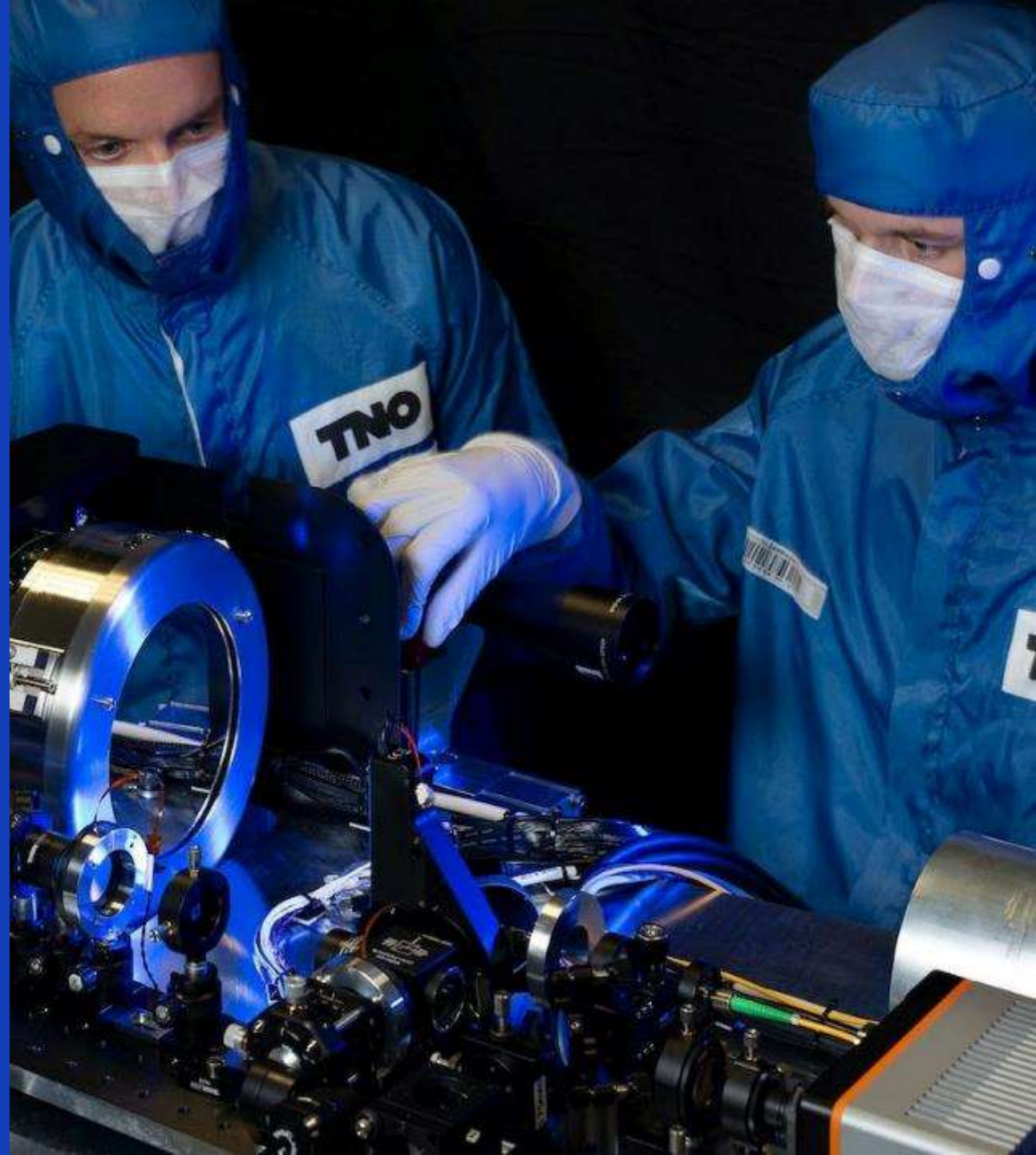
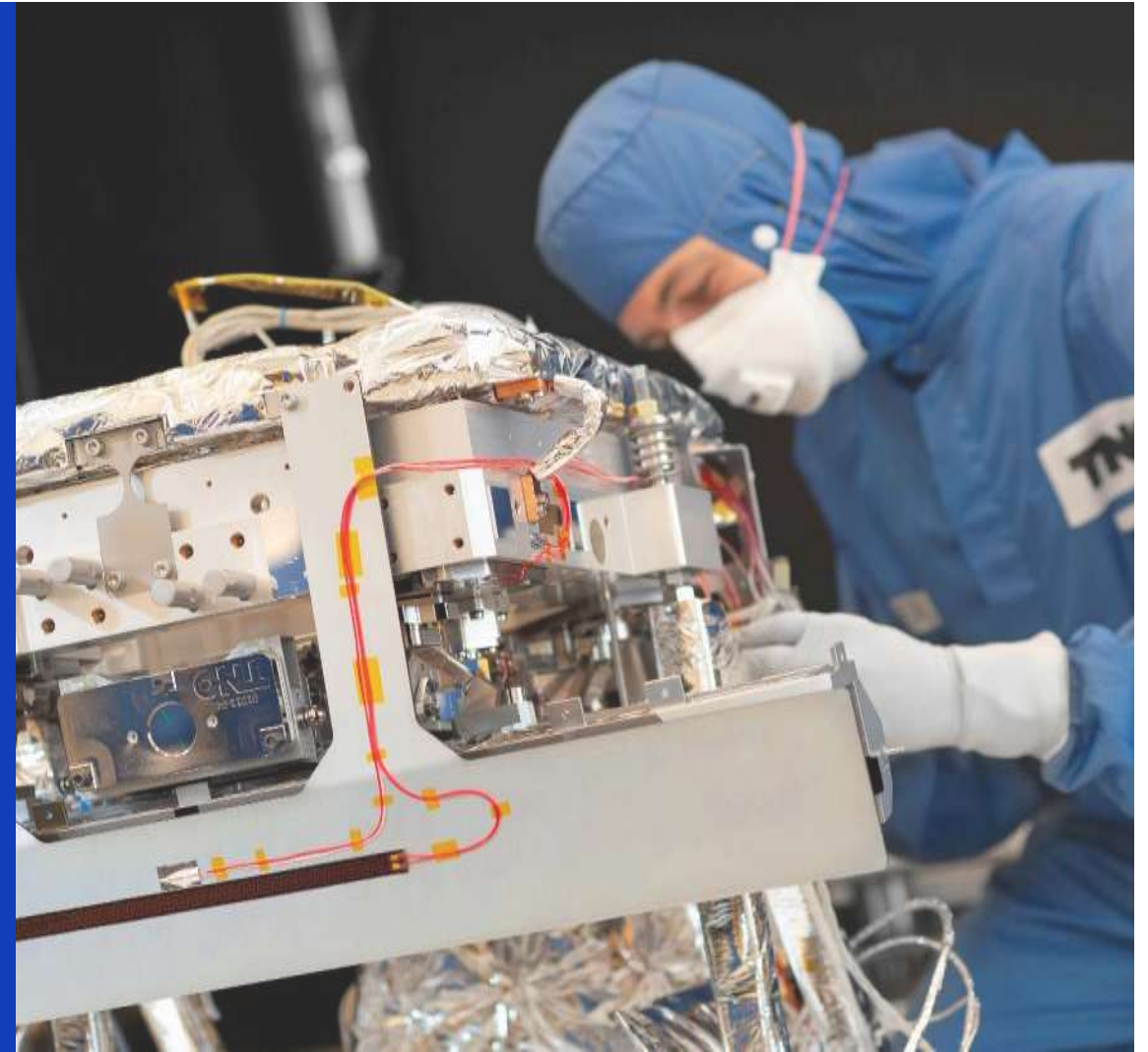


TNO Innovation for life



We are TNO

- › Founded by law in 1932 and regulated by public law.
- › Netherlands largest independent institute for Applied Scientific Research: not part of any government, university or company.
- › We innovate, investigate, and orchestrate, collaborating closely with governments, universities and the private sector.
- › We inform government on policies and empower evidence-based decision-making through rigorous investigations, cutting-edge scientific insights, and reliable measurements.

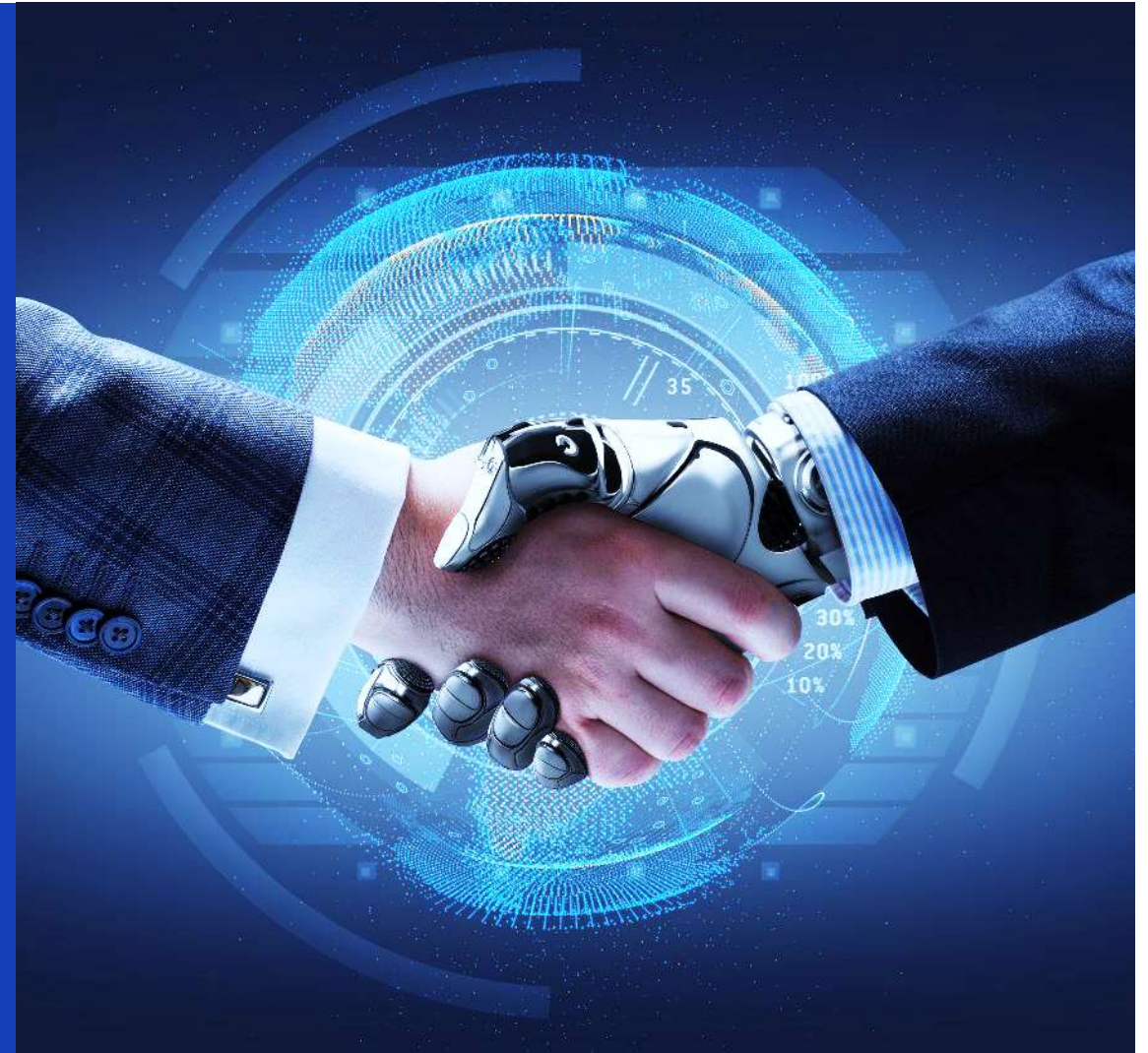


Our Mission

Creating impactful innovations for the sustainable wellbeing and prosperity of society.

Our Vision

Innovation is crucial in realising a secure, sustainable, healthy and digital society with TNO as leading innovator.



TNO: flywheel for innovation

Academia

Education
Publication



TNO innovation
for life

Making innovations market ready
TRL 4 > 7



Industry

Sales
Profits



Developing
Fundamental knowledge



Developing
knowledge



Applying
knowledge



Knowledge
Exploitation

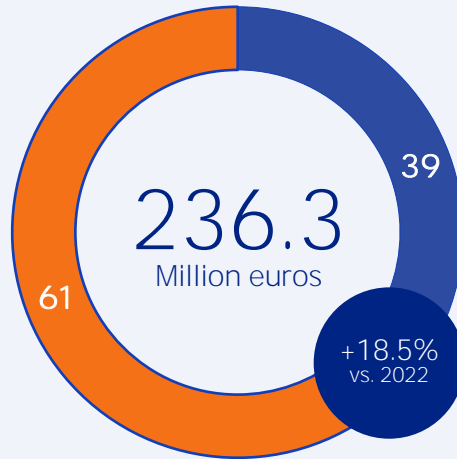
Financial Indicators 2023

TNO organisation revenue
(incl. state funding)



■ State funding

Revenue from national
clients



■ Business
■ Government

Revenue from international
clients



■ Other ■ International organisations

State funding and contracts
from business and
government



TNO Battery Proposition

Towards a Circular Battery Economy



TNO Battery Research Highlights

- Strong activity across multiple aspects of battery development
- National, European, and International interactions with the value-chain
- Multi-application; mobility, maritime, and stationary – spread across several units
- From material research, to application and beyond
- Core founding member of National Battery Competence Center
- Member of BEPA – Batteries Europe

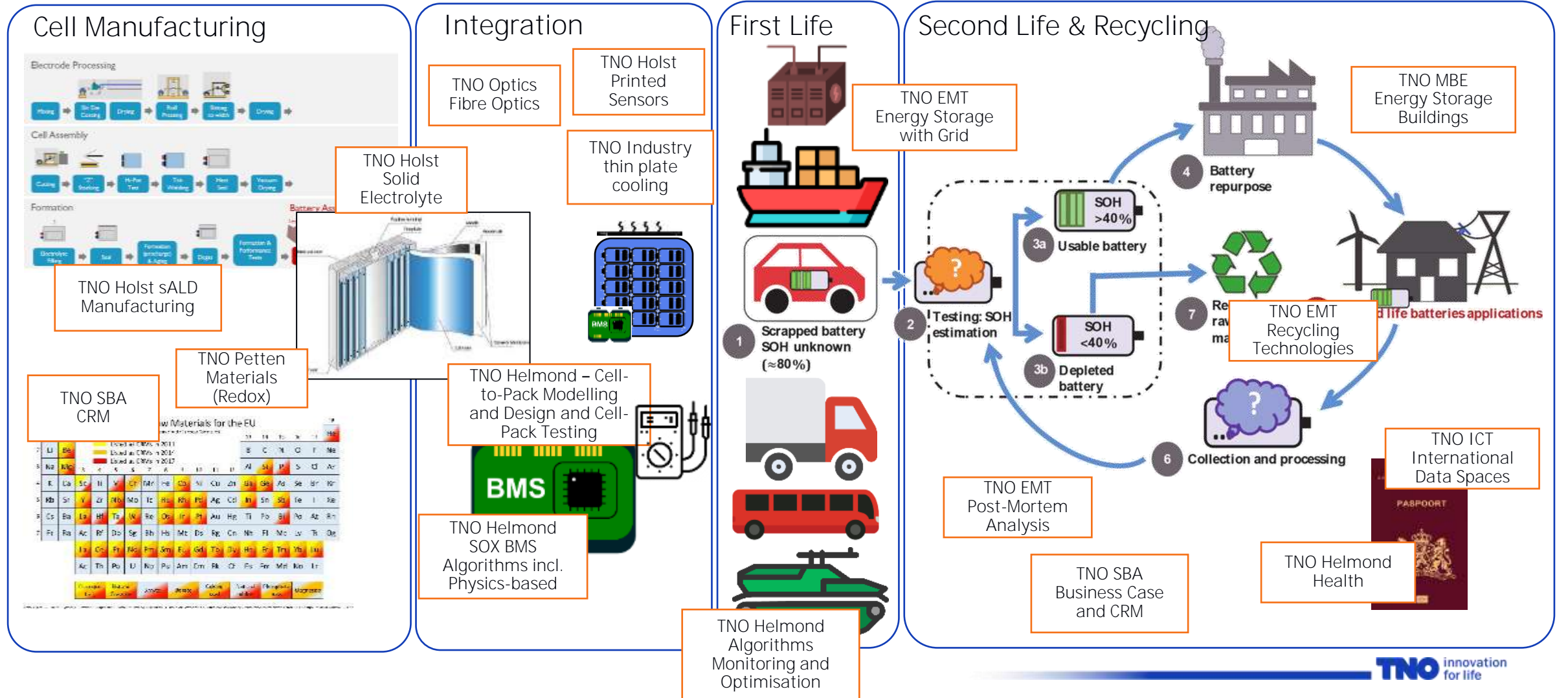


TNO Battery Research

Innovation, INVENTION, integration ...

Reduce, re-purpose, Reuse, repair, recycling

TNO views that batteries will be everywhere, from automotive (BEV, HEV, FCEV) to stationary



Battery Technology Innovation Highlights – Page 1



Integrated Printed Sensors

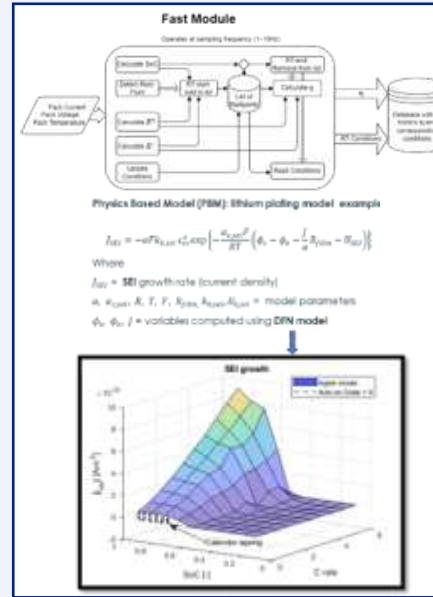
Combined with smart algorithms for safety and optimisation – printed electronics for diagnostics and performance - collaboration TNO Holst and Helmond



Module Prototyping

Prototyping of new technologies – shown novel pouch cells integrated into module with own BMS software; TNO supports customers with technical challenges or exploring new concepts

We use these to validate our model-based development



Physics-Based Models

TNO is active in leading EU projects developing usable physics-based models. Such models can be used for functions such as charge control [www.nextbms.eu]

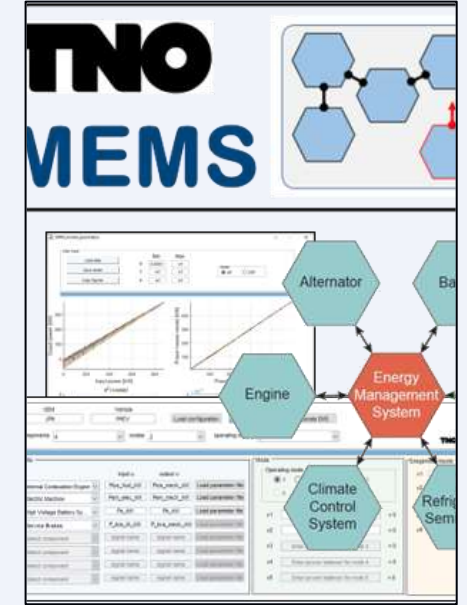
Our models are computationally fast enough for BMS, and support data-driven adaption



Novel Cooling Concepts

Patented integrated multi-phase cooling for high performance battery packs

TNO also models other cooling techniques



Charge and Thermal Management

TNO's unique Modular Energy Management (MEM) approach allows for control generation for multiple systems – already used by several international OEMs outside of Europe

Battery Technology Innovation Highlights – Page 2



Real-World Learning

TNO works with road-based, offroad, and maritime and defence applications to understand the real world performance – such approaches allow for Battery Digital Twinning with ICT innovation

This work includes second life applications, and V2X tests



Module and Pack Testing

Scalable testing facilities – from cell to module, and module to pack/vehicle – functional testing and model identification to 300kW

Includes Hardware-in-the-Loop battery testing for OEMs/Tiers

TNO leads EU projects on electric truck co-design



BMS Algorithms

Algorithm development for SOC, SOH, SOF, SOE, State of Safety, RUL, charging time estimation using ECM and physics-based methods – in combination with active diagnostics (diagnostic charging & chip-EIS)

We work with both rapid prototype and propriety platforms



Cell Testing

Cell characterisation for performance and ageing models – large automated testing array for cell model identification and model generation/validation

Used in combination with modelling and HiL

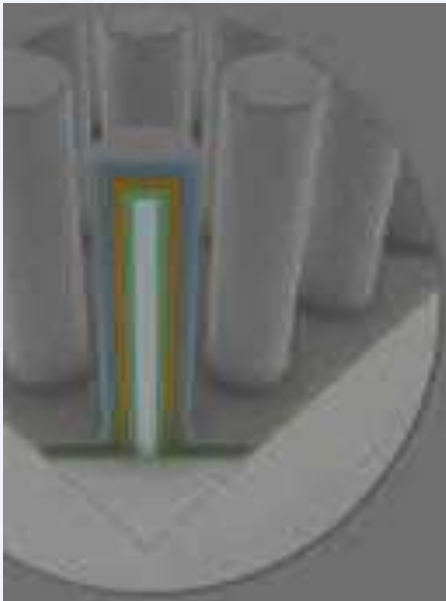
Vibration and safety testing



Battery Passport

Development of solutions towards battery passport – utilising international data-spaces with BMS and cloud-based data management and algorithms. TNO is also actively involved in standards and EU activities

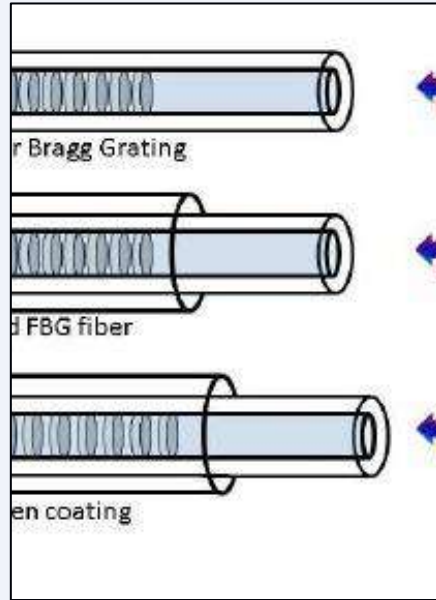
Battery Technology Innovation Highlights – Page 3



Solid-State Technologies

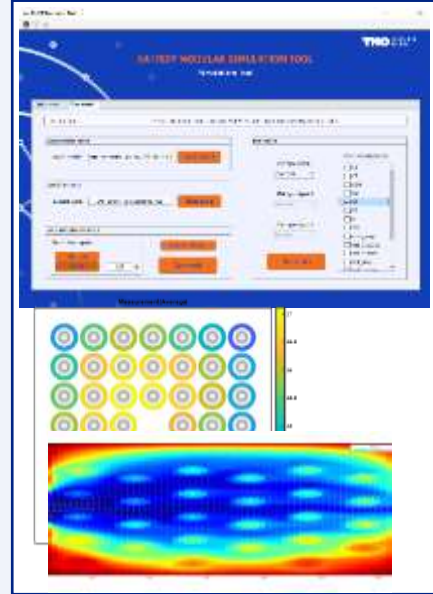
TNO has created manufacturing technologies (sALD) capable of forming new structures and thin layers within battery systems; one battery company LionVolt has already been spun out.

TNO continues to work on solid electrolytes.



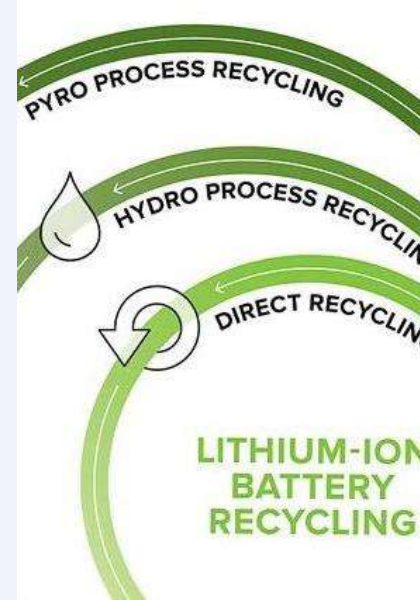
Fiber Optical Sensing

TNO has a position in the sensing of physical parameters from in-situ placement of fibre optics. Without disrupting operation these can take measurements.



Modular Design Tools

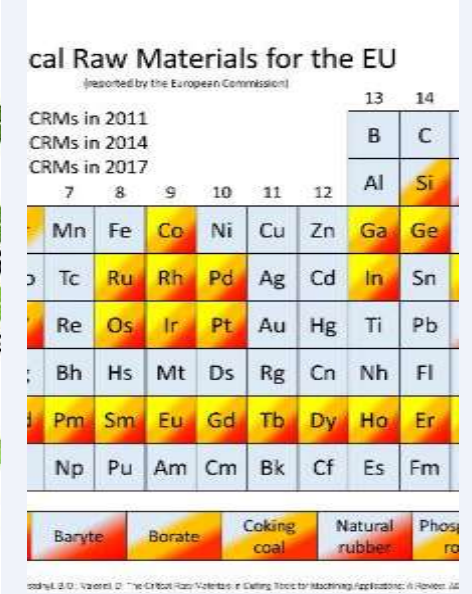
TNO has a workflow and set of design tools for exploring module and pack design. This is called the Battery Modular Simulation Tool – compatible with other platforms – including safety assessment



Battery Recycling

TNO has developed methods for the assessment of battery recycling as well as uniquely developed methodologies

TNO also explores new lightweight sustainable materials



Battery CRM and Policy

TNO is active in support of government and policy towards sustainable material use within Europe and the Netherlands

TNO provides an independent voice of assessment

Battery Competence Center

Overview of BCC-NL and NGF3 Project



Battery Competence Center

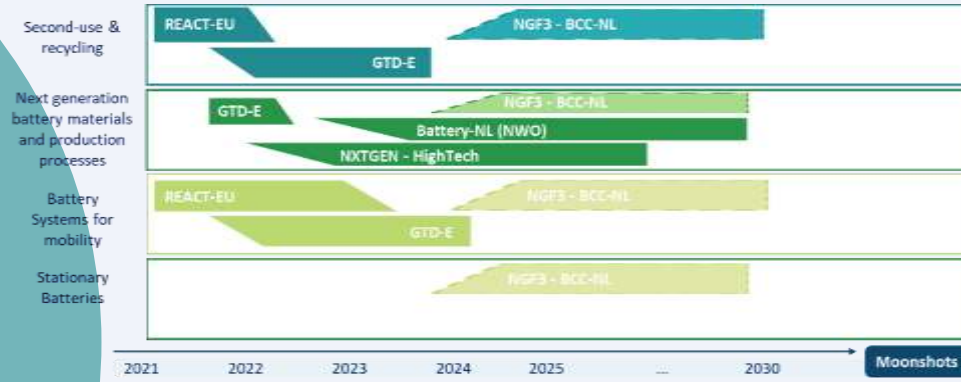
Building value for stakeholders

Our history in forming a Public-Private Partnership:

- › Since 2012, TNO has built a strong position in international battery research, through both a wide range of internal, national and European projects. Through these we have built our position and reputation in the area of batteries
- › With a focus on building both the knowledge, tools, and facilities, we are now in prime position has the strongest group in the Netherlands to support companies cross-domain
- › TNO is at the heart of the Battery Competence Center, with founding partners DAF, VDL, and DAMEN
- › Several projects are now funded out of the BCC umbrella, most notable from REACT.EU, Herstelfonds GTD-E, and the National Growth Funds project on battery circularity.
- › The longer-term ambitions are to broaden to a National competence center, and ultimately build R&D centers and NL battery factories through IPCEI2 funding
- › [Battery Competence Center](#)



The Battery Competence Cluster - NL is the cluster organization that formulates and implements the Dutch battery strategy and innovation programs to develop and grow the Dutch battery value chain. The public-private partnership enables companies, knowledge institutes and (public) organizations to develop the necessary knowledge and competences in the field of battery technology, bringing the Dutch battery, high-tech, chemical, mobility and energy industry together.



The goal of the cluster is to facilitate the growth of the Dutch battery value chain through:

- Ecosystem development, community building and knowledge sharing
- Developing long-term roadmaps and collaboration projects
- Positioning the Dutch battery value chain for more visibility

Facilitators

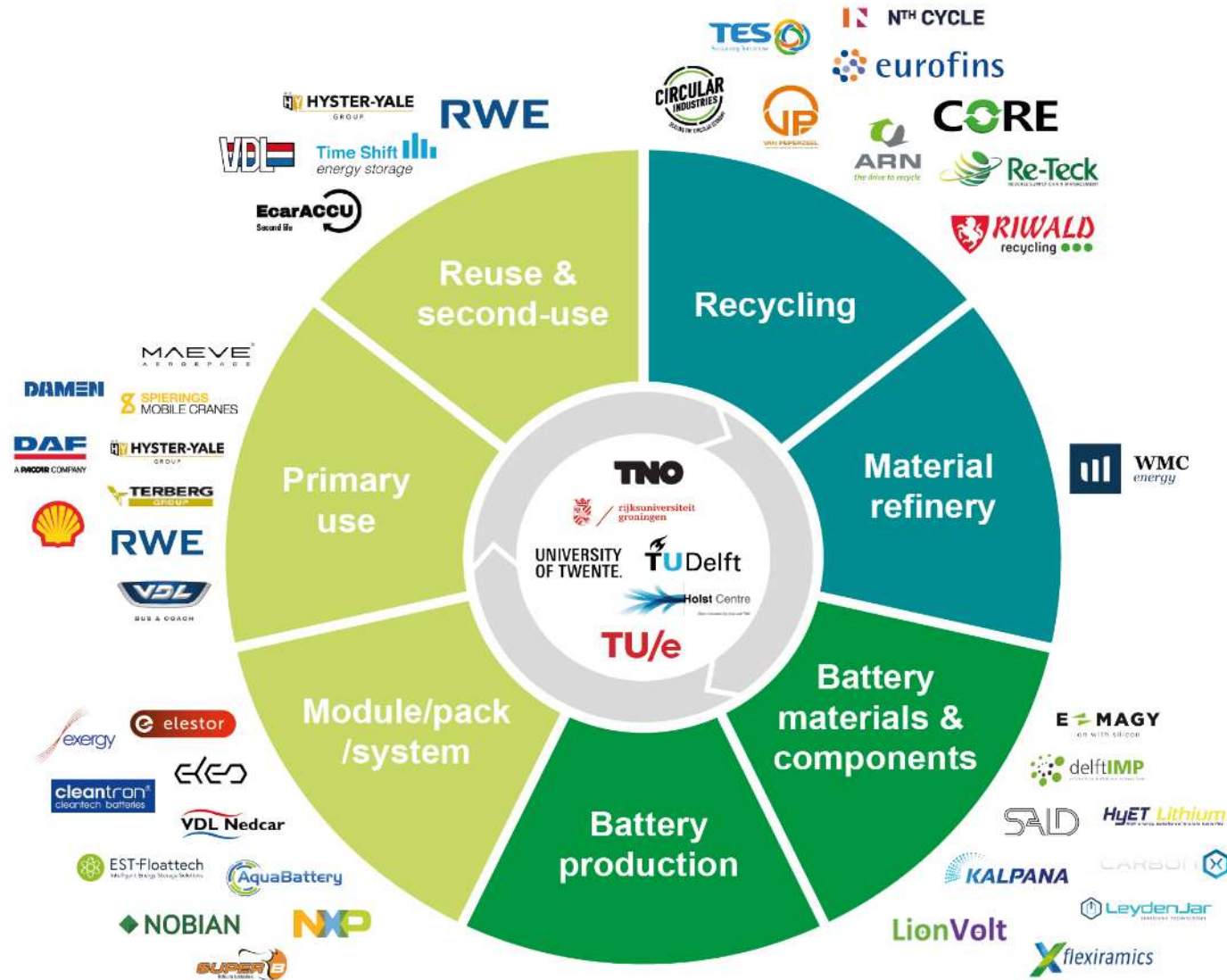


Ecosystem



and many more

Battery chain of the Netherlands

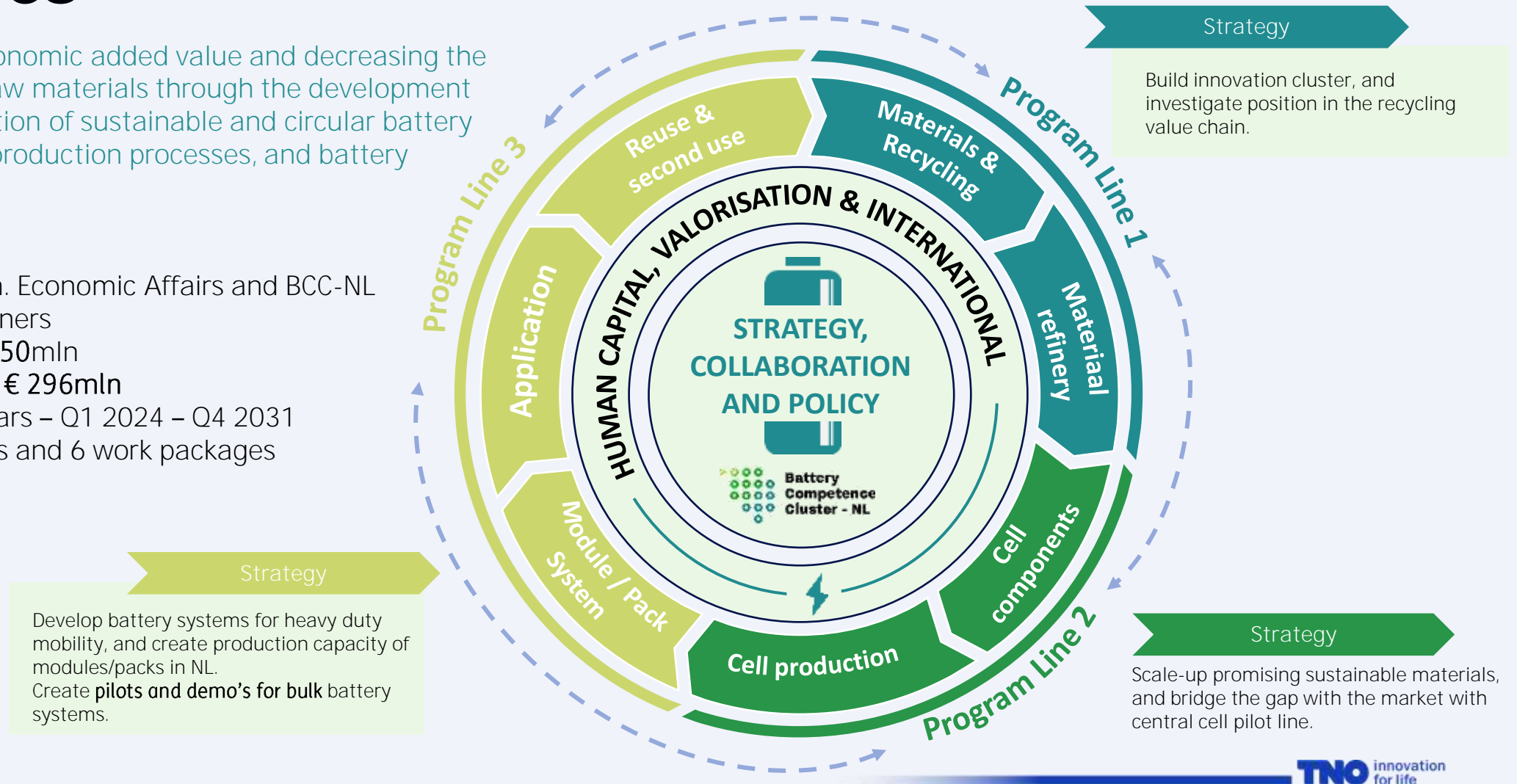


Growth Fund: Material Independence & Circular Batteries

Realisation of economic added value and decreasing the dependency of raw materials through the development and industrialization of sustainable and circular battery technology and production processes, and battery recycling.

Summarizing:

- › Applicants: Min. Economic Affairs and BCC-NL
- › 65 project partners
- › Total costs: € 750mln
- › Asked subsidy: € 296mln
- › Duration : 8 years – Q1 2024 – Q4 2031
- › 3 program lines and 6 work packages



A Dutch Perspective

- › The Netherlands forms a strong logistic hub for Europe - largest international sea port, and several main corridors within Europe
- › TNO has helped create the national battery agenda – and ongoing work on the blueprints for NL
- › Strong government – commercial interactions over upscaling
- › How to bring next-generation batteries to the market?
- › Where should we build factories and invest?



MKB Support Examples

Supporting NL Battery Startups – Case Studies



TNO support of NL battery MKB

USE CASE 1: ELEO (formerly SPIKE)

Our history together:

- › Very early support and consultation at company founding from 3 students from STORM challenge which we sponsored (in-kind and in-cash)
- › TNO supported company via the NWO Takeoff grant, transferring knowledge, testing, and algorithms via a feasibility support for their company
- › TNO continued supporting the second phase of Takeoff
- › Within DKTI, TNO actively involvement to build prototype systems and mature technology
- › TNO engaged with them via the Herstelfonds GTD-E helping significant growth
- › As of Q1 2022, ELEO have 22 open vacancies targeting ~50 FTE, existing customers and are expanding rapidly
- › ELEO is a member of the Battery Competence Center, alongside DAF, VDL, Damen
- › ELEO support customers directly in realising zero emission vehicles
- › ELEO were majority acquired by Yanmar in 2022

'TNO supported our battery startup from early phase onwards, by supporting on technological basis and by involving us in projects of increasing sizes. Without the collaboration, it would have been more difficult to get funded in early stage and to get into technologically relevant projects'



TNO support of electric bus MKB

USE CASE 2: EBUSCO

Our history together:

- › In 2012, very first testing using new UITP SORT on-road test method for energy consumption, publicly reported^[1]; at the time the company was 3-4 FTE
- › At the time, the NL production was dominated by VDL, but TNO worked transparently/independently
- › In 2014, COFI-based project on battery health, state, and ageing called **‘PULSE’**
 - › We helped with field issues from data from actual bus deployment for batteries
 - › We supported with algorithms and testing helping set the basis for supplier requirements and in-house development
- › We established a framework for testing/consultancy
- › From 2018 onwards, Ebusco rapidly grew following successful concession tenders (NL and abroad)
- › In 2021, Ebusco successfully went through an IPO, with a market capitalisation of 1.33B euros, directly raising 300M euros^[2]

‘TNO helped us in the early days with SORT testing of our electric buses, a collaboration project on battery technology, and shared involvement in both National and European proposals together.’

EBUSCO[®]

Peter Bijvelds
Founder and CEO



Battery Passport

Overview



Enabling Circularity - Battery Passport

Battery Passport Scope

- › Every industrial or electric vehicle (EV) battery on the EU market with a capacity of over 2 kWh
- › Responsibility of the party placing the battery on the market

- › This will require coordination between:
 - Cell producers
 - Module producers
 - Battery producers
 - Automotive OEMs
 - Battery service, refurbishing, and repurposing companies

Information

- › Identification of the battery in the form of a unique identifier.
- › Basic characteristics - battery type and model which will also be stored in the EU electronic exchange system.
- › Statistics on performance and durability must also be updated over the battery lifecycle by parties conducting repair or repurposing of the battery.

To gain access to the battery passport, the physical battery must have a QR code printed or engraved on it to act as a unique product identifier (per the 2022 amendment).

Battery Passport Timeline

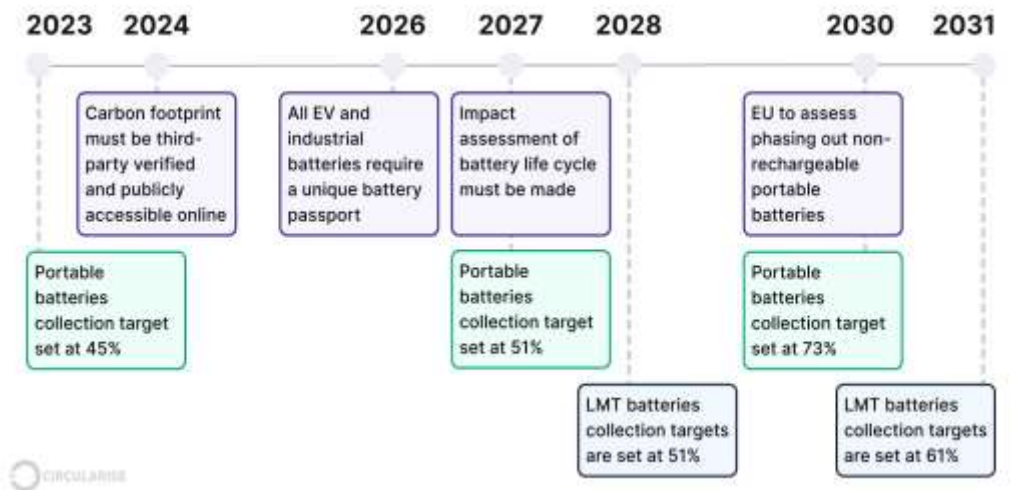
- › European Commission proposed new Battery Regulation on December 10, 2020*. Intended to replace Battery Directive 2006/66/EC and amend Regulation 2019/1020. Provisional agreement December 2022**. Agreed 2023.
- › Goal: Ensure safety and sustainability of batteries in the EU market throughout their lifecycle.
 - › From July 1, 2024: Carbon footprint specific to manufacturing site and batch of batteries must be third-party verified and publicly accessible online.
 - › By January 1, 2026: All EV and industrial batteries in the EU market require a unique battery passport.
 - › 1st July 2027 - impact assessment of battery life cycle to ensure it meets the carbon footprint threshold***
- › Battery information accessed via QR code: includes carbon impact, electrochemical performance, and durability classification.

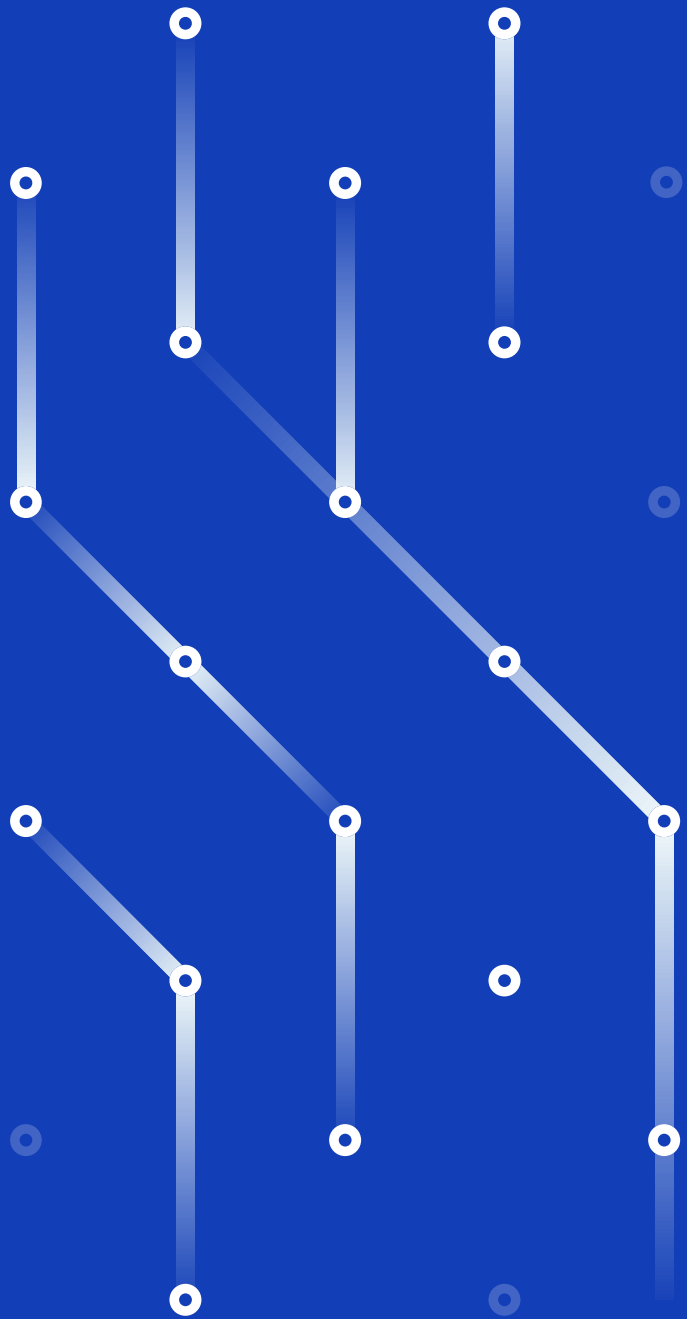
*[https://www.europarl.europa.eu/RegData/docs_autres_institutions/commission_europeenne/com/2020/0798/COM_COM\(2020\)0798_EN.pdf](https://www.europarl.europa.eu/RegData/docs_autres_institutions/commission_europeenne/com/2020/0798/COM_COM(2020)0798_EN.pdf)

**<https://www.europarl.europa.eu/news/en/press-room/20221205IPR60614/batteries-deal-on-new-eu-rules-for-design-production-and-waste-treatment>

***plus technical documentation detailing the percentages of CRMs which came from recovered sources.

Timeline Overview





TNO innovation
for life