Holst Centre

Vision Paper

Smart Wound Care

Welcome to the New Age of Wound Care



by

TNO

Abstract

Welcome to the New Age of Wound Care

Chronic wounds represent a growing “silent pandemic,” accounting for 2–4% of healthcare expenditure in Europe and exceeding 5% in advanced systems. This burden is driven by infection, delayed healing, rising antimicrobial resistance, and the increasing prevalence of chronic conditions such as diabetes and obesity. At the same time, healthcare systems face structural challenges, including staff shortages, aging populations, and rising costs. Much of wound care is delivered in community settings, placing significant strain on nursing capacity. Current care models remain largely reactive, resulting in inefficiencies, repeated interventions, and escalating costs.

Futureproofing Healthcare with SWC

Smart Wound Care (SWC) offers a shift toward preventive, personalized, and data-driven care. By integrating sensing, low-power electronics, data platforms, and algorithmic interpretation into wound dressings and wearable solutions, SWC enables earlier detection of complications, optimized treatment timing, and reduced unnecessary interventions. It supports the transition of care from hospitals to home and community settings, improving quality of care, reducing workload, enhancing patient empowerment, and delivering meaningful health-economic value.

Basic Applications Are Within Reach

The technological foundations for first-generation SWC applications are already available. Core components such as flexible printed electronics, for inertia, temperature, moisture and optical monitoring are already deployed in wearables. Also wireless connectivity are sufficiently mature to support early devices, particularly for lower-complexity use cases such as closed wounds.

Key Challenges Remain

Despite this progress, significant challenges remain. Seamless system integration in complex biological environments, multimodal sensing compatibility, and reliable data interpretation are ongoing hurdles. No single sensor can provide a complete picture, and open wounds introduce additional complexity in terms of biocompatibility, signal reliability, and safety. Future solutions will rely on combined sensing modalities and data-driven insights to achieve clinically meaningful outcomes.

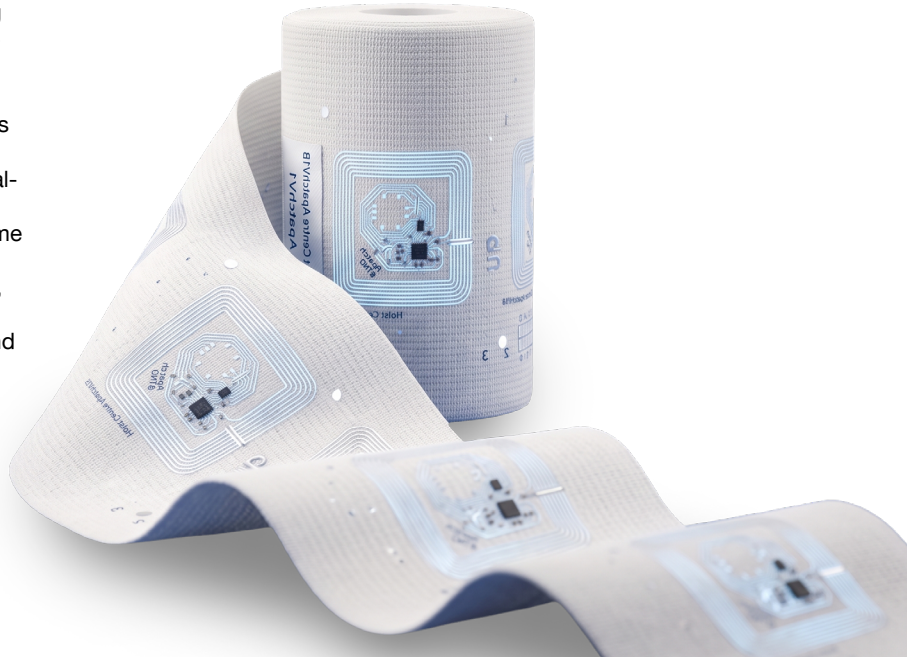
The development of robust real-world datasets is critical for algorithm training, clinician trust, reimbursement, and large-scale adoption. Real-world deployment is therefore as important as continued technological innovation. At the same time, sustainability must be embedded from the outset, with eco-design, material recovery, circularity, and clear end-of-life strategies essential to minimize environmental impact and strengthen economic resilience.

Beyond technology, the SWC ecosystem remains fragmented. Innovation currently outpaces alignment in regulation, reimbursement, and clinical practice. Key barriers include regulatory complexity, limited reimbursement pathways, data privacy and interoperability challenges, and constrained funding for early-stage development. Addressing these issues requires coordinated collaboration across industry, academia, healthcare providers, regulators, and payers.

Next Steps

A pragmatic, application-driven approach is essential. Within the next five years, success will be defined by the introduction of first-generation SWC devices with manageable complexity, supported by clinical validation and real-world adoption.

In the longer term, Smart Wound Care has the potential to become a cornerstone of preventive, personalized, and sustainable healthcare, improving patient outcomes while strengthening healthcare systems and economic resilience. ■



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Wearable multi-sensor research platform for pH, temperature and humidity for early indication of infection for venous leg ulcers within the home setting (showcased by woundIQ research platform).

Introduction

The Silent Pandemic

Wound care accounts for 2–4% of healthcare expenditure in Europe, rising beyond 5% in developed systems (EWMA; Guest et al., 2015; 2020). This burden is driven in large part by infection and delayed healing, particularly in surgical site and trauma wounds, and is further exacerbated in defence and austere environments where early detection is limited. There is a clear need for objective, continuous monitoring approaches to enable earlier intervention and improved outcomes. These costs are rising, often outpacing general healthcare budget increases, with chronic wound management representing a major, yet often overlooked, economic burden.

This “silent pandemic” is emerging at a time when healthcare resources are under increasing pressure, with the majority of wound care delivered in community settings, placing a substantial burden on nursing services. Wound management has previously been estimated for a significant portion of nursing time (Lindholm and Searle, 2016), hours that are urgently needed elsewhere. A considerable share of this effort is associated with the monitoring and management of infection and delayed healing, which often require repeated assessments over extended timeframes, increasing both clinical workload and cost. Furthermore, given the ageing population, rising infection rates, and growing antimicrobial resistance, and continued threat of diabetes and obesity, the incidence and cost burden of chronic wounds will only continue to rise (Lindholm and Searle, 2016; Sen, 2021).

These trends highlight the urgent need for scalable solutions that support long-term and decentralized care. At the same time, acceptance of health-related technologies is rapidly increasing. The widespread adoption of health and wellness wearables has made continuous monitoring more familiar and trusted by both users and clinicians, with a growing number of devices entering clinical evaluation.

Healthcare adoption remains relatively conservative, but breakthrough examples such as continuous glucose monitoring clearly demonstrate the value of medical wearables in improving care and reducing burden. These successes highlight both the need for and the impact of integrating wearable technologies into clinical practice.

This momentum aligns with broader system needs. Advanced wearable technologies can help shift care toward more preventive, data-driven, and independent settings, reducing the burden on healthcare professionals while improving patient engagement. However, meaningful impact will depend on strong user acceptance, integration into real-world workflows, and solutions tailored to specific care contexts.

At TNO Holst Centre, we believe that this convergence of technological maturity and healthcare demand creates a timely opportunity to introduce Smart Wound Care to the market. Our work builds on established wearable platforms, providing a strong technological foundation for smart wound dressings.

Expertise within integration of hybrid printed electronics on flexible, stretchable materials provides new opportunities for conformable, user-friendly form factors essential for prolonged wear.

Advancing Smart Wound Care from a promising concept to a viable, trusted healthcare device requires close collaboration across stakeholders and domains. By operating over higher technology readiness levels and focusing on feasibility and scalability, we help orchestrate collaboration and bridge the gap between academic research and industrial deployment, providing confidence to industry partners.

With extensive experience in the health domain, our aim is to reduce the burden of non-healing wounds for patients while simultaneously easing the workload and complexity faced by caregivers in daily wound management. ■

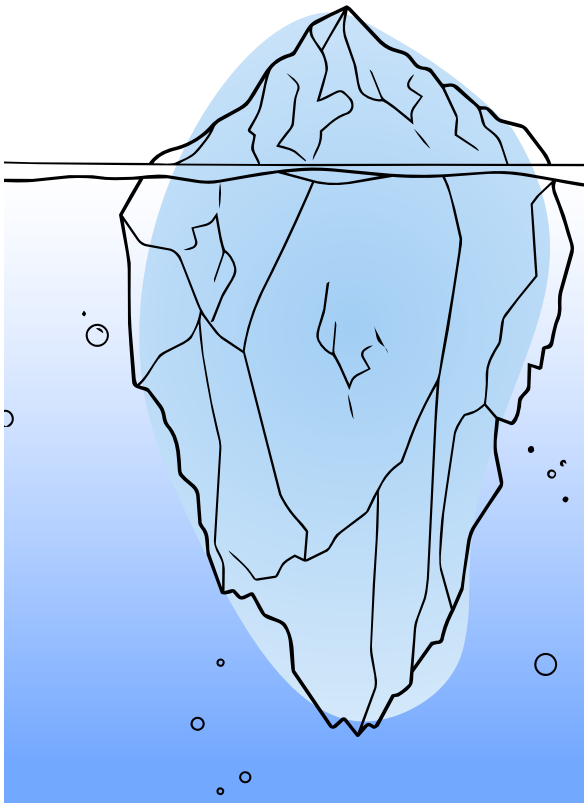
Jeroen van den Brand
Director of Operations,
TNO, Holst Centre, High Tech Industry

Helen Kardan
Director of Science & Technology,
TNO High Tech Industry

Ton van Mol
Managing Director,
TNO Holst Centre, High Tech Industry

Hidden System Failure

The True Cost of Wound Care



Visible, episodic care

US: 25 billion dollar annually
NHS(UK): ~8.3Billion GBP/ year)
Europe (Netherlands): ~1.5 billion euros per year

Hidden System Failure

US (Medicare systems): up to 96.8B dollars annually

Hidden system burden: **no clear ownership, poor data visibility**

NL: Delayed diagnosis and referral: **19-30 weeks**
82% of patients treated outside hospital.

"In wound care, we don't know the true cost — only that it is significant and highly underestimated."

Vision

Next Generation Wound Management

Our vision is to enable the future of Smart Wound Care through sustainable, high-performance wearable technologies that improve patient outcomes, strengthen healthcare systems, and reduce global resource burden.

TNO at Holst Centre holds a powerful, ambitious, yet realistic vision for the future of Smart Wound Care—one that holds tremendous promise for patients, society, the healthcare system, and the Dutch economy.

Our ambition centers on next generation wound management, combining continuous monitoring and intelligent actuation to reduce pain and accelerate healing. We envision integrated solutions for infection detection and treatment, built upon advances in flexible electronics and responsive materials that are not merely passive tools, but act as supportive digital twins with agentic AI characteristics.

Key challenges include seamless system integration, robust AI-driven communication, efficient energy management, and the development of adaptive, sustainable, and autonomous materials that can perform reliably over long periods.

We will explore the current commercial landscape, examining devices at higher TRL levels, and identify opportunities for patient-centered design that lead to better clinical outcomes. The benefits extend to all stakeholders—enabling remote care, reducing workload for healthcare professionals, and improving quality of life for patients.

In line with the European Wound Management Association's (EWMA) vision, this initiative positions TNO at Holst Centre at the forefront of Smart Wound Care innovation. ■

We envision integrated solutions for infection detection and treatment



Wearable spatial mapping of inflammation via temperature on radiation-induced skin injury.



Empowering personalised care through increased data and patient-centred decision-making.

Mission

Transforming Wound Care

Our mission is to pioneer next-generation wearable platforms, uniting hybrid-printed electronics, clinical insight, and industry collaboration to transform wound management from reactive care to proactive healing. We champion sustainability, patient empowerment, and meaningful innovation across the entire continuum of care.

To realize our shared vision, we define two complementary missions, each tailored to its specific audience and area of expertise.

Hybrid Printed Electronics

Hybrid printed electronics is a crucial enabler of Smart Wound Care. By combining flexible materials, printed circuits, and integrated sensors, we can create scalable, sustainable, and cost-efficient wound-care innovations that truly bridge the gap between technology and human experience. At the same time, this platform accelerates advanced material development, opening the door to the next generation of wearable device possibilities.

Smart Wound Care

Our mission is to revolutionize wound care through intelligent, connected solutions that monitor, assess, and support the healing process in real time. By integrating sensing, actuation, and data-driven decision-making, we aim to improve patient outcomes, empower healthcare professionals, and strengthen the Dutch innovation ecosystem in medical technology. Achieving this requires fast, transparent translation of challenges and clinical needs into technological solutions, striking the right balance between technology push and technology pull.

Focus on real world applications

Our pragmatic approach focuses on real world applications and on bridging the gap between academia and industry.
Success within the next five years would mean that OEMs introduce first-generation devices with manageable complexity, such as smart wound dressings for closed wounds. Demonstrating clinically relevant and practical solutions will help activate the broader market, drive adoption in the healthcare domain, and create momentum for more advanced Smart Wound Care innovations. ■

PESTLE Analysis

External Factors That Drive SWC Business Opportunities

Political and Regulatory

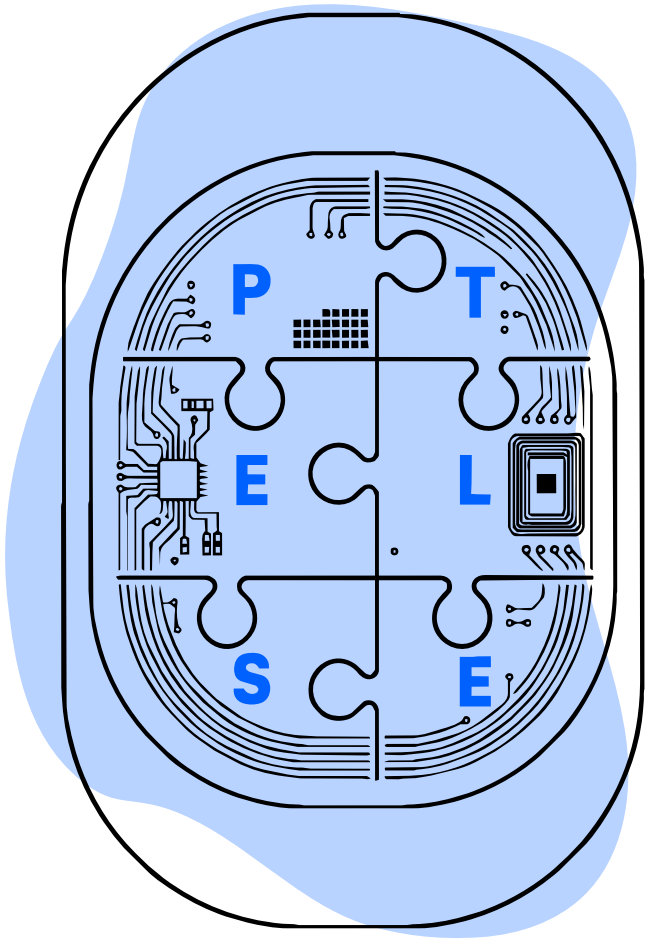
Wound care is increasingly embedded in policy agendas, including EU patient safety initiatives and defense-driven innovation programs such as advanced battlefield care. At the same time, reimbursement models and regulatory frameworks are under review, creating both uncertainty and opportunity. Public funding programs and cross-border collaborations are accelerating innovation, while emphasizing the need for clinical evidence and value-based outcomes.

Economic and Market

Healthcare systems face rising costs and workforce shortages, driving demand for cost-efficient, scalable solutions. At the same time, the market for wearable and flexible medical electronics is growing rapidly, with strong investment, industrial expansion, and consolidation across the value chain. This growth reflects a clear link between digital health technologies and cost reduction strategies.

Social and Demographic

An aging population and increasing prevalence of chronic wounds are intensifying care demand. At the same time, public awareness is rising, with smart wound care increasingly recognized as a transformative healthcare solution. Patients and caregivers are becoming more engaged, driving acceptance of technology-enabled, personalized care and greater patient empowerment.



Technological

Rapid advances in AI-integrated sensing, hybrid printed electronics, and multi-sensor systems are accelerating the maturity of SWC technologies. Developments in stretchable electronics, bioelectronic interfaces, and scalable manufacturing are enabling the transition from research to real-world applications. Increasing global collaboration is further driving progress and reducing time to market.

Legal

Healthcare regulation is increasingly focused on value-based care, digital integration, and device safety. This creates both compliance requirements and opportunities for SWC solutions that improve efficiency, outcomes, and data-driven decision-making.

Environmental and Sustainability

Sustainability is becoming a core design requirement. There is a clear shift toward bio-based, regenerative, and circular materials, including biodegradable substrates and adhesives. At the same time, regulatory pressure is increasing around lifecycle transparency, waste reduction, and material recovery, reinforcing the importance of eco-design. ■

Portfolio

With over a decade of experience in medical wearable development, TNO at Holst Centre is uniquely positioned to advance next-generation Smart Wound Care devices. Our portfolio spans smart biomaterials and sensors, human-centric design, and sustainable innovation.



Wearable research platforms spanning electrical, optical, chemical, and spatial sensing provide key insights to enable application-driven smart wound care demonstrators.



A multimodal chemical sensing platform measuring pH, temperature, and humidity to evaluate sensor integration and validate performance within wound phantoms, with a focus on scalable, biocompatible design for exploratory human testing.

Portfolio

Smart Biomaterials & (Multi-)Sensors

At TNO Holst Centre, we develop next-generation smart biomaterials and sensor technologies that enable new innovative solutions. These solutions address current hardware challenges by enabling reliable, flexible, and high-performance sensing and actuation for real-time wound monitoring and treatment optimization.

Integrability as a critical success factor

High expectations and complex, multifaceted requirements across all dimensions present a major challenge for smart wound care. Devices must be discreet, comfortable, and appealing to wear, while simultaneously delivering clinical-grade reliability to support decision-making in real-world care settings.

The promises of AI and edge computing further increases system demands, requiring ultra-low-power operation alongside the generation of high-quality, actionable data. This places strong constraints on sensing, processing, and energy management within highly miniaturized form factors.

At the same time, smart wound care solutions must integrate seamlessly into stretchable, breathable dressings and bandages, making flexible electronics a key enabling technology. Power supply choices, such as passive operation, energy harvesting, or small batteries, introduce important trade-offs, as added functionality can reduce flexibility and comfort. Ultimately, the core integration challenge is achieving maximum miniaturization, wear comfort, and programmability, without compromising performance or clinical reliability.

Current hardware challenges

Smart wound care technologies must address both closed and open wounds. Closed wounds are more compatible with existing wearable solutions, as parameters can be measured on the skin using flexible electronics with relatively fewer challenges.

Open wounds present significantly greater complexity. Sensor integration may fall between wearable and implantable systems, depending on the biomarker of interest, creating an intermediate category that is not yet clearly defined within current technology frameworks. The dynamic nature of open wounds further complicates signal reliability and requires additional evaluation.

Addressing these challenges calls for new approaches that combine biocompatibility, safety, and reliable sensing. Biomaterials and biofilms are promising candidates, but their integration with sensing functionalities remains at an early stage of development.

From a hardware perspective, direct contact sensing is often not feasible in open wounds. Sensors must operate above the wound surface or within exudate, leading to limitations in proximity, signal accuracy, and reliability. Achieving safe, clinically relevant measurements in the complex, dynamic environment close to the wound, and accurately interpreting what sensor readings indicate about physiological state, remains a key technical challenge.

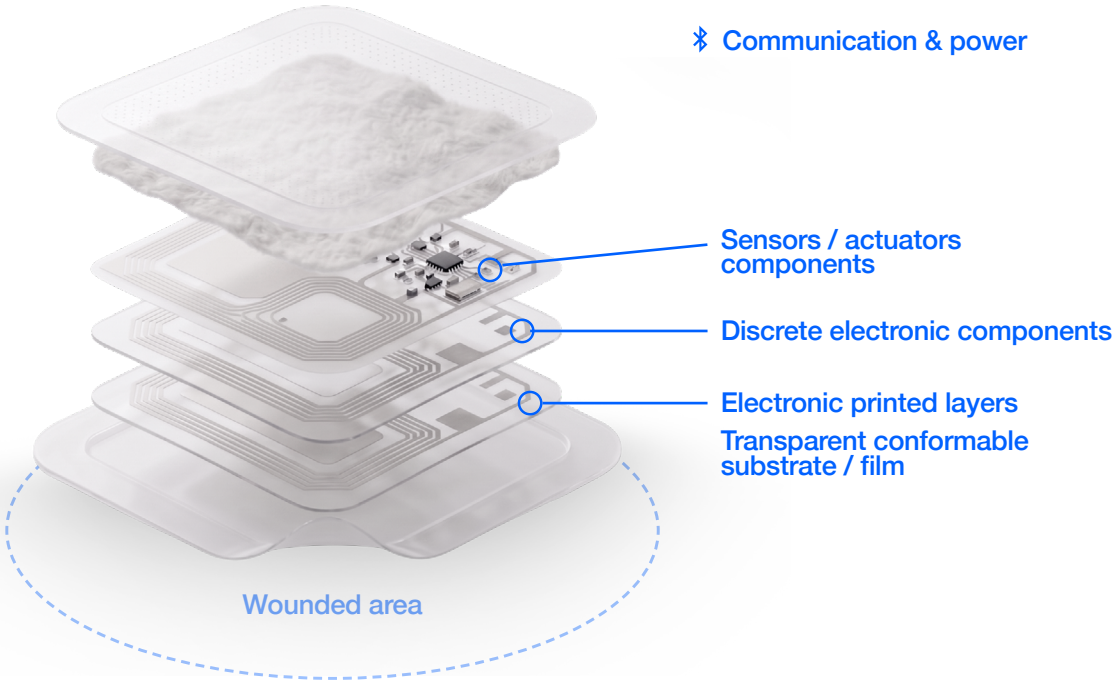
Experimenting with smart biomaterials

Flexible and stretchable printed electronics conform naturally to the skin, providing greater flexibility than conventional, rigid PCB-based substrates and enhancing comfort, mechanical compatibility, and user acceptance in wearable medical applications. However, electrical conductivity remains a key constraint, as circuits must maintain low resistance for reliable power delivery and signal integrity. Silver-based inks offer high conductivity, while more sustainable alternatives such as carbon-based inks introduce higher resistance, making them suitable for some low-power sensing applications but not all. Their adoption therefore requires careful co-optimization of device architecture, power management, and performance.

In parallel, substrate development is advancing toward recycled, bio-based, and potentially degradable materials, which must still meet strict requirements for reliability, repeatability, and manufacturing yield. As smart medical wearables scale, sustainability becomes increasingly important, requiring reusability, recyclability, and end-of-life strategies to be embedded from the design stage. Balancing conductivity, material innovation, and circular design is thus a central engineering challenge in next-generation smart biomaterials for smart wound care.

We support these developments with our broad innovation ecosystem spanning material developers, technology partners, universities, manufacturers, and end users across the value chain. Innovation is driven by both technology push and application pull, with novel materials emerging from suppliers and clear performance needs defined by our end users. By aligning these perspectives, emerging materials and academic research can be translated into application-driven, scalable solutions.

Exploded View: Generic Smart Dressing



Raising awareness for inclusivity

Current sensor technologies in wearables are increasingly moving toward more inclusive design, yet important gaps remain. While form factors are being adapted to suit diverse anatomies, sensor performance can still vary across different skin types.

Optical and electrode-based sensing modalities are influenced by physiological and optical skin properties, which can lead to performance biases, due to physical measurement constraints rather than intentional design.

At TNO Holst Centre, these limitations are actively addressed through collaboration with partners to develop improved sensing approaches, including optimized optical systems and material adaptations that perform reliably across a broader range of skin tones. Improving inclusivity in sensing is essential to ensure that future wearable and smart wound care technologies are accurate, equitable, and effective for diverse patient populations.

Open wounds require new approaches that combine biocompatibility, safety, and reliable sensing

Next steps

Many physical sensing modalities already operate at relatively high technology readiness levels. However, expanding smart wound care toward chemical and biological sensing, such as bacterial detection, introduces additional complexity and requires new sensing principles, validation pathways, and close collaboration with specialized research teams. By combining expertise in flexible electronics, system integration, and biochemical sensing, more advanced diagnostic capabilities can be developed for future smart wound care applications.

Our approach begins with wearable research platforms that are matured to an appropriate technology readiness level for early-stage patient studies. This staged development enables validation of core technologies before progressing to application-specific demonstrators, while also addressing the stringent regulatory requirements associated with wound-related technologies that interact directly with compromised tissue.

At the same time, the future success of smart wound care will depend less on the availability of core technologies and more on effective integration into clinical practice. Many sensing and electronic solutions are already sufficiently mature for early deployment, but real-world implementation, workflow alignment, and regulatory validation remain key challenges.

Early use in clinical, home-care and field environments is therefore essential. Generating real-world data enables faster clinical validation, refinement of materials and smart biomaterials, and clearer definition of performance requirements, ultimately accelerating targeted innovation and adoption.

No one-size-fits-all solution

At TNO Holst Centre, we are operating at the forefront of integration challenges in smart wearables and smart wound care. While certain claims suggest fully optimized sensors or regenerative capabilities, practical implementation requires careful evaluation of real-world constraints, integration barriers, and clinical validation.

There is no one-size-fits-all solution in smart wound care. Each patient, age group, and clinical context requires individualized consideration. Although many wound care products already exist, wounds differ widely in etiology, healing stage, infection level, and care environment. In high-risk or defense-related settings, these variables become even more critical. Effective smart wound care solutions must therefore be adaptable, evidence-based, and context-specific. ■



Wearable multiwavelength optical research platform for post-surgical wound care, enabling monitoring and future approaches for pain management and scar reduction.

Portfolio

Human-Centric Design



Wireless monitoring integrates vital signs and wound health data to support personalized decision-making and enable future predictive modelling .

Human-centric design supports the de-medicalization of healthcare by creating devices that are comfortable, intuitive, and seamlessly integrated into daily life. When medical technologies align with users' routines and lifestyles and no longer appear overtly clinical, adoption and sustained use increase significantly. Over time, these devices become natural extensions of the individual, similar to the evolution of phones from bulky communication tools to essential, multifunctional companions.

Personalized, Patient-centered Healthcare

Smart Wound Care represents a powerful application of human-centric design, with the potential to drive a broader shift toward personalized, patient-centered healthcare, similar to the growing adoption of wellness wearables and the success of continuous glucose monitoring technologies. By combining continuous sensing, data intelligence, and adaptive treatment strategies, care becomes tailored to the individual rather than standardized around episodic clinical visits.

Clinical expertise remains essential in defining optimal treatment pathways. Smart Wound Care systems can digitize, personalize, and standardize wound management, helping deliver consistent, high-quality care while supporting caregivers in their decision-making. This approach improves outcomes, expands access to best practices, and enables scalable, data-driven healthcare delivery.

Empowering Patients Through Smart Wound Care

Patients are increasingly informed and engaged, seeking greater control over their health, supported by stronger advocacy from caregivers. At the same time, workforce shortages and rising care demand mean that patients will need to take a more active role in managing their own health. Continuous access to high-quality, objective data enables more accurate assessment and supports this shift toward self-management. Smart wound dressings that are comfortable, personalized, and seamlessly integrated into daily life strengthen patient engagement while bridging the gap between clinical oversight and patient experience.

Unlike occasional clinical measurements, continuous monitoring throughout the day delivers richer insights, improved diagnosis, and minimal disruption to daily activities. The integration of AI enables personalized feedback and adaptive care strategies, translating wound data into actionable recommendations such as activity or nutrition adjustments. In the future, it may also provide quantitative indicators of pain or other patient-reported symptoms, helping patients to be better heard and supported in their care. Advanced sensing capabilities, such as detecting biochemical or odor-based markers, could further improve early detection of complications and guide interventions, including timely pain management. Together, these innovations shift wound care from episodic monitoring toward proactive, data-driven management.



Understanding and integrating bio-inspired concepts to advance smart wound care wearables (ScaleSkin concept).

Core Values in Human-Centric Smart Wound Care Design

At TNO Holst Centre, human-centric design is embedded in both mindset and development processes and strengthened by the expertise available within our broader ecosystem. By applying these principles alongside deep expertise in printed electronics, we support partners in creating high-performance prototypes for medical wearables that combine technical excellence with real-world usability.

Quality of Life

Smart Wound Care should enhance daily living rather than add burden. When seamlessly integrated into everyday routines, these technologies reduce the perception of being a patient and enable individuals to reduce anxiety, remain active, confident, and socially engaged. Personalized health insights, similar to advances in continuous glucose monitoring, illustrate how continuous sensing can move beyond clinical management to support overall well-being.

Inclusivity

Smart Wound Care solutions are designed to serve all users across ages, anatomies, skin tones, and social contexts. Wearable form factors must accommodate diverse bodies, while sensor technologies are optimized for accurate performance across different physiological characteristics. Applications are developed with varying lifestyles, health literacy levels, and cultural backgrounds in mind to ensure broad accessibility and effective use.

Identity and Personalization

Wearable medical devices and wellness devices are becoming extensions of personal style and lifestyle, much like eyeglasses or smartwatches. Human-centric design enables adaptability in form, materials, styles, and functionality to meet individual preferences and application needs, marking an early but rapidly evolving stage of personalized healthcare technology.

Data Safety and Trust

Secure handling of personal health data is fundamental to adoption. Smart Wound Care systems must comply with privacy regulations and ensure robust data protection. In high-security contexts, such as defense or remote operations, communication integrity is equally critical. Building trust begins with validated hardware performance and clinical reliability, alongside demonstrated cybersecurity and robust data governance.

Transforming the Patient Journey Through Smart Wound Care

Today's patient journey is largely reactive, with clinical intervention typically occurring only after complications arise. This approach leads to delayed treatment, extended care pathways, and increased burden for both patients and clinicians. As a result, the current model is increasingly inefficient and not sustainable for the future, highlighting the need for a fundamental shift toward more efficient, preventive, and data-driven care.

Smart Wound Care devices enable a shift toward preventive and continuous care. Early detection of abnormal healing patterns enables timely intervention, provides richer physiological data for new approaches to infection assessment and treatment, supports optimized treatment intervals, and improves the efficiency of clinical decision-making. In the longer term, these systems may support increasingly autonomous wound management and healing.

As healthcare systems face rising costs and increasing staff shortages, Smart Wound Care supports the transition of routine monitoring and basic treatment from hospitals to home and community settings. This targeted use of clinical resources improves efficiency while expanding access to preventive care, particularly for vulnerable populations who benefit most from early, continuous monitoring.

Integrating Target Audiences Into the Development Process

A strong emphasis is placed on understanding real-world use, patient perception, comfort, and wearability, in addition to technical performance. Stakeholders are actively engaged in the development process through interviews, focus groups, and co-creation activities to identify pain points and opportunities across the patient journey.

Patient groups and representatives contribute directly to design requirements, ensuring that lived experience informs technology development. This approach bridges the gap between patients, industry, and clinical practice.

Operational stakeholders, including healthcare providers and support staff, are also involved to ensure seamless integration into care workflows across diverse populations.

By demonstrating existing prototypes and near-term technologies, the program aligns expectations with practical innovation rather than speculative concepts. Student projects and early-stage pilots support rapid prototyping, user feedback, and data collection. Development priorities focus on solutions achievable in the near term, while maintaining a clear long-term vision for fully autonomous care. ■

Smart Wound Care devices enable a shift toward preventive and continuous care



Dual-use systems, spanning military and civilian applications, accelerate the development and integration of smart wound care solutions.



Longer wear, remote wearable vital signs patches, co-developed with partners and validated in volunteer and patient studies.

Case Study

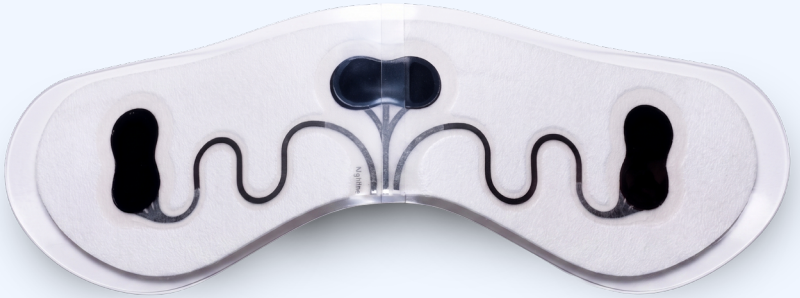
Vital Sign Patch

The Vital Sign Patch developed at TNO at Holst Centre illustrates how technical functionality can be advanced in parallel with long-term usability, sustainability, and user acceptance.

While early work focused on sensing performance, collaboration with partners expanded the design toward durable, skin-friendly, and aesthetically appealing solutions suitable for extended wear. This collaboration led to the development of a novel, scalable self-adhesive dry electrode technology that can be integrated into existing industrial infrastructure for commercialization.

Rather than traditional nonwoven medical tape with a clinical appearance, alternative transparent and smart tattoo-inspired designs were explored to promote everyday acceptance and a more lifestyle-oriented look.

Extensive volunteer studies evaluated comfort, skin sensitivity, and user perception across different material configurations. Qualitative feedback and visual assessments provided direct insights into wearability preferences and design improvements, ensuring that technical innovation was aligned with real-world user experience. ■





Developing sustainable, eco-designed wearables through advanced material build-ups, exemplified by multilayer WoundIQ printing with carbon conductive inks on paper.

Portfolio

Sustainable Innovation

Future Vision on Sustainable SWC

Smart Wound Care is an emerging innovation, particularly in the integration of electronics into dressings, and is not yet widely available on the market. This early stage presents an opportunity to establish more responsible development practices for wearable devices. By incorporating eco-design principles from the outset, developers can consider the full lifecycle of a device, addressing not only functionality and adoption, but also use-case impact and opportunities to improve sustainability.

By doing so, smart wound dressings, bandages, stockings and additional wearable wound management set-ups can be optimized for clinical performance while minimizing environmental impact.

Starting with sustainability by design allows these solutions to scale responsibly as demand increases. If sustainability challenges are not addressed early, they will intensify as adoption grows.

Conversely, when approached as an opportunity, smart wound care can deliver significant value through preventive and alternate process flows. By shifting care upstream, before conditions escalate, Smart Wound Care contributes to improved quality of life for patients, cost savings, improved system manageability, reduced infection risk and reduced environmental impact across healthcare systems.

Europe has a unique opportunity to set a new standard in sustainable medical technology. By rethinking product design, material use and re-use, and manufacturing strategies, economic resilience can be strengthened while reducing reliance on scarce raw materials. As prices of metals and other critical resources continue to rise, efficient and responsible material use is not only environmentally sound, but also economically compelling.

At the same time, smart wound dressings based on printed electronics enable local manufacturing, supporting compliance with safety and quality standards while reducing dependence on global supply chains. Local production also lowers environmental impact through cleaner manufacturing processes and shorter transportation distances.

Eco Design Benefits for Printed Electronics

For TNO at Holst Centre, sustainability is embedded across the full design and development lifecycle of electronics, from material selection to end-of-life strategies. Printed electronics on flexible carriers also offer significant sustainability advantages compared to conventional printed circuit boards, with a lower environmental footprint and more efficient production processes.

Sustainable Advantages of Printed Electronics Include:

- Production processes are optimized for low energy consumption, with printing on film requiring significantly less energy than conventional etching or printed circuit board technologies.
- These processes allow greater flexibility in material selection, enabling a wide range of lower-footprint substrates, including alternative bio-based, non-oil-derived materials such as paper. In addition recycled

(polyester) plastic substrates are potential substrates or substrates with end of life options like biodegradable properties.

Projected Lifecycle for Smart Wound Care

The long-term vision for smart wound care is to fully meet functional and clinical requirements while being designed for circularity. This enables safe material recovery, minimizes environmental footprint across manufacturing and use, and contributes to reducing the overall impact of healthcare. This approach also reframes sustainability as responsible design, where performance, usability, and environmental impact are addressed together from the outset.

Smart wound care is primarily focused on disposable, short-term use in dressings and bandages. However, longer-term reusable applications also exist, such as compression stockings and diabetic footwear, where durability and repeated use are key considerations.
For dressing applications with short lifespans, the recovery of valuable materials is essential. However, direct contact with skin or blood imposes strict safety and hygiene requirements, meaning used dressings must be treated as contaminated waste. As a result, standard e-waste, plastic, or paper streams are not suitable. Dedicated waste streams are therefore required to enable safe handling and effective material recovery.

Design strategies therefore focus on separation and reversibility. Reversible adhesives ensure reliable performance during use while enabling disassembly at end of life. A clear distinction between disposable and reusable components is a key principle. Elements intended for body contact, with minimal electronic content, can be safely discarded, while the electronic functionality is primarily concentrated in a reusable, shielded module that can be easily cleaned and disinfected. This approach leads to a lower overall environmental impact.

Biodegradability is an important ambition, as it helps prevent the use of microplastics. Where product requirements allow, lower impact alternatives such as carbon-based conductors or paper-based substrates can replace silver and fossil-based plastics. Together, these approaches reduce environmental impact while supporting safe and practical end of life solutions.

Rather than relying on a single end of life strategy, sustainable design requires parallel approaches. For each design, material choices, performance specifications, and end of life pathways must be considered in an integrated way, including whether electronics should be removed, reused, or safely recycled after use.

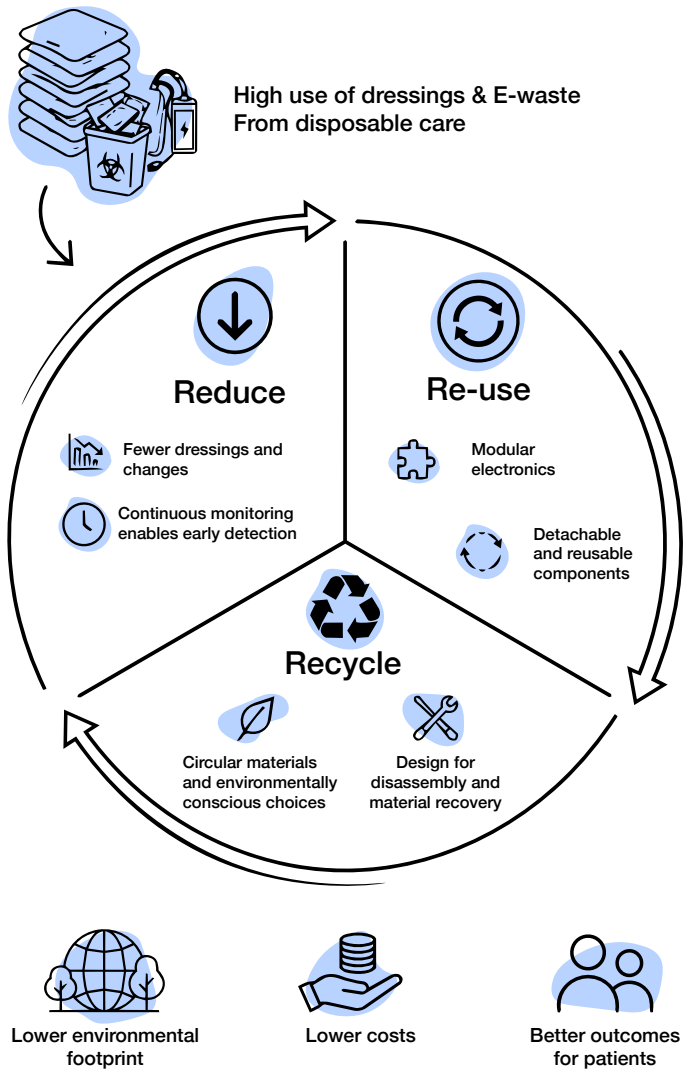
Extended Producer Responsibility

Current electronic waste processors are largely unfamiliar with printed electronics and the new product categories they enable. This is notable, as printed electronics often contain recoverable materials, such as silver, with significant residual value. As a result, the associated recycling and business models differ fundamentally from those of conventional electronics.

This shift affects the entire value chain. Organizations bringing smart wound dressings to market must consider product return or dedicated waste streams, material recovery, and end of life logistics as integral parts of their business model.

Local production and recycling further strengthen the case for Extended Producer Responsibility. Shorter transport distances reduce both environmental impact and logistical complexity, benefiting not only product distribution but also the efficient collection and recycling of used products. ■

Transition to Smart, Sustainable, Systems

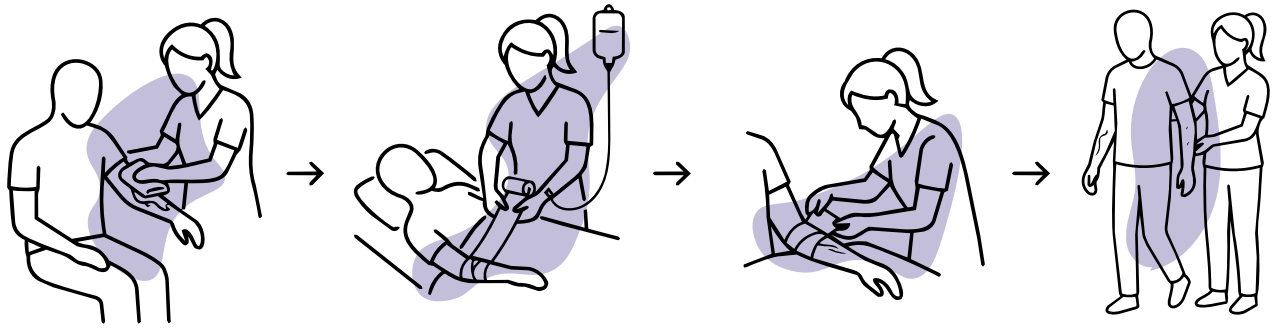


Patient Journey

From Reactive Treatment to Proactive Healing

Smart Wound Care enables continuous monitoring, earlier intervention, and personalized care, improving outcomes while reducing burden on patients, caregivers, and healthcare systems.

Current care pathway in a Hospital setting



Initial response

Cooling the burn, providing pain relief, stabilizing the patient, and beginning IV fluids.

Day 0

Definitive care

Applying burn dressings, performing debridement, administering IV fluids and antibiotics, and managing pain.

Day 1-3

Daily wound care

Frequent dressing changes, monitoring for signs of infection, and starting physical therapy.

Day 3+

Healing & recovery

Starting scar treatment, working to regain mobility, and providing ongoing wound care.

Day 14-28+

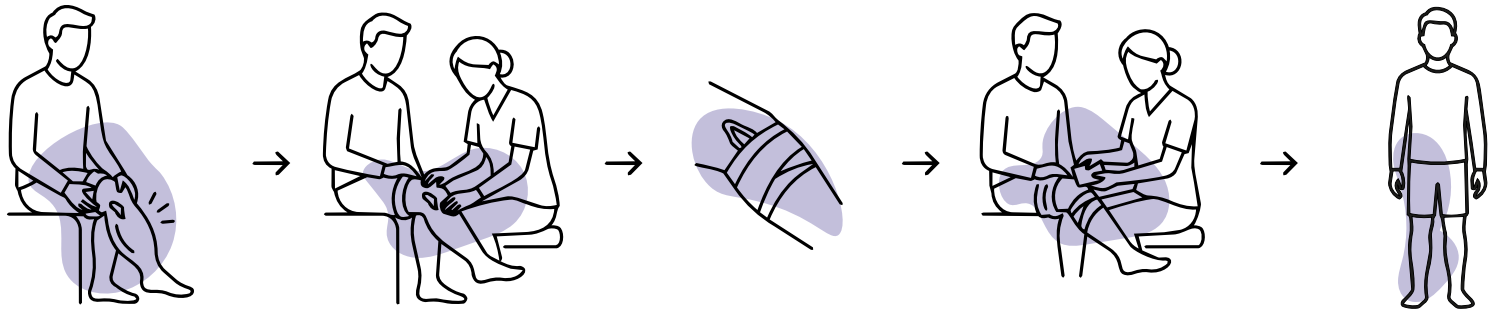
Risks: Missed infection & complications

Highest infection risk
Loss of skin barrier raises major infection risk

Infection develops
Within hours, infection can become more severe

Escalation
Sepsis, surgery or ICU stay

Current care pathway in a Community setting



Symptoms begin

Leg swelling, heaviness, skin changes or open sore

Day 0

Assessment

GP or nurse assesses ulcer, medical history and risk factors

Day 1-3

Care plan starts

Wound cleaning, compression therapy, and lifestyle advice

Day 3-7

Ongoing community dressings

Regular nurse visits to monitor healing and adjust

Day 7-80+

Healing & recovery

Ulcer heals, swelling mobility improves

Ongoing

If deterioration goes undetected

Delayed recognition → Infection and deterioration may not be obvious

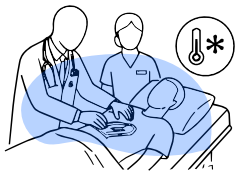
Infection develops → Can lead to more pain, tissue damage and risk

Escalation → Hospital referral, antibiotics, higher costs, longer healing

Greater burden → More visits, more dressings, more time off work

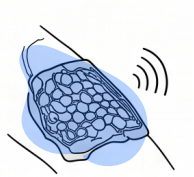
Smart Burn Wound Care Journey - Hospital Setting

Phase 1 - Monitoring Infection Risk



Initial Response
Immediate cooling, stabilization, and IV fluids within 60 minutes.

0-1 hours



Smart Sensing
Bio-patch tracks pH, O_2, and temp; data streams to dashboard.

1-24 hours



AI Insights
AI flags early infection risks and pain trends automatically.

Continuous



Care Review
Medics adjust treatment and pain plans based on live data.

Daily as needed



Better Outcomes
Early detection leads to fewer infections and faster discharge.

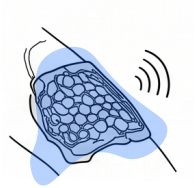
Ongoing

Risk detected or wound deterioration identified → **Triggers transition to phase 2**

e.g. rising temperature, pH changes, increased exudate, hypoxia, escalating pain, delayed healing

(Active care with closed-loop intervention)

Phase 2 - Closed-Loop System



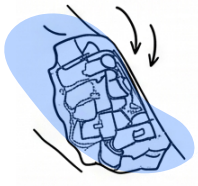
Site Sensing
High-fidelity sensors track real-time wound deterioration.

Real time



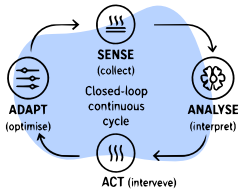
AI Detection
Rapid risk prediction triggers automated medical responses.

Minutes



Adaptive Acts
Automatic cooling, moisture, and antimicrobial delivery.

Automated response



Closed-Loop
System learns and optimizes therapy in a continuous cycle.

Continuous



Rapid Healing
Targeted care ensures minimal scarring and faster mobility.

Ongoing

Smart Wound Care Patient Journey - Home setting

Phase 1 - Monitoring Infection Risk



Initial Response
Leg symptoms develop. Patient applies patch.

0-1 hours



Smart Sensing
Patch collects biomarker data (Temp, pH, Moisture, Perfusion)

Daily



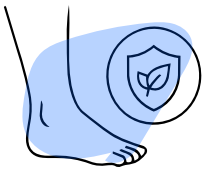
AI Insights
AI analyses trends to identify early risk signs.

Continuous



Care Review
Remote clinician reviews data & guides care.

Daily as needed



Better Outcomes
Prevent escalation. Fewer complications and hospital visits.

Ongoing

Risk detected or wound deterioration identified → **Triggers transition to phase 2**

e.g. rising temperature, pH changes, increased exudate, hypoxia, escalating pain, delayed healing

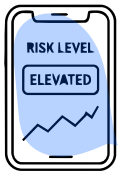
(Active care with closed-loop intervention)

Phase 2 - Closed-Loop System



Site Sensing
Patch system collects real-time data

Real time



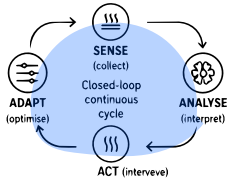
AI Detection
AI detects acute risk and automates response.

Minutes



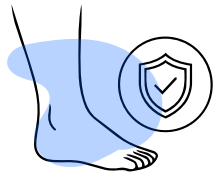
Adaptive Acts
Delivers adaptive heating or compression therapy.

Automated response



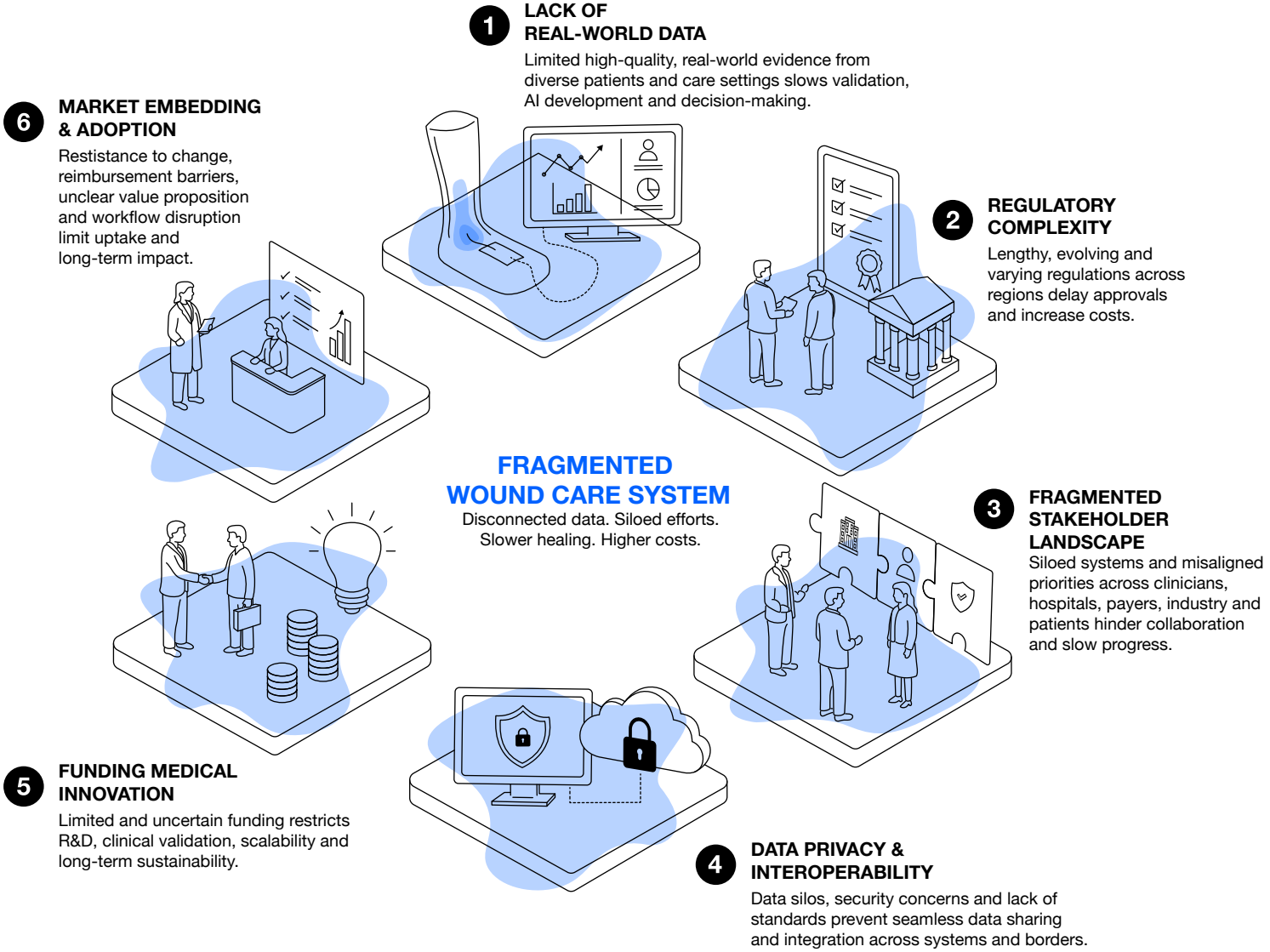
Closed-Loop
System learns and continuously optimises care.

Continuous



Rapid Healing
Faster healing & better quality of life.

Ongoing



Key Challenges

How to Bridge the Gap from Academia to Market?

Bridging the gap from academia to market, and ultimately achieving large-scale adoption of Smart Wound Care, is currently constrained by a range of technical, regulatory, clinical, and integration challenges.

1. Lack of Real-World Data

Transitioning from prototyping to first basic applications of smart wound dressings requires the development of robust datasets that link sensor signals to clinically meaningful endpoints, such as infection onset, healing progression, pain, and the need for intervention. These datasets are critical for algorithm training, clinician trust, and reimbursement pathways.

Widespread adoption will depend on strong clinical evidence. Therefore, early efforts should prioritize real-world data pipelines, supported by trusted frameworks for privacy, consent, and data governance that are accepted by both hospitals and patients.

2. Regulatory Complexity

Strict EU and Dutch medical device regulations play a critical role in ensuring patient safety, but they also extend development timelines and time-to-market. Efficient navigation of these frameworks requires close collaboration between innovators, regulators, and healthcare providers, particularly as regulatory boundaries between wellness solutions and medical claims continue to evolve.

At the same time, European policy increasingly supports local health technology development while maintaining high standards for safety and clinical efficacy. Reimbursement models are expected to gradually recognize the preventive value of medical wearables. In parallel, sustainability regulations will tighten, requiring clear end-of-life strategies, lifecycle transparency, and responsible disposal pathways for electronic medical devices.

3. Fragmented Stakeholder Landscape

The Smart Wound Care ecosystem remains highly fragmented, with rapid technological advances in miniaturized sensors, integrated electronics, and therapeutic functionalities outpacing adoption, reimbursement, and regulatory alignment. While these innovations enable more personalized and data-driven treatment, progress is slowed by stakeholder misalignment, high upfront costs, and a lack of standardized clinical evidence.

4. Data Privacy and Interoperability

Integration with existing electronic health record systems and compliance with strict data privacy regulations remain significant hurdles for large-scale clinical implementation.

5. Funding Medical Innovation

Securing funding remains a recurring challenge. A sustainable innovation pathway depends on the right mix of public funding, private investment, and shared-risk partnerships that can bridge early development and clinical implementation.

6. Market Embedding and Adoption

Finally, widespread adoption requires streamlined collaboration between all stakeholders to ensure new technologies are embedded effectively in existing care processes. Aligning clinical, regulatory, and economic interests will be crucial to accelerate uptake and deliver real-world impact. At the same time, greater clarity is needed on regulatory classification, such as risk-based categories Class I, IIa, or IIb, and the associated timelines and costs for bringing new wearable devices into clinical practice. ■



Configurable sensor integration supports personalised wound care pathways. Sole-Select demonstrator for diabetic foot ulcer applications.

Case Study

Health Patch Platform

With its Health Patch platform, TNO at Holst Centre demonstrated as early as 2019 a fully disposable, multi-sensor wearable that is customizable for home monitoring across a wide range of medical conditions. Its ultrathin, conformal form factor enables comfortable and reliable long-term wear on the human body.

The platform combines TNO's expertise in printed electronics and biocompatible material stacks with low-power, miniaturized readout electronics to deliver high-quality, multi-sensor body monitoring in a skin-friendly format. Years of R&D have resulted in a robust and versatile monitoring solution that can be tailored to specific patient needs and clinical use cases.

Wear Comfort up to Seven Days

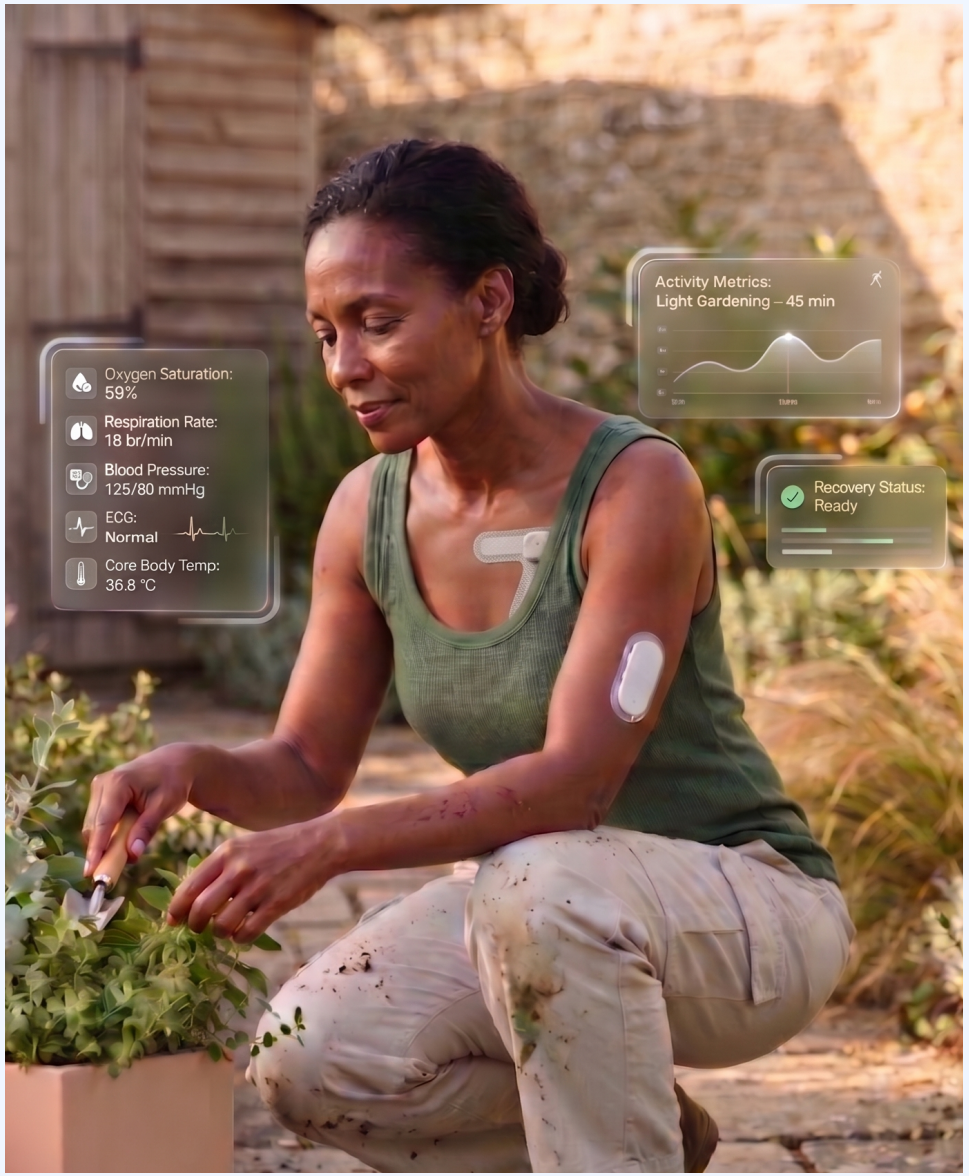
A key differentiator is the medical-grade base structure, built on stretchable, waterproof, and biocompatible flexible electronics. This design supports wear comfort for up to seven days and conforms to different body shapes. In addition, the dry-electrode technology, co-developed with materials partners, enables long-term wear without the skin irritation commonly associated with traditional hydrogel electrodes.

Low-Power System On-Chip

The platform is further strengthened by a highly versatile, low-power system-on-chip capable of measuring multiple vital signs, including ECG, bioimpedance-based respiration, and blood oxygen saturation (PPG). Data are pre-processed on-chip and transmitted wirelessly, enabling continuous monitoring and advanced data analytics. This compact and customizable architecture supports a wide range of applications, from chronic disease management to pre- and post-operative patient monitoring, within a single integrated wearable solution.

Multi-Party Innovation

Moreover, with the Health Patch platform, TNO at Holst Centre has demonstrated the effectiveness of open, multi-party innovation. Collaboration with material suppliers addressed the gap in long-term wearable electrodes. By jointly developing tailored sensor materials and system solutions, unmet needs were translated into practical innovations. This approach is equally relevant for Smart Wound Care, where key sensing modalities and standardized solutions are still emerging and require coordinated development across the supply chain. ■



Remote patient monitoring requires a balance of functionality, comfort, and wearability to ensure user acceptance and adoption. Designing for specific use cases demands a dynamic, user-centred approach.





Smart wound care development follows a two-phase pathway: monitoring to support decision-making and build real-world datasets, advancing toward closed-loop systems that deliver adaptive care—designed for seamless integration within current healthcare processes.

Technology Roadmap

Smart Wound Care

Smart Wound Care is technically within reach, but scalable clinical adoption depends on integration across the full ecosystem. Many building blocks already exist, including sensors, flexible electronics, data platforms, and algorithmic methods. The challenge is to combine these with clinicians, patients, and healthcare stakeholders in a way that reduces workload, improves equity, and delivers clear health-economic value at sustainable cost. This integration is increasingly urgent in the context of rising infection rates, antimicrobial resistance, constrained healthcare resources, and the rapid growth of elderly, diabetic, and immunocompromised populations. TNO at Holst Centre adopts a future-oriented approach to ensure that Smart Wound Care solutions are both impactful and scalable.

Guiding principles for successful implementation:

Clinical Confidence and Patient Empowerment
Acceptance by both patients and medical stakeholders is the first and most critical stage for the successful adoption of smart wound care systems. These technologies must be trusted, intuitive, and seamlessly integrated into daily life, enabling users and clinicians to rely on them with confidence, much like established consumer technologies. Comfort, usability, and perceived benefit matter as much as sensor accuracy.

Value first, not technology push
The roadmap must be grounded in clinical pain points, caregiver workload, patient comfort, and measurable health-economic impact. Measurement should reduce dependence on subjective visual inspection and individual skill. This improves consistency, supports training, and reduces errors. Improved outcomes alone are insufficient. Solutions must demonstrate cost neutrality or reduction, or provide clear cost offsets through the prevention of complications. Integration must be seamless, especially with electronic health records, because any additional administrative work reduces adoption.

Sustainability by design
Materials, disposability, and waste streams must be considered from early prototypes onward. Medical waste streams, electronics disposal, and energy consumption are coming under scrutiny, and future regulation is likely to demand transparency about materials, lifecycle, and disposal routes.
Rising costs of traditional electronic materials are driving interest in more economically viable alternatives, such as carbon-based conductors, which can also offer advantages in sustainability and biocompatibility.

Sustainability extends beyond waste management and must be considered across the full lifecycle of a device, from material composition to system architecture and real-world use. At the application level, smart wound care can further improve sustainability by reducing the need for nurse visits, extending dressing lifetimes, and preventing infections or worsening conditions, ultimately lowering overall resource consumption.

Robustness, Autonomy, Continuity of Data

In parallel, the geopolitical situation increases the relevance of dual use scenarios. Autonomous, robust, and low burden smart wound care devices can have value in civilian healthcare and in military settings, where continuity of information and care is challenged by disrupted logistics and communication.

0-5 years

Roadmap horizon 0 to 5 years – Validation and integration

In the next five years, the critical goal is to move from promising prototypes toward clinically relevant validation and workflow integration. The focus is less on having the perfect device, and more on proving where monitoring and decision support deliver measurable value for all stakeholders:

- **Enhanced patient empowerment and equity**
- **Higher care standards with reduced workload for caregivers**
- **Innovative new products and business models for industry partners**
- **Reduced care costs for hospitals and insurance companies**

Having real-world data studies that support the added value of SWC will lead to acceptance among patients and medical staff and market development.

Monitoring as the first adoption wave
A realistic entry point is monitoring-only smart wound dressings, because they can be positioned as decision support without immediately changing therapy. Early success will come from simple, robust functions that reduce uncertainty and workload, for example alerting when a wound state deviates from expected healing trajectories. Monitoring can also enable earlier escalation, reducing complications and preventing emergency interventions.

Key sensing modalities in wearable devices are likely to be adopted in waves, reflecting their maturity and level of interaction with the body. Early-stage deployment focuses on non-invasive sensing, such as temperature, pressure, bioimpedance, and optical measurements, which benefit from higher technological maturity and commercial availability.
As the field advances, more complex modalities will emerge that interact directly with the wound environment, including pH sensing, electrochemical biomarkers, and microbial detection.

No single sensor can provide a complete picture, given the complexity of inter- and intra-patient variability, including factors such as comorbidities and individual physiological differences.

The roadmap therefore should prioritize multi-sensor platforms and sensor fusion approaches, while acknowledging that real-world data for mapping signals to clinical outcomes is still limited. Animal models and simplified assumptions must be replaced by continuous clinical data collection and well-designed observational studies.

Data generation and real-world evidence
A foundational milestone is building datasets that connect sensor signals to clinically meaningful endpoints, such as infection onset, healing rate, pain, and need for intervention. This is required for algorithm training, for clinician trust, and for reimbursement. Widespread adoption will require a mindset shift toward prevention; but prevention requires evidence. Therefore, the 0 to 5 year phase should emphasize real-world data pipelines, including privacy, consent, and governance models that hospitals and patients accept.

Technology maturity and early TRL positioning
Component-level readiness varies. Simple NFC-based tags with basic sensing can already be used for early data capture and exploratory studies. However, higher accuracy sensors, miniaturization, and robust packaging for dynamic body movement remain development needs. Materials also require innovation. Conductive inks, substrates, and adhesives must support comfort, flexibility, and reliable contact, while moving towards, advanced, adaptive, programmable systems. Power remains a key barrier. Low-power electronics and energy harvesting approaches, including body-driven sources such as sweat and ambient energy from external electromagnetic radiation, are promising but still require system-level validation.

Stakeholder alignment is key
The next five years also require structured collaboration with clinicians, nurses, microbiologists, pharmacists, general practitioners, patients, industry, insurers, regulators, and policymakers. Education is central. The market will likely see many exaggerated claims. A credible roadmap must position smart wound care as hardware plus software plus clinical integration, not as a universal device that magically solves all healing.

Short-term use case target
Closed wounds and post-surgical monitoring: time windows are short and the value of early detection is clear.
For example: Tissue flap monitoring for breast reconstruction with cancer patients.

Early success will come from simple, robust functions that reduce uncertainty and workload

5-10 years

Roadmap horizon 5 to 10 years – Closed loop care and autonomy

Technological innovation in smart wound care is likely to be largely incremental at the component level, while application-level impact will be disruptive. Advances in low-power chips, energy harvesting, AI, and sensor fusion will play a crucial role in enabling next-generation solutions.

Between five and ten years, the roadmap shifts from pure monitoring and triage toward theranostic systems that combine sensing, diagnosis, and intervention in closed-loop solutions, supported by predictive models and partial autonomy.

From reactive to preventive and personalized
Healthcare today tends to treat diseases after they occur, rather than preventing them. Highly miniaturized, multi-parameter sensor systems will increasingly combine modalities to monitor wound status more accurately and continuously. The disruptive aspect is not a sudden sensor revolution, but the emergence of reliable clinical meaning from combined sensing and data-driven interpretation. For example, temperature and pH are well-established indicators for early infection detection, in addition to bioimpedance measurements via electrodes.

Materials and form factors: second skin reliability
A clear trajectory is toward wearables that feel like a second skin. Comfort, trust, and adherence determine impact. Devices must remain functional under motion, moisture, and prolonged wear, and should be designed to reduce stigma, including odor management and potentially even sensory experience management. Materials with adaptive or programmable properties may introduce new functionalities and performance characteristics, opening up novel pathways for monitoring, diagnosis, and responsive treatment.

Low power chips and connectivity
Higher density clinical environments and field settings need robust connectivity. Emerging communications, including the evolution toward 6G, may support lower power and better reliability in hospital settings. The roadmap should avoid dependence on always-on connectivity by emphasizing edge processing, intermittent synchronization, and resilient local storage, especially relevant for emergency and military contexts where data loss is a real risk.

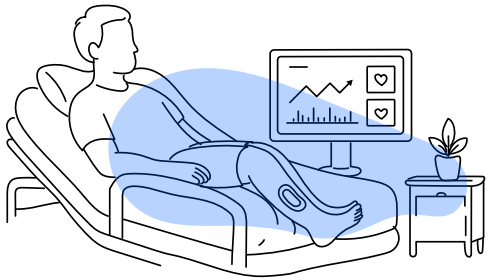
Sustainability and regulatory maturation
Regulatory frameworks are shifting, including differences between wellness positioning and medical claims. In Europe, there is pressure to support local health technology, while maintaining safety and efficacy. Over the 5 to 10 year horizon, reimbursement models will likely need to recognize the preventive value of medical wearables.

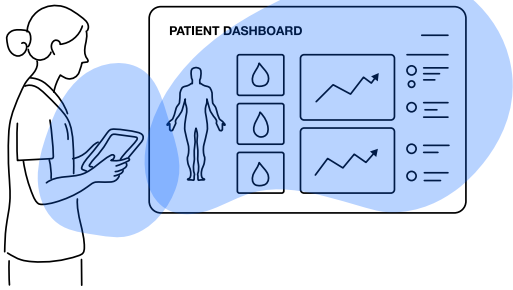
Longer term use case target
Chronic open wounds: when conditions are complex, wear duration is long, and sensor and materials requirements are tougher.
For example: diabetic foot ulcers and burns ■

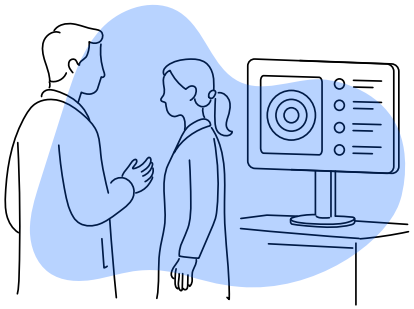


Wound management, often overlooked as a comorbidity, affects a large and diverse population.Synergised data integration is key to uncovering its true impact and reducing the burden on patients, healthcare, and the workforce.

HOSPITAL SETTING
Connected care.
Smarter decisions.
Better outcomes.







In 0-5 years
Reactive monitoring & usability

Core Use Cases
- Remote patient monitoring & prolonged field care
- Alternate infection monitoring

Key Technologies
- Sensor modality
- Sensor fusion
- AI integration
- User perception

Transition
Scaling insights into proactive closed-loop care

From reactive insights → To preventive actions

In 5-10 years
Preventive, closed-loop systems

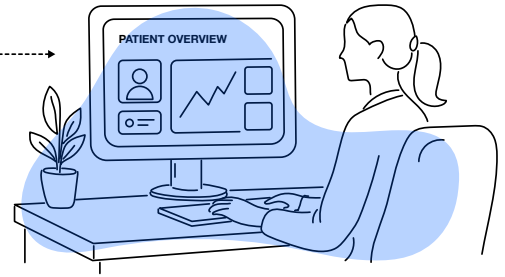
Core Use Cases
- Adaptive & autonomous
- Alternate infection therapy

Key Technologies
- Low-power electronics
- Energy harvesting
- Digital twins
- Sustainable design

HOME SETTING
Empowered patients.
Continuous care.
Connected everywhere.







Data-driven decisions

Proactive & personalized care

Improved outcomes & quality of life

Lower costs & resource use

Sustainable innovation

About TNO at Holst Centre

Accelerating Advanced Medical Wearables

As a leading, independent research partner with a proven track record in accelerating advanced medical wearables and bridging academia and industry, TNO at Holst Centre is ideally positioned to drive the development and large-scale adoption of Smart Wound Care. Here are five key reasons.

1. Our Track Record in Printed Flexible and Stretchable Electronics

We are a pioneering and globally recognized innovation partner in flexible and stretchable electronics, with deep expertise in the seamless integration of chips, sensors, and diverse electronic components. Building on this foundation, we develop novel wearable medical devices tailored to specific clinical use cases, enabling accurate monitoring and real-time therapeutic response.



Holst Centre, TNO, located at the High Tech Campus, Eindhoven, The Netherlands.



2. Experienced Innovator in Medical Devices

At TNO at Holst Centre, more than a decade of medical device innovation, starting with vital sign monitoring (see box text on Health Patch platform), has evolved into advanced wearable systems. Our expertise in hybrid printed electronics enables flexible, conformable designs with high design freedom and rapid iteration, allowing efficient adaptation of form factors, material stacks, and system architectures to specific application needs.

These capabilities strongly support seamless integration in Smart Wound Care. Although many academic concepts exist, most remain at low technology readiness levels and lack clear pathways to scalable manufacturing. The limited availability of commercial smart wound dressings reflects the challenge of translating promising sensing concepts into robust, manufacturable, and clinically viable products.

3. Our Unique Shared Innovation Model

Partners benefit from tailored engagement models that accelerate progress in Smart Wound Care. Our Shared Innovation Model enables faster, more cost-effective, and efficient multi-party innovation through long-term strategic collaboration.

Given the complexity and cost of developing Smart Wound Care technologies, no single organization can address all challenges alone. By sharing R&D efforts, costs, and risks, partners gain access to collective program expertise while reducing uncertainty and shortening time-to-market.
In this model, we act as an orchestrator of collaboration, bringing together clinicians, industry partners, and research infrastructure to accelerate innovation in targeted directions.

4. Our Position as a Neutral Contract Research Organization

Our independent and objective position enables us to provide unbiased guidance without competing with partners. Our focus is on designing the best possible solution for each challenge, free from commercial constraints. As a neutral contract research organization, we bring together stakeholders across the value chain, from medical centers to material suppliers, and facilitate collaboration in an independent and trusted manner.

In addition, we actively identify critical gaps in technology and integration. When external funding is not yet available, we invest internally to advance promising innovations to higher maturity levels. This proactive approach ensures that high-impact developments continue progressing toward market readiness and societal value.

5. Our Application Focused Innovation

The surrounding ecosystem of spin-offs and partner companies plays a key role in translating prototypes into market-ready solutions. This is highly valued by customers who are not only seeking innovation, but also clear pathways to commercialization.

Spin-outs like TracXon (see pg. 30), Aikon Health, and Touchwaves illustrate how innovations in wearables can progress across different stages of the value chain, from technology development to application-focused deployment. These collaborations enable tangible, application-driven results in areas such as advanced sensing, next-generation biomaterials, and wearable health technologies. ■

Case Study

TracXon

Spin-out TracXon illustrates how TNO at Holst Centre can scale promising technology with support from OEMs and material converters. The scaling knowledge gained is highly relevant for Smart Wound Care, as Hybrid Printed Electronics (HPE) offers strong advantages for developing and producing smart wound dressings.

Through ongoing process and product innovation, TracXon aims to make HPE a mainstream cradle-to-cradle manufacturing technology. HPE enables new form factors and integration options while reducing the environmental footprint of electronics through circular manufacturing. ■

HPE offers strong advantages for developing and producing smart wound dressings



TracXon provides a scalable manufacturing pathway, enabling TNO and partner developments to move from innovation to commercialisation.

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Contact



Shavini Stuart, PhD
Senior Scientist/ Program Lead for
Smart Wound Care, Wearables
Hybrid Printed Electronics
Holst Centre, TNO
Contact: shavini.stuart@tno.nl



Daniël van der Linden,
Business Development Manager
Medical Wearables
Hybrid Printed Electronics
Holst Centre, TNO
Contact: daniel.vanderlinden@tno.nl

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Contributors

Han Thoma, Copywriter, DRIFT

Dave Seldenthuis, Designer Campaigns & Branding, Curgoal Digital Marketing

Ugnė Rastauskaitė, Project Manager, Curgoal Digital Marketing

Moniek Falck, Freelancer Marketing and Communication

Contributors from TNO

Savitha Padullaparthi, Project Manager Marketing & Communications

Pradeep Panditha, Technical Project Lead / Test & Validation Lead Smart Wound Care

Adrian-Răzvan Petre, Electronic Development Lead, Smart Wound Care

Margreet de Kok, PhD, Project and Sustainability Lead, Wearables

Corne Rentrop, Project Manager, Hybrid Printed Electronics

Pieter Debrauwer, Research Manager, Hybrid Printed Electronics

Jeroen van den Brand, PhD, Director of Operations

Helen Kardan, Director of Science & Technology, High Tech Industry