georganiseerde en ondermijnende criminaliteit, versterken van de nationale veiligheid en aanpak van personeelsschaarste. TNO werkt in het VPVM samen met partners als politie, de Dienst Justitiële Inrichtingen (DJI) en het Bestuursdepartement van JenV en andere organisaties uit het justitie- en veiligheidsdomein aan innovatieve oplossingen om deze opgaven het hoofd te bieden. Drie lange termijn doelstellingen staan hierbij centraal:

Doorbraak in personeelsschaarste

Om de operationele slagkracht van veiligheidsorganisaties te waarborgen ondanks een afnemende personeelscapaciteit, zet het VPVM in op een systeemgerichte en organisatie overstijgende aanpak. Met onze kennis en innovaties stellen we organisaties in staat om samen te werken aan het versneld en effectiever opleiden van personeel, het duurzaam inzetten van medewerkers, het slim inrichten van werkprocessen en het integreren van arbeidsbesparende technologieën. In 2026 ligt de nadruk nog op het onderzoek binnen de context van een specifieke organisatie. Tegelijkertijd wordt gewerkt aan een gedeeld vocabulaire en denkwijze tussen organisaties om zo samenwerking mogelijk te maken. In 2026 wordt onder andere met de politie gewerkt aan het combineren van generatieve AI en data uit wearables om werknemers op verantwoorde wijze te coachen om hun (mentale) weerbaarheid te versterken. Daarnaast wordt gewerkt aan een digital twin van de veiligheidsprofessional, waarmee de belasting van individuen beter afgestemd kan worden op hun actuele vermogen. Zo wordt overbelasting voorkomen en de duurzame inzetbaarheid versterkt.

Effectieve besluitvorming onder druk

In een steeds complexere en dynamische veiligheidsomgeving is het essentieel dat organisaties snel en onderbouwd besluiten kunnen nemen. Het VPVM ontwikkelt een integraal instrumentarium dat het herkennen van patronen, het duiden van situaties en het formuleren van handelingsperspectieven ondersteunt. In 2026 wordt samen met het OM en de directie AI gewerkt aan een framework voor een interoperabel *agentic AI* systeem, opgebouwd uit gespecialiseerde generatieve AI-modellen. Dit systeem helpt gebruikers bij het analyseren van grote hoeveelheden data en ondersteunt bij het nemen van onderbouwde besluiten, waarbij robuustheid en uitlegbaarheid centraal staan. Daarnaast wordt samen met DGSenB gewerkt aan het JenV breed beschikbaar maken van systeemanalyse methodieken om beleidstheorieën expliciet te maken. Zo kunnen organisaties beter anticiperen op de gevolgen van keuzes en deze onderbouwen richting politiek, media en samenleving.

Techniek onder controle

De snelle ontwikkeling van technologie biedt zowel kansen als risico's voor het veiligheidsdomein. Het VPVM richt zich op het strategisch benutten en beheersen van geavanceerde technologieën, zodat organisaties technologisch wendbaar en robuust blijven. In 2026 ligt de focus op sensortechnologie, sensorfusie en intelligente systemen. Samen met de DJI worden innovatieve concepten ontwikkeld om de inspectie van cellen en luchtplaatsen te verbeteren door de inzet van de nieuwste sensoren. Daarnaast wordt samen met de politie geëxperimenteerd met visual-language modellen (VLMs) om camerabeelden

sneller te analyseren en wordt een brede verkenning gestart naar het tegengaan van de inzet van geavanceerde technologieën door kwaadwillenden, zodat de politie flexibel en toekomstbestendig kan blijven opereren.

Door deze drie doelstellingen integraal aan te pakken en te verbinden met de maatschappelijke opgaven, draagt het VPVM bij aan een veilige, weerbare en toekomstbestendige samenleving.

Titel	**VP Weerbaarheid (P108)**
MTIB Thema	Veiligheid
Contactpersonen TNO	Gwen Jansen-Ferdinandus (VPM), Christa Hooijer (DS&T)
Contactpersoon Regie-voerder	Ron Hanoeman en Bas ter Luun, Directie Innovatie, Kennis en Strategie (Min JenV)

Programma jaar 2026 - Samenvatting

De veiligheid en stabiliteit van Nederland staan onder druk. Naast het risico op grootschalige verstoringen door klimaatverandering en energietekorten neemt de dreiging vanuit andere landen toe. Statelijke actoren zetten steeds vaker sabotage, cyberaanvallen en economische ontwrichting in om de stabiliteit van Nederland en Europa te ondermijnen. De kans dat Nederland in NAVO verband in een oorlog verwikkeld raakt is reëel. Dit vraagt niet alleen de inzet van Defensie maar zal een groot beroep doen op de hele maatschappij. Het verhogen van onze weerbaarheid is dan ook noodzakelijk om de veiligheid, vrijheid en stabiliteit van de Nederlandse samenleving te beschermen. Weerbaarheid helpt om conflicten te voorkomen én zorgt ervoor dat we beter voorbereid zijn op onverwachte situaties en crisis.

Het rapport ‘Weerbaarheidsopgave. Versterken van weerbaarheid in het licht van militaire en hybride dreigingen’, gepubliceerd door de overheid, is een eerste stap in het duiden van deze opgave (hierna: de Rijksbrede weerbaarheidsopgave). Veel is echter nog onduidelijk: hoe bouwen we aan weerbaarheid in de fysieke, digitale en cognitieve dimensies? Welke interventies zijn effectief en wie neemt wanneer verantwoordelijkheid? Er is behoefte aan effectieve handelingsperspectieven die passen bij de huidige realiteit.

Het vraaggestuurd programma (VP) Weerbaarheid van TNO is bedoeld om de kennisbasis en het innovatievermogen van de Nederlandse maatschappij te versterken om de transitie naar een weerbare samenleving te versnellen. Op basis van de Rijksbrede weerbaarheidsopgave en de specifieke expertise van TNO zijn vijf doelstellingen gekozen waar het VP zich op richt tot 2029:

- *Beschermen van de vitale infrastructuur*

  Het VP Weerbaarheid stelt vitale infrastructuur organisaties in staat om dreigingen en verstoringen eerder te herkennen, sneller en effectiever te reageren en de maatschappelijke impact van verstoringen te beperken. Dit gebeurt door het bouwen van integrale analysemethodieken en detectiecapaciteiten. Dit doen we niet alleen vanuit het perspectief van één organisatie maar vanuit de hele keten. Daarnaast ontwikkelen we innovatieve oplossingen om snel te herstellen van verstoringen. In 2026 wordt o.a. gewerkt aan een geïntegreerd en dynamisch veiligheidsbeeld voor vitale infrastructuur organisaties waarmee dreigingen eerder herkend kunnen worden.

- *Herkennen en tegengaan van beïnvloeding*

  In het VP worden methodieken en technologieën ontwikkeld om beïnvloeding, zoals desinformatie en hybride dreigingen, tijdig te signaleren en effectief tegen te gaan. In 2026 werken we onder andere aan het ontwikkelen van modellen en het opzetten van een simulatie en experimenteer omgeving waarmee overheden en maatschappelijke organisaties zicht krijgen op hoe online beïnvloeding te werk gaat en welke tegenmaatregelen effectief zijn.

- *Versterken van strategic foresight en early-warning capaciteiten*

  Maatschappelijke en technologische ontwikkelingen volgen elkaar in rap tempo op. Het VP weerbaarheid helpt publieke en private organisaties om flexibel te blijven en zich tijdig aan te passen op nieuwe risico’s en dreigingen. Hiermee worden deze organisaties weerbaarder tegen dreigingen nu en in de toekomst. In 2026 werkt het VP aan het ontwikkelen van een instrumentarium waarmee publieke en private organisaties het strategisch vooruitkijken kunnen inbedden in hun operationele omgeving.

- *Strategisch omgaan met schaarste in tijden van crisis en conflict*

  Crises en oorlog leiden tot een toename van schaarste die grote impact zal hebben op de stabiliteit van de samenleving. Om ook onder deze omstandigheden de samenleving door te laten draaien is het van belang dat overheden en bedrijven van tevoren inzicht hebben in wat er nodig is en duidelijke afspraken hebben gemaakt over hoe de verdeling van mensen en middelen zal worden bepaald. Daarnaast moet civiel-militaire samenwerking worden versterkt. Het VP Weerbaarheid onderzoekt afhankelijkheden en ontwikkelt kennis en methodieken die de besluitvormers in staat stellen om deze keuzes snel en onderbouwd te maken.

- *Veerkrachtige en actieve gemeenschappen*

  Burgers en ondernemers hebben een belangrijke rol in het versterken van de Nederlandse samenleving. Dit VP bouwt kennis en tools waarmee burgers, gemeenten en veiligheidsregio's samen de veerkracht en samenredzaamheid kunnen bevorderen bijvoorbeeld op het gebied van effectieve communicatie en samenwerking tussen overheden, bedrijven en burgercollectieven.

Deze vijf doelstellingen vormen de kern van het vraaggestuurd programma Weerbaarheid. Met deze kennis en innovaties draagt TNO bij aan het beschermen van de veiligheid, vrijheid en stabiliteit van de Nederlandse samenleving.

Titel	VP Cyber Risk Management and System Resilience (P103)
MTIB Thema	Veiligheid
Contactpersonen TNO	Sjoerd-Jan Wiarda (VPM), Berry Vetjens, (DM)
Contactpersoon Regie-voerder	Lukas Roffel (HTSM/Security)

Programma jaar 2026 - Samenvatting

Growing digital risks require a proactive shift to embedded cyber resilience

The accelerating digitalisation of products, services, and infrastructures is reshaping society's opportunities and risks. The convergence of Information Technology (IT), Operational Technology (OT) and cyber-physical systems expands the attack surface, while global supply chains heighten dependency risks.

The impact is already visible: recent cyber incidents have disrupted healthcare delivery, halted manufacturing lines, crippled energy distribution, and compromised sensitive government data. Such events cause not only immediate financial and operational losses, but also long-term damage to public trust, national security, and economic competitiveness. With cyber threats—driven by state actors, organised crime, and AI-enabled attacks—evolving faster than current defences can adapt, and a persistent shortage of skilled professionals, critical infrastructures, products, and services remain vulnerable.

To safeguard public values, national security and Europe's economic competitiveness, cybersecurity must be proactive, scalable and embedded by design across products, systems and communication networks. This requires coordinated action and technological innovation at scale.

Strategic objectives for a resilient and competitive digital society

TNO's mission is to drive the transition to a secure, resilient and digitally autonomous society by delivering both immediate impact and long-term transformation. Our outcome is defined along three interlinked pathways :

1. *Availability* - Organisations have access to scalable, interoperable, and autonomous cybersecurity technologies.
2. *Adoption* - Industries integrate secure-by-design and lifecycle security into mainstream practice.
3. *Readiness* – Ecosystems can anticipate, withstand, and recover from advanced cyber threats while meeting regulatory obligations.

Three product-market combinations (PMCs) are driving the transition

TNO realises its ambitions through three interconnected PMCs, each with a clear ambition and concrete 2026 results and direct contribution to the Availability, Adoption, and Readiness pathways:

- *Cybersecure Products & Systems* – Ambition: embed security by design in digital products and supply chains from concept to deployment. By 2026, the launch of a Product Security Innovation Radar and the establishment of a large public–private partnership with industrial partners will increase the availability of secure products and accelerate the adoption of shift-left security practices and strengthen readiness for compliance with regulations such as Cyber Resilience Act (CRA) and Product Liability Directive (PLD).
- *Secure Data & Communication* – Ambition: deliver trusted, sovereign, and future-proof data handling and communications for critical sectors. By 2026, the introduction of a new methodology for complex Post-Quantum Cryptography (PQC) migrations and industrial uptake of formal hardware verification and computer-aided cryptography will expand the availability of quantum-safe and crypto-agile solutions, drive adoption of trusted communication practices, and enhance readiness against emerging cryptographic threats.
- *Cyber Resilient Digital Infrastructures* – Ambition: build resilience in complex IT/OT and cyber-physical systems to anticipate, withstand, and recover from advanced cyberattacks. By 2026, demonstrations of

autonomous, playbook-driven OT attack responses in the energy sector and the publication of a new international security playbook standard (OASIS CACAO v3.0) will expand the availability of autonomous resilience tools, foster adoption of automated incident response, and improve readiness to respond effectively to major cyber incidents.

Titel	VP ICT (P706)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Berry Vetjens (DM), Björn Håkansson (VPM)
Contactpersoon Regie-voerder	Frits Grotenhuis (Directeur Topsector ICT)

Programma jaar 2026 - Samenvatting

TNO aims to guide industrial and societal stakeholders in the digitalisation of their business or domain. We do this by integrating the enablers identified in national and European ICT agendas into first-time engineering solutions. These industrial and societal stakeholders have common needs; to overcome their challenges in operating in digital ecosystems. In VP ICT we have structured these common needs in three categories: Data sharing and AI, fast open digital infrastructures and trusted ICT solutions. To guide these developments, the VP ICT aims to reach the following goals:

Data sharing and AI

Data Spaces are a core concept in the cluster, with the completion of the Data Spaces Support Centre project with the Data Spaces Blueprint v3.0 as a very visible and influential result. Data sharing is further supported with Digital Identity solutions, where we focus on fraud detection and prevention in European Digital Identity Wallets, enabling complex use cases like organisational digital identity and dynamic data management for skills credentials. An important topic within a data ecosystem is the Digital Product Passport (DPP), where we support their adoption: comply with legislation, ecosystem development, research on business models, AI integration, and exploration of the use of DPPs for less tangible products. The actual usage of the data should respect confidentiality; therefore, we work on advancing privacy-enhancing technologies such as multi-party computation, federated learning, and synthetic data generation to support secure AI computations, data availability, and trustworthy collaboration. To create impact in the physical world, digital twin platforms are an effective concept; we focus on the delivery of a cross-domain digital twin platform for real-time collaboration and predictive analytics, with expansions into water management and European initiatives.

Building upon all these data sharing concepts, the development of AI is a logical focus of attention. We design AI systems for energy optimisation, personalised farming recommendations, improved recycling, and intersectional fairness methodologies to mitigate AI bias. Generative AI is a growing topic, where we work on development of personalised, trustworthy, and inclusive generative AI including chatbot validation, privacy-sensitive data use, multi-agent systems, and establishment of AI labs and factories.

Fast open digital infrastructures

In Fast Open Digital Infrastructures, we support the welfare and wellbeing by developing digital infrastructures that are fit to support consumers and businesses reliably and economically in their ever-demanding digital service's needs. This includes 6G networks for which we develop technologies and applications together with the partners in the national Future Network Services 6G program as well as sovereign and federated edge cloud and AI infrastructures. For high demanding industry verticals, we develop tailored digital infrastructure architectures, API's and pilots to enable services that have specific performance, reliability and/or latency needs. To support value creation in immersive and creative industries as well as to verify the capabilities of our digital infrastructures developments we lead the Immersive Innovation Labs of the CIIIC national growth fund program. Besides supporting Dutch economic welfare and competitive position our Digital Infrastructure research increase NL/EU digital sovereignty with our strong focus on creating standards and open technologies.

Trusted ICT

By 2026, VP ICT will have delivered first quantum-enabled Proof of Concept applications in domains such as health and energy, demonstrating the added value of hybrid quantum–classical computing and combinations with sensing and networking technologies. The establishment of a Quantum Applications Facility provides developers and end-users with structured access to multiple quantum platforms and accelerates the path from idea to proof-of-concept.

Through leadership in European and national standardisation, TNO ensures that Dutch stakeholders influence the rules of the game and benefit from early interoperability across hardware and software. With our active role in EU projects, the RTO network, and the Quantum Excellence Center, the Netherlands will be positioned as a frontrunner in the emerging European quantum ecosystem.

These outcomes strengthen digital sovereignty and prepare industry, government, and academia for the transition towards quantum-enhanced ICT, enabling new business opportunities and societal impact.

Titel	VP Digital Systems (ESI) (P707)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Wouter Leibbrandt (DM), Jacco Wesselius (VPM)
Contactpersoon Regie-voerder	Topsector HTSM Systems Engineering: Ronald Fabel, Topsector Energy Dir. Digitalization/Claire Groosman

Programma jaar 2026 - Samenvatting

VP Digital Systems focusses on complex cyber-physical systems that undergo a Digital Transition. For a wide range of societal challenges, innovation and functional improvements of cyber-physical systems are needed, e.g., for the energy system, the mobility infrastructure, and high-tech systems. Digitalization, when done right, will accelerate other transitions, enable crucial functions and features needed for cyber-physical systems, while conserving high standards of reliability, safety, autonomy/sovereignty, sustainability, etc. Both the engineering of digital solutions in a systems approach and digital system engineering will be essential for efficient design and optimal operation of cyber-physical systems and their constituent components. In many cases, the digital transition concurs with other societal transitions, such as the energy transition or the mobility transition. In these cases, we speak of a *twin transition*, resulting in significant societal impact.

VP Digital Systems 2026-2029 initially addresses two *twin transitions*:

- the digital transition of high-tech systems (product focus) + the transition of industry in their systems engineering approach (product engineering focus), building on the former VP ESI;
- the energy transition + the digital transition of energy systems.

In these domains, the challenges require systems engineering and systems-thinking methodologies, applied in the context of complex cyber-physical systems. There are strong synergies between the challenges the research previously aimed at in the high-tech industry and those in the digital transition of the energy system.

As similar challenges are observed in other societal domains, the scope of the VP is expected to be broadened even further, building on initial activities in 2024 and 2025 in the defence industry and in mobility infrastructure.

In those *twin transitions*, digitalization enables achieving unprecedented levels of functionality, performance, scalability, and flexibility. Digitalization makes the resulting systems inherently more complex, however. The VP enables research on methodologies to address the challenges of managing the complexity of such digital systems. These include the architecting of increasingly complex systems, the advent of collaborative systems as part of systems-of-systems, the impact of new technology developments like AI, lifecycle concerns, and in verification (testing) and validation of ever more complex systems. Overall, these innovative methodologies are needed to enable leveraging the promised benefits of the digital transition.

The VP contributes to solving complex societal challenges, driven by: (i) the complexity explosion as discussed above; (ii) the growth of international competition, and (iii) the shortage of skilled technical experts (the human capital challenge). Combining these three, we have the following vision for future engineering of complex digital systems:

> *In 2035, engineers will have more than doubled their productivity and effectivity by their intense "side-by-side" collaboration with digital engineering assistants tapping into the organization's system, domain, and engineering knowledge.*

VP Digital Systems will enable industry and engineering enterprises in the Netherlands to realize this vision with validated, usable innovative systems engineering (SE) methodologies, tools, and expertise (SE-transformation consultancy and competence development programs). It aims to have societal impact with:

- acceleration of innovation and engineering, strengthening the competitive position of the Dutch industry;
- acceleration of innovation and engineering, delivering digital (cyber-physical) systems for societal challenges and transitions;
- enhancing engineering productivity (both in terms of efficiency and effectiveness) to deal with the shortage of (experienced) engineers.

The VP is strongly connected to the major societal challenges and technology strategy, as described in the table below.

Major Societal Transitions	**Key Technologies**[6]
Digital Transition Industry Transition Energy Transition Circular Transition	**Engineering and fabrication technologies**: systems engineering digital manufacturing technologies **Digital and information technologies**: AI, data science, data analytics, software technologies and computing, digital twinning
National Technology Strategy[7]	**Thematic KIA**
Artificial Intelligence and Data **Application (via industry partners)**: Imaging Technologies Semiconductor Technologies	**Primarily:** Climate and Energy Public Earning Capacity Circular economy (engineering for circularity) Key Technologies Digitalization **Additionally (via partners)** Safety and security Health and care
(Inter)national Agendas and Roadmaps	**Strategic Program Plans TKI**
TKI-HTSM Systems Engineering[8] European Electronic Components and Systems Strategic Roadmap Agenda (ECS-SRIA) [9] Nationaal Plan Energiesysteem (NPE)[10] INCOSE Vision 2035[11] Agenda Digitalisering Energiesysteem[12]	**TKI-HTSM:** 23SP001 – Systems Engineering voor High-tech Systems[13] **TKI-Energie:** Digitaliseringsagenda Topsector Energie[14]

6 https://www.tno.nl/publish/pages/8843/tno_herijking_sleuteltechnologie_2023_v4.pdf
7 De Nationale Technologiestrategie | Titel uitgave (overheid.nl)
8 https://hollandhightech.nl/_asset/_public/Innovatie/Technologieen/z_pdf_roadmaps/Roadmap-Systems-Engineering-update-2020-final-v20200724.pdf
9 https://eureka-xecs.com/wp-content/uploads/2022/05/ECS-SRIA2022.pdf
10 https://www.rvo.nl/onderwerpen/energiesysteem/nationaal-plan-energiesysteem
11 https://www.incose.org/publications/se-vision-2035
12 Expected to be available in the second half of 2025.
13 https://hollandhightech.nl/programma-s-en-projecten/strategische-programma-s-2024-2027/systems-engineering-voor-hightech-systems
14 https://topsectorenergie.nl/documents/59/Digitaliseringsagenda_Topsector_Energie.pdf

Titel	**VP Sleutelmethodologieën voor Transities en Transformaties (P901)**
MTIB Thema	KIA Maatschappelijk Verdienvermogen / Sleuteltechnologieën
Contactpersonen TNO	Tessa Bruijne (VPM), Lotte de Groen (waarnemend marktdirecteur), Anne Fleur van Veenstra (DS)

Contactpersoon Regie-voerder	• Regievoerder: Ashna Raghoebarsing, Ministerie van Economische Zaken, Directie Innovatie en Kennis (I&K); regievoerder participeert tevens in Externe VP Klankbordgroep en Programmateam KIA MV.
	• Externe VP Klankbordgroep voorgezeten door DM en VPM – deelname van:
	  ○ Ministerie van Economische Zaken (EZ)
	  ▪ Directie Innovatie en Kennis (I&K)
	  ▪ Directie Algemene Economische Politiek (AEP)
	  ▪ Directie Strategie Energiesysteem (SES)
	  ○ Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK)
	  ▪ Afdeling Kennis, Internationaal, Europa, Macro-economie (KIEM)
	  ○ Ministerie van Infrastructuur en Waterstaat (I&W)
	  ▪ Directie Algemeen Strategisch Advies (ASA)
	  ○ Ministerie van Landbouw, Visserij, Voedselzekerheid en Natuur (LVVN)
	  ▪ Directie Strategie, Kennis en Innovatie (SKI)

Programma jaar 2026 - Samenvatting

De complexiteit van uitdagingen waar de wereld en Nederland voor staan, zoals klimaatverandering, (digitale) soevereiniteit en onafhankelijkheid, schaarste van ruimte, veranderingen in de arbeidsmarkt, sociale ongelijkheid en snel opkomende digitale technologieën, blijft onverminderd hoog. Met deze systemische uitdagingen staat de brede welvaart van Nederland onder druk, maar ontwikkelen zich ook kansen om innovatie en verandering teweeg te brengen[15]. Daarom is het doel van het VP Transities en Transformaties om bij te dragen aan maatschappelijke veranderingen en om handelingsperspectieven te bieden om uitdagingen aan te pakken. Het VP is gelieerd aan TNO Vector, centrum voor maatschappelijke innovatie en strategie. Als TNO Vector en met het VP realiseren we impact door op een strategische wijze innovaties te versterken, te implementeren en op te schalen. Daarbij maken we een belangrijke vertaalslag voor overheden, bedrijven en maatschappelijke organisaties, zodat zij weloverwogen beslissingen kunnen nemen om de brede welvaart van Nederland op structurele wijze te bevorderen.

Maatschappelijke innovaties gaan hand-in-hand met innovaties van business modellen en technologie. Door deze innovaties effectief samen te brengen kunnen vernieuwingen worden verankerd in de samenleving en opschaling worden gerealiseerd, zodat hun impact en rendement kan worden benut. Een interdisciplinaire aanpak met publiek-private samenwerkingen en verbintenis met het bredere ecosysteem is onmisbaar om tot systemische en blijvende verandering te komen. Voorbeelden zijn nieuwe manieren van samenwerking tussen overheden, bedrijven en burgers, aanpassingen van economische en organisatorische structuren of de ontwikkeling van nieuwe ecosystemen en business cases, en veranderingen in ruimtelijke planning en wetgeving.

Om kansen en risico's vroegtijdig te identificeren, voeren we strategische analyses uit. Zo begrijpen we trends en ontwikkelingen beter en helpen we toekomstvisies te vormen op belangrijke thema's voor innovatie zoals strategische autonomie, ruimtelijke inpassing, vitale innovatiecapaciteiten- en systemen, en internationale waardeketens en concurrentie.

Het VP richt zich in de periode 2026-2029 op vier impactgebieden en proposities:

1. **Innovatie:** Propositie Innovatiesystemen voor transities en transformaties
   - Kennisopbouw over innovatie-ecosystemen, control points (d.w.z. strategische ketens) en strategic intelligence.
2. **Digitaal:** Propositie Waardengedreven digitale samenleving
   - Kennisopbouw over (generatieve) AI, en ontwikkeling en adoptie van digitale technologie volgens publieke normen en waarden.

[15] Draghi-rapport vertaald naar Nederland: kwetsbaarheden en kansen voor innovatie - TNO Vector

3. **Ruimte:** Propositie Economische, governance en ruimtelijke strategieën (voorheen Waardengedreven duurzame steden en regio's)
    - Kennisopbouw over het verbeteren van de brede welvaart in Nederland door het versnellen van maatschappelijke transities in steden en regio's.
4. **Industrie:** Propositie Groene en strategisch autonome industrieën
    - Kennisopbouw over ketenvorming en -opschaling.

Het VP ontwikkelt kennis en methoden t.b.v. de volgende diensten voor opdrachtgevers en partners:

- Agenda setting: Uitvoeren van strategische studies, verkennen van technologische toekomstbeelden, analyseren van socio-technische systemen en ontwikkelen van innovatie- en transitieagenda's.
- Orchestrating innovation: Organiseren en coördineren van ecosystemen om innovatie te stimuleren voor transities en transformaties.
- Value chain and scaleup design: Organiseren en coördineren van waardeketens om innovatie, business en markten te stimuleren, met specifieke aandacht voor risico's, control points en finance.
- Economic impact and value analysis: Analyseren van de economische, maatschappelijke en duurzaamheid-impact van innovaties en transities op bedrijven en economieën.
- Societal impact assessments: Evalueren van de maatschappelijke impact van nieuwe technologieën en wetgeving.
- Governance and monitoring: Ontwerpen en implementeren van besluitvormings- en governance-processen binnen en tussen organisaties, en opzetten van monitoringsmechanismen om de ontwikkeling van innovaties voor transities en transformaties te volgen.
- Policy advice: Bieden van interdisciplinair beleidsadvies op Europees, nationaal en lokaal niveau.

Het VP heeft de ambitie om impact en opschaling te bereiken. Het VP richt zich op het versnellen van impact, integreren van verschillende expertises en disciplines, samenbrengen van publieke als private partijen, en strategisch agenderen van maatschappelijk relevante thema's. Ten behoeve van deze ambitie, onderhouden en ontwikkelen we een kennis- en toepassingsportfolio van Sleutelmethodologieën oftewel Key Enabling Methodologies (KEMs). We bouwen hierbij voort op de onderzoeksagenda Key Enabling Methodologies (2024-27), onderdeel van de KIA MV[16].

De beoogde resultaten voor 2026 richten zich op het versterken van kennisopbouw binnen vier impactgebieden, d.m.v. deelname aan Nederlandse en Europese ecosystemen:

- Innovatie: Innovatiesystemen voor transities en transformaties
    - Kennisopbouw en methodologieontwikkeling rondom control points t.b.v. technologisch soevereiniteit, strategische autonomie en verdienvermogen.
    - Opzetten van een strategic intelligence hub ten behoeve van het agenderen van maatschappelijke en economische thema's en onderbouwde besluitvorming.
- Digitaal: Waardengedreven digitale samenleving
    - Kennisopbouw rondom digitale autonomie en soevereiniteit
    - Accelereren van (gen)AI innovatie in Nederland en Europa door het bieden van praktische middelen voor de (gen)AI governance voor verantwoorde ontwikkeling, inzet en opschaling van AI.
- Ruimte: Economische, governance en ruimtelijke strategieën
    - Structurele en meetbare verhoging van brede welvaart.
    - Systeeminzichten voor besluitvorming, governance en samenwerkingsstrategieën, socio-economische en ruimtelijke (beleids-) analyses, en business en financieringsmodellen.
- Industrie: Groene en strategisch autonome industrieën
    - Kennisontwikkeling op het gebied van ketenvorming en -opschaling.

[16] Zie De KEM-agenda - CLICKNL

- Uitbouwen van rol als neutrale regievoerder voor ketenontwikkeling.

Voor het VP als geheel ligt de focus in 2026 op het aanscherpen en valideren van het dienstenportfolio in relatie tot het KEM-portfolio, waarbij specialisatie binnen de vier proposities centraal staat.

Titel	VP Space & Scientific Instrumentation (P607)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Kees Buijsrogge, Ton Marée
Contactpersoon Regie-voerder	Niek Lobé, Rob Postma, Frenk van den Berg (EZ)

Programma jaar 2026 - Samenvatting

Our multi-annual R&D program 2026 - 2029 supports our ambition to contribute to **preventing climate change and air pollution,** enable **secure broadband connectivity,** help **understanding the Universe**, and stimulate **economic growth in the Netherlands and Europe**, making this all happen in a **sustainable** way. Therefore, we organise the VP along program lines directly connected to this ambition; Instruments for **Earth Observation** and related **Space Data Utilization,** technologies for **Satellite Communication**, and **Scientific Instrumentation** focusing on instruments for **Ground Based Astronomy, Space Based Astronomy, Big Science and Diagnostics for Fusion Energy**, and system development for **In-Orbit-Servicing** to extend the lifetime of satellites and their payloads.

Our main objective in the area of Earth Observation and Space Data Utilization is to maintain and strengthen the Dutch position with regard to monitoring the composition of the Earth's atmosphere. We want to contribute to help monitor the Paris agreement and give detailed insight in emissions and spread of air pollutants and greenhouse gases. We have the long-term goal for in-orbit-demonstration of a small and very accurate instrument with related downstream models, specifically focused on measurement of greenhouse gases and air pollution. In addition to the instrument, given the focus in the commercial EO market on information products, we will work on the development of data processing methods that can enable global information services that provide actionable information to decision makers in governments.

Our goal for the 2026 and further is a next (after TANGO) Dutch small satellite instrument that will measure emissions (like NO_2, CH_4, CO, SO_2, aerosols) with a very high accuracy. Long-term development will focus on the measurement in Thermal Infrared (TIR) (NH_3, N_2O) and on Volatile Organic Component (VOCs). We will work on improving our LOTOS-EUROS and TOPAS models by including more air quality trace gases and CH_4.

In the domain of Satellite Communication our aim is to develop state-of-the-art optical terminals for ground, air and space usage for the value chain of global satcom providers. We follow four main use cases: Secure & Robust Comms for worldwide Mobile Security Operations; Cyber Proof/Quantum Resilient Comms over Ground Networks for Secure Connectivity; Ultra-High-Speed Global Secure Connectivity Network (constellations); Data Relay for Earth & Space Sciences from (deep) Space. Furthermore TNO started in 2024 to intensify investments in quantum communication and internet enabled by space nodes.

Each of these use cases have their own timeline of development, where the first laser satcom constellations are in industrial development right now, but deep Space data relay using laser satcom is foreseen to be further away in the future. We will work on our four main drivers; fast, secure, multi-point and far communication. For fast communication the long-term goal is ultra-high data throughput of 10 Tbit/s feeder link to a GEO- or MEO-satellite. Secure communication focusses on links with ultimate protection, suitable for the quantum era with a long-term target of a Quantum Key Distribution service with satellite nodes, which is resilient to hacking attacks. Multi-point communication facilitates simultaneous communication with multiple senders and receivers with a long-term target of a multi-beam optical space terminal in orbit, receiving data from various nodes (space, aerial, naval) and transmitting towards multiple users. With far communication TNO looks at data links over very long distances with a long-term target of a link to a deep space science mission, such as a planetary or asteroid mission.

These various use cases provide a very promising opportunity for Dutch industry to extend its space-related activities into a commercial market: in this development we will position Dutch high-tech companies as potential suppliers for the terminals and their subsystems based on user requirements from this market.

We intend to strengthen our position with regard to developing high-grade instruments to perform world-class science, both in space and on ground. For this, we work together with universities and scientific institutes. In the realization of the instrumentation we involve industry where possible. For each subdomain (Ground Based Astronomy, Space Based Astronomy, Scientific Instrumentation), we have a specific focus.

Our long-term goal for Ground Based Astronomy is to contribute to the development of the KECK telescope optics with a 1,4 m secondary deformable mirror expected to be achieved in the coming four to five years from now, and a segmented 15 m adaptive primary mirror expected to be achieved in about 10 years. Steps towards that goal are deformable mirrors of increasing size, better support structures and laser guide stars for the big telescopes in the world (UH88, EST, ELT, GMT, MAORY,

GEMINI, KECK). After successful demonstration in 2024 of the deformable mirror of 24cm on the NASA IRTF, for 2025/2026 the goal will be to test a deformable mirror of 60cm diameter on the UH-88 telescope and extend our on-sky-heritage.

In the Space Based Astronomy domain we use ESA's long-term planning for space science missions, the Voyage 2050 Senior Committee advice 'Voyage 2050', as a guideline in combination with the Dutch science community (SRON, NOVA, TU-Delft,..) ambitions and priorities. The coming years we will work on the Point Ahead Angle Mechanism (PAAM) for the LISA (detection of gravitational waves) mission. TNO's PAAM design is in the baseline design of the optical bench. Given LISA mission adoption by ESA beginning 2024 we aim to lead the further PAAM development until flight in close co-operation with the Albert Einstein Institute.

Within the domain of Scientific Instrumentation we started contributing to the development of silicon mirror technology and the metrology system of the Einstein Telescope, in co-operation with Dutch scientific institutes, universities and companies. In addition, we aim to contribute to nuclear fusion technology by applying our optical systems design expertise to develop technologies for diagnostic instrumentation in the extremely challenging environment of the nuclear fusion chamber. Within NL we co-operate on this with DIFFER and ITER-NL.

In the domain of In-Orbit-Servicing TNO's ambition is to contribute to a long-term space sustainability with its expertise in the field of Optics, Optomechatronics, Radar and Space System Engineering, enabling the required space systems for GNC, rendezvous proximity operations, inspection and docking. A first step is to get involved in the EU pilot mission for In-Space Operations and Services (ISOS).

Titel	VP Semicon & Quantum (P612)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Kees de Koning (VPM), Rogier Verberk (D.BS.),
Contactpersoon Regie-voerder	Medical - Roelien Attema (TKI Innovatieraad Imaging Systems), Semicon - A. Krijgsman (ASML, TKI Innovatieraad Semiconductor Technologies), Quantum - Mayra van Hout (TKI Innovatieraad Quantum Technologies), Min EZK - M. Smeets, Wilbert Schaap

Programma jaar 2026 - Samenvatting

The goal of TNO's roadmap on Semicon & Quantum is to stimulate the Dutch and European industry to take strategic positions ('control points') in critical value chains. TNO's technology leadership helps companies to innovate faster than its competitors, and is the foundation of new startups. The focus on the semiconductor industry and quantum technologies is because of the high geo-economic value, and the significant economic impact (high export value) , respectively, of these sectors. Any significant industry, vital infrastructure, and potential solution to societal challenges relies on integrated circuits (chips) to generate, process, and store data. The European Council states in its Strategic Agenda 2024-2029 that Quantum Technologies & Semiconductors are key topics, and these topics are also among the 10 priorities of the Dutch *Nationale Technologie Strategie*. It is our ambition to realize ground-breaking technological innovations in order to safeguard the position of Dutch leaders (like ASML), and to create new ones within the semiconductor industry, as well as in the emerging quantum industry. The focus on medical devices for non-invasive diagnostics and monitoring is motivated by the ambition to fight the congestion in the Dutch medical system. This portfolio contributes directly to the sovereignty of Europe, while these 'beyond state-of-the-art' technologies generate significant spillovers to other sectors as well.

TNO continues its support to ASML by developing new technologies to continuously improve the DUV and EUV lithography systems, e.g., more accurate sensors, and better performing optics and materials. In 2026 TNO will work together with partners to find replacements for PFAS containing materials, and investigate ways to reduce costs and energy for chemical conditioning and exhaust gas recycling of EUV systems. Also the demonstration of in-chip cooling (demonstrator based on AMD chips ready by the end of 2025) aims at sustainability improvements in this sector.

In 2026 TNO will demonstrate the next steps in the developments in innovative metrology concepts for the semiconductor industry: IR-AFM and new versions of acoustic metrology. We hope that the industrialization thereof, in the years ahead, will be as successful as the industrialization of our sub-surface SPM technology of recent years by Nearfield Instruments.

Building on years of knowledge development, like in the partnership with TU Delft, we will continue the development of quantum *technologies* in 2026, e.g., Quantum Photonic Integrated Circuits as building block of future quantum (computing and communications) systems, and quantum sensing platforms for navigation and metrology. But from 2026 on the priority will be on innovation, which means collaboration with the emerging industry. 2026 will be, for example, the first year of a program dedicated to metrology development (both methodologies and equipment) for quantum chips.

While waiting for the results of the clinical validation studies of multiple of our Medical Devices (running during 2025/2026), TNO will continue the development of its extremely sensitive IPUT acoustic sensor.

In 2026 TNO will innovate also in the innovation process itself. More Artificial Intelligence will be applied, for example in the design of a new sensor. The Quantum Startup Challenge (pilot) is a means to identify potential start-ups or other business cases in the field of quantum technologies, earlier in the innovation process.

Titel	VP Flexible and Freeform Products (P615)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Ton van Mol
Contactpersoon Regie-voerder	Erik van de Burgwal (EZK), Peter Stolk (Topsector HTSM), Casper Langerak (RVO),

Programma jaar 2026 - Samenvatting

In VP 'Holst Centre' it is our ambition to strengthen Dutch industry by creating innovations based on our capabilities in thin film electronics and hybrid printed electronics combined with our strong position in Brainport to link up to local industry. Our innovations combine economic impact with a contribution to a healthy, sustainable and digital society. Through our unique business model of shared innovation and industrial residents we actively transfer our innovations to our industrial partners as well as the establishment of new start-up companies.

Our technology portfolio enables technological solutions to important societal challenges such as energy storage, sustainable electronics, affordable healthcare and a digital society. They can also unlock significant new economic activity.

However, progressing from the laboratory bench to the point where it provides the basis of a commercially successful business or product has become increasingly challenging due to increasing complexity of the technology as well as the environment where the product will be implemented.

New approaches to innovation are needed such as a serial spinout model, focused programmatic initiatives and pilot lines that involve the relevant value chain players and stakeholders.

Our unique approach to innovation is applied to 5 growth platforms:

- **New manufacturing technologies** for electronics production with a focus on creating a sustainable production technology for electronic products and further leveraging printing technologies towards other markets such as displays, packaging, and integrated photonics. The key deliverable for 2026 is to develop a tool concept for laser transfer of integrated photonics to a enable placement at submicron accuracy.
- **Health**, focuses on platforms for wearables for remote patient monitoring and smart wound care, personalized medication for improved patient care and X-on-chip for advanced diagnostics and accelerated development of new drugs, partially executed in collaboration with TNO Unit Healthy & Work as well as in collaboration with the University of Twente. For 2026, the key deliverables are to launch a new platform for ultrasound wearables, and launch a spin off based on this platform for continuous blood pressure monitoring. Personalized dosing based on TNO equipment setup at Erasmus MC will be used for clinical trials with Flecanide and hydrocortisone. For X-on-chip the intention is to jointly with TNO H&W, imec-NL, and UT launch a joint technology demonstrator integrating membrane and/or sensor technologies for Gut-on-chip and using the demonstrator to generate the first relevant biological readout.
- **Energy storage** has the aim to enable a Dutch battery technology eco-system and a high-tech hydrogen electrolyzer eco-system, focusing on next-generation device concepts and the equipment and production technology for such devices. For Batteries a new pilot line will be built in 2026, while for electrolyzers a new device concept will be validated based on 3D battery technologies learnings to showcase higher power efficiency while using 10x less Ir. Additionally, an IP portfolio will be developed for manufacturing equipment to realize conformal coverage of anti-corrosion layers in porous structures.
- **Advanced packaging** focuses on creating unique solutions for next generation of power and RF electronics. This roadmap is branded under CITC. For 2026, the key deliverables are:
  - Proof-of-concept of a fully additively manufactured functional package for power electronics and reliability validation of such a package.
  - A prototype of fan-out package with 3D integration for mmWave applications.
- Integrated photonics with a focus on (i) upscaling InP and SiN production in Nl, (ii) creating solutions to heterogeneously integrate InP, SiN and its electronic driving chips in one package using panel level fabrication processes. The key deliverables for 2026 are to demonstrate functional PIC building blocks such as InP-SiN lasers and high-speed photodetectors, panel level optical interconnect technology using polymer waveguides, and first samples of ScAlN phase modulators. In 2026 the technology and building blocks will be directed towards three strategic application areas: high-speed transceivers for datacenters, short-range optical wireless communication and ultrasensitive PIC-based biosensors. This roadmap

is executed as part of the Photonics Integration Technology Centre (PITC), a collaboration between TNO and University of Twente, Eindhoven University of Technology and PhotonDelta.

Titel	VP Smart Industry (P617)
MTIB Thema	Sleuteltechnologieën
Contactpersonen TNO	Mark Courage (DM)
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Programma jaar 2026 - Samenvatting

The ***Vraaggestuurd Programma (VP) Smart Industry*** drives the development of smart manufacturing solutions aligned with the **National Technology Strategy (NTS)**. Its focus is on scaling up production capabilities and enhancing productivity for the high tech industry through innovation in five key technology domains:

- **Data & AI**
- **(Opto)Mechatronics, including robotics**
- **Optical systems**
- **Intelligent imaging**
- **Cybersecurity**

The long-term ambition is to accelerate productivity growth across all Dutch regions. A key milestone is to increase the number of companies applying Smart Industry practices from **600 (1%) to >6,000 (>10%)** in 2030, with the ultimate goal of sector-wide adoption.

Smart Industry aims to establish the Netherlands as a leader in **circular, interconnected, automated, and intelligent manufacturing**, capable of real-time adaptation to market and customer demands. The initiative supports improved efficiency, cost reduction, sustainability, quality, and customer satisfaction.

This transformation is essential for the **earning power and strategic autonomy** of the Dutch and European manufacturing sectors. It enhances the industry's resilience to future challenges such as circularity, supply chain disruptions, safety, demographic shifts, and technological sovereignty.

TNO contributes through R&D in Smart Manufacturing technologies, supporting the transition from manual labor to operator-guided and ultimately **fully autonomous production** within **integrated digital value chains**. The focus is on three strategic areas:

- **Scale-up:** Throughput and quality *"Hyper-efficient, zero-defect, first-time-right manufacturing"*
- **Productivity:** Flexibility and complexity *"High-mix, low-volume, high-complexity production"*
- **Strategic Autonomy:** Digital integration *"Digitalization, ecosystem orchestration, consistency, resilience and transparency"*

Towards 2027 significant funding will be directed towards co-financing ongoing **EU projects** and **National Growth Fund** projects to ensure a strong landing point. A key objective for 2026 is to further position Smart Industry within High Tech Defence value chains to meet NATO and Ministry of Defence requirements.

Key objectives for VP Smart Industry for 2026 are:

Scale up: Manufacturing throughput & quality control

- **Defence Scale-Up Program**: Integrate smart manufacturing technologies into MoD roadmaps for sensors, advanced materials, and autonomous systems.
- **Autonomous Manufacturing for Mobility & Defence**: Validate PoCs for in-line quality control of composite and metal structures using ultrasound (DVM) and operator support systems for lightweight, high-performance applications.
- **High-Tech Equipment (Semicon & LSC)**: Operationalize the SEAMIIC testbed for smart end-to-end additive manufacturing (identification, sorting, QC, handling). Demonstrate micro-assembly of freeform mirrors for optical modules in semicon and Laser SatCom.
- **Smart Sensors Clean Tech**: Launch a PPS with integrators and end-users to develop and test a novel fiber-optic sensor network for hydrogen and catalyst temperature monitoring in electrolyzers and fuel cells.

Productivity: Manufacturing variability & flexibility

- **Expand Industry 4.0 Portfolio**: Advance AI-based operator support, hybrid human-robot work cells, zero-programming robotics, precision QA tools, adaptive dashboards, DPPs, interoperable connectors, and fibre-optic sensing.
- **Smart Manufacturing Demonstrator Hubs**: Grow the capabilities of the Eindhoven and Delft hubs as SME-accessible testbeds for autonomous manufacturing and circular business models (e.g. Semicon).
- Expand **TNO Remanufacturing lab** with integrated quality control and circular economy technologies (e.g. 9R strategies).
- **Productivity Platform**: Launch TNO's Digital Work Instructions (DWI) platform to support scalable productivity improvements across sectors.

Digitalization & value chain integration

- Finalize and deploy **national interoperable data models and connectors** (NGF NGHT SI05).
- Standardize **digital twin frameworks** and decentralized intelligence modules (NGF NGHT + TEF).
- Scale adoption of **Digital Product Passport (DPP)** tools and standards across sectors (EDF).
- Expand **SCSN** to new ERP platforms and European data spaces (NGF NGHT SI06).
- Develop **domain-specific LLMs** for high-tech manufacturing applications (ROB4GREEN).