Annual Plan 2024

TNO Early Research Program

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Programme name

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TNO Early Research Program

Annual Plan 2024

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Contents

Introduction

The Early Research Programs (ERPs) represent TNO's early research activities. With these, TNO builds strong technology positions and contributes, together with knowledge partners and stakeholders, to answers to societal challenges and to the creation of economic impact. The ERPs represent about 5% of TNO's turnover. The remaining 95% is steered by TNO's stakeholders: clients, 'Topsectors' and Ministries (via consultation) and Defense, EZK and SZW (via task financing).
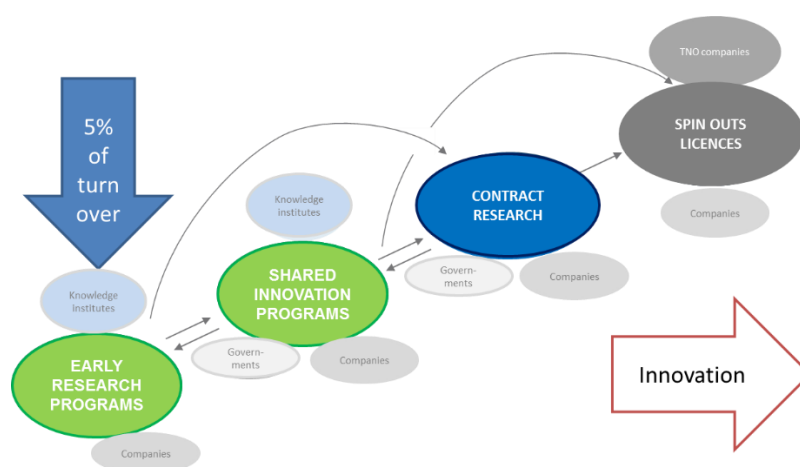

Figure I.1: Visualisation of how ERP's contribute to innovation

The main characteristics of the ERP portfolio are as follows:
⟩ The programs build technology positions within the focus areas defined in the TNO Strategy Plan 2022-2025
⟩ The programs are use-case inspired and have clear research goals: ERPs feed multiple innovation areas of TNO, often of various units but with common requirements for lower-TRL technology breakthroughs. The output of the ERPs is transferred to (higher TRL) shared innovation programs, contract research and start-up initiatives.
⟩ The programs aim for added mass through collaboration with knowledge partners such as universities and companies and for co-investments from public and private sources.
⟩ The programs have substantial mass (> 1 MEuro ERP budget per program per year) and have a typical duration of four years.
⟩ 'Full ERP' programs are usually preceded by one-year 'Seed ERP' projects that explore the feasibility of the topic, substantiate the impact to be expected and build required partnerships, thus developing the full ERP program. Out of the ten 'Seed ERP' projects 2023, the five strongest were selected for continuation as Full ERPs in the period 2024-2027.
⟩ ERP funnel management (involving reviews by TNO Corporate Science Office and by the board of TNO's Science Directors) is in place to monitor the progress and to adjust and reallocate resources if necessary.
⟩ Together with our ministry of Economic Affairs (EZK) we inform the Topsectors and Ministries of our portfolio of ERP's, aiming at early involvement of companies and other stakeholders in public-private cooperation.

An important goal of the ERP portfolio management is to bring the portfolio to a 'steady state' situation in which every year a similar number (4-5) of existing ERP's ends and new ERP's can be initiated. As can be seen in figure 1.1., this goal is almost reached. This enables TNO to respond continuously and with agility to new technology trends and needs. Moreover, TNO's researchers will thus be stimulated to continuously be on the outlook for impactful new research directions, knowing that there is an instrument to award and adopt the best ideas.

The ERP portfolio management conforms to four TNO policies / procedures:
1. TNO's 'Publication policy' provides guidelines and sets targets with regard to publicizing research outcomes.
2. The 'IP policy' describes TNO's way of working and goals regarding protectable intellectual properties. Publications and IP are key outcomes of all ERP projects.
3. The 'PhD policy' and the 'PhD procedure' guides project teams on how to properly and effectively involve PhD's in TNO's research.
4. TNO's 'Professorship policy' provides guidance with regard to the establishment of professorship positions of TNO scientists at universities. PhD's as well as TNO-enabled professorship play an important role in the execution of our ERP research.

Legenda: Icons used in Plan 2024

The targeted number of TNO-professors involved in this ERP in 2024

The targeted number of PhDs involved in this ERP in 2024

The targeted number of scientific peer reviewed publications in 2024

The targeted number of patent first filings in 2024

Summary

In 2023 we have selected 5 new four-year Full ERP's to start in 2024. A selection of 10 single-year Seed ERP's to be executed in 2024 is made before the end of 2023. We see a success rate of about 50% for Seed ERP's to be promoted to Full ERP's as a healthy situation: a balance between promoting quality and avoiding waisted proposal efforts.

The selected new Full ERP's that will start in 2024 are 'Asphalt rejuvenation using micro-algae', Atmospheric models for optical solutions', 'Empowering citizen collectives', 'Polymer design by machine learning' and 'Sustainable ICT'. These all concern domains with clear scientific challenges and high societal relevance. The topics were selected out of the ten 'Seed ERP' topics of 2023. The Seed ERPs 2023 not promoted to Full ERP's are 'Accelerating orchestrated innovation', 'Ammonia: a future proof commodity', 'Atmospheric CO2 removal', 'responsible hyper-nudging', 'robot orchestration' and 'sustainable wearable electronics'. Overall, quality and relevance of proposals was high: we had to distinguish between 'good' and 'even better'.
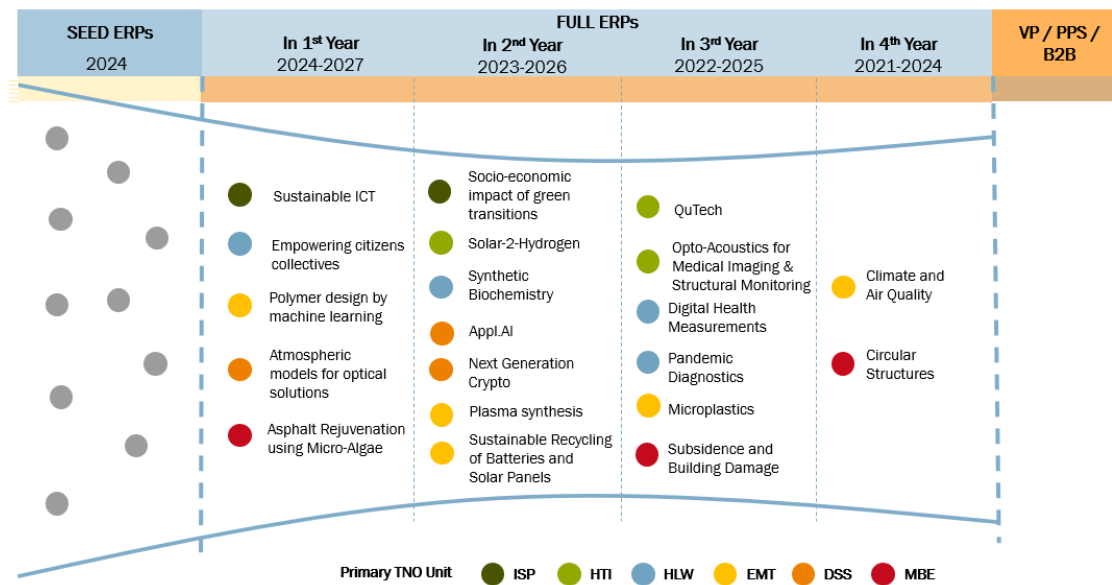
Figure I.2 shows the ERP portfolio in 2024.

Figure I.2: ERP Portfolio 2024
Legend – TNO unit names: ISP: ICT, Strategy and Policy, HTI: High Tech Industry, HLW: Healthy Living and Work, EMT: Energy and Materials Transitions, DSS: Defence, Safety & Security, MBE: Mobility and Build Environment

TNO's Strategy 2022-2025 indicates the four strategic areas in which TNO is active: Safe & Secure Society, Healthy Society, Sustainable Society and Digital Society. Table I.1.1 illustrates how the ERP portfolio relates to these TNO strategic areas and how the portfolio is divided over the TNO units.

Table I.1.1: Overview TNO ERP portfolio and its relation to TNO strategic areas (TNO strategy 2022-2025) and to TNO units (dark blue indicates the unit leading the ERP)

Early Research Project (ERP)		Digital Society	Healthy Society	Safe & Secure Society	Sustainable Society	MBE	DSS	EMT	HLW	HTI	ISP
4th year projects: Start 2021											
1	Circular Structures	○			○	●		○			
2	Climate Air Quality		○		○			●	○		
3rd year projects: Start 2022											
3	Digital health measurements		○						●	○	
4	Opto-acoustics for medical imaging and structural health monitoring	○								●	
5	Pandemic diagnostics		○					●			
6	Qutech	○		○						●	
7	Subsidense and building damage	○		○	○	●			○		
2nd year projects: Start 2023											
8	Appl.AI	○	○	○	○	○	●	○	○	○	●
9	Next generation crypto	○	○	○			●			○	
10	Plasmasynthese				○			●	○		
11	Socio-economic impact of green transitions	○			○						●
12	Solar-2-Hydrogen				○					●	
13	Sustainable recycling of batteries and solar panels				○			●			
14	Synthetic biochemistry		○		○				●		
1st year projects: Start 2024											
15	Asphalt rejuvenation using micro-algae				○	●		○			
16	Atmospheric models for optical solutions	○	○				●		○	○	
17	Empowering citizen collectives	○			○				●		
18	Polymer design by machine learning	○						●		○	○
19	Sustainable ICT	○			○						●

1   ERP Circular Structures

ERP Contacts: Angnieszka Bigaj-van Vliet, Siska Valcke (Lead Scientists)
Francesco Cinquini (Project Lead)
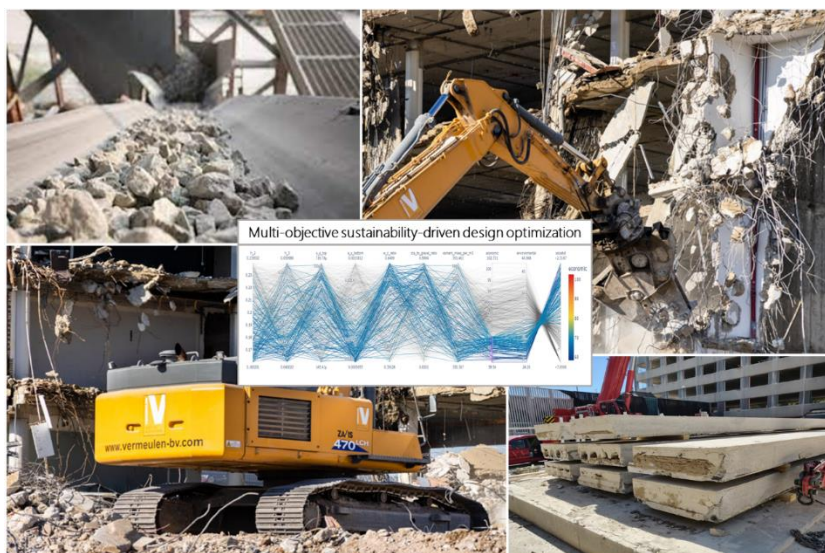Arjen Adriaanse – MBE, André Faaij - EMT (Science Directors)

ERP Duration: 2021 – 2024

ERP Description

We develop knowledge and technology that enables for concrete structures a shift from traditional design strategies to a new engineering design method driven by supply quality-demand integration. ERP Circular Strcutures delivers a novel and transparent design framework for multi-objective optimization and decision support for the design of sustainable structures made of Construction and Demolition Waste (CDW), in which CDW quality serves as the design pre-condition. Innovative circular solutions based on CDW are addressed, including reuse of reclaimed elements, use of recycled concrete aggregates and use of binders based on CDW

Summary Plan 2024

The plan for 2024 leads to the finalization of a novel approach to sustainability-driven design of concrete structures, employing multi-criteria optimisation and enabling the circular use of materials, supported by new models for predicting the performance of non-traditional solution (incl. recycling of construction and demolition waste and reusing reclaimed structural components).

Plan 2024 – ERP Circular Structures

⚛ Targeted key results	Plan 2024

Algorithmic approach to multi-objective optimization:
〉 Computation time reduction in phased design (level of detail) with data-driven multi-phase optimization
〉 Optimization of discrete parameters & objectives
〉 Incorporating result uncertainty in the interactive visualization framework for evaluation of candidate solutions

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New generation parametric performance models:
〉 Operationalizing probabilistic and semi-probabilistic approach for large size reclaimed elements' population
〉 Consideration of uncertainty and system boundaries in macro-economic indicators for environmental impact and circularity assessment
〉 Predictive model for long-term mechanical behaviour (shrinkage & creep) considering effects of CDW binder quality

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Validating developments in Use Cases:
〉 Finalizing use cases and assessing impact of innovation
〉 Exploring benefits of multicriteria design in Stakeholder workshops

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
〉 Research groups of: AG, BMS, CAS, DBE & SR
〉 University of Twente (pdEng), University of Delft (phD, MSc), Wageningen University, University of Eindhoven (MSc, postdoc)

Stakeholder involvement
〉 RWS (co-financing phD), Prorail
〉 BAM, Arcadis, Lagemaat, Consolis, IMdR
〉 Planalogic (co-organising stakeholder workshops)

Dissemination
Peer review papers planned:
〉 Multi-objective optimisation focussed on safety design
〉 Macro-economic material flow models
Conference or journal papers planned:
〉 Sustainability perspective in structural design
〉 Modelling creep & shrinkage RAC
〉 Application of multi-stage optimisation to use cases
Activities in commissions continue:
〉 RILEM, fib, NEN, CROW, CB23 commissions on sustainable concrete (incl. fib Special Activity Group Sustainable Concrete Structures)
〉 GLOBE - Global Consensus on Sustainability in the Built Environment
〉 European Commission Working Group on "Decarbonised construction of transport infrastructure"

Valorization actions 2024
〉 Multi-criteria optimisation embedded in PMCs & VPs under Buildings & Infrastructures, e.g. multi-criteria optimisation for bio-based solutions
〉 European collaboration in H2020 ReCreate "Development technologies for reuse of structural concrete elements"
〉 KIA/CE Proposal with BAM, Prorail, BTE on optimisation of new materials for demountable infra
〉 Collaboration with Arcadis on multi-criteria optimisation for green buildings, including MSc
〉 Involvement in RWS proposal (NWO programme), based on "Knowledge agenda for non-traditional sustainable concrete structures" developed by TNO
〉 Initiation resubmission NGF Beton Reinvented
〉 Exploration collaboration NGF TBL (Toekomstig Bestendige Leefomgeving)
〉 "Safety philosophy for reuse of reclaimed elements" (RWS B2B, ongoing)
〉 "Monitoring geopolymer concrete in structural applications" (RWS B2B in collab with a.o. SKG-IKOB, ongoing)
〉 RVO-granted PPP "CDW based concrete for precast structures" (BTE, Enci, ongoing)

Valorisation goals 2024
Public-Private Partnership (PPP) involvement:
〉 Follow-up existing PPP of PPP projects on reuse od CDW
〉 Collaboration in material-data driven multi-criteria optimisation

2   ERP Climate air quality

ERP Contacts: Martijn Schaap (Lead Scientist)
                   Rianne Dröge (Project Lead)
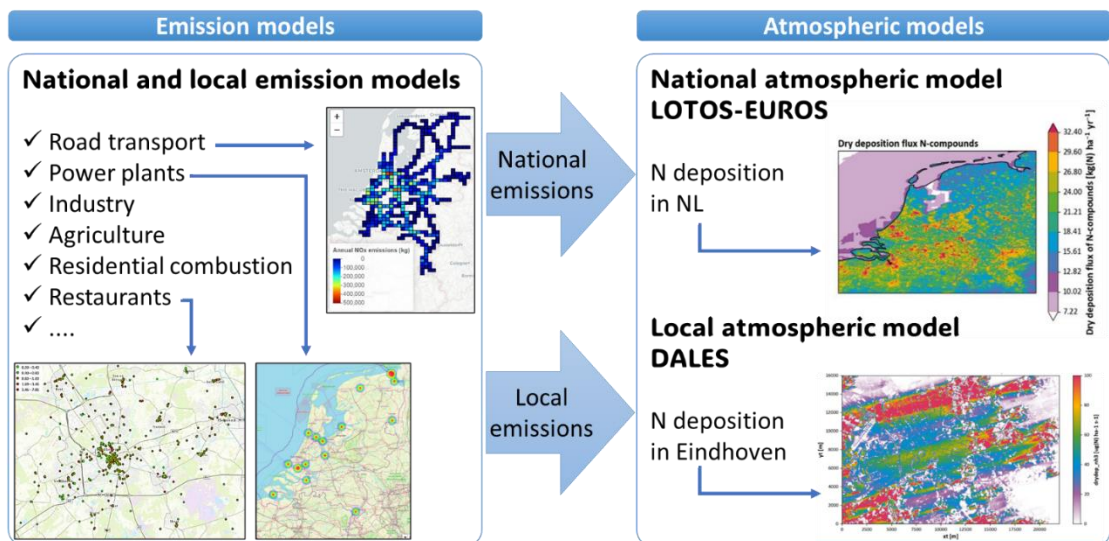   André Faaij – EMT, Christa Hooijer – HTI, Marieke Martens - MBE (Science Directors)

ERP Duration: 2021 – 2024

ERP Description
We develop a globally applicable, multi-scale atmospheric modelling system with resolution down to 25m to fully exploit the emerging observation capacities of satellites and sensors.

Summary Plan 2024
As 2024 is the final year of the ERP, this year will focus on the consolidation and integration of all knowledge, the validation of the results and the demonstration of its potential to ensure a lasting impact beyond the ERP lifespan.

Plan 2024 – ERP Climate air quality

⚛ Targeted key results	Plan 2024

Emission models (EM)
〉 Brake wear upgrade & first tyre wear emission model based on sensoring
〉 Complete agriculture emission scheme
〉 Emission uncertainty estimates

DALES
〉 Expand DALES chemistry with secondary inorganic aerosol
〉 Model flow around buildings with DALES
〉 Documentation and evaluation report

Evaluation and assimilation
〉 Quantification of ERP derived improvement of model skill w.r.t observations

System integration & demonstration
〉 Cloud based implementation of the emission forecast model and TOPAS
〉 Bayesian optimization scheme of performance
〉 Deliver the national air quality forecast through this system
〉 New national N-deposition maps, incorporating dynamic emission modelling
〉 High resolution air quality map over Eindhoven and portability of Emission models and DALES demonstrated for Amsterdam
〉 Development roadmap

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
〉 Units: EMT, MBE, HTI, ISP, HLW
〉 EM: FUB, WUR, BSC, RWS, FMI
〉 DALES: WUR, TUD, VU, KNMI
〉 NKS: RIVM, WUR, CML, KNMI

Stakeholder involvement
〉 Eindhoven & North-Brabant
〉 RIVM through NKS and national air quality forecast
〉 NPLG living labs
〉 Ministry of LNV, I&W

Dissemination
〉 10 peer reviewed publications, e.g.:
  - Emission model overview
  - EM: Traffic, Agri (2), Landfills
  - DALES: Deposition, Chemistry, Eindhoven
  - Model system and evaluation (3)
〉 International conference presentations (EGU, ITM, INI, CAMS)
〉 National workshop presentations (GLT, NAC, NKS, SLA, VNG, …)
〉 Presentations at provinces, ministries, 'omgevingsdiensten'

Valorisation actions 2024
〉 Roadshow relevant VPs
〉 Contribute model system to new ERP initiatives (ATMOS, Urban heat)
〉 Operational system implementation (EM, TOPAS and AQ forecasting) ensures societal benefit beyond ERP
〉 Dissemination in policy support gremia (SLA, GCN/GDN, EMEP, CEN, FAIRMODE)
〉 Release of LOTOS-EUROS open source version (used in NL, DEU, HRV, PT)
〉 BD in the following valorisation areas:
  - Nitrogen deposition (NKS & living labs)
  - Emission monitoring capacity (N, CH4)
  - Urban exposure (PM)

Valorisation goals 2024
〉 Transfer via assignments
〉 NKS, Provinces, EU, CAMS
〉 Attract adjacent external knowledge investments (2 PhDs)
〉 Position in NKS steering board

3 ERP Digital health measurements

ERP Contacts: Suzan Wopereis (Lead Scientist)
Sanne Kuijper (Project Lead)
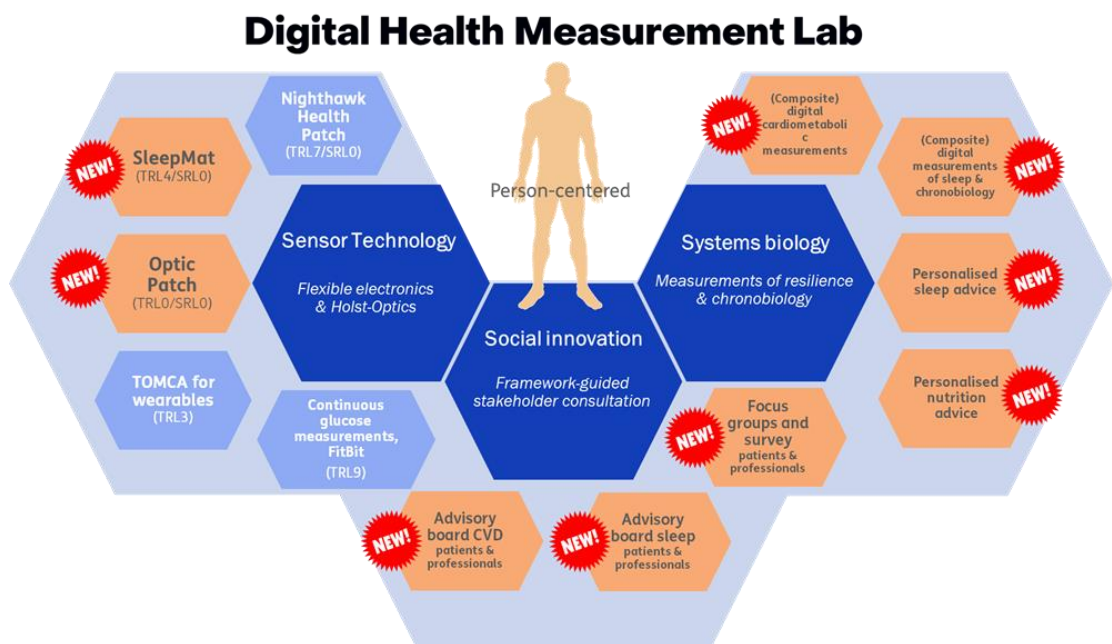Paulien Bongers – HLW, Christa Hooijer - HTI (Science Directors)

ERP Duration: 2022 – 2025

ERP Description
We will develop tools and methodologies for meaningful, inclusive, digital health measurements, which are a cornerstone in the upcoming transitions of healthcare.

Summary Plan 2024
In 2024 this ERP will continue the developments of meaningful digital health measurements for remote patient monitoring by TNO's Nighthawk health patch, non-obtrusive sleep mat and wearable optics patch.

Plan 2024 – ERP Digital health measurements

Targeted key results

Research line A (RLA) cardiovascular
〉 Validation of prototype digital biomarker microcardiometabolic characteristics
〉 Prototype digital biomarker based on electrical properties of the heart (corrected QC interval or QTc)
〉 Usability, drivers and barriers of adoption QTc and microcardiometabolic digital biomarkers

Research line B (RLB) sleep
〉 Sensor validation study execution @ Kempenhaeghe
〉 SOMNIA dataset analysis – algorithm development + draft manuscript
〉 Study protocol writing and Medical Ethics application for real life at home sleep and CVD monitoring

Research line C (RLC) Digital health platform
〉 Oxygen saturation of the blood (spO2) clinical validation study in the hypobaric chamber in Soesterberg
〉 Iteration of wearable optic patch for simultaneous multiwavelength, multi-distance signal acquisition
〉 Algorithm developed for cardiometabolic characteristics
〉 Active learning implemented in TOMCA (Tissue Optics Monte Carlo Analysis)

Plan 2024

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Partnership & Dissemination

Knowledge partners
〉 TNO DSS
〉 ERP NextGenCrypto

External knowledge partners
〉 Utwente (Monique Tabak)
〉 LUMC (Douwe Atsma)

Stakeholder involvement
〉 Kempenhaeghe (Sebastiaan Overeem)
〉 Sioux (AI pipeline; Philip Ruijten)
〉 Dime society
〉 Harteraad

Dissemination
〉 RLA Patent filed
〉 RLA Scientific papers on meaningful aspects cardiovascular health and cardiometabolic characteristics
〉 RLC Research paper on needs, drivers, barriers for remote patient monitoring
〉 RLC Research paper lifestyle monitoring with multimodal sensor systems
〉 RLC communication event

Valorisation

Valorisation actions 2024
〉 Orchestrating innovation
〉 Growth fund involvement: EdisonRPM
〉 Involvement EU projects XecS BioCurity, IHI iCARE4CVD
〉 eCMC further launched and defined

Valorisation goals 2024
〉 Projects granted, such as PPS IBDigital, PPS Remote, PhotonMed (EU)

4 ERP Opto-acoustics for medical imaging and health monitoring

|	
ERP Contacts:	Paul van Neer (Lead Scientist)
	Rob Jansen (Project Lead)
	Christa Hooijer – HTI, Adelbert Bronkhorst - DSS (Science Directors)
ERP Duration:	2022 – 2025

ERP Description

The ERP Opto-Acoustics will create a next generation acoustic platform, using optical means only, to generate and receive acoustic waves. Such a system will radically outperform existing systems, can be miniaturized or multiplexed to cover large structural areas and long distances.

Summary Plan 2024

In the first two years of the ERP Opto Acoustics we focussed on improving the efficiency of the PUT platform technologies on a component level and having a model for both technologies, IPUT and FOPUT, to transmit and receive an acoustic wave. Now in 2024 and 2025 the focus will shift from component proof-of-concept towards prototype proof-of-concept, including research on material platform dependencies and manufacturability.
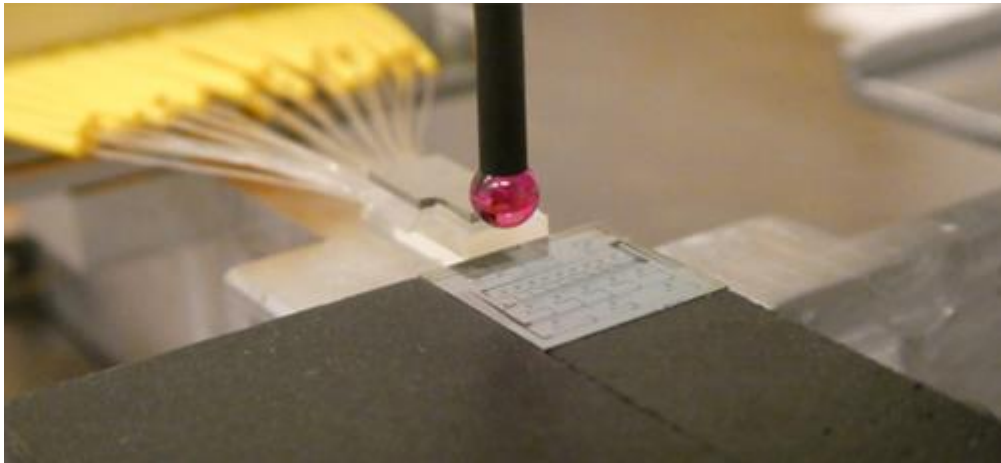
Integrated Photonic Ultrasound Transducer, read out with 32 fiber array

Plan 2024 – ERP Opto-acoustics for medical imaging and health monitoring

⚛ Targeted key results	Plan 2024

New knowledge / technologies / insights
- ⟩ In 2023 focus: Photonic Ultrasound Transducer (PUT) receiver, in 2024 focus: more on PUT transmitter
- ⟩ Predictive model will be further improved to encompass entire PUT system
- ⟩ 2022/2023: focus on component level
- ⟩ 2024/2025: the focus will shift:
  - From concept to System Architecture
  - From component proof-of-concept towards prototype proof-of-concept Includes research on material platform dependencies and manufacturability
  - Adding functionality to Opto-Acoustic (OA) technology platform (e.g. integrated detectors)
  - Leveraging OA platform technologies

Prototypes/demonstrators/models
- ⟩ Next generation 'packaged' PUTs and small PUT arrays/networks. First lab tests performed in targeted medium (tissue or composite structure)

Outcomes of evaluation/tests
- ⟩ Quantified acoustic performance of next generation PUT transmitter/receivers
- ⟩ Design input for third generation PUT transmitter/receivers
- ⟩ PUT system dependencies

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners

TNO Internal
- ⟩ Acoustics & Sonar, Optics, Opto-Mechatronics, Metabolic Health Research, Reliable structures & Wind Energy Systems

External
- ⟩ *University:* TU Delft (NL), ErasmusMC (NL), TU Twente (NL), VU Amsterdam (NL), etc (Leiden?)
- ⟩ *RTO:* VTT (Finland)

Stakeholder involvement
- ⟩ Government: RVO NL
- ⟩ Companies: Ligentec (Switzerland), EIBIR (Austria), VERMON (France), Optics11 (NL), Somni (NL), Photonfirst (NL), Lionix (NL), Hobré (NL), Airborne (NL), Kaminari (NL), etc

Dissemination
Publications
- ⟩ European Congress of Radiology 2024 (*invited*)
- ⟩ E.g. IEEE 2024/ASA 2024/SPIE 2024
- ⟩ 2 journal articles

Patents (2022-2024, focus)
- ⟩ 10 patents filed (Premier depot)
- ⟩ 2 to 5 pending / registered (PLT nr.)

Actions towards valorisation
- ⟩ Further embed the Opto-Acoustics technology in existing Product-Market Combinations (PMCs) of TNO
- ⟩ Medical & Smart Industry (HTI)
- ⟩ Offshore Renewable Energy (MBE)
- ⟩ Lifestyle-related disease models (HLW)
- ⟩ Sensor Technology (DSS)

Adjacent external knowledge investments
Projects:
- ⟩ Med-IPUT, 14AMI, Globalstar Blade Monitoring, NGF 'Duurzame luchtvaart – optische sensoren', NWA TNO-TUD IPUTs & Proton Therapy will continue in 2024.

Projects aimed for:
- ⟩ PUTs for Defense project
- ⟩ EU project proposal PhotonMed
- ⟩ ARPA-H proposal: IPUTs for improved steatosis/fibrosis diagnosis (with HLW)
- ⟩ Fiber Optic Ultrasound Transducers (FOPUTs) and next gen FBG design

5   ERP Pandemic diagnostics

ERP Contacts: Bart Keijser (Lead Scientist)
Jasper Kieboom (Project Lead)
Paulien Bongers – HLW, Adelbert Bronkhorst - DSS (Science Director)

ERP Duration: 2022 – 2025

ERP Description

To protect our society against the impact of future pandemic outbreaks, we aim to develop a scalable and multilevel diagnostic testing strategy, optimally aligned with the needs during different phases of a pandemic outbreak. The testing strategy comprises of an untargeted, mass spectrometry based method for identfication of pandemic pathogens in bioaerosols, as well as a ultrafast targeted point of care diagnostic tool for pathogen detection.

Summary Plan 2024

In 2024, the aim is to evaluate 3D printed filter designs for bioaerosol virus capturing and to validate its use in untargeted shotgun mass spectrometric based virus identification. We further aim to improve LAMP and CRISPR-Cas based detection for point of care diagnostics.

Plan 2024 – ERP Pandemic diagnostics

⚛ Targeted key results	Plan 2024

Research line: In search of the unknown
〉 Three new PVA nanospin filters evaluated for bioaerosol capturing in conjunction with MS, LAMP and CRISPR detection.

Research line: In pursuit of the known
〉 Method for increased sensitivity of CRISPR assay.
〉 Optimized integration of LAMP & CRISPR test
〉 Multiparameter read out strategy for LAMP
〉 Three demonstrators od point of care LAMP test on the POCT platform
〉 In silico model for LAMP primer design

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
〉 TNO HTI on nanospin filter
〉 WUR shared PhD on CRISPR Bolean operators. VU Altena institute on IP landscape

Stakeholder involvement
〉 VWS / RIVM / LFI

Dissemination
〉 2 key (Scientific) publications
〉 1 conference organised
〉 5 presentations
〉 2 Patent filings
〉 ? Awards

Valorisation actions 2024
〉 Business Development actions in DSS CBRN domain, New HLW BD on diagnostics
〉 Exploration external knowledge investments (NWO, NGF, …)

Valorisation goals 2024
〉 Consultation on valorisation and implementation with public stakeholders
〉 Exploration sustainable business model for pandemic diagnostic innovations through newly formed innovation network

6   ERP Qutech

ERP Contacts: Richard Versluis (Lead Scientist)
Kees Eijkel (Project Lead)
Christa Hooijer – HTI, Adelbert Bronkhorst - DSS (Science Directors)

ERP Duration: 2022 – 2025 (2nd period)

ERP Description
We exploit quantum effects in customized systems, materials and concepts, such as quantum computing and communication to pave the way for a quantum revolution.

Summary Plan 2024
We will further develop our roadmaps for Quantum Computing, Quantum Internet and protected qubits with a number of concrete steps.
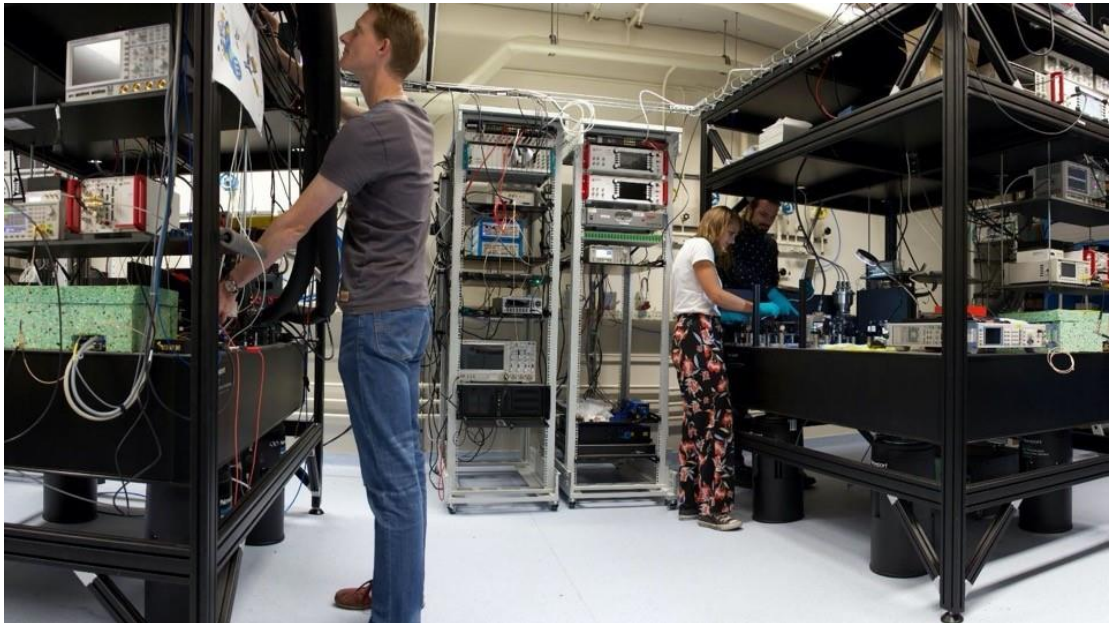
Plan 2024 – ERP Qutech

⚛ **Targeted key results**		Plan 2024
Qubit Research 〉 Increasing links with Quantum Computing in simulation of devices, dot tuning, Ge materials, CQED and integration, **Quantum Computing** 〉 Fabrication of 10 spin-qubit quantum processor chip 〉 Fabrication of Traveling-Wave Parametric Amplifier (TWPA) final version. **Quantum internet** 〉 Realization of 3rd node and connection of NV based hardware to the Quantum Network Explorer (QNE) web portal 〉 Start with implementation of engineering roadmap to improve the performance of the devices.		🎓 0 🏅 0 📄 20 💡 7

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners 〉 Expected increase of collaboration in NL on enabling technologies (photonics, integration) 〉 Expected increase in collaboration with other RTOs, specifically Imec, Fraunhofer **Stakeholder involvement** 〉 Continued focus on collaboration with the local ecosystem 〉 Push to engage more industrial players, especially EU 〉 Chips Act position **Dissemination** 〉 >20 refereed papers, (>70 papers together with TUD) 〉 8 patent filings (total 20 together with TUD) 〉 Present at many events, talks, presentations 〉 Various awards	**Valorisation actions 2024** 〉 Roll-out of B2B activity 〉 New QuTech partner covenant in place **Valorisation goals 2024** 〉 Spin off in Germanium and Quantum Networking 〉 Licensing agreements with these companies

7 ERP Subsidence and building damage

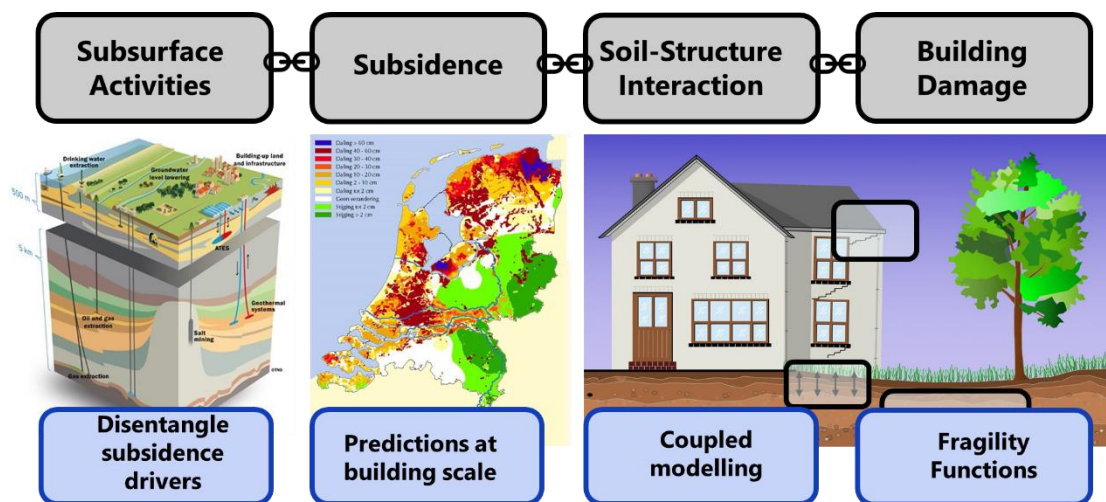|	
ERP Contacts:	Geert Geurst, Thibaut Candela (Lead Scientists) Andreas Höllbacher, J. Hasselman (Project Leads) Arjen Adriaanse – MBE, André Faaij – EMT, Anne Fleur van Veenstra - ISP (Science Directors)
ERP Duration:	2022 – 2025

ERP Description

We aim at the reduction of huge costs for subsidence induced damage, while enabling the safe continuation of pre-existing and future subsurface activities, by building a chain of models applied to assess the causal relationship between subsidence and damage to the built environment.

Summary Plan 2024

In 2024 we will test and validate the first version of the model chain with real-world data and extend it with other sources of subsidence and other building types. In order to do so we will combine the knowledge built up in our team with input from our external stakeholders. Furthermore, we will engage with focus groups related to the first application area of the model chain

Plan 2024 – ERP Subsidence and building damage

⚛ Targeted key results		Plan 2024

〉 Thoroughly tested 1st version of the model chain for one source of subsidence and one building type
〉 2nd version of the model chain, which is extended to multiple subsidence sources and multiple building types
〉 Real-world validation - Initiation of long term monitoring site for both soil and building deformation

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
〉 2 PhD projects with Universities of Utrecht, Padova and Delft
〉 Red team input from University of Allicante and ETH-Zurich
〉

Stakeholder involvement
〉 (semi-)public entities, knowledge partners, engineering entities; geodata entities and interest groups
〉 Focus group around the target area

〉 **Dissemination**
〉 International publications
〉 Paper in 'Binnenlands Bestuur'
〉 Conferences
- National congres 'bodemdaling'
- Eurorock 2024 – European rock mechanics symposium

Actions towards valorisation
〉 Strategic Market Plan in place
〉 ERP target area as example for further projects and programs
〉 Network activities at KBF, Platform Slappe Bodem, Coalitie Stevige Steden, NWO NWA Living on Soft Soil
〉 Information Sessions 'gas fields and damage'

Achieved valorisation (assignments)
〉 Fugro, AvecodeBondt: Valorize datasets
〉 IMG/EZK, subsidence damage
〉 SENSAR, InSAR analysis at building scale

Spin off-product
〉 PIO, ERP-model chain part of the GDN portal

8 ERP Appl.AI

8.1 Flagship – SNOW

ERP Contacts: Judith Dijk (Lead Scientist)
Willeke van Vught (Project Lead)
Adelbert Bronkhorst (Science Directors)

ERP Duration: 2023 – 2026

ERP Description
The overall goal of the SNOW flagship is to develop, integrate, demonstrate, and evaluate AI capabilities for a self-aware autonomous system that can operate safely and effectively in an open world.

Summary Plan 2024
The research focus in 2024 will be on open world aspects on system, perception and planning aspects for a robotic system with manipulation capabilities and on the development of the SNOW knowledge into an integrated demonstrator with stackable (functional) components.

Example of an autonomous system, the SPOT robot from Boston Dynamics. At this demonstration, the behaviour was coordinated by an operator (left person in the image). The goal of the SNOW flagship is to develop capabilities for such robots so that they are able to perform tasks autonomously in the open world.

Plan 2024 – ERP Appl.AI: flagship SNOW

⚛ Targeted key results

⟩ Research on estimation of affordance properties of objects in the current world state,
⟩ Research on planning and execution focusing on the pre- and postconditions of actions including manipulation of objects in the current physical world in line with the operational rules.
⟩ Developing a view on open world aspects,
⟩   including use of knowledge bases at different levels.
⟩ Exploration on the use of foundation models for SNOW applications.
⟩ Developing pipelines for open world autonomy for different use cases with an analysis of how this increases the autonomy of the system in this specific use case.
⟩ Integrating one of these pipelines on our completely integrated robotic system and performing experiments and demonstrations with this demonstrator based on the work of 2023.

Plan 2024

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🤝 Partnership & Dissemination

Knowledge partners
⟩ TNO internal
⟩ UvA, TUDelft and KMAR via Openbots
⟩ Fraunhofer IOSB
⟩ Applied Physics Lab of Johns Hopkins University
⟩ Boston Dynamics
⟩ NASA Jet Propulsion Lab

Stakeholder involvement
⟩ Government: KMAR, Defence, J&V
⟩ Companies: via use cases

Dissemination
⟩ Paper on estimation of affordance
⟩ Properties of objects
⟩ Paper on knowledge bases
⟩ Memo on foundation models

📊 Valorisation

Valorisation actions 2024
⟩ Structural Business Developer involvement
⟩ Adoption by 'Vraaggestuurde Programmas' (VPs)
  - National security
  - Radar and integrated sensor suites

⟩ Live demonstration of the in 2023 developed methods in a completely integrated robotic system

⟩ Demonstration @ICRA2024 in Boston Dynamics booth

⟩ Development of stackables for the SPOT robot for the purpose of the demonstration

Valorisation goals 2024
⟩ Transfer via assignments (further development, advice, consult, …)
⟩ Investigating the potential for selling stackables
  - via Avular?
  - Spin-off?

8.2 Flagship – FATE

ERP Contacts: Cor Veenman (Lead Scientist)
Milena Kooij-Janic, Lizette Maljaars (Project Lead)
Omar Niamut (Science Directors)

ERP Duration: 2023 – 2026

ERP Description

The FATE Flagship project is a research project to integrate capabilities for an adaptive decision support system prepared for the requirements for a trustworthy AI system, being robust, transparent/explainable, privacy respecting, and able to adapt to fairness constraints and other norms of the respective norms of the application. For demonstration we use prediction of Diabetes Type 2.

Summary Plan 2024

In 2024, we research 1) Can we prevent information leakage (privacy) of other patients, while explaining (explanability) how to prevent the development of DT2?, and 2) Has the quality of the explanation (explanability) for minorities/ majorities (fairness) effect on the advice of the doctor?. Further we start to research the adaptivity of the system towards feedback of patients on the advices given by the system.

To align with the MMAIS Flagship, we will develop metrics to quantify privacy, explainablity and fairness/norms to support the decision making while taking all the trustworty AI requirements into account from a DT2 perspective.
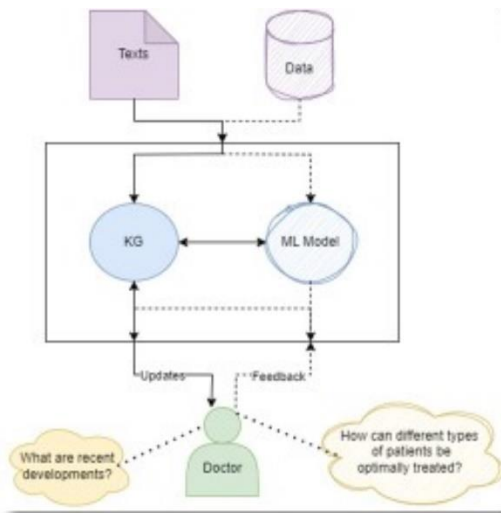
Plan 2024 – ERP Appl.AI: flagship FATE

⚛ Targeted key results	Plan 2024
⟩ Integrating Fairness and Explainability: To what extent do different quality explanations really impact the resulting decision by the medical professional? ⟩ Integrating Explainability and Confidentiality: Extend the capability to prevent information leakage in explanations towards federated databases. ⟩ Adaptivity: focus on adaptation of the data-driven AI models through feedback learning. ⟩ DT2 (HLW) stakeholder involvement in socio-technical development towards needs around trustworthy norms and linking these in collaboration with the MMAIS flagship; ⟩ Integration and demonstration	🎓 0 🎖 2 📄 3 💡 0

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners ⟩ TNO internal ⟩ Collaboration with HI zwaartekracht programma (Transfer Lab) ⟩ Radboud University (PersOn) ⟩ Utrecht University (ICAI AI4Oversight) ⟩ Leiden University (ICAI AI4Oversight) ⟩ Fraunhofer IOSB on Synthetic data **Stakeholder involvement (use cases)** ⟩ To be selected **Dissemination** Publications on ⟩ the combination of trustworthy topics ⟩ adaptivity ⟩ collaboration with MMAIS ⟩ results from collaborating PhD students in Transfer lab ⟩ Presentations at a.o. Appl.AI events	**Valorisation actions** ⟩ Moonshot ⟩ Business Developer involvement HLW and ISP in relation to FATE and Transfer Lab ⟩ At program level coordinated links to unit innovation areas and PMCs **Adjacent external knowledge investments** ⟩ PersOn (NWO-Perspectief) ⟩ ICAI Lab AI4Oversight (Inspectorates) extension of Lab with NVWA ⟩ EU project **Valorisation goals** ⟩ Through the use case projecs (see stakeholder involvement) ⟩ Connections to PMCs, VPs and innovation areas of the different units

8.3 Flagship – AutoADAPT

ERP Contacts: Frank Willems (Lead Scientist)
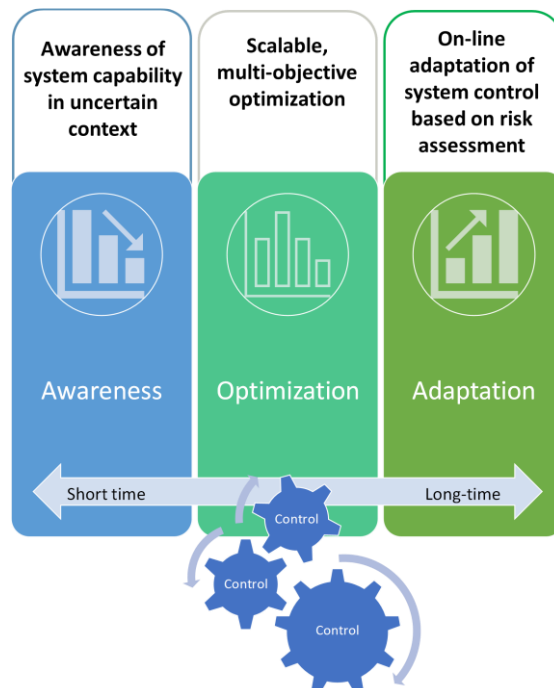Rene Corbeij (Project Lead)
Marieke Martens - MBE (Science Director)

ERP Duration: 2022 – 2025

ERP Description

AutoADAPT concentrates on challenges related to adaptation by learning from observed current system behavior and predicted, uncertain future behavior. Our goal is to optimize the performance of an AI system over its lifecycle in an open world using automation. AutoADAPT uses physics-based models as basis and adds data-driven/machine learning (hybrid AI) to reduce uncertainties in the entire lifecycle of a system

Summary Plan 2024

The research in 2024 will focus on implementation and demonstration of the in 2023 developed full self-adaptation technology. In addition, the self-adaptive technology concept will be extended to incorporate information from a set of similar systems, like a fleet of vehicles, for learning, to improve precision, and to reduce risks based on single system data. An important step towards real-world demonstration will be the implementation and integration of a self-optimization concept on a hard-ware-in-the-loop battery set-up that simulates battery electric vehicle operation and on a laser satelite communication lab set-up.

Plan 2024 – ERP Appl.AI: flagship AutoADAPT

⚛ Targeted key results	Plan 2024

New knowledge/technologies/methods/insights
〉 Dual purpose awareness on multi-scope time frames with learning
〉 Genetic programming for control structure adaptation
〉 Multi-time scale adaptation

Prototypes/demonstrators/models
〉 HIL demo run-time battery-life aware energy management using fleet data
〉 Self-tuning control optimization for space communication terminal

Outcomes of evaluation/tests
〉 Demo self-learning for integrated, long-time horizon adaptation loop
〉 Demo real-world, run-time implementation
〉 Integration of real-time awareness, mission optimization, risk-based decision making
〉 Adaptive satcom link solution for full sat2ground-link

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🤝 Partnership & Dissemination	📊 Valorisation

New knowledge partners
〉 TNO internal: EMT
〉 External knowledge partners: Fraunhofer and Linkoping University

Stakeholder involvement
〉 Targeted new members industrial steering group: Durapower, Eleo, Demcon, FSO

Dissemination
〉 Key (Scientific) publications (3) on integrated, long-time horizon adaptation loop and demo results for show cases
〉 Conferences (3)
〉 Presentations: conference (3), internal (2)
〉 Patent filings: examine potential for: 1) dual purpose awareness and 2) Genetic programming for control structure adaptation

Valorisation actions 2024
〉 Follow-up project of 2024 APPL.AI use case projects
〉 Define potential joint projects with industrial steering group members
〉 Define new PhD research project with TU/e (fleet-based learning, free energy principle for improved awareness)

Valorisation goals 2024
〉 Use developed hardware platforms in new projects
〉 Apply expertise in running growth fund projects, incl. GTD-E, Nextgen BMS, MENENS

8.4 Flagship – SEAMLESS

ERP Contacts: Michael Borth (Lead Scientist)
Zuzanna Domagala-Schmidt (Project Lead)
Marieke Martens - MBE (Science Directors)

ERP Duration: 2023 – 2026

ERP Description

The SEAMLESS flagship develops the system engineering and lifecycle management methodologies and tools that enable the development and maintenance of trustworthy AI systems. Targetting lasting performance and safety, SEAMLESS advances design as well as validation and verification techniques to integrate system engineering with continuous AI development, such that AI-based systems are fit for their purpose over their whole lifecycle.

Summary Plan 2024

The second year of the SEAMLESS flagship puts emphasis on analytical methodologies for system architecting, data quality management, scenario-based validation and formal verification, as well as diagnostics of AI-based systems. In this, the focus will be on data-driven and hybrid AI. This extends the SEAMLESS methodology towards object detection and classification functionalities implemented by data-driven AI based on machine learning, which are essential for sensing and recognition tasks of autonomous systems. For this, the project will initially continue to develop its novel methodologies using the SPOT showcase of the SNOW flagship, that contains many data-driven AI components and for which SEAMLESS already developed a digital twin as experimental platform. (We consider a switch to another showcase at a later stage for it's the later research focus on adaptive systems.)
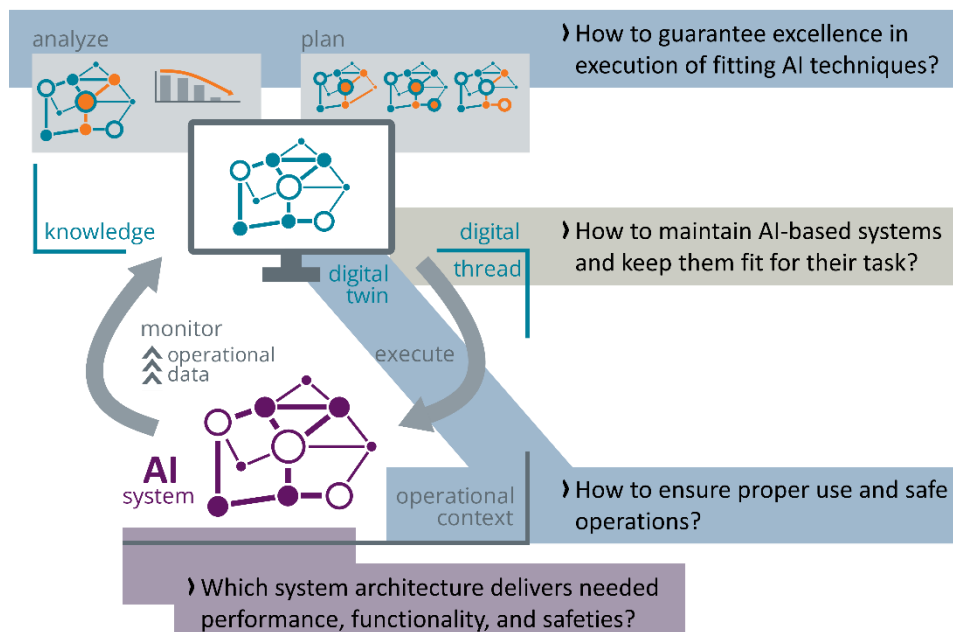
Challenges of SEAMLESS engineering of AI-based systems.

Plan 2024 – ERP Appl.AI: flagship SEAMLESS

Targeted key results

Extension in scope
⟩ Enabling SEAMLESS methodologies for data-driven and hybrid AI next to knowledge-driven AI

The How [methodologies]
⟩ Extension of SEAMLESS Information flow modelling, Failure Mode Effect Analysis, and risk analysis to the specific challenges of data-driven AI and data-based processes
⟩ Analytics of change and drift in systems / world and identification of fitting response
⟩ Automation of the generation of SEAMLESS analytical models
⟩ Extension of verification & validation methodology to computation of coverage and falsification techniques

The What [models + demonstration]
⟩ Digital Thread: the management of engineering artefacts, data, and configuration / usage information of a system from cradle to grave
⟩ Digital Twin: Use of a system's Digital Twin within experiments to complement design analytics and within validation and verification
⟩ Lifecycle Management: detection of a developing mismatch between AI and reality

Plan 2024

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Partnership & Dissemination

Knowledge partners
⟩ TNO : Research groups IVS, IAS, ESI, II
⟩ Radboud University, TU/e, TUD
⟩ Stakeholder involvement
⟩ Government: RDW
⟩ Companies: SEAMLESS established an industrial advisory board with international partners from the automotive domain and the Dutch HighTech industry. We will extend this circle towards providers of key technologies and engineering services.

Planned dissemination
⟩ Article on Composability + generative process for SEAMLESS analytical model
⟩ Article on Methods and framework for scenario-based V&V of data-driven AI components and hybrid AI
⟩ Article on Challenges of Lifecycle Management of AI-based Systems
(pending on industry interest)
⟩ TNO System Engineering Guild et al

Valorisation

New actions towards valorisation
⟩ Business development with Smart Industry programme

Valorisation goals 2024
⟩ Consultancy towards RDW
⟩ Support the execution of case project in Automotive that we setup with Torq Robotics (Daimler, Mercedes Trucks) and follow up.
⟩ Support the execution of case project in HighTech that ESI proposed together with Canon Production Printing (NL).
⟩ Setup 2025 use case project in Smart Industry

8.5 Flagship – MMAIS

ERP Contacts: Jasper van der Waa (Lead Scientist)
Tjeerd Schoonderwoerd (Project Lead)
Marieke Martens – MBE, Adelbert Bronkhorst - DSS (Science Directors)

ERP Duration: 2023 – 2026

ERP Description

The goal of the flagship MMAIS is to develop, demonstrate and deliver methods that enable ethical regulation of AI systems for high-risk and morally-sensitive contexts. These methods are part of a socio-technical feedback loop that describes how to empower multiple stakeholders (e.g., legislators, developers, end-users) to determine, monitor, and control the adherence of AI systems to relevant ethical norms and values.

Summary Plan 2024

In its second year, MMAIS will keep its focus on the four main topics of identification, specification, implementation and alignment of ethical values. The methods that have been developed in '23 will be validated and further adapted for the domain of healthcare. That is, we will collaborate with healthcare domain experts to identify relevant ethical values (such as safety, fairness and transparency), and moral standards and requirements for clinical AI decision-support systems. Furthermore, the MMAIS software framework for implementation of ethical values will be used to model the identified values. This allows assessment of the ethical adherence of the AI system's outcomes. Finally, the requirements for this ethical assessment (monitoring) of AI systems in healthcare will be investigated.

Plan 2024 – ERP Appl.AI: flagship MMAIS

⚛ Targeted key results	Plan 2024

Value elicitation & specification
⟩ Publication on the evaluation of '23 methods in healthcare showcase
⟩ Extended method for value specification in healthcare showcase

Value implementation
⟩ Framework for monitoring ethical adherence of decision-support systems
⟩ Publication on framework

Value alignment
⟩ H-AI interaction design pattern for monitoring and consolidating value alignment
⟩ Publication on role of H-AI interaction in iterative value alignment

Integration
⟩ Demonstrator of SOTEF methods

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
⟩ Internal: FATE, AI/DS
⟩ External: TUD, UU, LU (PhD)
⟩ HI gravitation programme
⟩ ELSA lab

Stakeholder involvement
⟩ MoD (Use Case)
⟩ CBR (Use Case)
⟩ Belastingdienst (Use Case)
⟩ TNO ISP Vector (PhD)

Dissemination
⟩ 3 publications of work (conference/journal/workshop)
Presentations at various venues (internal and external)
⟩ Discussions in EU WG2 TG risk management

Valorisation actions 2024
⟩ Business Development involvement (through Appl.AI)
⟩ DSS / MBE:IVS
⟩ Integration in V2343

Valorisation goals 2024
⟩ Involvement of Business Developers (through Appl.AI)
⟩ Appl.AI use case proposals

9 ERP Next generation crypto

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ERP Contacts:	Thijs Veugen (Lead Scientist)
	Sjoerd-Jan Wiarda (Project Lead)
	Adelbert Bronkhorst – DSS, Omar Niamut - ISP (Science Directors)
ERP Duration:	2023 – 2026

ERP Description
We want to bring quantum-secure analysis of distributed data to the next level, such that in a few years, secure data sharing solutions can be engineered, validated, and subsequently exploited, for applications that use large amounts of data, and require real-time output.

Summary Plan 2024
We continue the fruitful collaboration with other units and research institutes. First technical results and findings (RL1 and 2) will be extended to improve functionality of building blocks. In our work with stakeholders in RL3 focus will shift from ethical implications in two use cases to legal issues and business models.
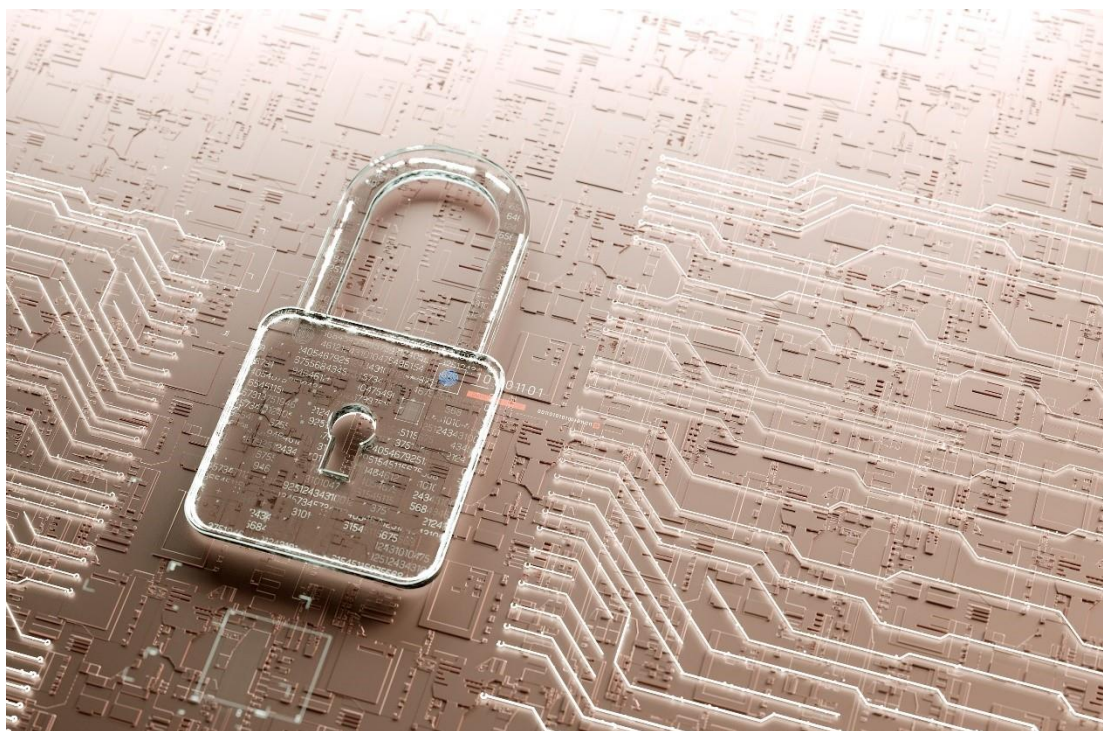
Plan 2024 – ERP Next generation crypto

⚛ Targeted key results	Plan 2024
Research Line 1: ⟩ Scalable and secure distributed learning on image data ⟩ Design and implementation of predictive maintenance model **Research Line 2:** ⟩ Improve TRL of protocol analyse tool (or functional correctness of hardware implementations) ⟩ Improve prover efficiency of ZKP **Research Line 3:** ⟩ Shift from ethical to legal aspects ⟩ Work out business model archetypes	🎓 2 🏅 2 📄 4 💡 0

🤝 Partnership & Dissemination	📊 Valorisation
⟩ CAC workshop at Real World Crypto (Toronto) ⟩ PhD 'Secure Cloud' at University of Twente **Journal papers:** ⟩ Journal special issue PP voor AI (RL1) ⟩ Journal paper RL3 ⟩ 4 peer-reviewed papers	⟩ TNO-CWI symposium on MPC (and other PETs) in January, inviting start-ups TNO meeting customer board (Q1 2024) ⟩ Invite BDs, PMC leads, VP managers ⟩ Share initial results ⟩ Prepare adjacent external knowledge investments (NWO, EU)

10 ERP Plasma synthesis

ERP Contacts:	Dirk van den Bekerom (Lead Scientist)
	Hans Linden (Project Lead)
	André Faaij – EMT, Christa Hooijer - HTI (Science Directors)
ERP Duration:	2023 – 2026

ERP Description

Electrification of chemical industry is crucial to reduce CO_2 emissions. Plasma synthesis is employed for electrically converting methane to value added chemicals. The focus of the ERP is direct production of ethylene; an important large volume, high value chemical (HVC) for the polymer industry.

Summary Plan 2024

The goal for 2024 is to continue efforts that will lead to the design and realization of a next-generation plasma for highly selective plasma synthesis. Focus will be on refining the models, which will be validated by experiments in the various reactors. This work should ultimately culminate into a predictive model that can be used as guide for optimizing reactor conditions. Additionally we will start experiments on the first scaled up (10kW & 50kW) reactors, as input for reactor design optimization.

Plan 2024 – ERP Plasma Synthesis

⚛ Targeted key results	Plan 2024
In 2024 will focus on expanding on and refinement of existing efforts: ⟩ Improved understanding of process through parameter scans of 10kW and 50kW systems ⟩ First version of integrated engineering model used for computer aided reactor optimization ⟩ Experimental validation of existing kinetic models, followed by refinement of said models ⟩ Following LCA in 2023, in 2024 an initial Techno-economic analysis (TEA) will be performed, including sensitivity matrix ⟩ Initial system integration plan to assess the potential for integration on a chemical site	🎓 1 📜 0 📄 1 💡 2

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners In addition to 2023: ⟩ Projected part-time professor at UM (Dirk van den Bekerom) ⟩ Keep growing academic network through collaborative research with universities **Dissemination** ⟩ Invited presentation at NWO Physics as well as presentations at other conferences ⟩ Scientific publication on kinetic model + experimental validation ⟩ New initial patent filing based on active plasma control	**Valorisation actions 2024** ⟩ Development of co-financed projects (RVO, Groeifonds) ⟩ Start construction of 500kW Pilot plant (financed through partner contributions; outside of ERP) ⟩ Establishment of B.V. for Pilot plant construction, operation, and incorporation of IP ⟩ Investigate possibility of starting shared research program

11 ERP Socio-economic impact of green transitions

ERP Contacts:	Peter Mulder (Lead Scientist)
	Caroline Schipper (Project Lead)
	Anne Fleur van Veenstra – ISP, André Faaij – EMT, Marieke Martens - MBE (Science Directors)
ERP Duration:	2023 – 2026

ERP Description
A grand societal challenge is to implement the transition to a sustainable and green society while maintaining and redefining societal welfare ('Brede Welvaart'). This ERP develops a comprehensive microsimulation approach to quantitatively assess the integral impact of the energy and mobility transitions on households' economic well-being, together with CBS, CPB, PBL and academic partners.

Summary Plan 2024
In 2024, we will we will further extend existing models, start linking of models and perform scenario analyses based on geo-coded micro data.

Plan 2024 – ERP Socio-economic impact of green transitions

⚛ Targeted key results	Plan 2024

Mobility
⟩ Improve Urban Strategy and ORANGE (link) to compute distribution effects and include and calibrate zoning and heterogeneity
⟩ Develop destination choice model
⟩ Apply models to 1 or 2 use cases

Built Environment
⟩ Using HESTIA and underlying microdata to develop method to assess impact of home renovation on housing values
⟩ Development of dashboard to make economic data from Hestia available for use by municipalities
⟩ Research into relationship between heating behavior and income

Labour
⟩ Matching additional labor demand from large-scale home renovation with labor supply
⟩ Identify (regional) labor market shortages and skill mismatches at sector level
⟩ Refine macroeconomic analytical model

Governance
⟩ Investigate what it takes to make data and evidence accessible to all relevant actors within a governance system

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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
⟩ Colleagues from TNO ISP Vector, EMT, MBE, HLW
⟩ CPB, CBS, PBL, VU, UU, UM/ROA, RWS

Stakeholder involvement
⟩ Sounding board group for CPB studies with ministries (EZK/BZK/SZW/Fin)
⟩ Waarborgfonds sociale woningbouw
⟩ Cooperation with RWS to benchmark TIGRIS XL and ORANGE

Dissemination
⟩ 6 scientific publications
⟩ CPB-TNO study
⟩ Dashboard to make economic data from Hestia available for use by municipalities

Valorisation actions 2024
⟩ Business Development involvement, adaption by 'Vraaggestuurde Programma's'

Valorisation goals 2024
⟩ Deploying model structures for policy questions on request of policy makers

12 ERP Solar-2-hydrogen

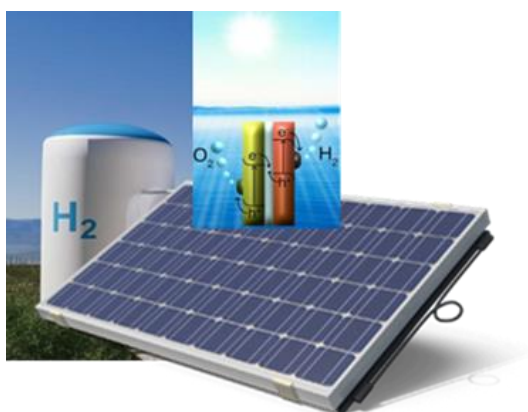| ERP Contacts:	Pascal Buskens (Lead Scientist)
	Nicole Meulendijks (Project Lead)
	Christa Hooijer – HTI, André Faaij – EMT, Paulien Bongers - HLW (Science Directors)

ERP Duration:	2023 – 2026

ERP Description

Based on commonly accepted scenarios for the energy transition in NL and EU, there will be a large demand for green hydrogen (H2). It is unlikely that this demand can be fully covered by large scale electrolysis. R&I activities on alternative technologies having the potential to produce green H2 at similar or lower costs are needed. The focus of ERP Solar-2-Hydrogen (S2H) is the development and demonstration of devices for water splitting that use sunlight as sustainable energy source and yield green H2 at a levelized cost of H2 (LCOH) ≤ 2€/kg (benchmark is green H2 from electrolysis).

Summary Plan 2024

The S2H ERP program will explore green H2 production based on a promising novel technology: sunlight-powered water splitting. Our aim is to progressively combine photovoltaic and electrolyser components into integrated devices – solar panels that produce H2 instead of electricity. We aim to proceed towards S2H devices which ultimately merely comprise a photoanode and photocathode as essential components. Within this ERP, a pilot scale S2H panel (14x14cm) for solar water splitting will be developed according to the iPVE approach, with solar-to-hydrogen (STH) efficiency >20%, validated using (concentrated) artificial sunlight (TRL5). Furthermore, a concept for solar water splitting according to the PEC approach with STH efficiency >10%. Individual device components (e.g. photo-electrodes, membranes) developed and tested on lab-scale (TRL3).

Plan 2024 – ERP Solar-2-hydrogen

⚛ Targeted key results	Plan 2024

New knowledge/technologies/methods
⟩ iPVE: Performance and stability tests under simulated real-life conditions for combinations Si-PEM, Si-AEM, 2T Si/Pk-PEM and 2T Si/Pk-AEM.
⟩ iPVE: Technoeconomic analysis of Si-PEM, Si-AEM, 2T Si/Pk-PEM and 2T Si/Pk-AEM.
⟩ iPVE: selection of system of choice based on performance and stability tests and technoeconomic analysis, and strategy for performance and cost optimization developed.
⟩ PEC: Study of structure-functional performance relationship for mesoporous $BiVO_4$ (pore size, shape, interconnections).
⟩ PEC: Electrodeposition of metal oxyhydroxides and Ni alloys as co-/electrocatalysts on porous $BiVO_4$.
⟩ PEC ('submerged PV'): manufacturing and performance validation of tandem cell FeNiOOH/ITO/a-Si/Si/PTA/CH3NH3PbI3/PCBM/SnO2/ITO/Pt.
⟩ Initial life cycle assessment study will be started for the system of choice selected for iPVE.
⟩ An initial risk assessment and safety study will be performed for a selection of PEC materials, and for the iPVE based hydrogen production system.

Prototypes/demonstrators/models
⟩ iPVE: Si-PEM, Si-AEM, 2T Si/Pk-PEM and 2T Si/Pk-AEM demonstrators for performance and stability tests.
⟩ PEC: lab scale demonstrator comprising mesoporous $BiVO_4$ electrode with co-/electrocatalyst.
⟩ PEC ('submerged PV'): lab scale tandem cell demonstrator.

Plan 2024 metrics:
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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
⟩ TNO internal: RGs MAS, SSE (HTI); ETS, STA, STIP (EMT); RAPID (HLW).
⟩ External knowledge partners: UHasselt, IMEC, UvA, UAntwerp.

Stakeholder involvement
⟩ Government: Province N-Br, EZK, co-funding Interreg project FOTON.
⟩ Companies: DCL, Soltech, Azteq involved via Interreg project FOTON.
⟩ User and advisory committee for Interreg FOTON (> 10 company partners).
⟩ WaterstofNet members.

Dissemination
⟩ At least one scientific paper in a peer reviewed journal.
⟩ At least one filed patent.
⟩ At least two presentations at relevant symposia.
⟩ At least one presentation for Interreg FOTON user- and advisory group, and one presentation for WaterstofNet members.

Valorisation actions 2024
⟩ Business Development involvement, adoption by VPs: Involved VPs: EMT CO2 Neutral industry, Clean Hydrogen, HTI Smart Industry.
⟩ At least two adjacent project proposals submitted (e.g., Interreg, HEU, TKI)

Valorisation goals 2024
⟩ At least one new project granted

13 ERP Sustainable recycling of batteries and solar panels

ERP Contacts: Mirjam Theelen, Devin Boom (Lead Scientist)
Ahmed Fawzy (Project Lead)
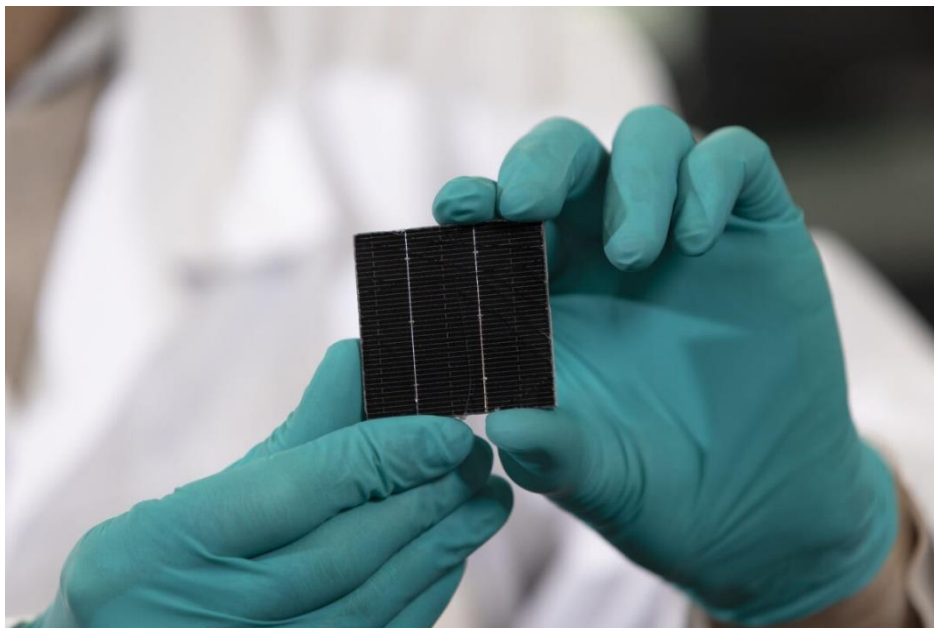André Faaij (Science Director)

ERP Duration: 2023 – 2026

ERP Description

This ERP will result in new sustainable technologies to promote strategic materials independence of the Dutch industry by recycling of electronic products and their design from and to recycling. Focus will be on batteries and PV panels as primary use cases.

Summary Plan 2024

In 2024, activities on sustainable battery and solar panel recycling will be continued. For solar panels, activities will focus on clean and sustainable opening of the panels, allowing direct access to the valuable components. Moreover, the silicon surface will be cleaned, allowing material collection and later reuse. For batteries, the focus will lay on sustainable and circular separation of black mass into valuable metals. Specific points of attention are the minimization of necessary process steps, and the possibility to completely reuse the chemicals needed for the separation process.

Plan 2024 – Sustainable recycling of batteries and solar panels

Targeted key results

PV recycling
〉 Development of a sustainable approach for PV module separation with minimal surface contamination
〉 Sustainable silver collection from silicon wafers
〉 Wet-chemical emitter removal
〉 Definition of required silicon purity for various products
〉 Estimation of CAPEX and OPEX of separation approach

Li-Ion battery recycling:
〉 Maximized sustainable dissolution process with minimal amount of chemical reagents
〉 Tested multiple electrodialysis modes for metal separation
〉 Advanced metal separation with electrodialysis separation
〉 Reagent regeneration is investigated and ligand recovery is achieved

Plan 2024

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Partnership & Dissemination

Knowledge partners
〉 TNO internal: Process engineering (SPES, STIP), engineering (EfAM), life cycle assessment (CAS), polymer chemistry (MAS), safety assessments (RAPID) and technical economic analysis (SPES)
〉 Hiring of two PhD students

Stakeholder involvement
〉 Producers and producer responsibility organizations

Dissemination
〉 Finalization of four publications started up in 2023 and start-up of one additional publication
〉 Potential filing of 1 patent
〉 Three conference contributions

Valorisation

Valorisation actions 2024
〉 Business case definition for PV panel and battery recycling
〉 Contact with possible industrial partners on materials recycling
〉 Alignment with "circular electronics" projects
〉 Close interaction with two growth funds

Valorisation goals 2024
〉 Submission of three related project proposals in national and international subsidy calls

14   ERP Synthetic biochemistry

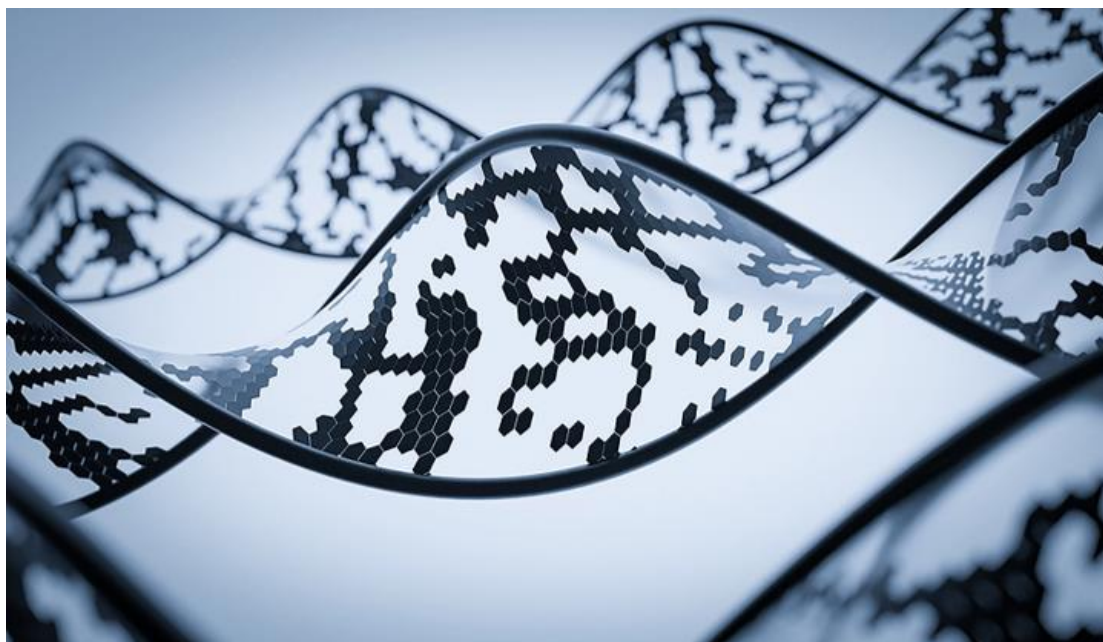| ERP Contacts: | Wouter Vaes (Lead Scientist) |
	Dide Reijmer (Project Lead)
	Paulien Bongers – HLW, André Faaij - EMT (Science Directors)
ERP Duration:	2023 – 2026

ERP Description
Our moonshot is to develop the world's most sustainable and efficient biosynthetic version of a biomaterials production platform with full focus on the ultimate product: biomass that consists of >90% of the product of interest at 10-20% of current production prices.

Summary Plan 2024
SYNBIO will expand the implementation of generically applicable technologies to the therapeutic proteins (TPs) and bulk chemicals and energy carriers (BCECs) use cases, while preparing the platform readiness for a first demonstrator study.

Plan 2024 – ERP Synthetic Biochemistry

⚛ Targeted key results	Plan 2024

Developing generic strategies for the Therapeutic proteins (TPs) and Bulk Chemicals and Energy Carriers (BCECs) use cases:
⟩ Assessment of generically developed technologies applied to two new biomolecules of interest
⟩ Lab-scale implementation of at least two new processes, one per use case, and determination of subsequent process yield

Sourcing sustainable biochemical process energy:
⟩ Updated search for sustainable and cost-effective biological energy supply systems and selection of a test candidate related to the BCECs use case
⟩ Design of a process proposal for the selected energy supply alternative in each use case

Planning for exploitation:
⟩ Assessment of TPs' platform readiness and preparation of a technical plan for a first demonstrator study

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🤝 Partnership & Dissemination	📊 Valorisation

Further expansion of the knowledge partner network
⟩ Leverage on current collaborations and expansion of network with two new key opinion leaders in the TPs case
⟩ Assessment of capabilities and requirements from vendors and partners for commercial exploitation of process-related materials
⟩ Approach of key universities, RTOs and companies relevant for the BCECs case
⟩
Consolidate stakeholder involvement
⟩ Follow-up with three stakeholders or prospective clients from the Pharma and Biotech sectors
⟩
Dissemination remains prudent
⟩ Dissemination activities restricted to internal use and under strict confidential agreement with external collaborators

Execute valorisation strategy in the TPs use case
⟩ Completion of the filing process for the first patent
⟩ Engagement in Business Development for the acquisition of a first demonstrator study

Initiate valorisation strategy in BCEC use case
⟩ Assessment of patentability of novel routes, with special focus on the selected test candidate products
⟩ First grant application
⟩ Definition of exploitation strategy, including the development of SYNBIO's Unique Buying Reason and IP valorisation

15 ERP Asphalt rejuvenation using micro-algae

ERP Contacts: Greet Leegwater (Lead Scientist)
Tim Dijkmans (Project Lead)
Arjen Adriaanse – MBE, André Faaij - EMT (Science Directors)

ERP Duration: 2024 – 2027

ERP Description
The proposal aims to develop a circular and fit for purpose asphalt recycling agent based on waste water grown micro-algae at an industrial scale to keep the Dutch road network operational in a new circular value chain.

Summary Plan 2024
In this first year preparatory work is executed to enable the design of a fit for purpose rejuvenator; a suitable microalgae strand is selected, the technical requirements for a rejuvenator are formulated, the chemical steps in the extraction process are captured and LCA and LCC tooling is created.
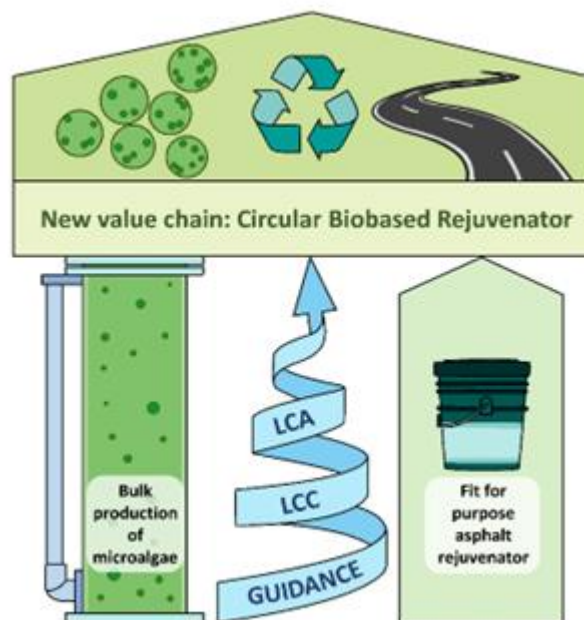
Plan 2024 – ERP Asphalt rejuvenation using micro-algae

⚛ Targeted key results	Plan 2024
⟩ Choice of wastewater and CO2-source(s) for cultivation of suitable microalgae strain ⟩ First SOP for efficient lipid-rich microalgae production at pilot scale ⟩ Chemical and physical requirements for a rejuvenator with improved performance ⟩ Initial results of lipid extraction and rejuvenator modification ⟩ Prototype of a 'tilting point tool' to reflect on the full (circular) value chain ⟩ Initial LCA results of micro-algae rejuvenated asphalt	🎓 1 🏅 3 📄 2 💡 1

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners TNO main departments involved: ⟩ Buildings Materials & Structures (MBE) ⟩ Circularity & Sustainability Impact (EMT) ⟩ Biobased and Circular Technologies (EMT) Wageningen University ⟩ Algae Parc 2.0 ⟩ prof. dr. ir. René Wijffels & prof. dr. Maria Barbosa **Stakeholder involvement** ⟩ Rijkswaterstaat ⟩ STOWA (Dutch Foundation for Applied Water Research) **Dissemination** ⟩ Publication with prospective LCA results and analyses on current material flows and environmental footprint of the total Dutch pavement market ⟩ Publication on integrating the systems and resource perspective in LCA, using micro-algae rejuvenated asphalt as a case study ⟩ Initiation of patent application for lipid extraction process from micro-algae	**Valorisation actions 2024** ⟩ Involve relevant Business Developer capacity from MBE and EMT units for evaluating additional knowledge investment and partnerships ⟩ Involve TNO Strategic Business Analysis for evaluation of the (new) value chain ⟩ Key stakeholder management to align value chain with market requirements ⟩ Alignment with PMC strategy and VP activities **Valorisation goals 2024** ⟩ Specific IP agreements with WUR in place ⟩ Finalize running patent application ⟩ Transfer via new assignments (consultancy)

16 ERP Atmospheric models for optical solutions

ERP Contacts: Lex van Eijk (Lead Scientist)
Heather Young (Project Lead)
Adelbert Bronkhorst – DSS, Christa Hooijer – HTI, André Faaij - EMT (Science Directors)

ERP Duration: 2024 – 2027

ERP Description

This ERP Atmospheric Models for Optical Solutions (ATMOS) creates a leading position for TNO in mastering the impact of the Atmospheric State on the technologies Adaptive Optics, Optical Communication Terminals and Earth Observation. This will strengthen our market position for Laser Satellite Communication, High-Energy Lasers and Monitoring Atmospheric Pollutants and result in effective communication, successful military operations and accurate monitoring of climate and pollution.

Summary Plan 2024

In 2024 the ERP ATMOS will kick off with a detailed investigation of (1) important atmospheric state parameters such as turbulence, aerosols and weather, and (2) how improved models of these parameters will benefit technology development in (a) laser satellite communication and high energy lasers through improved adaptive optics, and (b) the detection of trace gases using earth observation satellites for the monitoring of climate and pollution.
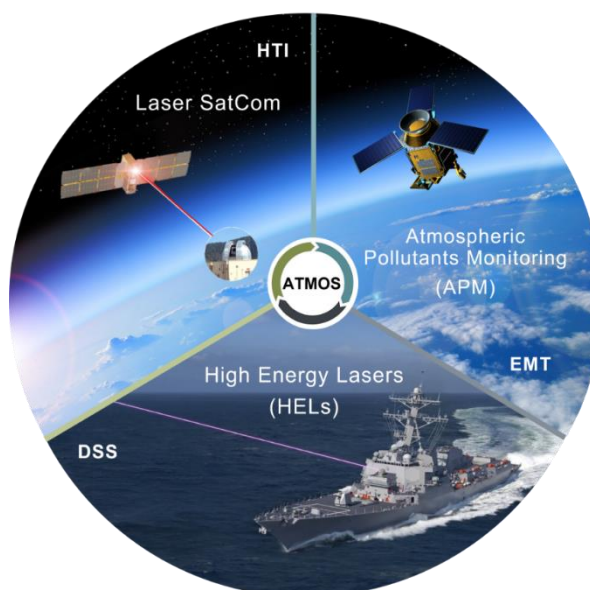
Plan 2024 – ERP Atmospheric models for optical solutions

⚛ Targeted key results	Plan 2024

1. New and improved characterizations of the atmospheric state (AS), specifically:
⟩ optical turbulence models
⟩ aerosol concentration models
⟩ weather prediction models (numerical weather prediction and ML/AI techniques)

2. Investigate the implementation of the improved models during the design of systems for each application area:
⟩ Laser Satellite Communication (implementation of AS models and systems design specifications)
⟩ High Energy Lasers (implementation of AS models and systems design specifications)
⟩ Monitoring Atmospheric Pollutants (Aerosol modelling schemes using new satellite data and optimization of atmospheric pollutants monitoring algorithms)

🎓 3
🎖 2
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🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
⟩ TNO internal: DSS, HTI, and EMT
⟩ External partners: Wageningen University, Leiden University, TU Delft, VU Amsterdam, University of Graz (AU), Durham University (UK), Universidad de Alcala (SP), Universidad de los Andes (CL), Ecole Centrale de Nantes (FR), 3MI consortium

Stakeholder involvement
⟩ Government: Ministries of Defence, EZK & VWS, KNMI, NWO, European Centre for Medium Range Weather Forecasts
⟩ Companies: Industrial users: FSO Instruments, Airbus; Large System Integrators: ADS-NL, Aircision; Communication Service Providers: SES, Eutelsat; R & D: Fraunhofer IOSB, KNMI, SRON, ESA; NOVA; NSO

Dissemination
⟩ Key (Scientific) publications, conferences, presentations: 3 academic publications and 1 popular science article planned
⟩ Patent filings: none yet in 2024
⟩ Awards: none yet

Valorisation actions 2024
⟩ Participation in "ERP Orchestrating Innovation"
⟩ Involvement of Business Developers from 3 units
⟩ Adoption of the ERP goals by Valorisation Partners
⟩ Pursue adjacent external funding with knowledge partners (NWO, NGF, …)

Valorisation goals 2024
⟩ Detailed plan for the valorisation landscape from the perspective of Business Developers and valorisation partners
⟩ Increase the ERP footprint through external funding and in-kind contributions from academic partners

17 ERP Empowering citizen collectives

ERP Contacts:	Pepijn Van Empelen, Wessel Kraaij, Geiske Bouma (Lead Scientists)
	Renate van Zoonen (Project Lead)
	Paulien Bongers – HLW, Anne Fleur van Veenstra – ISP, André Faaij - EMT (Science Directors)
ERP Duration:	2024 – 2027

ERP Description

This ERP will develop an evidence-based method to accelerate and scale societal transitions in neighbourhoods. This will be achieved by improving the agency of citizen collectives at neighbourhood level and engaging them in participatory policy making. This will lead to improved trust, social cohesion and support for governmental decisions, essential for every transition.

Summary Plan 2024

In 2024 we will build and evaluate 1) methodology for community development, 2) develop a prototype of the dialogue dashboard for citizen and stakeholder collaboration, 3) develop a monitoring and learning framework and method. In RL4, we will co-develop interventions for the health domain (Rotterdam, VCC) and heat/energy transition (Zutphen, Zutphen Energie, citizen collective Noordveen), in consultation with our broader network of partners, resulting in a domain model/ theory of change (ToC) that we review and update each 6 months.

Plan 2024 – ERP Empowering citizen collectives

⚛ Targeted key results	Plan 2024

RL1: Methodologies for sustainable citizen collective development and engagement
- Community engagement planning framework
- Engagement strategies

RL2: Novel participatory governance model for citizens and (local government and business) stakeholder collaboration
- Governance strategies
- Dialogue dashboard demonstrator V1

RL3: Tooling and methodology for collective learning of best practices
- Requirements for a learning and impact monitoring data infrastructure/method
- Impact measures, data sources, and data collection strategies
- Understandable data visualization and data analysis for collectives
- Prototype platform for monitoring and learning v1

RL4: Systems evaluation and learning Framework
- Systems map of heat and health transitions, theory of change
- Prioritized roadmap for empowering collectives
- Set of indicators for impact measurements, intervention selection for 2025 (health, energy consumption)
- Overall evaluation plan of living lab experiments

🎓 4
📖 3
📄 3
💡 0

🤝 Partnership & Dissemination	📊 Valorisation

Knowledge partners
- HLW , ISP & EMT
- Erasmus University Rotterdam (VCC), University of Leiden, Waag society

Stakeholder involvement
- VNG, CBS, BZK, AWPG-NZH, Health~Holland (LSH), municipalities Den Haag, Zutphen, Teylingen, Eindhoven, Unive, Amsterdam Economic Board, Impactpunt, Viteylingen, Iedereen aan boord, Buurkracht, EnergieSamen, ZutphenEnergie, GROZzerdammen, Best Duurzaam

Dissemination
- 3 scientific peer reviewed publications

Valorisation actions 2024
- Business Development involvement, adoption by Work & Youth Health (HLW), Digital Innovations (ISP/ICT), Transitions and transformations (ISP/TNO Vector, System Transition (EMT)
- Adjacent external knowledge investments: NWA, ZonMw, NWO-TTW

Valorisation goals 2024
- Further development through joint collaboration in Research project with Erasmus University Rotterdam / Vital Cities and Citizens – Collective, cocreative development of data needs, - sources and – strategies for collecting health and wellbeing data; use case Afrikaanderwijk Roterdam

18 ERP Polymer design by machine learning

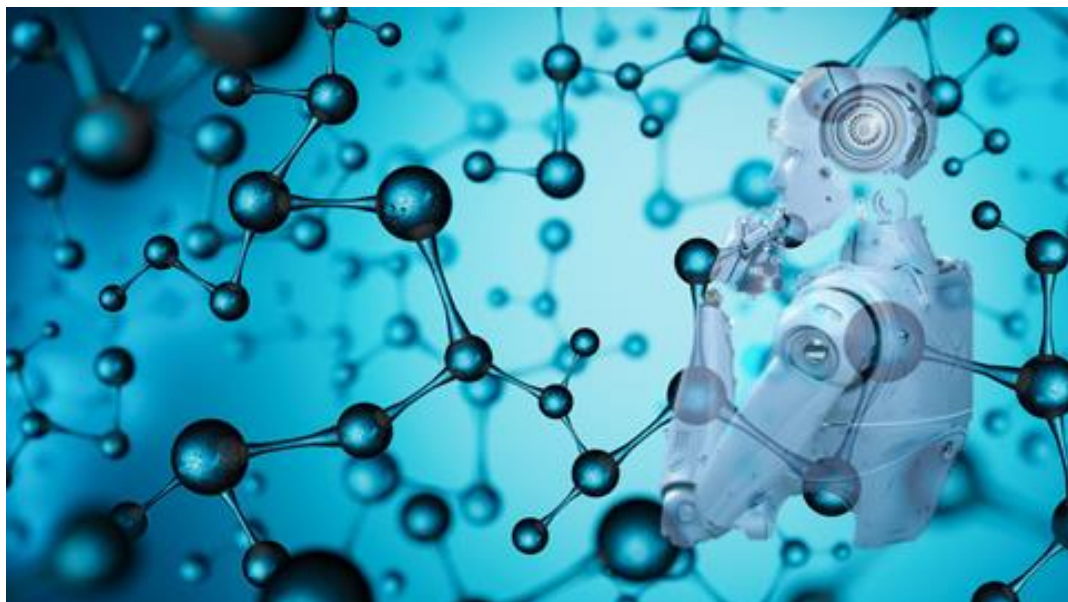|	
ERP Contacts:	Jan Harm Urbanus (Lead Scientist)
	Judith Kessens (Project Lead)
	André Faaij – EMT, Christa Hooijer – HTI, Omar Niamut - ISP (Science Directors)
ERP Duration:	2024 – 2027

ERP Description

To develop and validate a Polymer Informatics engine that realistically captures the complexity of polymers to design novel candidates that match with requirements for safe & circular plastics.

Summary Plan 2024

In 2024 the ERP will focus on 1) data generation through high-throughput experimental screening & data mining and 2) development of novel fingerprinting methods to capture the complexity of polymers as the basis for the design of novel polymers. The work will be focused on the first use case (pure polymer - textile). For this use case, industrially relevant specifications will be determined and several biodegradable polymers will be tested.

Plan 2024 – ERP Polymer design by machine learning

⚛ Targeted key results	Plan 2024
Research Line 1: Search & create data 〉 Protocol for data mining and automated literature search 〉 Development and demonstration of high-throughput experimental screening tool 〉 30+ polymer samples added to library 〉 Comprehensive database of polymer structures and properties **Research Line 2: Develop hybrid SPF's** 〉 >2 Polymer fingerprinting techniques evaluated and implemented 〉 Suitability of machine learning algorithms assessed for structure-property relation modelling **Research Line 3: Polymer design** 〉 Literature survey on predictive methods for novel polymer structures **Research Line 4: Test viability** 〉 No activities planned in 2024 **Research Line 5: Proof-of-validation** 〉 (specifications for) First use case defined (textile fibre)	🎓 1 🏅 2 📄 2 💡 0

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners 〉 TNO internal: Circularity & Sustainability Impact (EMT: CSI), Heat Transfer & Fluid Dynamics (EMT: HTFD), Work Health Technology (HLW: WHT), Material Solutions (HTI: MaS), Data Science (ISP: DS) 〉 TNO ERPs: Recycling of Solar Panels and Batteries, Synthetic Biochemistry, Asphalt Rejuvenation using micro-algae 〉 Universities: UL/TNO-ISP (prof S. Raaijmakers), UU (prof P. Bruijnincx), TU/e (prof Z. Tomovic), RUG (prof K. Loos), GioT (prof R. Ramprasad) **Stakeholder involvement** 〉 SME: e.g. Senbis, Paques Biomaterials, Arapaha, Avantium, Rodenburg Biopolymers, Helian Polymers 〉 Corporates: e.g. Sabic, BASF, Corbion 〉 Others: e.g. WEF-LCET community, Normec-OWS and WUR **Dissemination** 〉 2 scientific publications are planned for the first year of the ERP 〉 2 visits to conferences/workshops are planned for 2024	**Valorisation actions 2024** 〉 Adoption by TNO's innovation areas Sustainable Chemical Industry, Environment & Sustainability (both EMT-Industry) 〉 Involvement of Business Developement-capacity for expanding our network into bio-polymer companies and consortia building 〉 Continuation of BIOTTEK project (granted in 2023 – together with Senbis) 〉 Kick-off of CBE-funded project on bio-polymer development with AI (if proposal granted) 〉 Develop NWO-proposal(s) with pre-consortium with universities (UU, TU/e, TUD) **Valorisation goals 2024** 〉 Explore IPR-strategies of trade-secrets (on data) and patents (on new polymers/formulations)

19 ERP Sustainable ICT

ERP Contacts:	Hans Stokking, Ton Bastein, Mark Huijbregts (Lead Scientist)
	Joris van Diemen (Project Lead)
	Omar Niamut – ISP, André Faaij – EMT, Anne Fleur van Veenstra - ISP (Science Directors)
ERP Duration:	2024 – 2027

ERP Description

The ERP Sustainable ICT will develop actions and methods to enable 1) policy makers to get a grip on GHG emissions in the ICT sector and 2) ICT companies to react to such policies, based on providing clear insight in all emissions and in impacts of policies on market forces and demand drivers.

Summary Plan 2024

In 2024, TNO will develop an first initial, but comprehensive understanding of all GHG emissions in the ICT sector and first insights into the main influencing factors. Based on a broad set of disciplines, TNO will also start drafting an approach to reduce these emissions, together with stakeholders from the sector.

Plan 2024 – ERP Sustainable ICT

⚛ Targeted key results	Plan 2024
〉 Measurement technology for measuring scope 2 emissions in the end-to-end ICT service delivery chains. Goal for 2024 is to define an architecture and first protocol design, linked to a proof-of-concept demonstrator.	
〉 Model setup of scope 3 emissions of a digital ecosystem, including the complete LCA life-cycle analysis of hardware involved, for a given ICT service. Goal for 2024 is to have a clear analysis of the different model approaches for this, including modelling for changes over time, and have a high-level first version of the chosen model.	🎓 1
〉 Identifying user behaviours around ICT consumption and categorisze these to work towards determinants for explaining this behaviour. This includes a broad survey amongst consumers. Goal for 2024 is to have a comprehensive view of the behaviours and a first set of determinants.	🎖 1
〉 Analysing current sustainable business models and current policy effects, including a broad set of industry/stakeholder interviews. Goal for 2024 is to create a high-level map of the eco-system forces that explain corporate behaviours around sustainability in the ICT sector.	📄 4
〉 Do a first iteration of a Systems Innovation process with a select number of stakeholders, leading to first action perspectives (directions) for governments and ICT providers.	💡 1

🤝 Partnership & Dissemination	📊 Valorisation
Knowledge partners 〉 TNO internal: Unit ISP: Networks, ACE, SBA, S&P; Unit EMT: ETS, CAS; Unit Strategy: Systems Innovation. 〉 Radboud University Nijmegen 〉 Lancaster University 〉 VU Amsterdam. **Stakeholder involvement** 〉 Ministry of Economic Affairs & Climate 〉 BEREC 〉 Consumentenbond 〉 3 industry stakeholders from the group of network operators (e.g. KPN), cloud providers (e.g. LeafCloud) and corporate ICT users (e.g. ABN AMRO). **Dissemination** Publications on key findings from the research lines: 〉 on scope 2 emissions/measurements, 〉 on integrated scope 3 modelling approach, 〉 on user behaviour in ICT use and 〉 on ICT sector forces. Targets to be determined. 〉 1 patent filing on our measurement approach.	**Valorisation actions 2024** 〉 Set up pre-PMC (Product-Market Combinations) culster on Sustainable ICT within the cluster Fast & Open Infrastructures of the Unit ISP. 〉 Involve a few (≈ 4) external stakeholders in the first iteration of the Systems Innovation process. 〉 Join and contribute to standardisation and industry fora work packages on this topic in the NCDD, Greening of Streaming, 3GPP, NGMN, IETF, etc. Sub-action is to identify the most relevant set of organisations for us, choose the right focus. 〉 Contribute to a new project proposal in HORIZON-JU-SNS-2024-STREAM-B-01-07: Sustainability Lighthouse. **Valorisation goals 2024** 〉 Start Public-Private-Cooperation (PPS) discussion with industry stakeholders for a broad PPS on this topic starting in 2025/2026, leading to a first exploration project (e.g. TKI, small sponsorship project) for early 2025.

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