DC Research Projects

DC1: Laser Induced Graphene (LIG) on novel biodegradable polymers for the monitoring of humans and plants health status (Tyndall)

Objectives: To develop novel functional bioplastics and use them for monitoring of health status in plants and humans. 1. Develop chemically and mechanically biopolymer substrates displaying flexibility and stretchability 2. Develop methodologies for the universal fabrication of LIG electrodes on biopolymers 3. Fabricate and characterise multimodal LIG-based electrochemical sensors for monitoring of human and plant health biomarkers (pH, ions, uric acid, temperature)

Expected Results: a) realisation of a family of biodegradable LIG-biopolymer functional units suitable for the realisation of broad range of electrochemical (sensing, energy storage/harvesting) and physical (biophysical and mechanical sensors) modules; b) sustainable multimodal sensing platforms for health monitoring suitable for health and farming applications.

DC2: Sustainable self-powered sweat sensors and strategies for their incorporation into e-textiles (Tyndall)

Objectives: To realise self-powered electrochemical sensors for the Fitness application area. 1. Design and fabrication of LIG-based electrochemical biosensors on natural polymer sheets, fibers and strips (lactate, ions) and characterisation in artificial sweat 2. Fabrication of enzymatic LIG-based biofuel cells (BFC) and demonstration of self-powering electrochemical sensing 3. Design and fabrication of antennas for e-textiles using Laser induced Copper (LIC) technologies.

Expected Results: a) realisation of biosensors for sweat monitoring during exercise; b) realisation of self-powering modules Including BFC and RFID tags for wearable fitness applications (case study 1).

DC3: Sustainable and smart ear tags for livestock localisation and monitoring (CSEM/TAU)

Objectives: Combine components, materials and processes solutions from partners to realize fully operational systems. Sustainable ear-tags are bringing key perspectives to monitor ID, position, temperature, essential for livestock management. The following system-related activities are constitutive of both the realization of prototypes and the training brought to the PhDs: 1. System architecture and eco-design 2. Components selection and manufacturing processes combination 3. Exploitation of dedicated IC architectures to operate sustainable batteries, super-caps, sensors and antennas. 4. Prototyping in collaboration with the partners 5. Test and validation in laboratory with models.

Expected Results: Overall manufacturing process documentation, prototypes of ear-tags, laboratory measurements.

DC4: Bioderived materials for the additive manufacturing of sustainable and bio-degradable wearable electronics (RISE/LiU)

Objectives: Assessment of the use of low impact and possibly bioderived materials (e.g. lignocellulosic derivatives, natural gums, wax) as core components for the development of functional materials (inks and substrates) for application in printed wearables (e.g. e-patch and e-textile) technologies or smart farming. 1. Development of bioderived functional inks: conductive and dielectric inks based on bioderived/bio- and low impacting materials (e.g. biocarbon, low impacting metals and combination thereof) for the additive manufacturing (primarily screen printing) of primarily self-standing or textile-based wearable electronics. 2.

Development of bioderived films as substrates: self-standing films based on bioderived polymers (e.g. lignin or nanocellulose) or their composited with bio-derivable elastomers (e.g. polyurethane, natural gums) for the additive manufacturing of electronics components (e.g. sensors, antennas) and circuits for application in fitness and smart farming. 3. Development of processes for the printing of the developed materials on different commercial or project specific substrates. Processes (e.g. progressive rigidity) for the integration of rigid components (e.g. SMD components) onto stretchable circuits will be also developed.

Expected Results: Creation of wearable devices including circuits, sensors and driving electronic components and biodegradable electronics for smart farming. Design of the demonstrators will the results of coopeting effort between different members of the network. Performance metrics: Data on the electrical, mechanical, and sustainability of the developed materials will be collected. Materials and processes: Inks and substrate with intrinsic stretchability and bio-degradability for the realization of the above mentioned demonstrators.

DC5 Energy- and precision-aware computing for disposable sensors (QUB)

Objectives: Developing the software stack for biodegradable sensors that support on-device signal processing and communications under stringent power constraints, intermittent availability of energy and meeting Quality-of-Service (QoS) constraints. The solution will combine insights from the burgeoning field of intermittent computing and from transprecise computing, which studies the trade-off between accuracy, performance and energy consumption when the precision of the computation is varied in a controlled manner. 1. Characterisation of signal processing applications relevant to the use cases, their energy consumption profiles and tolerance towards reduced precision. 2. Design of resource management policies for scheduling computations and communications based on models of available energy and predictions on future energy availability. 3. Design of resource management policies that dynamically adapt the precision of the computation in order to meet energy constraints while maintaining QoS metrics. **Expected Results**: a) design and evaluation of resource management policies; b) a prototype implementation of the software stack and sample applications.

DC6 Co-creation of circular economy strategies (QUB)

Objectives: To facilitate successful and sustainable solutions for electronics use (focusing on theme 1-3) through circular economy principles by co-creation of sustainable practises for existing technologies and incorporation of sustainability into future products. 1. Identification and recruitment a diverse group of users for participation in the study 2. Use of creative methods (e.g., brainstorming, prototyping) to explore potential circular economy strategies in organised participatory workshops 3. Analysis of findings and development of a set of circular economy strategies based on user input share with relevant stakeholders 4. Develop an implementation plan for the proposed strategies outlining steps for adoption barriers.

Expected Results: creation of a set of tools and actionable strategies that can guide manufacturers and users to enhance the lifecycle management of these devices in a way that will be agreeable to consumers. Implementation of circular economy strategies to reduce waste by promoting reuse, recycling, and sustainable disposal methods. Engagement of users in the co-creation processes to ensures that the developed strategies are practical, user-friendly, and widely accepted.

DC7 Development of wearable green electronics for electrophysiological sensing (NOVA-FCT)

Objectives: Development of high resolution and long-term stability of electrophysiological sensors based on pressure sensors, able to monitor pulse waveforms and ECG signal acquisition, using a new technology based on laser-induced graphene (LIG), using polymers and cellulose based materials as precursors. Development of simple transfer methodologies for application of LIG-sensors on textiles. 1. Selection of new cellulosic based materials and membranes 2. Optimization of DLW on selected materials using alternative CO2 laser sources like UV 3. Development of simple transfer methodology based on a water-induced peel-off process that efficiently separates patterned LIG structures from paper/cellulose substrates to conformable, flexible substrates, harnessing the multifunctional capabilities of LIG toward applications in wearable electronics. 4. Sensors fabrication and characterisation.

Expected Results: production of strain gauge sensors for electrophysiological signals (case study 2); development of methodologies for the integration of LIG sensors on textiles for wearable applications.

DC8: Development of wearable green electronics for non-invasive electrochemical sensing (NOVA-FCT)

Objectives: Development of high resolution non-invasive for non-enzymatic glucose electrochemical sensors, using a new technology based on laser-induced graphene (LIG), using as precursor materials, different kinds of flexible substrates, like polymers and cellulose based materials. The sweat stimulation will be based on iontophoresis, also-LIG-based. 1.Development of an iontophoresis with electrodes produced by green LIG process, for sweat stimulation 2. Integration of glucose sensor and wearable sweat sensing demonstration 3. Assessment of sustainability and benchmarking against commercial wearable solution (not sustainable).

Expected Results: Development of a fully integrated and autonomous platform that enables continuous and non-invasive monitoring of glucose: a) optimization of sweat-stimulating using iontophoresis LIG electrodes and b) wearable electrochemical sweat sensing system for precise measurement of biomarkers in sweat.

DC9: Public acceptance and appropriation (BTU)

Objectives: Investigation of the relevance of consumer acceptance of Green/ Sustainable Electronics (G/SE), their "appropriation" readiness and how everyday social practices are changed be the new technologies/ products developed in the different FERNS case studies. Investigation of possible roles and requirements to involve consumers as either "co-designers", "prosumers", "promoters/ multiplayers" or "beneficiaries" of green electronics along the lifecycle of the new technologies/ products. 1. Conduct large-scale surveys to understand general electronic systems 2. Consumer trends, preferences, and behaviours related to purchasing green electronics 3. Conduct in-depth interviews or focus groups with consumers to explore different roles in the life-cycle of green electronics 4. Case studies on green electronics adoption in different regions or demographic groups.

Expected Results: a) Consumer typology based on social practices and roles in the lifecycle of G/SE; b) Toolkit for consumer research in green electronics research.

DC10: Social sustainability dimensions for green electronics (BTU)

Objectives: Combination of a meta-study of empirical research and theoretical concepts concerned with social sustainability issues in GE transition with participatory research on social dimensions in the FERNS case studies, towards development of a multi-dimensional assessment tool for designing as well as formative (continuous) and summative (retrospective) evaluation of Green/ Sustainable Electronics projects. The dimensional observation covers aspects like ethics along the value chain, social equity in production and consumption, access and affordability of sustainable electronics, impacts on health and wellbeing. 1. Participatory research on challenges and potentials to integrate social dimension in R&D on G/SE 2. Identification of critical points, success factors, obstacles 3. Development of design and evaluation tools to integrate SSD in G/SE.

Expected Results: Development of design and evaluation tools to integrate SSD in G/SE.

DC11: Smart Sustainable E-Textile Fitness and Wellbeing Monitoring System (UoS)

Objectives: Combination of replaceable enzymatic electrochemical lactate sensors alongside heart rate (electrocardiogram (ECG)) electrodes and breathing rate sensors (capaciflector). The systems will be combined with systems electronics and fabricated using sustainable, biocompatible and biodegradable materials where possible. The system will be implemented in a smart chest band and will be designed to facilitate end-of-life processing and separation of waste streams. 1. Evaluation of sustainable replaceable textile lactate sensor 2. Implement ECG and capaciflector electrodes. 3. Electronic systems design for capturing and storing data 4. System design for ease of end-of-life processing.

Expected Results: a) Design rules for disassembly; b) Novel integrated self-powered e-textile lactate sensor; c) Functional prototype system implemented in a textile chest strap; c) System performance characterisation and benchmarking.

DC12: Printed non-toxic bioderived and biodegradable supercapacitors for low-power wearable and farming applications (TAU)

Objectives: Development of supercapacitors using porous carbons from biochar using greener chemical activation methods 1. Preparation and optimization of electrode ink 2. Material characterization of the porous carbon will be conducted using BET and SEM techniques, along with electrochemical characterization for both three-electrode and two-electrode systems, including CV, GCD, and EIS analyses. 3. Development of an environmentally friendly electrolyte based on deep eutectic solvents, designed to operate within a voltage window of up to 2.5 V to extend the energy density. 4. Material characterization of the electrolyte will include FTIR and DSC analysis, along with electrochemical characterization using EIS to determine ionic conductivity.

Expected Results: a) The fabricated biodegradable printed supercapacitor, utilizing the developed electrode and electrolyte, will achieve a specific capacitance of up to 60 F g-1 and delivers an energy density of 50 W h kg-1; b) The developed supercapacitor will demonstrate exceptional long-term stability, maintaining performance for up to 50,000 cycles; c) The developed supercapacitor operates effectively within a temperature range of -40°C to +65°C.

DC13: Circular business model innovation for circular product service systems - with a focus on co-creation and testing with users / costumers to ensure acceptance (TAU)

Objectives: development of models for circular business model innovation for circular product service systems - with a focus on co-creation and testing with users / costumers to ensure acceptance 1. Circular product service system design with a user / consumer perspective. 2. Research how user/consumer acceptance of more sustainable circular electronics products and related circular business model innovations can be boosted by including consumer/user/customer co-creation activities in the front-end innovation phase. 3. Enable the co-creation of cradle-to-cradle product service systems with users/consumers 4. Incorporate life-cycle assessment analysis (LCA) data in the critical phases of electronics eco-design as well as circular product service system design and link it with the circular business model innovation process. 5. Explore in the context of consumer electronics how users/consumers could actively help to drive bottom-up change towards a circular economy or circular society beyond the role of more passive citizen-consumers associated with the linear economy.

Expected Results: a) Circular product service systems are designed so that they are perceived as easy-to-use and can replace existing electronics that have been designed with a linear economy thinking; b) User/consumer acceptance testing integrated in the front-end innovation phases that are the most critical for circular business model innovations; c) Integrate cradle-to-cradle product design principles and a more holistic circular product service system design thinking in circular business models with a user/consumer perspective; d) Development of a circular business modelling tool, for example a circular value proposition canvas, for mapping value chains across circular product service systems with a data-driven approach that is enabled by up-to-date LCA data.

DC14: Safe and Sustainably by Design for green electronics (EMPA)

Objectives: Advancement and the adaptation of the SSbD framework for green electronics in the context of the EU directive Eco-design for Sustainable Products Regulation (ESPR) and other relevant EU directives. 1. The adaptation of the SSbD concept will enable a comprehensive assessment of substances and materials used in green electronics with focus on MFA, Risk Assessment (RA) and LCA (multidimensional safety and sustainability evaluation). 2. The benefit assessment matrix (BAM) and Multi Perspective Application Selection method (MPAS) will be further developed and combined in the context of SSbD in order to identify application fields with high environmental sustainability potentials for SPoCs (LCA). 3. The basis for SSbD will be elaborated with MFA for selected SPoCs.

Expected Results: 1) Advanced and adapted SSbD framework for green electronics in the context of eco-design. 2) Identification of applications fields for selected SPoCs with high environmental sustainability potentials 3) Performed SSbD assessment for selected SPoCs in order to enable green electronics.

DC15: Sustainable plant and soil monitoring by wearable sensors (PoliTO)

Objectives: Design and implementation of a multi-sensing system for plant and soil monitoring. 1. Design of wearable plant sensors for measuring plant bioimpedance. 2. Sensor's installation in the soil (conductivity, humidity, temperature), creation of a multi-sensing system for data collection directly by the signals received from the plants and soil. 3. Assessment of bio-degrability.

Expected Results: Implementation of biocompatible and biodegradable sensors for plant and soil, integrated in a multi-sensing system that will collect the data and transmit them with a LoRaWAN connection. Implementation of the needed software platform for data processing and result presentation.