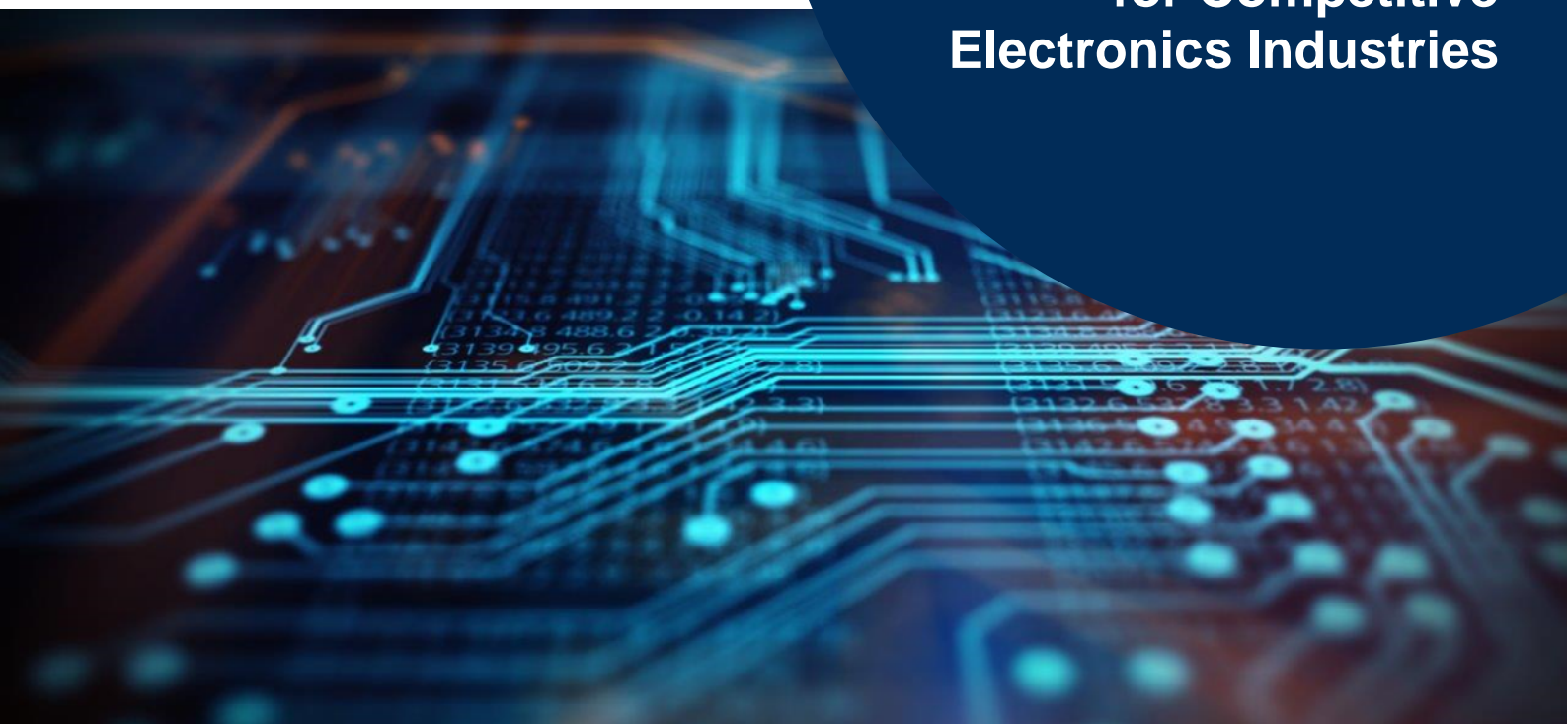


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5E

**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 European electronics industries 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, digitalisation of industry and society is a megatrend that urgently requires electronics as hardware building blocks complementing and interacting with other areas like software, communications, computing, robotics and photonics.

5E underpins digitalisation, and supports specifically the electronics industries 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 digitalisation, as well as on the European and regional policy levels.

In a previous step, the 5E consortium analysed 13 application sectors that are key for the European Electronics industry. For each sector this analysis was structured along 6 functionalities – actuating, communicating, computing/processing/data storage, energy harvesting/conversion/storage, sensing, signalling – and gathered information on technologies and applications currently available in the 3 electronics areas defined above. Together, the resulting “Sectorial States of Play” provide an overall description of the European electronics landscape.

Starting from this, the 5E partners selected 34 topics of mutual interest and with activities at technology and application level in at least 2 of the 3 electronics areas (the so called Grey Spots). For these 34 topics – all of which at the cross-section of a sector and a functionality and with a tangible economic or societal impact - the 5E partners developed a one-pager with the main technologies, applications, challenges and opportunities, and provided a short meaningful title. All one-pagers were put together in a catalogue. The following step consisted in consulting stakeholder communities, both face-to-face at workshops and events, and remote through an online survey. In these consultations, stakeholders were asked to vote on the 34 topics by stating whether they consider them “hot” or “cold”. They were also asked to comment on the topics and to suggest additional topics, also in the framework of a top-down approach considering the clusters and areas of intervention for the upcoming research framework programme Horizon Europe.

As a result, a ranking of topics from hot to cold is available, and 5 new Grey Spots were added to the catalogue, increasing the number of Grey Spots to 39.

A Helicopter Analysis of the 39 topics, their distribution along functionalities and sectors, and their ranking provided highly relevant insights into future opportunities at the interfaces of the three electronics areas. In order to bring into perspective, show the economic and societal impact, and better advocate these opportunities, the 5E partners decided to complement the catalogue with dedicated Vision Papers illustrating specific cross-sectorial or cross-functionality findings from the Helicopter Analysis.

All old and new Grey Spots are described in the present revised version of the 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 cover information on technologies, applications, challenges and opportunities.

This document is part of the work done in the 5E project (GA825113) to define a Joint Vision for the European Electronics Ecosystems.

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

In a first round, **34 Grey Spots (GS)** were identified where at least two of the electronics areas A1, A2 and A3 show activities at technology and application level. An overview of all Grey Spots across sectors and functionalities is given in Table 1.

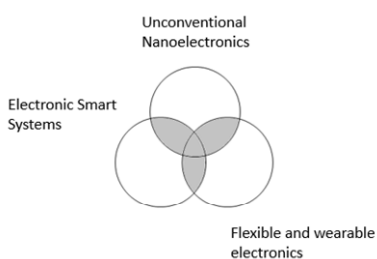
All Grey Spots were assigned a short meaningful title, which summarises the impact achieved by mastering the respective functionality in the respective sector and was carefully worded to be understandable by a large audience. The detailed one-page descriptions are uniformly formatted and include basic information on scope, technologies, applications, challenges, coupling functionalities, and opportunities. 5E conducted a 3-month consultation involving the different communities of the European Electronics Ecosystems and which consisted in 3 validation paths (4 community events, 2 workshops, 1 online consultation) involving a total of 150 stakeholders.

The first version of the catalogue of Grey Spots was updated with the results of the stakeholder consultation, including the addition of 5 entirely new Grey Spots and more than 100 minor changes and amendments to the existing ones.

This catalogue constitutes a key input for the next step of the process, as the identification of 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.

**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 / DATA STORAGE													
ENERGY HARVESTING / CONVERSION / 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.

During the consultation workshops done in November and December 2019, White Spots were investigated and correlated together with the community to the areas of intervention defined in the Horizon Europe Clusters in order to weight whether some of these White Spots may be turned into grey. A lot of external input was collected during this exercise and resulted in adding [5 new Grey Spots](#).

### 1.3 Next steps

The final list of 39 Grey Spots will undergo a further evaluation process to determine their sweetness (Figure 1) by applying a set of scientific, technical, industrial, economic, and societal criteria. This evaluation process will involve the 5E experts within the consortium, but will also rely on external expertise from selected associated partners.

In parallel to the evaluation of Grey Spots, the 5E consortium will develop Vision Papers, elaborating on concrete use cases highlighting the profound cross-area, cross-sector and cross-functionality character of electronics. These Vision Papers aim at emphasising the enabling role of electronics in addressing wider technological or societal issues such as sustainability. The final number and scope of these Vision Papers will be determined based on a Helicopter Analysis performed by the 5E consortium to detect major patterns and define the axes of the Joint Vision.

The resulting list of Sweet Spots together with the Vision Papers will feed the Joint Vision by providing concrete opportunities for the electronics ecosystems (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Once the Joint Vision is commonly agreed, a Meta Roadmap will be drawn and promoted with the goal to forge the path towards the Joint Vision. This Roadmap will define actions, support and cooperation activities required to meet the challenges and timescales in the Joint Vision. Specific focus will be on:

- **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.**

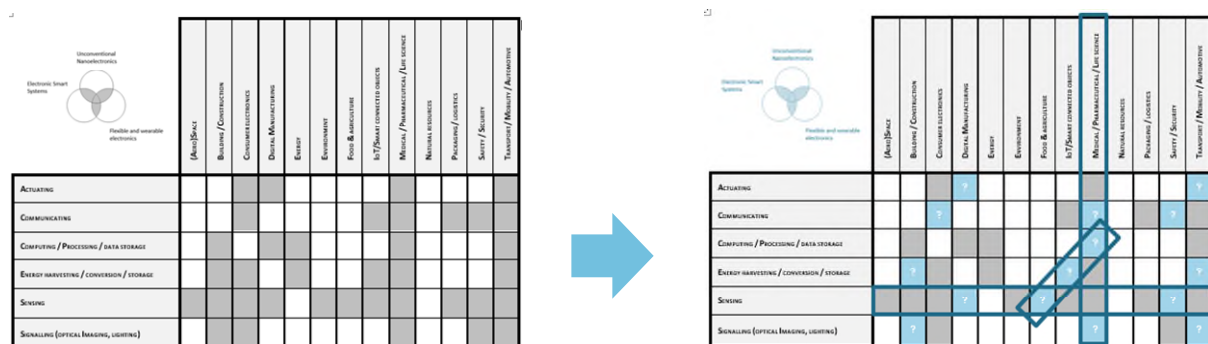
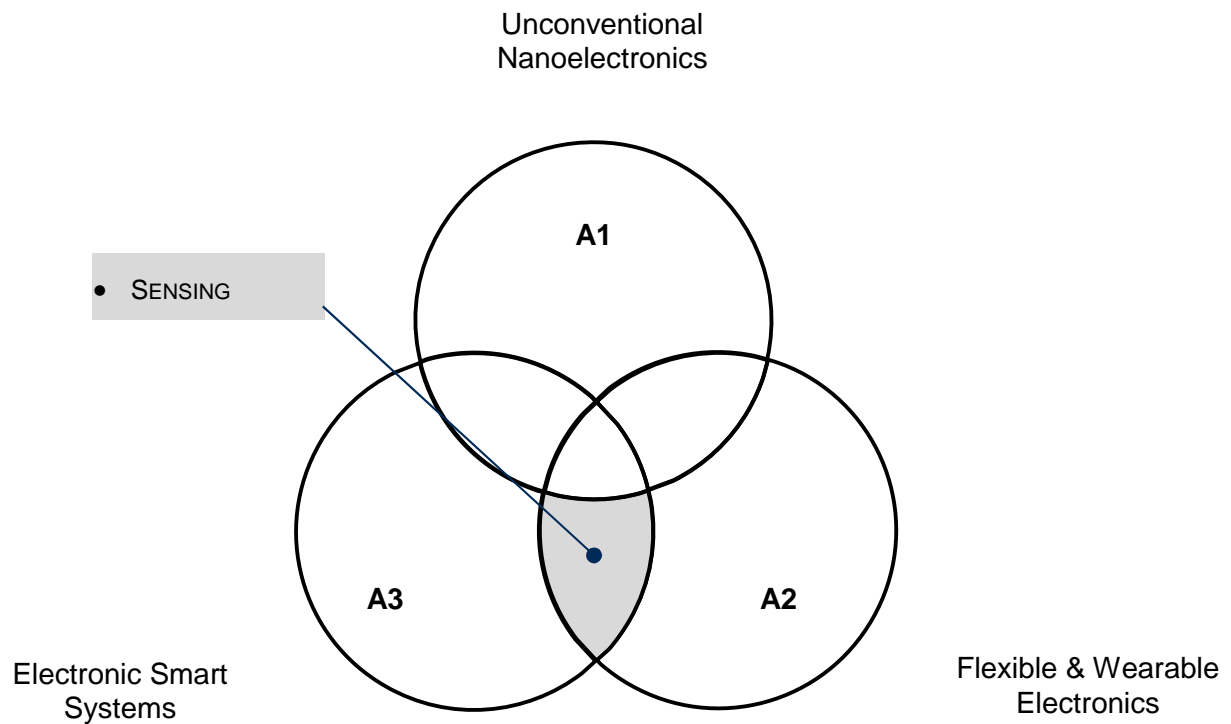


Figure 1: From Grey Spots to Joint Vision

## 2 Grey Spots per area of application

### 2.1 AEROSPACE



ID	Title	Interface	Functionality	Rank
A1	High performance and high reliability sensing tools & technologies for embedded applications in harsh environment such as aeronautics &/or (aero)space	A2A3	SENSING	N.A. NEW GREY SPOT



## ***A1: High performance and high reliability sensing tools & technologies for embedded applications in harsh environment such as aeronautics &/or (aero)space***

### Technologies / Values

- 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, smoke, dust sensing);
- Multispectral sensing from gamma rays to radiowaves.

### Applications

- Sensing in aircrafts, satellites;
- Weather monitoring;
- Space observation and exploration (telescope, probes);
- Earth observation (biodiversity in protected area, seas, forest), surveillance for protection, security and safety (human, fire, flood);
- Surveillance for cybersecurity (cyberattacks).

### Challenges

- Long-term stability, robustness, sensitivity of sensors;
- Maintenance-free systems;
- Energy autonomous sensing systems;
- Wireless communication, secure data handling and management;
- Recyclability & biodegradability;

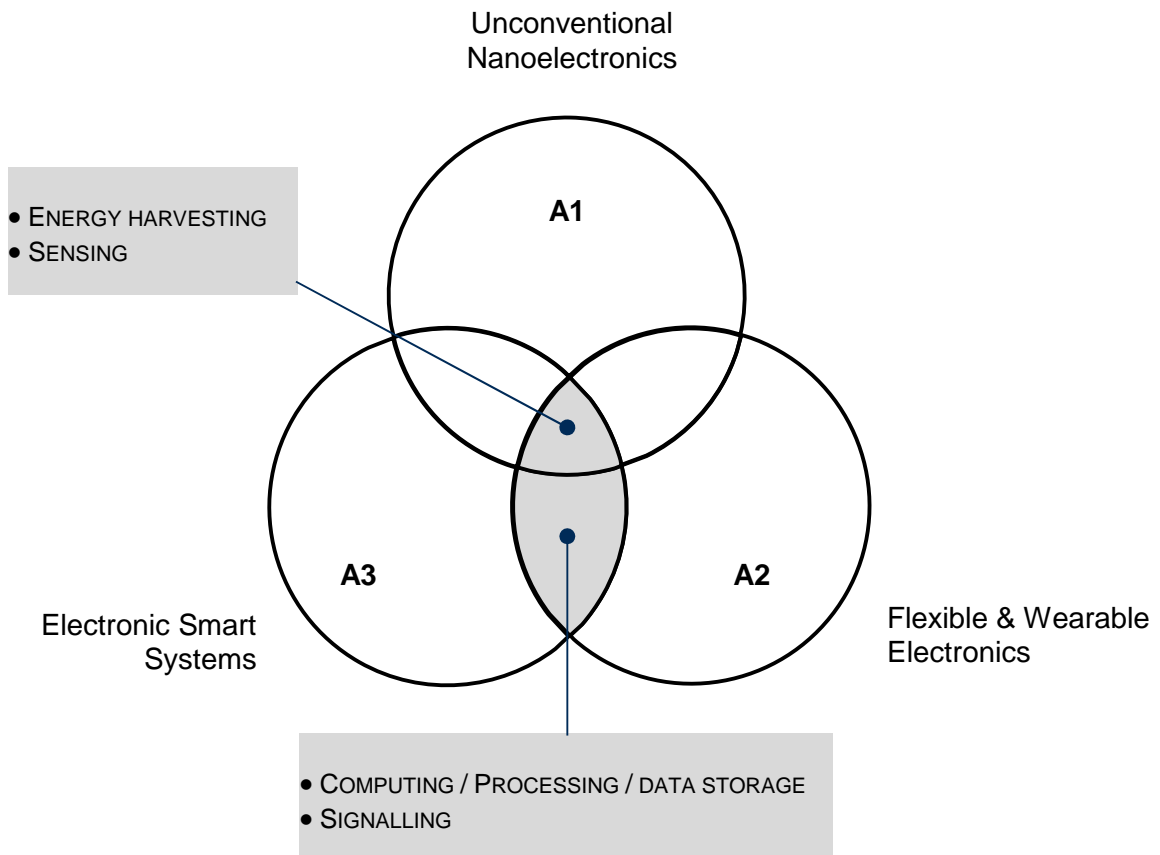
Coupling with other functionalities: communicating, energy harvesting

### Opportunities

- 1. Sensors integration: functional materials and wearables: news sensors with better flexibility, conformability (cockpit, seat...)**
- 2. Sensors networks for security / safety prediction**
- 3. Wireless/cloud communication hardware & protocols for environmental data transmission and management**

## 2.2 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.



ID	Title	Interface	Functionality	Rank
B1	High-power and real-time computing facilities to support planning, construction, use and maintenance of buildings	A2A3	COMPUTING / PROCESSING / DATA STORAGE	34
B2	Ubiquitous and reliable energy supply and harvesting technologies to achieve efficient construction, use and maintenance of buildings	A1A2A3	ENERGY HARVESTING	18
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.)	A1A2A3	SENSING	1
B4	Increasing security, safety and comfort of users of buildings with smart signalling solutions	A2A3	SIGNALLING	23

## ***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
- Low-power Neuromorphic computing and architecture for efficient AI & machine learning
- Communication technologies (short/wide range, incl. 5G/6G) to exchange data with the cloud / the user

### 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.
- Need for Efficient technologies over the full edge-to-cloud cyber physical systems not necessarily increasing performance but sustainability

Coupling computing / processing / data storage with other functionalities: Computing, processing and data storage 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
- Advanced materials with "sensing" properties
- Communication technologies to realise full edge-to-cloud data exchange, incl. short & long range communication (5G/6G)

Applications:

This includes sensors and sensor systems for

- Reliable (indoor) monitoring of spaces, habitats, environments (gas, temperature, humidity, energy consumption etc.);
- Sensing for hygiene of living / working place: early detection of toxic gas, of bacteria...
- 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)
- Sensors for in-house / outdoor tracking and navigation
- sensing of structural stability of historical buildings to protect cultural heritage

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, safety 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
- Integrated secure communication technologies (incl. 5G/6G) to increase security and safety of buildings

### 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).
- Buildings living safety (e.g. hygiene, infectious diseases) control & users awareness.

### 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

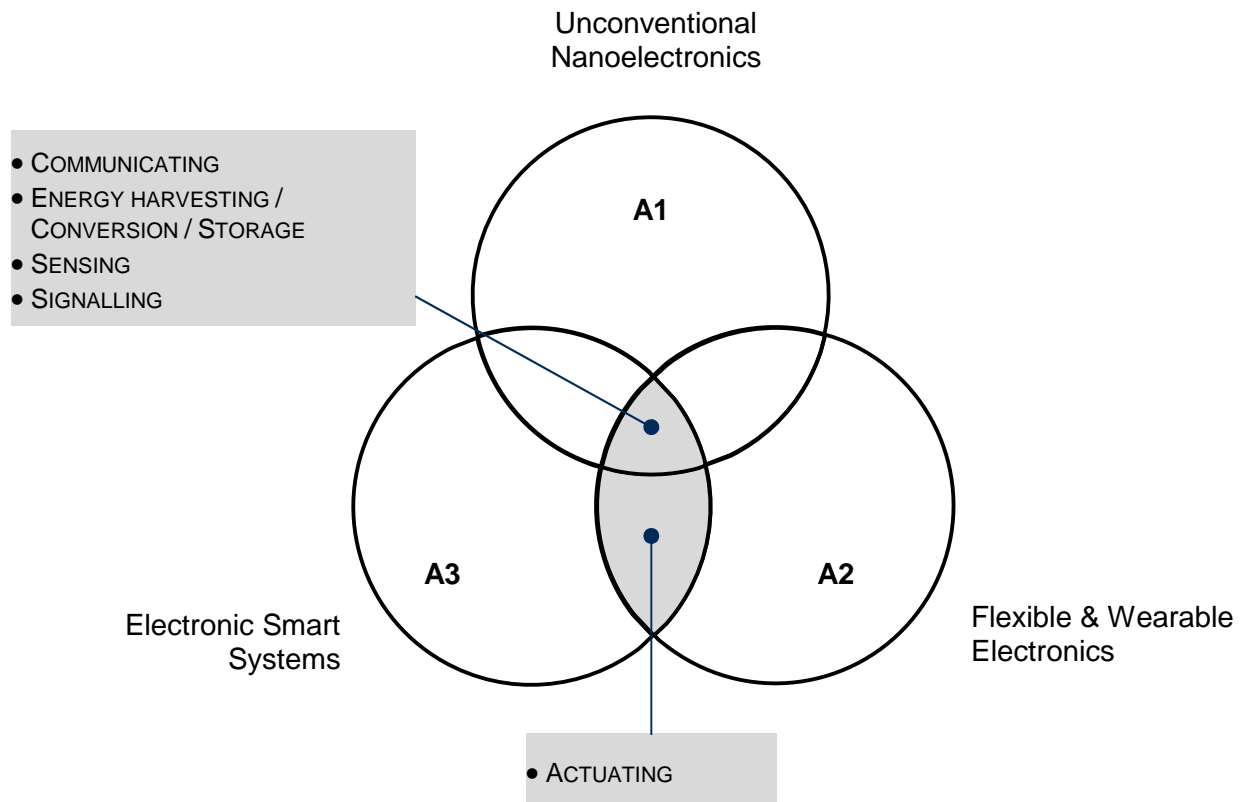
Coupling signalling with other functionalities: Modern OLED lighting is increasingly used to combine pure signalling functionality with decorative and architectural elements. Also pure functional lighting and signalling merge more and more, for instance in signage systems.

### 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**



## 2.3 CONSUMER ELECTRONICS



ID	Title	Interface	Functionality	Rank
C1	Actuating as a key functionality for enhancing Human Machine Interfaces (HMI), product value and enhancing users experience	A2A3	ACTUATING	26
C2	Independent high-speed connectivity and low-power communication for trusted nomad consumer solutions	A1A2A3	COMMUNICATING	28
C3	Low-cost, reliable and recyclable energy harvesting & storage solutions for high-volume consumer electronics markets	A1A2A3	ENERGY HARVESTING / CONVERSION / STORAGE	5
C4	Solutions for reliable and sensitive multi-sensing and data fusion/exploitation algorithms for signals dynamic management	A1A2A3	SENSING	6
C5	Signalling displays compatibility for sustainable manufacturing in Europe	A1A2A3	SIGNALLING	32

## ***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
- Sustain and foster Culture, Cultural Heritage and creativity with advanced HMI

### 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;
- 5G-6G Connectivity, Mini-cells & mobiles;
- 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.

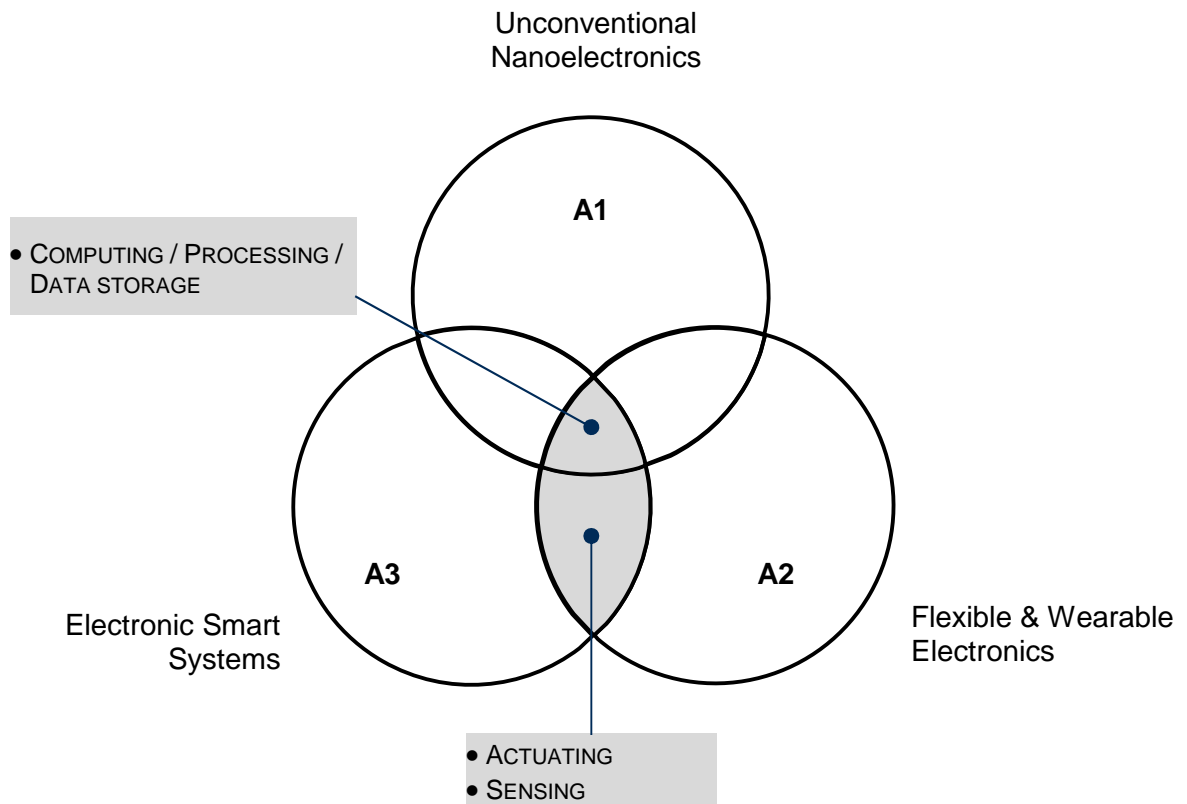
Coupling with other functionalities: Sensing and processing.

### 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**



## 2.4 DIGITAL MANUFACTURING



ID	Title	Interface	Functionality	Rank
D1	Actuating as key functionality for safe, efficient and optimised production processes in industry 4.0	A2A3	ACTUATING	17
D2	Next generation sensor systems for safe, efficient, optimised and self-enabled manufacturing	A2A3	SENSING	1
D3	Explainable AI – Transparent, comprehensible and traceable classification and decision processes in safety critical applications	A1A3	COMPUTING / PROCESSING / DATA STORAGE	N.A. NEW GREY SPOT

## ***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;
- Material processing techniques: subtractive / additive techniques, nanolayers...

### 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;
- High-quality and reliable manufacturing processes for transport applications such as aerospace or automotive (use of lightweight structures...).

### Challenges:

- Energy efficiency, resource efficiency, real-time, response to digitalisation;
- Lot size one vs. scaling-up and reproducibility, for instance for tailored digital manufacturing of personalised health and medical solutions (drugs, medical devices ...);
- 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 digitalisation 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;
- Advanced materials with "sensing" properties;
- 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**

### ***D3: Explainable AI – Transparent, comprehensible and traceable classification and decision processes in safety critical applications***

#### Technologies / Value:

- AI is usually realised in semiconductor technology and is needed to process and control sensing, actuation and communication;
- Hybrid modelling, i.e. the combination of data driven and physically based models for artificial neural networks, making use of sensor fusion and virtual sensing, and corresponding machine learning methods contribute to transparency of AI.

#### Applications:

Explainable AI is important in all sectors, where AI is intended to be used, and where the qualification process for products requires the complete understanding of the implemented information processing and the used reasoning. This is usually the case in all safety relevant applications, notably in manufacturing for machine control.

#### Challenges:

As a usual artificial neural network (ANN) is working like a black box in which it is not clear what criteria and what particular features finally lead to the classifications or decisions taken, the challenge is to make this process transparent, comprehensible and traceable.

One approach to achieve this transparency is to use so-called hybrid modelling, meaning the combination of data-driven and physically based models for ANN. This combination and the corresponding machine learning methods are subject to ongoing research activities.

#### Coupling with other functionalities:

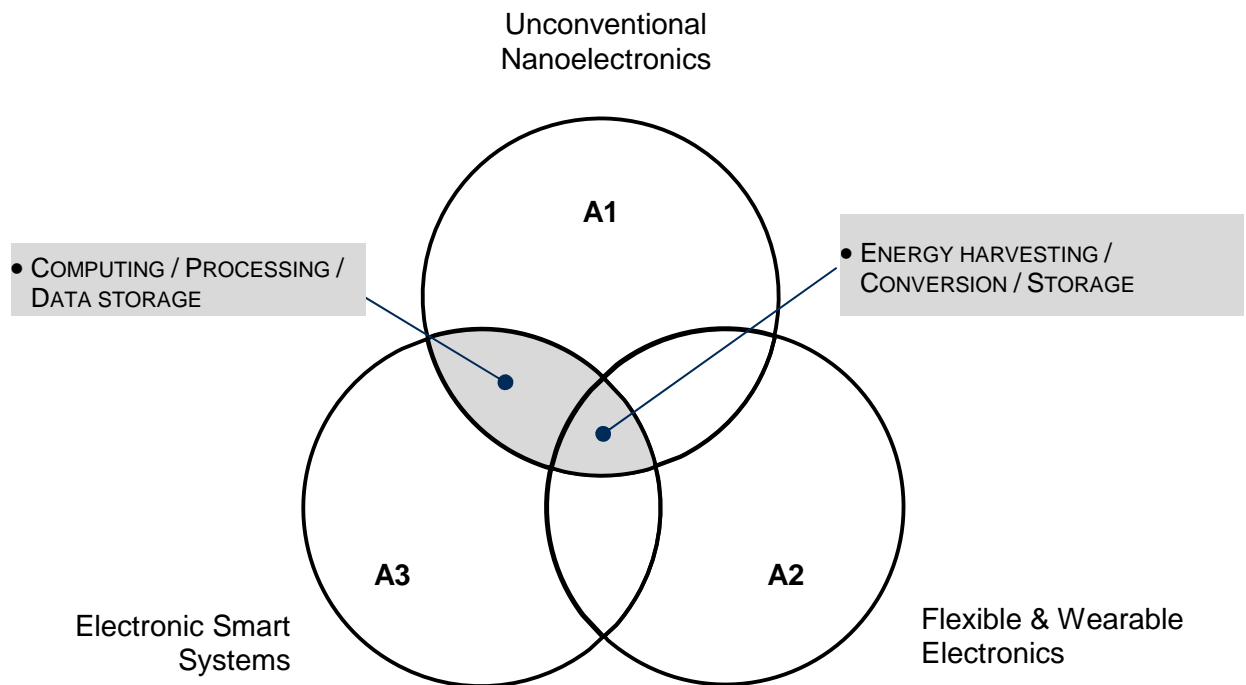
The demand for explainable AI arises wherever AI is intended to be used, which is a very broad scope, and wherever safety critical applications are tackled. Combination with actuating, communicating, sensing and signalling are of particular relevance.

#### Opportunities:

- **There is an opportunity for explainable AI whenever the qualification process of the products requires transparent and traceable information processing.**

## 2.5 ENERGY

Technologies have been identified for **ENERGY HARVESTING / CONVERSION** or **ENERGY STORAGE** that distribute across the interfaces as follow:



ID	Title	Interface	Functionality	Rank
N1	High-yield energy harvesting approaches for replacing or reducing primary energy uses	A1A2A3	ENERGY HARVESTING	8
N2	Flexible energy storage solutions with extended systems lifetime and multi-uses, including secondary use	A1A2A3	ENERGY STORAGE	29
N3	High-performance and compact power electronics for grid connection of distributed resources and storage, based on wide-band gap components	A1A2A3	ENERGY CONVERSION	N.A. NEW GREY SPOT
N4	Smart solutions combining monitoring, control and diagnostics for optimal operation of energy systems and smart grids	A1A3	COMPUTING / PROCESSING / DATA STORAGE	N.A. NEW GREY SPOT

## ***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;
- Use of advanced and functionalised materials for energy harvesting.

### 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
- Energy solutions for remote sensors in harsh environment;
- Applications in aerospace: drones / aircraft electrification.

### 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 CO2 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;
- Use of advanced and functionalised materials for energy storage.

### Applications:

- Generic by nature;
- Any applications in any sectors where energy supply does not match energy demand limiting products performance;
- Applications in aerospace: drones / aircraft electrification.

### 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

### ***N3: High-performance and compact power electronics for grid connection of distributed resources and storage, based on wide-band gap components***

#### Technologies / Value:

- Innovative power components: Silicon Carbide (SiC) and Gallium Nitride (Gan)
- Power component integration: packaging, power modules, discrete components
- Topologies: two levels, multi-levels, single-stage, multiple-stages
- Controls: algorithms and embedded code

#### Applications:

- Power converters for renewable energy sources (photovoltaic, windpower,...)
- Bidirectional power converters for batteries and hydrogen storage
- Power converters for electrical vehicles and charging infrastructure

#### Challenges:

- Optimally design the converters: selection of the topology, selection of the active power components, sizing of passive components
- Increase the switching frequency/speed
- Guarantee high reliability of power components

Coupling *energy conversion* with other functionalities: energy storage, energy management, sensing

#### Opportunities:

1. **Power electronics for energy systems for building applications:** road-mapping of technologies for products with low power (~kW), high compacity and high safety (eg hybrid converters for PV and battery systems with an energy self-consumption objective)
2. **Power electronics for Utility-Scale power plants for feeding into the grid and grid services:** road-mapping of technologies for products with mid/high power and low voltage (~100kW to ~MW; <1500Vdc <1000Vac)
3. **Power electronics for High-Voltage plants:** road-mapping of technologies for products with mid/high power and **HIGH** voltage (~100kW to ~MW; ~3 to 6 kVdc and ~10 kVac)
4. **Power electronics for Electrical Vehicle charging:** roadmapping of technologies for products with high power (~100kW) and high density integrated in the charging infrastructure or embedded in the electrical vehicle

## ***N4: Smart solutions combining monitoring, control and diagnostics for optimal operation of energy systems and smart grids***

### Technologies / Value:

- Sensors and field communication: for monitoring and transmission of data;
- Servers with software with algorithms: for supervision and high-level optimal control for predictive energy planning, as well as diagnostics;
- Real-time controllers: for power management and control of energy systems.

### Applications:

- Positive Energy Buildings;
- Micro-grids and neighbourhoods;
- Hybrid power plants: renewable, batteries, hydrogen...;
- Solar powered charging infrastructure;
- Smart grids with high integration of renewables, electrical storage and charging infrastructure.

### Challenges:

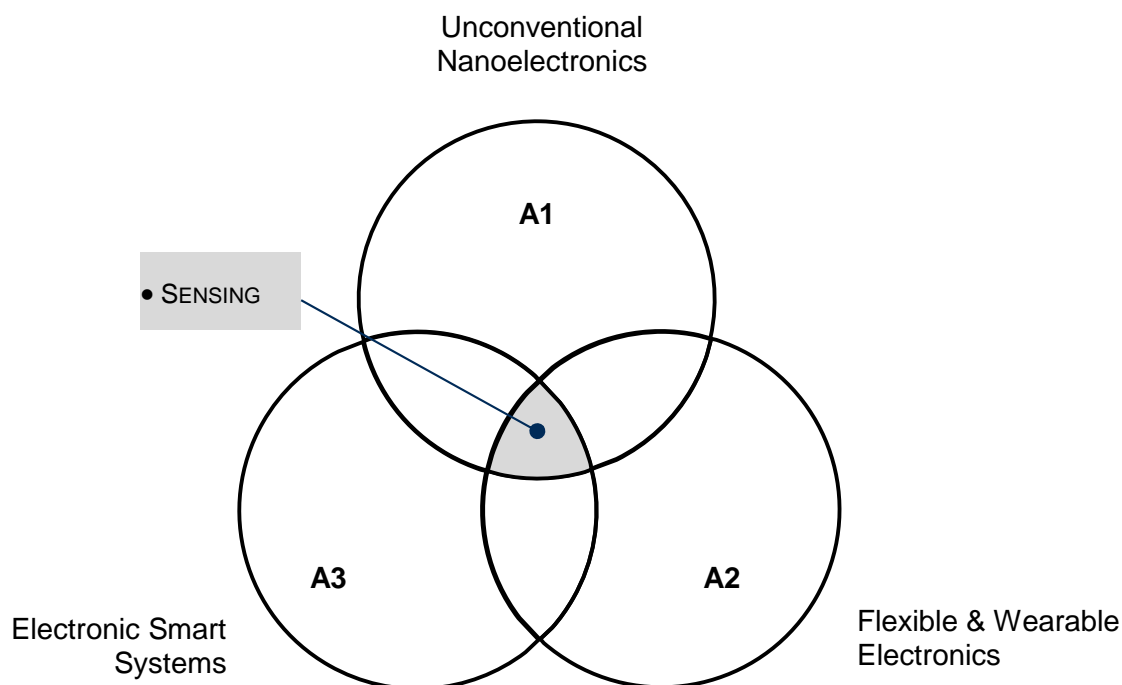
- Develop optimal predictive control algorithms;
- Develop production and consumption power forecasting;
- Develop diagnostic/prognostic algorithms;
- Develop cloud solutions;
- Develop robust solutions coping with data uncertainties and able to withstand cyberattacks.

Coupling energy management with other functionalities: energy harvesting, energy conversion, energy storage, sensing

### Opportunities:

1. **Energy management systems for Positive Energy Buildings and for Solar-power charging infrastructures:** roadmapping of technologies for products and software solutions for optimised self-consumption of locally produced energy, along with self-learning of behaviour
2. **Energy management systems for micro-grids and neighbourhoods:** roadmapping of technologies for products and software solutions for energy optimisation at small territories level considering new schemes for energy sharing
3. **Energy management systems for hybrid power plants:** roadmapping of technologies for products and software solutions for optimal planning of production according to multiple grid needs (from power generation to ancillary services) and for optimal dispatch between power systems, along with diagnostics and renewable power forecasting
4. **Energy management systems for grids with high share of renewables:** roadmapping of technologies for products and software solutions for optimal operation of grids (mix planning, dynamic reconfiguration, frequency/voltage regulations...) and for grid reliability / robustness in a context with high share of intermittent generation

## 2.6 ENVIRONMENT



ID	Title	Interface	Functionality	Rank
E1	Gas, pollutant, particle and waste monitoring solutions for healthy and safe working & living environments	A1A2A3	SENSING	9

## ***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 (but not restricted to indoor & outdoor).

### Applications:

- Air-quality monitoring indoor (home, office, building...) & outdoor (city, countryside, factory, transport);
- Environment safety control & users awareness;
- Waste collection: waste track-and-trace;
- Civil protection & security: early fire detection in forest: mesh of autonomous networked detectors able to manage their power supply/consumption and to regulate the flow of data transmitted (only „highly interesting“ information shall be sent). Combination of different types of sensors (earth observation, gas sensors, temperature, ...);
- Disaster-resilient societies: autonomous assessment of the extend of a (natural) disaster combining different types of networked sensors (earth observation, gaz sensors, ...)
- Sensing for water monitoring / purification.

### Challenges:

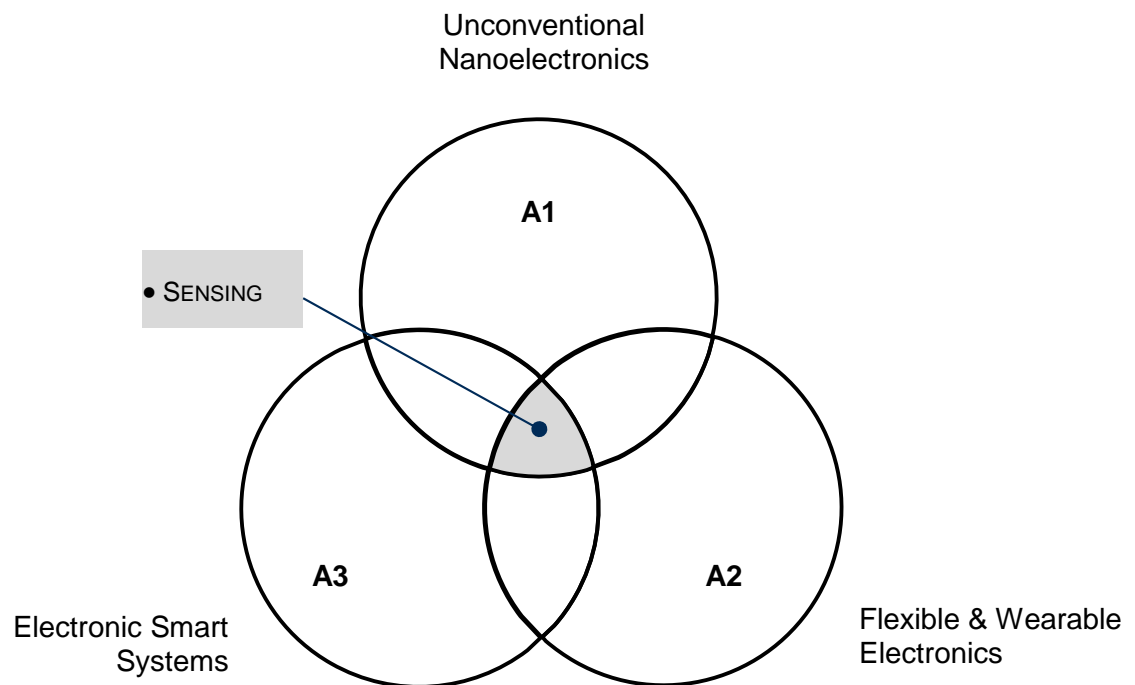
- Evaluate influence of the indoor / outdoor air-quality on people health;
- Long-term stability, robustness, sensitivity of sensors;
- Sensors integration into autonomous stationary or wearable systems: flexibility, stretchability, size;
- Wireless communication, secure data handling and management;
- Recyclability & biodegradability;
- Miniaturisation (optical);
- Energy harvesting – ultra low-power (communication).

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**

## 2.7 FOOD & AGRICULTURE



ID	Title	Interface	Functionality	Rank
F1	Sensing for quality, safety and security tracing & monitoring along food value chains	A1A2A3	SENSING	3



## ***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
- Localisation: sensing for precise tracking / navigation
- Sensing from space: Earth observation.

### Applications:

- Quality & security monitoring;
- Food safety control & users awareness;
- Automation in agriculture / food processing;
- Logistics track-and-trace.

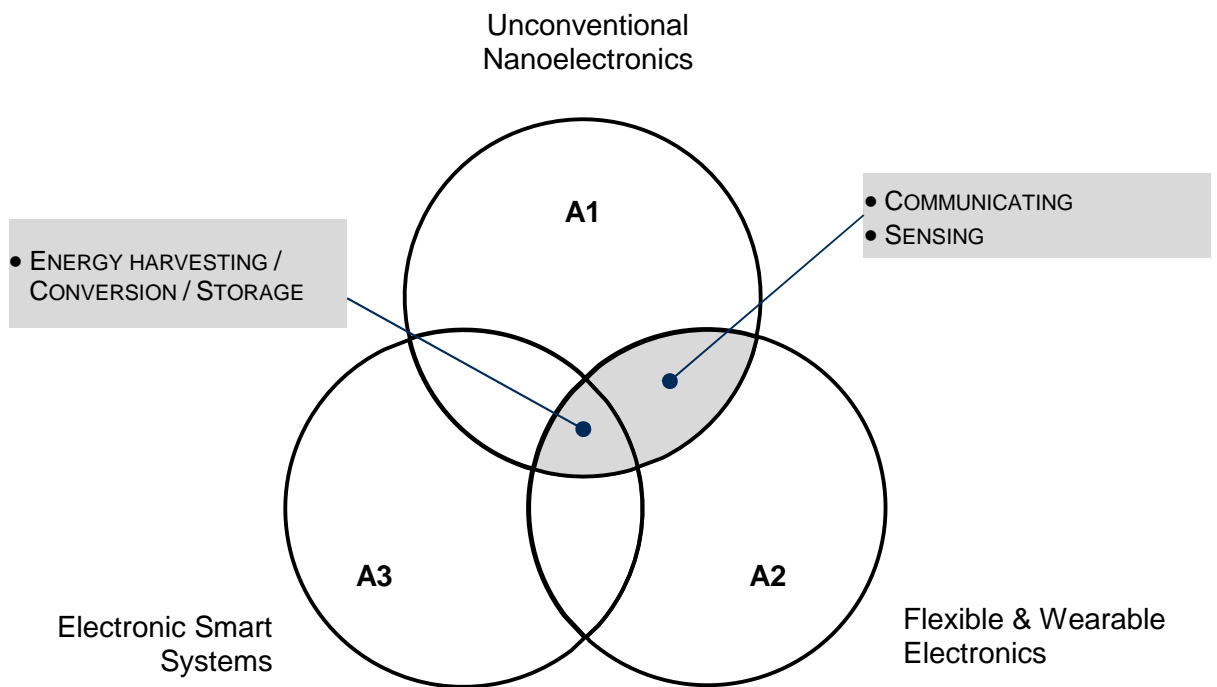
### Challenges:

- 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**

## 2.8 IoT/SMART CONNECTED OBJECTS



ID	Title	Interface	Functionality	Rank
I1	Efficient and secure protocols for high-data transmission rate of IoT devices	A1A2A3	COMMUNICATING	15
I2	Sustainable energy harvesting and energy storage solutions for low-power and autonomous IoT devices	A1A2A3	ENERGY HARVESTING / CONVERSION / STORAGE	4
I3	Multi-sensing capability to monitor complex environment via extended networks of connected devices	A1A2A3	SENSING	19

## ***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 & 6G technologies for wireless applications (in development) & Sigfox, LoRa outside, LTE-M inside, are used for the Outdoor Wireless Applications
- Advanced memory technologies for efficient data management in edge computing.

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
- Advanced memory technologies for efficient data management in edge computing.

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

- Medical wearables for preventing infectious diseases, including poverty related and neglected disease;
- Environment safety control & users awareness

#### Challenge:

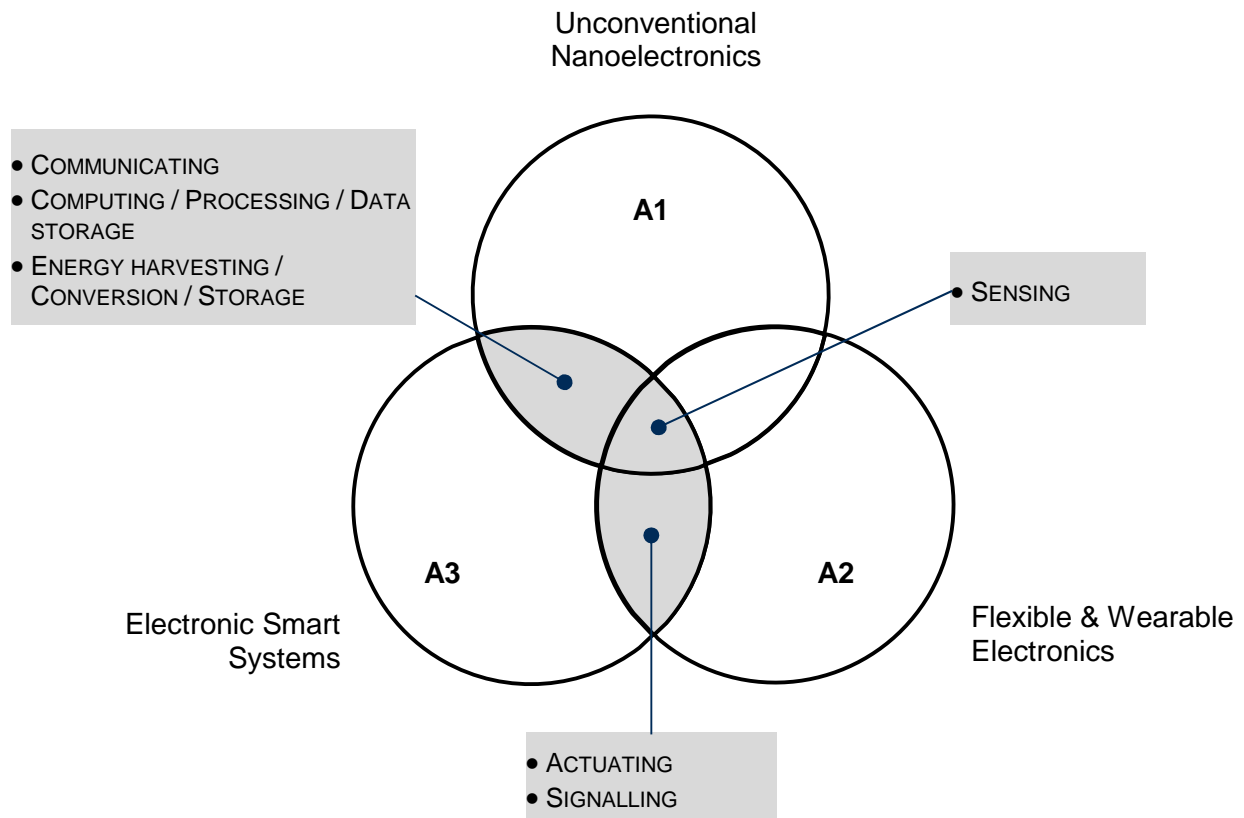
- Sensors capability and sensors interoperability depending on IoT product/environment cases (sizes, form factors, conformability, stretchability, environment, sensitivity, sensibility, integrability level and cost);
- Multi-sensors interconnectivity / sensors integration;
- Scaling-up and low-cost production.

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**

## 2.9 MEDICAL / PHARMACEUTICAL / LIFE SCIENCE



ID	Title	Interface	Functionality	Rank
M1	Efficient, safe and integrated actuating to improve healthcare outcome and assist professionals with advanced automation and HMI	A2A3	ACTUATING	11
M2	High-performance and secure communication building blocks to increase autonomy and efficacy of electronic devices intended for medicine and healthcare	A1A3	COMMUNICATING	6
M3	Advanced hardware/software processing for in-depth analysis of large and complex health-related datasets to improve decision-making and outcome of healthcare	A1A3	COMPUTING / PROCESSING / DATA STORAGE	30
M4	Combining energy harvesting, storage and efficiency to power complex, autonomous and interconnected medical & healthcare devices	A1A3	ENERGY HARVESTING / CONVERSION / STORAGE	25
M5	Disruptive & high-performance sensing capability as key enabler for Digital Healthcare and Well-being	A1A2A3	SENSING	15
M6	Advanced Signalling for immersive visualisation tools to improve interfaces with and proficiency of medical professionals	A2A3	SIGNALLING	23

## ***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 digitalisation in 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);
- Flexible substrates to provide form factors adapted to the body;
- Closed loop control.

### Applications:

- Ex- and in-vivo therapies and interventions (surgery, electrostimulation & electroceuticals, theranostics, phototherapy);
- Minimally-invasive drug delivery (intracorporeal, through the skin);
- Interface skin / wearable (medical) device;
- In-vitro processes (3D-Cell Printing, microfluidics, organ-on-chip);
- Prosthetics & implants (artificial limbs, muscles, organs), (tele-)rehabilitation (exoskeletons, robots), monitoring
- Tailored digital manufacturing of personalised health and medical solutions (Drugs, Medical devices).

### 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. Digitalisation in 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...);
- Medicines waste monitoring and tracking.

### 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;
- Low-power Neuromorphic computing and architecture for efficient AI & machine learning;
- 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-on-chip);
- Advanced HMI
- Edge AI for personalisation and user Adaptation: more accurate data adapted to user due to accumulating data of individual user only;
- Edge AI for privacy and security of user data: data is kept private due to edge data processing without cloud involvement;
- Edge AI for real time feedback: low latency due to avoidance of data transfer;
- Edge AI for improved battery life: lower power consumption due to occasional connectivity and data transfers.

#### 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. **Digitalisation in 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)
- Edge AI for improved battery life.

##### 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;
- Medical wearables for preventing infectious diseases, including poverty related and neglected diseases;
- Hospital monitoring;
- 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:

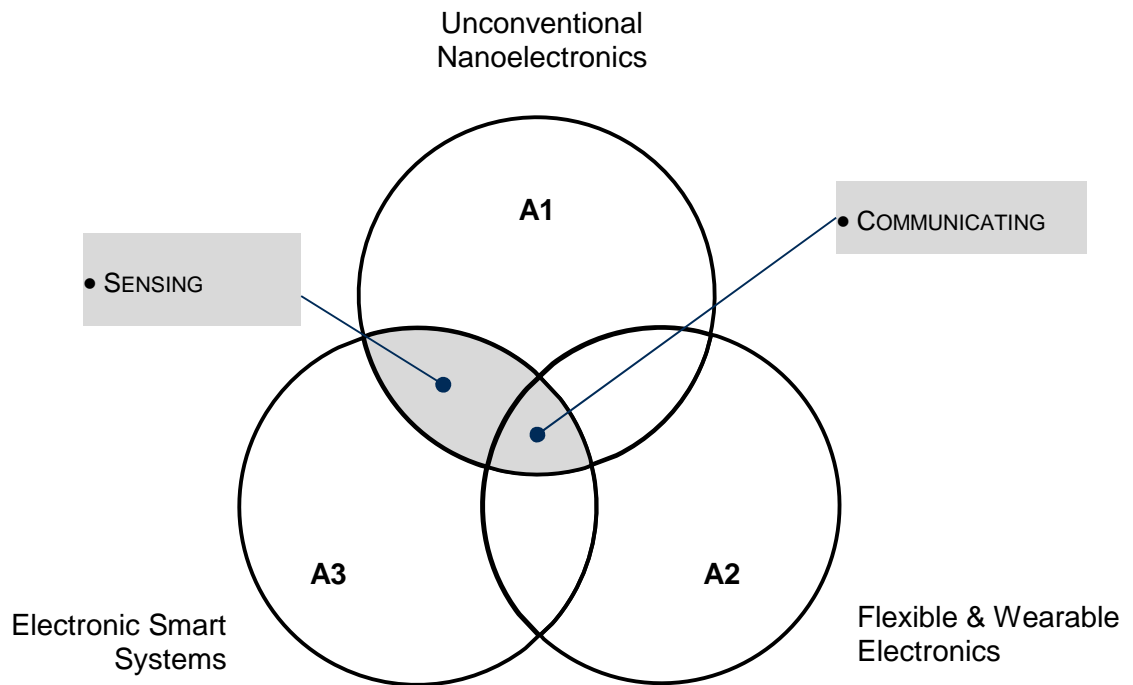
- Render complexity and multiplexity of medicine in a way to increase decision-making and proficiency of medical professionals.

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**

## 2.10 PACKAGING / LOGISTICS



ID	Title	Interface	Functionality	Rank
P1	Secure data/information wireless transmission in packaging/labels for goods interconnectivity and e-services	A1A2A3	COMMUNICATING	27
P2	Multi-sensing, data fusion and management in packaging/labels for goods interactivity and e-services	A1A3	SENSING	22

## ***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 protocols;
- 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
- Packaging of drug incl. quality & safety, Anti-counterfeiting, monitoring and patient compliance to medication.

### Challenges:

- Scalability, miniaturisation, adaptability, manufacturability, integration, complexity, and high technical yield at low cost;
- Recyclability and circularity to reduce environmental impact & waste streams;
- Electronics solutions for disaster-resilient societies by maintaining supply chains after a disaster.

### 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 (sensing for tracking and ensuring delivery).

### Challenges:

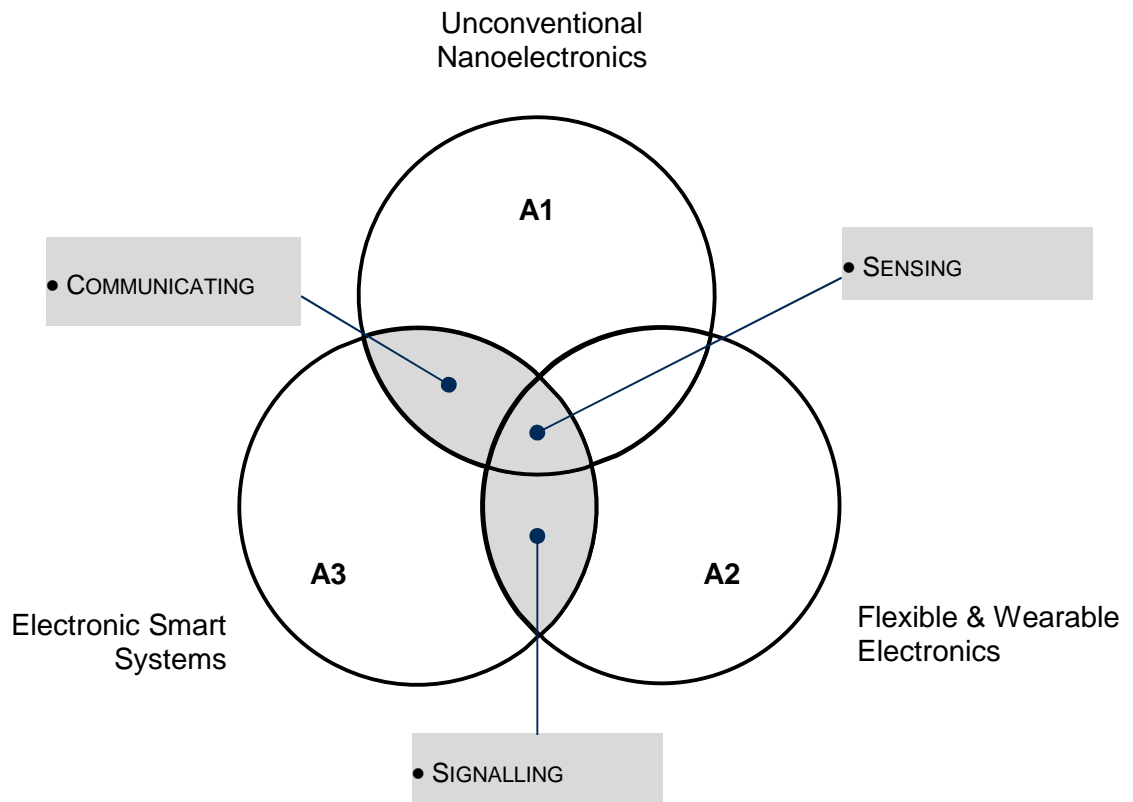
- Selecting the best sensing strategy for a given application (sensor type, selective / sensitive sensing, single/multi-sensing, sensing layout, sensors data management & algorithms (data sampling, fusion, interpretation), cost of overall sensing solution);
- Bio-degradability, biocompatibility and recyclability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

## 2.11 SAFETY / SECURITY



ID	Title	Interface	Functionality	Rank
S1	Secure data transfer technologies for flexible and adaptable IoT systems to enable trusted solutions in data communication, across wireless standards and applications	A2A3	COMMUNICATING	11
S2	Sensors systems with a "trusted label" for people and goods protection to be easily integrated into products	A1A2A3	SENSING	11
S3	Creating visibility or convey information as informative or preventive action to promote effective operation and physical safety	A1A2A3	SIGNALLING	33



## ***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;
- Multiple sensor systems with data fusion for reliable monitoring of spaces, environments.

### 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:

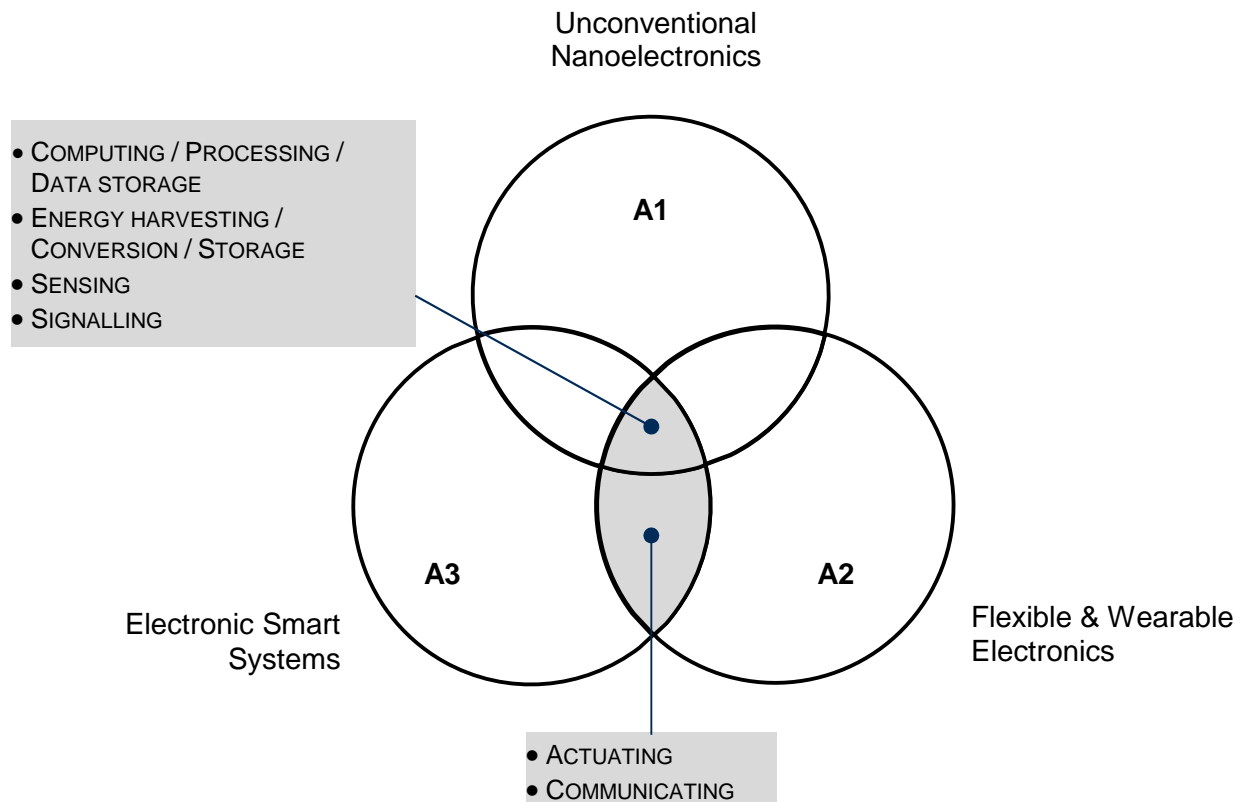
- Endurance during use;
- Washability of technologies.

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)**

## 2.12 TRANSPORT / MOBILITY / AUTOMOTIVE



ID	Title	Interface	Functionality	Rank
T1	Seamless integration of actuators, in car interiors for human-machine interaction	A2A3	ACTUATING	19
T2	Technologies to secure data transfer and enable trusted solutions for people and information in car2car communicating for autonomous / self-driving vehicles	A2A3	COMMUNICATING	11
T3	Low-power loss and energy harvesting for emission and CO <sub>2</sub> reduction in electrical driving	A1A2A3	ENERGY HARVESTING / CONVERSION / STORAGE	21
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	A1A2A3	SENSING	9
T5	Seamless integration of displays for human-machine interaction and signalling	A1A2A3	SIGNALLING	31
T6	Edge AI for autonomous mobility	A1A2A3	COMPUTING / PROCESSING / DATA STORAGE	N.A. NEW GREY SPOT

## ***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;
- Manned/unmanned Autonomous vehicles for harsh environment, for instance for protection & security applications / for first responders after a disaster / an attack
- Real time action, small form factors, 3D antennas, 5G.

### Challenges:

- Data transport;
- Coverage;
- Integration, lamination and curvature;
- 5G coverage;
- Cope with social and economic transformations by provided inclusive mobility solutions accessible for all.

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<sub>2</sub> 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;
- Charging roads;
- Energy for autonomous sensors (independent to engine);
- Efficient Heating/cooling systems for electric vehicles.

#### 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, braking);
- 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);
- Reliability of data from embedded sensors / from the cloud - lapse time.

Coupling with other functionalities: sensing, computing, communicating (5G/6G), 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-time 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**

## ***T6: Edge AI for autonomous mobility***

### Technologies / Value:

- Improve quality of (human) decision making in (time) critical tasks
- Decide on hand-over of control from system to human and providing sufficient time for hand-over process.
- Self-organising logistics can yield more efficient transport thereby reducing kilometres, costs and environmental impact. By less traffic jams also safety and comfort will be increased for drivers and passengers.
- Self organising will be achieved by connected vehicles as well as surveillance robots and monitoring satellite systems.
- Experience and comfort in the car interior will be enhanced by intuitive user interfaces supporting (passengers and drivers)

### Applications:

- Transport
- Mobility

### Challenges:

- Data ownership
- Privacy issues
- Legislation
- Ethical constraints
- Insurance and accountability
- Lack of data like unpredictability in surroundings of traffic including atmosphere, weather, animals etc.
- Acceptance by users linked to transparency of method of control – data handling
- The change to completely autonomous driving will be in phases that for each phase demand different tools, means and communication

### Coupling with other functionalities:

- Sensors and actuators inside vehicles and outside vehicles
- Control systems

### Opportunities:

- Increase of safety, comfort and efficiency of transport
- Increase of mobility of people of all ages
- Decrease of number of cars, parking spaces
- Decrease of environmental burden of transport of humans
- New business models for commercial industry, gaming, hotels, restaurant, sports etc. when a car can be applied for more than transportation

### 3 Newly created Grey Spots

A1	High performance and high reliability sensing tools & technologies for embedded applications in harsh environment such as aeronautics &/or (aero)space	Aerospace	A2A3	Sensing
D3	Explainable AI – Transparent, comprehensible and traceable classification and decision processes in safety critical applications	Digital Manufacturing	A1A3	Computing / Processing / Data storage
N3	High-performance and compact power electronics for grid connection of distributed resources and storage, based on wide-band gap components	Energy	A1A3	Energy conversion
N4	Smart solutions combining monitoring, control and diagnostics for optimal operation of energy systems and smart grids	Energy	A1A3	Computing / Processing / Data storage
T6	Edge AI for autonomous mobility	Transport / Mobility / Automotive	A1A2A3	Computing / Processing / Data Storage

The newly created Grey Spots are reflecting an obvious lack of coverage of this functionality in the original set of Grey Spots regarding the Computing / Processing / Data storage functionality, which many stakeholders highlighted as primary functionality for digitalisation, notably with respect to Artificial Intelligence (AI).

These additions are important for the whole portfolio of Grey Spots as they simultaneously allow linking hardware and software in the field of AI and address the impact of AI on embedded hardware, notably with the growing requirements for electronic design to integrate AI at device level (Edge AI).

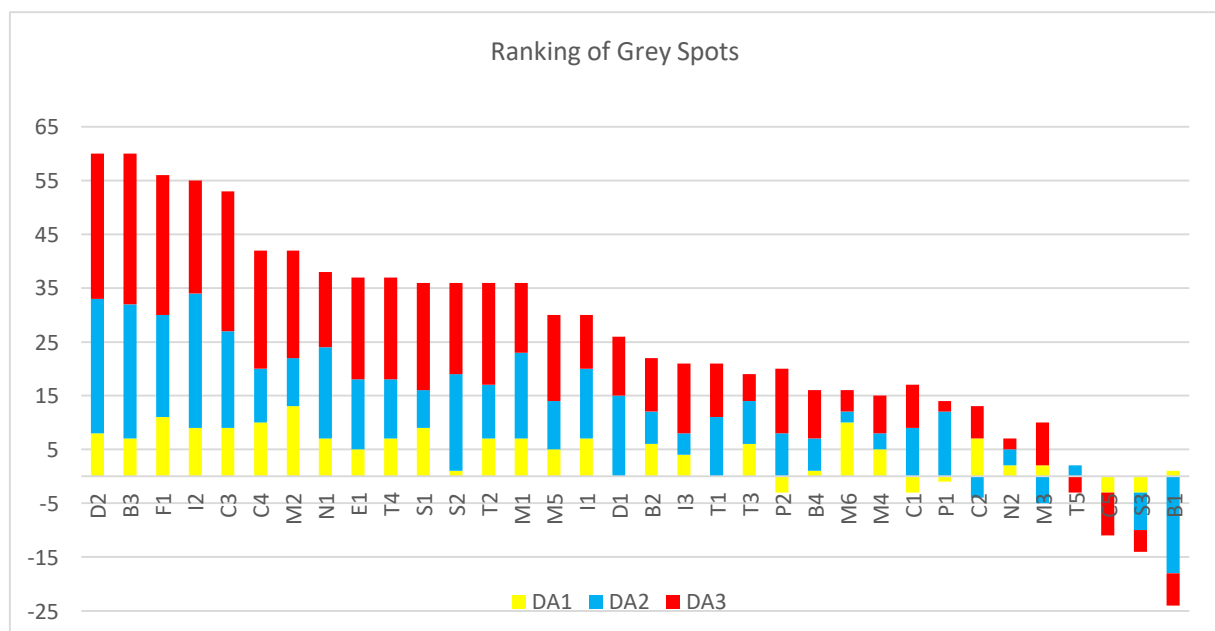
Furthermore, with the elaboration of the Grey Spot on sensing in the Aerospace sector, an additional sector of application is now covered by the Grey Spots.

## 4 Ranking of Grey Spots

A ranking of the original set of 34 Grey Spots was conducted based on feedback from stakeholders of the 3 electronics communities (A1: Nanoelectronics, A2: Flexible and Wearable Electronics and A3: Electronic Smart Systems), in which they stated if they consider the Grey Spots HOT or COLD.

Each HOT vote had a value of +1 in the total sum while each COLD vote had a value of -1. The 3 colours in the graph below shows the scores for each of the 3 Electronic Areas. The 5 new Grey Spots presented above are not included in this ranking as they were not defined at the time of the survey.

This ranking will serve as one of the criteria to define the Sweet Spots of Electronics (see section [1.3 Next steps](#)).



Rang	ID	Title	Application Area	Electronic Interface	Functionality	Score
1	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.)	Building / Construction	A1A2A3	Sensing	60
1	D2	Next generation sensor systems for safe, efficient, optimised and self-enabled manufacturing	Digital Manufacturing	A2A3	Sensing	60
3	F1	Sensing for quality, safety and security tracing & monitoring along food value chains	Food & Agriculture	A1A2A3	Sensing	56
4	I2	Sustainable energy harvesting and energy storage solutions for low-power and autonomous IoT devices	IOT / Smart Connected Object	A1A2A3	Energy	55
5	C3	Low-cost, reliable and recyclable energy harvesting & storage solutions for high-volume consumer electronics markets	Consumer Electronics	A1A2A3	Energy	53
6	C4	Solutions for reliable and sensitive multi-sensing and data fusion/exploitation algorithms for signals dynamic management	Consumer Electronics	A1A2A3	Sensing	42
6	M2	High-performance and secure communication building blocks to increase autonomy and efficacy of electronic devices intended for medicine and healthcare	Medical / Pharma / Life Sciences	A1A3	Communicating	42
8	N1	High-yield energy harvesting approaches for replacing or reducing primary energy uses	Energy	A1A2A3	Energy Harvesting	38
9	E1	Gas, pollutant, particle and waste monitoring solutions for healthy and safe working & living environments	Environment	A1A2A3	Sensing	37
9	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	Transport / Mobility / Automotive	A1A2A3	Sensing	37
11	M1	Efficient, safe and integrated actuating to improve healthcare outcome and assist professionals with advanced automation and HMI	Medical / Pharma / Life Sciences	A2A3	Actuating	36
11	S1	Secure data transfer technologies for flexible and adaptable IoT systems to enable trusted solutions in data communication, across wireless standards and applications	Safety / Security	A1A3	Communicating	36

11	S2	Sensors systems with a "trusted label" for people and goods protection to be easily integrated into products	Safety / Security	A1A2A3	Sensing	<b>36</b>
11	T2	Technologies to secure data transfer and enable trusted solutions for people and information in car2car communicating for autonomous / self-driving vehicles	Transport / Mobility / Automotive	A2A3	Communicating	<b>36</b>
15	M5	Disruptive & high-performance sensing capability as key enabler for Digital Healthcare and Well-being	Medical / Pharma / Life Sciences	A1A2A3	Sensing	<b>30</b>
15	I1	Efficient and secure protocols for high-data transmission rate of IoT devices	IOT / Smart Connected Object	A1A2	Communicating	<b>30</b>
17	D1	Actuating as key functionality for safe, efficient and optimised production processes in industry 4.0	Digital Manufacturing	A1A2A3	Actuating	<b>26</b>
18	B2	Ubiquitous and reliable energy supply and harvesting technologies to achieve efficient construction, use and maintenance of buildings	Building / Construction	A1A2A3	Energy	<b>22</b>
19	I3	Multi-sensing capability to monitor complex environment via extended networks of connected devices	IOT / Smart Connected Object	A1A2	Sensing	<b>21</b>
19	T1	Seamless integration of actuators, in car interiors for human-machine interaction	Transport / Mobility / Automotive	A2A3	Actuating	<b>21</b>
21	T3	Low-power loss and energy harvesting for emission and CO2 reduction in electrical driving	Transport / Mobility / Automotive	A1A2A3	Energy	<b>19</b>
22	P2	Multi-sensing, data fusion and management in packaging/labels for goods interactivity and e-services	Packaging / Logistics	A1A3	Sensing	<b>17</b>
23	B4	Increasing security, safety and comfort of users of buildings with smart signalling solutions	Building / Construction	A2A3	Signalling	<b>16</b>
23	M6	Advanced Signalling for immersive visualisation tools to improve interfaces with and proficiency of medical professionals	Medical / Pharma / Life Sciences	A2A3	Signalling	<b>16</b>
25	M4	Combining energy harvesting, storage and efficiency to power complex, autonomous and interconnected medical & healthcare devices	Medical / Pharma / Life Sciences	A1A3	Energy	<b>15</b>
26	C1	Actuating as a key functionality for enhancing Human Machine Interfaces (HMI), product value and enhancing users experience	Consumer Electronics	A2A3	Actuating	<b>14</b>
27	P1	Secure data/information wireless transmission in	Packaging / Logistics	A1A2A3	Communicating	<b>13</b>

		packaging/labels for goods interconnectivity and e-services				
28	C2	Independent high-speed connectivity and low-power communication for trusted nomad consumer solutions	Consumer Electronics	A1A2A3	Communicating	<b>9</b>
29	N2	Flexible energy storage solutions with extended systems lifetime and multi-uses, including secondary use	Energy	A1A2A3	Energy Storage	<b>7</b>
30	M3	Advanced hardware/software processing for in-depth analysis of large and complex health-related datasets to improve decision-making and outcome of healthcare	Medical / Pharma / Life Sciences	A1A3	Computing / Processing / Data storage	<b>5</b>
31	T5	Seamless integration of displays for human-machine interaction and signalling	Transport / Mobility / Automotive	A1A2A3	Signalling	<b>-1</b>
32	C5	Signalling displays compatibility for sustainable manufacturing in Europe	Consumer Electronics	A1A2A3	Signalling	<b>-11</b>
33	S3	Creating visibility or convey information as informative or preventive action to promote effective operation and physical safety	Safety / Security	A2A3	Signalling	<b>-14</b>
34	B1	High-power and real-time computing facilities to support planning, construction, use and maintenance of buildings	Building / Construction	A2A3	Computing / Processing / Data storage	<b>-23</b>



# 5E

**Federating European Electronics Ecosystems  
for Competitive Electronics Industries**

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