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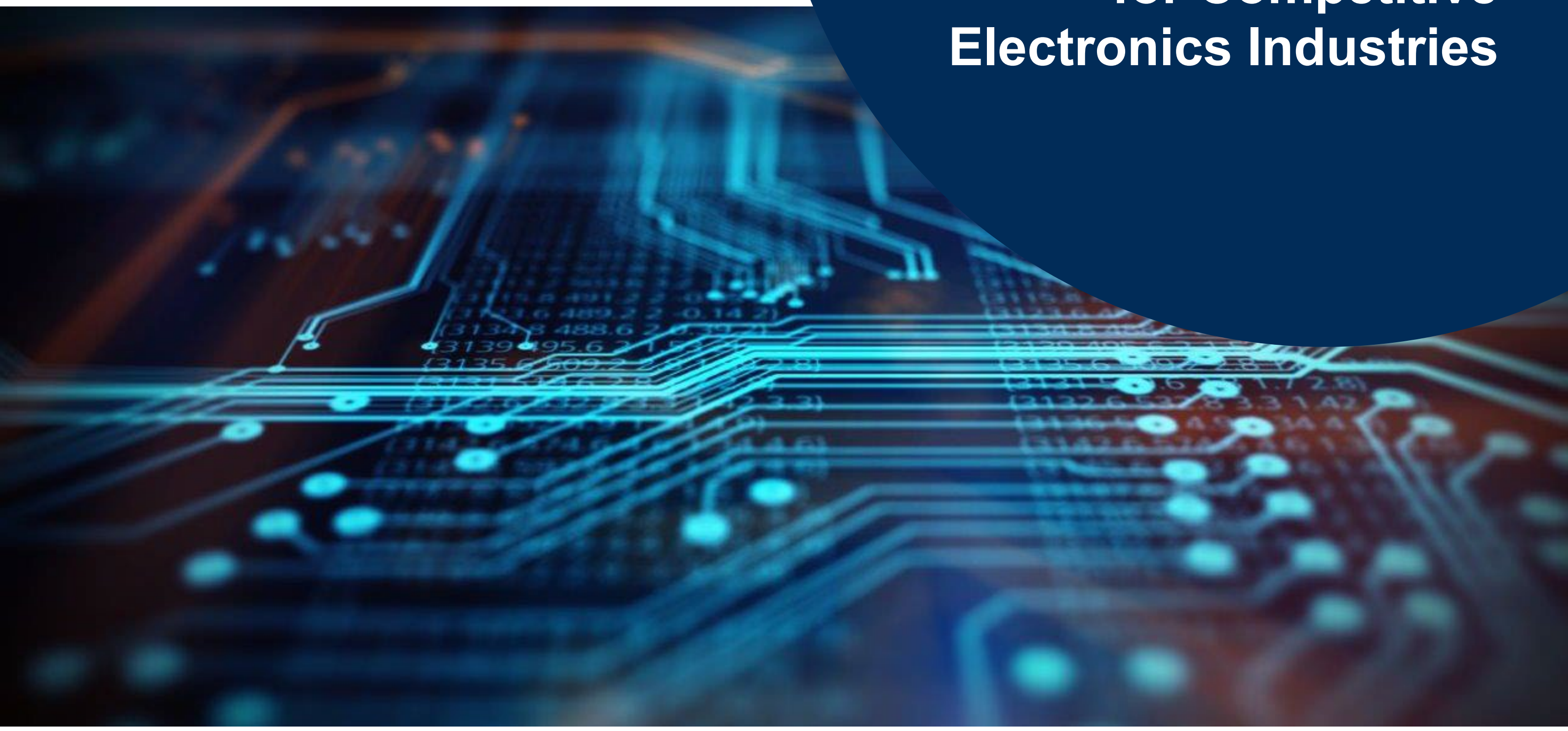
5E

Federating European Electronics Ecosystems for Competitive Electronics Industries



Catalogue of White & Grey Spots at the interfaces of the 3 electronics areas

Nanoelectronics – Flexible and Wearable Electronics – Electronic Smart Systems

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Context and Introduction

In view of the fierce global competition, decision makers in Europe acknowledge challenges that the electronics industry faces. The launch of large-scale investments and support measures to drive innovation, such as ECSEL, PENTA, IPCEI, are an important step in strengthening this key sector of the economy. Europe needs to define long-term visions and strategies for the whole European electronics industry in order to keep its competitive edge and foster value creation. A major contribution in this regard is the revision of the EC strategy on electronics. At the same time, digitisation of industry and society is a megatrend that urgently requires electronics as the hardware building blocks complementing and interacting with other areas like software, communications, computing, robotics and photonics.

5E underpins digitisation, and supports specifically the electronics industry in seizing opportunities by federating – not merging – the three European electronics ecosystems, namely Nanoelectronics (A1), Flexible and Wearable Electronics (A2) and Electronic Smart Systems (A3). Federation is being achieved by developing a joint vision based on the state of play and focusing on interfaces, as well as on opportunities for collaboration and cross-fertilisation. A technology and application meta-roadmap will be elaborated and implemented in the three electronics areas, in application sectors, in the areas of digitisation, as well as on the European and regional policy levels.

In a previous step, the 5E consortium analysed 11 application sectors that are key for the European Electronics industry. For each sector this analysis is structured along 6 functionalities – actuating, communicating, computing/processing, energy harvesting/storage, sensing, signalling – and provides technologies and applications currently available in the 3 electronics areas defined above. Together the resulting 11 so called “Sectorial States of Play” provide an overall landscape description.

From this landscape description, the 5E partners selected 33 topics of mutual interest between at least 2 of the 3 electronics areas. These “Grey Spots” are described in the present catalogue. In addition to a title that summarises the impact achieved by mastering the respective functionality in the respective sector, the one-page descriptions per Grey Spot covers information on technologies, applications, challenges and opportunities.

These Grey Spots are now being further qualified and validated by the Electronics Communities in order to be able to identify Sweet Spots for collaboration and cross-fertilisation between the three electronics areas, and based on this to define a joint vision for the European Electronics Industry.

The present catalogue is an excerpt from Deliverable D2.2 “White Spots at the interfaces of the 3 electronics areas” of the 5E project (GA825113).

Definitions:

- **White spots** are empty spaces where no evidence of electronics convergence is observable at the present stage but where creation of new opportunities & knowledge for electronics convergence should be investigated.

- **Grey spots** are populated spaces where electronics convergence is not organised yet but where identified sectors of applications could set the scene for such convergence.

- **Sweet spots** are white or grey spots, which show the highest promises in terms of electronics convergence on which the 5E project will focus to set a sectorial vision for electronics convergence.

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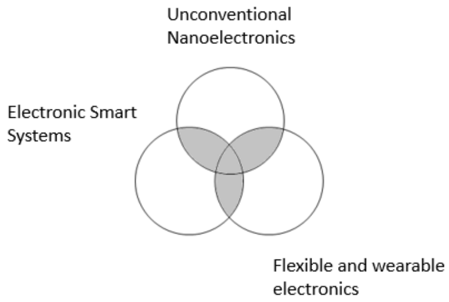
1 Methodology

1.1 Grey spots

As a whole, **33 Grey Spots (GS)** have been identified where A1, A2 and/or A3 have shown joint presence. An overview of all Grey Spots across sectors and product's functionalities is given in Table 1. All Grey Spots have been assigned with a title, which has been carefully worded to be understandable by a large audience in only one sentence. The detailed descriptions are uniformly formatted with wording including basic information on scope, technologies value, applications, challenges, coupling functionalities and opportunities. This catalogue constitutes a key input for the next step of the process as screening out Sweet Spots will rely on the cross-analysis of Grey Spots against scientific, technical, industrial, economic and societal criteria.

Please note that each Grey Spot is indexed with one letter indicating the sector of application and a running number within this sector. For instance D2 refers to the second Grey Spot in the "Digital manufacturing" sector. Please include this ID when commenting on a Grey Spot.

Table 1: 33 Grey Spots identified at A1/A2/A3 interfaces.



	(Aero)Space	Building / Construction	Consumer electronics	Digital Manufacturing	Energy	Environment	Food & agriculture	IoT/Smart connected objects	Medical / Pharmaceutical / Life science (*)	Natural resources	Packaging / logistics	Safety / Security	Transport / Mobility / Automotive (*)
Actuating			■	■					■				■
Communicating			■					■	■		■	■	■
Computing / Processing		■							■				
Energy harvesting / storage		■	■		■			■	■				■
Sensing		■	■	■		■	■	■	■		■	■	■
Signalling (optical Imaging, lighting)		■	■						■			■	■

1.2 White spots

White spots are the *empty spaces* where the 5E consortium has not found evidence of electronics convergence at the present stage but where creation of new opportunities & knowledge for electronics convergence could be investigated.

These new opportunities are not to be generated *ex-nihilo* but rather based to a large extent on the information gathered across the Grey Spots. These may share common needs & challenges across sectors of application, where 5E technologies could find new applications.

Hence, in a first step, white spots will be monitored during the Grey Spots workshop process as external inputs may turn certain of these white spots into grey. This means that new Grey Spots might appear in the current list while it passes through the Sweet Spots selection process.

In a second and later step, once the Sweet Spots are established, cross-sectorial opportunities will be sought to *activate* White spots, thus creating new fields for research & development in electronics where nothing is foreseen at the present stage.

1.3 Next steps

Information gained during dedicated workshops will help defining and applying scientific, technical, industrial, economic, societal criteria to this list of Grey Spots in order to be able to screen out Sweet Spots and setting up the final landscape for 5E Vision and Roadmap (Figure 1).

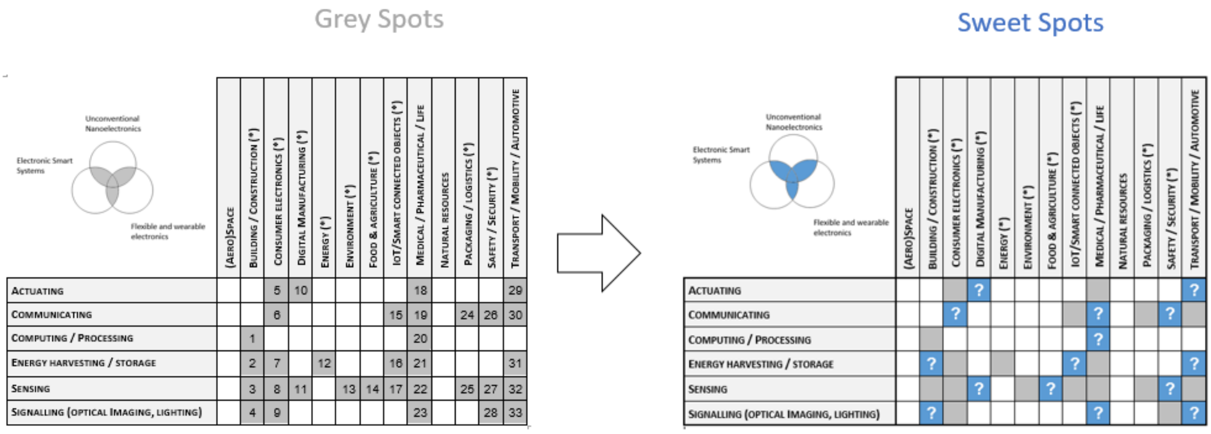


Figure 1: From grey to sweet spots.

Subsequently, and in alignment with strategic sources identified previously, Sweet Spots patterns will be established and a Meta Roadmap will be defined to realise the Joint Vision that will lead to:

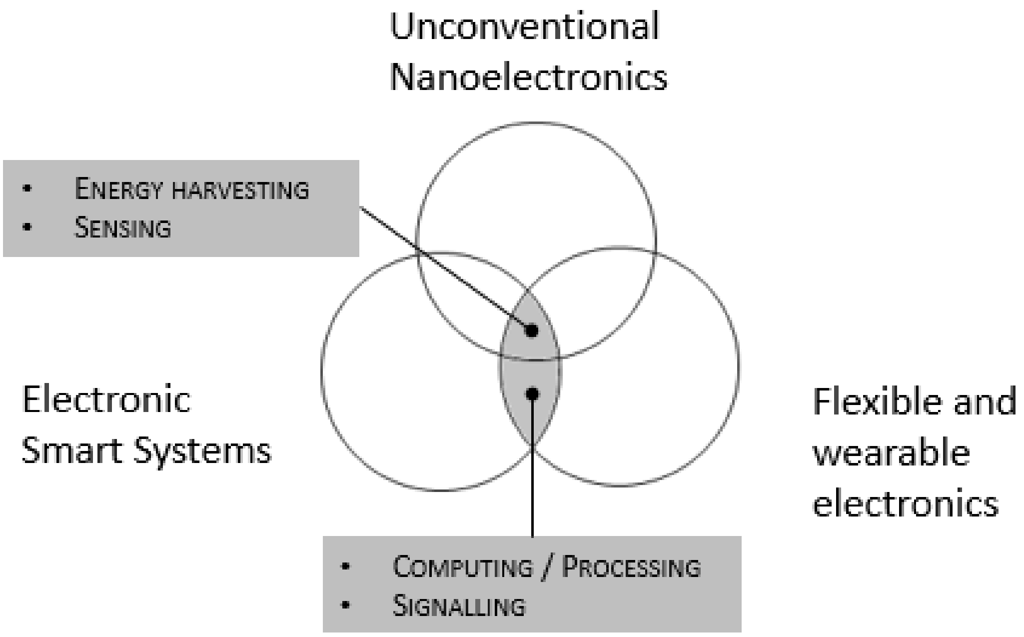
- **Widening the uptake & exploitation of key technologies across sectors and markets;**
- **Combining electronics technologies for Smarter Electronics Systems and new products;**
- **Truly benefit from hybrid integration based on joint development from components to systems by the three eco-systems.**

The Meta-roadmap will define required actions, support and cooperation to meet the great challenges and timescales to reach the Vision.

2 Grey Spots per area of application

2.1 BUILDING / CONSTRUCTION

Grey Spots at interfaces between the three electronics areas (see grey areas in the figure below) have been identified for buildings themselves as well as for their planning and construction.



B1 (Computing / Processing) – High-power and real-time computing facilities to support planning, construction, use and maintenance of buildings

B2 (Energy harvesting): Ubiquitous and reliable energy supply and harvesting technologies to achieve efficient construction, use and maintenance of buildings

B3 (Sensing): Low-power and energy autonomous sensing systems and IoT networks to monitor buildings with respect to their current status (structural health, user behaviour, occupancy, abrasion etc.)

B4 (Signalling): Increasing security and comfort of users of buildings with smart signalling solutions

B1: High-power and real-time computing facilities to support planning, construction, use and maintenance of buildings

Technologies / Value:

- Embedded: many networked devices are integrated into the environment
- Context aware: these devices can recognise persons and situational context
- Personalised: they can be tailored to specific needs
- Adaptive: they can change in response to persons or situations
- Anticipatory: they can anticipate desires or future situations without conscious mediation

Applications:

- Virtual and augmented reality techniques support architects as well as interior designers and town and country planning.
- Construction of buildings is directly and indirectly supported by improved computing facilities: Directly for example by the possibility that large functional and constructive parts of buildings as well as whole houses are additively manufactured in the meantime by use of various 3D-printing technologies (see D1). Indirectly for example by enhanced material scheduling and transport & logistics (see P1, P2, T2).
- Use and maintenance of buildings is based on appropriate sensing (see B3, I3) and communication systems (see I1), but the assessment of the signals and the pattern recognition is based on the access to high-power and real-time computing facilities.

Challenges:

- The challenges in this Grey Spot are not specific to the Building / Construction sector, but similar to those applying for every application based on high-power and real-time computing facilities (e.g. edge vs. cloud computing, bandwidth, latency, storage requirements etc.).
- A special challenge in buildings is the power supply (see B2, I2) and the wireless communication that might be limited due to (*reinforced*) concrete.

Coupling computing / processing with other functionalities: Computing and processing are to be taken into account nowadays and in future in many other functionalities usually addressed as “Smart Home / Smart Building”.

Opportunities:

1. **Smart Home / Smart Building sector as driving user platform for further developments in other application sectors**
2. **Further development in the high-power and real-time computing sector will directly influence Building / Construction specific applications as e.g. structural health monitoring**

B2: Ubiquitous and reliable energy supply and harvesting technologies to achieve efficient construction, use and maintenance of buildings

Technologies / Value:

- Low-power sensor systems for IoT
- Autonomous sensors harvesting ambient energy
- Smart building management

Applications:

This includes the complete or partial supply of,

- basic energy needs found in "every" building as e.g. electricity supply or heating/ hot water and air conditioning (HVAC)
- (additional) energy needed for application-inherent purposes (e.g. the energy to broadcast TV in case of a TV tower or the energy to open a gate for ships in case of a dam)
- additional energy needed for "smart" buildings as e.g. electricity supply for sensors and communication nodes to monitor presence/occupancy, intrusion protection or the physical health status of an office block, a bridge or a dam

Challenges:

The different "kinds" of energy needs as indicated in the above bullet points might vary according to different time-scales over the day, week and year. So it can be expected, that energy harvesting will not be able to satisfy every energy demand at every time. Other energy sources, energy storage and an energy management system will be needed.

Coupling *energy harvesting* with other functionalities:

Integrate e.g. photovoltaics into windows, roof tiles or facade installations, mechanical harvesters into floors or other construction elements.

Opportunities:

1. **Active energy management of buildings**
2. **Multi-purpose elements (energy harvesting and additional functionalities)**
3. **Transfer production (e.g. R2R manufacturing) or assembly (e.g. PV on facade) technologies designed for the building sector to other application domains**

B3: Low-power and energy autonomous sensing systems and IoT networks to monitor buildings with respect to their current status (structural health, user behaviour, occupancy, abrasion etc.)

Technologies / Value:

- Smart sensor systems for ubiquitous application
- (Wireless) communication techniques
- Networks of IoT integrated inside building environments
- Sensor systems harvesting the needed energy from the environment

Applications:

This includes sensors and sensor systems for

- Indoor monitoring (gas, temperature, humidity, energy consumption etc.)
- Control of structural integrity (stress/strain, vibration, inclination, material quality)
- Sensors to support the construction process of buildings (e.g. integrated in construction machines or construction materials)

Challenges:

Long-term stability of sensor elements (including long-term power supply), wireless communication, structural health monitoring including predictive assessment (detection of almost unnoticeable changes, recognition of failure patterns for early detection of emerging hazards). Find appropriate ab initio and retrofit solutions.

Coupling sensing with other functionalities:

Integration of e.g. humidity sensors into concrete or screed to allow monitoring of the maturation process, integration of sensors in constructive elements and combine them with actuator elements (adaptive construction)

Opportunities:

1. **Transfer sensor, harvesting and communication solutions developed and tested for the building sector to other application domains**
2. **Transfer monitoring and assessment techniques (algorithms, AI tools etc.) to other application domains**

B4: Increasing security and comfort of users of buildings with smart signalling solutions

Technologies / Value:

- Low-cost OLAE drive the uptake of affordable and easy to integrate signalling solutions
- Flat and flexible electronic elements are combined

Applications:

OLED Lighting (OLEDs are used to create digital displays in devices such as television screens, computer monitors, permanent or flexible signalling and signage).

FOLED (Flexible organic light emitting diodes) drive the combined functional and decorative lightning, especially in the smart building domain. Wallpaper FOLEDS are less than 5mm thin.

Organic solar cells or similar harvesting systems can be directly combined with OLED signalling (if needed with additional buffer element).

Challenges:

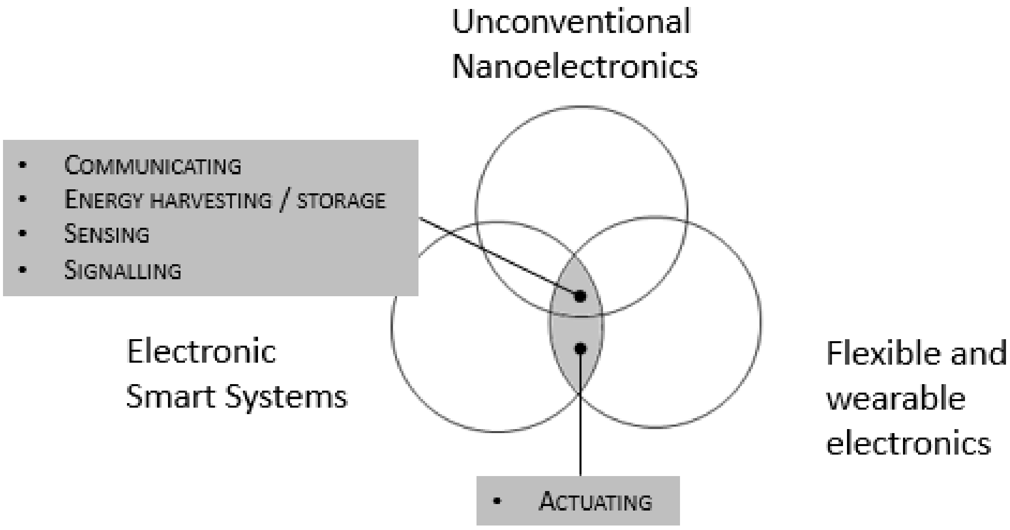
- Seamless integration of signalling / signage / display elements in building and their architectural design.
- Many signalling systems are also distributed systems, so the usual challenges for distributed systems have to be taken into account
- Buildings are long-lasting investments – so every electronic component has to be adapted to this situation, i.e. upgradable and/or interchangeable
- Electronic signalling is needed in any situation, so buffer batteries, UPS (uninterruptable power source) or alternative powering is needed

Coupling signalling with other functionalities: Modern OLED lighting is increasingly used to combine pure signalling functionality with decorative and architectural elements. Also pure functional lighting and signalling merge more and more, for instance in signage systems.

Opportunities:

1. **Products and Technologies Living-Labs speed up development and marketing of innovative products**
2. **Connected House and Smart Home solutions will increase the need for unobtrusive signalling solutions not impairing the comfort of the users**
3. **Indoor signalling solutions might be transferred to outdoor signalling and vice versa**

2.2 CONSUMER ELECTRONICS



C1 (Actuating): Actuating as a key functionality for enhancing Human Machine Interfaces (HMI), product value and enhancing users experience

C2 (Communicating): Independent high-speed connectivity and low-power communication for trusted nomad consumer solutions

C3 (Energy harvesting): Low-cost, reliable and recyclable energy harvesting & storage solutions for high-volume consumer electronics markets

C4 (Sensing): Solutions for reliable and sensitive multi-sensing and data fusion/exploitation algorithms for signals dynamic management

C5 (Signalling): Signalling displays compatibility for sustainable manufacturing in Europe

C1: Actuating as a key functionality for enhancing Human Machine Interfaces (HMI), product value and enhancing users experience

The next dimension in consumer electronics design will enliven user senses by combining natural touch, vibrations, sounds, and real-time surface deformation.

Technologies / Value:

- Thermoforming or in-Mould electronics
- Ink able to generate haptic feedback using piezo technology
- MEMS and MOEMS for digital micro mirror devices
- Electric, electroactive polymers, magnetic, hydraulic, thermic, electro-hydraulic and electro-mechanical actuators
- Eccentric rotating mass, linear resonant actuators, piezo actuators
- Air vortex rings, ultra sound for contactless haptic solutions

Applications:

- Gaming and virtual reality, sport, home appliances, personal and domestic robots

Challenges:
Major challenges related to Actuating in consumer electronics applications are:

- The integration challenge: combination of actuating with sensing and processing;
- The ethical & acceptance challenges in particular regarding health parameters;
- To reach the “ultimate display", more powerful haptic devices will need to be developed.
- Multidisciplinary approach is key.

Coupling with other functionalities:

- Actuating is an integral part of sensing and processing;
- Human Machine Interface (HMI) is the result of a smart interplay between Sensing, actuating and processing.

Opportunities:

1. **New generation of value product in gaming, sport, home appliance, personal and domestic robots, next generation of wearable/touchable devices**
2. **Consumer electronics products might irrigate the health sector**

C2: Independent high-speed connectivity and low-power communication for trusted nomad consumer solutions

The next dimension in consumer electronics design will enliven user senses by combining natural touch, vibrations, sounds, and real-time surface deformation.

Technologies / Value:

- NFC or RFID protocols;
- CMOS technology for circuit integration;
- SOI technologies with FET stacking architectures;
- 5G Applications: Log Range SIGFOX, LoRa outside, LTE-M inside for Outdoor Wireless applications;
- OLAE for RFID printed antennas;
- Acoustic sensors, NIR sensors;
- Multi-Hop-Networks.

Applications:

- Outdoor and Indoor applications, well-being applications, personal digital assistants, smartwatches, fitness trackers.

Challenges:
Major challenges related to communication in consumer electronics applications are:

- Integrity, confidentiality and accessibility to guarantee trust and secured communication;
- Interoperability of communications towards independent connectivity for nomad consumers.

Coupling with other functionalities: Communicating is an integral part of actuating, sensing and processing.

Opportunities:

1. **Trigger the development of manufacturing capabilities in Europe**
2. **Development of 5G wireless applications**
3. **Low-cost wireless communication solutions**

C3: Low-cost, reliable and recyclable energy harvesting & storage solutions for high-volume consumer electronics markets

The major factors driving the growth of the energy harvesting systems market include the growing demand for safe, power-efficient, environmentally friendly and durable systems that require minimum or no maintenance.

Technologies / Value:

- Power electronics;
- RF energy harvesting, wireless power transfer;
- Piezo-electric, electrostatic, electromagnetic transduction;
- Thermal and photovoltaic harvesting;
- Energy harvesting modules based on OPV;
- Thin-film batteries.

Applications:

- Outdoor and Indoor applications, well-being applications, home automation, mobile & wearables applications.

Challenges:
Major challenges related to communication in consumer electronics applications are:

- Replacing disposable batteries with wireless charging;
- Turning wired devices into wire-free versions;
- Reliability, cost and recyclability.

Coupling with other functionalities: Actuating, sensing and processing.

Opportunities: see Energy opportunities

1. **New approaches for energy harvesting & storage integration at component and system levels (two-in-one solutions)**
2. **Recyclable low-cost energy storage for mobile & wearable applications**

C4: Solutions for reliable and sensitive multi-sensing and data fusion/exploitation algorithms for signals dynamic management

Integrated sensors in consumer electronics are often closely related to well-being and wearable applications. Due to their compact size, reliability, low-power, performance and cost-efficiency, sensors have been widely adopted in consumers electronics applications.

Technologies / Value:

- MEMS sensing: accelerometer, gyroscope, pressure, temperature, humidity, acoustic, gas;
- Microcontrollers;
- Pressure sensors;
- ECG sensing;
- Electrochemical sensing;
- Bio-impedance sensors;
- Pulse-oximeter;
- Galvanic skin response.

Applications:

- Wearables, smart watches, intelligent clothing, sport gears, Human Machine Interface (HMI)
- Monitoring and analysing developing safety hazards

Challenges: Majors challenges related to sensing in consumer electronics applications are:

- Shrinking size and power of sensors;
- Multi-sensing systems;
- Sensing data fusion and data exploitation.

Coupling with other functionalities: Actuating and processing.

Opportunities:

1. **Build on the technologies spill-over effects of the adoption of sensors in automotive safety and wearable medical devices**
2. **Multi-sensing for security, safety prediction**

C5: Signalling displays compatibility for sustainable manufacturing in Europe

LED displays are becoming smaller while being integrated into various shapes. OLED will require technical breakthrough like passive components in order to be compatible with flexible design. Monitoring systems with signalling functions are emerging in the well-being domain and could lead to new products and services in the consumer electronics market.

Technologies / Value:

- LED and OLED displays;
- Hybrid system integration.

Applications:

- Whitegoods, luminaries, well-being, TVs;
- Wearable: smart watches, intelligent clothing, sport gears;
- Connecting people and places;
- Safety and security;
- E-textiles.

Challenges:
Major challenges related to signalling in consumer electronics applications are:

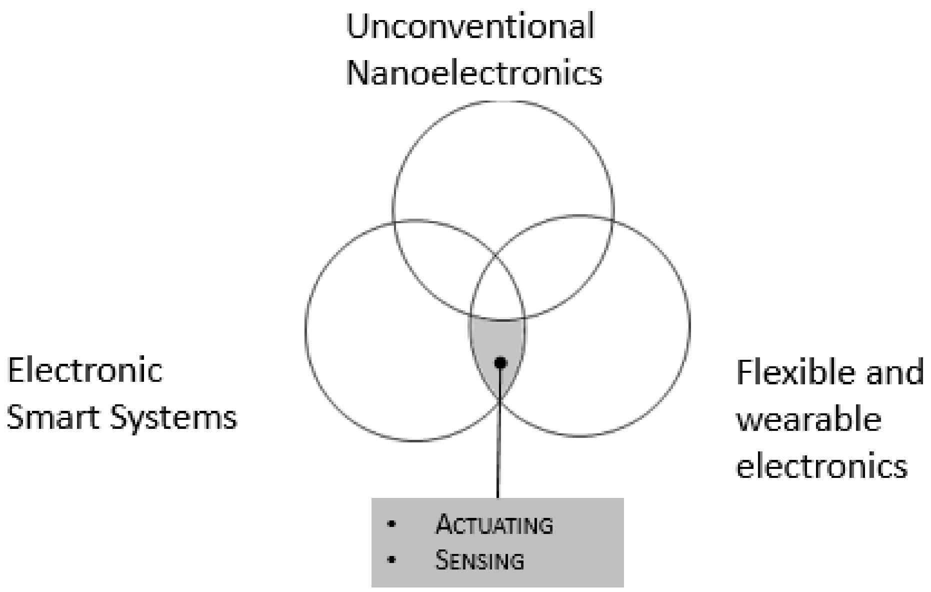
- Compatibility of components on flexible design to ensure less complexity in manufacturing;
- Seamless integration of displays in consumer electronics;
- Manufacturing cost.

Coupling with other functionalities: Sensing and processing.

Opportunities:

1. **Technological breakthroughs in flexible passive components, sensors, batteries New technological breakthroughs in flexible passive components, sensors, batteries and novel module designs**
2. **Hybrid system integration of printed electronics where OLAE can be a true enabler**

2.3 DIGITAL MANUFACTURING



D1 (ACTUATING): Actuating as key functionality for safe, efficient and optimised production processes in industry 4.0

D2 (SENSING): Next generation sensor systems for safe, efficient, optimised and self-enabled manufacturing

D1: Actuating as key functionality for safe, efficient and optimised production processes in Industry 4.0

Actuating is the counterpart of sensing at the opposite end of any control process, key feature in any automation process, and main driver for safety, efficiency and optimisation.

Technologies / Value:

- Electric, mechanical, magnetic, thermal, optical actuating within manufacturing processes, for HMI and assistive or collaborative robotics;
- Printed actuators;
- Advanced functionalised materials, e.g. advanced polymers.

Applications:

- Pick and place;
- Process step management;
- Configuration and calibration;
- Assistive and collaborative robotics;
- Implementation of safety aspects, preventive maintenance, resource efficiency and quality aspects.

Challenges:

- Energy efficiency, resource efficiency, real-time, response to digitisation;
- Lot size one vs. scaling-up and reproducibility;
- Self-organised and highly-flexible production and processes, and process optimisation;
- Advanced human-machine collaboration.

Coupling with other functionalities:

- In combination with sensing, processing and communicating for M2M, HMI, monitoring, closed-loop control and safety systems;
- In combination with signalling for quality control, maintenance and safety.

Opportunities:

1. **Mastering and transferring of actuating technologies and capabilities will make a valuable contribution to the digitisation of industry / Industry 4.0**
2. **Contribute substantially to multi-level efficiency and safety in manufacturing and in the process industry**

D2: Next generation sensor systems for safe, efficient, optimised and self-enabled manufacturing

Technologies / Value:

- MEMS, MOEMS, optical, chemical, electrochemical, magnetic, acoustic, inertial sensors for combinational sensing;
- Position, pressure, temperature, humidity, gas, acceleration sensors for multi-parameter sensing.

Applications:

- Monitoring of all relevant parameters at the level of equipment, machines, tools, parts, materials, workers, manufacturing environment and monitoring of processes;
- Delivering data for decision support in safe, efficient, optimised and smart manufacturing;
- Sensor systems for Industry 4.0.

Challenges:

- Combinational sensing, multi-parameter sensing and smart sensing;
- Interface with data processing and analytics, AI, software;
- Real-time.

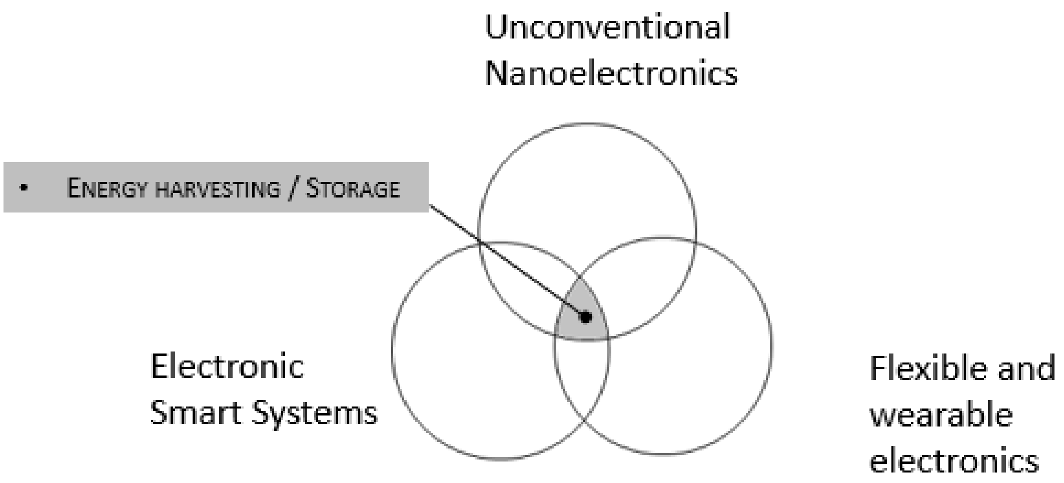
Coupling with other functionalities: Smart sensor systems for monitoring and control integrate sensing, processing, communicating and actuating

Opportunities:

1. **Next generation sensor systems will allow self-calibrating machines and tools as well as self-organised, self-learning and self-maintained manufacturing**
2. **Multi-level efficiency, safe production and overall process optimisation will be achieved thanks to the exploitation of combinational and multi-parametric sensing**

2.4 ENERGY

Technologies have been identified for **energy harvesting/conversion** or **energy storage** that distribute across the interfaces as follow:



N1 (ENERGY HARVESTING): High-yield energy harvesting approaches for replacing or reducing primary energy uses

N2 (ENERGY STORAGE): Flexible energy storage solutions with extended systems lifetime and multi-uses, including secondary use

N1: High-yield energy harvesting approaches for replacing or reducing primary energy uses

Technologies / Value:

- Several energy vectors: electric, piezo-electric, electrostatic, heat, light, chemical, magnetic, acoustic, mechanic;
- Large energy window: from mW (RF, piezo, electrostatic) to kW (e.g. PV module);
- Variety of transducer technologies for direct conversion of harvested energy (from any vectors) into electrical energy.

Applications:

- Generic by nature;
- Any applications in any sectors where energy is critical for the effective operation of a product and where fossil energy can be advantageously replaced or complemented.

Challenges:

- Selecting the best energy harvesting technology for a given application (e.g. harsh environment, remote sites) with high system/product integration level (energy vector, energy scale, reliability, lifetime & cost).

Coupling *energy harvesting* with other functionalities: energy storage, sensing, communicating for wireless sensors node (abandoned / remote sensors)

Opportunities:

1. **Energy harvesting as a (sole) primary energy source: roadmapping of technologies for self-powered products or product functionalities (e.g. PV for IoT)**
2. **Energy harvesting as a (significant) secondary energy source :** roadmapping of technologies for products with high harvested/primary energy substitution ratios and high CO_2 footprint reduction level (e.g. PV for street lighting, PV tiles)
3. **New approaches for energy harvesting and storage integration at system/component levels (two-in-one solution):** roadmapping of technologies for products with large energy autonomy and/or remote or low-accessibility needs

N2: Flexible energy storage solutions with extended systems lifetime and multi-uses, including secondary use

Technologies / Value:

- Two main energy storages: electric (capacitors) and electrochemical (batteries and supercapacitors);
- Energy & power windows: from mA.h/mW (e.g. microbatteries) to 10 A.h/kW (e.g. battery);
- Variety of technologies for static/dynamic storage.

Applications:

- Generic by nature;
- Any applications in any sectors where energy supply does not match energy demand limiting products performance.

Challenges:

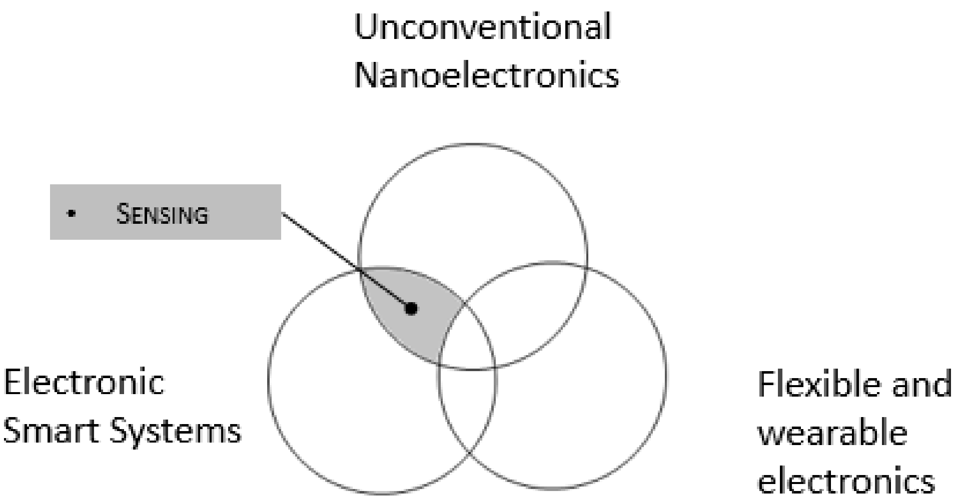
- Selecting the best energy storage technology for a given application with high system/product integration level (storage capacity, energy scale, reliability, lifetime & cost);
- Safety and recyclability are challenges to address.

Coupling *energy storage* with other functionalities: energy harvesting, sensing

Opportunities:

1. **Recyclable low-cost energy storage for mobile & wearable applications:** roadmapping of technologies for products with low-power and short-time storage (~few days) needs (e.g. printed batteries for smart textile)
2. **Re-usable high-capacity energy storage for transport and stationary applications**: roadmapping of technologies for products with mid/high power and mid-time storage (~few weeks) needs
3. **Smart energy storage management:** roadmapping of technologies for distributed & embedded sensing solutions to monitor storage performance & security (especially for Li-based storage)
4. **New approaches for energy harvesting and storage integration at system/component levels (two-in-one solution):** roadmapping of technologies for products with large energy autonomy and/or remote or low-accessibility needs

2.5 ENVIRONMENT



E1 (SENSING): Gas, pollutant, particle and waste monitoring solutions for healthy and safe working & living environments

E1: Gas, pollutant, particle and waste monitoring solutions for healthy and safe working & living environments

Technologies / Value:

- Wide sensing capability: physic-chemical sensors (T°, humidity, gas, particle) and optical sensors (gas);
- Sensors (physical) scale from nano to cm and from ppm sensitivity to qualitative (rain sensing);
- Smart sensor systems for indoor & outdoor air-quality monitoring.

Applications:

- Air-quality monitoring indoor (home, office, building…) & outdoor (city, countryside, factory, transport);
- Waste collection: waste track-and-trace.

Challenges:

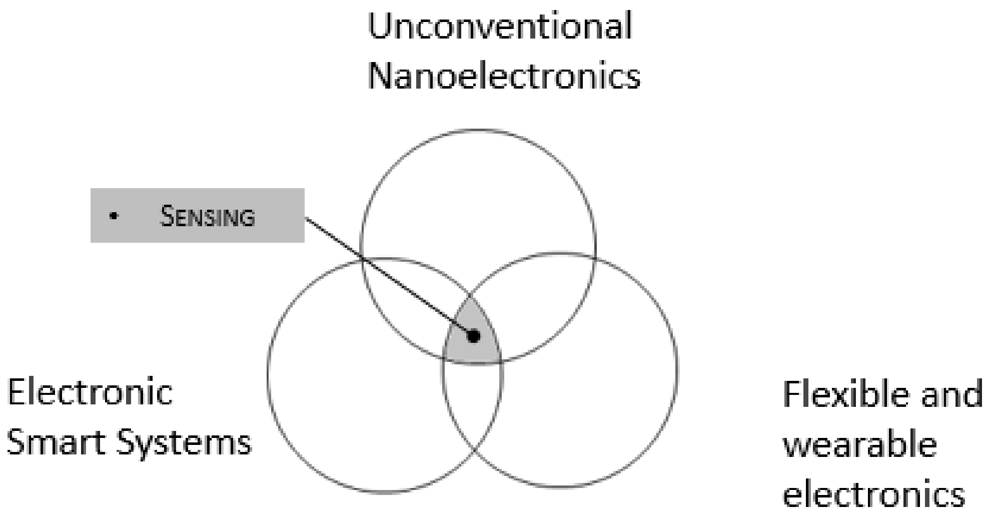
- Evaluate influence of the indoor / outdoor air-quality on people health;
- Long-term stability, robustness, sensitivity of sensors;
- Sensors integration into autonomous stationary or wearable systems: flexibility, stretchability, size;
- Wireless communication, secure data handling and management.

Coupling with other functionalities: communicating, energy harvesting

Opportunities:

1. **Autonomous sensing: implementing energy harvesting/storage solutions in sensors networks**
2. **Wireless/cloud communication hardware & protocols for environmental data transmission and management**
3. **Environmental monitoring and physiological sensing to correlate air-quality / health : diagnostic, prevention and prediction**
4. **Environmental/physiological sensors integration into wearables: new sensors with better flexibility, stretchability, conformability**

2.6 FOOD & AGRICULTURE



F1 (SENSING): Sensing for quality, safety and security tracing & monitoring along food value chains

F1: Sensing for quality, safety and security tracing & monitoring along food value chains

Technologies / Value:

- Wide sensing capability: time, physico-chemical (temperature, humidity, gas, integrity, freshness), optical (colour indicator), acoustic;
- Large portfolio of sensors with various sizes, form factors, sensitivity, sensibility, integrability level and cost.

Applications:

- Quality & security monitoring;
- Logistics track-and-trace.

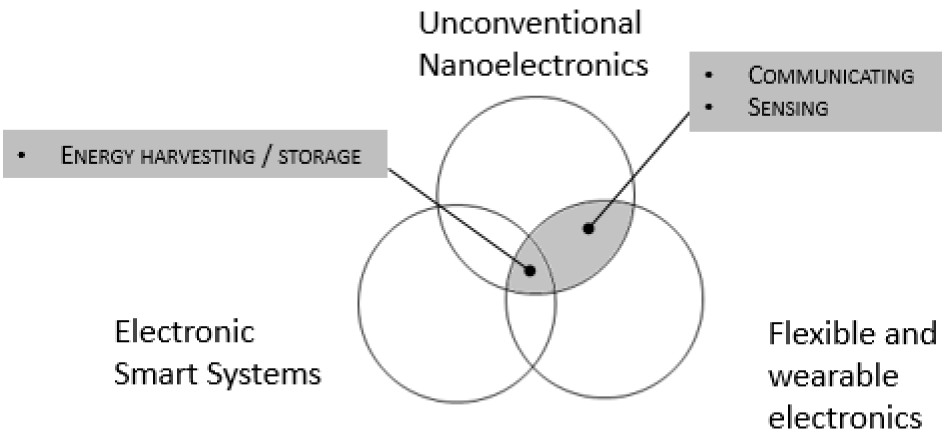
Challenges:

- Establish a set of protocols and regulations on the food security of IP implications;
- Passive sensing of eating behaviours in effective health intervention services as a mean of validating self-report measures;
- Providing personalised food based on a better understanding of ourselves/health and medical domain, implementation of coordinated traceability systems along the food supply chain;
- Combination of advanced models and AI-tools applied on collected data to support decision making;
- Ensuring high-security level in the management of data.

Opportunities:

1. **Development of a new generation of electronic devices to build future nanoprocessors, nanomemory, nanobattery and nanosensors**
2. **Printed electronics used to improve crops production**
3. **Passive sensing to self-report the caloric intake and eating behaviour**
4. **Smart systems for food quality and safety (e.g. smart sensor with diagnostic capabilities)**
5. **Given the vast economic scale of agricultural industry and current deployment of IoT devices for precision farming, the potential of deploying billions of systems for environmental monitoring is at the horizon**

2.7 IoT/SMART CONNECTED OBJECTS



I1 (Communicating): Efficient and secure protocols for high-data transmission rate of IoT devices

I2 (Energy harvesting / storage): Sustainable energy harvesting and energy storage solutions for low-power and autonomous IoT devices

I3 (Sensing): Multi-sensing capability to monitor complex environment via extended networks of connected devices

I1: Efficient and secure protocols for high-data transmission rate of IoT devices

Technologies / Value:

- Near-Field Communication (NFC) or RFID (Radio-Frequency Identification);
- Short-range communications: WBAN to WLAN through WSN for Indoor Wireless Application, ZiGBee and Bluetooth Low Energy (BLE) are the most commonly used standards;
- Long-range communications: 5G for wireless applications (in development) & Sigfox, LoRa outside, LTE-M inside, are used for the Outdoor Wireless Applications.

Applications: All IoT devices from physical world (persons, autonomous objects) to the cloud.

Challenges:

- Secure and reliable communications especially in consumer electronics, healthcare and industrial environment monitoring;
- High-volume data / high-transmission speed rate / Data fusion algorithms.

Coupling with other functionalities: sensing, processing and actuating

Opportunities:

1. **5G connectivity: increase data flows, security integration**
2. **Data / information security, privacy and data protection**

I2: Sustainable energy harvesting and energy storage solutions for low-power and autonomous IoT devices

Technologies / Value:

- Several natural energy vectors: electric, piezo-electric, electrostatic, heat, light, chemical, magnetic, acoustic, mechanic;
- Large energy window: from mW (RF, piezo, electrostatic) to kW (e.g. PV module);
- Variety of transducer technologies for direct conversion of harvested energy (from any vectors) into electrical energy;
- Low-power, low-consumption systems.

Applications: autonomous, wearable IoT devices / systems across all applications sectors

Challenges:

- Best match between energy harvester technology and environment energy sources;
- Long term stability and robustness of energy harvesting / storage components;
- Substitute battery;
- Low-power energy management;
- Environment sustainability and recycling of energy harvesting/storage components.

Coupling with other functionalities: communicating, sensing, actuating, computing

Opportunities:

1. **Multi-energy harvesting**
2. **High-yields energy harvesting and high-storage density technologies**
3. **Self-powered sensors and sensor networks**

I3: Multi-sensing capability to monitor complex environment via extended networks of connected devices

Technologies / Value:

- Wide sensing capability: physiologic (sweat, pH, ECG, blood pressure, pulse oximetry,…) physic-chemical sensors (T°, humidity, gas, particle) and optical sensors (gas);
- Sensors (physical) scale from nano to cm.

Applications: large domain of applications, in all sectors like well-being, industry performance, traveller experience improvement, safety in transportation or data exchange, energy prediction.

Challenge:

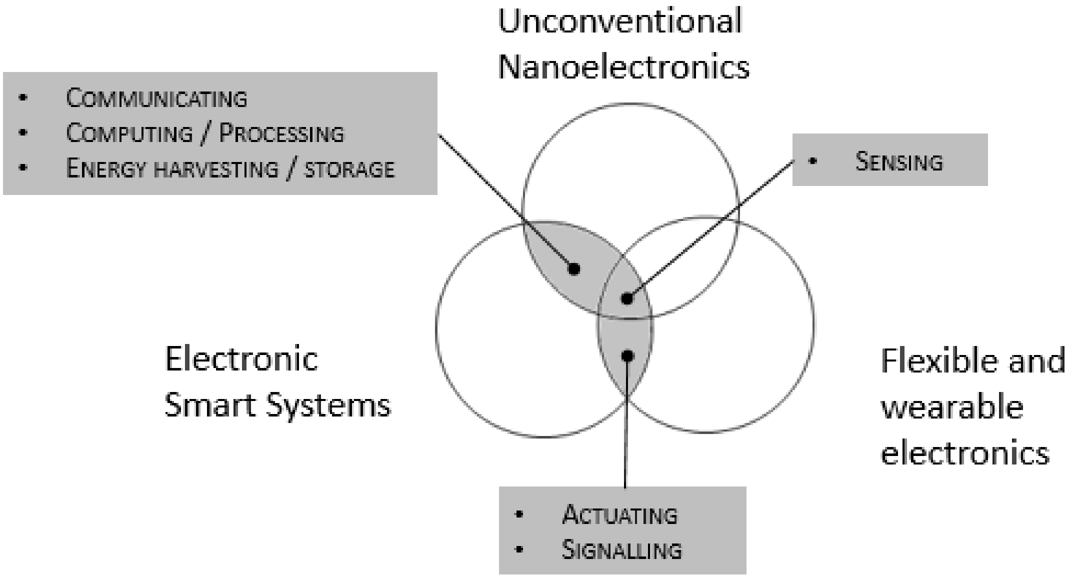
- Sensors capability and sensors interoperability depending on IoT product/environment cases (sizes, form factors, conformability, stretchability, environment, sensitivity, sensibility, integrability level and cost);
- Multi-sensors interconnectivity / sensors integration;
- Scaling-up and low-cost production.

Coupling with other functionalities: communicating, energy harvesting, actuating, computing

Opportunities:

1. **Novel sensing solutions for complex environment monitoring**
2. **Multi-sensors layouts and seamless integration of sensors in all objects and surfaces**
3. **Autonomous / Self-powered sensors and devices**
4. **(Wire)less communication: security and data management**

2.8 MEDICAL / PHARMACEUTICAL / LIFE SCIENCE



M1 (Actuating): Efficient, safe and integrated actuating to improve healthcare outcome and assist professionals with advanced automation and HMI

M2 (Communicating): High-performance and secure communication building blocks to increase autonomy and efficacy of electronic devices intended for medicine and healthcare

M3 (Computing / Processing): Advanced hardware/software processing for in-depth analysis of large and complex health-related datasets to improve decision-making and outcome of healthcare

M4 (Energy harvesting / storage): Combining energy harvesting, storage and efficiency to power complex, autonomous and interconnected medical & healthcare devices

M5 (Sensing): Disruptive & high-performance sensing capability as key enabler for Digital Healthcare and Well-being

M6 (Signalling): Advanced Signalling for immersive visualisation tools to improve interfaces with and proficiency of medical professionals

M1: Efficient, safe and integrated actuating to improve healthcare outcome and assist professionals with advanced automation and HMI

Scope: Actuating in medicine is not restricted to mechanical actuation but rather describes an electronic system's output and thereby how it is impacting its environment. This could happen through mechanical, electrical or optical means, for instance by providing a movement or a signal, by changing physical, chemical or biological properties (warming / cooling …) or by triggering an action. Actuating is decisive when it comes to treat diseases or disorders and to restore functionalities that may have been lost during or after a health event. At a larger scale, actuating is a fundamental building block for automation and robotics and thereby intrinsically linked to digitising healthcare.

Technologies / Value:

- Electric, magnetic, optical, hydraulic, thermic, electro-hydraulic and electro-mechanical, biochemical actuators;
- Electroactive polymers (artificial muscles, origami robots);
- Microfluidics, (micro)-pumps;
- Light and in particular Laser (in range 450–495nm for thermotherapy for instance);
- Closed loop control.

Applications:

- Ex- and in-vivo therapies and interventions (surgery, electroceuticals, theranostics, phototherapy);
- In-vitro processes (3D-Cell Printing, microfluidics, organ-on-chip);
- Prosthetics & implants (artificial limbs, muscles, organs), (tele-)rehabilitation (exoskeletons, robots), monitoring.

Challenges: Majors challenges related to Actuating in the Medical and Life Science sector are:

- Energy supply: powering actuators demands more power than for sensors, i.e. powerful, low voltage, ultra-low consumption;
- Integration: provide bio-inspired / hybrid / biocompatible / miniaturised actuators;
- Close-loop: reach high-degree of fusion between sensing, processing and actuating for close-loop systems with high reactivity, precision, efficiency and safety;
- Security: guarantee that actuation is hack-proof or cannot be hijacked.

Coupling with other functionalities: Actuating is often linked to automation and/or remote actuation, meaning requiring coupling with sensing, processing, communicating, signalling and energy. Furthermore interfaces (Machine2Machine or Human2Machine), monitoring activities and close-loops are resulting of a smart interplay between sensing, actuating and processing.

Opportunities:

1. **Increasing need for automation in Healthcare**
2. **Need for more natural, cognitive Human-Machine-Interfaces**
3. **Advances in Materials research and Robotics for new form factors in actuation**

M2: High-performance and secure communication building blocks to increase autonomy and efficacy of electronic devices intended for medicine and healthcare

Communicating is key for self-sustainability or autonomy of smart medical / well-being devices to safely handle high volumes of data as part of networked systems, including CPU and data storage. Furthermore, miniaturisation, in-vivo interventions and autonomous modes increasingly require remote control enable through embedded wireless communication modules. Digitising healthcare can only be achieved with high-performance and secure communication building blocks.

Technologies / Value:

- Short-range communications: ZiGBee and Bluetooth Low Energy (BLE) are the most commonly used standards;
- Long-range communications: SigFox, LoRaWAN and NB-IoT are the most commonly used standards for Low-Power Wide-Area Networks (LPWANs). The deployment and integration of 5G technologies is highly expected to generalise digital health;
- Specific electrodes technologies used at the neurointerface to provide new forms of Human-Machine communications.

Applications:

- Body area networks;
- Monitoring and diagnostics applications, control;
- Data exchange with intracorporeal, implanted, wearable devices and robots (assistive, interventional, rehabilitation…).

Challenges:

- Communications in Healthcare must be safe, secure and reliable;
- Nanoelectronics specific challenge: high-volume, low-cost communications with embedded hardware security and safety features;
- Communicating at the neurointerface to advance Human2Machine and Machine2Machine interfaces.

Coupling with other functionalities: sensing, processing and actuating for monitoring or automation applications and remote control of devices.

Opportunities:

1. **Future deployment of 5G offers new opportunities in healthcare, in particular transmitting huge amount of data with high speed (1 Gbps), low power and low latency (1ms or less)**, which is a prerequisite to generalise tele-surgery, -medicine and –rehabilitation
2. **Mastering communication at the neurointerface can change the way Human2Machine interfaces are designed and implemented**

M3: Advanced hardware/software processing for in-depth analysis of large and complex health-related datasets to improve decision-making and outcome of healthcare

The large number of health-relevant parameters and the trend towards personalised medicine makes *BigData* a key topic in healthcare. The ever increasing amount of data for effective decision-making in diagnoses, treatments and rehabilitations requires advanced computing. Even if a strong focus is set on software, the heterogeneity of data and devices, the need for immediate processing and data safety also require advanced hardware.

Technologies / Value:

- Chip design & hardware for high-performance computing, Artificial Intelligence on chip;
- Advanced memory modules for knowledge based tools;
- Machine-learning, pattern recognition, prediction.

Applications:

- Close-loop systems for partly or fully-automated tasks (robotics, prosthesis, monitoring);
- Sensors and data fusion (imaging, diagnostics);
- Preventional & predictive medicine;
- Advanced in-silico & pharmacokinetic models (simulation, organ-an-chip);
- Advanced HMI.

Challenges:

- Scales and variety in data, devices and standards represent a major challenge, notably for processing time and “embeddability”;
- Safety, security, reliability: data processing shall be at any point of the process guaranteed safe, secure and reliable;
- Ethical & acceptance aspects, notably regarding reliability and liability of decisions made by AI.

Coupling with other functionalities: Computing processing is a fundamental chain-link between sensing and actuating in order to adapt actuation to the situation (close-loop, monitoring, robotics), but as central unit, it has connections to all other functionalities.

Opportunities:

1. **Digitising healthcare and access to new health-relevant big data (genome or behaviour for instance) to develop AI-embedded chips to improve decision-making or automation in healthcare**
2. **Coupling with well-being and consumer electronics opens up new markets**

M4: Combining energy harvesting, storage and efficiency to power complex, autonomous and interconnected medical & healthcare devices

Powering electronic systems in medicine is a crucial issue, notably the capability towards energy autonomous systems. This capability encompasses combination(s) of energy conversion, energy transfer, energy storage and energy efficiency.

Technologies / Value:

- Exoenergetic Biochemical processes (Biomimicry), glucose biofuel cell;
- Mechanical, thermal, optical, biological harvesting (piezo-electric, capacitive, magnet, thermoelectric semiconductors, photovoltaics);
- Wireless energy transfer / Wireless power supply (resonant magnetic coupling, light).

Applications:

- Low-power and autonomous systems (e.g. embedded, implantable, wearable devices).

Challenges:

- Life-long energy autonomy for implantable devices;
- Battery-free powering for medical wearables;
- High-density energy storage;
- Low-powering approaches for energy consuming functionalities like actuating or communicating;
- Safety for users (professionals, patients): use of non-toxic material, safe radiations, recyclable products.

Coupling with other functionalities: energy is of particular relevance for actuating and communicating which are both energy demanding.

Opportunities:

1. **As a cross-sectorial common need, combination of energy harvesting, energy storage and energy efficiency is key to develop new systems with ever increasing complexity, autonomy and interconnectivity. Which is presently the case in health and medical applications where such systems are emerging**
2. **Energy/power supply in health & medicine can benefit indirectly from large investments at European level in battery manufacturing and in nanoelectronics**

M5: Disruptive & high-performance sensing capability as key enabler for Digital Healthcare and Well-being

Decision-making in Digital Healthcare requires systematic collection of high-quality data which are many and various, intricately interdependent, specific to individuals and fluctuate over time. Hence, versatile technologies are needed to provide professionals with critical information for decision-making. Today, sensing in medicine enables precise and early diagnostics based on physical and biological parameters (ECG, imaging, –omics…) and support personalised treatments. Recent digital tools add another dimension to sensing by accessing behaviour-related data or by enabling data fusion.

Technologies / Value:

- High-sampling rate sensing for real-time measurement to cope with huge amount of parameters and enable sensing at the Point-of-Care (PoC) and Point-of-Need (PoN);
- High-performance sensing to increase sensitivity;
- Multiplex integration to manage the broadband of parameters: biochemical (oxygen, biomarkers, glucose, cholesterol, DNA), physical (temperature, strain, flow, pressure, ...), imaging, background (genetic, epidemiologic , environmental), …;
- High product integration, advanced electronic packaging for contactless, mini- and non-invasive, painless sensing.

Applications:

- Health, well-being, in-vitro & in-vivo diagnostics;
- Imaging, theranostics, prosthetics & implants, rehabilitation, home-care;
- Sensing is a pre-requisite for (tele)monitoring (close-loop functions), automated tasks (medical robotics), functionalised tools (in surgery for instance).

Challenges:

- Sensing new parameters: enriching databank for decision-support with access to new parameters, for instance molecular imaging, DNA/protein assays;
- Improving current sensors to gain in sensitivity, real time and multiplex capacities;
- 3D-sensing, linked to 3D visualisation using notably augmented / virtual reality;
- Sensor integration & fusion: new form factors, integration in product design, increasing biocompatibility, integration of embedded pre-processing capacities;
- Autonomous sensing: energy self-sufficient, connected, non-invasive;
- Industrialisation issues: reduce production costs / increase volume, disposable sensing, recyclability, accessibility.

Coupling with other functionalities: with actuating for theranostics; with actuating, processing and energy for complex multifunctional perception systems, self-learning, pattern recognition, adaptation to human body; with actuating, processing, energy, communicating and biohybridisation to provide human-like perception, full interfacing with body & high cognitive functionalities.

Opportunities:

1. **Disruptive & high performance sensing capability as key enabler for Digital Healthcare as sensing is fundamental**
2. **Health & medical Big Data combination with AI for decision-making**
3. **Including well-being in healthcare process: more prevention, prediction and personalised medicine require sensing to continuously access individual data**

M6: Advanced Signalling for immersive visualisation tools to improve interfaces with and proficiency of medical professionals

Signalling encompasses topics such as advanced (displays, OLED, …) and immersive (augmented / virtual reality) visualisation tools. Signalling is therefore an important building block for simulation tools to provide total immersion and increase proficiency of medical professionals.

Technologies / Value:

- Flat and flexible electronics for OLED lighting & displays, integrated photonics for LEDs and lasers;
- Technologies for immersive visualisation, augmented / virtual reality;
- Biochemical signalling (biomimicry, biomarkers, active compounds).

Applications:

- Surgery: Virtual operation theatres, advanced simulation tools;
- Advanced HMI;
- Imaging and diagnostics;
- Prosthesis / exoskeletons.

Challenges:

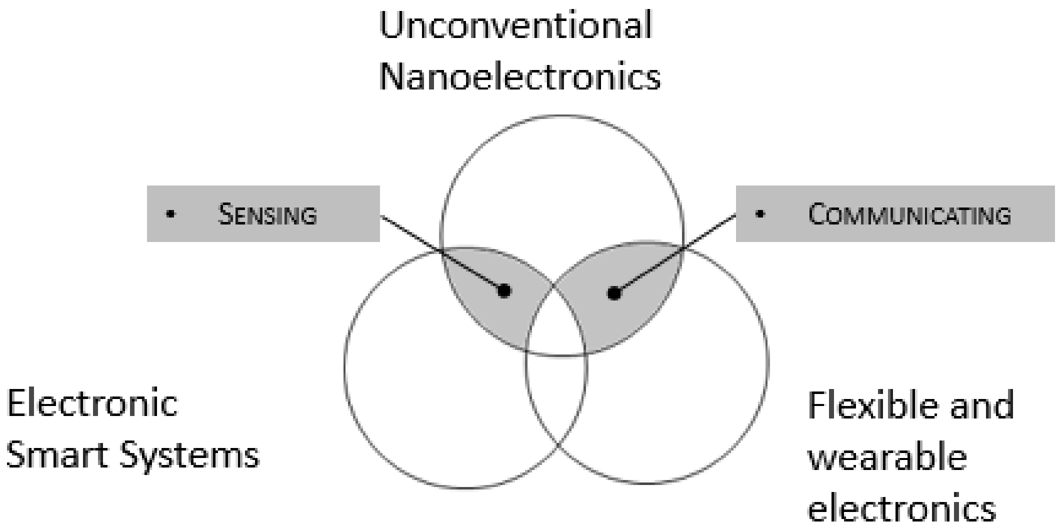
- Render complexity and multiplexity of medicine in a way to increase decision-making and proficiency of medical professionals.

Coupling with other functionalities: Signalling requires strong coupling with sensing and actuating in order to improve immersion

Opportunities:

1. **Transfer of advances in consumer electronics & IOT covering well-being and medical applications to fertilise medicine**
2. **Regulations assessment & recommendations to ease the entrance of innovative technologies on the market of digital health, well-being and medicine**

2.9 PACKAGING / LOGISTICS



P1 (Communicating): Secure data/information wireless transmission in packaging/labels for goods interconnectivity and e-services

P2 (Sensing): Multi-sensing, data fusion and management in packaging/labels for goods interactivity and e-services

P1: Secure data/information wireless transmission in packaging/labels for goods interconnectivity and e-services

Technologies / Value:

- Near Field Communication (NFC), Radio-Frequency Identification (RFID), UHF RFID protocoles;
- Solutions for printed antennas, printed / hybrid NFC/RFID modules, associated circuitry.

Applications:

- Anti-counterfeiting & brand protection, retail sector, tracking goods, ticketing, printing industry, food quality & safety.

Challenges:

- Scalability, miniaturisation, adaptability, manufacturability, integration, complexity, and high technical yield at low cost;
- Recyclability & waste streams.

Coupling with other functionalities: sensing

Opportunities:

1. **Low cost wireless communication solutions with high adaptability & reliability:** pushing technologies design & integration across products format (e.g. credit card, paper label, token…) and applications type (e.g. packaging, labelling, ticketing, printings…)
2. **Smart communicating packaging/labels:** integrating communication inside sensing solutions (P2) for interfacing packaged/labelled goods with suppliers & users (e.g. food quality & freshness monitoring)

P2: Multi-sensing, data fusion and management in packaging/labels for goods interactivity and e-services

Technologies / Value:

- Wide sensing capability: time, physico-chemical (temperature, moisture, gas), mechanical (touch, motion), optical, acoustic;
- Large portfolio of sensors across the 3 areas with various sizes, form factors, sensitivity, sensibility, integrability level and cost.

Applications:

- Goods content, quality & security monitoring, anti-counterfeiting & brand protection, logistics track-and-trace.

Challenges:

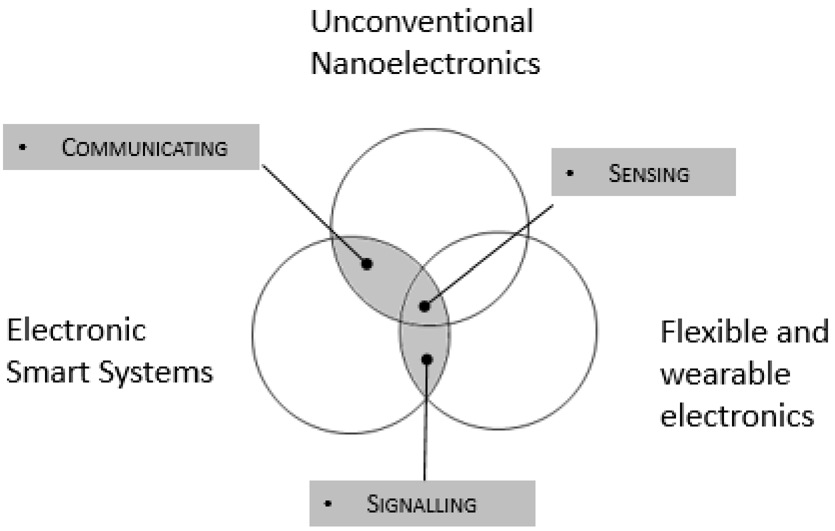
- Selecting the best sensing strategy for a given application (sensor type, selective / sensitive sensing, single/multi-sensing, sensing layout, sensors data management & algorithms (data sampling, fusion, interpretation), cost of overall sensing solution);
- Bio-degradability, biocompatibility and recyclability of sensors are also challenges to address (e.g. in food packaging);
- Recyclability & waste streams.

Coupling with other functionalities: energy autonomy (harvesting & storage), interactivity (communicating & signalling)

Opportunities:

1. **Low-cost single-signal sensing for common goods packaging/labelling:** roadmapping of technologies for goods packaging with sensitive sensing / large volume markets. (e.g. food packaging, anti-counterfeiting)
2. **Multi-signal sensing for specific goods packaging/labelling:** roadmapping of technologies for high reliability sensing solutions (e.g. security, safety, medical)
3. **Solutions for signals management:** roadmapping of technologies for read out signals and signals transmission

2.10 SAFETY / SECURITY



S1 (Communicating): Secure data transfer technologies for flexible and adaptable IoT systems to enable trusted solutions in data communication, across wireless standards and applications

S2 (Sensing): Sensors systems with a "trusted label" for people and goods protection to be easily integrated into products

S3 (Signalling): Creating visibility or convey information as informative or preventive action to promote effective operation and physical safety

S1: Secure data transfer technologies for flexible and adaptable IoT systems to enable trusted solutions in data communication, across wireless standards and applications

Technologies / Value:

- Flexible and adaptable IoT and System of Systems connectivity security technology (including over time);
- Engineering tools reducing security deployment, operations, and maintenance;
- Open security and integration frameworks and platforms.

Applications:

- Data communication security across wireless standards and applications.

Challenges:

- Ensure data protection at an appropriate level for each user and functionality regardless of technology;
- Hardware implementations enabling individual system/product specific physically unclonable function (PUF);
- Security semantics;
- Autonomous translation in connectivity chains and networks;
- Enabling IoT and SoS security evolvability over both time and technology generations.

Coupling with other functionalities: computing, sensing

Opportunities:

1. **Advance the European position with respect to US as present leader based on EU's leading role in 5G**
2. **High-volume data management at increasing numbers of IoT systems**
3. **Significant reduction in engineering cost of connectivity chains and networks**
4. **Leading in providing solutions for End-of-Life to End-of-Support functionality**

S2: Sensors systems with a "trusted label" for people and goods protection to be easily integrated into products

Technologies / Value:

- Wide range of sensor solutions: MEMS, OPD, lidar, imaging, chemical for e.g. motion, pressure, air composition, drugs, explosives;
- Methodical approach to sensor IT-security: risk management, countermeasures, removing vulnerability.

Applications:

- Safety & security of people and goods;
- Data security evaluation & Certification.

Challenges:

- Robust and affordable solution for safety critical applications;
- Maintaining secure & safe sensors system functionality from date-of-sale to end-of-life;
- Sensor systems represent a growing well known risk as end-node security is often poor and numbers of systems are increasing rapidly;
- High volume devices: availability of manufacturers and OEMs.

Coupling with other functionalities: communicating, computing

Opportunities:

1. **Sensor Systems with a 'Trusted label' represent a great opportunity for European companies**
2. **Providing a safe environment that prevents harmful situations**
3. **Safety, security and privacy cannot be plugged in 'at a later stage'. Rooting it in to the foundations now creates a clear advantage later.**

S3: Creating visibility or convey information as informative or preventive action to promote effective operation and physical safety

Technologies / Value:

- Flexible lighting systems in clothing;
- Structural electronics.

Applications:

- Creating visibility as preventive action for physical safety;
- Displaying relevant information.

Challenges:

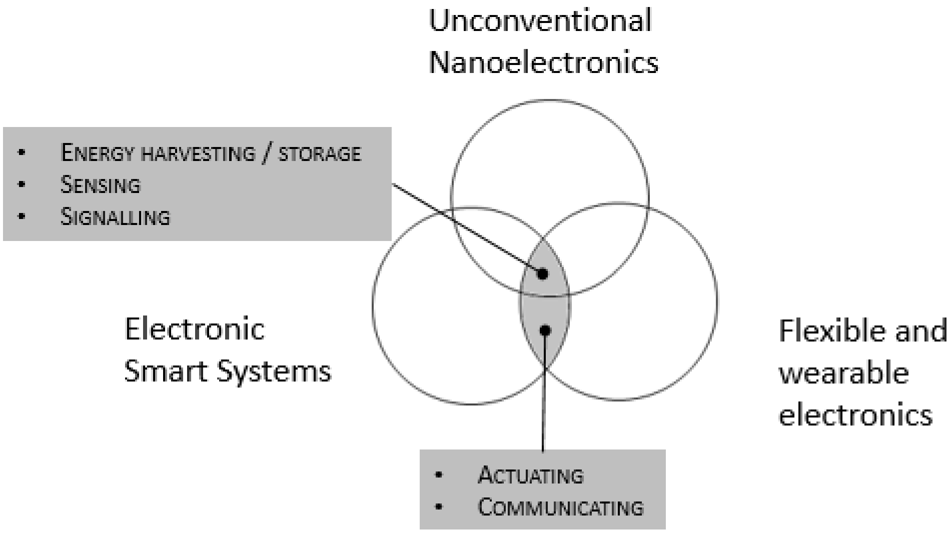
- Endurance during use;
- Washability of technologies.

Coupling with other functionalities: communication, computing

Opportunities:

1. **Functional professional clothing to convey peoples role or adapt in function of changing conditions**
2. **Reduce accidents (e.g. increase pedestrian, runner, cyclist visibility)**

2.11 TRANSPORT / MOBILITY / AUTOMOTIVE



T1 (Actuating): Seamless integration of actuators, in car interiors for human-machine interaction

T2 (Communicating): Technologies to secure data transfer and enable trusted solutions for people and information in car2car communicating for autonomous / self-driving vehicles

T3 (Energy harvesting / storage): Low-power loss and energy harvesting for emission and CO_2 reduction in electrical driving

T4 (Sensing): Novel sensors to act on changing situations in surrounding, varying from traffic, weather, … to assist in ADAS (autonomous driving assistance system), safety and power consumption

T5 (SIGNALLING): Seamless integration of displays for human-machine interaction and signalling

T1: Seamless integration of actuators, in car interiors for human-machine interaction

Technologies / Value:

- (Printed) haptic feedback actuators;
- Close-loop control;
- Electric, magnetic, hydraulic, electro-hydraulic and electro-mechanical actuators;
- Adaptive systems (aerodynamics, acceleration, breaking);
- Reaction to signalling / speed limits etc. (motor control, steering control, break control).

Applications:

- Dashboards, driver control, sensor systems, adaptive systems …;
- Autonomous driving: Act on changes in the surroundings, varying from traffic, weather and changing situations. Inform driver of these changes, give feedback on activities (e.g. haptic switches), assist in autonomous driving assistant system (ADAS), environmental control issues.

Challenges:

- Integration, lamination of haptic solutions;
- Creating actuators that are complying to automotive standards;
- Product integration (form factor, encapsulation, size limitation).

Coupling with other functionalities: sensing, computing, communicating, signalling

Opportunities:

1. **Integration of novel functionalities in ADAS in order to notify and act on changing conditions while driving**
2. **Integration of haptic, signalling functions into car interiors by structural electronics to decrease costs and allow form factor freedom**
3. **Actuators to decrease environmental pressure at changing conditions on a very localised level such as a car**

T2: Technologies to secure data transfer and enable trusted solutions for people and information in car2car communicating for autonomous / self-driving vehicles

Technologies / Value:

- (Printed) antennas;
- Mobile / wireless communication;
- In-vehicle communication;
- Real-time communication & real-time interaction car2car / car2x (influence streetlamps, pass taxis or buses, find parking sites).

Applications:

- Car2car communication;
- Autonomous driving cars;
- real time action, small form factors, 3D antennas, 5G.

Challenges:

- Data transport;
- Coverage;
- Integration, lamination and curvature;
- 5G coverage.

Coupling with other functionalities: sensing, computing, communicating, signalling

Opportunities:

1. **Data for ADAS needs to be secured and non-breachable and able to compute (and communicate) very fast. Thereto novel safe electrics need to be developed**
2. **Sensor data needs to be secure and safe. This involves sensor design and computed data**

T3: Low-power loss and energy harvesting for emission and CO_2 reduction in electrical driving

Technologies / Value:

- PV, Commercial devices c-Si cells;
- Thermal energy harvesting;
- Piezo-electricity with mechanical harvesting;
- Miniaturised Electromagnetic harvesters;
- MEMS electromagnetic harvesters;
- Energy conversion;
- Batteries.

Applications:

- Power car (engine);
- Remote sensor systems;
- Energy for autonomous sensors (independent to engine).

Challenges:

- Power management;
- Yield, Effectiveness;
- Battery lifetime and capacity.

Coupling with other functionalities: sensing, computing, communicating, signalling, actuating

Opportunities:

1. **Energy consumption in a car must be minimised at all times. Energy harvesting can be a novel route to reduce power consumption**
2. **IoT often requires (minimal levels of) power. In remote and hard to reach areas (e.g. in the engine area), the IoT devices can be powered through energy harvesting**
3. **Autonomous sensors fully embedded into a product will be powered by energy harvesting**

T4: Novel sensors to act on changing situations in surrounding, varying from traffic, weather, … to assist in ADAS (autonomous driving assistance system), safety and power consumption

Self-driving cars: Act on changes in the surroundings, varying from traffic, weather and changing situations. Human-machine interfaces inform the driver of these changes, give feedback on activities (e.g. haptic switches), assist in autonomous driving assistant system (ADAS), environmental control issues.

Technologies / Value:

- MEMS accelerometers, magnetic, chemical and gyroscopes), industrial (image sensors), infrastructures (air quality gas sensors) and defence (LiDAR sensors), electric, magnetic;
- Hydraulic, electro-hydraulic and electro-mechanical sensors and actuators;
- Adaptive systems (aerodynamics, acceleration, breaking);
- Reaction to signalling / speed limits etc. (motor control, steering control, break control);
- LIDAR, radar and cameras for lane control, level 2 automation, environment recognition;
- Accelerometers, GPS-navigators;
- Data fusion.

Applications:

- MEMS devices are extensively used in cars for airbag sensors, electronic stability control, tire pressure monitoring, fuel injector pressure sensors, roll over detection sensors, vehicle dynamic control VDC sensors, throttle position sensors and other safety features.

Challenges:

- Integration, lamination of sensors;
- Sensors capability and sensors interoperability complying to automotive standards;
- Product integration (form factor, encapsulation, size limitation).

Coupling with other functionalities: sensing, computing, communicating, signalling

Opportunities:

1. **Integration of novel sensors in the ADAS in order to notify and act on changing conditions while driving**
2. **Integration of sensors into car interiors by structural electronics to decrease costs and allow form factor freedom**
3. **Sensors to monitor environmental concerns on a very localised level such as a car**

T5: Seamless integration of displays for human-machine interaction and signalling

Technologies / Value:

- Structural electronics to adjust form factor;
- OLEDs (display and lighting);
- Vehicle positioning tracking;
- Optical, acoustic and sensorial warning systems e.g. real-rime actuation at the level of the steering wheel, the motor, drive-train and brakes;
- Position sensors and accelerometers for lane-position control, steering wheel movements;
- Vital-parameter sensing for automated cars (level 2 automation) to see, if driver can take back control;
- Warning systems for pedestrians (level 2 automation).

Applications:

- Interior, lighting, displays, Power car (engine), camera for eye tracking (Drowsiness-detection), machine-vision for lane position.

Challenges:

- Power management;
- Yield, Effectiveness;
- Battery lifetime and capacity.

Coupling with other functionalities: sensing, computing, communicating, signalling, actuation

Opportunities:

1. **Integration of PV, energy harvesters etc. to minimise the energy usage of a car**
2. **Seamless integration of IoT solutions in (automotive) structures to minimise space at low costs**
3. **Autonomous sensors that are integrated into the car to allow self-driving**

5E

Federating European Electronics Ecosystems for Competitive Electronics Industries

- ◊ ***Nanoelectronics***
- ◊ ***Flexible & Wearable Electronics***
- ◊ ***Electronic Smart Systems***