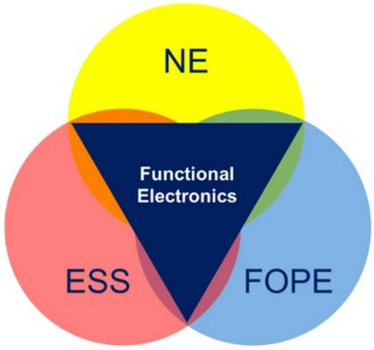
Vision Paper on the role of “Functional Electronics” enabled energy solutions for the digitalisation of European industries and societies

“Functional Electronics and energy”

September 2020

"Functional Electronics" definition



At the convergence of unconventional nano-electronics (NE), flexible, organic & printed electronics (FOPE) and electronic smart systems (ESS), the term 'Functional Electronics' encompasses this ever-increasing capability to integrate key digital technologies with cognitive functions, shifting from purely physical integration to functional integration. Smarter (hybrid) electronic components and systems will become viable notably at high structural density on and in novel substrates (including, but not limited to, flexible, organic, printed) and structural systems (e.g. textiles, plastics, laminates, glass, steel).

Functional Electronics will generate additional value from their use that is presently not realisable by using electronics forms independently, enabling new and efficient eco-design approaches at product, process and business model levels. They will have capability to capture & manage multi-physics data and contextual information in real time, with high sensitivity, selectivity and reliability as well as being networked, autonomous and complemented by bespoke software (incl. AI) solutions. Functional Electronics allow for their seamless integration in everyday objects and thereby enable the full realisation of their sustainability benefits in a broad spectrum of new applications.

1. Introduction

1.1 Identification of the issue

In the context of climate change and environment-related challenges, the European Green Deal[1], published by the European Commission in December 2019, broadcasts recommendations relating to the supply of clean, affordable and secure energy, energy efficiency conciousness such as building and renovating in an energy and resource efficient way, a zero pollution ambition for a toxic-free environment and accelerating the shift to sustainable and smart mobility.

In parallel, the European Commission defends "a new industrial strategy for a globally competitive, green and digital Europe"[2] that encompasses three pillars: green transition, global competitiveness and digital transition. The COVID-19 crisis also highlighted the necessity for Europe and Member States to host sovereign manufacturing capacities that are currently depending on suppliers located in other continents.

Undoubtedly, Digital Technologies play a significant role in answering these challenges and in paving the way to a transition towards sustainable digitalisation and circular economy. Both fields of electronics and energy must include now those aspects in their roadmaps to address upcoming market opportunities and societaly expectations.

Firstly, the European electronics value chain is well established, with strong R&D capacities. In the light of this transition context (both green and digital), this value chain must reinvent itself to face potentially contradictory needs: on the one hand it shall address the need for digital sobriety in order to reduce the impact of this sector in terms of resource consumption (materials, energy), data generation and environmental footprint; on the other hand it should accommodate to the demand for new and more efficient digital functionalities related e.g. to High Performance Computing (HPC) or Edge Artificial Intelligence. Both are complementary and crucial for the competiveness of European industries and must however appeal to local (controlled) and ethically acceptable solutions for the overall European society.

Similarly, the energy sector is in constant evolution and the integration of new society-compliant large energy infrastructures as well as renewable energies face the challenge of increasing capacities to be able to adjust demand and supply, to efficiently support at all levels (power plant, distribution network, individual building) with the profusion of connected objects (around 40 billion in 2025[3], a trillion by 2035[4]) carried by the wave of the "Internet of Everything" (*IoE*). Additionnaly, beyond accessibility, securing energy production and operation is a key challenge in the wider European geopolitical strategy directly impacting the European capacity to address global digitalisation.

1.2 Statement of the position

Europe is now in a position to take the lead in the development of "Functional Electronics" which is at the convergence of the three areas of electronics – (i) unconventional nano-electronics, (ii) flexible, organic and printed electronics, (iii) electronic smart systems – thanks to the progress achieved by the research and industry community. Within the 5E project and in this Vision Paper, we aimed at highlighting the two challenges for "Functional Electronics" with respect to energy:

- Develop and generalise core embedded electronics solutions enabling 'agile' **optimisation of energy consumption**, with a view to systematically **reduce**, on the large scale, the **environmental impact** related to the operation of electronic objects,
- Innovate and deliver **new functionalities**, i.e. robustness in **harsh conditions** (such as all combinations among high-voltage, high-current, high / low-temperature, remote (outdoor) sites) to ensure **safe operation** and **secure energy supply**.

From what we identify today, we expect such technological breakthroughs, which are multidisciplinary in essence, to mainly emerge from the convergence of the unconventional nano-electronics and electronic smart systems areas. Currently the flexible, organic and printed electronics has limited maturity, in particular in the context of harsh environments. For a wider adoption, we deem necessary for this research to also align with the recommendations of the 5E Vision Paper on "Functional Electronics for a circular economy".

2. Positioning

2.1 Powering electronics: towards the Internet of autonomous Things

Powering the Internet of Things (IoT), including Industrial IoT (IIoT), appeals to a new paradigm shift that enables the development of robust solutions for energy autonomy of electronic devices in a variety of contexts and for a significant lifetime (years).

Devices requiring lower level of energy should be developed together with the adapted **energy harvesting** solution. Such technologies have achieved significant progress in the past decades towards robust and industrially viable solutions but wider market uptake remains a challenge. Energy harvesting may apply today to sectors, in which monitoring is critical for the effective operation of products or infrastructures and where the use of conventional battery is complex or prohibited. Research towards multisource harvesting, adaptable and miniaturised harvesters and power management circuits, high system / product integration levels and simplified application-specific designs (energy vector, energy scale, reliability, lifetime & cost) are the priority.

In addition to energy harvesting, **energy storage** is a field of intensive research, encompassing new electric capacitors, electrochemical (micro) batteries, supercapacitors, covering the range from mA.h/mW to tens of A.h/kW in IoT. However, such solutions are not yet available for a large-scale market use. Furthermore, modularity, safety, reusability and recyclability are challenges that have to be addressed in order to increase take-up and reduce environmental footprint. Future energy storage solutions must fit within the overall system integration and usage: new paradigms of energy storage / release in the lifecycle of products may emerge in the context of extreme energy efficiency (e.g. “all-in-one” solutions). Huge opportunities lie ahead for recyclable low-cost energy storage for mobile & wearable applications, re-usable high-capacity energy storage for transport and stationary applications, smart energy storage management, among others.

Consequently, **low-power discrete electronics and integrated circuits** must become the standards of IoT and IoE and optimisation must occur at all levels of the system (hardware / firmware / software) in close relation to the application requirements. Similarly to systematic optimisation rules being implemented in software development for decades, optimisation and methodology should be envisioned at the hardware and firmware levels. Embedded data processing such as learning techniques have to be analysed in terms of their efficiency for the targeted application. Fully adaptive – or ‘agile” – systems (including for their security and connectivity aspects), aware of the evolution of their environments, will be a future important milestone for low-power electronics.

2.2 Functional Electronics for energy application

The energy sector is currently undergoing far-reaching changes with a shift from centralised to decentralised architectures initiated by the increasing penetration of renewable energy sources in the energy mix. The generation of energy through solar or wind power for instance introduces a high factor of intermittency into the grids, increasing thereby the need for higher flexibility, reliability, and resilience in transmission and distribution systems. Upgrading aging energy grids to smart grids, including technologies, techniques, control and management systems, is urgently required to meet the high requirements in term of cost-efficiency, stability and environmental footprint.

Functional Electronics has the potential to enable this transition by providing solutions at different levels:

a. **Smart energy management systems:** Functional Electronics is a key element for **automated, efficient, reliable and secure management** of power generation, transmission, storage and consumption of energy. It enables forecast, resilience and prediction for the management and maintenance of decentralised (battery, fuel cell management systems) and hybrid (electricity, gas, hydrogen, heat) energy grids while matching in real time demand and supply and balancing volatility in energy generation and consumption due to weather dependency and new consumer types.
   Peak shaving shall also be optimised with the help of modular solutions for energy storage (based on batteries and/or hydrogen), for flexible system architectures with dedicated power electronics, bidirectional converters and eco-designed systems anticipating their 2nd life.
   Furthermore, the field of **wireless power transfer** can be of interest with specific need in terms of materials to increase the security of application by reducing human intervention in hostile environments.

b. **Toward energy sobriety:** significant reduction of primary energy consumption along with the reduced carbon dioxide emissions is the key objective of the energy sector. **Electronic Components and Systems are key enablers for higher efficiencies as well as intelligent and reasonable use of energy** along the whole energy value chain, from generation to distribution and consumption. Functional Electronics enables products to reach the same level of performance and efficiency with (ultra)low-power approaches as well as to avoid wasting energy by optimising, planning and monitoring consumption, to secure the balance between sustainability, cost efficiency and security of supply in all energy applications.

Furthermore Functional Electronics provides alternative energy solutions for off-the-grid applications with advanced harvesting approaches and optimise the energy mix (electricity, gas, hydrogen, heat) to the real needs.

c. **Optimised energy conversion:** Energy conversion is necessary to meet the different requirements at grid level (power, distance, hurdles …). However energy losses are intrinsic to any conversion process and their optimisation is required to gain in efficiency.
From a technological point of view, energy generation is changing from inertia rotating machines (the current generators) to Power Electronic Interfaced Generators (PEIG), the RES generation. State of the art technologies allow for a penetration of max 60% of RES in the grid. Any higher RES penetration rate would lead to unmanageable situations and critical instability. **Power electronics systems** are key solutions for the increase of RES penetration in the grid up to 100%, modernising its architecture and control technologies. These advanced technologies—including high-voltage direct current (HVDC), solid-state transformers, fault current limiters, and power flow controllers—can reduce losses, optimise power delivery, protect critical assets, and enhance resilience. Despite these advantages, large-scale deployment of power electronics systems remains limited because of high costs. New power electronics solutions are also needed in the fast-growing sector of electro-mobility with e.g. bidirectional vehicle charging to support the grid.

Semiconductor switches provide the core functionality of today's power electronics systems and can comprise 50% of the cost. Silicon-based power electronics systems will be increasingly challenged to cost-effectively meet the new capabilities and growing performance demands of future grid applications, limiting deployment. Next-generation power electronics systems based on advanced materials, such as wide bandgap (WBG) semiconductors or diamond, allow for new designs and capabilities that can dramatically shift the cost-performance curves including with significant reduction in terms of size of overall systems (e.g. converter). This is crucial especially in several sectors such as automotive, space, industry and offshore applications where WBG semiconductors can reduce the size of the equipment and consequently, the costs. Such approach should encompass maintenance-free and long-lasting autonomy of power systems.

Power electronics is a cross-functional technology covering the very high gigawatt (GW) power (e.g. in energy transmission lines) down to the very low milliwatt (mW) power needed to operate a mobile phone. Research in the design of circuit and boards for IoT with new components and materials including bio-based but also with higher reparability and updating capacity is currently lacking.

Finally, new opportunities should also be investigated in terms of integration of energy generation in harsh environment such as building, transport and infrastructure (e.g. solar road) that requires robust and long lasting electronics.

3. Conclusion (& policy recommendations)

Being ranked as the most R&D-intensive sector by the European Commission, the European semiconductor ecosystem supports approximately 200.000 jobs directly and up to 1.000.000 induced jobs in systems, applications and services in Europe. Overall, micro- and nano-electronics enable the generation of at least 10% of GDP in Europe and the world. For 2020, all geographical regions are forecasted to grow with the overall market up 5.9 percent, with Optoelectronics contributing the highest growth followed by Logic. This gives the opportunity for Europe to strengthen its resilience and build its sovereignty in the field of electronics and especially take the leadership in Functional Electronics. Finally, the management of energy – consumption and efficiency – for electronics becomes a priority for European citizens and industry, with sobriety becoming a differentiator in the coming years.

Contribution/Support

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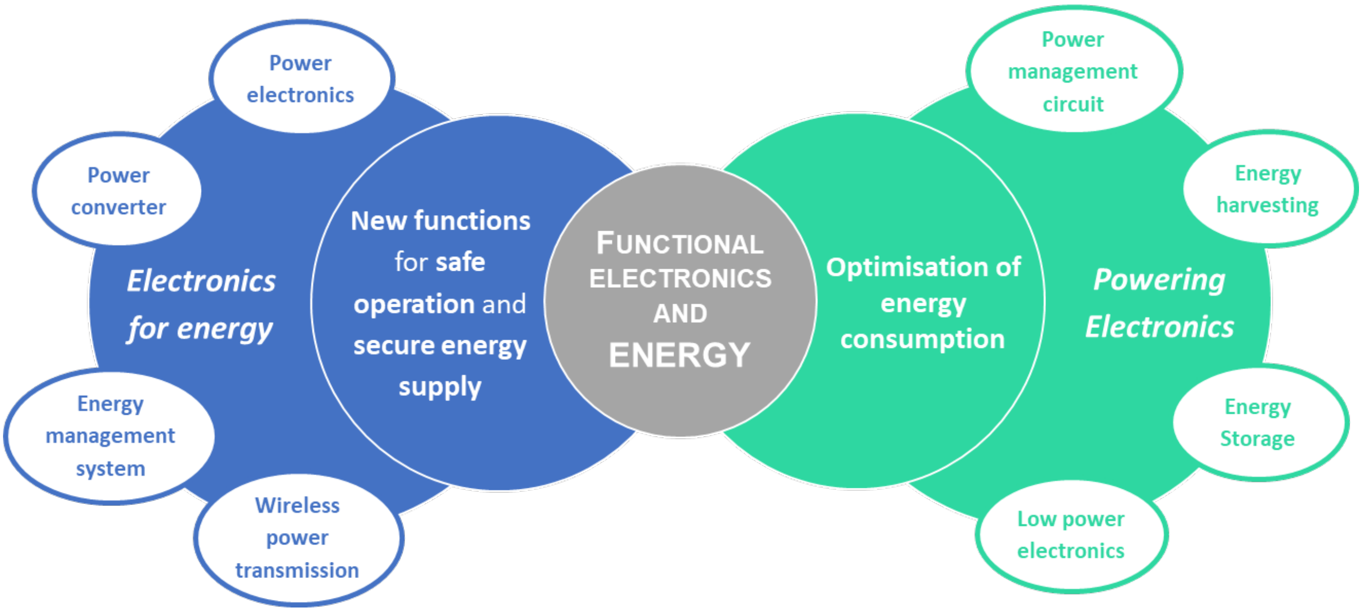

This Vision Paper is a result of the 5E project that reinforces collaboration and outreach of the electronics industry across Europe and supports its stakeholders in seizing opportunities.

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[1] The European Green Deal, European Commission, Brussels, 11.12.2019 COM(2019) 640 final
[2] https://ec.europa.eu/commission/presscorner/detail/en/fs_20_425
[3] A new forecast from International Data Corporation (IDC) estimates that there will be 41.6 billion connected IoT devices, or "things," generating 79.4 zettabytes (ZB) of data in 2025. June 2019
[4] ARM, the British semiconductor firm, acquired by SoftBank for $32 billion, estimates that one trillion IoT devices will be built between 2017 to 2035, adding $5 trillion to the global GDP. June 2017