Future
FET Flagships

FET Advisory Group
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Future FET Flagships

The FET program, although originating from the ICT area, became one of the most acclaimed excellent research initiatives of the European Commission and a crucial element of the Excellent Science pillar of H2020. The FET program is built hierarchically, with the signature FET FLAGSHIP built on the capacity of the exploratory bottom up FET-OPEN and the predefined thematic call FET-PROACTIVE. As stated by FETAG in our document,[1] *the FET-FLAGSHIP should be maintained as the ultimate FET program scheme.*

As the Member States are evaluating and deciding about a future FET FLAGSHIP program, the FET Advisory Group is submitting here a position paper, describing the threshold criteria and other considerations, for a consortium or a program to be granted a flagship and recommendation for 3 major Thematic Fields that a future flagship should belong to along with the argumentation how the chosen Thematic Fields fulfil the threshold criteria and additional criteria.

This report has been prepared as a joint effort of a whole FETAG, however we wish to acknowledge the stewardship role of Prof. Mina Teicher, a FETAG Deputy Chair, and a former CSA to the Government of Israel.

FET Advisory Group, January 2017

[1] THE FUTURE OF FET: A possible nucleus for the European Innovation Council, FETAG, Sept 2015, https://ec.europa.eu/futurium/en/system/files/ged/the_future_of_fet.pdf

1. FET FLAGSHIP CHARACTERIZATION

As stated by the European Commission *"Future and Emerging Technologies (FET) Flagships are science-driven, large-scale, multidisciplinary research initiatives built around an ambitious unifying vision. They tackle grand S&T challenges requiring cooperation among a range of disciplines, communities and programs, including both academia and industry. Their overarching nature and magnitude implies that they can only be realized through a federated and sustained effort, (in the order of 10 years duration)".*

To qualify as a potential FET-FLAGSHIP, a research initiative, in the form of a research program, should eventually satisfy the following conditions:

PRIMARY CHARACTERISTICS

Game Changer. A transformational program that is going to change the future of Europe and mankind, and have sufficiently long term objectives.

Relevance. A Scientific research program, essential to the public wellbeing and addressing major contemporary societal challenges.

Critical Mass of Resources Needed. The level of ambition of the program will require increased large R&D investments over the next ten or more years, at both European and national levels, and a multidisciplinary team of critical mass.

Scientific Excellence. It will address a grand scientific and technological challenge with a proposed solution based on scientific excellence.

SECONDARY CHARACTERISTICS

A Clear European Added Value. The flagship will address and contribute to solving major contemporary and emerging societal challenges. It will build, use and encourage European scientific and technological excellence and capabilities.

A Large Scale Academia/Industry Partnership Must build on existing and developing infrastructural capacity and have significant engagement from European industry.

Industry and Economic Added Value. The Flagship will have the potential to yield key competitive advantage to European industry, to encourage innovation, and to offer substantial benefits to Europe's economy in general.

OTHER CONSIDERATIONS

Mission Focused. Sharing a unifying specific goal, and having an S&T roadmap to achieve it.

Links with Member States. Potential to establish a close link between related activities at the European, national and regional level, and to ensure a mutual reinforcement from the EC and the MS of their research activities that would contribute to the Flagship, with clear financial and organisation commitments.

Effective and Efficient Management. Anticipate excellent management and financial responsibility essential for running such a complex and ambitious endeavour. The Flagships should exercise transparent management, be open to new partners, and be flexible enough to allow significant thematic and organisational adjustments. It should have the potential to create a lasting legacy.

2. RECOMMENDATION FOR THREE THEMATIC FIELDS

Currently there are two active FET-FLAGSHIP: "The Human Brain" and "Graphene". A FET-FLAGSHIP on "Quantum Technology" is under preparation for the ET Horizon 2020 Work Program as well as a large scale initiative on "Next Generation Internet" for the next LEIT-ICT Horizon 2020 Work Program". A public consultation resulted in 24 submissions for flagships. Based on the public consultation results and the AG members' capacity, expertise and scientific leadership, the AG identified 3 favourable Thematic Fields for flagships:

HEALTH and MEDICINE including Personalized Medicine, Gene Editing, Wearable and Implanted Technologies, Management of Health Systems, Technology for the Elderly.

CONNECTED SOCIETY including Big Data, Artificial Intelligence and Robotics, Complex System (e.g. cities), Transportation, Novel Functional Materials for Components and Systems.

ENVIRONMENT including Climate Change, Water and Air Availability and Quality, Alternative Energy Resources , Sustainability and Quality of Life.

Moreover,

- Any selected flagship within the above Thematic Fields, either within the Connected Society, the Environment or the Health and Medicine, should develop futuristic technologies or produce research outcome based on the following ICT–based Science and Technology challenges: "Big Data", Artificial Intelligence, Robotics, and New Materials.

- A FET-FLAGSHIP, while being multidisciplinary and interdisciplinary within S&T, focusing on the future and emerging technologies, that likely to influence society at large - should involve from the outset researchers from the Social Sciences and Humanities.

- As their long-term mission should have economic value, preferably on a global scale, the choice of the subject should be correlated with the analysis of the Key Enabling Technologies (KET). They also should allow R&D on a broad TRI scale, ultimately even to the implementation level.

3. THE CHARACTERISTICS OF THE THREE THEMATIC FIELDS

The above three Thematic Fields and the enabling S&T meet all characterization mentioned above - the Primary Characteristic, the Secondary Characteristic and the Other Considerations:

Game Changer: The above three Thematic Fields – improving public health and medical treatment of individuals - facilitate a Connected Society in the digital era and the thinking machines, and protecting the Environment are grand societal and political challenges that create a grand S& T challenge. A selected flagship is bound to apply radically different approaches and create of new paradigms that transform Science and Society

Relevance and European Added Value. These Thematic Fields and the related S&T challenges address the needs of society and are essential for Europe of today and Europe of the future. In particular, they addresses the aging of European society, transformation in the composition of society (Immigration, birth rate), societal digital gaps, variable access to technology, multi-linguistic society, inequality in access to resources, industry needs to penetrate the global market and increase competitive level of Europe.

Critical Mass of Resources Needed. Meeting the challenges requires vision, scientific leadership, large scale financial and personnel resources, efficient coordination of existing efforts, effective usage of current capacity and truly interdisciplinary research. Any of these challenges needs major financial investments as well as trained researchers and engineers, focus on the mission, interdisciplinary, leadership, management and coordination, understanding needs and capacity. A grand European Flagship can address these challenges.

Scientific Excellence. The three Thematic Fields mentioned above, as well as any of the common grounds – Big Data, Artificial Intelligence, Robotics, and New Materials, are a grand challenge that will need excellence in research and will further induce excellent research.

A Large Scale Academia/Industry Partnership: To be successful and ground breaking, a flagship in the above Thematic Fields will have to be a true partnership with Industry.

ICT Plays an Important Role in Addressing each of the Above Challenges: Any flagship in the three general Thematic Fields must be connected to the ICT, as the development in both hardware and software already have completely changed other techniques and technologies.

Most of the enabling technologies are ICT-based and in large based on robotics and big data:

- **Robotics** becoming a prime manufacturing technology assisting and substituting human manpower, especially in a mass production of complex products.

- **Big data** becoming a driver in practically all aspects of the XXI century human activity ranging from enabling transformations of the connecting society, to organisation and operation of complex environments like the cities, to storage and energy distribution (intelligent and adaptable grids), to medical analysis, production and care, down to the financial operations. Big Data technologies is needed for understanding and analysing the enormous amount of information, received from new recording devices of different scales – communication and remote sensors from space, geological and climate recordings, wearable sensors, implantable biosensors, and more.

Industry and Economical Value Added Europe's future economy will be based on the connected society, machine intelligence, personalized medicine and protected environment. The research produced by the flagship will be transformed to leading technologies and will increase the competitiveness Europe's Economy.

Links with Member States. The Three Thematic Fields are relevant to national initiatives. They should use the opportunities provided by European Regional Development fund, and can be seen in a broader context of various EC-based initiatives, programs and policies (the Key Enabling Technologies (KET) definition initiative, the EIT and the activity of the KICs, ERDF with its Smart Specializations Strategies.

4. THE FET-PROACTIVE AND FET-OPEN VS THE FET-FLAGSHIP

The FET FLAGSHIPS are a part of the broader Future and Emerging Technologies (FET) Horizon 2020 Program.

The FETAG would like to stress that while planning the future FET Flagships research initiatives, it is of utmost importance to preserve the integrity, interconnectivity and the logic of a whole FET program consisting also of the exploratory bottom up FET-OPEN and the predefined thematic call FET-PROACTIVE, the latter sometimes called a mini-Flagship. Both subprograms have resulted in building lively networks of researchers, innovators and SMEs working on ground breaking scientific ideas aimed at technologies of the future. The current flagships—The Brain and Graphene, as well as the upcoming one on Quantum Technologies have clear roots in the two Bottom-up programs.

The FET OPEN program is a bottom-up program where individuals get support for projects and developing ideas which are innovative, out of the mainstream, risky but with a potential for a breakthrough.

A FET PROACTIVE project is characterized differently from a FET FLAGSHIP: It is a combination of top-down and bottom-up approaches. It is scientifically based, with no requirement for direct industrial Involvement. A FET PROACTIVE project is not aiming towards a product that can be commercialized, does not necessarily carry a market potential, and it is further away from the market than a flagship. Size wise it is smaller than a flagship, typically about 5-10 M€ over 4 years. It is characterized as a High Risk, High Gain project and mostly interdisciplinary. FET PROACTIVE can act as a potential pre-Flagship medium scale cooperative scheme, and as such may form a preparatory platform for future flagship programs, particularly if a number of Proactive projects cluster under a common strategic objective.

Examples of PROACTIVE projects within the 3 Thematic Fields include: Machine Face Recognition – The next Generation; Nano Medical Robotics; Cyber Security for Health System; Extending the Scope of Environmental Monitoring by Combining Satellite Remote Sensing (Earth Observation; Extending Wearable Sensing into Bio-sensing).

The Flagships are the pinnacle of a much broader FET program. Thus, providing FLAGSHIP funding must not endanger the funding of the two ‘bottom up’ programs - the PROACTIVE and the OPEN which are clearly very popular in the research community. Damaging these programs, through reduction of the available budgets would have the effect of blocking the pipeline of emerging ideas and concepts that will form the basis of future Flagships. Thus, it is extremely important that FLAGSHIP funding must not endanger the funding of these two ‘bottom up’ programs,

5. The FETAG ROLE

The existing process of selecting topics for the Flagship programs is based on public consultation, Member State priorities, and an open call whose submission goes to a selection committee for finite choice. The AG strongly recommends that an independent Council should be created to overlook the process in a transparent way. This council should be composed of people of authority from all relevant stakeholders (policy makers, scientists, industrialists, funding agencies). FETAG offers to work in such a capacity until the Council is established.

6. SUMMARY OF RECOMMENDATIONS

1. ***A FET FLAGSHIP should be a mega transformational program, with relevance to societal needs, based on academic excellence and Industrial capacity, with the potential to increase European competitiveness, for the benefit of the general public and the Member States.***

2. ***A Future FET FLAGSHIP should belong to one of the following three thematic fields: Connected Society, Health and Medicine, the Environment. With current challenges, each Flagship should be aligned with the KET and involve the fastest ICT-based components, namely: Big Data, Robotics and AI, and new materials based components.***

3. ***A FET FLAGSHIP focusing on the future and emerging technologies, should be multidisciplinary and interdisciplinary around its main S&T goal, but should involve researchers and scholars from the SSH area, to address the societal view point.***

4. ***FET-FLAGSHIP funding must not endanger the funding of the two ‘bottom up’ programs FET-PROACTIVE and FET-OPEN.***

5. ***During the duration of a Flagship Program, transparency will be upheld regarding the process, the development and growth, and above all the tangible results emerging from the program.***

6. ***There should be an independent Council created to overlook the process in a transparent way and FETAG offers process until an independent council is established.***

APENDIX

*In the appendix we detail the 3 Thematic Fields, **HEALTH and MEDICINE**, **CONNECTED SOCIETY** and **ENVIRONMENT** that we have identified as candidate topics for future flagships.*

The process of identification of these favourable Thematic Fields for future flagships has been informed by three essential concepts that shape R&D policies:

- *First is the **Smart Specialisation Strategy**. In plain words it simply advises involvement in activity that is smart and may lead to a competitive advantage.*
- *Second is **6 Key Enabling Technologies** - micro and nano electronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies, technologies - which are ICT based, and will most likely lead to the emergence of futuristic industries.*
- *Third is **TRL scaling** (technological readiness level), which tells where a given R&D is placed between pure science and industrial production. Because of the scale of Flagships, and the extent of precursor research, it is expected that they will generate significant outputs at high TRL level through to full commercialisation.*

*Moreover, the three thematic fields have a strong **SSH** (Social Sciences and Humanities) component, as all of these novel technologies will strongly affect society and thus a proper analysis of the societal aspects is an absolute must.*

*Finally, a convincing **EAV** (European added value) was essential for justifying the choice of topics and associated challenges presented below.*

7. THE SIGNIFICANCE OF A "HEALTH AND MEDICINE" FLAGSHIP

A Flagship in "Health and Medicine" thematic Field will sit at the intersection of fundamental biology, neuroscience, biomedicine, advanced materials, micro and nano-robotics, global ICT, cloud computing, psychology, and health system managements, and much more.

7.1 What is the grand S&T challenge that a FET-FLAGSHIP in HEALTH AND MEDICINE should address?

The interface between the human body and devices is a fundamental challenge that could transform society if appropriate advances are made. It has the potential to improve the quality of life and medical outcomes for many millions of people.

A device is useful and effective if it can function continuously and reliably for long periods of time in a 'deploy and forget' mode; i.e., users are only interested in the improved outcome, not how the outcome is generated. This requires a major effort to integrate currently fragmented research efforts aiming at wearable devices, wearable bio/chemical sensors, implantable biosensors, emerging imaging diagnostics, drug delivery platforms, artificial organs, gene editing and more. Moreover, creating platforms to provide personalized medicine, intelligent decision support and improved data systems will close one of the biggest gaps in Health systems and provide the basis for a more effective and sustainable model for delivering personalised health services than the current, unsustainable model.

Significant focus areas include:

Artificial Organs Tissues and cells:

Creating systems that can mimic the behaviour of biological (living) entities, for creation of artificial organs, and specialist tissue types like nerves and muscle and for regeneration and restoration of key body functions. These systems are 4D systems i.e. *materials with a 3D structure that can change over time, for example, in response to an external stimulus such as light, electronic charge, magnetic fields, or changes in the local chemical environment*. This will integrate breakthroughs emerging across fundamental materials science (stimuli-responsive polymers/gels and conducting polymers, graphene and silicon-hybrid materials), ranging over biomaterials (including DNA, cells, tissue) and exquisite control over 3D morphology of materials from molecular scale, through nano/micro/meso scale to macro scale. This is inherently multidisciplinary, requiring collaborative input from areas like surface chemistry, molecular self-assembly, layer-by-layer deposition, 2-photon polymerisation, 3D printing, micromachining, nanofabrication technologies; and culminating in the creation of stimuli-responsive molecules/materials/devices/cells that can replicate complex biological behaviour.

Intelligent Devices

Implementing 'intelligence' into all wearable and implantable devices, devices communicating with the wearer and providing online feedback on the person and the device condition. Devices will become self-aware, with some capability for self-repair and maintenance to extend functional lifetime. Platforms will embrace the vision of informed, real-time decision making (generating data for external use) by the external system e.g. predictive medicine.

Futuristic diagnostics:

Diagnostic based on non-invasive, minimally invasive and implantable autonomous sensing technologies that can provide reliable, continuous information about the health status of an individual for a period of weeks to years will become a reality. This will combine tracking of general indicators with highly specific biomarkers, together with appropriate data analytics, to enable early detection of condition deterioration that requires an intervention, with minimal false positives and negatives.

This will encompass the following areas:

- **Wearable devices**: Developing on-body and on-skin devices. The future of wearable devices is integrating general indicators of wellness with tracking of specific biomarkers in a non- or minimally invasive manner; examples include use models that extend to several weeks and beyond (e.g., wearable patch-based devices for tracking interstitial glucose in real time), extending wearables into bio/chem sensing through the skin; skin tattoo sensing and electronic devices, sensorised contact lenses, and devices for tracking and reporting stress and emotion in real-time.

- **Futuristic Imaging**: Imaging approaches such as multispectral Visible/Infrared/Raman Spectroscopy that allow imaging through skin and tissue, providing non-invasive access to underlying structure and molecular information; Integrating these miniaturised Imaging devices into endoscopes for real-time in-vivo tissue categorization.

- **Implantable devices with advanced functions** (e.g. sensing and response): This is perhaps the most challenging of all – aiming at life-time implantable devices that can last and function on a wide time spectrum from weeks (e.g. during intensive care hospitalization and recovery time) to years (for chronical diseases' and artificial organs). Such are well beyond the current state of the art.

- **Proactive Personalized ICT Technologies**: Integration of data from all of the above devices and into ICT technologies, moving beyond the established exercise-focused APPs to APPs that can track personal health status; technologies that will drive a transformational model of health management from reactive, to proactive processes. Creating an ICT framework into which the data will be drawn and integrated, to create new person-centric applications for future personalized health models or the internet of humans is fundamental to realising this vision.

7.2 Why a FET-Flagship is necessary to address this challenge?

These are major technological, societal and political challenges. Meeting these challenges requires vision, scientific leadership, large scale financial and personnel resources, efficient coordination of existing efforts, effective usage of current capacity, and truly interdisciplinary research.

The challenges are indeed grand: After 30 years of research involving massive investment of resources, there is still not a single example of an implantable chem/bio sensor that functions for more than a few days. As for biosensors, the predominant model is single use disposable test-strips. This is due to issues related to device stability, need for regular recalibration, or incorporation of arrays of single use devices, and use of platforms that can only be used outside the body.

The solutions will require application of emerging micro/nano-3D fabrication technologies, combined with smart functional materials, and futuristic fluidic handling platforms.

Only a major focused well managed flagship can address these challenges.

7.3 Why is it good for Europe?

The application of the above developments to healthcare (e.g., remote, sophisticated measurement and diagnostic) has potential to revolutionise healthcare, while also providing breakthrough technologies that will positively impact other areas such as environmental sensing, water quality monitoring, security and threat detection, and precision agriculture. It addresses the needs of society. For example, it addresses the aging of European society and its impact on the economy, and will provide the means for industry to penetrate the global market and strengthen Europe’s competitive position.

7.4 What would it take to do it?

A successful Flagship would require input from materials science, analytical science, materials engineering, advanced fabrication technologies, systems integration, communication technologies, cloud computing, power management, packaging, validation, microfluidics, functional design, clinical relevance, use model definition, financial/business modelling. It sits at the intersection of huge industries – ICT, medical devices, health services delivery, human performance and the human condition.

Currently, research on this topic is not advancing as it should – too much research attention is placed on producing very elegant chem/biosensors (that on their own cannot perform measurements inside the body), and not enough research on creating a platform or system that might be able to take these sensing approaches inside the body. At the end, the sensor is only a small part of the solution involving a more multifunctional device, and not an end in itself.

Moreover, it needs major financial investments as well as trained researchers and engineers, focus on the mission, interdisciplinary, leadership, management and coordination, understanding needs and capacity.

7.5 What could be the role of ICT in addressing this challenge?

ICT is a major factor in future medicine and health systems. The collision between medical devices and information infrastructure will be one of the most profound developments in society, and will create a fundamental change to delivery of health services. This is already happening – for example, the recent cooperation between Novartis and Google in on-body diagnostic sensing. Understanding and analysing of the enormous amount of information received and recorded, needs significant ICT capacities. The vision is that all devices will generate data – implantable, wearables, imaging scanning units (pushed towards hand-held or smaller implantable imaging devices), personalised interconnectivity and personal health tracking. It can already be seen that many developments will be coming from 'left-of-field', and early adopters could initially employ devices targeting human performance rather than certified medical devices.

This is one of the most important areas of focus for the largest ICT worldwide companies – Microsoft, Google, Apple all have major research initiatives in this area and it intersects inherently with social media – Facebook etc.

Ultimately this will transform the way health services are provided to citizens, from a largely reactive (and therefore unpredictable) model, to a much more personalised proactive model, in which health issues are identified earlier, and managed much more effectively.

7.6 Summary of significance and Possible Outcome – technological breakthrough, Industrial enhancement and societal impact.

Technological breakthroughs will be revolutionary in terms of the impact, driving transformational changes in the way health services are managed for society.

Materials that can regenerate vital body functions weakened or lost through disease or damage will enhance the quality of life for millions of people. This offers a way to transform the current unaffordable model for health services management by providing access to new types of data that enable personal health to be remotely tracked and managed in a much more effective manner.

New industries will emerge based around revolutionary personalised health informatics management APPs that go far beyond the current exercise focused products offered by major ICT companies. These will draw on new information sources from diverse on-body/in-body diagnostics and monitoring devices that will emerge from fundamental breakthroughs in materials science. It will generate significant commercial opportunities for both multinationals (pharmaceutical, medical devices, and ICT), and for specialist SMEs/high tech spinouts.

8. THE SIGNIFICANCE OF A "CONNECTED SOCIETY" FLAGSHIP

8.1 What is the grand S&T challenge that a CONNECTED SOCIETY Flagship should address?

The main challenge is to understand how coordination, movement, integration and interdependence of people, information, and resources through physical and social networks influence cultural, political and economic behaviours shaping the Society of the Future. We also need to be able to have a "wind-tunnel"-like platform that enables anticipating, understanding and monitoring changes, so that education, industry and policy-makers at large can understand, decide and adapt.

Hundreds of millions of connected people and billions of sensors yield previously unimaginable amounts of information. Similarly, more data is generated by people simply going about their lives, as a by-product of other activities such as their Internet browsing and searching or moving around with their smartphones in their pocket. The modern world thus relies on a collection of increasingly interdependent cyber-physical, cyber-human, socio-technical and socio-ecological networks. Each of these systems is extremely complex, with properties that cannot be anticipated by studying them in isolation and millions of degrees of freedom.

Moreover, the society will be largely using robots and intelligent machines that are able to "learn", "think" make decisions and act. This artificial intelligent, is in its starting point and has no limits on its future impact on our lives. Build these machines and teach them how to improve our wellbeing and longevity, decrease the gaps in society, protects our globe, is a mega challenge.

8.2 What would it take to do it?

Some of the current challenges need to be addressed, in a multidisciplinary, cross disciplinary way putting together the classical basic scientific fields with contemporary interdisciplinary areas, high tech industry, engineering, as well as the Social science, and philosophy:

- **Computer Sciences**: machine learning, artificial intelligence, new visualization tools and methods, virtual reality platform, games, data analytics, new algorithms for Big Data gathering and mining, new algorithms for automated processing of text and digital content (like audio/video/images), emerge network, storage, new "open finance" technologies, etc.

- **Physics**: Advances in how to deal with out-of-equilibrium, interdependent complex systems, how to extract out of a myriad of features those that are effective and essential across scales using, for example, knowledge from statistical physics, entropy and topology. Also needed are new developments within network and complex systems science that account for systems' (positive and negative) feedback and adaptation. A new framework able to control nonlinear interdependent systems. New understanding about mechanisms of knowledge diffusion within disciplines. New forecasting models, development of containment strategies. Extreme electromagnetism-enabled technologies, etc. Of paramount importance is the development of new materials and technologies (components and systems) to enable meeting these challenges accompanied by design and architecture strategies.

- **Mathematics**: New mathematical tools for Big Data analysis (topology, algebra, etc.). New mathematics for social and technological systems; extending traditional mathematical graph and control theories, etc.

- **Social sciences**: developing new conceptual and theoretical foundations for human behaviour in the sociotechnical era, provide a better understanding of how to improve human decision making, how to evaluate and contribute to public awareness of chances and risks, how to deal with new societal needs, how to improve the usability and attractiveness of technologies, development of strategies that address privacy concerns and ethical issues, Technologies that will help maintain accountability and fair governess, etc.

- **Engineering**: How to optimally design new transportation and distribution systems, to further develop the new science of cities, how to integrate the many technological and social scales in a sustainable way (from addressing preventing medicine in a connected way, to different mobility modes, resources, autonomous technologies, how to develop novel functional materials and design for Components and Systems,), etc.

- **Neuro-Engineering**: Developing new tools for brain-computer interaction for complementing and supplementing the capacities and the impairments of healthy agents; inter-individual communication at a distance, avatar embodiment for remediation and for entertainment, games and education.

Methodological advances would allow having a system wide perspective via integrative tools to analyse the abundance of data expected in social and biological systems. New computational modelling would also make it possible to evaluate micro-level, possibly multi-channel interventions, to steer system-wide behaviours.

8.3 Why a FET-Flagship is necessary to address this challenge?

On the S&T side, all the previous questions and challenges clearly call for an important foundational and methodological transformation of current theoretical and modelling paradigms. Addressing the challenges mentioned before, to achieve significant scientific, technological and methodological advances would require an interdisciplinary consortium, with a very broad spectrum of domains - ICT through physics, energy, environmental sciences, biomedical sciences to Social Sciences and the Humanities. Such progress can only be achieved by a proper level of team integration, along with investment in personnel and technology and European-wide initiatives. The scope ranging from science and technologies of atoms to human societies is extremely ambitious and requires a strategy to tackle this in an efficient manner, after a focus is identified. The challenge requires also a large timeframe that is typical for a FET-flagship.

8.4 Why is it good for Europe?

Society connected via intelligent machines will influence how we live our lives. Europe needs to be prepared to have these systems developed in Europe, in order to be able to plan, make decisions and protect Europe.

A Connected Society Flagship based on technological approaches could deal with the contemporary societal challenges Europe is facing such as the aging population, transformation in the composition of society (Immigration, birth rate), societal digital gaps, variable access to technology, multi linguistic society, and inequality in access to resources. European industry needs to penetrate the global market and increase the competitiveness level of Europe. A Connected-Society Flagship should be seen as a unique opportunity to significantly advance and integrate different types of elements (social, psychological, technological, distribution systems, transportation, etc.)

The flagship will need to develop a strategy that can be applied to various aspects of the connected societies concept. This preparatory phase alone will be invaluable to Europe and more so if followed by a winning proposal. It will demonstrate that a combined multidisciplinary approach with a suitable focus can provide a path towards meeting the Connected Societies challenge. Testing of the research and innovation results in a case study would be a major achievement admired in global scale.

8.5 What could be the role of ICT in addressing this challenge?

ICT has everything to do with the Connected Society grand challenge: practically all challenges are naturally within the ICT domain, as they are related to how human and new technologies emerge, interact, coexist and impact each other.

ICT is the key in Connected Society. It helps to generate, understand and store information, ease the communication among people and things (e.g., autonomous vehicles) and the development in ICT is going to boost the Connected Society approach.

8.6 Summary of significance and Possible Outcome – technological breakthrough, Industrial enhancement and societal impact.

The future society will be connecting computers, databases, things, people, human brains, thinking machines and robots. The future internet will be the Internet of Things (IoT), Internet of Humans (IoH), physical cyber systems (which are called today cities). It will affect every part of our life - education, health systems and medicine, safety and security, employment, art and culture.

In order to prepare we need mega investments, true collaboration of Industry with academia, and think tank of physical scientists, mathematicians, engineers, social scientists, scholars and philosophers, entrepreneurs, and visionary policy makers.

To sum up, Europe needs to be in the front of this development in order to be able to plan ahead, take knowledge based decisions and protect the European Society.

9. THE SIGNIFICANCE OF AN “ENVIRONMENT” FLAGSHIP

Environment Flagship will address one of the greatest challenges of mankind, namely responsible use of natural resources and adaptability to, and mitigation of, environment changes enhanced by the human activities in recent decades. This includes climate change and its impact on sustainability and quality of life including the food chain, freshwater availability, air quality, as well as soil and natural greenery.

The delivery for alternative energy resources is centrally connected with the battle for reduction of greenhouse gases. In parallel, climate change modelling and mass computation will enhance the ability of the scientific community to separate natural causes from the influence of human activities on climate, leading to more accurately targeted priorities and interventions.

9.1 What is the grand S&T challenge that a FET-Flagship in Environment should address?

a. **Develop alternative sources of energy** to the currently dominant energy production based upon burning fossil resources, which damage the environment and have a limited time-scale of supply. Develop sources made from renewable natural resources, with practically unlimited access, such as sun radiation, wind, geothermal resources and water flow. Moreover, address the full chain - efficient and effective production, conversion, transport, storage solutions, distribution and use of energy, as well as security of energy infrastructure.

b. **Big Data approaches based on smart data collection from earth, ocean and atmosphere sources** by remote sensing, ground and in-situ chemical/bio-sensors, movement of living organisms, and ocean based sensors for tracking changes in water movement

c. **Processing vast amounts of big data** is essential to accurately model the global environment. These models will be built based on data generated from a densely deployed network of in-situ sensors, coupled with satellite remote sensing with ever-improving range of sensors and spatial resolution.

d. **Building models for prognosis of climate change.** Models that Integrate different data sources and provide a more informed picture of the dynamics of environmental processes, from local to global scale, leading to much improved predictive models and assessment of the influence of current energy usage on climate change.

e. **Provide the derived social and economic understanding** and trigger political and cultural changes, and life style choices.

There are also other grand issues related to environment that require major S&T efforts - such as air pollution, quality and availability of clean water for all, consumption of cleaning water, smart or precision agriculture raw materials and their use, and ocean biosphere- that will benefit from an environment flagship.

9.2 What would it take to do it?

It needs understanding of the needs and capacity, distributed and European level leadership and coordination, (compatible with the European regional and national initiatives), major financial investments as well as trained researchers and engineers with appropriate skills and experience to deliver the flagship mission.

It will acquire interdisciplinary and multidisciplinary efforts and contributions from materials science, biosciences, computational sciences, Information and Communication Technologies (ICT), and Social

Sciences and the Humanities (SSH). It will need integration of currently diverse research communities but also close involvement of leading European industries such as the energy production and storage and the entire transportation/logistics sector (especially automotive, as the replacement of gas and oil products in powering the automobile engines by hydrogen and electricity is at sight).

The scale of the problem, as well as the societal consequences, requires concerted involvement of governments, NGOs and ERDF with its Smart Specializations Strategies. The interdisciplinary character of the theme spans several KETS and link to other large research initiatives, such as the KICs of the EIT.

Climate-related data accumulation will integrate satellite based earth observation information with instrumented drone technologies (both air and water), widely deployed large-scale sensor networks tracking key chemical and biological parameters. Analysing/visualising/understanding the huge volumes of data that will be generated will stimulate the emergence of more effective tools for water (waste & drinking) and land/soil management. Inherent to this flagship will be making this information available in an accessible manner to specialists and non-specialists alike, to underpin more informed decision making at societal and individual levels.

9.3 Why a FET-Flagship is necessary to address this challenge?

The need for a flagship is derived from the scale of the problem, the technological challenges, the magnitude of the financial investments needed, and from the diverse multidisciplinary nature of the challenges involved.

The EU has a wealth of globally competitive expertise in all necessary sub-disciplines ranging from fundamental research in physics, chemistry and mathematics, through to a highly innovative industrial sector. Inclusion in a single, mega-scale, integrated project would foster interdisciplinary collaborations, avoid duplication of efforts, attract private and public interests and investments, and optimize resource use efficiency. This is particularly important also considering the time factor for tackling climate change issues.

The computational power will be built up modularly by the different stakeholders. Technologically, the challenges in complex system modelling are enormous. High-end computing infrastructure will be needed to realize and test such models. It will be used by geographers, social and political scientists, anthropologists, economists, biologists, the agro-food industry and others.

The flagship will design a European and global network of communities of sensors. The design should ensure that the connected networks of sensors function efficiently and effectively, and are scalable from local to regional (European to global) levels.

9.4 Why is it good for Europe?

A flagship in Environment will benefit Europe in many aspects.

Europe has a very dense population and thus more efforts are needed to ensure sustainability - affordable clean air, affordable clean water, food/water security, sustainable agriculture, energy supply, and protection against climatic disasters.

The current domination of coal and hydrocarbons (gas and oil) as the main energy resources (either directly in combustion engines or in electricity power stations) is not sustainable in the time scale of just a few decades due to natural supply limitations of these fossil resources (whose built up took millions of years to form). Furthermore, these resources have much more valuable potential applications than energy creation through combustion.

A flagship in Environment could focus efforts on sustainable technologies for energy production. It would play an essential role in strengthening diversity in the European energy sector by integrating multiple renewable technologies, improving security of energy supply and by avoiding dependency on energy from countries outside of the EU. Turning the EU into energy efficient and low-carbon economy will also deliver jobs and growth and will contribute to the EU's commitments to address climate change and renewable energy targets. The FET Flagship would contribute to the vision of a European Energy Union.

Europe is very vulnerable to currently observed climate changes, and hence must be motivated to maintain the generally high quality of life that will be adversely affected by drastic atmospheric phenomena and the extent of increasing average temperatures, especially in the Southern regions of Europe. Therefore, both understanding and predicting these changes as well as technologies that can minimise or reverse climate change is vital for our population. Solutions will obviously positively impact on neighbouring areas such as Africa and Western Asia. The climate focused efforts of the Environmental Flagship should aim at minimising the impact of extreme weather events, observed through much more advanced computer modelling fed by more accurate data the diverse data sources listed above.

The flagship will also further strengthen the competitive advantage for European industry, including automotive industries – one of the leading innovative industries of Europe.

It will also drive the interaction of climate and energy researchers across Europe and will mobilize large, but yet dispersed, European research and development communities under a well-defined goal, thus creating a new network across Europe that maximises our intellectual and infrastructure capacity. It will simplify data harvesting and analysis, and drive the creation of data standards that will render compatibility across the globe, and will decrease the inequality in access to resources. Determining an optimum balance of social and market-driven goals will be a key outcome of this flagship.

9.5 What could be the role of ICT in addressing this challenge?

ICT is crucial to achieve the above goals. Environmental 'Big Data' will witness the merging of information from satellite based sensing and ground observation with widely distributed sensor networks and locally generated data to provide, for the first time, the capability to understand and track the quality of our environment from global to local scale. This will require significant advances in data analytics to extract the relevant information this information will form the basis of more effective services for food production via smart and precision agriculture, improved water management, and resource forecasting.

ICT will play a crucial role in terms of advanced storage technologies, intelligent distribution systems and grid reliability issues. ICT is essential for the transition of today's grid infrastructure into the smart energy systems of tomorrow, as future grids will have to be much more intelligent, in order to deal with issues like diverse multiple energy sources, storage and highly dynamic demand. Components and Networks will play a crucial role in the program. Design of networks of sensors, their protocols and functioning with a high degree of reliability, autonomy and accuracy and with low power consumption, will require novel ICT technologies. Similarly, dealing with the massive data sets will require new storage and access technologies, as well as innovative analytical and visualisation approaches, and data management algorithms.

9.6 Summary of significance and Possible Outcome – technological breakthrough, Industrial enhancement and societal impact.

Climate change is now affecting every country on every continent. It is disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow. It is therefore crucial to anticipate, adapt and become resilient to the current and future impacts of climate change, and accurate and evidence based predictions are key to reaching this goal.

Finding an alternative source of energy to the currently commonly used fossil burning is essential to prevent human effects on climate change, to prevent air pollution, and in view of the fact that fuels suitable for energy production hardly exist in Europe and are limited resources on a global scale. New efficient and sustainable energy sources are clearly vital for minimising the impact of climate related natural disasters and associated disease outbreaks.

All these challenges call for public investment, while similarly creating investment opportunities for companies. There are estimates that Eastern Europe, Central Asia, the Middle East, and North Africa could support up to $1 trillion in climate-related investments. This Flagship will enhance the ability of the scientific community to more accurately model climate, and separate natural causes from the influence of human activities with improved precision.

As the connectivity and proximity of everything has an effect on our climate, its prediction is becoming more and more complex. Globally scaled and more accurate data is essential to provide better climate models that will inform timely and coordinated policy decision making, which is already critical for safeguarding the future of our planet.

FET Advisory Group Members[2]

Individual experts appointed in her/his personal capacity:

- **Mr Jerzy Langer**, Professor of Physics Polish Academy of Sciences, PL, Chair FET Advisory Group
- **Ms Marja Makarow**, Professor of applied biochemistry and molecular biology, Director of Biocenter Finland, FI, Vice-Chair FET Advisory Group
- **Ms Mina Teicher**, Professor of Mathematics, Director of Emmy Noether Research Institute for Mathematics, IL, Vice-Chair FET Advisory Group
- **Ms Ana Cristina Amoroso Neves**, Director of the Department of Information Society at the Science and Technology Foundation (FCT), PT
- **Ms Béatrice De Gelder**, Professor in the Department of Cognitive Neuroscience, Faculty of Neuroscience and Psychology, Maastricht University, NL
- **Mr Dermot Diamond**, Science Foundation Ireland Principle Investigator in the 'INSIGHT Centre for Data Analytics', National Centre for Sensor Research, Dublin City University, IE
- **Mr Dario Floreano**, Director of the Laboratory of Intelligent Systems (LIS) at the École Polytechnique Fédérale de Lausanne (EPFL), CH
- **Mr Nigel Gilbert** , Professor of Sociology at University of Surrey, UK
- **Ms Ana Helman** , Science Officer European Science Foundation, HR
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[2] https://ec.europa.eu/digital-single-market/en/future-emerging-technologies-advisory-group-fetag